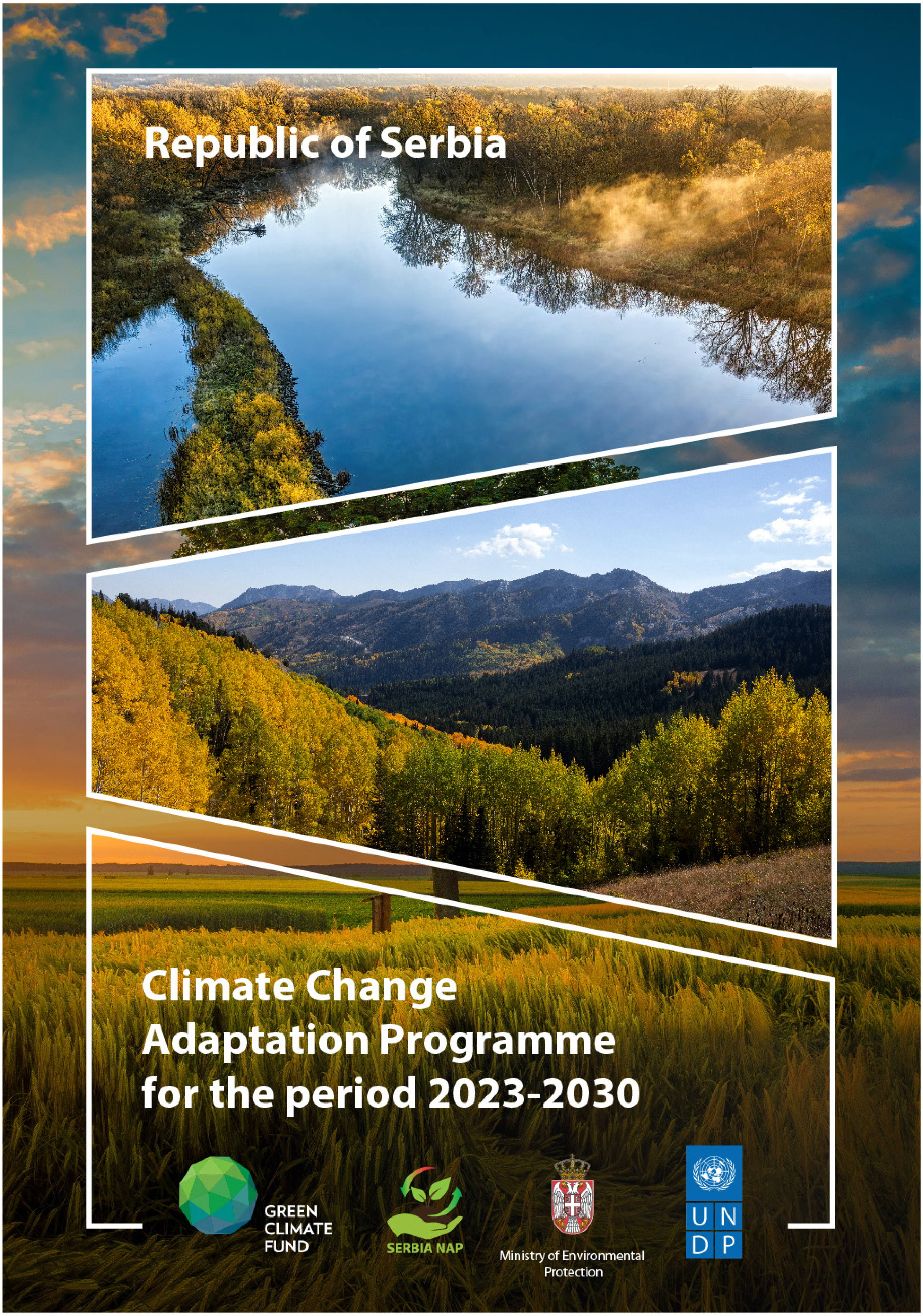

Republic of Serbia

Climate Change Adaptation Programme for the period 2023-2030

GREEN CLIMATE FUND

SERBIA NAP

Ministry of Environmental Protection

UNDP

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Pursuant to Article 13, paragraph 2 of the Law on Climate Change ("Official Gazette of the RS", Number 26/21), Article 38, paragraph 1 of the Law on the Planning System of the Republic of Serbia ("Official Gazette of the RS", Number 30/18), and Article 17, paragraph 1 of the Law on Government ("Official Gazette of the RS", Number 55/05, 71/05 - corrected, 101/07, 65/08, 16/11, 68/12 - Constitutional Court Decision, 72/12, 7/14 - Constitutional Court Decision, 44/14, and 30/18 – separate law),

.... the Government hereby adopts

CLIMATE CHANGE ADAPTATION PROGRAMME FOR THE PERIOD 2023-2030

INTRODUCTION

Climate change, which is occurring at least ten times faster than ever before in the history of the planet Earth, has increased damages and losses, threatened people's lives, and disrupted the functionality natural systems, both globally and in the Republic of Serbia.

Estimates show that the Republic of Serbia is warming more intensively and faster than the global average. While the observed increase in the global average temperature is 1.1°C, Serbia is already at 1.8°C, and in the summer, it is as much as 2.6°C. At the same time, since 2000, the Republic of Serbia has faced several significant extreme climate and weather events that have caused significant material and financial losses, as well as the loss of human lives. The total minimum material damages caused by extreme climatic and weather events in the 2000-2020 period amount to EUR 6.8 billion[1]. More than 70% of the damages were caused by droughts and high temperatures due to climate change and extreme weather events. Another major cause of significant losses was flooding. Therefore, the adoption and implementation of the 2023-2030 Climate Change Adaptation Programme (hereinafter: the Programme) is of general interest for the Republic of Serbia.

The climate hazards frequency and intensity will continue to increase in the future, with a clear trend of change until the mid-21st century period, after which the changes depend on the success of the implementation of the climate change mitigation measures specified in the Paris Agreement, which was signed and ratified by the Republic of Serbia.

The climate hazards that cause the most significant damage and losses in the Republic of Serbia and whose intensity and frequency are increasing are: heat waves, intensive precipitation and droughts. Other climate hazards that are caused by climate change and manifested depending on the regional characteristics are: floods, landslides, rockfalls, fires, etc. Vulnerability to climate change is exacerbated by air, water and soil pollution. The way that climate change impacts the territory of Republic of Serbia further amplify the problems caused by the pollution.

Natural and social systems, including the economy and ways of living, cannot adapt to the accelerated climate change without special plannings and interventions in the processes of implementation of activities related to disaster risk reduction, food production, preservation of forest and other ecosystems, infrastructure construction and restoration, energy production, public health protection, etc.

The climate change adaptation process represents implementation of measures to ensure reduced vulnerability to climate change of people, infrastructure, economy and environment, including natural resources. These measures must not contribute to a net greenhouse gas emissions.

[1] https://unfccc.int/sites/default/files/NDC/2022-08/NDC%20Final_Serbia%20english.pdf

The Programme ensures implementation of the climate change adaptation measures in a “smart” and “systemic” manner, meaning it relies on the existing knowledge and ensures future implementation of the science-based solutions as well as the adjustments of policies and methodologies to ensure sustainable future planning in the context of climate change.

Therefore, the Programme aims to provide the capacities for improving timely public dissemination of the information about weather and climate conditions and the climate hazards to increase the preparedness of individuals, entrepreneurs, and employers. At the same time, the Programme enables the implementation of the adaptation measures that have been identified as most urgent to prevent a multiple increase of damages and losses due to climate change impacts. The Programme also ensures the implementation of interventions related to direct defence against climate hazards where the impacts cannot be mitigated, the implementation of measures enabling the initiation and maintenance of the adaptation process in the future in a sustainable manner, as well as the implementation of measures enabling rapid incorporation of new scientific findings into the adaptation process.

The global experience in the development of climate change adaptation policy and other crosscutting policies implies two possible approaches:

1) preparation of a separate law and/or strategic documents regulating a specific issue/area;

2) inclusion of specific issues/areas in sectoral legislation and policies.

The experience has shown the latter approach to be more practical and ensure a more efficient implementation. Additionally, the experience has shown that a large number of policies, plans and activities do not include climate change scenarios, and rather base their objectives on climate trends (past changes), which does not ensure a reduction in the risk of natural disasters and climate hazards and risks. That is true for Serbia as well, and it is a problem that needs to be addressed through awareness raising and capacity strengthening.

The Programme provides information on climate change and its impacts even beyond the Programme implementation period, identifying the needs for further development of the multidimensional adaptation process, and the gaps in knowledge and information necessary for further sustainable development under the climate change. Appendix 1, which is printed along with this Programme and is an integral part of the Programme (hereinafter: Appendix 1), provides a contribution to the climate change assessment for the Republic of Serbia. Appendix 2, which is printed along with this Programme and is an integral part of the Programme (hereinafter: Appendix 2), provides a contribution to the climate change impact assessment for the agricultural sector. Appendix 3, which is printed along with this Programme and is an integral part of the Programme (hereinafter referred to as Appendix 3), provides a contribution to the climate change impact assessment for forests and forestry. Appendix 4, which is printed along with this Programme and is an integral part of the Programme (hereinafter: Appendix 4), provides measures impact assessment (this technical addition is not included in the version in English).

The Action Plan for the implementation of the 2023-2030 Climate Change Adaptation Programme (hereinafter: Action Plan), which is printed along with this Programme and is an integral part of the Programme, establishes the activities for the implementation of the measures and the achievement of the objectives defined by the Programme. The first Action Plan is valid for a period of three years (from 2024 to 2026).

1. Basis for the adoption of the Climate Change Adaptation Programme

In order to ensure the systemic implementation and monitoring of the climate change adaptation, which the Republic of Serbia committed to by signing the Paris Agreement (ratified in 2017), the Law on Climate Change, adopted in 2021, (hereinafter: the Law) prescribes the preparation of the Climate Change Adaptation Programme with the Action Plan.

The Programme was developed in accordance with the European Union Climate Change Adaptation Strategy principles (adopted in 2021), which prescribe the need for "smarter", "swifter" and "systemic" adaptation implementation, with an emphasis on the importance of preserving water resources, which are considered to be particularly affected by climate change. In the course of the final drafting of the Programme, the Guidelines on Member States' adaptation strategies and plans from June 2023 have also been taken into account.

1.1. National characteristics[2]

The Republic of Serbia is a continental European country located in the central part of the Balkan Peninsula, occupying an area of 88,499 km2. In the terms of physical geography, it comprises three dominant geographical regions: the Pannonian Plain, which includes Vojvodina, the northern, lowland part of Serbia, and a narrow strip south of the Danube and Sava rivers; the hilly landscapes with lower mountains and plains; and the mountainous areas. The highest mountain peak is Djeravica on the Prokletije mountain (2,656 m).

The largest part of the Republic of Serbia belongs to the Danube Basin. The total length of the Danube River flow in Serbia is 588 km. The Sava (206 km long), the West Morava (308 km), the Velika Morava (185 km), the Tisa (168 km), the South Morava (295 km), the Ibar (272 km), the Drina (220 km), the Timok rivers (202 km) and a number of smaller rivers also flow through Serbia.

Serbia has a moderate continental climate with more or less pronounced local characteristics. All four seasons are well pronounced. The warmest month is July, and the coldest month is January. Most of Serbia has a continental precipitation regime, with higher precipitation amounts in the warmer part of the year, and the highest monthly precipitation during June, while the lowest monthly precipitation is recorded in February and October. Snow cover occurs in the period from November to March. The highest number of days with snow cover is in January. The northwest and west winds prevail in the warmer part of the year, while the east and southeast winds (Košava) are characteristic for the colder part of the year.

The Republic of Serbia is a parliamentary democratic republic based on the rule of law. The political system is based on the separation of the legislative, executive and judicial powers. In administrative and territorial terms, the Republic of Serbia is divided into provinces, regions and administrative districts. The Republic of Serbia includes the Autonomous Province of Vojvodina and the Autonomous Province of Kosovo and Metohija, as forms of territorial autonomy. In addition, the territorial organization consists of five regions and the City of Belgrade, as a separate territorial unit. The Republic of Serbia is divided into 30 administrative districts. The local self-government system is a unitary and monotypic system, and consists of municipalities, cities and the City of Belgrade, as the local self-government units (29 in total, including Belgrade as a special status city). The total number of local self-government units is 197 (municipalities/city municipalities and cities). According to the average territory size and population, local self-government units in Serbia are among the largest basic territorial units in Europe (535 km^2 and approximately 49,000 inhabitants).

Since March 2012, the Republic of Serbia has EU membership candidate status.

[2]The national characteristics are shown in the Programme in accordance with the requirements of the Paris Agreement, which establishes the legal basis for the development of national climate change adaptaiton plans/programmes, as well as reporting on priorities, plans, activities and required assistance in this area, through an international public registry.

According to the first results of the 2022 Census of Population, Households and Apartments in Serbia, the Republic of Serbia has a population of 6,690,887 inhabitants[3]. The average population age in the Republic of Serbia has increased from 42.1 (2011) to 43.5 years (2021). In 2019, 56.26% of the total population in Serbia lived in urban areas. The largest cities are Belgrade (the capital, 1,688,667 inhabitants), Novi Sad (363,789), Niš (252,655) and Kragujevac (174,322). Besides Serbs, who are the majority population (83.3%), the most numerous ethnic groups in Serbia are Hungarians (3.5%), Roma (2%) and Bosniaks (2%).

According to the Sustainable Urban Development Strategy of the Republic of Serbia until 2030, there are 222 urban centres with more than 2,000 inhabitants identified in Serbia, of which 30 have the status of cities. According to the CORINE dataset, the surface area of urban zones in 2012 was 3.46% of the territory of Serbia, and the population density of urban settlements was 1,591 inhabitants per km^2.

The energy sector is the second largest sector in Serbia, with 10% of the GDP share. Electricity production in Serbia is mainly based on coal and, to a lesser extent, on hydropower. Although it produces smaller amounts of crude oil and gas domestically, the country remains highly dependent on imports, especially natural gas import. The adoption of the Law on the Use of Renewable Energy Sources in 2021 ("Official Gazette of the RS", Number 40/21 and 35/23) opened the way to a more successful transposition of the EU legislation on renewable energy sources and an increase in the renewable electricity production capacities.

The industrial sector generates approximately one quarter of GDP, employing slightly more than 27% of the employed population. The dominant industry is manufacturing - automotive, electrical and electronic industry, machine and equipment manufacturing, textile industry and metallurgy, with a 13% GDP share in 2021. Although the export of industrial products accounts for more than 90% of Serbia's total exports, the industry is plagued by a range of structural problems, from low competitiveness and a low levels of automation of business processes in the traditional industrial sectors, through limited and inadequate financing for innovative activities, to insufficient cooperation between the industrial sectors and the scientific and research community.

Traditionally, the dominant type of transport is road transport, with approximately 80% share in the total freight transport volume, i.e., with approximately 74% share in the total number of passengers transported. The physical volume indices for land transport services in the 2016-2021 period increased by 43.8%, mainly due to the increase in the volume of road (72.9%) and river (103.3%) transport, while the volume of rail and air transport services decreased. In the same period, a large increase in the volume of road freight and air transport was recorded, with a decrease in passenger transport.

Serbia has a high share of agriculture in GDP (7.5% in 2020), which ranks it among the agricultural countries. The share of plant production is 68.4%, while livestock production is 31.6%. The production of agricultural goods and services has increased by 39.3% since 2011. The largest part of agricultural land is used as arable land and gardens (75%), of which 67.7% is used for grain crops. There is a pronounced trend in land use repurposing, primarily as a result of the uncontrolled urban construction area growth and the intensive urban settlements expansion at the expense of agricultural land.

According to the First National Forest Inventory data, forests cover 29.1% of the country's territory, while preliminary results from the Second National Forest Inventory of the Republic of Serbia show that forests cover 39.3% of the total area of Serbia. In relation to ownership, the Second National Forest Inventory preliminary data shows a change in the ownership structure. While in the First National Forest Inventory, state-owned forest ownership dominated with 53%, compared to 47% of private forests, the situation is now different and private forests cover 57.5% of the area, while state-owned forests are represented by 42.5%.

In 2020, 2.95 million tons of municipal waste were generated in the Republic of Serbia, i.e. 1.17 kg per capita per day, or 0.43 t/year. Of this waste 19% is disposed in sanitary landfills, while the remaining waste is disposed in garbage dump sites.

[3]Since 1999, the Statistical Office of the Republic of Serbia does not have some of the data for AP of Kosovo and Metohija, and this data is not included in the data for the Republic of Serbia (aggregate data).

Water supply is provided through more than 150 public water supply systems. The share of population connected to the public water supply in 2013 was 82%, while the share of urban population connected to the public water supply is significantly higher. Water supply systems are mostly old, with high distribution losses. The key water pollution sources include untreated industrial and municipal wastewater, agriculture drainage water, landfill leachate and drain water, as well as pollution caused by river navigation and thermal power plants operations.

1.2. Climate change adaptation legal framework

1.2.1. International context

As a response to one of the greatest global challenges of our time - climate change, the United Nations Framework Convention on Climate Change (UNFCCC)[4] was adopted and introduced the climate change adaptation concept and term, but its primary goal was the reduction greenhouse gas emissions. The Paris Agreement[5] (adopted in 2015) introduced for the first time climate change adaptation in legally binding terms and included loss and damage as a component. The Paris Agreement establishes the legal basis for the development of the National Adaptation Plans/Programmes (NAPs), as well as reporting on the priorities, plans, activities and the assistance needs in this area, through an international public registry[6].

The Republic of Serbia has been a member of the UN Framework Convention on Climate Change since June 10, 2001 (Non-Appendix I Party), and a member of the Paris Agreement since August 24, 2017, having passed the Law on Ratification of the United Nations Framework Convention on Climate Change, including Annexes ("Official Gazette of the FRY - International Treaties", Number 2/97), and the Law on Ratification of the Paris Agreement ("Official Gazette of the RS - International Treaties", Number 4/17).

In institutional terms, alongside the UN Framework Convention on Climate Change, the Intergovernmental Panel on Climate Change (IPCC) plays a significant role in shaping global climate change policies and goals.

The 2030 Agenda for Sustainable Development came into force on January 1, 2016. This global development agenda for the period after 2015 to 2030 expects the signatory countries to mobilize all resources to eradicate poverty, combat inequality and address climate change. These three dimensions of sustainable development are embedded in the 17 Sustainable Development Goals (SDGs). A specific Sustainable Development Goal, SDG 13 - Climate action, is in direct correlation with several other Sustainable Development Goals and is expected to achieve synergistic effects. These include, inter alia, SDG 7: Affordable and clean energy, SDG 11: Sustainable cities and communities, and SDG 15: Sustainable forest management, combating desertification and reversed land degradation.

The 2021 Glasgow Leaders' Declaration on Forests and Land Use was signed by 145 presidents of the countries that contain almost 91% of all forests on the planet, including the Republic of Serbia. As part of the Declaration, the signatory countries committed to work together to halt deforestation and land degradation by 2030, while contributing to sustainable development and rural transformation.

1.2.2. EU framework

The EU Climate Change Adaptation Strategy[7] - was adopted in February 2021, based on the previous 2013 EU Strategy, with the main goal of increasing the resilience of the EU and the Member States to climate change. Within the EU Strategy framework, Member States are invited to adopt their comprehensive strategies and provide financial resources for the implementation of identified/necessary adaptation actions and for the national adaptive capacity strengthening. The EU Strategy emphasizes in particular the necessity of establishing an effective adaptation system at the level of local self-government units under the Covenant of Mayors for Climate and Energy Initiative. In principle, the EU insists

[4] https://aarhusns.rs/wp-content/uploads/2021/01/Okvirna-konvencija-UN-o-promeni-klime.pdf
[5] http://www.parlament.gov.rs/upload/archive/files/lat/pdf/predlozi_zakona/3074-16%20-LAT.pdf
[6] https://www4.unfccc.int/sites/NAPC/Pages/national-adaptation-plans.aspx
[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:82:FIN

on establishing an efficient monitoring, reporting and evaluation system, prioritizing monitoring and reporting. The Strategy has four main objectives: to make adaptation smarter, swifter and more systemic, and to enhance international action on adaptation to climate change.

The new EU legislation, which has been implemented since in 2021, in accordance with the Paris Agreement, introduces for the first time adaptation to climate change. Regulation (EU) 2018/1999[8] requires the inclusion of climate change impact on the energy supply security assessment in the National Energy and Climate Plans (NECPs), primarily through the availability of cooling water for power plants and biomass availability for energy production. The biennial NECP implementation reports should contain, inter alia, information on climate change adaptation. Regulation (EU) 2018/1999 also mandates biennial reporting on national climate change adaptation planning and strategies, planned and implemented actions to facilitate adaptation to climate change, specifically:

1) the main objectives and institutional organization;
2) climate change scenarios, climate extremes, climate change impacts, vulnerability and risks assessment and major climate hazards;
3) capacity for climate change adaptation;
4) adaptation plans and strategies;
5) monitoring and evaluation framework;
6) implementation progress, including good practices and governance changes.

In addition, the subject of Regulation (EU) 2018/1999 is reporting on financial, technical and capacity-building assistance provided to developing countries for the implementation of climate change adaptation and mitigation measures and activities. Regulation (EU) 2020/1208[9] specifies the reporting format in which Member States need to submit information on their national climate change adaptation measures, in accordance with Article 19 of Regulation (EU) 2018/1999, as well as the observed climate hazards.

For the EU, the overall policy and legislation effectiveness is conditioned by the inclusion of climate change adaptation in the sectoral policies, especially in the areas of: infrastructure, agriculture, forest and water management, health, and disaster risk reduction, and continued progress is required in strengthening adaptive capacity and resilience to climate change.

European Green Deal was presented in 2019, and sets out an ambitious plan for a climate-neutral economy enabling economic growth simultaneously with greenhouse gas emission reduction and climate change adaptation.

Green Agenda for the Western Balkans - envisages the climate action, including decarbonization and climate change adaptation, as one of its five pillars. The Western Balkans countries fully supported it and adopted the regional Action Plan[10] for its implementation, based on the Sofia Declaration on the Green Agenda for the Western Balkans.[11]

1.2.3. Planning documents

The Programme was developed as a public policy document in parallel with other public policy documents, primarily with the Draft Environmental Protection Strategy, and it specifies the measures and activities within the first pillar of the Strategy. In addition, the Programme is linked to a number of other public policy documents that have been adopted or are under preparation. At the national level, the key public policy documents that relate to climate change adaptation and which have recognized this subject area are presented below. However, a significant number of public policy documents of importance for this field do not contain any climate change adaptation measures, nor do they take this area into consideration.

[8] REGULATION (EU) 2018/1999 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1999&from=EN

[9] EUR-Lex-32020R1208-EN-EUR-Lex(europa.eu)

[10] https://www.rcc.int/files/user/docs/637b6b83ba51c1b8607763d6c557d121.pdf

[11] https://www.pregovarackagrupa27.gov.rs/wp-content/uploads/2021/06/Deklaracija-iz-Sofije-o-Zelenoj-agendi-za-Zapadni-Balkan-SRP.pdf

The revised Serbian Nationally Determined Contribution (NDC)[12] , submitted in August 2022, includes an assessment of damages and losses caused by climate change for the 2000-2020 period.

The Low Carbon Development Strategy of the Republic of Serbia for the period 2023-2030 with projections by 2050 ("Official Gazette of the RS", Number 46/23)[13] ,adopted in June 2023, recognizes the risks of climate change for the sustainable development of the Republic of Serbia. In particular, the Strategy defines two specific objectives that take into account climate change adaptation - Specific Objective 4: Preserving the potential of mitigation measures, specified for the periods until 2030 and until 2050, by increasing climate change resilience in the priority sectors; and Specific Objective 5: Promoting transition to climate-neutral economy and climate-resilient society.

The Nature Protection Programme of the Republic of Serbia for the period from 2021 until 2023 ("Official Gazette of the RS", Number 53/21)[14] recognizes the direct impact of climate change on nature at the national level; weak interaction between climate change and biodiversity research networks, policy makers and stakeholders; lack of systematic monitoring of climate change impacts on biodiversity, as well as insufficient number of climate change impact projection models. A low public awareness of the climate change impact on biodiversity has been recognized. The Programme specifies the measure "Establishing monitoring of climate change impact on biodiversity and the impact of biodiversity on mitigating climate change effects" (within Special Objective 1.1. Mitigated adverse impacts on biodiversity). The Nature Protection Programme Implementation Action Plan identifies also specific activities under the responsibility of the Ministry of Environmental Protection.[15]

The Sustainable Urban Development Strategy of the Republic of Serbia until 2030 ("Official Gazette of the RS", Number 47/19)[16] has identified the uneven quality of environment, public health protection and safety, and the lack of climate change adaptation in urban settlements as some of the key issues relating to urban development. In order to address these issues, the Strategy provides sets of measures, including Adaptation to climate change and the establishment of a response system for high-risk and emergency situations in urban settlements (4.2). Considering that the revised Sustainable Urban Development Strategy is under preparation, the parts of the Programme related to climate change adaptation are harmonized with the Draft Strategy.

The Agriculture and Rural Development Strategy of the Republic of Serbia for the period 2014-2024 ("Official Gazette of the RS", Number 85/14)[17] - as well as the IPARD II and IPARD III programmes, include issues related to climate change and specify adaptation measures both at the level of agricultural producers/farms and the agriculture sector as a whole. The document does not take into account different climate change scenario results and indicators derived from those scenarios. Nevertheless, the above documents, in addition to the support measures, provide a detailed list of indicators for measuring progress in this area. *However, there are no identified objectives that relate to climate change adaptation.*

[12] https://unfccc.int/sites/default/files/NDC/2022-08/NDC%20Final_Serbia%20english.pdf
[13] http://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/vlada/strategija/2023/46/1/reg
[14] https://www.ekologija.gov.rs/sites/default/files/inline-files/Program%20zastite%20prirode%20RS%202021-2023.%20godine.pdf
[15] The proposed activities within the Nature Protection Programme that relate to climate change include: Defining methodologies and indicators, the number of species, habitats and ecosystems used for monitoring climate change impact on biodiversity (1.1.1.1); Developing specific measures to protect the species and habitats vulnerable to climate change in the relevant planning documents and implementing measures to adapt and mitigate climate change effects on natural ecosystems and wild flora and fauna species at the national, regional and local levels (1.1.1.2); Preparation and publication of media announcements and scientific papers and preparation and implementation of campaigns to raise public awareness about climate change impact on biodiversity (1.1.1.3).
[16] https://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/vlada/strategija/2019/47/1/reg
[17] https://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/vlada/strategija/2014/85/1

The Forestry Development Strategy of the Republic of Serbia ("Official Gazette of the RS", Number 59/06)[18] - recognizes the role of forests in climate change mitigation, and in the part related to the financial requirements for the implementation of the Strategy, it is stated that the government will improve income generating opportunities through the introduction of a new contributions scheme for preservation and improvement of the forest ecosystems regulatory function in mitigating global climate change and other generally beneficial forest functions.

The 2018-2026 Serbian Public Health Strategy ("Official Gazette of the RS", Number 61/18)[19] - specifies the health improvement and health inequality reduction activities, which stipulate, inter alia, improving the environment status and response to climate change, as well as developing action plans for responding to climate change in cities. These activities are not recognized in the Strategy, nor in the Action Plan. It is stated that the "health in all policies" concept is an integrated and recommended approach that enables the achievement of the goals of all government departments, through an institutionalized and intersectional process involving all stakeholders.

The National Security Strategy of the Republic of Serbia ("Official Gazette of the RS", Number 88/09)[20] - recognizes climate change as a challenge and a threat to the environment and resources, and thus to the national security of the Republic of Serbia. Preservation of the environment and resources is achieved, as envisaged in the Strategy, through monitoring, assessment, and planning and implementation of measures to mitigate the climate change impacts.

The Tourism Development Strategy of the Republic of Serbia for the period 2016-2025 ("Official Gazette of the RS", Number 98/16)[21] - in the key tourism trends review, the Strategy refers to climate change only once, specifying that it could influence the tourists' behaviour and motivation.

The Energy Development Strategy of the Republic of Serbia until 2025 with projections until 2030 ("Official Gazette of the RS", Number 105/15)[22] - does not take into account aspects of climate change adaptation in the energy sector.

The Water Management Strategy of the Republic of Serbia until 2034 ("Official Gazette of the RS", Number 3/17)[23] recognizes climate change as an important factor in the water management sector, in terms of preserving the water regime, especially in the future, when more intense flooding events and drought periods are expected due to temperature and precipitation regimes changes. However, there is a need to revise the measures and activities in accordance with the latest data and information on climate change to adequately integrate climate change adaptation into the Strategy.

The Industrial Policy Strategy of the Republic of Serbia from 2021 to 2030 ("Official Gazette of the RS", Number 35/20)[24] recognizes climate change as one of the strategic challenges in the field of new industrial policy interventions, as part of the requirements for sustainable, green and resource-efficient industrial production.

1.2.4. Legislative framework analysis

The Constitution of the Republic of Serbia[25]- guarantees the right of every citizen to a healthy environment and to timely and complete information about the status of environment (Article 74).

The Law on Climate Change ("Official Gazette of the RS", Number 26/21)[26]- establishes the basis for planning, updating and implementing policies, measures and activities in the field of climate change adaptation. The Law prescribes the obligation to develop the Climate Change Adaptation Programme, which is also an obligation under the Paris Agreement and Regulation (EU) No 525/2013 of the European Parliament and of the Council of the European Union of 21 May 2013 on a greenhouse gas monitoring and

[18] https://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/vlada/strategija/2006/59/1
[19] http://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/vlada/strategija/2018/61/1/reg
[20] https://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/skupstina/strategija/2019/94/2
[21] https://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/vlada/strategija/2016/98/1
[22] https://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/skupstina/ostalo/2015/101/1/reg
[23] https://www.paragraf.rs/propisi/strategija-upravljanja-vodama-u-srbiji-do-2034.html
[24] https://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/vlada/strategija/2020/35/1/reg
[25] http://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/skupstina/ustav/2006/98/1/reg
[26] http://www.parlament.gov.rs/upload/archive/files/cir/pdf/zakoni/2021/337-21.pdf

reporting mechanism and reporting other information at national and EU level relevant to climate change.[27]

The Law on Meteorological and Hydrological Activity ("Official Gazette of the RS", Number 88/10)[28] - governs meteorological and hydrological activities of interest to the Republic of Serbia, which include, *inter alia*: systemic meteorological and hydrological measurements and observations within the national meteorological and hydrological stations network, climate database development and maintenance, establishment and operational functioning of the multi-purpose hydrometeorological and early warning and alerts system for extreme weather, climate and hydrological events, disasters and catastrophic events in the territory of the Republic of Serbia, including assessment and mapping risks of meteorological and climate natural disasters and catastrophic events for the purposes of the Disaster Risk Assessment in the Republic of Serbia, climate change monitoring and research, and multidisciplinary research of the climate change impacts on health, water resources, agriculture and other sectors, development of climate models and their application, development of regional and local climate change scenarios, and provision of climate services in the function of climate change vulnerability assessment and the climate change adaptation measures implementation.

The Law on Disaster Risk Reduction and Emergency Management ("Official Gazette of the RS", Number 87-18)[29] governs disaster risk reduction and emergency management, with disaster risk reduction including also climate change monitoring and adapting communities to expected consequences. Based on this law, the Instruction on the Methodology and Content of Disaster Risk Assessment and Protection and Recovery Plan ("Official Gazette of the RS", Number 80/19) has been developed.

This methodology recognizes 12 hazards in total, including the Extreme Weather Events hazard (heavy precipitation; hail; stormy wind; blizzards, snow drifts and ice; heat waves; cold waves; drought) and specifies the parameters and criteria that should be used to assess this group of hazards. The criteria refer to the statistical presentation of the phenomena over the last 30 years and the presentation of the consequences over the last ten years that have caused significant changes in the daily functioning (vital products supply interruptions, electricity supply interruptions, traffic interruptions, emergency medical assistance delivery delays, etc.) and potential impacts on agriculture, human and animal health, as well as the possibility of generating other hazards, etc. The Republic Hydrometeorological Service of Serbia (RHMSS) has prepared a hazard assessment in accordance with all the above parameters and the professional estimates, and developed future events scenarios, taking into account the probabilities, i.e., the increasing frequency or the likelihood of the extreme weather events occurrence.

The parameter "climate change impact" has not been specified explicitly for specific hazards, as it was done in the case of flood risk, for example.

Considering that the methodology for the preparation and the contents of the disaster risk assessment and the protection and recovery plan is to be revised, as foreseen in the Action Plan, it will be amended also to include the parameter related to the climate change. Considering that the Ministry of Internal Affairs, other ministries, authorities and special organizations, as well as local self-government units are to be involved in the preparation of the Disaster Risk Assessment in relation to the relevant levels and sectors of their competence, they will obtain the information on climate factors from the competent institution (The Republic Hydrometeorological Service of Serbia) as was the case during the first assessment development cycle.

After the revised methodology is adopted, the Serbian Disaster Risk Assessment, including all other assessments at lower governance levels, will also be revised.

Article 12 of the Law on Disaster Risk Reduction and Emergency Management prescribes the development of the Disaster Risk Reduction and Emergency Management Strategy, which will specify disaster risk management policy and direction of the activities of the state authorities and other entities in disaster risk management, provide

[27] Agreement and Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 March 2013
[28] https://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/skupstina/zakon/2010/88/9/reg
[29] https://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/skupstina/zakon/2018/87/1/reg

the guidelines for committing human and material resources, and for the development of the normative and institutional framework aimed at reducing risk and providing an efficient response to disaster challenges. The disaster risk reduction policy and the identification and implementation of measures and activities in this area are strongly correlated with the climate change adaptation policy. The Law on Disaster Risk Reduction and Emergency Management, in Article 11, Item 9, specifies that risk reduction includes, inter alia, "monitoring climate change and adapting the community to the expected consequences". The Law on Disaster Risk Reduction and Emergency Management , in Article 16, prescribes the development of the National Disaster Risk Reduction Plan, the Provincial Disaster Risk Reduction Plans, and local disaster risk reduction plans.

The Law on Reconstruction after Natural and Other Disasters ("Official Gazette of the RS", No. 112/15) governs the post-disaster recovery and reconstruction process, as well as assistance to individuals and businesses that have suffered disaster-related damages. The Ministry for Public Investment is responsible for coordinating the needs assessment and the reconstruction implementation. This law is harmonized with the international standards, and among other important principles, Article 10 establishes the "Building Back Better" principle, which implies that the authorities participating in the reconstruction preparation and implementation should strive to ensure that the building and infrastructure reconstruction implies the construction of a better system that would make the buildings, infrastructure and society as a whole more resilient to natural and other disasters.

Article 16 of the Law on Reconstruction after Natural and Other Disasters stipulates that damage assessment is to be carried out in accordance with the Integrated Methodology for Assessing Damage from Natural and Other Disasters. In the Republic of Serbia, the Instruction on Integrated Methodology for Assessing Damage from Natural Disasters ("Official Gazette of SFRY", Number 27/87) is still in force. Although that is a high-quality document, which is still used when natural and other disasters occur, considering the time that has passed since its creation and the different social and political circumstances of the present time, the document is currently being improved and harmonized with the international standards and the international Post Disaster Need Assessment methodology (PDNA), which was jointly adopted by the United Nations, the European Union and the World Bank. This methodology arose out of the need for a standardized and comprehensive post-disaster needs assessment, which would be multi-sectoral and all-inclusive. Such assessments would provide quality basis for the reconstruction process and building a more disaster resilient society. In addition, the revised document will take into account the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts, which was established under the United Nations Framework Convention on Climate Change, and implements Article 8 of the Paris Agreement. This mechanism aims to ensure development assistance for countries that are particularly vulnerable to climate change, inter alia, by strengthening knowledge and understanding of comprehensive risk management approaches to address loss and damage issues. The aim of integrating these two documents and the climate-related loss and damage inventory is to further assess the climate effects and impacts in the sectors that are most vulnerable to disaster-related damage and losses.

1.2.5. Institutional framework analysis

The Ministry of Environmental Protection (MEP) is responsible for climate change at the national level. Pursuant to the Law on Climate Change, the Ministry is responsible to prepare the Climate Change Adaptation Programme to identify the climate change impacts on specific sectors and systems, and to identify climate change adaptation measures in the sectors and systems where there is a need to reduce the adverse impacts. The Law further stipulates that the public policy documents in the sectors most affected by climate change, as well as the planning documents of the Autonomous Provinces and local self-government units, shall take into account the Adaptation Programme objectives. The authorities and organizations responsible for implementing the adaptation measures specified in the Adaptation Programme are obliged to submit to this Ministry, by March 15 of each year, a report on the implemented adaptation measures, as well as weather events such as floods, extreme temperatures, droughts, etc., and their effects in relation to the year of adoption of the Adaptation Programme.

The Republic Hydrometeorological Service of Serbia (hereinafter: RHMSS) is a separate organization within the Serbian public administration system, in charge of the professional tasks and public administration activities related to: meteorological, meteorological-radar, agro-meteorological and hydrological observation and analytical-prognostic systems; systematic meteorological, climatological, agrometeorological and hydrological measurements and observations; bank of observed and measured hydrological and meteorological data; weather, climate and water status, and changes monitoring, analysis and forecasting conditions and changes in weather, climate and waters, development of methods, operational observation and warnings of atmosphere and hydrosphere phenomena; aviation meteorology; research of processes in the atmosphere and hydrosphere and development of methods and models for forecasting weather, climate and water, and weather modification; hail protection; development of proposals for the use of solar and wind energy potentials; hydrometeorological support to river navigation; creation and storage of etalons and calibration of meteorological and hydrological instruments; cooperation in the field of international hydrological and meteorological information systems; fulfilment of international obligations in the field of meteorology and hydrology. Within international meteorological and hydrological organizations, the RHMSS performs the functions of the National Hydrometeorological Service of the Republic of Serbia, and, in accordance with the ratified international agreements, fulfils the Republic of Serbia's obligations in the World Meteorological Organization (WMO), the European Centre for Medium-Range Weather Forecasts (ECMWF), the European Association of National Hydrometeorological Services of EU Member States (EUMETNET), and is the focal point for the Intergovernmental Panel on Climate Change (IPCC).

The Environmental Protection Agency (EPA), as an administrative authority within the Ministry of Environmental Protection, carries out the national air and water quality monitoring, it is responsible to collect and monitor the environmental indicators, including those that relate to climate change adaptation, and cooperates with the European Environment Agency (EEA) and the European Environmental Information and Observation Network (EIONET).

Considering the multi-sectoral nature of climate change issues, the National Climate Change Council is one of the important institutes for achieving social consensus on climate change. In accordance with the Law on Climate Change, the Council consists of representatives of the Ministry and other government institutions, as well as representatives from the scientific and professional community, civil society and others whose field of activity is important for identifying and implementing activities in the field of climate change, and one representative from the Office of the Commissioner for the Protection of Equality of the Government of the Republic of Serbia. The Council members are appointed by the Government for a five-year term with the possibility of re-election. The Council is chaired by the minister responsible for environmental affairs. The task of the Council, inter alia, is to consider the status, development and implementation of the national climate change policy, sectoral policies and other planning documents, as well as to examine the fulfilment of the Republic of Serbia's international obligations in the field of climate change, etc.

2. The Programme drafting procedure

In accordance with the provisions of Articles 32 and 34 of the Law on the Planning System of the Republic of Serbia ("Official Gazette of RS", Number 30/18), the start of drafting the Climate Change Adaptation Programme with an Action Plan was announced on February 11, 2022, and the stakeholders were invited to participate in its development. The Working Group for the development of the Programme, in accordance with the Decision on Establishment, included representatives of state authorities, as well as representatives of the economy, local self-governed units and non-governmental organizations.

As part of the development of this Programme, an analysis of the existing knowledge about climate change and its impacts has been conducted, and the necessary additional analyses has been made in accordance with the existing and available information.

Due to the accelerated changes in the climatic impact-drivers, a new climate change analysis has been prepared and included the observed state until 2020 and future climate projections based on two scenarios of future greenhouse gas emissions, RCP4.5 and RCP8.5, for the selected future climate periods, following the methodology from the most recent IPCC report, i.e., IPCC Sixth Assessment Report. The results are presented in *Chapter 3* and *Appendix 1.*

In order to identify the adaptation measures, the vulnerability and risk assessments have been conducted for the sectors where there was sufficient knowledge, i.e. data and information, available, while for other sectors, the climate change impacts and specific measures have been identified in accordance with the current knowledge, with the aim of expanding that knowledge in the future. The prepared analyses and the proposed measures have a scientific background and are supported by the scientific literature and methodologies.

Assessing vulnerability to climate change implies understanding the sensitivity of systems or sectors to weather and climate conditions and their exposure to these conditions. Vulnerability is identified based on the observational data and knowledge, i.e., by connecting the system (sector) parameters to the climatic impact-drivers. Future climate projections show the changes in the relevant climatic impact-drivers in the future. The connections with system parameters (identified impacts, damages and losses), determine whether there will be an increase in the climate change risk in the future. After the growing risks have been identified, the climate change adaptation measures have been specified to reduce the future risk of negative climate change impacts, by reducing the vulnerability of the sector in the future or by increasing the speed of recovery. In order for the adaptation measures to be feasible in the short term, the priority measures that must be implemented or start to be implemented during the life of this Programme have been identified. It has to be noted that the adaptation measures identified at the national level provide the conditions for initiating and maintaining the adaptation process in the future, which should continuously evolve in line with the climate change. They enable individuals and sectors to achieve and maintain the highest possible level of resilience to climate change.

For the agriculture sector, vulnerability and risk analysis has been conducted by sub-sectors *(Chapter 5.2* and *Appendix 2)*. Based on the obtained results, and with the priority of achieving resilience to the climatic conditions of the middle of the 21st century, the measures have been identified that would ensure the capacities for protection against the highest risk extreme weather conditions, enable timely action with the aim of reducing damages and losses, and enable future production planning in accordance with the changed climatic conditions. All this would be achieved ensuring also the preservation of water and land resources and the environment. The measures would serve to provide education, capacities and necessary timely information and to expand knowledge, while the adaptation is carried out by the manufacturer.

For the forestry sector, a vulnerability and risk assessment has been conducted (*Chapter 5.3* and *Appendix 3*). In this sector, the measures have been identified that would enable the implementation of the activities aimed at maintaining and improving the forest and forest ecosystems health and productivity under the altered climate conditions, in accordance with the range of most likely future climate conditions outcomes by the end of the 21st century. The measures indicate the need for education and regulatory changes that would ensure the sustainable adaptation process. The analyses also show the need to establish forest cover in the areas with the increased risk of degradation due to climate change.

For the sectors of the road infrastructure, urban planning, health and biodiversity (*Chapter 5*), a vulnerability and risk assessments have not been conducted, but the climate change impacts, i.e., changes and damages that occur as a consequence of climate change, have been identified. Due to the lack of data, it was not possible to make a comprehensive analysis at the national level. For these sectors, the Programme proposes, inter alia, to expand the knowledge for future assessments. For the energy sector, a vulnerability and risk assessment has not been conducted, but the impacts are known, and a climate change impact assessment based on the climate parameters relevant to production planning is envisaged. While water resources have not been not considered as a separate sector, the information from the climate vulnerability assessment for water resources has been included in the sectoral analyses through the nexus approach. This Programme considers the atmosphere, soil and water are as inseparable climate system components, necessary for the social systems functioning. The adaptation measures, where relevant, take into account the vulnerability of all components of the climate system and their implementation must not cause an increase in the vulnerability of another sector or any of the components of the climate system. This approach has been considered necessary during the development of the Programme to ensure that the adaptation process is effective and sustainable in the future.

The assessment of the changes in the climatic impact-drivers and other climate hazards has indicated the need to include this information in the processes aiming at reduction of disaster risks due to the intensified climate hazards. For the successful climate change adaptation and achieving the sustainable resilience to climate change in the future, it is necessary to ensure the implementation of vulnerability and risk assessments and adaptation measures at the local level considering the specificity of climate change impacts in different areas. Due to the significant increase in the risk of climate hazards, there is a need to make possible for all individuals to be involved in the adaptation process to ensure that they can protect themselves, their property and their jobs. That is why the Programme, through its measures, ensures the adaptation mainstreaming through amendments and changes to national regulations and methodologies, and provides the conditions for increasing the capacity for education on climate change and risks and for timely informing the public about the climate hazards whose frequencies and intensities are increasing.

The Adaptation Programme measures are grouped by sectors, according to the sector responsible for implementing the measures, with the cross-sectoral connections in the adaptation process also identified. In addition to the sectoral measures, the measures of general importance have been identified that have a wider contribution, i.e., direct and indirect multisectoral benefits, or that provide the possibility for monitoring the national-level adaptation activities.

The Programme measures have been developed within a consultative process with the stakeholders and the members of the Working Group.

3. Analysis of the observed and future climate change

This Chapter provides the relevant information on climate change at the global level and in the Republic of Serbia and their analysis, in order to understand the rate of change of climate conditions compared to the global and regional averages and a high degree of confidence of the presented assessments due to the long-term monitoring and regular updating of the analysis. Appendix 1 provides additional information on climate change, methodology and reliability of assessments, which can be useful for education and understanding of the interconnections between the environmental components and the social systems in terms of climate change vulnerability and risk, adaptation planning in different sectors, and planning at the local level. The references and data sources used in this analysis are also listed in Appendix 1. In addition to the analysis, this Chapter also provides the recommendations based on the obtained results and identified gaps.

3.1. Overview of the climate change monitoring in the Republic of Serbia

In the Republic of Serbia, changes in climate conditions are being monitored for more than ten years, including the observed climate change and the future changes until the end of the 21st century under different greenhouse gas emission (GHG) scenarios. The reporting to the United Nations Framework Convention on Climate Change (UNFCCC) related to climate change adaptation is conducted through the national reports (National Communications). Serbia has adopted two such reports (Initial National Communication of the Republic of Serbia under the United Nations Framework Convention on Climate Change, Ministry of Environmental Protection, 2010; Second National Communication, Ministry of Environmental Protection, 2017). The Second National Communication under the United Nations Framework Convention on Climate Change provides an analysis of the observed climate change effects until 2012, while the predicted future climate changes are considered according to the IPCC Special Report on Emissions Scenarios (SRES) greenhouse gas emission scenarios, in line with the IPCC Fourth Assessment Report (Working Group Report I; IPCC, 2007). The selected scenarios for analysis at that time were SRES A1B and A2, or the so-called “medium” and “extreme” scenario, considering that the future climate condition assessments under these two scenarios envelope the most likely outcomes of climate change for the purposes of adaptation planning.

Considering that the Second National Communication had been adopted relatively late considering when the analysis are being done and after the publication of the IPCC Fifth Assessment Report, which includes new scenarios of future greenhouse gas emission - RCP (Representative Concentration Pathways; IPCC, 2013), and that the observed climate change and its impacts in the Republic of Serbia have become more pronounced, the preparation of new analyses for the Third National Communication was initiated immediately. The new analyses of the observed climate changes were completed for the period until the end of 2017, and the analyses of future climate change projections were made according to the RCP4.5 and RCP8.5 scenarios for the selected future climate periods (Đurđević et al., 2018) in accordance with the IPCC Fifth Assessment Report (the near-future period (2016-2035), mid-century period (2046-2065), and the end-of-century period (2081-2100), in relation to the base period 1986-2005. These scenarios were adopted as the scenarios under which the climate projections provide the results that include the most likely range of future climate conditions and thus provide a basis for the climate change risk assessment for sectors. The RCP4.5 scenario considers the stabilization of GHG emissions after 2040 and that the global air temperature increase will be in the range 2 °C to 3 °C compared to the average temperature for pre-industrial period. This scenario is considered to be “the middle of the road” scenario toward the fulfilment of the Paris Agreement, i.e., it implies a partial implementation of the Agreement. The RCP8.5 scenario assumes that the GHG growth trend will continue, i.e., that the mitigation measures (reduction in the global GHG emissions) will not be implemented. The most likely expected mean global air temperature increase by the end of the century compared to the pre-industrial period under the RCP8.5 scenario is approximately 4.5°C. In addition to the climate change assessment, an impact assessment under the selected scenarios for the agriculture sector was conducted and published, including also an analysis of the farmers survey on the effects of climate and weather conditions on agricultural production (Stricevic et al., 2019). The impact assessments for other vulnerable sectors were also prepared and were used or improved in the process of the development of this Programme.

The climate change monitoring in the Republic of Serbia to date indicates unequivocally the main characteristics of climate change in the Republic of Serbia[30] that include: (a) increase in the mean temperature, with the mean maximum temperature increase exceeding the mean minimum temperature increase, and with the most significant increase during the summer season; (b) no significant change in the mean annual precipitation; the change in the distribution of precipitation by intensity as an average decrease in the number of moderate and low precipitation days and an increase in the number of heavy and extreme precipitation days; the change in the annual distribution of precipitation as the prolongation of the drier summer season and the shift of the average monthly precipitation maximum toward an earlier period (on average, from late spring and early summer to an earlier period in the spring); (c) increased frequency and intensity/duration of heat waves; (d) increased frequency and intensity/duration of droughts.

As part of the project “Advancing Medium- and Long-term Adaptation Planning in the Republic of Serbia”, financed by the Green Climate Fund, the necessary support was provided for a further improvements in climate analyses, impact assessments and availability of the climate data, to ensure a systematic approach in the adaptation process in the Republic of Serbia, as well as to enable the implementation of the adaptation measures relevant at the local level.

The IPCC issued their Sixth Assessment Report of the Working Group I in 2021 (IPCC, 2021). The Law on Climate Change, which was adopted in 2021, prescribes the obligation to prepare the Climate Change Adaptation Programme, which is to be adopted in 2023. Parallel with the preparation of the Third National Communication, the Republic of Serbia has also initiated the preparation of this Programme. Considering that the Green Climate Fund grant funding had been secured, and that the new IPCC report results have become available (including the improved climate change and climate change impact assessment methodology), as well as the need to include the climate assessment results in the Programme in accordance with Article 14 of the Law, the following steps have been taken to improve and systematize the results: credibility of the selected climate change assessment methodologies in the Republic of Serbia has been verified (the observed climate data source and selection of models to be used for the future climate conditions assessment), the most important climate indicators for climate change and its impacts monitoring have been selected, and data have been made available for use for the impact assessments in the sectors where was possible to implement such information.

For the purposes of developing the Programme and in order to harmonize it with the IPCC Sixth Report methodology, taking into account the record-breaking high average temperatures in the Republic of Serbia in 2018 and 2019 and the outdated previous assessments for the near-future, a new climate analysis has been prepared.
Simultaneously with the development of this Programme, the web-portal *Digital Climate Atlas of Serbia* was created with the relevant climate data[31] for the climate change and impact assessment for adaptation planning purposes from the national to the local level, with the easy data viewing and downloading options. The creation of this portal content is also in accordance with the analyses presented in this Programme.

3.2. Climate change as a growing global problem

Different climate change indicators show evidence of the accelerated climate change and its consequences. Global mean near-surface air temperature is rising, precipitation patterns are changing, and the frequency and intensity/duration[32] of extreme events

[30] Extracted from previous results (Ministry of Environmental Protection, 2017; Djurdjevic et al., 2018, Vukovic at al., 2018, Vuković Vimić at. al., 2022)
[31] https://atlas-klime.eko.gov.rs/
[32] Intensity and duration of extreme events may be synonymous in some cases when referring to impact, as the intensity of an extreme event may be greater if it has a longer duration.

is increasing globally, far beyond their natural variability (IPCC, 2013; IPCC, 2021). The mean global temperature for the 2011-2020 period is 1.1°C higher than that for the 1850-1900 period (IPCC, 2021). In case that the ambitious reductions in greenhouse gas emissions are not achieved, the rise in mean global temperature will continue and most likely reach 2.0°C (the most likely range 1.6°C-2.5°C) under the so-called "medium" scenario (SSP2-RCP4.5), i.e., 2.4°C (the most likely range 1.9°C-3.0°C) under the “high emissions” scenario (SSP5-RCP8.5) in the mid-century climate. In the second half of the 21st century, the increase in the mean global temperature under the “medium” scenario is slowing down and is expected to be most likely 2.7°C (with the most likely range 2.1-3.5°C), while under the “high emissions” scenario, it is expected to be 4.4°C (with the most likely range 3.3-5.7°C) by the end of the century. The climate change is assessed as the integral impact of GHG emissions and Shared Socio-Economic Pathways (SSPs)[33] to ensure a sustainable development of society, including the conservation of resources and the preservation and improvement the quality of life on the Earth in the future.

The global goal of limiting the global warming to 1.5°C above the pre-industrial average by the end of the century, set by the Paris Agreement as a result of global efforts to reduce net greenhouse gas emissions, is further presented in the IPCC Special Report "Global Warming of 1.5°C" (IPCC 2018). The impacts of global warming on the land on the planet Earth, i.e., land surfaces and natural and human systems, are shown in the IPCC Special Report “Climate Change and Land” (IPCC, 2019a), and the impacts on the ocean and ice surfaces on the planet Earth are shown in the IPCC Special Report “Ocean and Cryosphere in a Changing Climate” (IPCC, 2019b).[34] That has consolidated the current knowledge about the impacts of climate change in different regions of the world and on different components and processes of the climate system, including the environment and human activities. The climate change impact clearly depends on the climate change characteristics of the region, which are closely related to the location and terrain characteristics, the distribution and type of human activities, and other socio-economic characteristics. For this reason, the IPCC Sixth Assessment Report (IPCC, 2021; IPCC, 2022) links the climate change indicators, which are expressed through climate hazards or climatic impact-drivers, to the identified impacts or potential future impacts of climate change on the specific components of natural and human systems.

3.3. Assessment of climate change in the Republic of Serbia

3.3.1. Climate hazards and climatic impact-drivers

The climate change assessment for the wider region, i.e., the Western Balkans region (Vukovic and Vujadinovic Mandic, 2018), clearly indicates an intrisuion of the subtropical climate characteristics from the south to the north of the region, as well as in the Republic of Serbia, in terms of the general characteristics that include increased duration of warmer and drier periods during the year. The territory of the Republic of Serbia is located in the zone where the climate trend in annual accumulated precipitation changes (IPCC, 2013; IPCC, 2021), i.e., average annual precipitation decreases in the Mediterranean area (southern parts of Europe) and increases in the north (central and northern Europe). Consequently, in the central parts of Serbia, the precipitation change trend has a large uncertainty in the climate projections. Analysis of the observed and the future climate change projections, shows a high probability that the change in annual precipitation will not be significant until the middle of the 21st century, on average, for the territory of Serbia, according to the current knowledge. Although Serbia is located relatively close to the sea, the high mountains reduce the maritime influence on the climate in the country, and the continental climate characteristics persist regardless of the temperature rise. This implies warmer summers and colder winters compared to the areas with a subtropical climate and the areas more exposed to the maritime influence that moderates the seasonal temperature variations.

[33] SSPs are scenarios that predict socio-economic development, expressed through the main global society characteristics, such as the population size, standard of living (income), type of economic development, mitigation and adaptive capacity, etc. A brief description of these scenarios is provided in IPCC (2019a).
[34] The IPCC Special Reports “Global Warming of 1.5°C” and “Climate Change and Land” summaries for policymakers have been translated into Serbian as part of the Project “Establishing Transparency Framework According to the Paris Climate Agreement”.

Consequently, the expected climate conditions in the Republic of Serbia should be understood as the conditions specific for this territory, with the unique dynamic of change, in which it is necessary to preserve the health, living conditions and safety of the population and to enable the adaptation of food production, functioning of the infrastructure and sustainability of the economy in general, while preserving the environment, because of the high sensitivity of the adaptive capacity on the health of the living environment.

Climate change affects the increase in the climate hazards, which include climate and weather conditions that can directly or indirectly[35] cause damage to nature, property and human health and safety. Climate hazards are grouped depending on the type of hazards they cause: hazards related to too warm conditions, hazards related to too wet conditions, hazards related to too dry conditions, and hazards related to storms. Impacts of each climate hazard group are recognized at the sector level, as well as their consequences.

From the assessment of the climate change and the observed and/or expected climate change impacts in the Republic of Serbia, climatic impact-drivers have been identified, indicating the climate hazards caused by climate change. They represent the changed climate conditions and the dynamics of climate change, which have caused a significant climate change impact on various sectors.

The climatic impact-drivers that reflect the main characteristics of climate change in the territory of the Republic of Serbia include: (1) increased climate variability, (2) increase in temperature and heat waves, (3) change in the annual precipitation distribution, (4) change in precipitation intensity distribution, (5) change in droughts, (6) change in climate aridity/dryness. The climatic impact-drivers can contribute to one or more climate hazard groups.

The results of the analysis of the observed and future climate changes (climatic impact-drivers) in the Republic of Serbia, conducted for the purposes of this Programme, are shown in *Appendix 1*.[36] The 1961-1990 period was adopted as the base climate period in relation to which the analysis of climate changes in the recent past and in the future, by the end of the 21st century, are presented, as it is considered as a representative period for the climate conditions before the climate changes has become significant. The analysis of the observed climate changes was conducted for the recent past climate period (2001-2020), and particularly for the second decade of that period (2011-2020), in order to demonstrate the significant acceleration of temperature rise and other climate hazards. The future climate change analysis was prepared for the climate periods: the near-future (2021-2040), the mid-century, (2041-2060), and the end-of-century (2081-2100). Future climate changes were analysed according to the RCP4.5 and RCP8.5 GHG emission scenarios, which cover the most likely range of future climate conditions in the territory of the Republic of Serbia.

This Programme considers climate-soil-water as a connected system (the nexus approach), and thus, in addition to the analysis of climate variables, the available information on the observed and predicted changes in soil degradation, surface waters and groundwater caused by climate change have also been included in the assessments *(Appendix A1.5)*. The significance of the predicted changes in these climate system components indicates the necessity of mitigating the land degradation risk and disturbances in water resources availability, as integral components of the adaptation measures in this Programme. That implies integrating the Nature-based Solutions concept in the adaptation planning wherever possible to ensure the long-term functionality of the adaptation measures, the sustainability of these natural resources and their ability to provide services *(Appendix A1.5.3.)*.

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[35] Direct impacts include the impact of heat waves on living beings, the impact of drought on plant growth, damage caused by wind and hail, etc. Indirect impacts occur when weather or climate conditions cause other events that can cause impacts, such as floods, fires, lack of drinking water due to extreme weather events, etc.

[36] The data source and methodology used for this analysis are presented in Appendix A1.1. The results of the analysis of the changes in heat conditions, including the analysis of heat extremes, are presented in A1.2. The results of the analysis of the changes in precipitation, including the analysis of extreme precipitation events, droughts and changes in climate humidity/aridity conditions, are presented in A1.3. The climate change impact on extreme events that occur as a result of storms is analysed in A1.4. Considering that climate, water resources and soil are an inseparable whole that provides conditions for life and economic development, the connection between the changes in these three climate system components is shown in A1.5. A1.6 provides an overview of the climate hazards that are caused by adverse weather and climate conditions and depend on terrain characteristics, human activities, etc., such as floods, landslides, fires, impacts on water and air quality, etc. A1.7 (Table A2) provides an overview of selected climatic impact-drivers, specifying their closer meanings and the climatic parameters that can be used to determine their change significance.

The most important information on climate change in the territory of the Republic of Serbia, presented by climate hazard groups, based on the results of the climatic impact-driver analysis and integrated climate-soil-water analysis are presented in Table 1.

A special analysis of climate hazards caused by unfavourable weather and climate conditions due to the climate change, i.e. to which contribute climatic impact-drivers, is presented in Appendix A1.6. Those hazards include floods, landslides, rockfalls, fires, and reduced water, soil and air quality. They require the existence of other conditions that enable their occurrence, such as the specific terrain features, certain human activities, pollution sources, etc. For this reason it is necessary to take these climate hazards risk assessments into account when planning at the level of local self-government. Because climate change increase the frequency of extreme events, there is a need to include climate change impact assessments in disaster risk management plans, and in the spatial and general urban planning, with the aim of reducing these risks and increasing the capacity for recovery from damages caused by extreme events, which would contribute to the increased resilience of the Republic of Serbia to climate hazards. Climate change contributes to the increased water, soil and air pollution risk, dominantly as a factor that amplify the existing problems, with an increasing impact tendency in the future. This fact highlights the importance and urgency of the adoption of plans and the implementation of measures to reduce pollution, preferably taking into account the expected climate changes, in order to avoid the multiplication of damages and losses that may exceed the point of irreversibility, increase remediation costs and necessary investments, and contribute to a significant deterioration of public health and socio-economic situation in the Republic of Serbia.

The climate hazards, specific to each sector, are presented in the chapters on the climate change impact assessment for specific sectors, taking into account the change of the climatic impact-drivers and climate hazards presented also in this section through a general analysis of climate change in the Republic of Serbia, as well as sector-specific climate hazards analysis, wherever possible.

Table 1. Summary of the results of the analysis of the observed and future climate change in the territory of the Republic of Serbia, shown by the groups of climate hazards they cause, obtained based on the results of the analysis of the identified climatic impact-drivers that are relevant in the Republic of Serbia and that have had identified impacts on specific sectors. The results are presented based on the analysis of the observed climate changes for the 2001-2020 climate period and the second decade of this period (2011-2020) in relation to the climate conditions in the 1961-1990 period, and the analysis of future climate changes for the near-future (2021-2040), mid-century (2041-2060), and end-of-century (2081-2100) climate period, according to the RCP4.5 and RCP8.5 scenarios in relation to the climate conditions in the period 1961-1990. The difference in results according to these two scenarios for 2021-2040 is not significant, while for 2041-2060, it is especially underlined if it is significant. The difference in the results of climate projections according to these scenarios becomes significant only in the second half of the 21st century, i.e., in the period 2081-2100.

Climate hazard group	Climatic impact-drivers *(Appendix A1.7)*	Climate change and changed climate conditions (observed and future) in the 21st century in the territory of the Republic of Serbia *(a summary of the results shown in Appendix 1)*
Too warm	• Increased climate variabiLity *(Appendix A1.2.4.)* • Increase in temperature and heat waves *(Appendices A1.2.1., A1.2.2., A1.2.3. and A1.2.5.)*	Mean temperature increased by +1.4°C in 2001-2020 (+1.8°C in 2011-2020) compared to 1961-1990. On average, the increase of mean maximum temperature is higher than of the mean minimum temperature. The largest increase in mean temperature is found in JJA season, i.e., +2.0°C (+2.4°C). The increase in mean maximum temperature for JJA is +2.2°C (+2.6°C). In 2021-2020, the expected increase is +2.2°C, in 2041-2060 +2.5 and more likely +3.1°C, and in 2081-2100 approximately +3.1°C under RCP4.5, i.e., + 5.8°C under RCP8.5, compared to 1961-1990. *(A1.2.1.)* Heat waves did not occur every year in 1961-1990 (frequency less than 1 per year). Increase in the number of heat waves per year is +2.4 in 2001-2020 (+3 in 2011-2020) compared to the 1961-1990. Increased climate variability has led to the occurrence of more extreme years (in the 2011-2020 there were 6 years with 4 heat waves per year). The increase in the average number of heat waves per year in the 2021-2020 is +3.5, in the 2041-2060 is approximately +4 to +5, in the 2081-2100 is +5 under RCP4.5 and +8 to +10 under RCP8.5, compared to the 1961-1990. *(A1.2.2.)* Days with high temperature (maximum daily temperature above 30°C and above 35°C) happen in the lowland areas. Tropical days (days with maximum temperature above 30°C) in the lowland areas in 1961-1990 was in average 20-30 per year, and their number doubled in 2001-2020. In 2021-2040 is expected to be in average 55-60 per year, in 2041-2060 approximately 65, and in 2081-2100 approximately 70 under RCP4.5, i.e. approximately 85-96 under RCP8.5. Hot days (maximum daily temperature above 35°C) in the lowland areas was, in average, 2-3 per year in 1961-1990, the increase in 2001-2020 was +4 to +7, and in 2011-2020 in some areas even +10. In 2021-2041 will be, in average, 13-15 hot days per year in lowlands, in 2041-2060 more than 20, in 2081-2100 period approximately 25 under RCP4.5, and 35-45 under RCP8.5. In the future, the risk of high temperatures will continue to climb to higher altitudes further into the future *(A1.2.3.)*. Due to the increased climate variability, the probability of the occurrence of years/periods with deviations greater than the expected climatic average increases, i.e., the occurrence of extreme heat events that have not yet been recorded in the Republic of Serbia can be expected. *(A1.2.4.)*. The greatest heat extremes occur in the urban areas (the urban heat island effect), where the deviations in temperature compared to the surrounding areas are on average approximately 2°C, and during some periods even approximately 4°C. *(A1.2.5.)*
Too wet	• Increased climate variability *(Appendix A1.3.4.)* • Change in annual precipitation distribution *(Appendices A1.3.1. and A1.5.1.)* • Change in precipitation distribution by intensity *(Appendices A1.3.2., A1.5.1. and A1.5.2.)*	It has been observed that the annual maximum of monthly accumulated precipitation has shifted towards an earlier period of the year (from the late MAM and early JJA season to earlier periods in the MAM season). *(A1.3.1.)* The number of days with very heavy (daily precipitation 20mm-30mm) and extreme (daily precipitation over 30mm) precipitation and the amount of precipitation accumulated during such events have increased, while the events with light and moderate precipitation have decreased. The proportion of precipitation falling in the form of extreme precipitation has increased by over 100% in 2001-2020 compared to 1961-1990. Moderate risk of extreme precipitation in 2001-2020 covers 45% of the territory of the Republic of Serbia, with high risk covering 7% (central/western Serbia, parts of Vojvodina and eastern Serbia). The extreme precipitation risk will increase in the future and high risks will affect larger areas. In the 2041-2060 period, it is expected that 34% of the country will be under moderate, and 56% will be under high and very high risk of extreme precipitation. *(A1.3.2.)* The increased climate variability implies that it has been observed and that it is expected that certain years, and certain periods during the year, have significantly higher precipitation than the average climate values, which means that an increase in the extreme precipitation conditions is expected. *(A1.3.4.)* Increasing of values of river discharge is expected during the period with higher river flows, as well as an increase in the maximum flows. *(A1.5.1.)* The risk of soil degradation due to soil erosion caused by extreme precipitation is increasing. *(A1.5.2.)*

Too dry	• Increased climate variability *(Appendices A1.2.4.and A1.3.4.)* • Change in annual precipitation distribution *(Appendices A1.3.1. and A1.5.1.)* • Increased droughts *(Appendix A1.3.3.)* • Increased aridity/ *dryness (Appendices A1.3.3. and A1.5.2.)*	Mean annual accumulated precipitation will not change significantly until the second half of the 21st century, and in the 2081-2100 period, it is expected to decrease under RCP8.5 by 8% to 14% compared to 1961-1990. The decrease in precipitation during the JJA season in 2001-2020 is 10% to 20% in a large part of the Republic of Serbia, a further decrease is expected in the future, in 2041-2060 over 20%, and in 2081-2100 under RCP8.5 even over 40%, compared to 1961-1990. *(A1.3.1.)* The percentage of years with drought, in average, for the territory of the Republic of Serbia, increased by +30% in 2001-2020 (+40% in 2011-2020) compared to 1961-1990. In 1961-1990 the frequency was 10%. It is expected that in 2041-2060 every year will be a year with drought, on average for the territory of the Republic of Serbia. The frequency of years with severe drought (occurred once in 2011-2020) is increasing, and in 2021-2040 will be 2-3 per decade (in a period of 10 years), in 2041-2060 3-4 per decade, and according to RCP8.5 in 2081-2100 severe drought are expected in 7-8 years per decade. An increase of the level of aridity of the climate in the Republic of Serbia is expected, meaning increasingly drier average climate conditions. In 2001-2020 the average climate class for Serbia is "humid climate", while in the lowland areas (Vojvodina, central Serbia, eastern and south-eastern Serbia and locally in other areas) is "dry sub-humid climate". Due to the unfavourable distribution of precipitation during the year, in the largest part of the country, except in the high mountains of the western Serbia, the JJA season is "semi-dry". The other seasons belong to the "wet" category. In 2041-2060, on average, the territory of the Republic of Serbia will have a "dry sub-humid" climate, and according to RCP8.5 it will be "semi-arid" in 2081-2100. *(A1.3.3.)* The increased climate variability means more frequent occurrence of years with drier conditions, as well as the aforementioned increase in droughts. Temperature increase has a significant impact on drier conditions *(A1.2.4. and A1.3.4.)* The low river flow periods are extending and the values of minimum rivers discharges are decreasing. Groundwater recharge rate is decreasing. The average soil moisture content has decreased due to the increase in evapotranspiration. *(A1.5.1.)* The increasing level of aridity of the climate impacts land degradation. *(A1.5.2.)*
Storms	• Change in precipitation distribution by intensity *(Appendices A1.3.2 and A1.4.)*	No change in mean wind speed and its spatial distribution has been observed. While these changes currently cannot be quantified, an increase in extreme precipitation events can be considered as an indicator of an increase in storm events. The increase in very heavy and extreme precipitation events *(A1.3.2)* indicates an increase in the number and intensity of events that produce such precipitation and are accompanied by strong winds and possible snow (possible higher snowfall, but decreased snow cover retention) and hail, depending on the time of the year and the location they occur. The area under increased risk of such events is extending. *(A1.4.)*

3.3.2. Improving climate change monitoring knowledge

Climate change assessments, particularly for the purposes of adaptation planning, are linked to the identified climate change impacts, which also defines the parameters used for the assessment and quantification of climate hazards or climatic impact-drivers, which provides the basis for future climate change risk projections by sectors and adequate climate change adaptation planning.

To further advance the knowledge on the significance of the climate change risks in the future, there is a need to:

- Increase the capacity for monitoring of meteorological, soil and water related parameters - review the existing data, ensure their availability, and provide additional data as needed;

- Ensure monitoring of climate change impacts, including monitoring of losses and damages - adopt the monitoring methodology by sectors and ensure the availability of this information, as well as the obligation to use it; consider incorporating information from scientific and other projects results;

- Adopt drought monitoring methodology - establish the responsibility to monitor and declare drought, drought declaration criteria, and adopt the methodology for monitoring and declaring drought from the national to the local level, taking into account all possible aspects of drought (meteorological, hydrological, soil related, physiological, etc.) relevant to the sectors in the Republic of Serbia and the various time scales at which the drought is identified (from long-term to short-term), as a condition for drought impact/consequences monitoring.

All three components require coordinated work of the scientific community, relevant state institutions, decision makers, policy makers and other stakeholders in order to reach a consensus on the choice of the best solutions. As the proposed activities are closely related to climate change reporting under the United Nations Framework Convention on Climate Change and enabling the national climate change adaptation planning, which fall under the competence of the Ministry of Environmental Protection, the proposed activities need to be implemented under the coordination of this Ministry.

4. Relevant socio-economic indicators

The adverse impact of climate change on GDP increases significantly with the increase in the mean global temperatures. According to the Revised Nationally Determined Contribution of the Republic of Serbia,[37] Serbia had suffered damages of at least EUR 1.8 billion in just five years (2015-2020). In addition, Table 2 shows the potential reduction of Serbia's GDP in case of a global mean temperature increase compared to the projected GDP without global warming.

	GDP decrease (in USD billions and in %)	
Temperature increase	2020 – 2040	2020 – 2100
1 °C	15,465 (1.20%)	344,364 (4.19%)
2 °C	58,124 (4.53%)	766,317 (9.32%)
3 °C	59,107 (4.97%)	890,403 (11.65%)
4 °C	97,536 (6.87%)	2,002,410 (17.06%)

Table 2. **Estimation (projection) of the reduction of the GDP of the Republic of Serbia in case of various average global temperature increases in relation to the projected GDP without an increase in the average global temperature for the near-future period and until the end-of-21st-century period.**

The increase in the average global temperature by the end of the century within the limits determined by the Paris Agreement (under 2°C) would result in a Serbia's GDP loss of 4.53% in the near future period, which could be significantly reduced by investing in climate change adaptation.

The analysis of the expected GDP changes indicates that the climate change will affect all population groups and all individuals. However, some population groups are significantly more vulnerable to these impacts due to a range of factors. The overview of the groups vulnerable to climate change and the assessment of the population at high risk of climate change is provided in *Chapter 5.1* of this Programme.

The above presented GDP change indicates an increase in the population's vulnerability to climate change, reducing their ability to adapt to the changes and their ability to recover from the damage caused, which in turn increases the losses. The presented estimates cannot cover all the direct and indirect climate change impacts on the population and the economy, considering the complexity of the impacts themselves (particularly the climate hazards), the interconnections between the sectors and the population in terms of their vulnerability to climate change, and the unequal impact with the increasing non-linear intensity on different population groups depending on their spatial distribution, their socio-economic status and the type of their activities. The recommendations for the measures to increase the resilience of population of Republic of Serbia to climate change are presented in *Chapter 5.1.* In addition to the above, the climate change impacts on sectors can increase vulnerability and further threaten the population's resilience to climate change, and that is why the impact assessment and recommendations for climate change adaptation measures have been developed specifically for the priority sectors in *Chapters 5.2. - 5.7.*

This Programme takes into account various socio-economic aspects relating to population, including gender differences, age structure and adaptive capacity based on the poverty risk assessment data. This has been taken into account where it was possible and where it was considered to be of highest importance, while in the course of the implementation of certain adaptation measures additional data collection and expansion of knowledge has been planned in order to improve the understanding of the impact of climate change on different population groups in terms of gender and age structure and other aspects in order to ensure adequate adaptation measures planning and implementation *(Chapter 8).*

[37] https://unfccc.int/sites/default/files/NDC/2022-08/NDC%20Final_Serbia%20english.pdf

5. Climate change impact assessment and recommendations for adaptation

Based on the analysis of the existing knowledge and the available climate change vulnerability assessments, an assessment of risk levels and identification of gaps and needs for further knowledge development were conducted. The adaptation measures identified based on the assessment should reduce the risk, i.e. to reduce the future vulnerability, and to increase the speed of recovery, while contributing to the sustainability of the investments in question.[38]

5.1. Human health and safety

Climate change affects the physical, mental and emotional health of individuals and society. Climate change directly affects human health and safety due to the increased frequency of climate hazards (the climate hazards and their changes are described in *Chapter 3 and Appendix 1*). The indirect impact occurs through the reduced availability of water and water of satisfactory quality due to the impact of climate change, an increase in the frequency and duration of conditions that lead to the deterioration of air quality in the conditions where there are pollution sources, reduced availability and quality of food, more frequent and widespread outbreaks of vector-borne diseases and diseases spread by rodents, etc. The increase in the rate of injuries, deaths, infections, etc., is also linked to the climate change impacts. The long-term impacts of climate hazards on human health and safety are reflected in the deterioration of the living conditions due to damaged property and the deterioration of the living environment and natural resources, when there is no possibility of quick recovery, i.e. damage restoration. The climate hazards that threaten human health and safety are increasing and they will continue to increase in the future in Serbia *(Chapter 3)*. Table 3 provides a summary of the climate change impacts and consequences by the climate hazard groups that are known to have or may have a significant impact in Serbia.

Table 3. **Impacts of climate change on human health and safety.**

Climate hazard groups	Impacts	Consequences
Too warm	Heatstroke and exhaustion, reduced availability of food and drinking water. Increased risk of diseases, allergies and chronic illnesses. Increased risk of fire leading to increased air pollution.	Worsening of health conditions, premature deaths. Deteriorated living conditions. Healthcare system overload due to climate hazards and inadequate public health care and rescue services overload. Reduced functionality of emergency health services.
Too wet	Increased risk of diseases and other health problems. Increased risk of injuries and deteriorated living conditions due to floods and flash floods. Reduced availability of drinking water and reduced availability and quality of food. Reduced capacity to provide emergency medical assistance. Infectious diseases outbreaks due to deteriorated hygiene conditions.	
Too dry	Reduced availability of water for drinking and maintaining hygiene, reduced availability and quality of food.	
Storms	Increased risk of injuries and damages to properties, i.e., deteriorated living conditions. Reduced capacity to provide emergency medical assistance.	

The climate change vulnerability and risk assessment for the public health sector of Republic of Serbia have not been implemented systematically at the national level. However, there are some informations that indicate a high level of population sensitivity because of the existing socio-economic conditions, i.e., unfavourable age structure, income levels and distribution, types of activities that they perform, the lack of an adequate

[38] Vulnerability and risk assessment has been conducted for the selected sectors (agriculture and forestry). For a number of sectors, vulnerability and risk assessment has not been performed, but the impacts are known (biodiversity, urban planning, public health, and (road) transport infrastructure). For the energy sector, vulnerability and risk assessment has not been conducted, but there was a need to assess the impact parameters. Finally, water resources are addressed under the nexus approach, and are not considered separately. Due to their direct contribution to increasing resilience to climate change of the population of the Republic of Serbia, the public health sector and the disaster risk reduction sector have been highlighted, and the main analyses and needs for those sectors are presented in the first chapter addressing the public health and safety under the climate change.

warning system and response guidelines, etc. In the conditions of climate change, with increasing frequency and intensity of weather conditions that affect human health and safety, population vulnerability also increases. The climate hazards to which the population is sensitive will continue to increase in the future, and it can be concluded with a high confidence that the climate change risks in the public health sector will increase in the future.

Table 4[39] shows the vulnerable populations by groups, including their main characteristics and the reasons why they are vulnerable to climate change. The members of the listed groups are considered to be at a high risk of climate change, while those who belong to more than one of the vulnerable groups are considered to be at an extremely high risk of climate change, meaning they are already exposed to a significant negative impact of climate change and urgent implementation of measures to reduce their vulnerability is required.

According to the presented data, a preliminary estimate of the share of population of Republic of Serbia in high risk (very likely to suffer the consequences of climate change that will affect their health and living conditions) from climate change is in the range from 45% to 55%, of which 20% to 30% are in extremely high risk (they will surely suffer the consequences of climate change, which will affect their health and living conditions). Taking into account the population aging trend, and the increased intensity and duration of weather extremes (*Chapter 3*), this number is expected to increase significantly by the mid- of the 21st century period. In addition, the increase in heat extremes, which will reach significant extremes, especially in the lowland urban areas (due to the urban heat island effect, *Chapter 5.6*) will also impact vulnerability increase in population not included in the vulnerable groups.

Table 4. **Population groups that are vulnerable to climate change and their characteristics. If a person belongs to multiple groups, their vulnerability is greater.**

Groups	Characteristics
Elderly population	Population over 65 years of age currently accounts for 21% of the population and is increasing, with more than a half of them having difficulties in performing personal care and household activities (this problem is the most pronounced among the elderly population in the Serbia-South region) There is a trend of aging households, with approximately 25% of the elderly living alone. Limited access to information - fewer opportunities for timely information and education. Reduced mobility and ability to protect oneself and one's property in the extreme conditions.
Poor population	21% of the population is at risk of poverty (women have greater vulnerability with 22% of them at risk of poverty), and, without social transfers, as much as one third of the population is at risk. In every age category, women are at greater risk of poverty. Among minors, 21% are at risk of poverty, while the greatest risk in the 18 to 24 age group (at 28%). Based on the household type assessment, single-member households - women are at the greatest risk (over 39%), followed by households with two adults and three or more dependent children (almost 39%). In the population over 65 years of age, 23% is at risk of poverty, on average, with women being at greater risk (25% of women in this group are at risk of poverty). The share of the population unable to cover unexpected expenses from the household budget is 34%, while 44% cannot afford a one-week vacation during the year. There is a large income disparity between regions. For example, the average income in the Belgrade region is more than 40% higher compared to those in the Serbia-South region, with even greater disparity at the municipal level. There is a particularly high vulnerability among the homeless in urban areas due to extreme heat conditions, and particularly the lack of water. There is particularly high vulnerability of the elderly households in the mountain villages. Limited access to timely information (limited Internet and media access) and reduced capacity to respond in extreme conditions. Inadequate living conditions and limited opportunities to reduce the risk of extreme conditions impacts (for example, cooling of living spaces).
Rural population	The age structure is unfavourable. There is a clear trend of population aging in rural municipalities and a large share of the population is over 65 years old. The average age outside urban areas is 45 years for men and 47 years for women, which is higher than in the urban areas. Income is mostly 40-60% lower than the Belgrade region average, i.e., for the most parts, more than 20% lower than the Serbia average. Limited access to public healthcare services (emergency service routes, availability of emergency services, distance from hospitals, and access to medical care). Living conditions are deteriorated due to a limited access to life-sustaining services, water supply and sewage systems. Exposure to climate change is high due to outdoor work. On average, access to information is limited (timely notification of dangers and behaviour recommendations) – limited Internet and media access.

[39] Data taken from a large number of Serbian Statistical Office reports

Outdoor workers	Includes approximately 3 million people. Working conditions are extreme and there is a high exposure to climate change. Inadequate access to healthcare services in the conditions of climate change and inadequate equipment for working in extreme conditions. Unfavourable age structure. Inadequately regulated workers' protection during extreme weather conditions, i.e., regulations governing suspension of work operations if weather conditions pose risk to human health and safety at the work location.
Particularly vulnerable groups	• Children – increased sensitivity of the organism; unable to understand the dangers of extreme weather conditions and the necessary behaviours in these conditions; • Pregnant women – increased sensitivity of the organism, limited ability to engage in recommended recreational activities in adequate conditions, increased health risk due to performing necessary life activities outdoors. • Chronic illnesses sufferers (cardiovascular, respiratory, malignant) - increased sensitivity of the organism, limited ability to engage in recommended recreational activities in adequate conditions, and increased risk to health due to performing necessary life activities outdoors. • People with disabilities.

Base on the existing knowledge, recommendations of measures that need to be implemented to ensure the capacities for reducing the population vulnerability to climate change, i.e. the priority adaptation measures, are presented in Table 5.

Although climate hazard warnings exist, it is necessary to improve the system and to ensure that warnings can reach everyone, but also to enable people to know how to react and to have capacity to react as recommended. In addition, there is a need to raise awareness about the climate change impacts, which would put an emphasis on climate-responsible behaviours, considering that the risks will significantly increase in the future. This means creating a culture that promotes people informing themselves and behaving in extreme conditions in a way that will protect them. Children and young people need to be included in these activities through programmes adjusted to different ages, as well as parents which need to be educated how to protect their children. In addition to population preparedness, there is a need also to increase the population protection capacities, in terms of providing behaviour guidelines, evacuation plans, organizing shelters during heat waves (for cooling), storms and other climate hazards.

Because of the increasing risks of climate hazards and a large share of the population at high risk, more frequent and larger interventions by emergency medical services, health institutions and rescue services are expected. There is a need to assess their response capacities and develop recommendations for capacity and efficiency strengthening. As the rural population and the poor, including the Roma population living in inadequate living conditions, have a limited access to healthcare services, there is a need to determine the methods and the requirements to increase the capacities to help these population groups. The availability of means of communication, distance from healthcare facilities, and roads allowing timely arrival of assistance and evacuation also need to be taken into account.

Protecting outdoor workers has become one of the priorities in terms of increasing safety and health protection due to changes in the climate hazards and their intensification. Consequently, there is a need to revise the existing regulations on protection at work during extreme weather conditions and adjust them to the conditions of climate change. A more complex approach is needed for specifying the criteria for dangerous situations due to the combined effects of high temperatures and air humidity, elevated temperatures at work site compared to the official data, the frequency of occurrence of local and extremely intense storms, etc. There is a need to review the effectiveness of the existing system and its implementation by employers and develop guidelines and regulations on the necessary measures to be implemented in the event of climate hazards (suspension of work, reduced working hours, provision of necessary protective equipment, etc.). In addition, there is a need to enable employers, outdoor work managers and outdoor workers to have timely information about weather conditions and climate hazards for work planning and occupational safety purposes.

It is necessary to improve knowledge about other hazards caused by climate change, specifically the quality and availability of drinking water and food, the increasing risk of diseases, particularly vector-borne diseases and new diseases emerging due to climate change. It is recommended to improve monitoring and conduct analyses to understand the connections between these potential hazards and climate change, which would enable predicting their increase and ensuring timely response.

Table 5. **Recommended measures that need to be implemented to increase the Serbian population's resilience to climate change, i.e., measures to reduce vulnerability in future climate conditions and consequently reduce risks, and measures to increase the speed of recovery.**

Recommended measures	Implementation method	Notes
Increase population preparedness for extreme weather conditions and other climate hazards	Ensure timely information sharing to the public on extreme weather events, including strengthening the population's capacity to receive information on-time, and provide guidelines on behaviour and ways to reduce risks, including health and property protection. Improve communication with the media and conduct trainings for journalists to increase the reporting efficiency. Increase and adapt capacities of emergency medical services and healthcare institutions to provide timely assistance in the conditions of increased risks. Organize timely risk reduction activities at the local level (ensuring access to shelters, providing water, food, evacuation plans, etc.). Engage organizations that support the poor and the homeless in the implementation of measures to reduce risks due to climate hazards.	Particularly important for vulnerable population groups with the reduced capacity for accessing timely information, such as the elderly population, the poor, and the rural population. The potential importance of gender differences also needs to be taken into account in the developing guidelines and providing assistance. Local self-governments must be involved in these activities.
Increase the capacities for interventions of emergency services and healthcare institutions	Increase/adjust the capacities of emergency medical services and healthcare institutions to provide timely assistance in the conditions of increased risks. Increase the accessibility to healthcare services (particularly for vulnerable populations). Improve timely information of healthcare workers about upcoming climate hazards. Conducting trainings on climate change for healthcare workers.	Particularly important for the poor and the rural population. In terms of increasing access to healthcare services, gender differences also need to be taken into account.
Strengthen the capacities of other emergency response services	Ensure education for rescue services. Develop citizen protection plans in case of extreme weather events, taking into account climate change and additional citizen protection needs arising from climate change. This measure enables the implementation of the first recommended measure.	Important at the national and local levels, to ensure better preparedness and timely planning and response.
Protect outdoor workers	Revise or supplement regulations on the criteria for health risks due to extreme weather events and other weather hazards. Raise awareness among employers, outdoor work managers and outdoor workers about climate hazards with guidelines for timely risk reduction.	When specifying the criteria, it is necessary to take into account the extreme conditions that occur due to the combined effects and other hazards (increased temperature and humidity, increased risk of diseases and infections, etc.), conditions at the work site, the risk of new extremes, etc.
Improve disease and infections monitoring and prevent disease spreading or implement early interventions	Educate health workers and veterinarians about climate change. Monitor the occurrence and spread of diseases and expand knowledge about their connections with the climate change impacts. Increase awareness about disease spread with increased risks due to climate change with guidelines on how to prevent disease spreading and ensure early interventions, particularly for vector-borne diseases.	Important for strengthening knowledge about the impacts of climate change on health and enabling the prevention of the spread of new diseases. Awareness raising is particularly important among the poor population, which has the greatest exposure.
Improve monitoring of food and water quality	Increase efficiency during and after climate hazard events. Improve knowledge about the connections with the climate change impacts.	Important considering the increased impact of climate hazards due to climate change or the combined effects of climate hazards and water and soil pollution.
Strengthen education and raise awareness among children and youth	Develop and implement education programmes for children and youth about climate change, climate hazards, and the impacts. Educate the teachers. Adapt the information channels and increase understanding of children and youth about the emerging climate hazards and behaviours to reduce risks.	Important for creating climate-responsible behaviours, as one of the main conditions for achieving and maintaining resilience to climate change in the future. It is important to include local self-governments and local organizations in these activities.
Expand knowledge about vulnerability and risks to human health and safety	Develop an analysis of the spatial distribution of climate change vulnerability and risks to human health and safety for the territory of Republic of Serbia, taking into account the distribution of vulnerable population groups, age distribution and gender differences, and identify risk types and levels. Develop guidelines for measures that would increase the population resilience to climate change, i.e. the measures to reduce risks and increase the capacity to recover. Enable local self-governments and organizations to have the capacity and potentially an obligation to carry out population vulnerability and risk assessments at the local level, with a greater level of detail, and to plan and implement priority adaptation measures.	The data that would become available through the above listed monitoring system improvements would also contribute to this. This vulnerability and risk assessment would provide information on the distribution of the priority risk reduction measures.

The recommended measures aim to ensure the capacities for timely information sharing and protection of every individual in the Republic of Serbia in the conditions of climate change. Some of the necessary capacities for the implementation of these measures represent also the capacities required for the implementation of measures in other sectors, and they relate to the improvement of the warning and alert system, and the improvements of the RHMSS products. Furthermore, there is a need to improve capacities and warning system of the Institute for Public Health "Dr Milan Jovanovic Batut", and also to increase the capacity for the organization of activities related to preventive activities and citizen protection, which implies preparedness and response capacities of the health sector and the disaster risk reduction sector. In order to effectively implement these measures, it is necessary to involve local self-governments, organizations engaged in supporting the poor and the homeless, the media, educational institutions, etc. In planning interventions in case of climate hazards, it is necessary to take into account different needs and capacities due to gender differences, age differences (particularly for the elderly and children) and poverty. The planned interventions, i.e. measures, must not have a negative impact either on the environment and natural resources or people (for example, water restrictions in the event of a drought during heat waves can significantly endanger the population; excessive consumption of water from the water supply system in the event of a drought can endanger resources for the upcoming periods of increased demands, etc.).

5.2. Agriculture

The climate change impact assessment includes the following agriculture sub-sectors: crop farming, fruit growing, viticulture, and livestock farming. Table 6 provides a brief overview of the impacts and consequences caused by climatic impact-drivers and other climate hazards related to climate change in the agriculture sector. These impacts and consequences have been observed and/or projected in the future climate conditions.

Table 6. **Impacts of climate change on the agriculture sector shown by climate hazard categories and the consequences of such impacts on agricultural production.**

Climate hazard groups	Impacts	Consequences
Too warm	Disruptions of plant phenological development, phenological rate acceleration and earlier ripening; Earlier vegetation onset and increased risk of frost during vegetation period; Plants and animals suffer from heat stress during the warmer part of the year; Damage to fruits during hot days; Reduced soil quality due to disruption of favorable conditions for soil restoration.	Increased yield variability in terms of quality and quantity in different years; Reduced yield quality and quantity; Increased water demand; Reduced soil quality; Damage to agricultural infrastructure.
Too wet	Soil waterlogging creates unfavourable conditions for germination and root development; During flowering and pollination, it can reduce fertilization, and consequently the yield; Reduced soil quality due to erosion; Favours the spread of plant diseases; Floods can cause total destruction of crop yields, livestock deaths and damage agricultural infrastructure.	
Too dry	Plants are under water stress; Due to frequent seasonal water deficit or water deficit during the vegetation period, there is a significant long-term decrease in average production; Reduced soil quality due to insufficient moisture content and wind erosion.	
Storms	Physical damage to plants and fruits; Possible damage of agricultural infrastructure.	

The assessment of the climate change impacts on agriculture has been conducted taking into account the climate hazards relevant to determine vulnerability, including future climate projections to determine future risks, in order to identify the priority climate change adaptation measures. This assessment has been performed in accordance with the climate change analyses presented in this Programme *(Chapter 3)*. The assessment takes into account the observed and future changes in climate conditions and their observed and potential future impacts. For each agricultural sub-sector specific analyses are designed to the specific vulnerabilities of the sub-sector, i.e. additional sub-sector climate hazards and their impact were identified, as recommended in *Chapter 3*. The methodology and the results of the analyses are discussed further in *Appendix 2*, from which the main conclusions presented in this Chapter have been derived. The analysis includes the distribution of agricultural species by administrative regions of the Republic of Serbia, while the data on the distribution of agricultural land plots are not available. Consequently, the assessed risks show only the risks of climate change in case there are present different types of production.

The obtained results indicate the need to implement priority measures to adapt agricultural production, including mitigating the impact of extreme weather events and increasing the capacity to adapt to future climate conditions, i.e., providing additional services and information to agricultural producers to allow them to make decisions that would mitigate the adverse effects of climate change and use the potential benefits. In addition, adaptation measures aim to strengthen the national capacities in agricultural production planning through zoning for different sub-sectors, which would provide information on the territorial potential for cultivation various species and on the associated risks, as well as on the dynamics of change in those potentials due to climate change.

5.2.1. Fruit production

The climate hazards in fruit growing caused by climate change are the occurrence of frost in growing season (*Appendix 2 - A2.1.1.*) and of extremely high summer temperatures (*Appendix 2 - A2.1.2.*), as well as storm and hail risks (*Appendix 2 - A2.3.*). In addition, the accelerated climate change causes a shift in the optimal conditions for cultivating various species, particularly towards higher altitudes. Due to the changed precipitation distribution and temperature increase (*Chapter 3*), water requirements for fruit varieties and the need for irrigation also increase (*Appendix 2 - A2.7.*).

The risk of frost during growing season (*Figure A2.3*) is high for varieties of group 1 (almond and apricot) in all administrative districts of the Republic of Serbia, while for group 2 (peach, strawberry, currant, walnut), the frost risk is high in the Šumadija and West Serbia region and in the East and South Serbia region, and has a tendency of reaching high risk level in the coming decades, and for group 3 (plum, sour cherry, cherry, raspberry, blackberry) there is a moderate risk in some areas, with a tendency of increasing by the middle of the 21 century. For other species (group 4: apple, pear, quince, blueberry) the risk is low, acceptable or inconclusive, with no significant increase by the middle of the 21st century.

The risk of extremely high temperatures, i.e. high summer temperatures, is increasing throughout the entire territory of the Republic of Serbia. Late ripening species, meaning the species with fruit development during the entire summer period (pear, apple, quince, raspberry, blackberry), are at the greatest risk. However, due to the extension of the so-called hot period *(Appendix 2 - A2.1.2.*), extremely high temperatures can also occur during the ripening period of other types of fruits (plum, sour cherry, cherry, etc.). As expected, the highest level of risk is present in the administrative regions at predominantly low altitudes (Vojvodina, Kolubarski, Mačvanski, Podunavski administrative regions), while in other areas the risk is moderate with an increasing tendency or low/acceptable risk (*Figure A2.6.*).

The climate change impact assessment results indicate the need to protect plantations under high risk of frost in growing season and under high risks of extreme temperatures and hail, and to plan increased investments to subsidize the protection systems in the near future considering the increasing risks.

Due to the accelerated climate change, there is a need to regularly update the fruit production zoning in the Republic of Serbia (using high spatial resolution data) with recommendations for verieties selection and assessed climatic impact-drivers risks. In addition, it is needed to take into account the irrigation needs, irrigation water availability and potential irrigation solutions that will be consistent with water resources conservation and sustainable land management. As the dynamics of climate change calls for rapid changes, during the adaptation period, agricultural producers need to be protected from the impacts of extreme weather conditions, meaning they must be provided agricultural insurance that would enable them to recover from losses caused by the increasing climate hazards.

5.2.2. Viticulture

The identified impacts of climate change in viticulture include changes in the optimal cultivation conditions that may lead to changes in the phenological development and the reduced quality (*Appendix 2 - A2.2.1.*), an increased risk of frost occurrence in growing season (*Appendix 2 - A2.2.2.*), risk of extremely high temperatures (*Appendix 2 - A2.2.4.*), and increased hail risk (*Appendix 2 - A2.3.*). Although grapevine is not significantly sensitive to water deficit during a large part of its vegetative development, the increased frequency of droughts, which have intensified, can lead locally to the reduced yield and/or quality (*Chapter 3, Appendix 2 - A2.7.*).

The changes in the climatic categories for grapevine cultivation show a shift in the optimal conditions for grape growing and high-quality wine production (*Appendix 2 - A2.2.1.*). The analyses show that, due to climate change, the potential for high-quality production in this sub-sector has increased, and that in the coming decades the expansion of areaswith favorable conditions for cultivation can be expected. In other words, with the optimized production, in the coming decades, viticulture could benefit from climate change. The risk of frost during growing season will increase in some areas of the Republic of Serbia in the future (*Figure A2.10.*), while the risk of low winter temperatures will decrease, but could still cause damage locally (*Appendix 2 - A2.2.3.*). The increased prevalence and frequency of the hail risk (*Appendix 2 - A2.3., Figure A2.12*) indicates a high hail risk in viticulture.

In order to enable benefits from an increasing cultivation potential, there is a need to regularly update the viticultural zoning in the Republic of Serbia, including the assessment of potential risks due to climate change, with recommendations for the selection of varieties, locations, cultivation methods and various agro-technical measures that would ensure the yield quality. In the high-risk areas, the plantations need to be protected from hail and high temperatures, and also plan for the introduction of frost protection.

5.2.3. Crop farming

In the assessment of the climate change impacts on the crop farming, the greatest risk has identified as precipitation deficit in the sensitive periods of plant growth and precipitation deficit in combination with high temperatures (*Appendix A2.4.*). In that respect, maize is under the greatest risk, specifically under high and moderate risk with a tendency to increase in almost all administrative districts in the Republic of Serbia (*Figure A2.17*). Soybean is also vulnerable to these risks (*Figure A2.23*), but with a smaller yield loss. The sunflower yield shows vulnerability to severe droughts, but without the pronounced losses as in the case of maize and soybean (*Figure A2.20*). Sugar beet fields are in larger share owned by legal entities, unlike other crops, and it is assumed that due to irrigation implementation and the application of specific agricultural techniques, losses in the years with the increased risk have been significantly reduced (*Figure A2.24*), although there is a high risk in the Vojvodina region, where sugar beet is mostly cultivated (*Figure A2.26*). As winter crops complete their development before the onset of the period with the highest risk of high temperatures and precipitation deficit due to changes in precipitation distribution, this impact is at least pronounced in wheat and other winter crops, and that is why no significant yield losses were recorded as for the other crops (*Figure A2.27*). Nevertheless, disturbances of climate conditions increase the frequency of droughts, and also the occurrence of droughts in the periods of risk for wheat, and it has been estimated that some areas in Vojvodina (Severnobanatski and Severnobački districts) is high, while most parts of the Republic of Serbia will have moderate and low precipitation deficit risk (*Figure A2.29*). It should be noted that these risk assessments for crops take into account the optimum sowing times and the changed dynamics of phenological development in the conditions of climate change. The impact of climate change on the yield quality has not been quantified due to a lack of data, and it should be taken into account that the yield reduction is not the only indicator of negative impacts, another indicator is the quality of the yield itself, which is very sensitive to weather extremes, which are increasing in frequency and intensity.

To ensure a better insight into the distribution of the optimal growing conditions for agricultural crops in the territory of the Republic of Serbia, to assess the adverse climate change impact risks, to develop the recommendations for further crop production development, and to assess the needs to develop a system to mitigate the impacts of precipitation deficit and high temperatures, related to the increased irrigation requirements (*Appendix A2.7.*), the crop production zoning methodology for the Republic of Serbia needs to be developed and zoning needs to be implemented at the national level using high-resolution data. The methodology must consider the recommendations in accordance with the specifics of annual crop production, including the crop rotation recommendations and other agrotechnical measures. As the negative climate change impacts on soil and water resources have been identified (*Chapter 3 and Appendix A1.5.*), the adaptation of crop production to new climatic conditions must be implemented by looking at all three climate system components that enable plant development (atmospheric conditions, water and soil).

5.2.4. Livestock farming

The greatest risk of the direct impact of climate change in livestock production is the risk of extremely high temperatures, causing heat stress in livestock and affect their health and productivity (*Appendix 2- A2.6.*). The indirect impacts are caused by the lack of drinking water and food, which reflects in the vulnerability of water resources (*Appendix 1 - A1.5.1.*), crop production (addressed in previous chapters), and the condition/productivity of meadows and pastures, which are at a high risk of precipitation deficit in some areas of the Republic of Serbia (*Appendix 2 - A2.5, Figure A2.31.*).

Due to the growing risks of heat stress and other climate hazards (*Chapter 3*), it is recommended to increase an investments for the construction of appropriate livestock housing facilities and strengthening the adaptive capacity of livestock production to climate change. This implies a preparation of the livestock production zoning for the Republic of Serbia, with direct and indirect climate change impact risk assessments, including appropriate recommendations for livestock producers and assessments of future investment needs for mitigating negative impacts.

5.2.5. Agriculture sector adaptation to climate change

The agriculture sector is the most sensitive to climate change and is highly exposed to climate change considering that largest portion of agricultural production is implemented in open spaces. The conducted impact assessments indicate a need to provide the capacities for adapting agricultural production to climate change in a sustainable manner, i.e. while preserving the endangered resources (water and soil) necessary for agricultural production. Considering the dynamics of climate change, climate change adaptation is a process that needs to be maintained in the future by updating and expanding knowledge and information, ensuring their availability to agricultural producers and other stakeholders, and by including these information in planning, i.e. strategic and policy documents.

The information about changing climate conditions, the dynamics of their change and risk assessments, as well as the recommendations for measures that need to be implemented, need to be systematized through the zoning of the Republic of Serbia for the purposes of specific agriculture sub-sectors. Regular and mandatory training of advisors within the Serbian Agricultural Advisory and Extension Service (hereinafter: AAES) is necessary in order to ensure effective dissemination of new knowledge and information, through education of agricultural producers and other stakeholders, including the implementation of that knowledge under programmes for schools and higher education institutions.

Considering the need for faster application of scientific information and methods for climate change adaptation in practice, it is necessary to strengthen the cooperation with the scientific community and to enhance the interdisciplinary approach in the development of methodologies and information and provision of other services. In addition to the above, ensuring the adaptive capacity also means enabling agricultural producers to protect their production from hail, high temperatures and frost, and to secure sufficient water for sustainable production.

In addition to a relatively long-term planning of agricultural production climate change adaptation, there is a need to provide capacities for the short-term production "adjustments" to respond to the announced upcoming unfavorable weather events and reduce potential damages. That implies the need to strengthen the capacities of the agrometeorological services in the Republic Hydrometeorological Service of Serbia (RHMSS) to improve monitoring and forecasting of weather conditions on different time scales (from long-term to short-term forecasts), tailored to meet the agricultural producers' needs and to ensure the effective access to information.

Table 7 provides a brief overview of the steps that need to be implemented to ensure the conditions for the agricultural sector to adapt and continue adapting to climate change in the future. Based on the implemented analysis, listed recommendations on ways to maintain and potentially improve agricultural production in the conditions of climate change, priority climate change adaptation measures and activities for the agricultural sector have been specified in this Programme.

Table 7. **Activities that need to be implemented to ensure capacities for sustainable agricultural production in the Republic of Serbia in the conditions of climate change. They are derived from the agriculture sector climate change impacts assessment, conducted for each sub-sector taking into account the available data and knowledge, analyses of the observed and future climate change effects, and the analyses of the identified sub-sector specific climate hazards (*Chapter 2, Appendix 2*). The table provides a closer description of the activities and the effective implementation methods based on which the adaptation measures in the agriculture sector within this Programme have been specified.**

Necessary steps for implementation of climate change adaptation	Meaning	Method of implementation	Priority sub-sector beneficiaries
Improvement of agrometeorological services	Effective dissemination of information on heat and humidity/moisture conditions and on upcoming weather conditions according to the needs of agriculture production	Expanding the agrometeorological observational network, development of operational forecasts (long-term, monthly, medium/short-term) designed for agricultural purposes, and ensuring the availability of this information with necessary spatial and temporal resolution.	All agriculture sub-sectors
Optimize irrigation in line with the needs and resources	Increasing irrigation capacity and improving irrigation efficiency	Incorporating information on climate change and its impacts on water and soil resources and on irrigation needs into the planning of irrigation systems constructions and into the irrigation practices	Crop farming and fruit growing (increased needs in viticulture predicted)
Sustainable soil management	Preservation and potentially improving soil quality through implementing measures such as optimal tillage, fertilization, and pesticide use, erosion control, more efficient regeneration, etc., due to changing climate conditions	Developing training manuals/guidelines for education of agricultural advisors and other stakeholders, developing recommendations within the zoning projects in various agricultural sub-sectors	Crop farming (increased needs in fruit growing and viticulture predicted); In livestock farming, protection against erosion through implementation of optimal grazing practices
Assess change in climate conditions and dynamics of the change to ensure adaptive production	Developing georeferenced data and information on high spatial resolution to identify optimal growing conditions and assess risks, including future climate data and regular updating of these information	Incorporating climate change and climate risk information in the zoning projects, manuals/guidelines and other educational materials	All agriculture sub-sectors

Expand scientific knowledge about impacts and measures for mitigating negative impacts	Expanding and updating impact assessments for specific agriculture sub-sectors and identifying effective methods for mitigating negative impacts	Incorporating new results in the zonings, manuals/ guidelines and other educational materials	All agriculture sub-sectors
Agricultural production insurance	Providing protection for agricultural producers' income from increasing climate hazards	Considering options for insurance policies in agriculture for weather extremes that exceed the current adaptation capabilities	All agriculture sub-sectors
Protect plantations against frost in growing season	For the existing plantations: frost protection applying the optimal methods (fogging, heating and air mixing) in accordance with the available resources without endangering the environment. When planning new plantations: selecting more resilient species/ varieties, selecting lower-risk locations.	Increasing the capacity to implement storm and hail protection by providing subsidies to agricultural producers for its implementation, and by educating about risks.	Fruit growing and viticulture
Protect plantations against high temperatures	For the existing plantations, installation of shade nets. When planning new plantations, selecting more resilient species/varieties, selecting lower-risk locations.	Increasing the capacity to implement protection against high temperatures by providing subsidies to agricultural producers for its implementation, educating about risks and integrating risk information in the zoning projects.	Fruit growing (increasing risk in viticulture predicted)
Protect plantations against storms and hail	For the existing plantations, installation of anti-hail nets, raising of windbreak belts. When planning new plantations, selecting species/varieties that are more resilient to strong wind gusts.	Increasing the capacity to implement storm and hail protection by providing subsidies to agricultural producers for its implementation, and by educating about risks.	Fruit growing and viticulture
Provide climate-efficient livestock housing facilities	Protecting livestock from heat stress in climate-smart housing facilities, with optimal ambient conditions maintained with minimal energy consumption.	Subsidizing construction of new facilities or adaptation of the existing facilities.	Livestock farming
Increase the capacity to achieve sustainable livestock production in the conditions of climate change	Selecting species and breeds that are more resilient to adverse climate conditions expected at the location of production (drought and heat stress).	Developing livestock production zoning with risk assessment and recommendations on species/breeds selection and breeding methods.	Livestock farming
Enable the implementation of short-term adaptation: adaptation of agricultural production to weather conditions (mitigation the impact of weather extremes)	Using information about current and expected weather conditions (from long-term to short-term forecasts) and adjusting production activities to reduce negative impacts (short-term adaptations, i.e., "production adjustments").	Education on the availability and use of forecasting products and possible measures that can mitigate the negative impacts of extreme weather.	All agriculture sub-sectors
Enable the implementation of long-term adaptation: adaptation of agricultural production to changed climate conditions	Spatial mapping of suitable conditions for cultivating various species/varieties and mapping different levels of risk from the identified climate hazards, with recommendations on species/ variety selection and cultivation methods.	Implementation of activities in accordance with the zoning recommendations. Due to accelerated climate changes, there is a need for the zoning revision and update, and education about the changing climate conditions and adaptation methods.	All agriculture sub-sectors

5.3. Forestry

The impact of climate change on forests in the Republic of Serbia has been monitored through UNFCCC reports (through National Communications) since 2010 and through various scientific studies (the selected studies are listed herein). Understanding and monitoring the impact of climate change in this sector is extremely important, particularly considering that, according to the Forest Inventory preliminary data, the forest cover in the Republic of Serbia is 39.3%. The lowest forest cover is in Vojvodina, at approximately 8%. It has been identified that there is vulnerability and growing risks due to climate change for the sustainability of this sector, i.e. for the vitality and productivity, as well as the survival of forest species. Table 8 provides a brief overview of the impacts of climate change on forests and consequences. In addition to the above, it has to be taken into account that forests are complex ecosystems, which can be indirectly threatened by the impacts of climate change on other components of the system, i.e. on the biodiversity in these areas and other components of the climate system (water, soil, etc.; *Appendix 1 - A1.5*). Due to the importance of forests for maintaining the biodiversity, the impacts on forests are monitored also in this sector (*Chapter 5.7*).

Table 8. **Impacts of climate change on forests by climate hazard groups and potential consequences of such impacts.**

Climate hazard groups	Impacts	Consequences
Too warm	Temperature increase causes a shift in the phenological stages of plants development. Temperature increase generally favours the development of plant pests. High summer temperatures, along with precipitation deficit, slow down the radial growth of trees, reducing the resilience of trees to diseases and pests. High summer temperatures, along with dry conditions, can lead to forest fires.	Increased yield variability in terms of quality and quantity in different years; Reduced yield quality and quantity; Increased water demand; Reduced soil quality; Damage to agricultural infrastructure.
Too wet	Wet and warm summers favour the development of bacterial infections. Heavy snowfall can cause physical damage to trees.	
Too dry	Drought slows down the radial growth and reduces tree resilience. Decrease in groundwater levels causes drying and reduced vitality of pedunculate oak, narrow-leaved ash, willow, poplar and other hygrophilous species.	
Storms	Strong wind gusts can cause physical damage to trees, including windfalls and windbreaks.	

The assessment of risks of future climate change has been carried out according to the RCP4.5 and RCP8.5 scenarios for the climate conditions for the mid-century and the end of the 21st century periods for the timely planning and implementation of adaptation measures. In forestry, early planning and timely intervention to reduce risks is of extreme importance considering the long life span of forest species and consequent additional risks from the impacts of slow onset climate changes (such as increasing level of aridity, increasing average temperatures, etc.; *Chapter 3.3 and Appendix 1 - A1.2 and A1.3*), in addition to the climate hazards related to extreme weather events (fires, extreme storms and precipitation, floods, droughts, etc.; *Appendix 1 - A1.4 and A1.6*).

The most recent assessments[40] of the climate change impacts on different types of forests confirm that the conditions for the survival of the existing forests have deteriorated to such an extent that it is necessary to plan and implement timely interventions to prevent the extinction of forests and ultimately the total loss of certain species in the territory of the Republic of Serbia in the future climate conditions, which would have a significant impact on the economy, environment, soil conservation, carbon sink reduction, etc.

In the climate conditions that are expected at the mid- 21st century period, the area with favourable general climate conditions for fir, beech, spruce, white and black pine forests is expected to decrease on average in the range of approximately 15% to approximately 30% compared to the recent past climate, and by the end of the century, under the scenario that predicts a further increase in greenhouse gas emissions (RCP8.5), the areas with favourable climate conditions will be reduced by more than 70%, and possibly by even more than 90%. Pedunculate oak and other hygrophilous tree species will be threatened due to the reduced groundwater availability (*Appendix 1 - A1.5.1*). The change in the conditions is spatially variable, and it is expected that the risk of climate change impacts will be lowest in the western and central parts of Serbia, while a greater impact is expected in the southern areas, southeast and eastern Serbia and in Vojvodina.

[40] Miletić, B., Orlović, S., Lalić, B., Đurđević, V., Vujadinović Mandić, M., Vuković, A., Gutalj, M., Stjepanović, S., Matović, B., Stojanović, B.D., 2021. The potential impact of climate change on the distribution of key tree species in Serbia under RCP4.5 and RCP 8.5 scenarios. Austrian Journal of Forest Science,138. Jahrgang, Heft 3, S. 183–208.

It is important to note that areas with a low forest cover are particularly affected. Additional information on forest species vulnerability assessments can be found in *Appendix 3*. These assessments do not take into account the impacts of extreme weather events and other climate hazards (*Appendix A1.6*) and the information on the condition of forests, which affects their sensitivity to weather and climate conditions.[41] This means that, taking into account the climate hazards whose impacts on forests have been identified, the vulnerability of forests can be even greater, and that negative impacts can become evident earlier and cause even greater consequences in the later period.

From 2019 to the spring of 2022, the Forestry Directorate had used subsidy funds to finance the afforestation on 1726.94 hectares of area where the negative impacts of climate change had been recorded related to long-term drought and extreme temperatures. After one growing season, the seedlings survived only on 884 hectares, i.e. more than a half of the afforested areas dried up already during the first year (Source: Forestry Directorate). This result indicates the need for a different approach in the forestry interventions planning and implementation, taking into account the climate change impact assessments for forest species, and for other components of the climate system that enable the survival of the selected species.

As the characteristics of climate change and changes in climate hazards show spatial variations, afforestation and forest restoration efforts need to take into account the future climate change and risk assessments to ensure the long-term sustainability and thus the profitability and multifunctionality of the implemented activities. The latter is extremely important for the implementation of the measures which fit the Nature-based Solutions concept (*Appendix 1 - A1.5.3.*).

Based on the current knowledge and the identified gaps, the following measures are recommended that enable further climate change adaptation implementation in the forestry sector and ensure the survival of the forest cover in the conditions of climate change:

• Incorporating knowledge about the climate change, impacts and adaptation in the educations for the forestry sector professionals;

• Continuous improvement of the knowledge about climate change vulnerability and risks in order to plan afforestation and reforestation with the aim of achieving forest resilience to climate change in the future;

• Adopting a systemic approach to climate change adaptation by revising the documents which determine frameworks for forest planning and management;

• Considering increasing forest cover in the areas with a low forest coverage (including urban areas) and in the areas subject to degradation due to the impact of climate change (species more resilient to drought conditions are recommended, but with an additional assessment of the capacity to adapt to changed climate conditions:[42] turkey oak, honey oak, field maple, hornbeam, hackberries, acacia, etc.)

• Modifying the forest tree population species and genetic structure by using different provenance types and genotypes that are less sensitive to the expected changed climate conditions.

5.4. (Road) transport infrastructure

The road infrastructure in the territory of the Republic of Serbia is vulnerable to the impacts of climate change, including both the increased frequency, intensity and duration of extreme weather events, and the temperature and precipitation changes (*Chapter 3*). Extreme weather events can cause infrastructure damage and transport disruptions.

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[41] For example: (a) climate change increases the risk of occurrence of weather conditions favouring forest fires (*Appendix A1.6*). In the 2011-2020 period, 17,500 ha of forests were affected by forest fires. The greatest fire damage was recorded in 2012, which had an extremely hot and dry summer, when over 7,000 ha of forest burned down (Source: Serbian Statistical Office); (b) the dry and warm years in the 2011-2013 period favoured the outbreak of the bark beetle epidemic in 2015 and 2016 on the Kopaonik mountain, leading to a massive die off of spruce trees, which had already been physiologically weakened due to the heat and drought stress (Source: Matović B. et al., 2018: Uticaj klime na rast i vitalnost smrče na Kopaoniku, Topola 201-202, 99-116).

[42] The ability to adapt to climate change, i.e. the adaptive capacity, which enables achieving the resilience to climate change, implies that species, as well as ecosystems, can withstand the future climate impacts, including slow-onset climate changes (heat conditions, changes in the aridity level, etc.), as well as changes in the frequency and intensity of extreme weather events (heat waves, storms, extreme precipitation, etc.) and other climate hazards (flash floods, fires, landslides, etc.). Consequently, it has to be highlighted that the resilience of forests depends both on the tree species adaptability, and on the resilience of the entire system.

The vulnerability of road infrastructure to climate change depends also on the terrain characteristics and the road infrastructure condition. Therefore, there is a need to assess the vulnerability and risks due to the impacts of climate change on the road infrastructure at the national level, using the analysis of the observed and future scenarios of climate change and extreme weather events, taking into account the terrain characteristics and the road infrastructure condition.

The road infrastructure is complex and consists of a network of first-class and second-class national roads with a length of 16,380.9 km, a local roads network that is almost twice as long as the national roads network, a total of 3,465 bridges with a length of 151 km, and 109 tunnels with the length of 31.8 km.

Table 9 shows the relationship between specific climate hazards (Table 1, *Appendix 1 - A1.7*), which are increasing in the territory of the Republic of Serbia due to climate change, and the impacts they have or could have on the road infrastructure.

Table 9. **Climate hazards in the territory of Serbia and other climate-related hazards that affect the increased climate vulnerability of road infrastructure and the types of impact they cause.**

Climate hazard groups	Impacts*	Consequences
Too warm	Reduced road structure load-bearing capacity and occurrence of damage to the asphalt surface in the form of ruts and cracks. Roadway deterioration.	Reduced road traffic safety. Reduced road infrastructure functionality. Increase in damages and losses. Increase in needed interventions and investments for damage restorations.
Too wet	Road infrastructure flooding. Drainage system dysfunction. Road substructure erosion and road surface and bridge pile landslides. Impacts on bridge and culvert structures (negative impact on the river banks and watercourse culverts). Road surface deterioration. Changed road maintenance schedule due to snow storms and snow drifts.	
Too dry	Slope instability. Increased road dust. Reduced visibility due to wind erosion and fires.	
Storms	Physical damage to road signs and other road infrastructure components. Reduced visibility.	

**The impacts of climate change on road infrastructure are manifold and it is not possible to list them all. Here, only the most obvious impacts have been selected, without providing details on the mode of action of climate hazards. The critical climate hazards values may differ depending on the characteristics of specific road sections (characteristics of the surrounding terrain, open sections, tunnels, bridges, etc.).*

Individual data shows that in 2016 RSD 20.2 billion were invested in the first-class and second-class national road maintenance, of which RSD 1.3 billion were invested in the rehabilitation of 60 road sections and facilities damaged during the 2014 and 2015 floods. The total material damages on the critical infrastructure caused by the floods have been categorized at the highest level - catastrophic (>5% of the budget).

The road infrastructure data (roads, bridges, tunnels, landslides, traffic management, etc.) is stored in several databases across different institutions, but the updating and comprehensiveness of these databases varies. The databases are not interconnected, which presents a significant problem and makes it impossible to fully analyse the road network including all road assets.

Climate change and its impacts on the road infrastructure, including the increased frequency of extreme weather events, also necessitate revisions to the existing construction standards and practices. Parallel with the revisions of the construction standards and practices, there is a need to adapt the transport sector regulatory framework and public policy framework as well.

The next steps, following the road infrastructure vulnerability and risk assessment, with the aim of climate change adaptation, include the development of adaptation measures and their prioritization.

Due to the increased frequency of extreme weather events, which could lead to more frequent reduced traffic functionality events or traffic interruptions in specific road sections, there is a need to consider the improvement of the early warning system for road infrastructure and the transport.

While the above analyses and the conclusions refer to road infrastructure and road transport, the necessary analyses and adaptation measures could be beneficial also for railway infrastructure and rail transport.

5.5. Energy sector

The climate change assessment (*Chapter 3*) indicates an increase in the changes in the parameters that affect the stability of the energy sector, a change in the distribution of energy demand and changes in the distribution of water resources for energy production. Table 10 provides a brief overview of the impact of the climatic impact-drivers and other climate hazards (Table 1) by climate hazard categories and the consequences.

Table 10. **Impacts of climate change in the energy sector shown by climate hazard groups and the consequences.**

<table>
<tr><th>Climate hazard groups</th><th>Impacts</th><th>Consequences</th></tr>
<tr><td>Too warm</td><td>Impacts of heat waves and rising average temperatures;
Increased need for cooling in the warmer part of the year;
Reduced heating needs in the colder part of the year;
Increased temperature of the water used for power plant cooling.</td><td rowspan="4">Disruptions in the energy demand distribution (change in the annual consumption distribution) and the increased risk of excessive demand during the summer months.
Disruptions in the availability of water resources for energy production and power plant cooling, with the risk of a large deficit during the summer season.
Aggravating the endangerment of aquatic ecosystems due to the impact of climate change.
Production and supply interruptions due to damaged production facilities infrastructure and the power grid.</td></tr>
<tr><td>Too wet</td><td>Due to the change in the annual distribution of precipitation and reduced snow cover retention, the availability of water resources increases in the colder part of the year, and it decreases in the warmer part of the year due to the decreased precipitation during the summer.
A change in the distribution of precipitation by intensity, i.e., an increase in the frequency and intensity of heavier precipitation, can lead to disruptions in the expected available water resources estimated based on average climate parameters.
Flooding can lead to infrastructure damages to production facilities and the power grid.</td></tr>
<tr><td>Too dry</td><td>Reduced availability of water resources for energy production and power plant cooling.
Due to the climate aridity level increase, such deficit could pose a constant threat in some parts of the country.
Due to the increase in the frequency and intensity of droughts, there could be a significant disruption of the available water resources estimated based on average climate parameters.</td></tr>
<tr><td>Storms</td><td>Damage to the power grid.</td></tr>
</table>

The increase in temperature and the increase in the intensity and frequency of heat waves (*Appendix 1 -A1.2.*) cause a change in the distribution of heating and cooling energy demand.[43] Considering that until the middle of the 21st century, i.e., the climate period 2041-2060, the maximum temperatures and temperatures during the JJA season increase faster, greater changes (increases) in the "cooling degree days" values are expected than those (decrease) in the "heating degree days" values. Due to the increased climate variability (*Appendix 1 - A1.2.4.*), it is expected that during extreme conditions there will be greater deviations in these values from average multi-year values than in the past climate conditions. Consequently, there is a need for an analysis of the changes in the distribution of cooling and heating degree days due to the current and future climate changes based on a climate model ensemble representative for the territory of the Republic of Serbia (*Appendix 1 - A1.1.*).

[43] Janković, A., Podraščanin, Z., Djurdjević, V., 2019: Future climate change impacts on residential heating and cooling degree days in Serbia, Idojaras (Budapest, 1905) 123(3):351-370, doi: 10.28974/idojaras.2019.3.6

In addition to the changes in average values, due to the increased variability of climatic conditions, there is a need to develop an analysis of extreme values (values, frequency, duration). For the preparation of this impact assessment, it is recommended to first establish the assessment methodology according to the guidelines provided here, and then proceed with the preparation of the impact assessment study in accordance with the specified methodology.

In order to ensure timely information that would contribute to the planning of energy production in accordance with the needs (demand), there is a need to develop forecasting products to forecast the needs based on the Republic Hydrometeorological Service of Serbia long-range (seasonal) and medium-range (monthly) weather forecasts and regularly update them to include new information. For those purposes, it is recommended to first develop the methodology for the development of this forecasting system for the energy sector, in order to coordinate the forecast ensemble products and the information necessary for the energy sector, the method of presenting the ensemble of special forecasts, and the reliability verification.

The change in the annual distribution of precipitation and the change in the distribution of precipitation by intensity (*Appendix 1 - A1.3.*) have caused changes in the availability of water resources for energy production and power plant cooling. The climate change impact assessment for water resources (*Appendix 1 - A1.5.1.*) shows an extension of the low flow periods in rivers, an increase in the flows during the cold part of the year, a shift in timing of the maximum monthly flow period, a decrease in the minimum flow values, but also an increase in the maximum flow values. Preliminary assessments of the climate change impact on the availability of water for hydro and thermal power plants based on the LISFLOOD model[44] and the ensemble results based on different EURO-CORDEX climate models under the RCP4.5 and RCP8.5 scenarios indicate the following: (1) a change in the seasonal distribution of water availability is expected, with an increase in the DJF and MAM seasons along the Sava and Danube rivers, and a decrease in the JJA season along the Sava river and in the southern areas, (2) water shortages are expected, for example, for HPP Vrla 1-4, Bajina Bašta, Zvornik, Pirot and Potpeć, particularly in the JJA period, (3) at the thermal power plant locations, the highest water availability is expected during the DJF season, with negative changes in the JJA season, for example, in the locations of Novi Sad, Zrenjanin and Kostolac. It is important to note that the annual estimates, which show small changes (mostly increased availability of water resources, with a higher uncertainty of the results), do not reflect accurately the vulnerability due to climate change, considering that the seasonal variations in availability are increasing. It has to be taken into account that during the season with deficit in the available water resources, the need for water will increase in other sectors as well, which would require optimized water consumption redistribution in order to satisfy all consumers' needs. In addition to this, the energy needs grow due to the increase in the cooling needs during the season of reduced availability of water resources. Due to the increase in climate variability (*Appendix 1 - A1.2.4. and A1.3.4.*), an increase in extreme conditions and their impacts is also expected. All of the above indicates an increase in the risk of water shortages for the sufficient power production.

As all indicators of the potential impact of climate change on the availability of water for the energy sector indicate an increase in the climate change risk in the energy sector, it is recommended to develop a study on climate change impact on hydrological parameters for the energy sector needs to be prepared in accordance with a previously established methodology. The methodology should include: establishing relevant future periods for which the risks would be assessed, selecting models and methodology of application of a climate models ensemble and specifying the ensemble values range, selecting and verifying a model (or several models) that would be used for the assessment of hydrological parameters, selecting parameters for which the assessment would be made, and including frequency and intensity of extreme events in the assessment, in addition to the analysis of the changes in mean values. It is recommended to verify the established methodology on the observed period (selected past climate period), and consequently it would be necessary to collect relevant existing data and information on flows, production, water resource needs, etc.

[44] https://ec-jrc.github.io/lisflood/

These assessments of the impact of climate parameters on water resources should take into account the climate change impacts in the wider region that impact also the water resources and parameters in Serbia. Due to climate change and expected changes in the availability/consumption ratios, further efforts are needed relating to the water policy between Serbia and neighbouring countries, as well as the international water resources management in river basins. While this already operates in accordance with the Water Framework Directive and through the work of various international river basin commissions, such as the Danube and the Sava River Commissions, there is a need for the international water resources management to be adapted to the expected climate change impacts.

Due to the increase in temperature, an increase in water temperature is also expected, which should be taken into account in assessing the efficiency of using warmer water for power plant cooling. Plants with disposable cooling systems will become significantly more vulnerable with the increase in frequency and intensity of droughts and changes in the annual distribution of precipitation. On the other hand, periods of increased rainfall and increased flow could result in the increased occurrence of flooding at dam sites, including overflows, breaks, equipment damage, and adverse downstream impacts. In these events, water needs to be discharged safely to minimize damage to power plants, downstream ecosystems and human infrastructure and activities.

The increase in climate variability, i.e., the increase in the deviation of extreme weather conditions from the average climate conditions, as previously stated, requires a timely response in order to reduce the damages and losses in this sector. Consequently, it is recommended to have a system in place for timely information on the availability of water resources for the energy sector needs. This implies the development of seasonal forecast products indicating the state of these resources in the upcoming period (season) and the related risks. Therefore, it is recommended to consider the possibility of using seasonal and medium-range forecasts for timely wanings, i.e., forecasts, of relevant hydrological and related parameters for the energy sector.

In addition to the above, climate change can damage production facilities and the energy distribution system due to extreme weather events, but the climate change vulnerability and risks in the energy sector in this sense have not been considered thus far.

5.6. Urban planning and urban development

Urban areas have been recognized globally as particularly vulnerable to climate change, with the increasing risk in the future climate conditions.[45] The high risk level is caused by the urban heat island effect and a large share of impermeable surfaces, as well as the increased air pollution. Due to the high population density in the urban areas, the exposure of the population to climate change is high, and these areas are a global priority in terms of the implementation of the climate change adaptation measures. In addition to the threat to infrastructure and other urban system functions, there is an extremely high risk for human health and safety.

In the Republic of Serbia, the frequency and intensity of climate hazards is increasing, which will increase the risks of climate change (such as risks of heat waves, heavy precipitation, droughts, etc.) in urban areas. Table 11 provides a brief overview of the climate change impacts and consequences in the urban areas.

Table 11. **Climate change impacts on urban environments by climate hazard groups and potential consequences of those impacts.**

Climate hazard groups	Impacts	Consequences
Too warm	Due to temperature increase and more extreme and frequent heat waves, heat stress has significantly increased compared to the areas outside urban centres, due to the urban heat island effect.	High risks to human health and safety. Property and infrastructure damage.

[45] PCC, 2022: Summary for Policymakers [H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.)]. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–33, doi:10.1017/9781009325844.001.

Too wet	The increased frequency and intensity of events with heavier precipitation increase the frequency of flash floods, flooding and landslides. Increase in surface runoff and the occurrence of flash floods due to large impermeable surfaces.	Interruptions or reduced availability of the utility services (drinking water, electricity, transportation, etc.). Environment degradation.
Too dry	Precipitation deficit, drought and reduced groundwater levels decrease availability of water for drinking and increase other needs in urban areas. Drought and high temperatures have a stressful effect on urban vegetation.	
Storms	Strong wind gusts can cause physical damage to property and infrastructure.	

In the urban areas, a large share of solar radiation is absorbed by asphalt and concrete and other building materials, which in turn warm up the surrounding air. In addition, due to tall buildings, the reflected solar radiation bounces back against materials that absorb the radiation of these wavelengths very well, and the energy that comes from the sun is "trapped" more effectively than in an open space. During the daytime, asphalt and concrete heat up by approximately 10°C more than bare soil, and even by approximately 20°C more than grassed surfaces.[46] Air temperatures above asphalted and concrete surfaces can be approximately 10°C higher than those above soil and grass. This means that the air temperature in the urban areas with a pronounced urban heat island effect is significantly higher than the standard meteorological measurements made in places that are not affected by such local effects. In mean climatic values, temperatures in the urban areas are on average approximately 2°C higher than in the city periphery (*Appendix 1 - A1.2.5*).

Taking into account the climate models' results (Source: Digital Climate Atlas of Serbia) record high temperatures of above 44°C (in some cases even above 45°C) are expected in the coming decades, which means that in the cities in the Republic of Serbia during heat waves in the warmer part of the year, in the lowland areas, there will be periods with temperatures above those considered dangerous for human health (42°C at a relative humidity level of 50%).[47] These temperatures refer to the values that are expected to be measured according to the World Meteorological Organization standard, i.e., at the locations of the RHMSS meteorological stations that do not reflect the urban heat island effect. The average number of days with temperatures above 40°C will average between once in every three years and once a year by mid-century, which mean that in the urban areas with a pronounced heat island effect, air temperatures that during the day will exceed even 50°C. Such high temperatures can cause heat stroke and other health problems even at low relative air humidity values. The especially vulnerable population groups (*Chapter 5.1.*) are at risk during the summer months even in the current conditions.

Due to the increasing risk of extreme precipitation in the territory of the Republic of Serbia (*Appendix 1 - A1.3.2*), there is a growing risk of large surface runoffs and water accumulation (floods, flash floods, landslides) in the urban areas. Due to droughts, some cities are left without sufficient water for the public water supply, which is an additional growing climate change risk.

The extent to which the urban environment is truly threatened by climate change depends on its location and structure, and it is essential to take climate change into account in the vulnerability assessments and planning at the local level.

The climate change vulnerability and risk assessment for urban areas, in terms of the impacts on population, is closely related to the assessment of the climate change impact on human health and safety (*Chapter 5.1.*) and requires improvement of knowledge and climate change monitoring , particularly in the urban areas.

[46] Yilmaz, H., Toy, S., Irmak, M.A., Yilmaz, S., Bullut, Y., 2007: Determination of temperature differences between asphalt concrete, soil and grass surfaces of the City of Erzurum, Turkey, Atmosphere, 21(2), 135-146.
[47] Mora, C., Dousset, B., Caldwell, I. et al. Global risk of deadly heat. Nature Clim Change 7, 501–506 (2017). https://doi.org/10.1038/nclimate3322

In accordance with the EU Adaptation Strategy (Priority Measure 3: Promoting adaptation activities by cities), this Programme focuses on initiating activities that would lead to progress in the climate change adaptation measures planning and implementation in the urban areas in the Republic of Serbia. This Programme sets out the following priority measures:

• Maintaining and increasing "green" surfaces in the urban areas, in accordance with the green infrastructure concept, and improving their maintenance in accordance with the changing climate conditions;

• Urban areas climate change adaptation planning and implementation at the local level;

• Microclimatic (heat) conditions monitoring in the areas with a pronounced urban heat island effect.

Green surfaces represent the implementation of the Nature-based Solutions concept in the improvement of living conditions in the urban areas and climate change adaptation,[48] including human health and safety. This approach implies green infrastructure improvement in the urban areas to achieve multiple benefits, such as reducing the urban heat island effect, increasing the surface water infiltration capacity, and improving air circulation.[49] The city greening initiative is in line with the EU Adaptation Strategy activities for urban environments climate change adaptation and urban development in general.

To ensure the implementation of the proposed framework measures, this Programme focuses on the following steps that must be implemented during the life of the Programme:

• Adopting a systemic approach to the implementation of the green infrastructure concept and climate change adaptation nexus through urban development regulatory frameworks;

• Providing support to local self-governments for implementing climate change adaptations in urban areas by strengthening green infrastructure;

•Considering the possibility of monitoring the urban heat island effect in urban areas to ensure public alerts and monitor its impacts on public health.

5.7. Biodiversity

Increasing biodiversity resilience to climate change is a multisectoral task. Climate change adaptation measures in different sectors must contribute to increasing biodiversity resilience or, at least, must not in any way increase biodiversity vulnerability to climate change. Monitoring biodiversity indicators in the conditions of climate change, in addition to indicators of water quality, food, vector-borne diseases and other, can indicate the health state of the environment and natural resources in the conditions of climate change. That is why it is necessary to have an adequate biodiversity monitoring system in place, especially to monitor the indicators that are more sensitive to climate change.

A brief overview of the identified climate change impacts and the potential consequences for biodiversity is presented in Table 12. According to current scientific research and assessments, climate change has a tendency of becoming a dominant factor in the loss of biodiversity (including agrobiodiversity) and significantly change the species distribution range by the end of the 21st century. Particularly sensitive species categories include the following: endemic species, species inhabiting higher altitudes, and species with narrow habitat niches and limited ranges. In addition, together with climate change, habitat loss and degradation has been identified as the cumulative threat to biodiversity vulnerability, and as a specific threat in the context of climate change caused invasive species spreading and endangering equilibrium of natural communities. A trend of species recomposition and a greater influx of more xerophilic, Mediterranean-sub-Mediterranean and continental species, including ruderal and allochthonous representatives,

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[48] Vuković Vimić, A., Petrović, N., Weinreich, A., Pistorius, T., 2021: Rešenja zasnovana na prirodi za klimatske promene i potencijal za njihovu primenu u Srbiji, UNDP, Belgrade, Serbia, ISBN: 978-86-7728-304-9.

[49] In addition to large green areas, which include parks, green corridors and other areas designated mainly for recreation, green infrastructure also includes the provision of smaller green areas, such as green roofs and walls, smaller green areas in the vicinity of buildings and at parking surfaces, etc. Tall vegetation, i.e., trees, also contributes to providing natural shade, which, due to evapotranspiration, also reduces the air temperature. Green surfaces locally lower the air temperature and increase the difference in temperature compared to surfaces that heat up intensively (concrete, asphalt, etc.), resulting in local air circulation. Green roofs improve the conditions for vertical air mixing, as well. This effect also contributes to the local pollution reduction. Due to accelerated climate change, there is a need to use planting materials resistant to changing climate conditions, which contributes to the sustainability of urban greenery, and green infrastructure in general.

can be expected.[50] The danger of local populations extinction is the greatest in regions with fragmented (split) remnant natural habitats such as Vojvodina and some parts of Central Serbia where, due to the increasing isolation of natural areas, the possibilities of migration to more favourable habitats are significantly reduced.

Table 12. **Climate change impacts on biodiversity by climate hazard groups and potential consequences of those impacts.**

Climate hazard groups	Impacts	Consequences
Too warm	Disruption of species' phenological phases. Drying out and overheating of habitats. Physiological weakening of species Fires can threaten the communities structure and the survival of specific species.	Disruption of the species' life cycle. Physiological drying of forests. Prolonged droughts lead to increased species mortality. Disappearance of frigoriphilic species, along with the spread of thermophilic species. Extinction of species due to slow natural migration, particularly in areas with pronounced habitat fragmentation. Habitat shrinking for endemic, endemo-relict and relict species. Disappearance of species with narrow ecological niches (low tolerance to changing habitat conditions). Disappearance of hydrophilic and the spread of xerophilic species. Loss of suitable habitats for alpine and subalpine species. Colonization of disturbed habitats by ruderal species or foreign species of wide ecological amplitude (invasive species). Reduced biomass production causing disruptions in herbivores food chain. Reduced biomass production contributing to the "pollinator crisis". Loss of species in fires leading to a long-term disturbance in the ecosystem functioning. Windfalls and windbreaks open the way for pest attacks and diseases. Drier topsoil layers lead to reduced biomass production.
Too wet	Heavier precipitation can lead to physical damage to plants: disturbed oxygen balance in soil, resulting in root rotting. Flooding can lead to coenobionts population decline in the affected ecosystems.	
Too dry	Drought leads to reduced biomass production, physiological weakening of species. Increased risk of forest fires and other fires - disrupted community structure. Autumn and winter drought lead to reduced water levels in wet habitats.	
Storms	Strong winds cause physical damage to plants. Increased intensity and duration of wind leads to surface soil layers drying, increased evapotranspiration and physiological weakening of species. Increased wind intensity and duration is a disturbance factor for movement and cycle of pollinator species.	

The Republic of Serbia still has implemented an integrated functional national biodiversity geo-information system available to the wider scientific public and interested professionals, and consequently, the comprehensive monitoring and study of the climate change impact on biodiversity is limited. In addition, integrated lists of priority species, habitats and ecosystems for monitoring the climate change impacts on biodiversity still need to be developed. Monitoring needs to include natural habitat inventory and status (as a priority, for the protected natural resources), as well as digital habitat mapping in accordance with the European Nature Information System (EUNIS) classification. The INISB database should be made available to the wider scientific public online, in accordance with the INSPIRE Directive, similarly as other databases.

The methodologies and indicators used by the parties to the United Nations Convention on Biological Diversity (UNCBD) are not harmonized. In 2023, the Convention on Biological Diversity planned to update and adopt an improved methodology and sets of indicators that will quantitatively monitor the progress in achieving the specified objectives. The Republic of Serbia needs to define the methodology, harmonize biodiversity indicator sets and main variables (parameters) for status monitoring and vulnerability assessment, and that methodology needs to be harmonized with the UNCBD recommendations.

[50] Aleksić V., Lazaravić, P., Krizmanić, I. (2019). Klimatske promene i upravljanje zaštićenim područjima u Srbiji. Belgrade: BOŠ and WWF

IPCC AR6 (WG2)[51] recognizes, with a very high confidence, that biodiversity loss and degradation, as well as damage and changes to ecosystems, have already become key problems in all regions of the world due to current global warming, and will continue to increase with the increase in global temperatures. The risks of impact on biodiversity are closely related to the ability to use ecosystem services, and in general to the population well-being and certain economic sectors that use natural resources. In the Republic of Serbia, this problem has not been considered so far to a sufficient extent and requires further research.

For the preparation of the Sixth Report under the United Nations Convention on Biological Diversity, the Republic of Serbia identified the indicators for monitoring climate change impacts on biodiversity.[52] A clear connection between the occurrence of tree drying and pronounced defoliation of beech, Austrian oak, Hungarian oak and spruce with the occurrence of dry and very hot summers in Serbia was established. Damages to forests caused by natural disasters are being reported to increase. Areas affected by fires were particularly large during the dry and hot years of 2003, 2012 and 2016. The analysis has found that the decrease in the number of forest mushroom species is associated with a decrease in annual precipitation, relative air humidity, and soil humidity, and consequently, with further changes in the precipitation regime, changes in the number and diversity of mushrooms can be expected, which would further affect the natural processes involving mushrooms, as well as forest vegetation. The analysis has shown that it is very likely that the change in heat conditions had caused the wild cherry laurel (Zeleniče) blooming in its natural habitat (Oštrozub mountain). The cherry laurel blooming was recorded in only 5 years, 1983, 1998, 2008, 2012 and 2017. For the winter aconite, an extremely endangered and strictly protected species, the analysis shows a shift of blooming towards an earlier period of the year due to temperature increase and more frequent occurrence of heat waves. The black-headed bunting bird species has expanded its habitat from the south towards the north of Serbia, due to temperature increase and the more frequent occurrence of drier conditions. The analysis of the waterbird populations over a relatively short-term observation period did not show a significant trend of change, but for two species, the tufted duck and the little grebe, a negative trend was observed that may indicate potential changes in the population. Based on the above examples, and taking into account the results of the study on the impact of climate change on Serbian forests (*Chapter 5.3.*), there are indications that confirm that biodiversity has been affected. The focus in the Republic of Serbia has so far been on the species: Picea abies (L.) H.Karst., Fagus sylvatica L., *Quercus petraea L.*; vulnerability assessment for dry, wet and high mountain grassland communities; on insect species: Cacyreus marshalli Butler, Diptera: Syrphidae; on specific bird species, and on monitoring populations of invasive plant species .

The recommended measures for increasing biodiversity resilience to climate change, which would also have multisectoral benefits, are provided in Table 13. In terms of the measures identified under this Programme, it is recommended to focus on the measures for establishment or improvement of monitoring systems and the measures that would have significant multisectoral benefits. In terms of climate change adaptation, it is recommended that biodiversity should be integrated into the adaptation measures for other sectors, wherever possible. When considering priority measures, the measures specified under the 2019-2025 Serbian Nature Protection Strategy and the Action Plan, which envisage monitoring the climate change impacts on biodiversity and the impact of biodiversity on mitigating the climate change effects, should be taken into account.

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[51] IPCC, 2022: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.
[52] https://bioindicators.sepa.gov.rs

Table 13. Recommendations in the field of biodiversity for preserving biodiversity and ensuring biodiversity resilience in the conditions of climate change, by measure groups and types.

Measures groups	Measures
Mapping and monitoring	Recording and expanding areas of national importance and priority habitats for protection to ensure their monitoring and preservation in the conditions of climate change. Establishing a crowdsourcing platform on invasive species at the municipal level. Developing a comprehensive database and establishing interspecific genetic diversity monitoring.
Planning and reducing risks of climate change and climate hazards	Developing adaptation management plans or revising the existing plans to include a set of measures aimed at reducing the risk of climate hazards in the conditions of climate change and potential solutions for adaptation and mitigating the climate change impacts on biodiversity. Establishing a system for remote detection of the impacts of climatic hazards (fires, floods, windbreaks, snowbreaks) and timely response and remediation of the consequences.
Education	Educating the public/local population about nature and the importance of natural resource protection systems in the conditions of climate change. Educating the public/local population (in the protection zones within the protected areas) about invasive and non-native species of importance.
Interventions	Strategic expropriation of areas in the protection zones within the protected areas and ecological restoration of habitats in accordance with the Nature-based Solutions principles. Increasing the connections/connectivity of priority habitats by strengthening the protection of ecological corridors and through ecological restoration projects, applying the newly established Nature-based Solutions concept. In accordance with the possibilities (and as a priority within the protected zones in the protected areas), ensuring transition from intensive agriculture to organic agriculture and agroforestry systems (>50% of the area). Establishing wind protection/field protection belts (particularly in Vojvodina). Restoring disturbed habitats, which are not within the protection system (degraded, neglected areas) in order to establish a network of near nature habitats, which would contribute to better landscape connectivity. Controlling and suppressing invasive species to ensure the existing community balance. Revising water regime management plans and adapting hydrotechnical facilities to increase water retention in wet habitats of protected areas located within agricultural areas. Revitalizing wet habitats affected by agricultural drainage systems.

6. Desired change (vision) and Programme General and Specific Objectives

The Programme vision is: The Republic of Serbia is resilient to climate change.

This Programme will enable increasing the resilience of the Serbian economy to climate change, as well as adequate quality of life for the citizens in a climate-resilient society.

6.1. Programme General Objective

Increasing the capacity to achieve greater climate change resilience implies building a system and society with a high level of awareness about climate change, its impacts and the need for adaptation. It also implies the timely provision of the necessary information to professionals in different sectors and to all citizens. This is the basis for the development of a successful climate change adaptation process, and in turn, ensuring the capacities for greater resilience.

The Programme General Objective, the indicator for monitoring during the Programme implementation period, its baseline value and its target value at the end of the Programme are shown in Table 14. The General Objective could be monitored through a composite indicator obtained based on the weighted values of the indicators for the Specific Objectives in relation to the target value.

Table 14. **Programme General Objective definition, its monitoring indicator, baseline value and target value.**

General Objective	Indicator (impact level)	Baseline Value	Target Value
Increasing the capacity to achieve greater climate change resilience to ensure population well-being, economy and the living environment improvements.	A) The percentage share of respondents in the national-level public opinion survey, with monitoring the increase in the awareness about climate change issue. B) The percentage share of respondents in the national-level public opinion survey, with monitoring the increase in the awareness about the increased risk of climate hazards	A) 51% B) data not available	A) > 65% B) > 70%

The increase in the capacity to achieve greater resilience to climate change will be monitored based on a national-level public opinion survey on a representative sample conducted by the UNDP on an annual basis.[53] These surveys enable the development of the indicators showing the state of public awareness and knowledge about the problem of climate change, increasing risks of climate hazards, and the needs of citizens and preparedness of citizens to adapt to climate change. According to the 2022 survey, the share of respondents who believe that climate change is a problem and that it is necessary to introduce measures to prevent its consequences is only 51%, which indicates a low awareness level.

In addition to the above indicators, the Republic of Serbia will regularly monitor other available indicators that show Serbia's position in relation to other countries. These include primarily: 1) *University of Notre Dame Global Adaptation Index* (ND-GAIN index),[54] which ranks countries according to climate change vulnerability and resilience; and 2) *Climate Risk index* by the German Watch organization,[55] which examines at the levels of material damage and losses due to extreme weather events.

[53] https://www.undp.org/sites/g/files/zskgke326/files/2022-06/undp_rs%20Istra%C5%BEivanje%20%C5%A0ta%20javnost%20u%20Srbiji%20misli%20o%20%C5%BEivotnoj%20sredini-converted.pdf
[54] The indicator and methodology are available at https://gain-new.crc.nd.edu/
[55] The indicator and methodology are available at https://www.germanwatch.org/sites/default/files/Global%20Climate%20Risk%20Index%202021_2.pdf

6.2. Programme Specific Objectives

The Programme Specific Objectives and their monitoring indicators, baseline values and target values at the end of the Programme are provided in Table 15. Four Programme Specific Objectives have been identified based on the type of measures and activities that would be implemented. Special Objective 1 includes a group of measures in different fields and sectors that aim to improve the climate change awareness and preparedness of the citizens and the sectors, which would further increase climate change resilience through their activities, and to enable further development of knowledge to improve and sustain climate change resilience in the future. The number of the Digital Climate Atlas users represents the indicator of the increasing use of the observed and future climate change data. The use of such data is a precondition for the professional and scientific public to include climate change in their analyses, assessments and research studies. The data could also be used in more advanced education activities, but it is not expected it will be mainstreamed in the primary and secondary education programmes during the period of the Action Plan, due to insufficient training material available for the teaching staff. In the course of the Action Plan, it is expected that the data will be used mainly for academic education and scientific research purposes. That is why the expected number of the Digital Climate Atlas data users, after the implementation of the Programme, will be greater than 1500, which includes approximately 15% of the researchers in the Republic of Serbia. The number of the produced studies and manuals would be monitored as the indicator of the produced and published materials that serve to expand knowledge and to educate about climate change and its impacts and the necessary adaptation measures. The number of the developed methodologies would be monitored as the indicator of the development of the approaches to assessments of climate change impacts, vulnerability and risks, as well as the methods for informing the sectors and systems where such an assessment has not been previously conducted due to the lack of interdisciplinary collaboration and the lack of data, or the fact that climate change data were not included in the activities where necessary. This indicator shows the necessary intermediate step in the further implementation of studies, regulations changes, other assessment methodologies, monitoring and warning systems developments, etc.

Special Objective 2 includes a group of measures that aim systemic implementation of climate change adaptation, by revising documents and regulations in the sectors included in the Programme, which would ensure the implementation of the recommended priority measures from the national to the local level. The indicator for this Special Objective will be determined based on the reports from the Ministry of Environmental Protection, by assessing the percentage share of the adopted public policy documents in the sectors included in the Programme that have recognized the climate change impacts, i.e. that have included climate change adaptation measures,.

Special Objective 3 includes a group of measures that would contribute to ensuring the increased climate change resilience of critical infrastructure and natural resources. It will be measured by an indicator that describes the number of capital projects whose planning, i.e., construction and maintenance, took into account climate change. Special Objective 4 includes measures related to providing financial support and means for the implementation of measures that contribute to increasing climate change resilience. These measures can be financed from the budget of the Republic of Serbia, from international funds, by the private sector, including public-private partnerships, and from the local self-government funds. The achievement of this objective will be measured through the number of programme activities that provide or encourage investments in climate change adaptation.

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Table 15. **Definitions of four Specific Objectives of the Programme, indicators for their monitoring, baseline values and target values at the end of the Programme implementation, and the data source for the indicator monitoring.**

	Specific Objective Definition	(Outcome) Indicator			Source
		Indicator	Baseline Value	Target Value	
Specific Objective 1	Raising awareness and improving knowledge and understanding about the climate change impacts and consequences	A) Number of the Digital Climate Atlas unique visits B) Number of studies and manuals C) Number of methodologies	A) not available B) 0 C) 0	A) > 1500 B) 10 C) 7	Report on the number of the Digital Climate Atlas users, completed studies, manuals and developed methodologies
Specific Objective 2	Establishing and strengthening capacities for the systemic implementation of the climate change adaptation process from national to local levels	The percentage of adopted public policy documents in the sectors included in the Programme that have recognized the climate change impacts, i.e., included climate change adaptation measures	0	100 %	Ministry of Environmental Protection Report
Specific Objective 3	Increasing climate change resilience of critical infrastructure and natural resources	The number of capital projects whose planning, construction or maintenance, takes into account climate change issue	0	100 %	Report in accordance with the Regulation on Capital Projects
Specific Objective 4	Strengthening financial support for the implementation of the climate change adaptation process	The number of Programme activities that provide or promote investments in adaptation based on green expenditure tagging methodology in the course of the preparation of the 2025 Annual Budget Law	0	20	Budget Execution Report

7. Proposed climate change adaptation measures to be implemented during the Programme

The adaptation measures proposed to be implemented during the implementation period of this Programme have been developed based on the proposed measures presented in the Programme, which result from climate change assessments (*Chapter 3*) and the impact assessments (*Chapter 5*). The measures have been selected based on the need for urgent implementation and the feasibility of the implementation depending on the available financial and human capacities. The selected measures (25 measures) are provided in Table 16, classified into the following groups: crosscutting measures (measures with multisectoral benefits and benefits for the general public) – measures 1 to 9; measures whose primary contribution would be felt in a specific sector – agriculture (measures 10 to 15), forestry (measures 16 to 18), road infrastructure (measure 19), urban planning (measures 20 and 21), energy (measures 22 and 23), health (measure 24), and biodiversity (25).

The measures impact analysis is provided in Appendix 4 to the Programme (this technical addition to the Programme is not included in the English version, because their impacts are explained through already provided impact assessments by sectors).

Table 16. **Climate change adaptation measures proposed to be implemented during the life of this Programme (group, name, number of the Programme Special Objective it belongs to, and measure description) with the listed key implementation institutions, partners and stakeholders.**

CROSSCUTTING MEASURES
1. Monitoring the implementation of measures with benefits in the climate change adaptation process when integrating green aspects in public policy documents
Specific Objective 2
The measure envisages the development of the Guidelines for the integration of green aspects in public policy documents to recognize adaptation measures and activities. That would support the systemic integration of the climate change adaptation processes within the public policy documents. After the Guidelines are developed, there is a need to deliver training for their implementation.
Key implementing institutions: Serbian Public Policy Secretariat (hereinafter: PPS)
Partners: Government
Stakeholders: international financial institutions and funds, investors, local self-government units, and civil society organizations
2. Monitoring green expenditures in the budget of the Republic of Serbia that contribute to the climate change adaptation process
Specific Objective 4
This measure aims to ensure by the end of 2023 that the Ministry of Finance (1) will have developed a methodology that will define the term “green expenditures” in the budget of the Republic of Serbia, which would specifically recognize and tag green expenditures that contribute to climate change adaptation, (2) establish the procedure and deadline for the implementation of the methodology in the course of the preparation of the annual budget of the Republic of Serbia. The adopted methodology, along with the “Road Map” for its implementation, should be used for the preparation of the Serbian 2025 budget (to be adopted by December 2024). During the Programme implementation period, and after the implementation of the first Action Plan, it is necessary to improve the green expenditure tagging methodology, so that improvements are made during the preparation of the Instructions for the preparation of the Republic of Serbia’s Budget for the year 2028.
Key implementing institutions: Ministry of Finance
Partners: Government
Stakeholders: National Bank of Serbia, international financial institutions and funds, investors, civil society organizations

3. Establishing a system for monitoring climate change, its impacts, implementation and success of climate change adaptation measures
Specific Objective 1
This measure includes: • Climate change monitoring - improvement of climate change monitoring through a portal with georeferenced climate data, which is regularly updated and has a data download option • Climate change impacts monitoring through an improved damage and loss monitoring system • Adaptation measures success monitoring through a reporting system on implemented measures and outputs. During the Programme implementation period, review the indicators for monitoring climate change recommended at the EU level and, if possible, harmonize the indicators to reflect the EU indicators. The measure implies the adoption of a bylaw on reporting on the Adaptation Programme implementation in accordance with Article 15 of the Law on Climate Change, enabling climate change impact monitoring at the local level, including climate hazards such as droughts, floods, etc. This measure includes the development and establishment of a system to monitor the success of measures aiming to increase climate change resilience, which is a key requirement for reporting under the United Nations Framework Convention on Climate Change, and the Paris Agreement, with the additional benefits in terms of reporting under other United Nations Conventions. This would provide the necessary information and data to further improve the understanding of the climate change impacts and the development of measures to increase resilience.
Key implementing institutions: Ministry of Environmental Protection, Ministry for Public Investment
Partners: Republic Hydrometeorological Service of Serbia, Serbian Geodetic Authority, local self-governments, universities and other institutions
Stakeholders: general public, scientific researchers, international financial institutions and funds, investors, civil society organizations, educational institutions
4. Developing climate change adaptation research programme
Specific Objective 1
Within the existing science and research financing models, such as the Science Fund, there is a need to establish a research financing programme in the field of climate change adaptation. Ideally, the expected scientific results should contribute to new information about climate change in the territory of the Republic of Serbia, vulnerability and risk assessments, and adaptation methods in different sectors. That would ensure the sustainability of the "smart" adaptation concept supported by this Programme, and the adaptation approach as a process that will go in line with future climate changes.
Key implementing institutions: Science Fund, Ministry of Science, Technological Development and Innovations
Partners: Ministry of Environmental Protection
Stakeholders: universities and other scientific institutions, scientific researchers, educational and other institutions, private sector
5. Improving disaster risk assessment by including changes in climate hazards frequency and intensity caused by climate change
Specific Objective 2
There is a need to revise the bylaw "Methodology for preparation and content of disaster risk assessment and protection and rescue plans" to include, among others, the climate change impact on the identified hazards.
Key implementing institutions: Ministry of the Internal Affairs
Partners: Ministry of Environmental Protection, Republic Hydrometeorological Service of Serbia, Ministry for Public Investment
Stakeholders: local self-governments, Autonomous Provinces
6. Integrating drought as a multidimensional climate hazard in the system for monitoring, timely alerts and impact assessment, including damages and losses
Specific Objective 1
The problem of increased drought frequency and intensity has been recognized in various sectors, and it affects the yield quality and quantity, the forest ecosystems survival and development, water availability, road infrastructure, etc. Consequently, there is a need to establish a drought monitoring methodology, which would be of importance for all relevant sectors in the Republic of Serbia, taking into account all aspects of this climate hazard (meteorological, hydrological, soil, physiological, etc.), and the time dimensions for which it is identified: from long-trange to short-range. The development and implementation of this methodology is a precondition for improvement of drought monitoring, impact identification, including damages and losses assessment, and early warning system strengthening.
Key implementing institutions: Ministry of Environmental Protection
Partners: Republic Hydrometeorological Service of Serbia, Ministry of the Internal Affairs, Ministry for Public Investment, Ministry of Agriculture, Forestry and Water Management, universities and other scientific institutions
Stakeholders: commercial sector, private sector

7. Strengthening capacities to satisfy the increased needs for timely information dissemination on climate and weather conditions
Specific Objective 4
The measure implies strengthening the capacities (institutional, technical and human capacities) of the Republic Hydrometeorological Service of Serbia for the implementation of other measures foreseen under this Programme, which relate to the main infrastructure components of the hydrometeorological early warning and alerts system, particularly upgrading the designated high performance computing system, observational capacities (surface and high-altitude meteorological measurements and radar observations), as well as timely information dissemination on weather conditions and climate hazards, to reduce damages and losses. This measure would also provide capacities for climate change monitoring and other contributions to impact monitoring, climate hazard risk assessments, etc. In addition, an integral part of this measure is the provision of efficient information dissemination capacity (development of databases, interactive portals, user communication tools, etc.). During the Programme implementation period, it is necessary also to ensure the conditions for maintaining the improved capacities of the RHMSS. This measure is a precondition for increasing population safety and economy strengthening, with contributing to the protection of the environment and its resources from the impacts of more frequent and intense climate hazards.
Key implementing institutions: Republic Hydrometeorological Service of Serbia
Partners: Universities and other scientific institutions
Stakeholders: Ministry of the Internal Affairs, Ministry of Environmental Protection, commercial sector, private sector, local self-government units
8. Improving the preparedness of the citizens of the Republic of Serbia for weather and climate extremes
Specific Objective 1
This measure refers to the improvement of the products and information dissemination methods of the Republic Hydrometeorological Service of Serbia, enabling the citizens and the economy, including the private sector, to be informed in a timely manner about the upcoming weather events and potential consequences on various time scales (from long-range to short-range forecasts), and with the necessary spatial resolution (high-resolution forecasts), in order to mitigate or prevent adverse impacts and capitalize on the potential benefits. This measure implies strengthening of forecasting and its high spatial resolution products, and the improvement of tools for timely information dissemination. Due to the increased security risks, the volume of new products, information and the growing user demands, there is a need to create a new website for the Republic Hydrometeorological Service of Serbia, using new tools and other methods of modern information technologies, which would ensure stable and reliable operation of the new website. During the Programme implementation period, there is a need to improve the products with the aim to improve road traffic safety (providing information on expected road conditions). During the Programme implementation period, there is a need to conduct education for the media to ensure timely and regular reporting on climate hazards. There is a need to develop education programmes for children and youth and to adjust the products to their age, and the educational materials available to all population groups. The implementation of this measure is closely related to the implementation of the measure 7 of this Programme.
Key implementing institutions: Republic Hydrometeorological Service of Serbia
Partners: Universities and other scientific institutions
Stakeholders: Ministry of Health, Ministry of the Internal Affairs, local self-government units, civil society organizations, general public, the media, commercial sector, including private sector, investors, etc.
9. Addressing regulatory issues regarding land use to mitigate and prevent the degradation process
Specific Objective 2
In order to increase land resilience to climate change in the Republic of Serbia, there is a need to identify the unused and degraded agricultural areas and determine land management methods in these areas by applying sustainable land management practices, and by considering the the Nature-based Solutions concept.
Key implementing institutions: Ministry of Agriculture, Forestry and Water Management
Partners: universities and other scientific institutions, local self-governments
Stakeholders: Ministry of Environmental Protection, commercial sector, private sector
AGRICULTURE
10. Improving the protection of perennial plantations against extreme weather conditions
Specific Objective 4
Due to changing climate conditions (increased risk of hail and extremely high temperatures, and increased risk of frost in growing season) there is a need to: - Increase the amount allocated for subsidies for anti-hail nets and shading nets for orchards and anti-hail nets for vineyards. - Increase the amount allocated for subsidies for frost protection systems in these the perennial plantations.
Key implementing institutions: Ministry of Agriculture, Forestry and Water Management

Partners:
Stakeholders: agricultural producers
11. Increasing the resilience of livestock production to climate change
Specific Objective 4
Due to changing climate conditions (increased risk of extremely high temperatures) there is a need to increase subsidies for the construction of new or adaptation of existing livestock housing facilities, preferably using the climate-smart facility concept.
Key implementing institutions: Ministry of Agriculture, Forestry and Water Management
Partners:
Stakeholders: agricultural producers
12. Increasing the resilience of meadows and pastures to climate change
Specific Objective 1
The measure includes mapping endangered land plots with meadows and pastures where the climate change adaptation measures need to be implemented based on the Nature-based Solutions concept, focusing on conservation agriculture, nutrient management through a permanent vegetation cover (growing legumes for fertilizer purposes), sowing grass mixtures, and expanding areas under drought-resilient species. During the Program implementation period, and after the expiration of the first Action Plan, there is a need to plan actions as adaptation measures on the mapped endangered land plots with meadows and pastures.
Key implementing institutions: Ministry of Agriculture, Forestry and Water Management
Partners: universities and other scientific institutions, Ministry of Environmental Protection, local self-government units
Stakeholders: agricultural producers
13. Optimizing irrigation in line with needs and resources
Specific Objective 3
Due to the climate change impacts on the increased irrigation demand for agricultural crops, on water availability and soil quality, it is necessary to increase irrigation capacities in a sustainable way. Under this Programme, the priority of optimizing irrigation is using collected atmospheric water for irrigation purposes. This measure includes: - Preparing a study at the national level to assess the needs and capacities for use of accumulation reservoirs, including micro-reservoirs, the possibility of building reservoirs and the associated costs. - Assessment of the capacities for using water from the existing reservoirs (irrigation ponds) in central parts Serbia. - Designing and building infrastructure for using water from the existing reservoirs in central parts Serbia. - Providing support for regional and local water resources management planning in central parts Serbia for irrigation in the conditions of climate change.
Key implementing institutions: Ministry of Agriculture, Forestry and Water Management
Partners: universities and other scientific institutions, Ministry of Environmental Protection, local self-government units, Provincial Secretariat for Agriculture, Water Management and Forestry, Public Water Management Company Srbijavode, Public Water Management Company Vode Vojvodine, and others
Stakeholders: agricultural producers, investors
14. Capacity strengthening and awareness raising for adaptation of agricultural production to climate change
Specific Objective 1
Due to the high exposure of agricultural production to climate change, it is necessary to ensure timely and appropriate education of agricultural producers about climate hazards and adaptation measures, but also to strengthen the national decision-making capacities relating to agricultural production. - Serbian Agricultural Advisory and Extension Service capacity strengthening and knowledge improvement through the development of manuals for climate change adaptation of fruit, viticulture, crop and livestock production and integrating them into the certification system. - Development of the zoning of fruit and viticulture production areas, i.e., production, to assess the impacts of climate change on the benefits and risks in production (the methodology first needs to be developed and then implemented to ensure the zoning update and revision). - Conducting studies on climate change-related benefits and risks in livestock and crop production, which will include spatial mapping and recommendations for climate change adaptation of production. - Strengthening the capacities of agricultural producers to access financing for investing in technologies that contribute to increasing resilience to climate change - Agroecological measures analysis and selection, as support for strengthening the agroecosystem resilience and the agricultural production sustainability.

Key implementing institutions: Ministry of Agriculture, Forestry and Water Management
Partners: universities and other scientific institutions, Ministry of Environmental Protection, Serbian Agricultural Advisory and Extension Service
Stakeholders: agricultural producers, investors, international funds, local self-governments
15. Improvement of agrometeorological services to provide the necessary information for increasing the resilience of agricultural production to climate change
Specific Objective 1
The development of climate service of the Republic of Serbia with the aim of increasing the resilience of agricultural production to climate change, including: improving the climate change impact monitoring in the agriculture sector, increasing the capacities to provide timely information to reduce risks in production and enable adaptation to climate change, as well as improving communication between providers of timely information and users. This measure includes: - Development of an integrated Republic Hydrometeorological Service of Serbia and Serbian Agricultural Advisory and Extension Service database for agrometeorological and phenological observations with data control and user access. - Improvement of the Republic Hydrometeorological Service of Serbia agrometeorological monitoring system through increasing the number of agrometeorological measuring stations and soil moisture measurements. - Development and operational production of agrometeorological products by the Republic Hydrometeorological Service of Serbia based on weather forecast (short-range, medium-range, monthly and long-range forecasts), including weather and climate risks forecasts for agricultural production. - Training of agricultural extension advisors and other stakeholders on forecasting products, including agrometeorological forecasting products. The implementation of this measure is closely related to the implementation of the measure 7 of this Programme.
Key implementing institutions: Republic Hydrometeorological Service of Serbia
Partners: Universities and other scientific institutions, Ministry of Environmental Protection, Ministry of Agriculture, Forestry and Water Management, Serbian Agricultural Advisory and Extension Service
Stakeholders: agricultural producers, investors, international funds, local governments
FORESTRY
16. Strengthening the capacity to ensure forest ecosystems resilient to climate change
Specific Objective 1
This measure aims to improve capacities and knowledge of forestry engineers relating to the implementation of climate change adaptation measures through the existing training for the licencing of forestry engineers. This measure includes: - Development of a manual for training of forestry engineers on the climate change impacts on the forests status and forest management, and consequently including these subjects in the licensed training programmes for forestry engineers. - Training for forestry engineers in the development of cultivation plans taking into account climate change. - Conducting an analysis of afforestation success by species, type and age of seedlings and planting technology in the conditions of climate change. - Strengthening the professional and technical capacities of the forest management authorities and institutions to ensure early forest fire detection.
Key implementing institutions: Forestry Directorate
Partners: Universities and other scientific institutions, Chamber of Forestry Engineers, Ministry of Environmental Protection, Ministry of Agriculture, Forestry and Water Management
Stakeholders: State Enterprise for Forest Management Srbijašume, Public Company Vojvodinašume, investors, international funds, forest owners, local self-governments
17. Improving knowledge and information for the assessment of the development of specific forest types under future climate conditions
Key implementing institutions: Ministry of Agriculture, Forestry and Water Management
The measure aims to improve the knowledge necessary for adequate planning of the development of different types of forests taking into account climate change vulnerability and risk assessments. In order to achieve this, it is necessary to develop models for the development of different types of forests over the next 50 years under the conditions of climate change.
Key implementing institutions: Forestry Directorate
Partners: Universities and other scientific institutions, Chamber of Forestry Engineers, Ministry of Environmental Protection, Ministry of Agriculture, Forestry and Water Management
Stakeholders: State Enterprise for Forest Management Srbijašume, Public Company Vojvodinašume, investors, international funds, forest owners, local self-governments

18. Revising the forest planning and management regulatory framework with regard to climate change adaptation

Specific Objective 2

The aim of the forest planning and management regulatory framework revision is the adoption of the Regulation on the contents of the Forestry Management Master Plan, the manner and procedure for its adoption and preparation, material deficiencies or changed circumstances requiring its revision, the method of keeping records of performed works, and the contents and method of keeping forest chronicles in order to include climate change observations and projections.

Key implementing institutions: Ministry of Agriculture, Forestry and Water Management

Partners: Forestry Directorate, universities and other scientific institutions, Chamber of Forestry Engineers, Ministry of Environmental Protection

Stakeholders: State Enterprise for Forest Management Srbija šume, Public Company Vojvodinašume, forest owners, local self-governments

ROAD INFRASTRUCTURE

19. Road infrastructure climate change vulnerability and risk assessment

Specific Objective 3

As it has already been observed that there are damages to the road infrastructure due to the effects of climate hazards whose frequencies and intensities are increasing, it is necessary to conduct a climate change vulnerability and risk assessment for the national road infrastructure. This measure includes:

- Developing a climate change vulnerability and risk assessment methodology for road infrastructure, including the identification of indicators for monitoring the climate change impacts. The assessment should provide recommendations for measures of adaptation of normative acts, and transport infrastructure design and construction standards and instructions in line with the climate change impact assessment.

During the life of the Programme, to ensure the implementation of the climate change adaptation process in this sector, a vulnerability and risk assessment needs to be prepared for the road infrastructure in accordance with the established methodology, after which the normative and legal acts, standards and instructions for transport infrastructure design and construction need to be revised in line with the climate change impact assessment.

Key implementing institutions: Ministry of Construction, Transport and Infrastructure, Public Enterprise Roads of Serbia

Partners: universities and other scientific institutions, Republic Hydrometeorological Service of Serbia, Ministry of Environmental Protection

Stakeholders: investors, international funds, construction companies

URBAN PLANNING

20. Providing support to local self-government units in implementing climate change adaptation through green infrastructure strengthening

Specific Objective 3

This measure includes the announcement of public tenders for the allocation of funds to local self-government units for co-financing the implementation of green landscaping and afforestation projects using species resilient to climate change. That would at the same time improve the green infrastructure in urban areas.

Key implementing institutions: Ministry of Environmental Protection

Partners: local self-government units

Stakeholders: seedling producers, Public Utility Company City Greenery and others.

21. Increasing the resilience of urban areas to climate change through strengthening of green infrastructure

Specific Objective 2

Taking into account the climate change impacts in the urban areas (extremely high temperatures, floods, etc.), the use of services provided by green areas has been recommended as a multifunctional solution, in accordance with the Nature-based Solutions concept. That refers to natural or semi-natural surfaces in the urban areas that perform the following ecosystem services: they contribute to temperature reduction due to evapotranspiration and reduced heating of surfaces and provide shadow, increase water permeability of surfaces, improve air circulation, etc. Such structures are recognized as urban green infrastructure and provide benefits in mitigating climate hazards, improving the environment and population health and quality of life in urban areas.

This measure aims to support the development of green infrastructure in the urban areas in the Republic of Serbia by introducing the relevant term into the legislative and planning framework at the national and local level.

This measure includes:

- Conducting of a study that will consider regulatory framework revision in order to implement the green infrastructure concept, including the consideration of the ecological index

- During the Programme implementation period, the green infrastructure concept needs to be implemented through revision of the relevant legislation and legal acts in line with the study results, as well as through improved planning, management and development of urban green areas, taking into account the climate change. - During the Programme implementation period, prepare a feasibility assessment for the inclusion of climate change in the Spatial Plan and General Urban Development Plan.
Key implementing institutions: Ministry of Construction, Transport and Infrastructure, local self-government units
Partners: universities and other scientific institutions, Ministry of Environmental Protection
Stakeholders: Public Utility Company City Greenery, investors, international funds, civil society organizations
ENERGY SECTOR
22. Assessment of the climate change impact on hydrological parameters relevant for planning in the energy sector
Specific Objective 1
This measure includes conducting a study to identify and quantify climate change impacts on hydrological parameters (water availability in hydro power plants and the level/temperature of surface water streams used for cooling water in thermal power plants) and planning in energy sector, including management of risks related to the listed impacts.
Key implementing institutions: universities and other scientific institutions
Partners: Ministry of Mining and Energy, Serbian Hydrometeorological Institute, Ministry of Environmental Protection
Stakeholders: Electrodistribution of Serbia
23. Assessment of the changes in the distribution of heating and cooling degree days under climate change and development of the monitoring and forecasting system for heating and cooling degree days, to improve planning of capacities for energy production
Specific Objective 1
This measure includes: - Conducting a study on the climate change impacts on heating and cooling degree days distribution in the observed and future climate conditions. - Developing the methodology for monitoring and forecasting of heating and cooling degree days. - Establishing operational forecast for heating and cooling degree days at the seasonal level in accordance with the developed methodology. The feasibility of this sector oriented operational forecast is conditioned by the implementation of the measure 7 of this Programme.
Key implementing institutions: universities and other scientific institutions, Republic Hydrometeorological Service of Serbia
Partners: Ministry of Mining and Energy, Ministry of Environmental Protection, Ministry of Construction, Transport and Infrastructure
Stakeholders: Electrodistribution of Serbia
HEALTH SECTOR
24. Improving the prevention and monitoring of the climate change impact on human health
Specific Objective 1
This measure aims to improve the monitoring of the climate change impacts on human health, the regulatory framework for protection of health and security of people, and the prevention system for health impacts through an improved early warning system for all climate hazards. The measure includes: - Preparation of a study to develop the methodology for monitoring climate change impacts on human health, including strengthening the capacity of healthcare professionals to monitor these impacts. - Establishing this monitoring system in accordance to the developed methodology. During the Programme implementation period, the health sector early warning system for all climate hazards needs to be improved in accordance with a collaboration model between the Institute for Public Health and Republic Hydrometeorological Service of Serbia in case of heat and cold waves. The implementation of this measure is conditioned by the implementation of the measure 7 of this Programme. In addition, during the Program implementation period, it is necessary to include the climate change adaptation aspect in the Public Health Strategy and healthcare procedures.
Key implementing institutions: universities and other scientific institutions, Ministry of Health, Republic Hydrometeorological Service of Serbia
Partners: Institute of Public Health, Ministry of Environmental Protection
Stakeholders: general public, healthcare institutions, civil society organizations, international funds, investors, donors

BIODIVERSITY
25. Developing a methodology for monitoring the biodiversity and its climate change vulnerability
Specific Objective 1
The measure aims to establish a methodology for identifying indicators that will be used to monitor the climate change impact on biodiversity, and for the biodiversity climate change vulnerability assessment. During the Programme implementation period, there is a need to implement measures to regulate the monitoring networks, develop the integrated database, create lists of priority habitat and species monitoring, establish a set of biotic and abiotic parameters for in-situ measurements and remote sensing assessment, define protocols for data flow and reporting, as well as plan and implement priority biodiversity preservation measures.
Key implementing institutions: universities and other scientific institutions, Ministry of Environmental Protection
Partners: protected natural resources, State Enterprise for Forest Management Srbijašume, Public Company Vojvodinašume, Ministry of Agriculture, Forestry and Water Management
Stakeholders: general public, civil society organizations, international funds, investors, donors

8. Institutional framework - coordination, management and outcome reporting

The Ministry of Environmental Protection (hereinafter: the MEP) is responsible for coordinating the Programme implementation and monitoring implementation progress. The MEP is responsible to provide support to other entities participating in climate change adaptation in the implementation of the activities within their scope. In addition, the Ministry communicates with the partners and the public, including civil society organizations, regarding the Programme implementation. The competent authorities and implementing agencies are responsible to implement the activities within their scope in a timely manner and report about it at the request of MEP, to ensure full compliance with the implementation time schedule and efficient implementation of the identified objectives.

The Action Plan implementation progress reports are prepared by the MEP, through the Unified Information System for Planning, Monitoring Implementation, Policy Coordination and Reporting (JIS), in accordance with the Law on the Planning System of the Republic of Serbia and the by-laws regulating reporting procedures and mandatory reporting elements.

The MEP prepares the Action Plan implementation progress reports based on the adaptation measures implementation reports and the phenomena such as floods, extreme temperatures, droughts and other events and their consequences, which are to be submitted by all the authorities and organizations responsible for the implementation of the measures and activities by March 15 of each year, in accordance with the Law on Climate Change. The reporting by these authorities and organizations starts from the second calendar year after the year of adoption of the Adaptation Programme, in accordance with the Law on Climate Change.

The list of the authorities and organizations, and the contents and form of the reports, will be specified under the by-law on reporting on the implementation of the Adaptation Programme that is to be adopted, in accordance with the Law on Climate Change.

The competent authorities and organizations, as well as the authorities and organizations recognized as the partners in the implementation of the measures and activities, have the obligation to report annually to the MEP on the progress in the implementation of the activities under their scope as specified by the Programme, on the progress in the implementation of projects relevant to climate change adaptation and potential issues in achieving the expected results. Based on that, the MEP will evaluate the Programme implementation progress and identify current issues and potential risks and the need to adjust activities accordingly and will make timely decisions to ensure that the expected results are achieved.

The preparation of the Annual Action Plan implementation reports and their submission to the Government will be carried out in accordance with the timelines specified by the Law on the Planning System of the Republic of Serbia.

The MEP will prepare a report on the outcomes in achieving the specified Programme objectives based on the ex-post outcome assessments, after every three years of the Programme implementation, and that report can propose a possible Programme revision. The final report will be submitted to the Government for adoption after the Programme closing date, in accordance with the Law on the Planning System of the Republic of Serbia. The Programme performance evaluation is carried out by analysing whether and to what extent the outcomes achieved are in accordance with the impact indicators at the level of the General Objective, the outcome indicators at the level of Specific Objectives, and the output indicators at the level of specific measures.

The MEP may request the competent authorities and organizations and partners to submit more frequent data and reports, in addition to the regular annual reporting.

If needed, i.e., in case the proposed measures fail to ensure the reduced climate change vulnerability of the population, infrastructure, economy and environment, including preservation of natural resources, as well as in other circumstances, the MEP may initiate a review of the need for revision and propose a revision of the Programme at an even earlier date, before the expiry of the first three years the Programme implementation.

9. Programme Action Plan cost estimate

An integral part of the 2023-2030 Programme is the Action Plan for its implementation, covering the period from 2024 to 2026. The Action Plan provides specific measures and activities that contribute to the implementation of the Programme Specific Objectives, including the cost assessment, i.e., assessment of the financial requirement for their implementation. The Implementation Action Plan cost assessment was prepared in accordance with the Handbook for Determining the Costs of Public Policies and Regulations, and the Methodology for Calculating Standard Costs for the Preparation of Planning Documents and Regulations. The cost assessment is methodologically based on the calculation of additional, direct and variable costs of the new activities or the increased scope of the existing activities necessary for the implementation of the measures proposed under the Action Plan and the achievement of the Programme Specific Objectives. Accordingly, the cost calculation did not take into account regular activities of the authorities, but only the additional activities or the increased scope of the existing activities that the MEP and the relevant institutions of the Republic of Serbia have foreseen in their budgets and programme activities within their budgets.

In the first three years of the Programme implementation, an additional RSD 851,001 million needs to be provided from the budget funds. The financial requirements schedule over the observed period by the Programme Specific Objectives is shown in the table below. In addition to the above, the regular budget allocation funds will be used to implement the measures and activities under the Programme.

	2024	2025	2026	Total (2024-2026)
2023-2030 CLIMATE CHANGE ADAPTATION PROGRAMME ACTION PLAN TOTAL ESTIMATED FINANCIAL REQUIREMENT IN RSD 000	160,683	363,198	327,120	851,001
Specific Objective 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences	800	44,700	61,009	106,509
Specific Objective 2: Establishing and strengthening capacities for the systemic implementation of the climate change adaptation process at the national and local levels	0	0	0	0
Specific Objective 3: Increasing climate change resilience of critical infrastructure and natural resources	0	0	0	0
Specific Objective 4: Strengthening financial support for the implementation of the climate change adaptation process	159,883	318,498	266,111	744,492

For the Programme development purposes, the donor funding required for the measures and activities, which will be used to finance the development of studies and other activities foreseen by the Programme, have also been estimated. For the first three years, it is necessary to provide RSD 160,845 million

	2024	2025	2026	Total (2024-2026)
2023-2030 CLIMATE CHANGE ADAPTATION PROGRAMME ACTION PLAN TOTAL ESTIMATED FINANCIAL REQUIREMENT IN RSD 000	15,212	101,250	44,383	160,845
Specific Objective 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences	8,700	20,050	43,533	72,283
Specific Objective 2: Establishing and strengthening capacities for the systemic implementation of the climate change adaptation process at the national and local levels	2,512	0	0	2,512
Specific Objective 3: Increasing climate change resilience of critical infrastructure and natural resources	4,000	21,200	850	26,050
Specific Objective 4: Strengthening financial support for the implementation of the climate change adaptation process	0	60,000	0	60,000

The estimated financial requirement for the implementation of the Programme beyond 2026 will be known after the completion of studies and the implementation of other activities foreseen under the Programme. It is certain that, due to the expected climate change, increasing budget allocations will be required.

10. Programme preparation process and consultation process description

The stakeholder consultation process has been carried out in the course of the preparation of the Climate Change Adaptation Programme with the Action Plan. The relevant stakeholders have been identified based on institutional mandates and responsibilities, and on the recognized activities of specific stakeholders in relation with climate change adaptation in the Republic of Serbia, such as MEP, other relevant ministries and authorities under those ministries, and the scientific research institutions. In addition, identified are participants such as: local authorities, institutes, civil society organizations and the media, public companies' representatives, secondary vocational school teachers, etc.

The MEP, as the authority coordinating the Programme preparation, established and maintained a constructive communication with the stakeholders during the preparation of the analyses in the course of the Programme development. The data and information necessary for the current situation analysis, future projections development, and various climate change adaptation options potential assessment were collected trough various activities and consultation methods (meetings, workshops, trainings, written communication) in the consultation process.

As part of the Advancing Medium and Long-Term Adaptation Planning in the Republic of Serbia Project, the United Nations Development Programme (hereinafter: UNDP) supported the Programme development process and the organization of the public consultation process. A series of trainings has been organized at the national and local levels to strengthen institutional capacities for climate change adaptation. The consequences of climate change and the proposed measures for the five priority sectors were presented at the trainings. In addition to the proposed measures, the focus was on the activities carried out with the national professional, research and scientific institutions, and measures aimed at reducing the risks of disasters and natural hazards.

The trainings were used also for consultations with the representatives of different target groups, such as the local self-governments, the scientific sector, and the civil and private sectors. Specifically, with respect to local self-government unit representatives, the consultations included individuals involved with agriculture, energy and infrastructure, water management, project preparation, local development, and risk reduction. The two-day workshops enabled also consultations with representatives of the relevant public companies, agricultural extension services, and teachers in agricultural and construction secondary schools.

The preparation of the Programme was preceded by the preparation of an ex ante analysis, which was also prepared with the support of the UNDP, based on the findings and recommendations of the climate change impacts assessments for agriculture, forestry, road infrastructure, energy sector, health and biodiversity, as well as the report on the climate change adaptation capacities and capacity strengthening needs at the national and local self-government levels, and the review and assessment of the existing adaptation policy, regulatory and institutional framework for the adaptation, with the recommendations for the development and improvement of a separate policy and a regulatory framework.

In accordance with the decision of the Ministry of Environmental Protection, Number: 119-01-00027/2022-05, dated June 6, 2022, a Working Group was established for the preparation of the Draft Climate Change Adaptation Programme with the Action Plan. In order to select civil society organizations that will take part in the Working Group in question, in the period from April 4-14, 2022, and in cooperation with the Ministry of Human and Minority Rights and Social Dialogue (hereinafter: MHMRSD), a Public Call was published for civil society organizations to participate in the Working Group for the Programme preparation. This procedure was carried out in accordance with the Guidelines for the Inclusion of Civil Society Organizations in Working Groups for the Development of Draft Public Policy Documents and Regulations ("Official Gazette of the RS", Number 8/20 and 107/21). On October 26, 2022, the National Assembly passed the Decision on the Election of the Government. In addition, the National Assembly passed the Law on Amendments to the Law on Ministries regulations ("Official Gazette of the RS", Number 112/22) at the First Session of the Second Regular Sitting in 2022, on October 22, 2022. This Law introduced changes in a number of ministries. In addition, it included organizational and personnel changes in the bodies whose representatives are members of the Working Group, as a result of which the MEP adopted a Decision on amendments to the Decision on the establishment of the Working Group for the preparation of the Draft Climate Change Adaptation Programme with the Action Plan, Number: 119-01-00027/2022-05/2, dated January 19, 2023. The Working Group consisted of representatives of the MEP, the Ministry of Construction, Transport and Infrastructure (hereinafter: MCTI), the Ministry of Public Administration and Local Self-Government (hereinafter: MPALG), the Forestry Directorate, the Directorate for Agrarian Payments, the Ministry of Science, Technological Development and Innovation (hereinafter: MSTDI), the Ministry of Mining and Energy (hereinafter: MME), the Administration for Agricultural Land, the Serbian Water Directorate, the Ministry of Finance (hereinafter: MF), the Ministry of Health (hereinafter: MH), the Ministry of the Internal Affairs (hereinafter: MI), the Ministry for Public Investment (hereinafter: MPI), the Ministry of Education (hereinafter: ME), the Provincial Secretariat for Urban Planning and Environmental Protection, the Serbian Geodetic Authority (hereinafter: SGA), the Serbian Statistical Office, the Institute for Nature Conservation of Serbia, RHMSS, the Provincial Institute for Nature Protection, the Serbian Chamber of Commerce (hereinafter: SCC), the Standing Conference of Towns and Municipalities (hereinafter: SCTM), the Association of Young Researchers Bor, and the Environmental Protection Engineers.

From June 2022 until the end of July 2023, the Working Group conducted consultations through a series of meetings where it was presented with the *ex ante* analysis, the proposed measures and activities under the Programme and the First Action Plan, as well as the Strategic Environmental Impact Assessment Report. The Working Group made a significant contribution in identifying the objectives, measures and activities. In addition, a series of bilateral meetings were held with the state authorities and institutions in order to further confirm the relevance of the proposed measures and activities, and collect the necessary data.

In addition, the Ministry of Environmental Protection issued a Public Call for public participation in the consultation process related to the development of the Climate Change Adaptation Programme with the Action Plan. The Public Call was published on

June 1, 2023, on the website of the Ministry of Environmental Protection, and on the e-Consultation portal, in accordance with the provisions of Article 77 of the Law on Public Administration (“Official Gazette of the RS”, Number 79/05, 101/07, 95/10, 99/14, 47/18 and 30/18 – separate law); Article 41, Paragraph 1, Item 3 of the Law on Planning System of the Republic of Serbia; and Article 40 of the Regulation on the methodology of public policy management, impact analysis of public policies and regulations, and the content of individual public policy documents (“Official Gazette of the RS”, Number 8/19).

The consultations were conducted in the period from June 1-12, 2023, in order for all stakeholders to be timely and properly informed about the proposed solutions, to enable them to contribute to the further improvement of the proposed solutions. The draft version of the document and the template for submitting suggestions and comments were attached as part of the above Public Call, and all stakeholders were able to provide their objections, proposals, suggestions and comments to the MEP electronically.

The received proposals, suggestions and remarks were reviewed and the possibility to integrate them into the text of the draft of the Programme was considered. After that, the MEP published the information on the results of the consultation process, with the responses to the received comments, objections and suggestions.

11. FINAL PART

11.1. Publishing

This Programme is to be published on the website of the Government and the Ministry of Environmental Protection and on the e-Government portal, within seven working days from the date of adoption.

This Programme is to be published in the “Official Gazette of the Republic of Serbia”.

05 Number: 353-10351/2023-2
In Belgrade, dated 25 December 2023

G O V E R N M E N T

PRIME MINISTER
Ana Brnabic, duly signed

The First Action Plan of the 2024-2026 Climate Change Adaptation Programme

General Objective: Increasing the capacity to achieve greater climate change resilience to ensure population well-being, economy and living environment improvements						
Institution responsible for monitoring and implementation oversight: Ministry of Environmental Protection						
General Objective Indicator(s) *(Impact Indicator)*	Unit of Measure	Source of Verification	Baseline Value	Baseline Year*	Target Value in AP Closing Year	AP Closing Year
A) The percentage share of respondents in the national-level public opinion survey, with monitoring the increase in the awareness about climate change issue B) The percentage share of respondents in the national-level public opinion survey, with monitoring the increase in the awareness about the increased risk of climate hazards	A) % B) %	"Public opinion survey on the environment and climate change in Serbia" Annual Report	A) 51% B) data not available	A) 2022 B) 2022	A) > 60% B) > 70%	2026

*The year in which the survey was conducted

Action Plan measures contributing the achievement of Programme Specific Objective 1

SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences							
Institution responsible for coordination and reporting: Ministry of Environmental Protection							
Specific Objective Indicator(s) *(Outcome Indicator)*	Unit of Measure[1]	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
A) Number of the Digital Climate Atlas unique visits	A) Number	A) MEP	2023	A) not available	A) 100[2]	A) 400	A) > 1000
B) Number of studies and manuals	B) Number	B) MEP		B) 0	B) 2	B) 6	B) 11
C) Number of methodologies	C) Number	C) MEP		C) 0	C) 1	C) 1	C) 7

[1] Target values indicated on aggregate basis

[2] Number of the Digital Climate Atlas visits will be monitored from 2024

ACTION PLAN MEASURE NO. 1.1	ADAPTATION PROGRAMME MEASURE NO. 3: Establishing a system for monitoring climate change, its impacts, implementation and success of climate change adaptation measures	AREA: Cross-cutting
	SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences	

Institution Responsible for Implementation: MEP, Ministry for Public Investment (MPI), RHMSS

Implementation Period: 2024-2026	Type of Measure: Regulatory and informative/educational
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	Adopting the by-law on reporting on the implementation of the Adaptation Programme in accordance with Article 15 of the Law on Climate Change

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Adopted the by-law on reporting on the implementation of the Adaptation Programme	Yes/No	By-law published (Official Gazette of RS)	2023	No	Yes	Yes	Yes
Developed Methodology for assessing damages, losses and needs related to natural and other disasters, including damages, losses and impacts caused by climate change	Yes/No	MEP Report	2023	No	Yes	Yes	Yes
Developed and regularly updated a web portal with georeferenced climate data	Yes/No	Web portal publicly available (RHMSS)	2023	No	No	Yes	Yes

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds	Budget 0403, 410, 4014, 515		8,000	16,000
Donor funds				

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026

1.1.1 Preparing and adopting the by-law on reporting on the implementation of the Climate Change Adaptation Programme in accordance with Article 15 of the Law on Climate Change.	MEP	Public administration, Autonomous Province and local self-government authorities	2025	Regular allocation				
1.1.2 Developing the Methodology for assessing damages, losses and needs related to natural and other disasters, including damages, losses and impacts caused by climate change	MPI	MEP	2024	Regular allocation				
1.1.3 Development, maintenance and updating of the georeferenced climate data portal	RHMSS	Serbian Geodetic Authority	IV 2025	The Budget of RS - additional funds in the RHMSS budget section	Programme 0403, function 410, Programme activity/project 4014, economic classification 515		8,000	16,000

ACTION PLAN MEASURE NO. 1.2	ADAPTATION PROGRAMME MEASURE NO. 4: Developing climate change adaptation research programme	AREA: Cross-cutting
	SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences	

Institution Responsible for Implementation: MEP	
Implementation Period: 2024-2026	Type of Measure: Informative/educational
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	-

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Report on the representation of projects contributing to climate change adaptation	Number	MEP Report	2023	0	0	0	1

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds			600	

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
1.2.1 Preparing an analysis of the representation of scientific research projects financed by the Science Fund with a contribution to climate change adaptation (completed and ongoing) and identifying priority scientific topics contributing to climate change adaptation.	MEP	Serbian Science Fund, universities and other scientific institutions	2026	Donor funds*			600	

ACTION PLAN MEASURE NO. 1.3	ADAPTATION PROGRAMME MEASURE NO. 6: Integrating drought as a multidimensional climate hazard in the system for monitoring, timely alerts, and impact assessment, including damages and losses	AREA: Cross-cutting
	SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences	

Institution Responsible for Implementation: MEP	
Implementation Period: 2024-2026	Type of Measure: Informative/educational
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	-

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Developed the Methodology for monitoring drought as a multidimensional climate hazard	Yes/No	MEP Report	2023	No	No	No	Yes

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds	-			
Donor funds			1,950	1,000

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
1.3.1 Developing of a Methodology for Drought Monitoring (as a multidimensional climate hazard) of importance for all relevant sectors in the Republic of Serbia, taking into account all aspects of drought climate hazard (meteorological, hydrological, soil related, physiological, etc.), and the time dimensions for which it is identified: from long-term to short-term.	MEP	RHMSS, MOI, MAFWM, Serbian Chamber of Commerce, universities and other scientific institutions	2026	Donor funds *			1,950	1,000

ACTION PLAN MEASURE NO. 1.4	ADAPTATION PROGRAMME Measure NO. 8: Improving the preparedness of the citizens of the Republic of Serbia for extreme weather and climate extremes	AREA: Cross-cutting
	SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences	
Institution Responsible for Implementation: RHMSS, MEP		

Implementation Period: 2024-2026	Type of Measure: Informative/educational
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	-

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Report on improved forecast products	Number (aggregate)	RHMSS Report	2023	0	0	1	2
Developed improved RHMSS web-site	Yes/No	Test version available online	2023	No	No	Yes	Yes
Children's educational material	Number	Material available to public	2023	0	0	0	1
Media trainings delivered	Number (aggregate)	MEP Report	2023	0	1	2	3
Report on the public opinion survey findings	Number (aggregate)	Report issued by the UNDP	2023	1	2	3	4

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds	Budget of RS 0403, 410, 4014, 423 Budget of RS 0403, 410, 4014, 515		30,000	35,000
Donor funds				

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026

1.4.1 Improving forecast products and testing improved forecasts using the new High Performance Computing system (HPC)	RHMSS	Universities and other scientific institutions	IV 2026	Budget of RS - additional funds in the RHMSS budget section	Programme 0403, function 410, Programme activity/project 4014, economic classification 423		15,000	15,000
1.4.2 Developing the RHMSS web-site that supports the dissemination of the improved operational products, information, forecasts and warnings	RHMSS		IV 2026	Budget of RS - additional funds in the RHMSS budget section	Programme 0403, function 410, Programme activity/project 4014, economic classification 515		15,000	20,000
1.4.3 Developing educational materials about climate change and adaptation for children of different ages	MEP	UNICEF, universities and other scientific institutions	2026	Donor funds *				
1.4.4 Conducting training for media representatives on climate change, dangers and risks and climate change adaptation	MEP	The media, universities and other scientific institutions, civil society organizations	2026	Donor funds *				
1.4.5 Conducting a public opinion survey on awareness of the climate change issue and the increased risk of climate hazards (extreme weather events and other climate hazards such as flash floods, floods, fires, etc.)	MEP	UNDP	Annually	Donor funds (UNDP)				

ACTION PLAN MEASURE NO. 1.5	ADAPTATION PROGRAMME MEASURE NO. 12: Increasing the resilience of meadows and pastures to climate change	AREA: Agriculture
	SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences	

Institution Responsible for Implementation: Administration for Agricultural Land, MAFWM	
Implementation Period: 2024-2026	Type of Measure: Informative/educational
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	-

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Conducted climate change impact assessment for meadows and pastures	Yes/No	Assessment available to pubic on the MAFWM web-site	2023	No	No	No	Yes

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds	Budget of RS 0102, 420, 0001, 451		5,000	5,000
Donor funds				

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
1.5.1 Preparing a climate change impact assessment for meadows and pastures including mapping of areas under increased climate change risks, with recommendations for climate change adaptation measures	MAFWM - Administration for Agricultural Land	MEP, universities and other scientific institutions, LGUs	2026	Programme 0102, function 420, Programme activity 0001, economic classification 451			5,000	5,000

<table>
<tr><td rowspan="2">ACTION PLAN MEASURE

NO. 1.6</td><td colspan="6">ADAPTATION PROGRAMME MEASURE NO. 14: Capacity strengthening and awareness raising for adaptation of agricultural production to climate change</td><td colspan="2">AREA:

Agriculture</td></tr>
<tr><td colspan="8">SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences</td></tr>
<tr><td colspan="9">Institution Responsible for Implementation: MAFWM</td></tr>
<tr><td colspan="4">Implementation Period: 2024-2026</td><td colspan="5">Type of Measure: Informative/educational</td></tr>
<tr><td colspan="4">Legislation to be Adopted/Revised to Allow for the Measure Implementation:</td><td colspan="5">Regulation establishing the Annual Programme for the development of agricultural advisory services</td></tr>
<tr><td rowspan="2">Measure-level Indicators (Output Indicator)</td><td rowspan="2" colspan="2">Unit of Measure</td><td rowspan="2">Source of Verification</td><td colspan="2">Baseline Value</td><td colspan="3">Target Values</td></tr>
<tr><td>Baseline Year</td><td>Value</td><td>2024</td><td>2025</td><td>2026</td></tr>
<tr><td>Developed manuals for agricultural advisors’ education on climate change adaptation of agricultural production</td><td colspan="2">Number (aggregate)</td><td>Manuals published by MAFWM</td><td>2023</td><td>0</td><td>1</td><td>4</td><td>0</td></tr>
<tr><td>Number of implemented education modules for agricultural advisors’ training on climate change adaptation of agricultural production</td><td colspan="2">Number (aggregate)</td><td>MAFWM Report</td><td>2023</td><td>7</td><td>8</td><td>12</td><td>15</td></tr>
<tr><td>Developed zoning methodologies for viticultural and fruit production areas in conditions of climate change</td><td colspan="2">Number</td><td>MAFWM Report</td><td>2023</td><td>0</td><td>0</td><td>0</td><td>2</td></tr>
<tr><td>Conducted studies on suitability of growing conditions and risks for crop farming and livestock farming</td><td colspan="2">Number</td><td>Publicly available studies published by MAFWM</td><td>2023</td><td>0</td><td>0</td><td>0</td><td>2</td></tr>
<tr><td colspan="2" rowspan="2">Measure Source of Financing</td><td colspan="2" rowspan="2">Programme Budget Reference</td><td colspan="5">Total Estimated Financial Requirement in RSD 000.</td></tr>
<tr><td colspan="2">2024</td><td colspan="2">2025</td><td>2026</td></tr>
<tr><td colspan="2">Budget funds</td><td colspan="2">Budget of RS 0103-0002-451</td><td colspan="2">300</td><td colspan="2">1,200</td><td>900</td></tr>
<tr><td colspan="2">Donor funds</td><td colspan="2">EU-funded project "Strengthening Disaster Resilience in Agriculture" and other donor funds</td><td colspan="2">8,700</td><td colspan="2">3,500</td><td>13,824</td></tr>
</table>

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
1.6.1 Developing manuals and including the materials from the developed climate change adaptation manuals into the system for agricultural advisors' education, by types of agricultural production (viticulture, fruit growing, crop farming, livestock farming, good agricultural practices in altered climate conditions, etc.)	MAFWM	MEP, Universities and other scientific institutions	2026	EU project, Other donor funds*		8,700	3,500*	3,500*
1.6.2 Delivering education modules on climate change adaptation using the materials developed for the manuals	MAFWM	MEP, universities and other scientific institutions	2026	Serbian budget 01	0103-0002-451	300	1,200	900
1.6.3 Developing zoning methodology for fruit production areas in conditions of climate change	MAFWM	MEP, universities and other scientific institutions	2026	Donor funds*				2,212*
1.6.4 Developing zoning methodology for viticulture production areas in conditions of climate change	MAFWM	MEP, universities and other scientific institutions	2026	Donor funds				2,212
1.6.5 Conducting a study on suitability of growing conditions and risks for agricultural production in conditions of climate change, including spatial mapping of areas with favourable climate and areas under climate risks, with recommendations for climate change adaptation	MAFWM	MEP, universities and other scientific institutions	2026	Donor funds				2,950
1.6.6 Conducting a study on suitability of growing conditions and risks for livestock farming in conditions of climate change, including spatial mapping of areas with favourable climate and areas under climate risks, with recommendations for climate change adaptation	MAFWM	MEP, universities and other scientific institutions	2026	Donor funds				2,950

ACTION PLAN MEASURE NO. 1.7	ADAPTATION PROGRAMME MEASURE NO. 15: Improvement of agrometeorological services to provide the necessary information for increasing the resilience of agricultural production to climate change							AREA: Agriculture
	SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences							
Institution Responsible for Implementation: RHMSS								
Implementation Period: 2024-2026			Type of Measure: Informative/educational					
Legislation to be Adopted/Revised to Allow for the Measure Implementation:			-					
Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values			
			Baseline Year	Value	2024	2025	2026	
Conducted the feasibility assessment for use of meteorological data from stations owned by other institutions and entry into the Registry	Yes/No	RHMSS Report	2023	No	No	No	Yes	
Installed new agrometeorological stations, stations for measuring soil moisture content, and hydrological stations	Number (aggregate)	RHMSS Report	2023	0	0	20	40	
Developed new and improved existing RHMSS agrometeorological products	Yes/No	RHMSS Report	2023	No	No	No	Yes	
Number of consultations on the use of the improved agrometeorological products	Number (aggregate)	RHMSS Report	2023	0	0	1	2	

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds	Budget of RS 0403, 410, 4014, 423			109
Donor funds			14,000	14,700

1.7.1 Feasibility assessment for use of meteorological data from stations owned by other institutions (Agricultural Advisory and Extension Service stations and other) and entry the stations in the RHMSS Stations Registry, as the supplementary RHMSS network	RHMSS	MAFWM, Serbian Agricultural Advisory and Extension Service	IV 2026	Budget of RS	Regular allocation			
1.7.2 Improvement of the RHMSS agrometeorological monitoring system by increasing the number of meteorological and agrometeorological stations, stations for measuring soil moisture content, and hydrological stations for surface water and groundwater	RHMSS		IV 2026	Donor funds			14,000	14,700
1.7.3 Developing new and improved RHMSS agrometeorological products in accordance with the identified user needs (monitoring and forecast products) for agricultural production	RHMSS	MAFWM, universities and other scientific institutions	IV 2026	Budget of RS	Regular allocation			
1.7.4 Consultations for the preparation of products for agricultural extension advisory service and other stakeholders relating to preparation and use of the RHMSS products (monitoring and forecast products) relevant for agricultural production	RHMSS	MAFWM, Serbian Agricultural Advisory and Extension Service, universities and other scientific institutions	2026	Budget of RS	Programme 0403, function 410, Programme activity/ project 4014, economic classification 423			109

<table>
<tr><td rowspan="2">ACTION PLAN MEASURE NO. 1.8</td><td colspan="6">ADAPTATION PROGRAMME MEASURE NO. 16: Strengthening the capacity to ensure forest ecosystems resilient to climate change</td><td colspan="2">AREA: Forestry</td></tr>
<tr><td colspan="8">SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences</td></tr>
<tr><td colspan="9">Institution Responsible for Implementation: Forestry Directorate and Chamber of Forestry Engineers (MAFWM)</td></tr>
<tr><td colspan="3">Implementation Period: 2024-2025</td><td colspan="6">Type of Measure: Informative/educational</td></tr>
<tr><td colspan="3">Legislation to be Adopted/Revised to Allow for the Measure Implementation:</td><td colspan="6">-</td></tr>
<tr><td rowspan="2">Measure-level Indicators (Output Indicator)</td><td rowspan="2">Unit of Measure</td><td rowspan="2">Source of Verification</td><td colspan="2">Baseline Value</td><td colspan="3">Target Values</td></tr>
<tr><td>Baseline Year</td><td>Value</td><td>2024</td><td>2025</td><td>2026</td></tr>
<tr><td>Developed manuals for training forestry engineers on climate change impacts on forest condition and forest management</td><td>Number (per year)</td><td>Chamber of Forestry Engineers, MAFWM</td><td>2023</td><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>Climate change impacts topic incorporated into the licensed training programmes for forestry engineers</td><td>Yes/No</td><td>Chamber of Forestry Engineers, MAFWM</td><td>2023</td><td>No</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Conducted afforestation success analysis by species, type and age of seedlings and planting technology</td><td>Yes/No</td><td>Analysis published by the Forestry Directorate, MAFWM</td><td>2023</td><td>No</td><td>No</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Delivered trainings for forestry engineers on developing cultivation plans that take into account altered climate conditions</td><td>Yes/No</td><td>Report, Chamber of Forestry Engineers, MAFWM</td><td>2023</td><td>No</td><td>No</td><td>Yes</td><td>Yes</td></tr>
</table>

<table>
<tr><td rowspan="2">Measure Source of Financing</td><td rowspan="2">Programme Budget Reference</td><td colspan="3">Total Estimated Financial Requirement in RSD 000.</td></tr>
<tr><td>2024</td><td>2025</td><td>2026</td></tr>
<tr><td>Budget funds</td><td rowspan="2">Budget of RS 0106, 420, 0002, 451</td><td>500</td><td>500</td><td>4,000</td></tr>
<tr><td>Donor funds</td><td></td><td>1,000</td><td></td></tr>
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<tr><td rowspan="2">Activities</td><td rowspan="2">Implementing Institution</td><td rowspan="2">Implementing Partners</td><td rowspan="2">Activity Implementation Date</td><td rowspan="2">Source of Financing</td><td rowspan="2">Programme Budget Reference</td><td colspan="3">Total Estimated Financial Requirement by Sources in RSD 000.</td></tr>
<tr><td>2024</td><td>2025</td><td>2026</td></tr>
</table>

1.8.1 Developing manuals for training forestry engineers on climate change impacts on forest condition and forest management	Forestry Directorate, MAFWM	Chamber of Forestry Engineers, MAFWM	2024	Budget of RS	Programme 0106, Function 420, Programme activity/project 0002, Economic classification 451	500		2,000
1.8.2 Incorporating climate change impacts on forest condition and forest management topic into the licensed training programmes for forestry engineers	Forestry Directorate, MAFWM	Chamber of Forestry Engineers, MAFWM	2024	Budget of RS	Programme 0106, Function 420, Programme activity/project 0002, Economic classification 451	0	500	0
1.8.3 Preparing afforestation success analysis by species, type and age of seedlings and planting technology	Forestry Directorate, MAFWM	State Enterprise for Forest Management Srbijašume, Public Company Vojvodinašume, universities and other scientific institutions, Chamber of Forestry Engineers, National Parks, Serbian Orthodox Church, “Pokret Gorana Srbije” Environmental Organisation	2025	Donor funds		0	1,000	0
1.8.4 Delivering trainings for forestry engineers on developing cultivation plans that take into account altered climate conditions	Chamber of Forestry Engineers, MAFWM	Forestry Directorate, MAFWM	2025	Budget of RS	Programme 0106, Function 420, Programme activity/project 0002, Economic classification 451	0	0	2,000

ACTION PLAN MEASURE NO. 1.9	ADAPTATION PROGRAMME MEASURE NO. 17: Improving knowledge and information for the assessment of the development of specific forest types in future climate conditions	AREA: Forestry
	SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences	

Institution Responsible for Implementation: MAFWM	
Implementation Period: 2024-2026	Type of Measure: Informative/educational
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	-

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Developed the development model for most dominant forest types over the next 50 years	Yes/No	Forestry Directorate, MAFWM	2023	No	No	Yes	Yes

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds			2,000	

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
1.9.1 Developing the development model for most dominant forest types over the next 50 years	Forestry Directorate, MAFWM	Universities and other scientific institutions	2025	Donor funds *			2,000	

ACTION PLAN MEASURE NO. 1.10	ADAPTATION PROGRAMME MEASURE NO. 22: Assessment of the climate change impact on hydrological parameters relevant for planning in the energy sector	AREA: Energy
	SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences	

Institution Responsible for Implementation: MEP	
Implementation Period: 2024-2026	Type of Measure: Informative/educational
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	-

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Report on the established methodology for assessment of the climate change impacts on the availability and condition of water resources for the energy sector purposes	Number (per year)	MEP Report	2023	0	1	0	0
Conducted study on the climate change impacts on the availability and condition of water resources for the energy sector purposes	Yes/No	MEP Report	2023	No	No	No	Yes

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds				4,424

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
1.10.1 Developing climate change impact assessment methodology and preparing a study on the climate change impacts on the availability and condition of water resources for the energy sector purposes	MEP	MME, RHMSS, universities and other scientific institutions	2026	International funds*				4,424

ACTION PLAN MEASURE NO. 1.11	ADAPTATION PROGRAMME MEASURE NO. 23: Assessment of the changes in the distribution regime of heating and cooling degree days under climate change and development of the monitoring and forecasting system for heating and cooling degree days, to improve planning of capacities for energy production	AREA: Energy
	SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences	

Institution Responsible for Implementation: MEP	
Implementation Period: 2024-2026	Type of Measure: Informative/educational
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	-

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Report on the established methodology for assessment of the climate change impacts on the heating and cooling degree days distribution regime in the observed and future climate conditions	Number (per year)	MEP	2023	0	1	0	0
Conducted assessment of climate change impacts on the heating and cooling degree days distribution regime in the observed and future climate conditions prepared for the purposes of the energy sector with the available data	Yes/No	The study available to public, MEP	2023	No	No	No	Yes
Report on the methodology for heating and cooling degree days forecasting, from long-term to short-term forecasts	Number	MEP	2023	0	0	0	1

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds				5,898

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
1.11.1 Developing the impact assessment methodology and preparing a study on the climate change impacts on the heating and cooling degree days distribution regime in the observed and future climate conditions	MEP	MME, RHMSS, MCTI, universities and other scientific institutions	2026	International funds*				2,949
1.11.2 Developing the methodology for monitoring and forecast of heating and cooling degree days, including seasonal forecasts	MEP	MME, RHMSS, MCTI, universities and other scientific institutions	2026	International funds*				2,949

ACTION PLAN MEASURE NO. 1.12	ADAPTATION PROGRAMME MEASURE NO. 24: Improving the prevention and monitoring of the climate change impact on human health						AREA: Health	
	SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences							
Institution Responsible for Implementation: MH, MEP								
Implementation Period: 2024-2026			Type of Measure: Informative/educational					
Legislation to be Adopted/Revised to Allow for the Measure Implementation:			-					
Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values			
			Baseline Year	Value	2024	2025	2026	
Developed methodology for the climate change assessment and vulnerability monitoring for the health sector	Yes/No	MH Report	2023	No	No	No	Yes	
Measure Source of Financing	Programme Budget Reference		Total Estimated Financial Requirement in RSD 000.					
			2024	2025	2026			
Budget funds								
Donor funds					1,475			
Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
1.12.1 Developing a methodology for climate change assessment and vulnerability monitoring for the health sector, and particularly for the vulnerable populations (children, persons with disabilities, the elderly, outdoor workers, etc.), with a proposal for climate change adaptation measures	MH	MEP, RHMSS, universities and other scientific institutions	2026	Donor funds *				1,475

ACTION PLAN MEASURE NO. 1.13	ADAPTATION PROGRAMME MEASURE NO. 25: Developing a methodology for monitoring the biodiversity status and climate vulnerability	AREA: Biodiversity
	SPECIFIC OBJECTIVE 1: Raising awareness and improving knowledge and understanding about the climate change impacts and consequences	

Institution Responsible for Implementation: MEP	
Implementation Period: 2024-2026	Type of Measure: Informative/educational and regulatory
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	Nature Protection Programme

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Developed methodology for status monitoring and vulnerability assessment of species, habitats and ecosystems, with proposed climate change adaptation measures	Yes/No	MEP Report	2023	No	No	No	Yes
Climate change adaptation aspects integrated in the Nature Protection Programme	Yes/No	MEP	2023	No	No	No	Yes

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds				2,212

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026

1.13.1 Developing methodology for status monitoring and vulnerability assessment of species, habitats and ecosystems, with proposed climate change adaptation measures	MEP	Environmental Protection Agency, Institute for Nature Protection of Serbia, Provincial Institute for Nature Protection, Plant Gene Bank, universities and other scientific institutions	2026	Donor funds				2,212
1.13.2 Integrating climate change adaptation aspects in the Nature Protection Programme	MEP	Environmental Protection Agency, Institute for Nature Protection of Serbia, Provincial Institute for Nature Protection	2026	Budget of RS	Regular allocation			

Action Plan measures contributing the achievement of Programme Specific Objective 2

SPECIFIC OBJECTIVE 2: Establishing and strengthening capacities for the systemic implementation of the climate change adaptation process from national to local levels							
Institution responsible for coordination and reporting: Ministry of Environmental Protection							
Specific Objective Indicator(s) *(Outcome Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
The percentage of adopted public policy documents in the sectors included in the Programme that have recognized the climate change impacts, i.e., included climate change adaptation measures	%	MEP Report	2023	0	50	100	100

ACTION PLAN MEASURE NO. 2.1	ADAPTATION PROGRAMME MEASURE NO. 1: Monitoring the implementation of measures with benefits in the climate change adaptation process when integrating green aspects in public policy documents	AREA: Cross-cutting
	SPECIFIC OBJECTIVE 2: Establishing and strengthening capacities for the systemic implementation of the climate change adaptation process from national to local levels	

Institution Responsible for Implementation: Serbian Public Policy Secretariat (PPS)	
Implementation Period: 2024-2026	Type of Measure: Regulatory
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	-

Measure -level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Climate change adaptation topic included during the development of the Guidelines for the integration of green aspects in public policy documents	Yes/No	Contents published on the PPS web-site	2023	No	Yes	Yes	Yes

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds				

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
2.1.1 Including climate change adaptation topic during the development of the Guidelines for the integration of green aspects in public policy documents	PPS	MEP	2024	Budget of RS	Regular allocation			

ACTION PLAN MEASURE NO. 2.2	ADAPTATION PROGRAMME MEASURE NO. 5: Improving disaster risk assessment by including changes in climate hazards frequency and intensity caused by climate change	AREA: Cross-cutting
	SPECIFIC OBJECTIVE 2: Establishing and strengthening capacities for the systemic implementation of the climate change adaptation process from national to local levels	

Institution Responsible for Implementation: Ministry of the Internal Affairs (MI)	
Implementation Period: 2024-2026	Type of Measure: Regulatory
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	Risk assessment and protection and recovery plan preparation methodology and contents

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Revised and updated of the Methodology for the development and content of disaster risk assessment and protection and recovery plans	Yes/No	MI	2023	No	No	No	Yes
Adopted improved Methodology for the development and content of disaster risk assessment and protection and recovery plans	Yes/No	MI	2023	No	No	No	Yes

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds				

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
2.2.1 Revising and updating the Methodology for the development and content of disaster risk assessment and protection and recovery plans to include climate change (observed and projected)	MI	MEP, RHMSS, universities and other scientific institutions	2026	Budget of RS	Regular allocation			

2.2.2 Adopting improved Methodology for the development and content of disaster risk assessment and protection and recovery plans (taking into account climate change observations and projections)	MI	MEP	2026	Budget of RS	Regular allocation			

<table>
<tr><td rowspan="2">ACTION PLAN MEASURE NO. 2.3</td><td colspan="8">ADAPTATION PROGRAMME MEASURE NO. 9: Addressing regulatory issues regarding land use to mitigate and prevent the degradation process</td><td>AREA:
Cross-cutting</td></tr>
<tr><td colspan="9">SPECIFIC OBJECTIVE 2: Establishing and strengthening capacities for the systemic implementation of the climate change adaptation process from national to local levels</td></tr>
<tr><td colspan="10">Institution Responsible for Implementation: Ministry of Finance (MF)</td></tr>
<tr><td colspan="4">Implementation Period: 2024</td><td colspan="6">Type of Measure: Regulatory</td></tr>
<tr><td colspan="4">Legislation to be Adopted/Revised to Allow for the Measure Implementation:</td><td colspan="6">The Law on Fees for the Use of Public Goods</td></tr>
<tr><td rowspan="2">Measure-level Indicators (Output Indicator)</td><td rowspan="2">Unit of Measure</td><td colspan="2" rowspan="2">Source of Verification</td><td colspan="2">Baseline Value</td><td colspan="4">Target Values</td></tr>
<tr><td>Baseline Year</td><td>Value</td><td>2024</td><td colspan="2">2025</td><td>2026</td></tr>
<tr><td>Revised the Law on Fees for the Use of Public Goods</td><td>Yes/No</td><td colspan="2">MF</td><td>2023</td><td>No</td><td>Yes</td><td colspan="2">Yes</td><td>Yes</td></tr>
<tr><td colspan="2" rowspan="2">Measure Source of Financing</td><td colspan="2" rowspan="2">Programme Budget Reference</td><td colspan="6">Total Estimated Financial Requirement in RSD 000.</td></tr>
<tr><td colspan="2">2024</td><td colspan="2">2025</td><td colspan="2">2026</td></tr>
<tr><td colspan="2">Budget funds</td><td colspan="2" rowspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2">Donor funds</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
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<tr><td rowspan="2">Activities</td><td rowspan="2">Implementing Institution</td><td rowspan="2">Implementing Partners</td><td rowspan="2">Activity Implementation Date</td><td rowspan="2">Source of Financing</td><td rowspan="2">Programme Budget Reference</td><td colspan="3">Total Estimated Financial Requirement by Sources in RSD 000.</td></tr>
<tr><td>2024</td><td>2025</td><td>2026</td></tr>
<tr><td>2.3.1 Revising the Law on Fees for the Use of Public Goods – abolishing fees for repurposing uncultivable land for afforestation using species more resilient to climate change in state-owned and privately owned forests</td><td>MF</td><td>Forestry Directorate and Administration for Agricultural Land, MAFWM, MEP, Serbian Chamber of Commerce</td><td>2024</td><td>Budget of RS</td><td>Regular allocation</td><td></td><td></td><td></td></tr>
</table>

ACTION PLAN MEASURE NO. 2.4	ADAPTATION PROGRAMME MEASURE NO. 18: Revising the forest planning and management regulatory framework with regard to climate change adaptation							AREA: Forestry
	SPECIFIC OBJECTIVE 2: Establishing and strengthening capacities for the systemic implementation of the climate change adaptation process from national to local levels							
Institution Responsible for Implementation: MAFWM								
Implementation Period: 2024			Type of Measure: Regulatory					
Legislation to be Adopted/Revised to Allow for the Measure Implementation:			Adoption of the Regulation					
Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values			
			Baseline Year	Value	2024	2025	2026	
Prepared and adopted the Regulation with climate change information included	Yes/No	Official Gazette of RS, Forestry Directorate, MAFWM	2023	No	Yes	Yes	Yes	

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds				

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
2.4.1 Adopting the Regulation on the contents of the Forestry Management Master Plan, the manner and procedure for its adoption and preparation, material deficiencies or changed circumstances requiring its revision, the method of keeping records of performed works, and the contents and method of keeping forest chronicles in order to include climate change observations and projections	MAFWM -Forestry Directorate	Chamber of Forestry Engineers	2024	Budget of RS	Regular allocation			

ACTION PLAN MEASURE NO. 2.5	ADAPTATION PROGRAMME MEASURE NO. 21: Increasing the resilience of urban areas to climate change through strengthening of green infrastructure							AREA: Urban Development
	SPECIFIC OBJECTIVE 2: Establishing and strengthening capacities for the systemic implementation of the climate change adaptation process from national to local levels							
Institution Responsible for Implementation: Ministry of Contraction, Transport and Infrastructure (MCTI), MEP, Standing Conference of Towns and Municipalities (SCTM)								
Implementation Period: 2024-2026			Type of Measure: Combined (informative/educational and regulatory)					
Legislation to be Adopted/Revised to Allow for the Measure Implementation:			Urban Development Strategy					
Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values			
			Baseline Year	Value	2024	2025	2026	
Conducted feasibility study for the regulatory framework revision to ensure the implementation of the green infrastructure concept	Yes/No	Publicly available study, MEP	2023	No	Yes	Yes	Yes	
Climate change adaptation topic integrated in the Draft Urban Development Strategy	Yes/No	Publicly available draft revised Strategy, MCTI	2023	No	No	Yes	Yes	
Developed improved Methodology for local climate change adaptation plans preparation	Yes/No	Publicly available methodology, SCTM	2023	No	No	No	Yes	

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds		2,512		

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026

2.5.1 Conducting a study that will consider regulatory framework and public policy documents revision to ensure the implementation of the green infrastructure concept	MEP	MCTI, universities and other scientific institutions, City of Belgrade - Secretariat for Environmental Protection	2024	Donor funds		2,212		
2.5.2 Improving climate change adaptation topic in the Urban Development Strategy of the Republic of Serbia	MCTI	MEP	2026	Budget of Serbia	Regular allocation			
2.5.3 Improving the Methodology for local climate change adaptation plans preparation through a participatory process and intersectoral cooperation	SCTM	MEP, MCTI, universities and other scientific institutions, civil society organizations	2026	Donor funds "Partnership for Good Local Government" project funds, Swiss Government		300		

Action Plan measures contributing the achievement of Programme Specific Objective 3

SPECIFIC OBJECTIVE 3: Increasing climate change resilience of critical infrastructure and natural resources							
Institution responsible for coordination and reporting: Ministry of Environmental Protection							
Specific Objective Indicator(s) *(Outcome Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
The number of capital projects whose planning, construction or maintenance, takes into account climate change issue	Number (aggregate)	Report based on the Regulation on Capital Projects	2023	0	0	5	10

ACTION PLAN MEASURE. NO. 3.1	ADAPTATION PROGRAMME MEASURE NO. 13: Optimizing irrigation in line with needs and resources	AREA: Agriculture
	SPECIFIC OBJECTIVE 3: Increasing climate change resilience of critical infrastructure and natural resources	

Institution Responsible for Implementation: MEP	
Implementation Period: 2024-2026	Type of Measure: Informative/educational
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	-

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Assessment of needs and capacities for artificial water reservoirs storage	Number	Published Assessment, MEP	2023	0	0	0	1
Conducted assessment of the capacity for using water from existing artificial reservoirs	Yes/No	Report, MAFWM	2023	No	Yes	Yes	Yes

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds		4,000	6,000	

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
3.1.1 Preparing assessment of needs for artificial water reservoirs and atmospheric water reception and storage capacities (including micro-reservoirs) to assess the possibility for reservoirs construction and costs, for agricultural crop irrigation purposes	MAFWM	MEP, universities and other scientific institutions	2026	Donor funds			6,000	
3.1.2 Assessment of the capacities for using water from existing artificial reservoirs in Central Serbia for irrigation purposes	MAFWM	MEP, universities and other scientific institutions	2024	Donor funds		4,000		

ACTION PLAN MEASURE NO. 3.2	ADAPTATION PROGRAMME MEASURE NO. 19: Road infrastructure climate vulnerability and risk assessment							AREA: Infrastructure
	SPECIFIC OBJECTIVE 3: Increasing climate change resilience of critical infrastructure and natural resources							
Institution Responsible for Implementation: Public Enterprise Roads of Serbia (JP Putevi Srbije), (MCTI)								
Implementation Period: 2024-2026			Type of Measure: Informative/educational					
Legislation to be Adopted/Revised to Allow for the Measure Implementation:			-					
Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values			
			Baseline Year	Value	2024	2025	2026	
Developed methodology for climate change vulnerability and risk assessment for road infrastructure	Yes/No	Publicly available methodology, Public Enterprise Roads of Serbia or MCTI web-site	2023	No	No	No	Yes	

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds			15,000	

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
3.2.1 Developing methodology for climate change vulnerability and risk assessment for road infrastructure, with the possibility of vulnerability and risk levels spatial distribution mapping	Public Enterprise Roads of Serbia, MCTI	RHMSS, MEP, universities and other scientific institutions	2026	Donor funds			15,000	

<table>
<tr><td rowspan="2">ACTION PLAN MEASURE NO. 3.3</td><td colspan="8">ADAPTATION PROGRAMME MEASURE NO. 20: Providing support to local self-government units in implementing climate change adaptation through green infrastructure strengthening</td><td>AREA:
Urban Development</td></tr>
<tr><td colspan="9">SPECIFIC OBJECTIVE 3: Increasing climate change resilience of critical infrastructure and natural resources</td></tr>
<tr><td colspan="10">Institution Responsible for Implementation: MEP</td></tr>
<tr><td colspan="4">Implementation Period: 2024-2026</td><td colspan="6">Type of Measure: Provision of goods and delivery of services</td></tr>
<tr><td colspan="4">Legislation to be Adopted/Revised to Allow for the Measure Implementation:</td><td colspan="6">-</td></tr>
<tr><td rowspan="2">Measure-level Indicators (Output Indicator)</td><td rowspan="2">Unit of Measure</td><td rowspan="2" colspan="2">Source of Verification</td><td colspan="2">Baseline Value</td><td colspan="4">Target Values</td></tr>
<tr><td>Baseline Year</td><td>Value</td><td>2024</td><td>2025</td><td colspan="2">2026</td></tr>
<tr><td>Number of approved applications for co-financing to local self-government units for the implementation of afforestation projects using species resilient to climate change, to reduce risks of adverse climate change impacts</td><td>Number (aggregate)</td><td colspan="2">MEP Report</td><td>2023</td><td>0</td><td>2</td><td>5</td><td colspan="2">10</td></tr>
<tr><td>Delivered trainings for LGU employees to increase the capacities for climate change adaptations</td><td>Number (aggregate)</td><td colspan="2">Report, SCTM</td><td>2023</td><td>0</td><td>0</td><td>2</td><td colspan="2">5</td></tr>
</table>

<table>
<tr><td rowspan="2">Measure Source of Financing</td><td rowspan="2">Programme Budget Reference</td><td colspan="3">Total Estimated Financial Requirement in RSD 000.</td></tr>
<tr><td>2024</td><td>2025</td><td>2026</td></tr>
<tr><td>Budget funds</td><td>Budget of RS</td><td></td><td></td><td></td></tr>
<tr><td>Donor funds</td><td>“Partnership for Good Local Government”, Swiss Government</td><td></td><td>200</td><td>850</td></tr>
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<tr><td rowspan="2">Activities</td><td rowspan="2">Implementing Institution</td><td rowspan="2">Implementing Partners</td><td rowspan="2">Activity Implementation Date</td><td rowspan="2">Source of Financing</td><td rowspan="2">Programme Budget Reference</td><td colspan="3">Total Estimated Financial Requirement by Sources in RSD 000.</td></tr>
<tr><td>2024</td><td>2025</td><td>2026</td></tr>
</table>

3.3.1 Announcing public competitions for the allocation of co-financing to local self-government units for the implementation of afforestation projects using species resilient to climate change, to reduce adverse climate change impacts	MEP	Local self-government units (LGUs)		Budget of RS	Regular allocation			
3.3.2 Strengthening LGU capacities for implementation of climate change adaptation - delivery of accredited trainings for LGU employees	SCTM	MEP, LGUs	2026	“Partnership for Good Local Self-Government”, Swiss Government			200	850

Action Plan measures contributing the achievement of Programme Specific Objective 4

SPECIFIC OBJECTIVE 4: Strengthening financial support for implementation of the climate change adaptation process							
Institution responsible for coordination and reporting: Ministry of Environmental Protection							
Specific Objective Indicator(s) *(Outcome Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
The number of Programme activities that provide or promote investments in adaptation based on green expenditure tagging methodology in the course of the preparation of the 2025 and 2026 Annual Budget Law	Number	Budget Execution Report	2023	0	0	5	10

ACTION PLAN MEASURE. NO. 4.1	ADAPTATION PROGRAMME MEASURE NO. 2: Monitoring green expenditures in the budget of the Republic of Serbia that contribute to the climate change adaptation process						AREA: Cross-cutting
	SPECIFIC OBJECTIVE 4: Strengthening financial support for implementation of the climate change adaptation process						
Institution Responsible for Implementation: MF							
Implementation Period: 2024			Type of Measure: Regulatory				
Legislation to be Adopted/Revised to Allow for the Measure Implementation:			Green expenditure tagging methodology				
Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Developed Green expenditure tagging methodology that recognizes the expenditures contributing to climate change adaptation	Yes/No	Publicly available methodology, MF web-site	2023	No	Yes	Yes	Yes
Methodology and Road Map adopted	Yes/No	Road Map adopted and published on MF web-site	2023	No	Yes	Yes	Yes

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds				

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
4.1.1 Developing Green expenditure tagging methodology that recognizes the expenditures contributing to climate change adaptation	MF	MEP	2024	Budget	Regular allocation			
4.1.2 Adopting the developed Green expenditure tagging methodology that recognizes the expenditures contributing to climate change adaptation and its Road Map	MF	MEP	2024	Budget	Regular allocation			

ACTION PLAN MEASURE NO. 4.2	ADAPTATION PROGRAMME MEASURE NO. 7: Strengthening capacities to satisfy the increased needs for timely information dissemination on climate and weather conditions	AREA: Cross-cutting
	SPECIFIC OBJECTIVE 4: Strengthening financial support for implementation of the climate change adaptation process	

Institution Responsible for Implementation: RHMSS	
Implementation Period: 2024-2026	Type of Measure: Provision of goods and delivery of services
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	-

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Report on RHMSS technical capacity strengthening	Yes/No	RHMSS Report	2023	No	No	Yes	Yes
Installed upgraded integrated high-performance computer system in RHMSS, to enable the necessary services	Yes/No	RHMSS Report	2023	No	No	No	Yes
Meteorological observation system upgraded in accordance with the needs of the hydrometeorological early warning and alerts system and the climate change monitoring system	Number of observation system stations	RHMSS Report	2022	0	0	37	37
Employees who have undergone training	Number	RHMSS Report	2023	0	0	10	20

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds	Serbian budget 0403, 410, 4014, 512 Serbian budget 0403, 410, 4014, 423		151,000	91,000
Donor funds			60,000	

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026

4.2.1 Strengthening technical capacities for the Early Warning and Alerts System (EWS) by upgrading and enhancing the high-performance computer system (HPC) in RHMSS, to ensure the needs for carrying out operational activities in accordance with the needs for improved forecasting and climate products and monitoring products, in the field of weather and hydrological forecasts and climate change monitoring	RHMSS	MEP, universities and other scientific institutions	IV 2026	Serbian budget – additional funds in the RHMSS budget section	Programme 0403, function 410, Programme activity/project 4014, economic classification 512		Additional Budget of RS funds: 100,000	Additional Budget of RS funds: 90,000
4.2.2 Upgrading the meteorological observation system: by upgrading the radiosonde system components necessary for the operational functioning of 2 automatic radiosonde stations; by purchasing and installing 15 automatic meteorological stations (AMS) to restore the operation of the stations within the national ordinary climatological stations network and 20 AMS to restore the operation of the stations within the national precipitation stations network	RHMSS		IV 2025	Budget of RS – additional funds in the RHMSS budget section, potential GCF financial assistance through MAFWM project: Strengthening Resilience of Fruit and Vegetable Production in Central Serbia to Changes in Water Regime as a Consequence of Climate Change, with UNDP support	Programme 0403, function 410, Programme activity/project 4014, economic classification 512		Additional Budget of RS funds: 50,000 Potential donor funds 60,000	
4.2.3 Employees training for the use of new methods for forecasting and warning of extreme weather, climate and hydrological events, based on their impacts, risks and potential for generating other natural disasters	RHMSS	MEP	IV 2026	Budget of RS	Programme 0403, function 410, Programme activity/project 4014, economic classification 423		1,000	1,000

ACTION PLAN MEASURE NO. 4.3	ADAPTATION PROGRAMME MEASURE NO. 10: Improving the protection of perennial plantations against extreme weather conditions						AREA: Agriculture
	SPECIFIC OBJECTIVE 4: Strengthening financial support for implementation of the climate change adaptation process						
Institution Responsible for Implementation: MAFWM							
Implementation Period: 2024-2026			Type of Measure: Combined (provision of goods and delivery of services and regulatory)				
Legislation to be Adopted/Revised to Allow for the Measure Implementation:			Regulation on subsidies for investments in physical assets of agricultural holdings for the purchase of new machines and equipment for the improvement of primary plant production				
Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Total disbursed funds (amount of subsidies) for the physical assets of agricultural holdings for the purchase of new machines and equipment for the improvement of primary plant production for the climate change adaptation purposes	RSD	Serbian Directorate for Agrarian Payments	2022	728,137	764,544	800,951	837,358
Total number of approved applications for subsidies in the physical assets of agricultural holdings for the purchase of new machines and equipment for the improvement of primary plant production for the climate change adaptation purposes	Number of approved applications	Serbian Directorate for Agrarian Payments	2022	3,421	3,592	3,763	3,934
Regulation on subsidies for investments in the physical assets of agricultural holdings for the purchase of new machines and equipment for the improvement of primary plant production revised to include new and group the existing investments relating to climate change adaptation	Yes/No	Serbian Directorate for Agrarian Payments	2022	No	No	Yes	Yes

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds	Budget of RS 0103, 420, 0103-0002, 451	159.883	167,498	175,111
Donor funds				

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
4.3.1 Increasing total subsidy amount for anti-hail nets, shade nets and protection nets for perennial plantations and mother plantations	MAFWM	MEP	2024 and continued	Budget of RS	Programme 0103, function 420, Programme activity 0103-0002, economic classification 451	152,068	159,310	166,551
4.3.2 Increasing total subsidy amount for frost protection for perennial plantations and mother plantations	MAFWM	MEP	2024 and continued	Budget of RS	Programme 0103, function 420, Programme activity 0103-0002, economic classification 451	7,815	8,188	8,560
4.3.3 Revising the Regulation on subsidies for investments in the physical assets of agricultural holdings for the purchase of new machines and equipment for the improvement of primary plant production, to include special subsidies for investments in the acquisition of new machines and equipment intended for climate change adaptation	MAFWM	MEP	2025	Budget of RS	Regular allocation	0	0	0

ACTION PLAN MEASURE NO. 4.4	ADAPTATION PROGRAMME MEASURE NO. 11: Increasing the resilience of livestock production to climate change	AREA: Agriculture
	SPECIFIC OBJECTIVE 4: Strengthening financial support for implementation of the climate change adaptation process	

Institution Responsible for Implementation: MAFWM	
Implementation Period: 2024-2025	Type of Measure: Regulatory
Legislation to be Adopted/Revised to Allow for the Measure Implementation:	Regulation on subsidies for the construction of new and improvement of existing livestock housing facilities

Measure-level Indicators *(Output Indicator)*	Unit of Measure	Source of Verification	Baseline Value		Target Values		
			Baseline Year	Value	2024	2025	2026
Adopted revised Regulation on subsidies for investments in physical assets of agricultural holdings for the construction and equipping of facilities for the improvement of primary agricultural production in terms of the introducing new and grouping the existing investments related to the climate change adaptation of primary livestock production	Yes/No	MAFWM	2022	No	No	Yes	Yes

Measure Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement in RSD 000.		
		2024	2025	2026
Budget funds				
Donor funds				

Activities	Implementing Institution	Implementing Partners	Activity Implementation Date	Source of Financing	Programme Budget Reference	Total Estimated Financial Requirement by Sources in RSD 000.		
						2024	2025	2026
4.4.1 Revising the Regulation on subsidies for investments in physical assets of agricultural holdings for the construction and equipping of facilities for the improvement of primary agricultural production in terms of the introducing new and grouping the existing investments related to the climate change adaptation of primary livestock production	MAFWM	MEP	2025	Budget of RS	Regular allocation			

Appendix 1: Appendix to climate change assessment in the Republic of Serbia

A1.1. Data sources and methodology

The analysis of the observed climate conditions and the observed climate change impacts has been performed using the E-OBS database for the 1961-2020 period, which includes the interpolated daily temperature and precipitation data at 0.11° horizontal resolution. The E-OBS database was produced using the data available in the international data exchange for Europe, and includes data from about 28 stations in the Republic of Serbia. The verification based on other available observations in the Republic of Serbia has confirmed the quality of this dataset for the purposes of climate change assessments (Djurdjevic and Krzic, 2013).

The climate projections data were taken from the EURO-CORDEX database, i.e., daily temperature and precipitation data until 2100 obtained under the RCP4.5 and RCP8.5 GHG emission scenarios. From this database, selected are the results of the models that form an ensemble that produces the values that best reflect the main climate change characteristics for the territory of the Republic of Serbia. This multi-model ensemble consists of 8 selected models:

- gcm-ICHEC-EC-EARTH-rcm-CLMcom-CCLM4-8-17,
- gcm-ICHEC-EC-EARTH-rcm-DMI-HIRHAM5,
- gcm-ICHEC-EC-EARTH-rcm-KNMI-RACMO22E,
- gcm-MOHC-HadGEM2-ES-rcm-CLMcom-CCLM4-8-17,
- gcm-MOHC-HadGEM2-ES-rcm-KNMI-RACMO22E,
- gcm-MPI-M-MPI-ESM-LR-rcm-CLMcom-CCLM4-8-17,
- gcm-MPI-M-MPI-ESM-LR-rcm-MPI-CSC-REMO20091,
- gcm-MPI-M-MPI-ESM-LR-rcm-MPI-CSC-REMO20092.

The above data, which was used for the analysis of the observed and future climate change, is available on the Digital Climate Atlas of Serbia web-portal. In addition to the daily data, the results obtained based on this data are also available, i.e., the values for various climate indices for different periods under both the scenarios, at the national, regional and municipal levels, as well as for specific locations.

The data from the above datasets (observations and climate projections) were used in various climate change assessment studies in the region and in Serbia, for impact assessments (Vukovic et al., 2018; Đurđević et al., 2018; Vukovic and Vujadinovic, 2018; Stojanović et al., 2021; Vuković Vimić et al., 2022; Životić Vuković Vimić, 2022, etc.), in the preparation of the Third National Communication, and the sector-level impact assessments prepared for this Programme.

The analysis of the climate change in the territory of the Republic of Serbia was performed by comparing the prevailing climate conditions in the 20th century, more precisely during the selected base period (1961-1990), with the conditions in the recent past and in the future climate periods. The observed climate change was analysed for the near-past period (2001-2020), and particularly for the second decade of this climate period (2011-2012) when the major climate change impacts were observed. The changes in climate conditions in the future are analysed for the climate periods: the near-future period (2021-2040), the mid-century period (2041-2060), and the end-of-century period (2081-2100). The analysis was performed according to the RCP4.5 and RCP8.5 GHG emission scenarios.

The results of the ensemble of future climate projection values for the 2021-2040 period under the RCP4.5 and RCP8.5 scenarios overlap to a large extent within the most probable range values, indicating that no significant differences are expected in the climate characteristics for this period under these two scenarios, which is also expected taking into account the projected emissions increase under these scenarios. The presented analysis for this period includes the most probable climate outcomes under both the scenarios.

In the mid-century period (2041-2060), the expected changes are significantly greater in relation to the differences in the projections according to these two scenarios, i.e., the uncertainty of the results according to one scenario is greater than the difference of the most probable values obtained according to these two scenarios, which means that for this period it could be also considered that the difference in the projected changes under the two scenarios is not as significant as the change in climate conditions compared to the base period. For this reason, in order to simplify the presentation of the results, the most probable climate outcomes will be considered for this period, taking into account both the scenarios combined, and in accordance with the observed change trends. Where it was observed that there could be a noticeable difference under the lower end scenario, it is particularly emphasized.

In the second half of the century, it is expected that a significant difference in climate conditions under the RCP4.5 and RCP8.5 scenarios will start to be show, i.e., that the impact of the implementation of climate change mitigation measures will lead to the stabilization of climate conditions in relation to the further climate change acceleration caused by the increased emissions in the absence of these measures. Consequently, the results obtained for the end-of-century climate period of (2081-2100) according to these two scenarios are considered separately and present the range of possible climate outcomes that should be taken into account comprehensively when planning and implementing measures to increase the capacity of the Republic of Serbia to adapt to future conditions.

NOTE: As the analysis presented in this Programme shows that the frequency and intensity of climate hazards with high spatial variability (extreme precipitation, floods, etc.) is increasing, for the climate change monitoring purposes, it is necessary to improve the RHMSS observing system to enable it to adequately monitor the growing climate and weather extremes in the territory of the Republic of Serbia. There is a need also to improve the observing system to provide the necessary data for identifying and monitoring climate change related damages and losses. The national meteorological stations network is specified by the Decree on establishing the national meteorological stations networks and the work programme and reporting methods of the national meteorological stations networks ("Official Gazette of the RS", Number 123/12) and the Decree on determining locations of the national network meteorological and hydrological stations, and protection zones around stations where restrictions are introduced ("Official Gazette of the RS", Number 34/13). In addition to the synoptic stations network, the above regulations establish a national network of 82 ordinary climatological stations and 576 precipitation stations, where observations are made by part-time observers. Over the last 10 years, the number of ordinary climatological and precipitation stations in the national meteorological stations network has been reduced by as much as 50%, and that applies also to the capacities for maintaining the functionality of the system and ensuring the quality of data. In addition, it is estimated that upper-air measurements need to be upgraded as well, in order to improve monitoring of the atmospheric conditions and identifying the changes in the conditions of the stable weather conditions and cyclonic activities. The improved observing system would contribute to the further strengthening of knowledge about climate change and its impact in the Republic of Serbia.

A1.2. Analysis of the climatic impact-drivers contributing to the "too warm" climate hazard group

A1.2.1. Change in mean temperature values

The mean surface air temperature for Serbia for the climate period 2001-2020 is 1.4°C higher relative to the average value for the base period (1961-1990), while the average value for the later decade 2011-2020 is 1.8°C higher. The mean maximum temperature for 2001-2020 is higher by 1.6°C and the minimum by 1.3°C, with a larger increase in the later decade (2.0°C for the maximum and 1.6°C for the minimum temperature). The largest increase was observed during the JJA season. The average maximum temperature for the 2011-2020 decade is even 2.6°C higher than the 1961-1990 value. Other changes (anomalies) in mean temperatures for these two periods are shown in Table A1.1. Maps of changes (anomalies) in mean temperatures for the 2001-2020 and 2011-2020 periods, as well as changes in the mean maximum temperature for JJA for 2011-2020 are shown in

Table A1.1. Maps of changes (anomalies) in mean temperatures for the 2001-2020 and 2011-2020 periods, as well as changes in the mean maximum temperature for JJA for 2011-2020 are shown in Figure A1.1.

Table A1.1 Anomalies of mean surface air temperatures averaged for the territory of the Republic of Serbia compared to the correspodnig values for the reference period 1961-1990: mean temperature (*Tmean*), mean maximum daily temperature (*Tmax*) and mean minimum daily temperature (*Tmin*). Presented are anomalies for mean annual values, and mean seasonal values: DJF (December-January-February), MAM (March-April-May), JJA (June-July-August) and SON (September-October-November).

Parameter	Period	ANN	DJF	MAM	JJA	SON
Tmean	2001-2020	1.4	1.3	1.2	2.0	1.1
	2011-2020	1.8	1.7	1.4	2.4	1.8
Tmax	2001-2020	1.6	1.5	1.5	2.2	1.1
	2011-2020	2.0	2.0	1.7	2.6	1.7
Tmin	2001-2020	1.3	1.3	1.0	1.8	1.2
	2011-2020	1.6	1.7	1.1	2.1	1.7

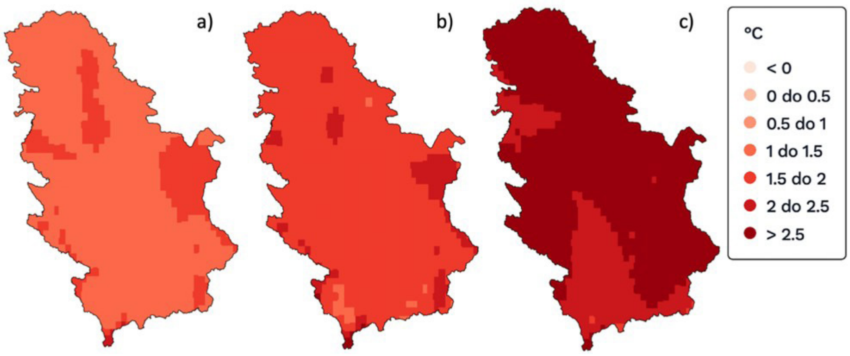

Figure A1.1. Anomalies of mean temperatures for the periods 2001-2020 (left) and 2011-2020 (middle) and anomalies of mean maximum temperature for JJA for 2011-2020 (right) in relation to the 1961-1990 base period.

The expected increase in the mean surface air temperature for the period 2021-2040 compared to 1961-1990 is about 2.2°C, in the mean maximum temperature about 2.5°C, and in the mean minimum temperature about 2.1°C. The increase in the mean maximum temperature for JJA in this period will reach an increase of about 2.8°C compared to 1961-1990.

The expected increase in the mean temperature for the 2041-2060 period compared to 1961-1990 is higher than 2.5°C, most probably around 3.1°C, and the change in the mean maximum temperature will be higher than 2.7°C, and most probably around 3.4° C, while for the minimum temperature is expected to be 2.4°C higher, with increase most probably around 2.9°C. The increase in the mean maximum temperature in this period for JJA will be in the range of 3.6°C to 4.2°C compared to 1961-1990.

The increase in mean surface air temperature in the period 2081-2100 is expected to be most probably around 3.1°C under the RCP4.5, and as high as 5.8°C under the RCP8.5 scenario, compared to the value for the reference period 1961-1990. The warming during other seasons catches up with the warming during the JJA season, and the faster warming during DJF is assumed to be due to a significant loss of snow cover, and thus a decrease in surface albedo in the mountainous areas, which causes greater warming. In this period, the increase in the mean maximum temperature in the JJA season is expected to exceed 6.0°C compared to the 1961-1991 under the RCP8.5 scenario.

A1.2.2. Change in heat waves

A heat wave is a period of at least 6 consecutive days with maximum daily temperatures exceeding the 90th percentile value of the maximum temperatures observed in the that period of the year during the base period, in this case 1961-1990.

Warming, i.e. temperature increase, has caused an increase in the number of warm days that can cause heat stress due to too warm conditions. The average number of occurrences of heat waves per year in the period 2001-2020 increased by 2.4, and in 2011-2020 by 3, compared to the number of occurrences per year during 1961-1990, when such events did not occur in average in the territory of Serbia in every year. Another important fact is that during the decade 2011-2020, in as many as 6 years, the average number of heat waves was greater than 4, i.e., the years with a relatively high number of occurrences of exceptionally warm periods have become significantly more frequent. If we take into account the average number of heat wave days per year, in the recent past in the territory of Serbia there was an average of approximately one month in heat wave per year, and in the three years during the 2011-2020, heat waves lasted more than 40 days on average (as many as 50 days in 2012).

In the period 2021-2040, there will be about 3.5 more heat waves per year than during 1961-1990, which means that more frequent occurrence of years with a greater number of heat waves than that observed in the 2011-2020 period is expected, with a possible occurrence of years with the record number of heat waves.

The average number of heat wave events per year in the territory of Serbia in the period 2021-2040 is expected to increase by approximately 4-5 per year compared to the 1961-1990, with a greater increase in the southern, southwestern and southeastern parts of Serbia.

In the period 2081-2100, according to the RCP8.5, the average number of heat waves per year is expected to be 8-10, which means that the total duration of extremely warm weather in the territory of the Republic of Serbia could be to around two months during the year. Due to the increase in the variability of weather conditions, some years will have even higher number of heat waves. Under the lower end scenario, RCP4.5, according to which climate conditions are expected to stabilize, the average number of heat waves per year is expected to be around 5.

A1.2.3. Change in the number of high temperature days

Heat waves do not have equally critical impacts across the territory of Serbia, because a heat wave in a specific location is determined in relation to the climate of that location, which means that heat waves in warmer climates reflect periods with significantly higher temperatures than those in colder climate conditions. In addition, determining heat waves in variable climate conditions is sensitive to the choice of the base period, i.e., if later (warmer) periods are taken as the baseline, the temperature criteria used to define a heat wave are increased. In order to further understand the criticality of heat wave events or generally warmer periods, one must take into account other climate indices that serve to determine the occurrence of days with critically high temperatures, such as *the number of tropical days (average number of days per year with a maximum daily temperature above 30°C, TRD), number of hot days (average number of days per year with a maximum daily temperature above 35°C, TVD) and number of tropical nights (average number of days per year with a minimum daily temperature above 20°C, TRN).*

During the base period, days that meet the above criteria occurred only in lower altitude areas (such as Vojvodina, the Sava and Danube river valleys, eastern Serbia, in the Velika Morava, Zapadna Morava and Južna Morava river valleys, as well as in other lower altitude areas in southern and southeastern Serbia). In these areas, *TRD* was about 20-30, *TVD* was 2-3 (and locally up to 5) and *TRN* was lower than 1 (except in the Belgrade area). In the period 2001-2020, in these areas of Serbia, TRD increased by about 20 days per year, and in 2011-2020 in some areas by 30 days per year. *TVD* in 2001-2020 increased by 4-7 days, and in 2011-2020, the increase was even several days greater (locally in the low altitude areas in the central, southern and southeastern Serbia during this decade, the increase was more than 10 days). Largest increase in *TRN* was in Vojvodina, in the Belgrade area, and in the low altitude areas in the central and eastern Serbia, by about 5-10 days and even by more than 10 days in the Belgrade area in the period 2001-2020, and the increase was somewhat greater in the second decade of this period. The spatial distribution of *TRD* and *TVD* values for the 1961-1990 base period and their change (anomaly) distribution in the periods 2001-2020 and 2011-2020 are shown in Figures A1.2 and A1.3.

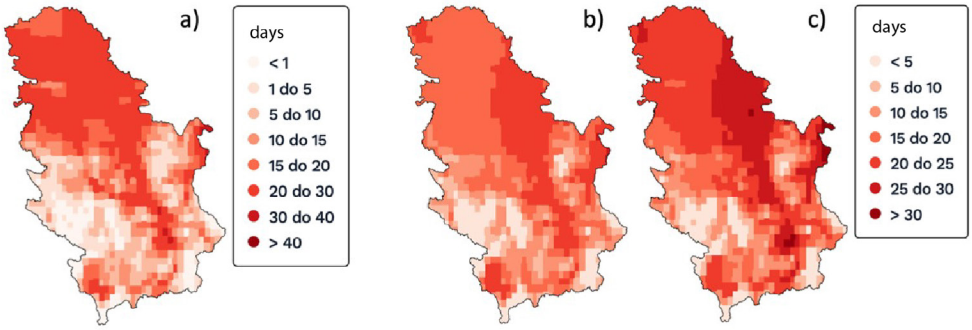

Figure A1.2. **Average number of tropical days per year (TRD) for the 1961-1990 base period (left), and changes in TRD for the periods 2001-2020 (middle) and 2011-2020 (right) in relation to the 1961-1990 values.**

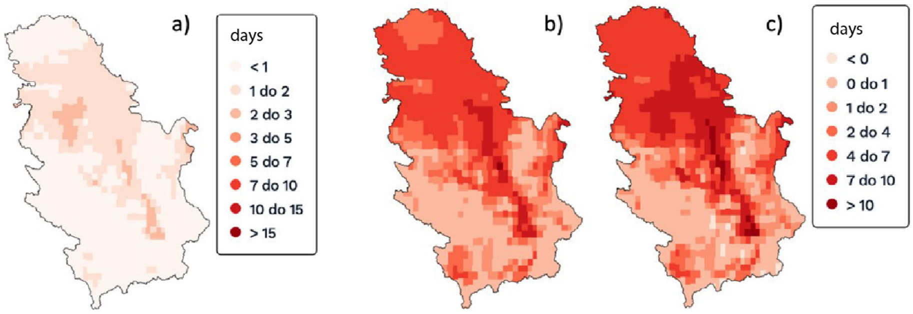

Figure A1.3. **Average number of hot days per year (TVD) for the 1961-1990 base period (left), and changes in TVD for the periods 2001-2020 (middle) and 2011-2020 (right) in relation to the 1961-1990 values.**

In the period 2021-2040, the number of tropical days (*TRD*), hot days (*TVD*) and days with tropical nights (*TRN*) will continue to increase compared to the values observed in the 2011-2020 period. The increase in *TRD* is expected to exceed the increase of 35 days per year compared to 1961-1990 in the lowland areas, meaning that such days in the lowland areas are expected to average around 55-60 in the period 2021-2040. The increase in *TVD* in the lowland areas is expected to be about 12 days compared to 1961-1990, i.e., there will be 13-15 such days per year on average. The increase in *TRN* is expected to be in the range of 3-8 days per year more than in 1961-1990 in the lowland areas. As in the observed near-past period, days with such high temperatures are becoming more frequent at higher altitudes as well.

In the period 2041-2060, the increase in *TRD* is expected to be about 45 days per year compared to 1961-1990 in the lowland areas, which means that such days in the lowland areas are expected to average about 65. The increase in *TVD* in the lowland areas is expected to be about 20 days more compared to 1961-1990, i.e., there will be more than 20 such days per year on average. The increase in TRN is expected to be in the range of 8-16 days per year more than in 1961-1990 in the lowland areas. The lowland areas are most affected by high temperatures, but in the climate of this period the risks also appear at higher altitudes, i.e., the observed values shift to several hundred meter higher terrains, which additionally indicates the importance of climate risk assessments at the local level to assess the vulnerability and risks for different sectors.

In the period 2081-2100, the increase in TRD under the RCP8.5 is expected to be about 65-75 days per year more than in 1961-1990 in the lowland areas, which means that such days in the lowland areas are expected to average about 85 -95. Under the RCP4.5, *TRD* is expected to increase by a few more days in the second half of the 21st century, and to average around 70 per year in the lowland areas. According to the RCP8.5, *TVD* in the lowland areas in the 2081-2100 period is expected to be about 35-45 days on average per year, while according to the RCP4.5 it is expected to be about 25. *TRN* according to the RCP8.5 will be about 40-50 days on average per year, and according to the RCP4.5 about 20. In the expected climate conditions of this period, the risks of high temperatures also affect even higher altitudes.

A1.2.4. Change in climate variability of heat conditions

A change in climate variability of heat conditions implies an increased range of possible mean annual heat conditions in a climate period or heat conditions during a certain period of the year. On average, the temperature is increasing, and consequently the mean annual heat conditions have positive anomalies in relation to the base period mean value (Figure A1.4). However, their values have a larger range than during the base period, indicating an increased variability in the mean annual heat conditions.

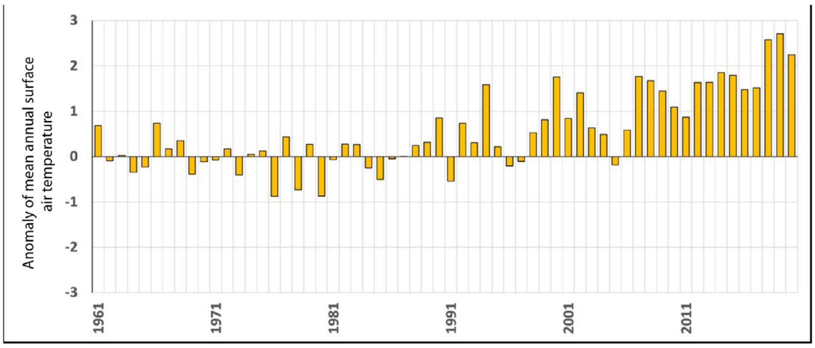

Figure A1.4. **Deviations (anomalies) of mean annual air temperatures, averaged for the territory of the Republic of Serbia, for the 1961-2020 period in relation to the 1961-1990 base period mean value.**

A sharp increase in the number of heat waves, a greater increase in maximum temperatures and uneven seasonal warming, i.e., the greatest warming of the JJA season, contribute to the increased climate variability. In other words, the warm period warms faster than the cold period and the rate of increase in extreme events with high temperatures is larger than warming of periods with cold temperatures, and than decreasing in low temperature events. Consequently, the probability for shits between of very different heat conditions has increased, as well as frequency of periods with more intense alternation of heat conditions (from colder to warmer and vice versa), both on the average annual level and on a seasonal level or in shorter time intervals during the year.

A1.2.5. Additional comments for impact-drivers analysis related to "too warm" climate hazard group

Temperature increase in the colder part of the year can also cause stress for living organisms due to too warm conditions during the period when they require low temperatures. In that sense, additional climate indices that show a possible risks from temperature increase (too warm conditions) include the average number of frost days and ice days, i.e., their decrease during the 21st century. The average number of frost days (days with minimum temperatures below 0°C) per year during the reference period 1961-1990 in the territory of Serbia was about 106 days per year, in the lowland areas below 100, in the mountainous areas above 130, and in the highest mountain areas even above 150. In the period 2001-2020, the average number of these days in the territory of Serbia decreased by about 15, and in 2011-2020 by about 20. In the mid-century period (2021-2040) is expected to have decrease of 30 in frost days on average in the territory of Serbia compared to 1961-1990, and according to the RCP8.5, in the end-of-century climate (2081-2100), the decrease will be in the range 60-70. The average number of icing days (days with maximum temperatures below 0°C) per year during the 1961-1990 base period in the territory of Serbia was about 28 days per year, in the lowland areas 10-20, in the mountainous areas above 30, and in the highest mountain areas even above 45. In the period 2001-2020, the average number of these days in the territory of Serbia decreased by about 8 days, and in 2011-2020 by about 12 days (with the largest decrease, of over

15 days, is in the mountainous areas). In the mid-century period (2041-2060), in lowland years without icing days are expected to be frequent, while in mountainous areas their number will be halved. In the period 2081-2100 under the RCP8.5 scenario, there will be almost no icing days in the lowland areas, while their occurrence in the mountainous areas will be reduced to such an extent that there is a high probability that there will be an average of about 10 such days per year. It is possible that in this period there will be years without icing days in the entire territory of Serbia.

Increased climate variability (Vuković et al., 2018) is a consequence of the uneven seasonal warming and a greater increase in maximum daily temperatures, increased frequency of heat waves, and the occurrence of temperature extremes in different years and different seasons, as explained in the previous Chapter (*A1.2.4.*). In other words, the ranges of the temperature values in the near-past and in the future climate has both shifted towards higher values and expanded, which indicates an increased climatic variability of heat conditions. That means that despite the warming, cold periods with snow will still occur, as they were more frequent and longer in the 1961-1990 base period climate, and the preparedness to such events should not be neglected. What is not apparent from the analyses of average values is that the frequency of years with extremely high temperatures has increased significantly. For example, in 2012 and in 2017, the JJA season was extremely warm and caused notable damages, especially in food production (Drought Initiative – Republic of Serbia (draft), Djurdjević, 2020). The *TRD, TVD*, and *TRN* values observed during these years are comparable to the mean values for these indices in the mid-century period (2041-2060), but considering the increased climate variability, years with far greater temperature extremes can be expected in the future.

Risks of high temperatures are particularly high in urban areas due to their thermal characteristics, i.e., their ability to warm more and retain heat. Urban areas where the temperature is higher than in the surrounding areas are urban heat islands, and their temperature depends on the urban architecture, i.e., its form (distribution of built and green areas, materials, ventilation, proximity to water bodies, etc.). Regardless of the size of the urban settlement, if the urban architecture design is unfavourable, there would be a pronounced urban heat island effect. These areas are not "visible" in the climate models because they have a smaller spatial scales than climate models resolutions. Standard meteorological measurements performed in cities are placed in locations with grassy surfaces, and consequently do not measure values that reflect realistically the conditions in the locations with the most pronounced urban heat island effect. In other words, there is no established monitoring of the urban heat island effect. To estimate roughly how much warmer these areas are, data from the C3S (Copernicus Climate Change Service) database was used. This database contains the data for Belgrade and Novi Sad for the 2008-2017 period. The data are of 100m resolution and derived using an urban model simulation. Figure A1.5 shows an example for Belgrade, the mean temperature for the 2008-2017 period, and an example of the mean minimum temperature for JJA in 2012 (spatial distribution of temperature anomalies in relation to the mean value for the entire area). According to these results, the average temperature in the built environment is about 2°C higher than in the peripheral areas or areas with vegetation. An even more pronounced urban heat island effect can be seen in the example for the mean minimum (night) temperature during the extremely warm summer of 2012, when the temperature in the city was on average more than 3°C higher than in the periphery. In Novi Sad (not shown here), the urban heat island area anomaly in relation to the periphery during the summer is as much as 4°C. Based on these results, it can be concluded that the temperatures in parts of urban areas with the pronounced urban heat island effect are actually close to those estimated for the mid-century climate in the territory of Serbia, and that the heat stress is extremely high. Further into the future, these areas will continue to heat up with continued pronounced anomalies in relation to the surrounding temperatures and, consequently, the question is raised whether these areas would be suitable for life and normal daily activities in the future climate.

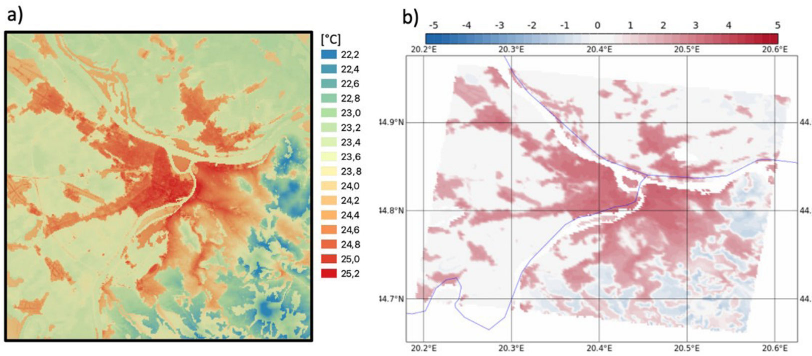

Figure A1.5. **Mean surface air temperature for the Belgrade area for the 2008-2017 period (left) and the anomaly of the mean night (minimum) air temperature in relation to the mean value for the entire area for JJA in 2012 for the Belgrade area (right); Data source: Copernicus Climate Change Service (C3S).**

A1.3. Analysis of climatic impact-drivers contributing to the “too wet" and “too dry” climate hazard groups

The climate hazards related to too wet and too dry conditions are caused by a change in the annual distribution of precipitation and a change in precipitation distribution by intensity, and also by an increased variability in the precipitation accumulations during the year or in a part of the year, which means an increase in the extreme events with large amounts of water or with insufficient water (Vukovic et al., 2018; Djurdjevic et al. 2018, Zivotic and Vukovic Vimic, 2022). In addition to a change in precipitation, the temperature increase contributes also to the increased water deficit risk due to the increased evapotranspiration, i.e., evaporation due to warmer conditions and the capacity of air to hold larger amounts of water vapour.

A1.3.1. Change in the mean accumulated precipitation

The observed changes in the annual accumulated precipitation are not significant, and their signal of change depends on the choice of the climate period. The annual precipitation accumulated in the territory of the Republic of Serbia was slightly lower in the climate of the end of the 20th century compared to 1961-1990, after which it had increased, and in the period 2001-2020 it was 8% and in 2011-2020 was 5% higher compared to the average annual precipitation in the period 1961-1990 (Životic and Vuković Vimić, 2022). An increase in average total amount of precipitation over the territory of Serbia was observed in all seasons except in the JJA season, when in the period 2001-2020 a decrease of less than 1% was observed, and in the 2011-2020 about 8% compared to 1961-1990. It is important to note that the JJA season for Serbia is, on average, the season with the highest precipitation accumulation, i.e., during the month of June. The most significant increase in precipitation in the 2001-2020 period was in the SON season, while in the period 2011-2020, the most significant increase was in the MAM season, by as much as 20%, which was contributed mostly by 2014 due to the extremely large amount of precipitation precipitation in May. However, the spatial distribution of precipitation anomalies compared to1961-1990, presented in Figure A1.6, shows the actual extent of the spatial change in precipitation. The annual precipitation amount in the territory of Serbia has spatial variations and ranges from below 600 mm in the Vojvodina region to over 800 mm at the higher altitudes, and over 1000 mm in the mountainous areas. The precipitation rate decrease during the JJA season in the 2011-2020 period is between 10% and 20% in a large part of Serbia. The decrease in the JJA season combined with the highest temperature increase in this season causes this season to be the most critical period with multiple climate change impacts observed in different sectors.

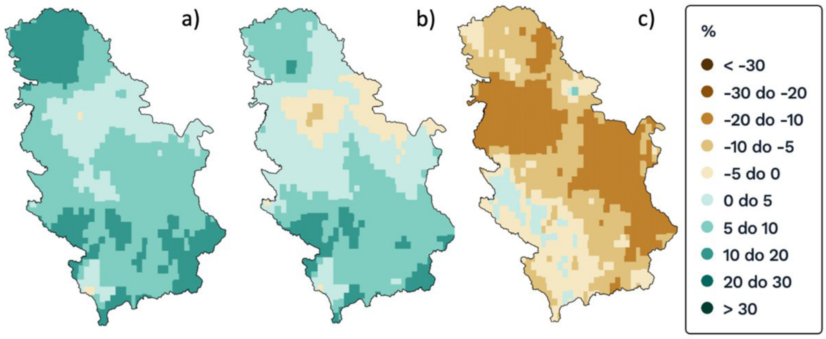

Figure A1.6. **Anomaly average annual accumulated precipitation for 2001-2020 (left) and 2011-2020 (middle) compared to 1961-1990, and anomaly of accumulated precipitation for the JJA season for 2011-2020 (left) compared to 1961-1990.**

Climate change in the territory of the Republic of Serbia has therefore affected a change in the annual distribution of precipitation, i.e., a shift of the maximum monthly accumulated precipitation from the late spring and early summer (from June, on average) to the earlier periods in the spring (to May, on average). This change is unfavourable, among other reasons, considering the increased risk that the mountain snow melting period and the high precipitation period are getting closer, i.e., that high precipitation will fall on already wet soil (close to saturation), increased river flow, etc., providing more favourable conditions for increased surface runoff and flooding.

Changes in the average annual precipitation in the future show that most probably there will be no significant change by the mid-century period, but with a tendency for a slight decrease, while in the second half of the century, according to the RCP8.5 scenario, the average amount of precipitation accumulated in the territory of Serbia is expected to decrease by about 8% to 14 % compared to 1961-1990. A further decrease in the average accumulated precipitation for the JJA season is expected, by the mid-century by over 20%, and by the end of the century by 25% and up to over 40% under the RCP8.5 scenario. By the end of the century, according to the RCP8.5 scenario, a decrease in the precipitation amount is not expected only in the DJF season, while in the MAM and SON seasons, there is a greater uncertainty in the change assessement, i.e. whether the values would remain similar to those in the base period or decrease.

A1.3.2. Change in very heavy and extreme precipitation events

Due to climate change, the change in precipitation distribution by intensity has also been observed, with a decrease in the low and moderate precipitation events (days) and an increase in the higher precipitation events, and thus a decrease in the precipitation amount during the low and moderate precipitation events and an increase in precipitation amount in higher precipitation events (Životić and Vuković Vimić, 2022), as shown in Figure A1.7. Unlike the change in annual mean accumulated precipitation, which had a variable trend signal, change in precipitation distribution by intensity has a clear trend of shifting towards heavier precipitation during the entire observed period. For example, the share of precipitation in the entire territory of Serbia which falls in very heavy precipitation days (daily precipitation range of 20-30 mm) increased by about 40% (from 6.1% in the period 1961-1990 to 8.5% in the neat-past period 2001-2020, in share of total accumulated precipitation), and the share of the precipitation accumulated in extreme precipitation days (daily precipitation amount above 30mm) increased by over 100% in the near-past period, with an even more pronounced increase in the second decade of that period (2011-2020). The share of the precipitation accumulated during days with extreme precipitation in total accumulated precipitation, in Republic of Serbia, in 1961-1990 was 2.4%, in 2001-2020 it was 4.9%, and in 2011-2020 was 5.6%.

The spatial distribution of the changes in the number of days with very heavy and extreme precipitation (days with precipitation over 20mm) and days with extreme precipitation (over 30mm) for the period 2001-2020 compared to 1961-1990 are shown in Figure A1.8, together with their values in base period1961-1990. The average number of days with very heavy and extreme precipitation in total was more than 2 days per year in 1961-1990 in the largest part of the territory of the Republic of Serbia, and in some areas, mostly in the central and western Serbia, more than 5 days per year. The change in the number of these days for 2001-2020 shows an increase throughout the territory of Serbia, and mostly in Vojvodina, central and southwestern parts of Serbia, where the increase is more than 1, and in some areas even more than 2 more days per year. Days with extreme precipitation were a relatively rare in the territory of the Republic of Serbia, i.e., their average occurrence in the territory of the Republic of Serbia was less than 1 per year in the 1961-1990 period, i.e., they did not occur every year. The spatial distribution of their change in 2001-2020 compared to 1961-1990 shows an increase in the entire territory of the Republic of Serbia, at most in the area of Vojvodina, central and southwestern Serbia, where the increase is more than 0.5 additional days per year, and locally more than 1, meaning that in these parts the increase has caused the conditions in wich days with extreme precipitation are expected to occur every year.

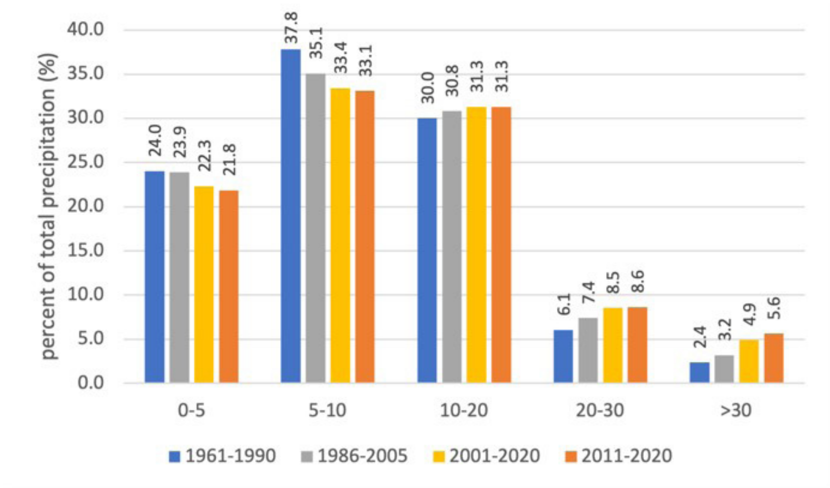

Figure A1.7. **Accumulated precipitation in days with precipitation within a certain range (< 5mm low precipitation days, 5-10mm moderate precipitation days, 10-20mm heavy precipitation days, 20-30mm very heavy precipitation days, and over 30mm extreme precipitation days) expressed as a percentage of the total accumulated precipitation in the territory of Serbia for the periods: base period (1961-1990), end-of-20th century period (1986-2005), near-past period (2001-2020), and the 2011-2020 decade. Source: Životić and Vuković Vimić (2022).**

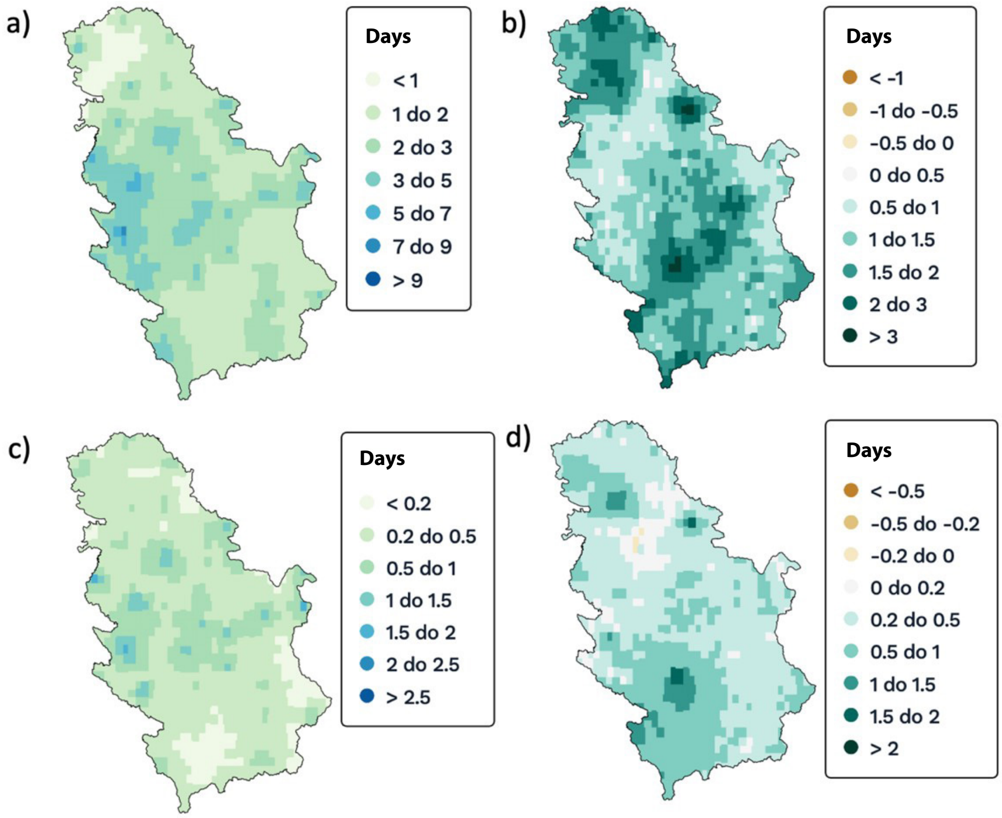

Figure A1.8. **Average number of days per year with very heavy and extreme precipitation - days with precipitation above 20mm for 1961-1990 (upper left) and the anomaly for 2001-2020 compared to 1961-1990 (upper right), and the average number of days per year with extreme precipitation - days with precipitation above 30 mm for 1961-1990 (bottom left) and the anomaly for 2001-2020 compared to 1961-1990 (bottom right).**

The future projections of change of extreme precipitation events depend on the models' ability to reproduce such events, which are a consequence of larger-scale intensive weather systems, but also local intense convective cloud developments that can produce extreme precipitation. While the models can adequately reproduce larger systems, they have a relatively coarse resolution for local events. Consequently, in order to analyse the future changes in extreme precipitation events, we chose to identify tendencies of their changes (anomalies) in the future, rather than to rely only on future extreme precipitation indices values, as was done for heat indices. Figure A1.9 shows the linear trend of change of anomalies of average number of days with extreme precipitation in the period 1961-2100 compared to the 1961-1990 values, according to the RCP4.5 and RCP8.5 scenarios (the model ensemble median values and 75th percentiles) and the observed trend of change. Under both scenarios, there is an increasing trend in the average number of days with extreme precipitation in the territory of the Republic of Serbia. The observed trend shows a tendency of more intensive increase than the projected trends, and the mean average increase in these events in the territory of the Republic of Serbia is expected to exceed 1 in the mid-century period 2041-2060. As the annual variability of these events has increased, i.e., the occurrence of years with a higher number of these precipitation events is more frequent (also shown in Figure A1.9), it is expected that years with a significantly higher number of extreme precipitation days than the average will become more frequent, even in the near future. The most probable range of future values, taking into account the observed trends, is in the range between the model ensemble 50th and 75th percentiles. According to the RCP4.5 scenario, the increase in extreme precipitation days is expected to stabilize by the end of the century at the maximum values of around 1 (on average, in the territory of the Republic of Serbia, occurrences per year at least once), while according to the RCP8.5 scenario, a further increase is expected, more likely according to the 75th percentiles, i.e., of about 1.5. It should be noted that changes in such events do not have to follow a linear trend, and that there may be a greater increase in the second half of the century according to the RCP8.5 scenario due to climate change acceleration, which should be taken into account in special assessments of impacts in different sectors.

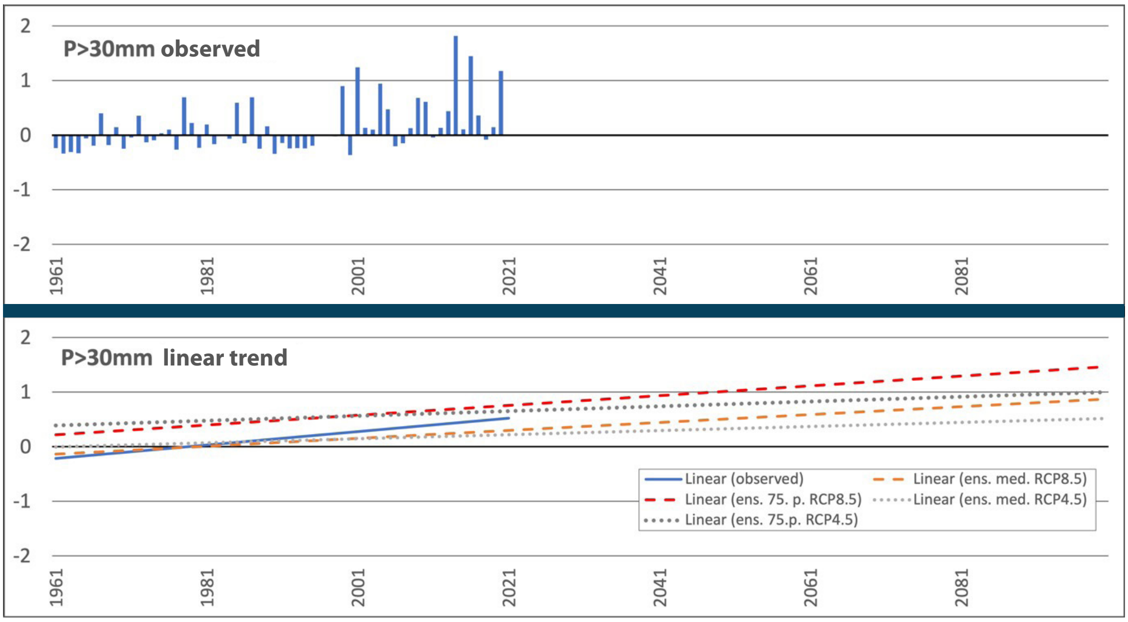

Figure A1.9. **Anomaly of the average number of days per year with extreme precipitation - days with precipitation over 30 mm, in the period 1961-2020, compared to the average value for 1961-1990 (above) and linear change trend in these anomalies obtained based on the observations for the 1961-2020 period and the climate model ensemble projections for the 1961-2100 period under the RC4.5 and RCP8.5 scenarios (below).**

The spatial distribution of the high precipitation risk, developed under the study by Životić and Vuković Vimić (2022), shows an extension of the territory affected by the extreme precipitation risk in the mid-century period (2041-2060). Figure A1.10 shows the spatial distribution of different levels of risk from extreme precipitation events in the period 2001-2020 and the period 2041-2060 (according to the RCP8.5 scenario). According to this risk assessment, in the period 2001-2020, about 48% of the territory of the Republic of Serbia is under low risk of extreme precipitation, 45% under moderate risk, and 7% under high and very high risk. In the mid-century period, about 10% of the territory is under low risk, 34% under moderate risk, and as much as 56% under high and very high risk of extreme precipitation. Therefore, in addition to increasing, the risks will also cover a larger territory. In this period, the difference in the results according to the RCP4.5 and RCP8.5 scenarios is expected to be significantly smaller in relation to the expected changes, and by the end of the 21st century, the trend of increasing risk according to the RCP4.5 scenario will slow down and stabilize, and according to the RCP8.5 scenario, it will continue to increase.

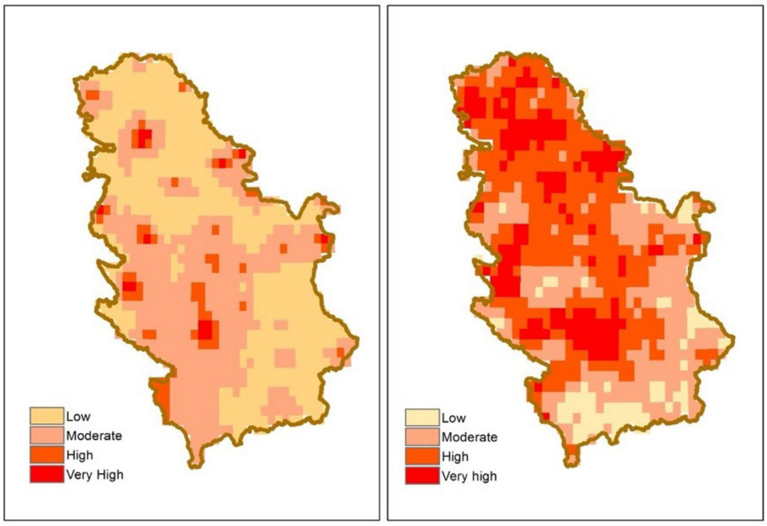

Figure A1.10. **Spatial distribution of the extreme precipitation hazard (risk) estimated for the 2001-2020 period (left) and for the 2041-2060 period (right). Taken from the study by Životić and Vuković Vimić (2022).**

A1.3.3. Change in droughts and climate aridity

Drought is a weather event during which there is a precipitation deficit and/or insufficient water/moisture available, which has multiple consequences (soil moisture deficit, insufficient moisture for plant development, drinking water scarcity, low groundwater levels, low river flows, etc.). Too dry conditions are caused by the precipitation lack over a certain period, the distribution of precipitation over a certain period, and temperature increase that affects the increase in evaporation and transpiration. Recognizing and defining drought depends on the system affected by water/moisture deficit, i.e. its water/moisture requirements and the speed of response to this deficit (IPCC, 2021). WMO and GWP (2016) provide a large number of existing indices for drought monitoring and show diversity in the monitoring approaches. Due to differences in regional characteristics and water/moisture requirements, drought monitoring requires linking observations that point to the water/moisture deficit and the impacts of those deficiencies. The changes in droughts due to climate change were analysed using the SPEI index, as explained below. The Republic of Serbia does not have an integrated drought monitoring approach (with cause and effect indicators), nor a prescribed set of indicators for different types of droughts depending on the system they affect, as proposed by WMO and GWP (2016), within the Integrated Drought Management Programme (IDMP).

In the territory of the Republic of Serbia, an increase in the frequency of years with drought has been observed (Djurdjevic et al., 2018, Vuković Vimić et al., 2022). In the period 2001-2020, the frequency of years with drought in the territory of the Republic of Serbia was 40%, and in 2011-2020 was 50%, with respect to the total number of years in the period, while the frequency of such years in the 1961-1990 period was 10%. The drought indicator (index) used in these estimates is the SPEI6a (Standard Precipitation-Evapotranspiration Index, Begueria et al. 2013, for the period of 6 months ending in August, calculated based on the 1961-1990 base period values). The variation of this index is related to the change in yield in agriculture (Djurdjevic, 2020) and other impacts (presented as part of the analyses for the Third National Communication) and, in the absence of the established methodology for drought monitoring and declaring, for this analysis thisone was chosen as the representative indicator of "years with drought" in the territory of the Republic of Serbia. In addition to the precipitation deficit in this period, the increased frequency of droughts was also caused by temperature increase (Vuković Vimić et al., 2022), whose impact on the drier conditions in the 21st century is much more pronounced due to the accelerated warming, while at the end of the 20th century it was generally somewhat lower precipitation amount that contributed more to the increase in drier years.

Figure A1.11 shows the average values of SPEI6a index by years in the observed period (1961-2020). Years with drought in the territory of the Republic of Serbia are considered the years with a average index value below -1. The same Figure shows also the linear trend for SPEI6a for the observed period and for the 1961-2100 period under the RCP4.5 and RCP8.5 scenarios. These results show a decreasing trend in the SPEI6a values, i.e. an increase in the years with drought in the territory of the Republic of Serbia. If the observed trend continues, it is expected that the average SPEI6a values for the territory of the Republic of Serbia will exceed the value of -1, i.e. that in the territory of the Republic of Serbia in the 2041-2060 period, every year will be, in average, a year with drought. By the end of the century, according to the RCP4.5 scenario, the increase in this hazard will stabilize, while according to the RCP8.5 scenario, it will increase to the level where the mean SPEI6a values in the end-of-century period (2081-2100) can reach the values close to -2, i.e. that significantly stronger droughts can be expected almost every year.

It has to be noted that changes in the occurrence of years with drought do not follow a linear trend in the future, considering that, according to the RCP4.5 scenario, the change slows down somewhat due to the climate change stabilization, and according to the RCP8.5 scenario, it continues to increase. In this case, if a severe drought is defined as the drought observed in 2012, with the greatest observed damages in the recent past (food production, wildfires, river flow decrease, etc.), and then prevailing conditions are set as the "severe drought" criteria, it can be concluded that the number of years with droughts at least as strong as 2012 drought will increase in the future. The number of severe drought events per decade until the end of the 21st century is shown in Figure A1.11 - bottom panel. In the 2041-2060 period, there will be 3 to 4 years with severe drought per decade (a period of 10 years), and in the 2081-2100 period, according to the RCP8.5 scenario, there will be 7 to 8 such years per decade.

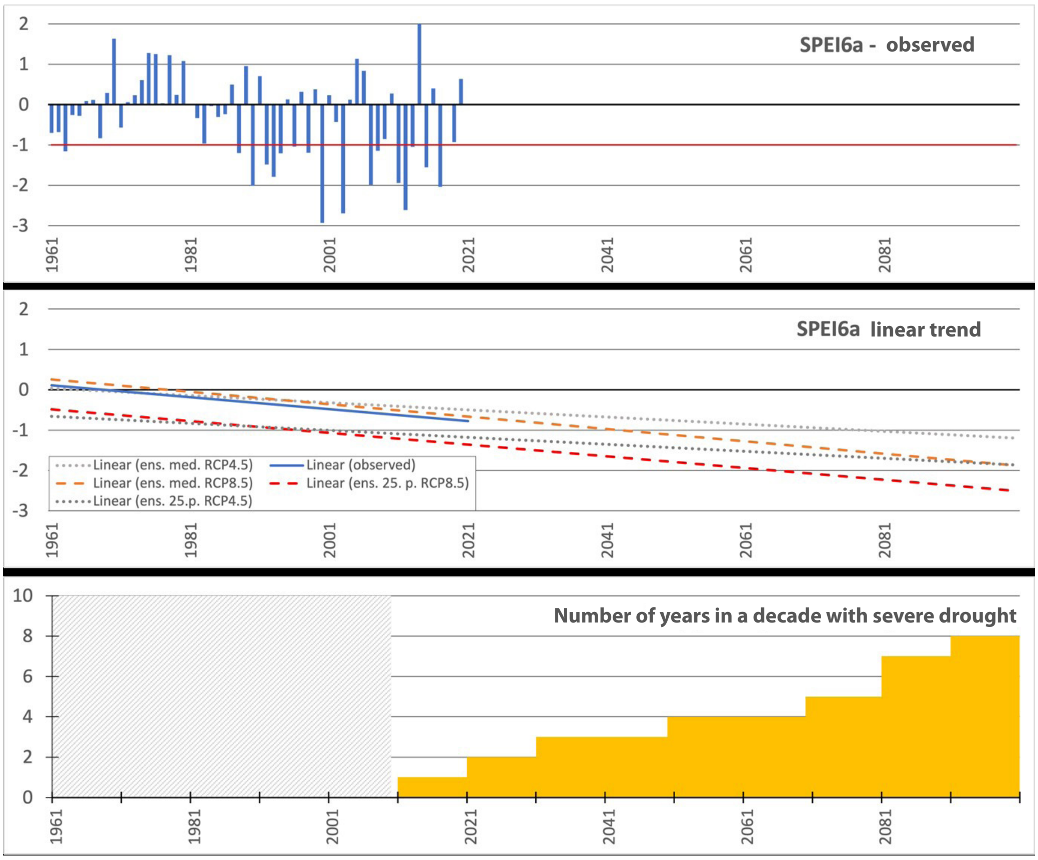

Figure A1.11. **SPEI6a values by years in the period 1961-2020 (top panel), SPEI6a linear trend for the period 1961-2011 based on the observed values and projected values of the models ensemble (middle panel) under the RCP4.5 and RCP8.5 scenarios (the models ensemble median and 25th percentile values), and the frequency of years with severe drought per decade in the 2011-2100 period, obtained from the models ensemble projections under the RCP8.5 scenario (bottom panel).**

Aridity is a permanent feature of the climate in a certain region. The aridity (dryness) or humidity (wetness) of the climate is identified based on the climate indices that are generally defined (parameterized) as the ratio of mean climate heat (temperature) and precipitation conditions for a certain period of the year or for a year.

The change in the precipitation regime, temperature increase, and consequently the increased frequency and intensity of years with drought in the territory of the Republic of Serbia affect a change in the general climate characteristics, which are measured by the degree of climate humidity, i.e., the aridity (dryness). This classification of general climate conditions is shown in Životić and Vuković Vimić (2022), where it was also used as an indicator of the impact on soil degradation. According to the average Aridity Index (AI) values, the Republic of Serbia has an average humid climate, with a slight AI index decreasing tendency in the observed period. However, due to the uneven seasonal distribution of precipitation, the JJA season is semi-dry according to this index (Životić and Vuković Vimić, 2022). Figure A1.12 shows the spatial distribution of the average AI values for the 2001-2020 period and the average AI value for the JJA season during this period. Values from 0.5 to 0.65 indicate a dry sub-humid climate, which is in this period represented in the lowland areas, in Vojvodina and partly in the central Serbia. During the JJA season, most of the territory of Serbia, except for the mountainous areas in the western parts of the country, has an average value below 0.5, which indicates that this season is semi-dry according to this index classification. In the future, the average AI value for the territory of the Republic of Serbia will continue to decrease, and in the 2041-2060 period, the average climate is expected to be in the dry sub-humid category, and by the end of the century, according to the RCP8.5 scenario, even in the semi-arid category. The mountainous areas will continue to have more precipitation, while the lowland areas will be particularly affected by the increased aridity of the climate, and dry conditions will prevail in most of the area in the JJA season.

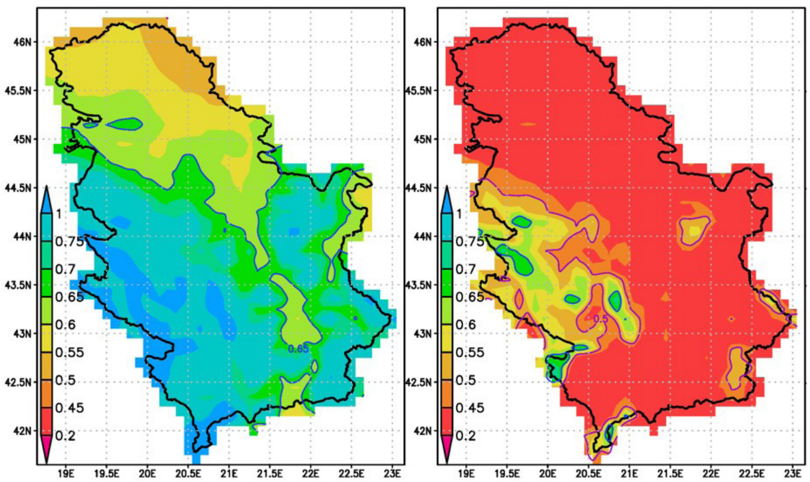

Figure A1.12. **Mean annual AI value (left) and mean AI value for the JJA season for the period 2001-2020, according to the AI classification. AI values from 0.5-0.65 indicate a dry sub-humid climate, and seasonal values from 0.2-0.5 indicate semi-dry conditions during the season. Taken from Životic and Vuković Vimić (2022).**

The general climate characteristics such as those represented by the AI index are permanent features of the region and are not sensitive to occasional occurrence of extreme weather events. In other words, a change in these characteristics is inert to changes in other analysed climate indices. However, the average climate category changes for the Republic of Serbia according to this index, which are expected to occur by the mid-century period (from humid to dry sub-humid climate) and further into the future, according to the RCP8.5 scenario (by the end of the century to semi-arid climate), indicate significant and rapid changes in the "slow-onset" climate events. These changes in the long history of the Earth's climate are measured in centuries or thousands of years, not in decades as is the case now due to the accelerated climate change. Natural systems, commercial sector and human activities in each region are adapted to these general climate conditions. The problem with the accelerated changes in the general climate characteristics is that they require systems and people to adapt faster, which is far beyond their natural adaptive capacity. The rate of global climate change is estimated to be at least 10 times faster (depending on the region) than ever recorded in Earth's history (Diffenbaugh and Field, 2013).

A1.3.4 Change of the climate variability in precipitation conditions

A change of the climate variability in precipitation conditions implies an increased range of possible annual precipitation accumulations in a climate period or of precipitation accumulations during a different periods of the year. There was no significant change in the mean value of annual precipitation recorded in the past climate periods or in the future until the mid- 21st century. However, annual accumulated precipitation in the recent past have a greater range of values than during 1961-1990, indicating an increased climate variability at the annual level (Figure A1.13).

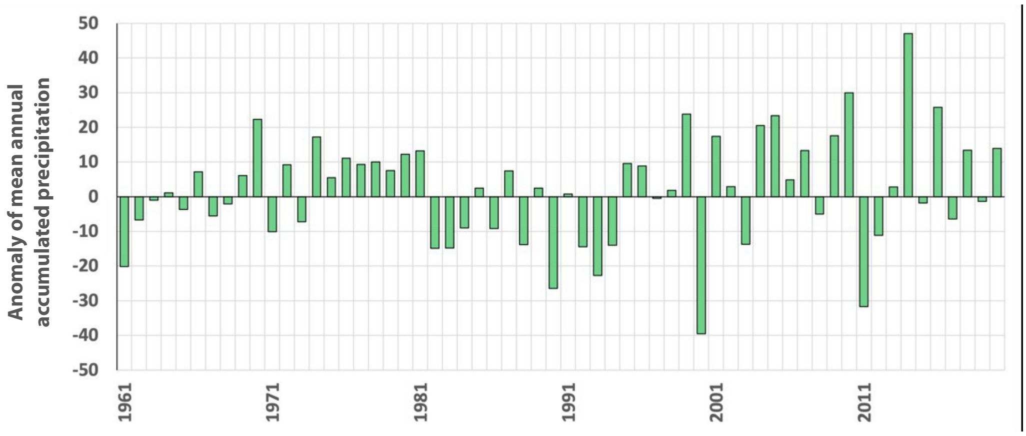

Figure A1.13. **Deviations (anomalies) of the mean annual precipitation sums in the territory of the Republic of Serbia for the 1961-2020 period in relation to the mean base period value (1961-1990).**

A change in the annual distribution of precipitation and a change in its distribution by intensity and an increase in the frequency and intensity of droughts contribute to an increased climate variability. An increased frequency shifts with of periods with heavier precipitation a period with significant precipitation deficit is highly probable. Given that these changes are also expected during the colder part of the year, the occurrence of greater snowfall events also is highly probable, but certainly with an average shorter duration of snow cover due to temperature increase and the decrease in the number of days when snow cover retention is possible. Due to the occurrence of events with heavier precipitation during spring, summer and early autumn, hail events will likely intensify, which is explained further in the next Chapter. Contrary to the intensification of intense precipitation events that define the upper end of the range of expected possible precipitation conditions, the increase in droughts indicates a shift of the lower end of the range of expected possible precipitation conditions, which together cause the increasing of the range of expected (possible) precipitation conditions, i.e., increased climate variability.

A1.4 Analysis of climatic impact-drivers related to storms and accompanying extreme weather events

Storms are weather hazards that can produce large amounts of precipitation in a short period, strong wind gusts and hail, depending on the type of storm and the time of year it occurs. The areas exposed to strong winds are mostly those in the eastern areas of the central Serbia and the northern part of the country (Vojvodina), i.e. the areas affected by the Košava wind (Figure A1.14). There is no evidence to date of a possible change in the mean wind values and a change in the spatial distribution of wind intensity (Podrascanin and Djurdjevic, 2020). However, the increase in intensive precipitation, which is mainly due to storms with strong wind gusts, may indicate an increased frequency of short-duration strong wind gusts. Storms that produce intensive precipitation create also cold dowdrafts from clouds that form strong storm fronts when they hit the ground, and that is why it can be assumed that a change in extreme precipitation can also be an indicator of more frequent and potentially stronger wind gusts. In the event that such storms occur in the warmer part of the year, especially in the MAM and JJA seasons, they are likely to produce hail, and it can be assumed that the area frequently affected by hail will expand, and that hail events will be more frequent and more intense. An increase in intensive precipitation during the cold part of the year can produce greater snowfalls, but due to the temperature increase, the number of days with possible snow retention (frost and icing days) will decrease significantly.

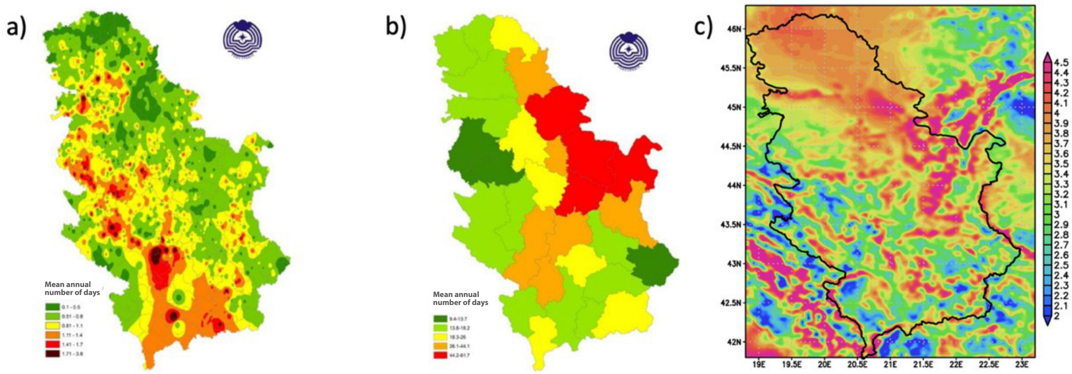

Figure A1.14. **Average number of days per year with hail and ice pellet for the 1981-2015 period (left panel, Source: RHMSS), average number of days per yer with strong winds for the 1981-2015 period (middle panel, Source: RHMSS) and mean 10 m wind speed for the 1981-2010 period (right panel). Taken from Životic and Vuković Vimić (2022).**

In a study for the Europe area (Radler et al., 2019), the mean annual frequency of the occurrence of hail diameters greater than 2 cm and greater than 5 cm was calculated for the 1971-2000 base period and the end of the 21st century (2071-2100), according to the RCP4.5 and RCP8.5 scenarios. The results derived from the models projections show that the average annual probability of the occurrence of hail diameters greater than 2 cm in the largest part of Serbia ranged from 0.4 to 0.8 days and up to 1.2 days in the mountain areas in the west, southwest and east of the country. The mean frequency of the occurrence of hail diameters greater than 5 cm during the base period was between 0.07 and 0.14 days annually. By the end of the 21st century, according to the RCP8.5 scenario, an increase in the frequency of hail is predicted from 40% to 80% in Vojvodina and from 20 to 40% in the other parts of Serbia for hail larger than 2 cm in diameter, and from 40 to 80% in the entire territory of the country for hail larger than 5 cm in diameter. This study also shows an increasing tendency in the number of days with wind gusts stronger than 25m/s. By the end of the 21st century, according to the RCP8.5 scenario, the selected climate models predict an increase in the frequency of these events from 20% to 40% in the entire territory of Serbia. The above results additionally confirm the expected increase in the frequency of storms accompanied by wind gusts and hail and their distribution in the territory of the Republic of Serbia.

A1.5 Climate change, water resources and soil interconnections

A1.5.1. Climate change and water resources

A brief nexus analysis of the climate change and water resources, floods and water quality is derived from the report prepared as part of the analyses for the preparation of the Third National Communication.

Transboundary waters make up 92%, and inland waters 8% of the total surface waters in the territory of the Republic of Serbia (Markoviski et al., 2017; Eurostat Water Statistics). That means that the vast majority of surface water depends on the wider region characteristics, i.e., the region where it forms and through which it flows, while a smaller part depends on the climate change characteristics in the territory of the Republic of Serbia. In addition to the complex impact of climate-related changes in precipitation on surface waters, the temperature increase also has a significant impact and is responsible for the observed increase in the average annual potential evapotranspiration in the recent past in the territory of the Republic of Serbia by approximately 10% compared to the 1961-1990 period average (obtained from E-OBS data). The sensitivity to these climate change effects increases from the northern to the southern regions of Serbia, considering that the southern regions are more dependent on the inland waters (Isailović et al., 2007). In addition, a negative trend in soil moisture content was observed in the largest part of the territory of the Republic of Serbia, which is an additional indicator of the change in the aridity level (Chapter A1.3.3). The most critical trend is the negative trend of change in soil moisture content during the JJA season, which is also the driest season. River flows in the central and southern Serbia river basins have mostly negative change trends. Based on the analysed data from 24 hydrological stations, there is a negative trend in 21 stations, and in most stations the decreasing flow trend is around 2-3% per decade (Dimkic, 2017). While the water consumption and climate change impacts cannot be clearly separated in these results, the combined climate and hydrological models simulation results clearly show the significance of the climate change impacts (Source: European Environment Agency, Indicator assessment - River flow).

Climate change cause an increase in water temperature, which can have negative consequences in several sectors, e.g. in energy production, through the use of river water as a coolant in power plants (Bisselnik et al., 2018), or on its quality, the aquatic life, etc. In the case of the River Danube, an increasing trend in water temperature was identified in three stations in Serbia (Basarin et al., 2016).

After 2014, when the highest ever material damage from floods was recorded in the Republic of Serbia, floods that led to the declaration of a state of emergency, evacuation of population and/or damage occurred also in 2016, 2017, 2019, 2020, and in 2021 (Source: FloodList, European Centre for Medium-Range Weather Forecast). The recorded consequences of floods, mostly caused by flash floods triggered by extreme precipitation events, include landslide events, dam bursts, destruction of houses, etc. The flood data presented in the Disaster Risk Assessment for the Republic of Serbia shows an increased flood frequency in the 21st century. The Water Management Strategy (Official Gazette, No. 3/2017) estimated that, although flood defence activities had been implemented, the state of protection was still not satisfactory. The assessment of the change in the distribution of precipitation by intensity indicates the importance of including future climate change information in risk assessments, considering the increasing frequency of weather events that may cause floods.

The fact that Serbia's share of inland waters in the total waters is 8% means that it has approximately 1500m3 of water per capita, which is below the European average. This indicates that the central and southern Serbia are potentially threatened, where inland waters are the dominant available water resource. An additional factor that has an adverse effect on water availability is long periods of low water levels, considering that during such periods the watercourses have the lowest self-purification ability (Veljković et al., 2012).

Decreasing water quality and insufficient water purification ability (significantly lower than the European average, Source: Eurostat - Statistics Explained) increases the risk of adverse climate change impacts on water availability, due to extreme events such as droughts, large precipitation amounts and flood events, as well as the increasing summer season dryness trend.

The assessments of future climate change impacts on water resources, i.e. river flows and changes in the groundwater recharge rate, were prepared using the EU Copernicus Programme project data: Service for Weather Indicators in Climate Change Adaptation (SWICCA) and End-to-End Demonstrator for improved decision-making in the weather sector in Europe (EDgE).

The analysis of the results of the combined climate and hydrological models shows that the average change in the mean river flow in Serbia in the near-future climate period will be positive, and by the middle of the century and in the second half of the 21st century, it will start to decrease. According to the RCP4.5 scenario, these changes are milder, while according to the RCP8.5 scenario, the average reduction could be even more than 10%; the changes in river discharges in the central and southern Serbia, which depend on climate change in the territory of the Republic of Serbia, are significant.

During the DJF season, river flow is expected to increase in the future periods under both the scenarios, which is associated with the increased precipitation during this season, absence of snow cover or reduced snow cover retention due to rising temperatures. A decrease in flow is expected in the period from April to October (April to November according to the RCP8.5 scenario). The most significant average flow reduction, according to both the scenarios, is expected in April, by the end of the century by 16% according to the RCP4.5 scenario, and by 26% according to the RCP8.5 scenario. The changes obtained according to the RCP8.5 scenario for the end of this century increase drastically during the low flow season, while the changes according to the RCP4.5 scenario in the second half of the century show a stabilization of the flows. The most significant percentage decrease in flow is expected in smaller streams in the southern parts of Serbia.

Future changes in average monthly river flows in the territory of Serbia show a shift of the maximum annual flow regime from April to the winter period and an extension of the low average monthly flow period.

The mean change in the distribution of daily flows by intensity shows, according to the RCP4.5 scenario, the greatest positive change for maximum daily flows in the near future. Further into the future (mid-century period), the reduction in daily flows below the 50th percentile significantly increases, with the largest reduction in the smallest flows. By the end of the century, according to the RCP4.5 scenario, this change in discharge intensity distribution is maintained due to the climate stabilization. According to the RCP8.5 scenario, the maximum daily flows are expected to increase by about 15% and the minimum flows will decrease by about 25%. In the end-of-century climate, the maximum daily flows are expected to return to the present period values, but the other lower flow values will decrease significantly. The expected decrease in minimum flows is as much as 40%. In this analysis it should be taken into account that, in absolute flow values, a large decrease in lower daily flows represents a smaller change in terms of the amount of discharge than the same percentage decrease in larger flows, but it may also mean the occurrence of periods when rivers with medium and small minimum daily flow will dry up completely. That is a consequence of temperature increase, evaporation and precipitation decrease, mostly during the summer season, i.e., a consequence of the increased drought hazard. The obtained results show that the future change in the mean flow distribution by percentiles in the territory of Serbia will have a greater slope than during the base period, i.e., there will be a greater difference between the maximum and minimum daily flows on the rivers. For some watercourses, there is a large variation in model results for future changes in high daily flows, which means that significantly more drastic changes towards higher or lower values are possible further into the future. For lower daily flows, the models show good agreement.

The analyses of the change in the groundwater recharge rate show a decreasing trend throughout the territory of Serbia, and by the mid-century period, the expected average decrease is 10-20% in the largest part of Serbia, and even up to 35% in the eastern and southeastern regions. The decreasing trend in the second half of the 21st century is expected to continue according to the RCP8.5 scenario, and by the end of the century, the reduction in the groundwater recharge rate will be in the range of 40-50% in most of the country (30-40% in the west and southwest and 50-70% in the east and southeast). The change in the groundwater recharge rate differs by seasons. The reductions are expected in all seasons in most parts of the country. The largest expected decrease is projected for the SON season, followed by the JJA season, which is actually a consequence of the decrease in precipitation in the JJA season and the extension of the drier season.

A1.5.2 Climate change and soil

An overview and analysis of the climate change impact on soil degradation in the

Republic of Serbia have been prepared as part of the study “Soil Degradation and Climate Change in Serbia” (Životić and Vuković Vimić, 2022), from which are derived information that indicate the significance of the climate change impact on soil quality reduction, increased erosion and the need for better planning of the practices based on the “land degradation neutrality” concept (LDN), which was adopted under the United Nations Convention to Combat Desertification.

Taking into account the climate factors and the factors related to vegetation, soil and terrain features, it was estimated that in the near-past period (2001-2021) 29% of the territory of the Republic of Serbia was in moderate risk of degradation, and 28% in higher risk levels, of which 14% in very high and extremely high risk of degradation. In the mid-century period (2041-2060), 52% of the territory will be in moderate risk and 42% in higher risks levels, of which 25% in very high and extremely high risk. On average, Serbian territory could be considered as a territory at a high risk of soil degradation by the mid-century period. These assessments take into account the risks of desertification due to increased degree of aridity, leading to a slow onset degradation process, which is more difficult to reverse, and the risks of extreme precipitation events causing soil erosion. It has to be noted that in this study agricultural soils are not considered to be prone to degradation as their condition is controlled by anthropogenic activities, i.e. future agricultural practices. In these areas, there is an increased risk of climate change, but with the application of the agricultural practices based on the LDN concept, they may not be vulnerable to climate change. As unsustainable land management affects the reduction in soil organic content, the risk of wind erosion also increases, particularly in the area of Vojvodina and other areas of Serbia with relatively flat terrain, exposed to high winds. If the expected risks manifested, reversing the degradation process would require significant capacities, both material and human, as well as time, to halt and revers the degradation process. That is why effective adaptation in this sense implies measures to reduce future high risks of degradation by reducing soil vulnerability, i.e. soil susceptibility to degradation.

A1.5.3 Climate-water-soil nexus and Nature-based Solutions

Climate conditions, water and soil are all components of the natural system that enable the development and survival of ecosystems, people and the economy. The accelerated climate change impact on water and soil has been identified as significant, even if the impacts of anthropogenic activities are to be excluded, and the rate of change far exceeds the adaptive capacity. Therefore, water and soil in the territory of the Republic of Serbia are endangered by climate change. This directly or indirectly affects human health and the living conditions, food production, conservation of the natural systems that provide environmental services, infrastructure functioning, etc. The sectors affected by climate change in the Republic of Serbia for which risks have been assessed under this Programme and the climate change adaptation measures or measures that enable planning and implementation of adaptations have been proposed, suffer additional impacts caused by the climate change threats that affect water and soil. That is why the adaptation measures for these sectors also take into account the importance of sustainable land and water management in the conditions of climate change.

A good way to ensure the interaction between activities in various sectors, the environment and health in the implementation of climate change adaptation measures is adopting the Nature-based Solutions concept (NbS) (Cohen-Shacham et al. 2016). With that respect, the Republic of Serbia produced a study ”Nature-based Solutions for Climate Change and the Potential for their Implementation in Serbia” (Vuković et al. 2021), justifying the importance of the adoption of that concept in climate change adaptation planning and implementation and the accompanying IUCN Framework Standard (IUCN, 2020), which ensures the fulfilment of the NbS potential. The application of this adaptation concept ensures the implementation of adaptation measures that will not negatively affect other sectors, the environment and human health, and that are sustainable and profitable in the long term and can contribute to climate change mitigation. The study provides an overview of the existing measures specified in the national documents (strategies, plans, etc.) which have a potential to be implemented as NbS or as combined green-grey measures in the forestry, agriculture, water management, spatial and urban planning and the energy sectors. Additional benefits of these measures in other sectors have also been recognized. In addition, the study provides the methodology for planning and implementation of the NbS based measures and additional activities in the Republic of Serbia necessary for this concept to be adopted and used.

As the NbS concept is yet to be recognized in the existing strategic documents of the Republic of Serbia, the study proposes the adoption of this concept in the measure planning process, i.e., the development of an provisional measure within the NbS concept or a combined green-grey solution according to the IUCN Framework Standard to ensure the long-term sustainability of the measure, realize its full potential in terms of ensuring benefits to a larger number of sectors, and the potential to contribute to climate change mitigation.

The implementation of the NbS based adaptation measures contributes to the fulfilment of the goals under three United Nations Conventions (the United Nations Framework Convention on Climate Change, the United Nations Convention to Combat Desertification, and the United Nations Convention for the Conservation of Biodiversity) and the Sustainable Development Goals by 2030, to which the Republic of Serbia formally adheres.

A1.6 Other climate hazards caused by unfavourable weather and climate conditions due to climate change impacts

In addition to the climate hazards that present unfavourable climate and weather conditions, which are in this case considered as the consequences of climate change by the specified climatic impact-drivers, there are also climate hazards that are caused by weather and climate conditions and are the result of the influence of those conditions in specific locations whose specific features contribute to their occurrence. These include the phenomena such as floods, landslides and rockfalls and other forms of erosion, fires, etc. Also, depending on the identified impact of weather and climate conditions, in this case caused by climate change, climate hazards can be amplification of water, soil and air pollution, in case that there are pollution sources, i.e. that pollution is present. In other words, the hazards that already exist but are or may be additionally exacerbated by climate change are discussed below, with the recommendations at which levels risk assessment needs to be implemented.

Floods, landslides, rockfalls and soil erosion in general caused by extreme precipitation events are a consequence of the changed precipitation distribution by intensity in the Republic of Serbia and the terrain characteristics in the localities affected by such extreme precipitation conditions (*Appendix A1.5*). Due to the specific characteristics of the localities that influence the manifestation of these climate hazards and the implemented protection measures, it is recommended that vulnerability and risk assessments are developed at the local self-government level.

Soil wind erosion due to drier and warmer weather conditions and the increased aridity of the climate from the mid- 21st century in the Republic of Serbia can be increased in the event that soil is left exposed to erosion (without vegetation cover) and with a reduced soil organic content due to inadequate agricultural practices (*Appendices A1.3.3 and A1.5.2*). In addition, due to its dependence on local characteristics, this hazard needs to be determined and, if needed, vulnerability and risk assessments need to be made at the local self-government level.

Fire hazard increases due to the increased frequency of warmer and drier weather (*Appendix A1.3.3.*), i.e. the frequency of favourable conditions for the occurrence of fires, as well as for their spread and/or longer duration in the locations that have suitable characteristics for their occurrence, such as forests, landfills and waste dumps, etc. It has to be noted that the occurrence of fire that is analysed here does not refer exclusively to forest fires, but to weather conditions that can affect processes in different environments that could lead to self-ignition or easier ignition caused by human activity. Based on the estimates using the Fire Weather Index from the Copernicus Climate Change Service dataset (C3S, Giannakopoulos et al., 2022), the Republic of Serbia belongs, on average, in the areas with a moderate fire risk according to the climatic conditions of the end of the 20th century (1981-2005), which is determined based on the average conditions in accordance with this index in the fire season (June-September). This level of risk also includes parts of the Mediterranean area where a shift towards drier climate conditions has been identified, such as parts of Spain and Italy, and the south of France. Slightly more vulnerable areas include southern Italy and southern Spain, Greece, etc. The annual average number of days with high fire risk in the Republic of Serbia in the climate of the end of the 20th century was in the range of 30-40 days in the largest part of the country, and 10-15 days with very high risk. An increase in the number of days with a moderate fire risk is expected, and particularly in the number of days at a high fire risk. In the climate conditions of the middle of the 21st century (2041-2060), the average increase in the number of days with a high fire risk compared to the climate at the end of the 20th century will be by 10-15 days on average per yer, i.e. in the range of 30-50%, and in the number of days with very high fire risk by about 50%, depending on the region. The expected increase by the end of the 21st century under the RCP8.5 scenario is over 20 and 25 days annually in the number of days with high fire risk, and by 15-20 days in the number of days with very high fire risk, depending on the region. As these estimates refer to weather conditions that favour fires, they indicate an increased risk of fire occurrence but also fire spreading, intensification and prolonged duration of fire and generally events of combustible materials burning in the open air. The data is provided by administrative district in the Republic of Serbia and can be used for the fire risk assessment purposes at the local self-government level.

The climate change impact on water quality/pollution and water availability is associated with extreme events (*Appendix A1.5.1.*). In case there is a pollution source and/or pollutants, the climate change impacts through the increase of climate hazards (droughts, floods, etc.) increase the risk of water pollution. As the level of risk depends on pollution in the area affected by the climate hazard, but also on the availability of water in general, these risks need to be assessed and the measures for impacts mitigation need to be identified at the local self-government level.

The climate change impact increases the risk of soil pollution. In addition to the impact on soil degradation (*Appendix A1.5.2*), in case there is a potential soil pollution source (for example, inadequate fertilization practices), climate change can exacerbate these adverse impacts. In addition, soil pollution is closely related to water pollution and vice versa, due to events that cause the detachment and transport of particle matter between these two components of the climate system (floods, surface and underground runoff, groundwater surfacing, etc.). Due to the increased soil pollution risk and soil degradation risk in general caused by the climate change impacts, and a high dependence of this impact on the local terrain characteristics, water and soil condition, and the pollution source, this climate risk impact needs to be taken into account in the assessments at the local self-government level and in planning of measures that include prevention and/or mitigation of the increased pollution and soil quality deterioration risks.

Climate change affects an increase in the air pollution risk, in case there are active pollution sources that degrade air quality. In case that there are air pollution sources, i.e., polluting substances in the lower atmosphere layers, the weather conditions that favour their longer retention and harmful effects on health and the environment have increased in frequency and duration. The weather systems that cause such effect are the so-called blocking systems (Nabizadeh et al., 2019), which imply large-scale high-pressure systems that are stable by their nature. The indicators for these weather systems have already been discussed under changes in the number of heat waves and changes in droughts (Appendices A1.2.2 and A1.3.3.) as the major climate hazards. They indicate an increase in the prevalence of these systems in the Republic of Serbia, but these systems can also cause other climate hazards. They cause weather conditions with no wind or low surface wind speed and prevent vertical mixing in the atmosphere, i.e. limiting the transport of harmful substances (small particles and gases) into the higher atmosphere layers, where they enter large-scale circulations and are carried farther away from the pollution source. In addition, these weather systems bring also drier weather, i.e. weather with no precipitation or with reduced precipitation, whose role is to washout harmful substances from the air. Consequently, the climate change impacts can be considered to increase the risk of degraded air quality. Air quality degardation in the short term, due to the climate change impacts, can be caused by fires and burning of various materials outdoors, as explained in the previous section. The World Meteorological Organization

(WMO) recognizes the connection between the air quality and climate change, and reports on it at the global level (WMO Air Quality and Climate Bulletin). IPCC emphasized the problem of air pollution and climate change as a single issue, in terms of its two-way amplification effect, through its Working Group II reports, in its previous, but also in the last report (IPCC, 2022).

Identifying additional climate hazards is specific to each sector, and the sector-specific analyses and links to specific climate hazard groups are provided in the parts of the Programme that address the climate change impacts on specific sectors, with the purpose of specifying adaptation measures.

A1.7 Overview of climatic impact-drivers and linking their contributions to the identified climate hazard groups

The climatic impact-drivers that stand out from the previous analysis are shown in Table A2. For the specified climatic impact-drivers, significant changes in the observed and/or future climate conditions and their impact on specific sectors in previous studies, as well as in the analyses prepared for this Programme, were determined. Table A2 provides an overview of the climate hazard types associated with the specified climatic impact-drivers, the climate indices based on which they can be evaluated and the climate hazard group to which their change contributes. Taking into account the effects that these climatic drivers have on different sectors, as stated in this Programme, their change due to climate change has already reached the level when it is necessary to plan and implement adaptation measures to ensure that the sectors would become more resilient to their changes in the future. Their future changes, to a varying extent and depending on the region and the sector affected, reach the values that are critical for normal functioning of the sector, human health and the survival of the environment and natural resources by the mid- century period, if the resilience to climate change is not increased by that time. In the second half of the century, there is a high probability that these changes will continue, at a slower rate under the RCP4.5 scenario, and at an accelerated rate under the RCP8.5 scenario, as indicated in the previous analysis.

Table A2. **Climatic impact-drivers, climate and weather hazards they cause and other hazards they can cause, climate parameters (indices) that indicate the significance of changes in the climatic impact-drivers and climate hazard groups to which they belong.**

Climatic impact-drivers	Identified and/or monitored based on	Climate indices*	Meaning	Climate hazard category
Increased climate variability *(Appendices A1.2.4. and A1.3.4.)*	Increased frequency of weather variations: from normal (colder) heat conditions (temperature) to warm or very warm weather on annual, seasonal and monthly level; increased frequency of shifts from dry (or drier than normal) to wet (or wetter than normal) conditions on seasonal and annual level.	Variability of climate values of temperature and precipitation indices and extreme weather event indices during the climate period. It can also be identified based on other climate hazards, such as an increase in dry periods and heavy and extreme precipitation events, an increase in the number of heat waves, etc.	This change requires preparedness for extreme precipitation events in both extremes (precipitation excess and deficit) and for an increase in warm, but also continued normal heat conditions (in addition to temperature increase, the risk of snowfall hazard is still possible). That is due to an increase in drier weather conditions and an increase in extreme weather events and a faster rise in maximum temperatures than minimum temperatures and uneven seasonal warming. This change requires preparedness for extremely warm, but also normal cold weather conditions.	• too warm • too wet • too dry
Increase in temperature and heat waves *(Appendices A1.2.1., A1.2.2. A1.2.3. and A1.2.5.)*	Persistently warmer average seasonal and annual temperatures and temporarily much warmer conditions than normal in some periods of the year.	Number of heat waves (hwfi), heat wave duration (hwfid), number of warm periods (hwdi) and their duration (hwdid), number of days with Tmax>30 (tropical days, TRD), Tmax>35 (hot days, THD), Tmin >20 (tropical nights, TRN), increase in mean Tmax and Tmin values (seasonal anomalies). Other derived/ combined impact assessment indices: mean annual occurrence of critical events characterized by temperature values above/below a certain limit, their frequency (number of years in the climate period with critical events), change in occurrence date, etc.	This change requires general preparedness for warmer climate conditions, and particularly for stress caused by extremely warm conditions and other related hazards. Some of the other associated hazards include food production disturbances, favourable conditions for vectors and vector-borne diseases, more favourable conditions for the occurrence of fires, etc.	• too warm

Change in annual precipitation distribution *(Appendices A1.3.1., A1.3.3. and A1.5.1.)*	Change in mean seasonal/ monthly precipitation accumulations, climatic shift of periods with higher and lower precipitation accumulations. Water excess or deficit during specific months/seasons. Possible contribution to increased floods and droughts.	Anomalies of mean precipitation sums during a month/season, compared to normal values (the base climate period values).	This change requires preparedness for changes in water availability, for example: a prolonged summer deficit, while excess water is possible in the spring, with a tendency to shift toward earlier periods and overlap with the snow-melting season, which can cause floods and landslides. A summer deficit may cause an increased risk of drought. It affects the extended duration of low river flow periods.	• too wet • too dry
Change in precipitation distribution by intensity *(Appendices A1.3.2., A1.4., A1.5.1. and A1.5.2.)*	Temporary water excess caused by short-duration events. A decrease in light and moderate precipitation events and an increase in the number of heavy and extreme precipitation events and precipitation accumulation during heavy and extreme precipitation events. Possible contribution to the creation of floods, heavy snowfall, soil overwetting (exceeding the infiltration capacity). Possible hail and other storm effects (strong wind gusts).	Number of days with precipitation above 20mm (rr20), above 30mm (rr30), maximum one-day (rx1d), maximum five-day precipitation accumulation (rx5d). Mean values per year and number of years in the climate period with occurrence of specified critical precipitation events, etc.	This change requires increasing resilience to short-duration excess surface water/moisture, i.e., large surface runoff, increase in maximum river flows, floods. It can affect the quality of drinking water and cause landslides. It is recognized as a soil degradation risk factor. Since such events are caused by intense weather events, which often produce strong wind gusts and hail (depending on the time of the year they occur and region in which they occur), this climate hazard can also serve as an indicator of an increase in storms with strong winds and hail.	• too wet • storms (wind gusts, hail)
Change in droughts *(Appendix A1.3.3.)*	Temporary water/moisture deficit, including river discharge, groundwater, water reservoirs, soil content, etc.	Anomalies of seasonal accumulated precipitation, SPEI (SPEI6a), Forest Aridity Index (FAI), Hydro-Thermal Coefficient (HTC). The frequency of specified critical events (number of years in the climate period with their occurrence), determined by the limit values of the water/ moisture deficit indices.	The increase in this climatic hazard requires increasing resilience to temporary water/moisture deficit, which affects the living world and, in combination with high temperatures, creates favourable conditions for the occurrence of fires. It can temporarily affect reduced water quality and availability. There is no universal definition of drought, and its manifestations can vary in different environments and sectors. Consequently, the criteria for defining drought may also differ.	• too dry

Change in aridity/ dryness *(Appendices A1.3.3. and A1.5.2.)*	Persistent water/moisture shortage at annual or seasonal level. The aridity level refers to the climatic characteristic of the region on an annual level, while the dryness level refers to the climatic characteristic of a season.	Change in the mean (climatic) index value beyond a certain limit: Aridity Index, Hydro-Thermal Coefficient (HTC), SPEI.	The increase in this climate hazard requires increasing resilience to persistent water shortage, on average on an annual basis or during a certain period of the year (during a season). It affects water quality and availability. It can cause a decline/extinction of the living world. It is recognized as a soil degradation risk factor.	• too dry

*** The listed climate indices have been used in the assessment of climate change and its impacts for the Republic of Serbia, and the data for most of the indices are available on the “Climate Atlas of Serbia” web portal. The choice of indices for climate change assessment depends on the purpose of use, i.e. impact assessment they are used for (they depend on the sector for which the assessment is prepared and the region for which the assessment is prepared).**

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Appendix 2: Contribution to the agricultural sector climate change impact assessment

The assessment of the climate change impact on the agriculture sector was conducted taking into account the climate change assessments presented in this Programme (Chapter 2, Appendix 1), wit identification of specific climate hazards for cultivated species and their vulnerabilities to specific climate hazards and changes in those hazards due to climate changes. This assessment takes into account the knowledge from previous climate change impact assessments in agriculture, implemented for the National Communications purposes, other studies and projects (MEP, 2010, 2017; Stričević et al. 2019; Stričević et al. 2020; Vujadinović Mandić at al., 2022; Vuković Vimić et al., 2022, etc.).

The agriculture climate change impact assessments have been performed for perennial plantations, i.e., for fruit and viticulture production, as well as for crop production and livestock production.

This Chapter includes the appendices, i.e. data, which support the conclusions presented in the Programme and which served as the bases for identifying the priority climate change adaptation measures in the agriculture sector. The results presented for climate conditions and risk changes cover the period until the end of the 21st century (the data for the last period is presented according to the RCP8.5 scenario), while the risk assessment was made taking into account the changes by the mid- 21st century, considering that that is the period for which the most probable outcomes are known, as stated in the climate change analysis under this Programme.

The analyses are based on the climate data and the data on the species distribution by administrative districts in the Republic of Serbia. The data on the spatial distribution of agricultural plots within the districts is not available, and consequently the climate change impacts that are presented reflect the climate change risk at the level of the region. For a more detailed assessment of the suitability of the changed climatic conditions and risks within the district, it is necessary to use higher resolution data due to the topographical characteristics that influence the local climate characteristics, as established in the process of development of the viticulture and fruit growing zoning for the Republic of Serbia.

Based on the obtained results, and taking into account the limitations of the performed analyses, the next steps in the implementation of the agricultural production adaptation to climate change were identified.

A2.1 Impact of climate change on fruit growing

The percentage share by species, by their growing areas, in relation to the total orchard area in the Republic of Serbia is shown in Figure A2.1. (upper panel). The presented data was obtained from the Serbian Statistical Office database, as the most current data (from 2018). Almost 40% of the total orchard area is used for growing plums, almost 15% for growing apples, followed by raspberries (13.6%) and sour cherries (10.7%). The share of other species is significantly lower, below 4%. The distribution of orchard areas is also shown in Figure A2.2. The largest share is that in the Zlatibor region (12.6% of the total orchard area in the Republic of Serbia), in the Belgrade region, Kolubarski, Mačvanski, Moravički regions, between 7% and 8%, etc. The species distribution by regions was implemented subsequently, as part of the climate change impact risk assessment.

The specific climate hazards identified in fruit growing, for which the risks due to climate change in the future are increasing, include: the risk of frost in growing season (the period of vegetative development when plants are sensitive to the occurrence of frost days) and the risk of high temperatures during summer. These risks have also been identified as the limiting factors for the cultivation of certain species in the zoning of fruit-growing areas for the Republic of Serbia (Djurović et al., 2020; Djurović et al., 2022). Through regular zoning updates (Đurović et al., 2022), education of producers and making information available to producers, it is possible to increase the resilience of fruit production by proper species/varieties selection (Nikolić, 2022), selecting appropriate cultivation locations and methods, and implementing timely activities to mitigate the upcoming extreme weather events, in case such forecasting information is available.

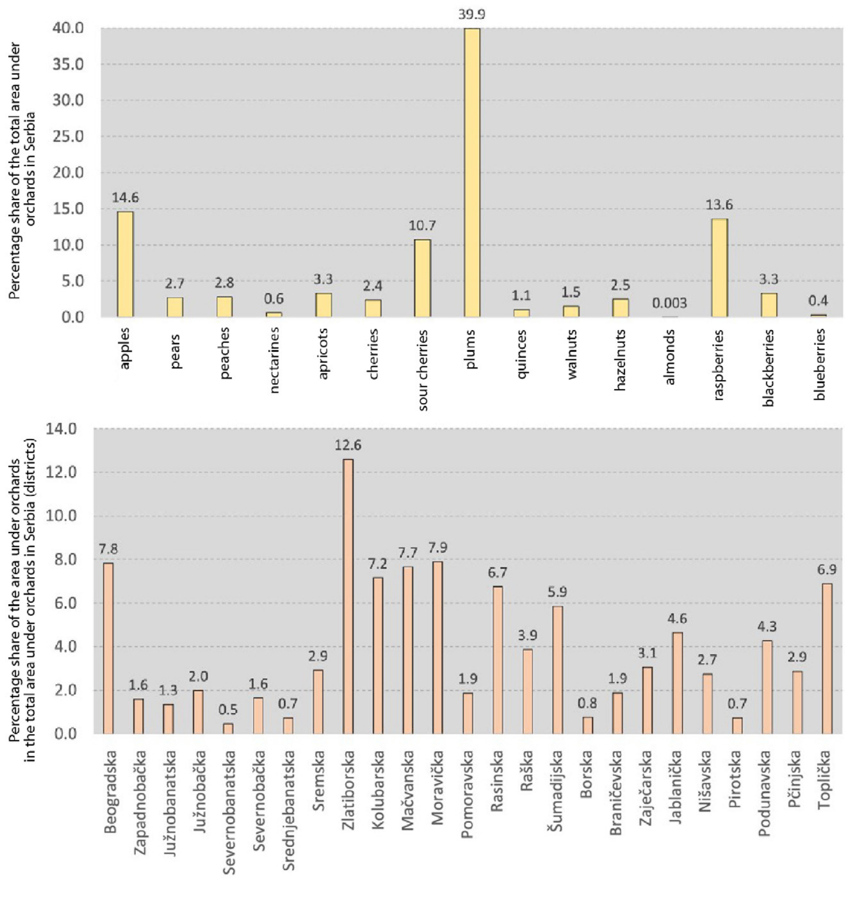

Figure A2.1 **The share of species abundance by area they occupy in relation to total orchard area (upper panel) in the Republic of Serbia, and distribution of orchard areas by administrative regions (percentage share in relation to total orchard area in the Republic of Serbia; lower panel). The data is provided by the Serbian Statistical Office (updated in 2018).**

A2.1.1. Analysis of the climate change impact on the change of risk of frost growing season in fruit production

The methodology applied in assessing the risk of frost in growing season involves determining the percentage of years during the analysed climate period when frost occurs after the beginning of the plant vegetative development (vegetation).

To identify the beginning of growing season for each species, the base temperature or the biological minimum, has been determined. After the first period (six consecutive days) with mean daily temperatures above the base temperature in a year, it is considered that the plant is in the period of development when it is sensitive to frost. This methodology has been taken from the methodology of zoning the fruit growing areas in the Republic of Serbia. Table A2.1 shows the base temperatures for the most abundant species, and group them into four groups. The risk of frost growing season was mapped for each group, as shown in Figure A2.2.

Table A2.1. Fruit tree species groups made by values of base temperatures. Abundance is expressed in relation to the total orchard area in the Republic of Serbia.

Frost risk groups	Base temperature range	Species	Abundance (%)
Group 1	9°C-10°C	apricot and almond	3.3
Group 2	10°C-11°C	peach, strawberry, currant, walnut and hazel*	6.9 (4.4*)
Group 3	11°C-12°C	plum, sour cherry, cherry, raspberry and blackberry**	69.9
Group 4	12°C ≤	apple, pear, quince, blueberry	18.4

***hazel is resilient to this risk, although it starts its vegetative development relatively early; the share in the total area is provided with and without hazel;**

****in the analysis of risk of high temperature, raspberries and blackberries are considered group 4 species.**

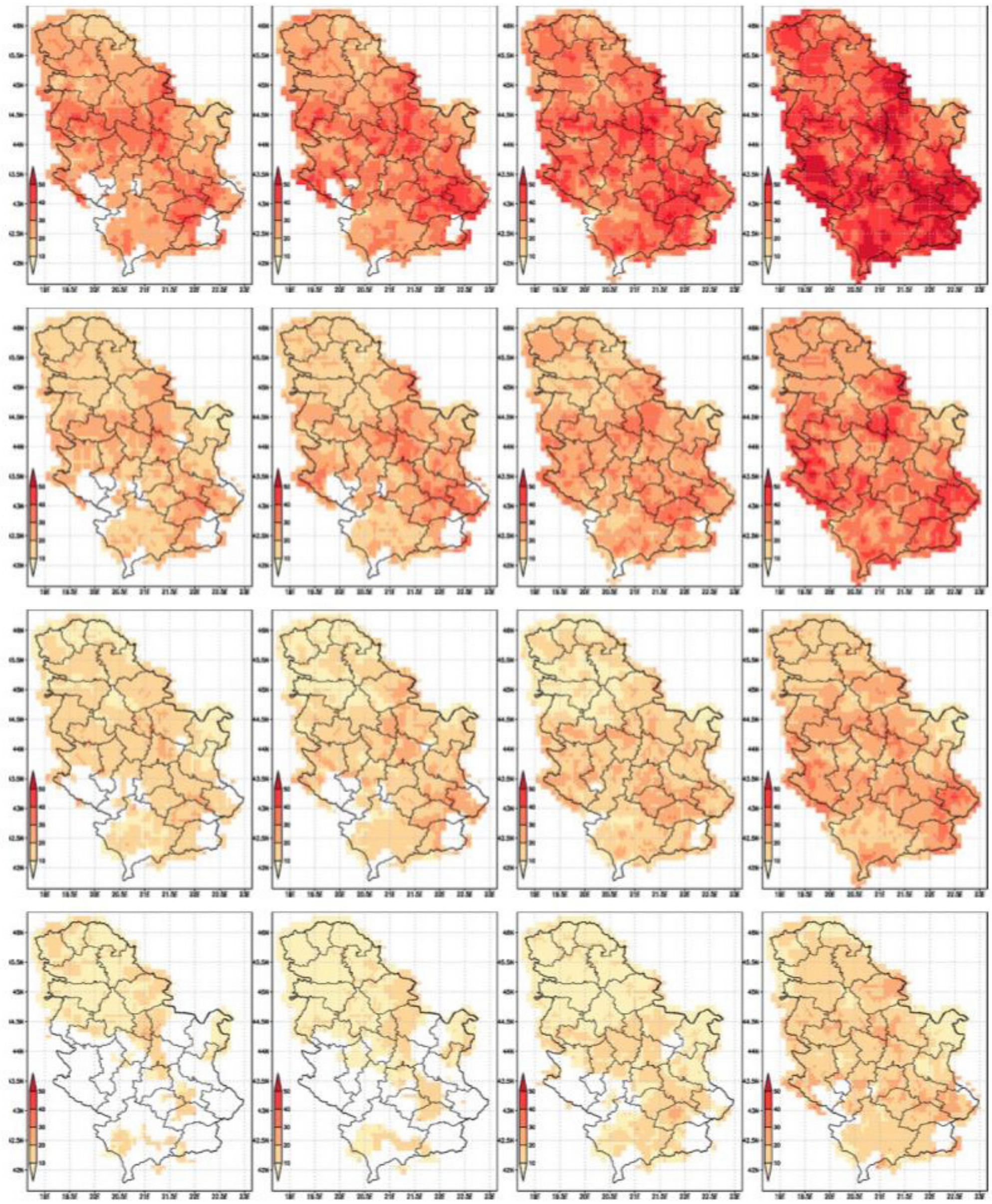

Figure A2.2. **Maps for risk of frost in growing season (above 20% is considered to be increased risk). Group 1 values are shown in the first row, group 2 values in the second row, group 3 values in the third row, and group 4 values in the last row. Values for the end of the 20th century climate period values are shown in the first column, for the near-future 2021-2040 in the second column, for the mid-century 2041-2060 in the third column, and for end-of-century 2081-2100 according to the RCP8.5 scenario in the last column. The data source is indicated in the climate change assessment methodology (Appendix 2). In accordance with the observed changes of the risk (not shown here), the Figure shows the 75th percentiles of the climate models ensemble.**

Table A2.2 provides the analysis of the change in the surfaces under risk of frost in growing season at the national level. Due to climate change impact, the risk of frost in growing season is increasing, affecting larger areas and intensifying.

Table A2.2. **The percentage of the area under a specific level of risk of frost growing season in the total area of the Republic of Serbia. The presented results were obtained in accordance with the results shown in Figure A2.2. The growing conditions limit value is taken according to the normal duration of vegetation, i.e. number of days a plant needs to be in growing period in order to develop normally (depending on the species in specific groups, the criteria are also taken from the criteria used in the zoning development).**

	<10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	not suitable
Group 1								
end of 20th century	0.9	16.3	55.4	20.3	0.8	0.0	0.0	6.3
near future	1.3	8.4	45.5	35.5	6.1	0.1	0.0	3.1
middle of this century	0.5	4.3	29.4	49.1	15.6	0.3	0.0	0.9
end of this century	0.0	0.8	8.7	35.1	39.1	15.5	0.9	0.0
Group 2								
end of 20th century	6.6	59.6	24.3	0.5	0.0	0.0	0.0	9.1
near future	3.1	50.7	34.0	6.0	0.1	0.0	0.0	6.2
middle of this century	2.2	35.8	50.6	10.1	0.0	0.0	0.0	1.3
end of this century	1.3	8.1	45.3	35.5	9.6	0.3	0.0	0.0
Group 3								
end of 20th century	29.8	57.0	1.3	0.0	0.0	0.0	0.0	11.9
near future	31.2	50.9	9.0	0.1	0.0	0.0	0.0	8.8
middle of this century	30.9	30.9	10.8	0.0	0.0	0.0	0.0	2.1
end of this century	5.9	47.1	42.2	4.9	0.0	0.0	0.0	0.0
Group 4								
end of 20th century	40.7	13.3	0.0	0.0	0.0	0.0	0.0	46.0
near future	52.0	12.1	0.0	0.0	0.0	0.0	0.0	35.9
middle of this century	62.5	21.0	0.2	0.0	0.0	0.0	0.0	16.4
end of this century	25.6	61.6	6.8	0.1	0.0	0.0	0.0	6.0

If the categorization of the climate hazard levels as shown in Table A2.3 is adopted, and the spatial representation of species is taken into account (in hectares, according to 2018 data provided by the Serbian Statistical Office), the spatial distribution of risk in combination with the representation of species by administrative districts in the Republic Serbia is shown in Figure A2.3.

Table A2.3. **Categorization of the risk of frost growing season.**

Risk level	Risk level meaning	Value in terms of data
level 1	low, acceptable, inconclusive no significant change projected until the mid- 21st century period	the region is dominated by risk lower than 20%, not projected to reach the higher risk category
level 2	moderate, an increase in the future projected by the mid- 21st century period	some parts of the region under risk above 20% in the past and/or future period
level 3	high, an increase in the future projected by the mid-21st century period	significant part of the region under risk above 20% and projected to increase in the future

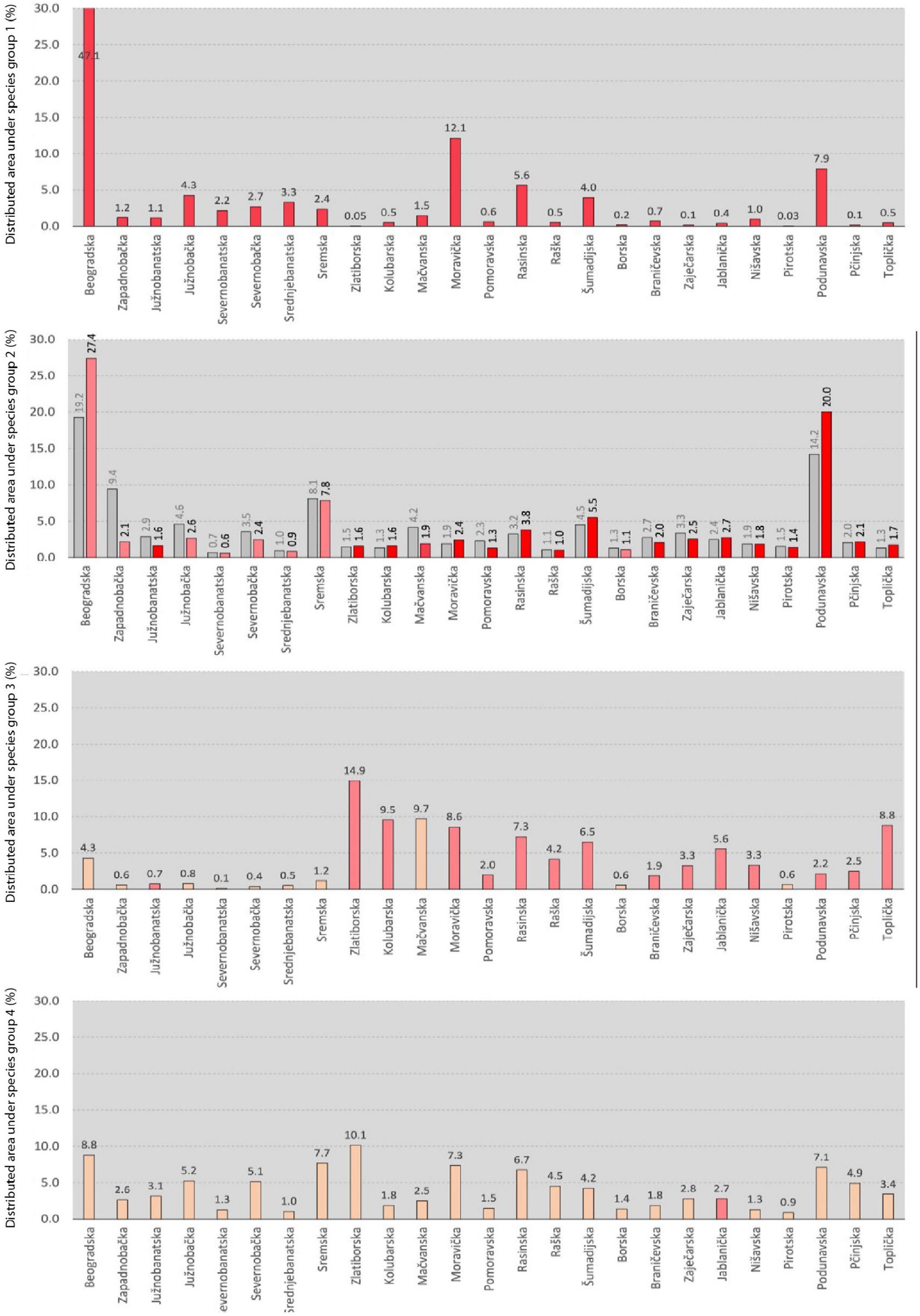

Figure A2.3. The percentage abundance of species by groups from Table A2.1 by regions of the Republic of Serbia and levels of risk of frost growing season by region, as specified in Table A2.3. For group 2, the abundance is shown with and without hazel, as it is considered that frost in growing season does not pose a significant risk for this species. The risk levels are indicated for the distribution without hazel.

In accordance with the obtained results, it is estimated that the risk of frost in the growing season will increase in the Republic of Serbia and that it will affect an increasing number of fruit tree species. Group 1 species (apricot and almond) have the most widespread and highest level of risk, and even in the observed period the level of risk is high and requires urgent measures implemented to reduce the impacts. For group 2 species the risk level is on the rise, and for these species it is also necessary to plan protection measures, while for group 3, and especially group 4 species, the risks is significantly lower. Nevertheless, for group 3 species, in some regions, the risk is moderate, and it is to be expected that potential frost problems will occur in the future for these species as well. However, the occurrence of frost in growing period can be extremely local, i.e., it cannot be accurately assessed using relatively coarse resolution data. Consequently, there is a need for a more detailed spatial risk analysis. The actual exposure of the species to this risk is not known also because the data on these species growing locations is not available.

A2.1.2. Analysis of the climate change impacts on the risk of high summer temperatures in fruit production

High summer temperatures have been identified as one of the greatest risks by the producers (Vuković Vimić et al., 2022), and have been taken as a limiting factor in the fruit production zoning. Days during which the temperature exceeds 35°C (the so-called "hot" days) are considered days of a high risk of adverse effects on the yield (Vujadinović Mandić et al., 2022). The most significant damage from extremely high temperatures occurs during the fruit ripening period. As the number of these days is increasing drastically (*Chapter 2, Appendix A1.2.*), the risk is expected to increase for the species that have not completed ripening by the period when the probability of this risk occurring is the highest.

Fruit species ripen in different periods, and while some species can ripen early and avoid the period with the highest risk of occurrence of days with extremely high temperatures, other species ripen during the period of highest risk. In order to identify this risk, the frequency of extremely high temperatures and the period of their potential occurrence, as well as the overlaps with the various species' ripening periods were assessed.

The "hot period" is defined as the period between the date of the first and the last occurrence of a day with a maximum daily temperature above 35°C in the year. Due to climate change, the average "hot period" duration is extending, and the frequency of hot periods is increasing. It should be noted that these extreme temperatures were rare in the period when the climate change still did not have a significant impact (*Appendix A1.2.*). Figure A2.4 shows the change in the duration and frequency of "hot periods" in the future climate.

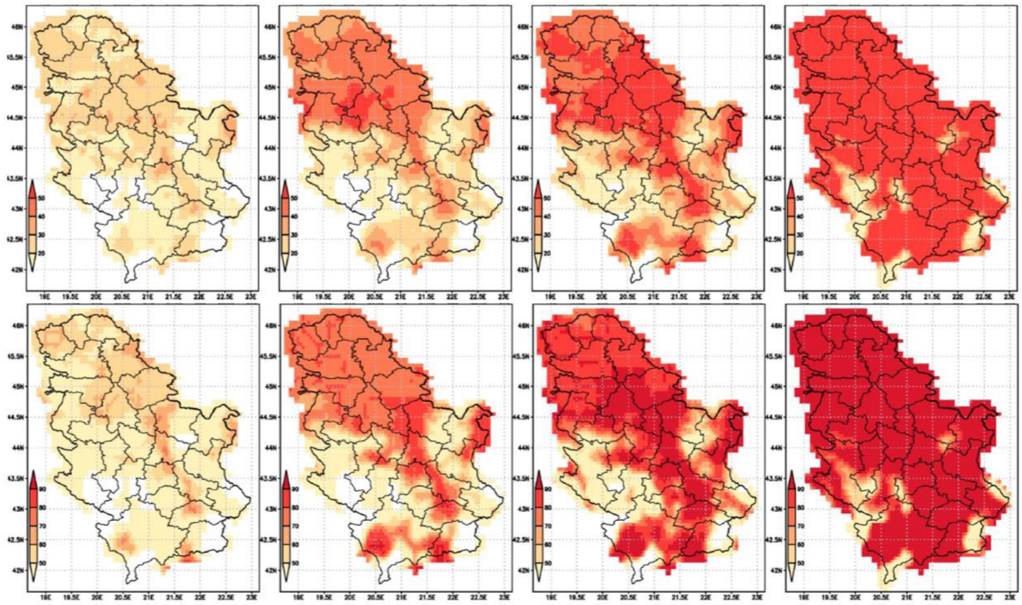

Figure A2.4. **Average "hot period" duration (upper panels) and frequency (lower panels). The values are shown for the end of the 20th century climate period (first column), the near-future period 2021-2040 (second column), the mid-century period 2041-2060 (third column) and the end-of-century period 2081-2100 according to the RCP8.5 scenario (last column). The frequency is expressed as a percentage of years in the climate period when "hot periods" occurred.**

Taking into account the duration of growing season, i.e. the period of fruit development, and the period of the year when the "hot period" occurs, the number of days when these two periods overlap was estimated. That was used to analyse the representation of the risk of extremely high temperatures for normal fruit development. The results of the analysis are shown in Table A2.4 and in Figure A2.5.

For the species that enter growing season early and whose fruits ripen early, problems caused by high temperature will be less pronounced. Apricot and almond (group 1 species, Table A2.1) will have lower risk. For these species, in the near-future period (2021-2040), the number of days of the warm period overlapping with the end of the harvest will exceed 50 days in approximately 32% of the territory of Serbia, in the mid-century period (2041-2060) in approximately 25% of the territory, and in the end-of-century period (2081-2100) in approximately 32% of the territory of the Republic of Serbia. For these two species, as we move towards the future, the average growing conditions will most likely not worsen due to this climatic hazard. That is due to shift of their phenological development stages towards the earlier period, caused by the temperature increase, when the risk of this climate hazard is lower.

For the species that begin their growing season later in the year, number of days of the hot period overlapping with the end of the ripening in the largest part of the country will range from 50 to 70 days (mostly in the range of 50-60 days), for the species with longer fruit ripening period. In the near-future period, it will cover almost 70% of the country, in the mid-century period, approximately 80%, and in the end-of-century period, according to the RCP8.5 scenario, approximately 90% of the country. For group 3 species (Table A2.1, plum, sour cherry, cherry) the risk of high temperatures is slightly higher in the largest part of the territory and ranges 50-80 days (mostly in the range of 60-70 days). In all future periods, around or more than 90% of the territory is represented in this range of number of days, with a shift toward the increased number of days with risk of this climate hazard. In the near-future period (2021-2040), the number of days of the hot period overlapping with the period up to the end of the harvest will be greater than 60 in 54.6% of the territory. In the mid-century period (2041-2060), in 70.7% of the territory, and in the end-of-century period (2081-2100) in 90.3% of the territory of the Republic of Serbia.

The species with a longer growing season are at the greatest risk (Table A2.1, group 4 species: apple, pear, quince, as well as raspberry and blackberry). Although for all species there is an increase in the number of days of the ripening period overlapping with the period of possible extreme temperatures (hot period), for these species, in the near-future period (2021-2040), the number of such days is over 90 (mostly in the range of 100- 110 days) in over 60% of the territory of the Republic of Serbia, in the mid-century period (2041-2060) in approximately 80%, and in the end-of-century period (2081-2100) according to the RCP8.5 scenario, in more than 90% of the territory. The consequences of this risk are yield reduction, fruit burns and lower yield quality.

Figure A2.6 shows the risk distribution by administrative districts of the Republic of Serbia for the species with the highest risk of high temperatures.

Table A2.4. **The percentage representation of the number of days of the hot period overlapping with the growing season for species with different duration of growing season and different fruit ripening period and the percentage of the territory without suitable conditions for cultivation. The above species groups are specified in Table A2.1. The required period for normal vegetative development is understood to be range from 150 to 180 days. The presented results are obtained based on the climate models ensemble results (75th percentiles) in accordance with the previously derived conclusions about the most likely ensemble result outcomes and based on the comparison of the observed changes (not shown here) and future change trends.**

	<30	30-40	40-50	50-60	60-70	70-80	80-90	>90	not suitable
Group 1									
end of 20th century	0.0	5.2	47.6	32.0	4.2	1.2	0.0	0.0	9.9
near future	0.5	15.7	46.3	31.0	0.7	0.0	0.1	0.0	5.8
middle of this century	0.6	9.0	62.2	24.8	0.6	0.1	0.0	0.0	2.7
end of this century	0.1	6.0	60.6	30.8	1.3	0.6	0.2	0.3	0.0
Group 2									
end of 20th century	0.0	0.9	14.9	58.1	12.2	2.3	0.5	0.0	11.2
near future	0.1	1.0	23.6	41.0	26.5	0.2	0.0	0.0	7.6
middle of this century	0.0	0.6	14.0	72.2	10.2	0.3	0.0	0.0	2.7
end of this century	0.0	0.1	6.2	64.2	27.2	1.2	0.6	0.5	0.0
Group 3									
end of 20th century	0.0	0.2	1.8	37.3	42.3	4.8	0.5	0.1	13.1
near future	0.1	0.1	3.3	32.6	42.6	12.0	0.0	0.0	9.4
middle of this century	0.0	0.0	1.1	25.1	67.8	2.7	0.2	0.0	3.1
end of this century	0.0	0.0	0.0	9.5	77.9	10.4	1.5	0.5	0.3
Group 4									
end of 20th century	0.0	0.0	0.0	0.0	0.0	0.6	11.7	41.6	46.0
near future	0.0	0.0	0.0	0.0	0.1	1.6	10.3	52.1	35.9
middle of this century	0.0	0.0	0.0	0.0	0.0	1.2	5.9	76.6	16.4
end of this century	0.0	0.0	0.0	0.0	0.0	0.2	1.3	92.7	6.0

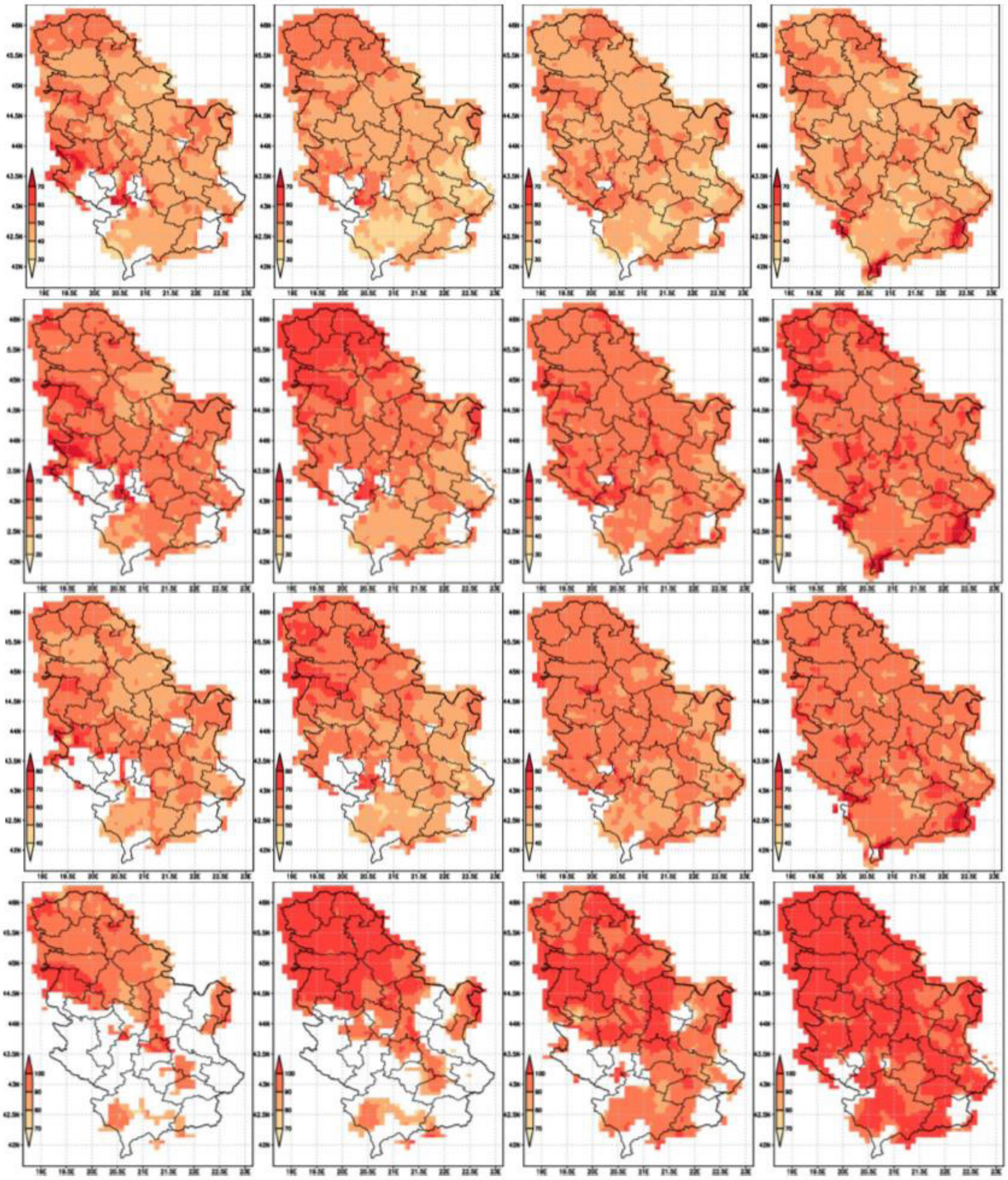

Figure A2.5. The number of days of the growing season overlapping with the "hot period". The values are shown for the climate periods: end of the 20th century (first column), the near-future period 2021-2040 (second column), the mid-century period 2041-2060 (third column) and the end-of-century period 2081-2100 according to the RCP8.5 scenario (last column). The rows show the results for different species groups (Table A2.1), group 1 in the first row, group 2 in the second row, group 3 in the third row, and group 4 in the bottom row. The assumption is that the hot period occurs in at least 50% of the years in the climate period. Areas with no data are areas where the growing conditions in terms of the required duration of growing season (150 to 180 days depending on the species) do not exist. Note: different scales are used in the figures, in the first two rows, the range is 30 to 70, in the third row 40-80, and in the bottom row 70-100.

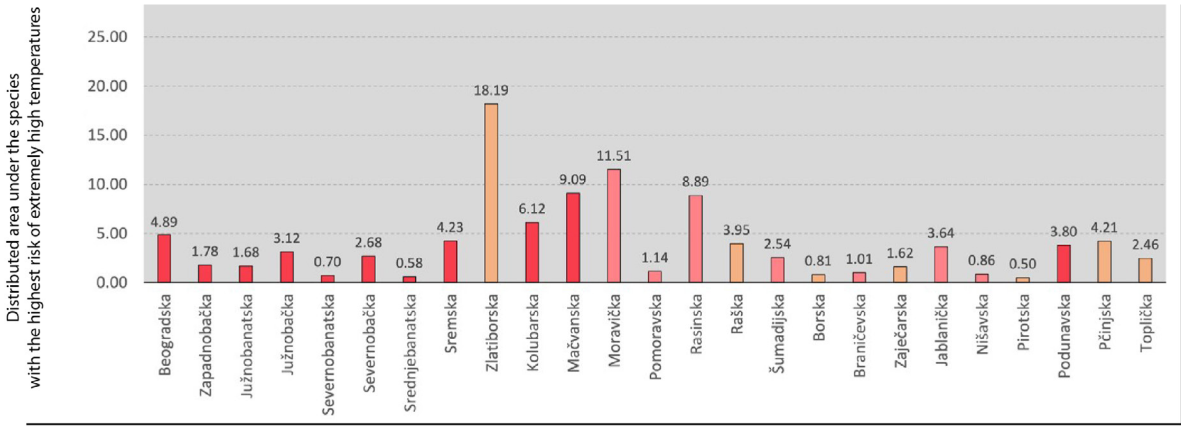

Figure A2.6. **The distribution of the abundance of the species with the highest risk of extremely high temperatures (the greatest overlap of the vegetation period and the "hot period") and the assessment of the risk level depending on the spatial distribution and changes in the climate hazards, i.e., the risk of high summer temperatures. The meaning of the risk levels is explained in Table A2.3, where the highest level of risk means an overlap of the vegetation period and the hot period of at least three months, in a large part of the administrative district (the representation has already been observed or will increase to a significant level by the middle of the century).**

The assessment of the risk of extremely high temperatures, i.e., high summer temperatures, indicates that the risk prevalence and level are increasing in the territory of Serbia. The species with later fruits development, i.e. fruit development during the period of high (and increasing) probability of occurrence of extremely high temperatures that can damage the yield (reduce quality, cause earlier ripening if they occur over a longer period, cause fruit burns, etc.), are at the greatest risk. The presented results show an approximate distribution of the growing problem and indicate the need for planning to reduce the adverse impacts of this climate hazard. However, local climate and terrain characteristics may vary significantly, i.e. the presented estimates cannot be considered representative for decision-making at the location and species level. In certain areas (for example, Jablanicki, Nišavski districts, etc.) at the district level, this climate hazard does not pose a high risk, but in the sub-areas at lower altitudes, the greatest increase in extremely high temperatures was recorded (Appendix A1.2.). For such assessments, it is necessary to perform more detailed risk assessment for this climate hazard with a more detailed spatial resolution data (for example, Vujadinović Mandić et al., 2022) to avoid underestimating the real risk and inadequate planning and implementation of adaptation measures.

A2.2 Impact of climate change in viticulture

The distribution of vineyard areas in the Republic of Serbia by administrative regions (Source: Serbian Statistical Office, data updated in 2017) is shown in Figure A2.7. The largest share of the vineyard area is in the Rasinski district (almost 30% of the total vineyard area). Between 5% and 8% of the vineyard area is in certain areas of Vojvodina, followed by Pomoravski, Borski, Jablanički and Nišavski district. In other districts, the share of vineyard areas is less than 5%.

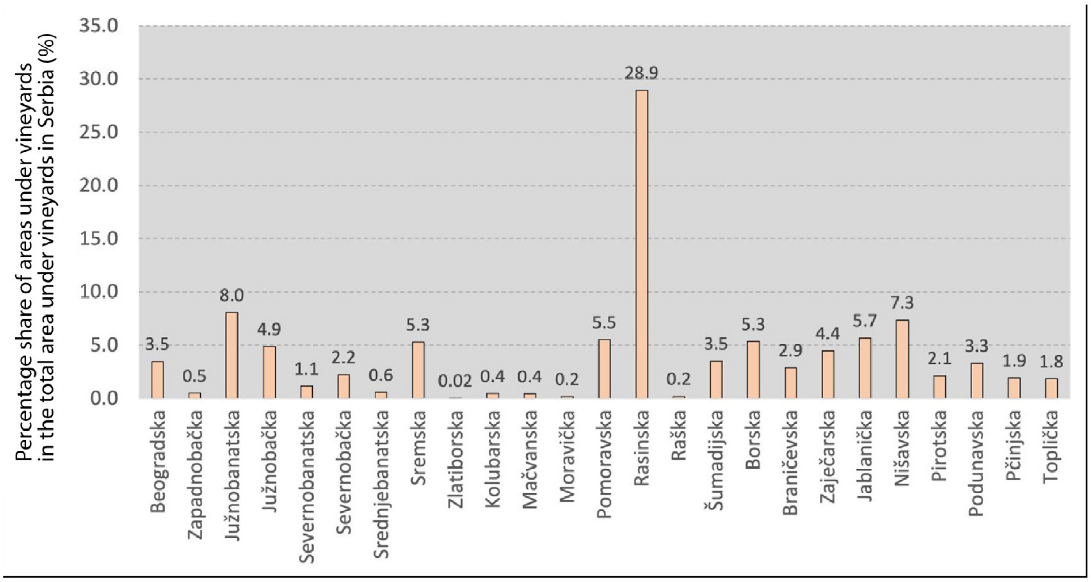

Figure A2.7. **The share of vineyard areas by administrative regions in relation to the total vineyard area in the Republic of Serbia. The data is provided by the Serbian Statistical Office (updated in 2017).**

Climate change has a significant impact on viticulture in the Republic of Serbia, as already shown in numerous studies (for example, Ruml et al., 2012; Vujadinović et al., 2018; Vukovic et al., 2019; Muždalo et al., 2019; Vujadinović Mandić et al., 2022). Consequently, the current zoning of the wine-growing areas of the Republic of Serbia took into account the high-resolution climate parameters analysis in order to develop recommendations and inform about potential risks (Ivanišević et al., 2015; Jakšić, 2019). The observed and future climate change increasingly affects the grapevine, causing changes in the grapevine phenological development stages, changes in the grape and wine composition, changes in the grape yield, the expansion of vineyards to areas that were previously not suitable for grapevine growing and significant geographical shifts in the traditional wine-growing regions. For that reason, it can be considered that climate change affects changes in the wine-growing regions terroir (Ranković-Vasić, 2013; Ruml et al., 2016; Ranković-Vasić et al., 2022).

The climate change impact assessment for viticulture production indicates the need for the adaptation of this sector to changing climate conditions, for both exploiting the potential for high-quality production and increasing the resilience of production to the identified risks. Updating the zoning and introducing new knowledge about climate change, risks and ways to adapt (Ranković-Vasić et al., 2022; Nikolić et al. 2022; Petrović et al., 2022), educating producers on plantation planning and mitigating the potential consequences of upcoming extreme weather events and enabling the effective access to important information are necessary for further sustainable development of this sub-sector.

A2.2.1. Analysis of the climate change impacts on the climate conditions for grapevine growing

Temperature increase affects the extension of the period when the vegetative development of the grapevine is possible, due to the earlier start and later end of the sufficiently warm period, as shown in Figure A2.8. In addition, temperature increase causes the shift in the ripening period towards an earlier period. Increased frequency of droughts and the intensification of dry periods may affect the yield quality if they occur during the unfavourable period for the grapevine development. As in fruit growing, the risk of extremely high summer temperatures can also have adverse effects.

During the grapevine flowering phenophase (end of May-beginning of June), the precipitation amount has a very large impact on the rate and dynamics of flowering, pollination, fertilization, fruit setting and yield. In the vineyards in Serbia, the amount of precipitation in that period does not exceed 30 mm, while future climate projections for this period show, albeit with great uncertainty, an extension of the dry summer period and a shift of the maximum precipitation period towards the colder part of the year (*Chapter 2, Appendix A1.3*).

The International Organization of Vine and Wine has prescribed the viticulture indices and climatic classification according to their values (International Organization of Vine and Wine, 2012). They include Winkler index (WI), Huglin Heliothermal index (HI), Cool night index (CI) and Dryness index (DI). The analysis of the observed climate change effects indicates a change in the climate classification according to WI and HI values (Vujadinović Mandić et al., 2022), and in some areas also according to CI. The Dryness Index does not show any significant changes in contrast to the increased frequency of droughts and the prolonged duration of the drier period during the year. Due to the shift of phenophases and earlier ripening in the extremely warm years, it is necessary to revise the methodology for assessing the Cool night index and the potential precipitation deficit risk. The analysis of the observed climate change effects has shown that the heat conditions, calculated according to WI, have already shifted to about 200 m higher altitudes, while in the lowest areas the heat conditions that did not exist in the 20th century climate now prevail.

The change in heat conditions in accordance with the specified indices in the future is shown in Figure A2.9. The significance of these changes is reflected in the fact that the selection of assortment, rootstock, cultivation method, etc., depends on the specified climate class. In the production of wines with the geographical indication, the zoning of wine-growing areas and the prevailing climate conditions also determine the wine production method.

According to the obtained results, a large part of the territory of the Republic of Serbia is in the climate optimum (regions III and IV according to WI) for the grapevine growing and high-quality wine production. By the mid-century period, in some areas at lower altitudes, heat stress could be high and could affect the yield quality, and the climate optimum will shift to higher altitudes.

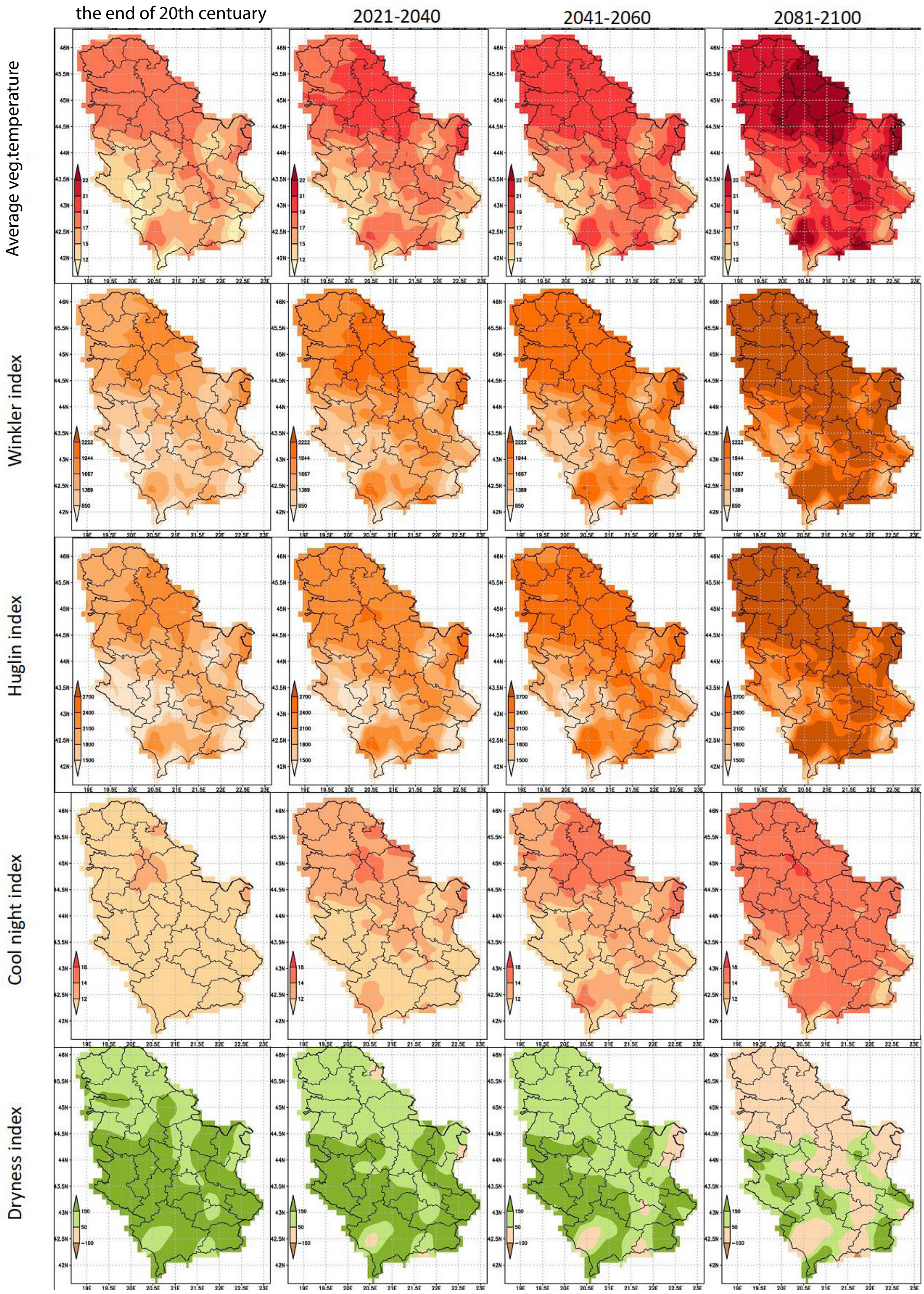

Figure A2.9. **OIV indices values (mean vegetation temperature, WI, HI, CI, DI) for the end of the 20th century and future climate periods. The presented results were obtained according to the climate model ensemble 75th percentiles, according to which the trend of changes corresponds to the observed trend of changes (the analysis of the observed change is not shown here).**

A2.2.2. Analysis of the climate change impacts on the changes in the risk of frost in the grapevine growing season

Frost causes freeze injuries on very young shoots and leaves. Low temperatures during this spring (beginning of April) in some wine-growing regions have caused significant damage to newly activated buds. Differences between individual varieties in this respect can be significant, even up to 15 days. The varieties that start this phase earlier are more vulnerable to this climate hazard. As in the frost risk assessment for fruit growing, the occurrence of frost is defined as the occurrence of days with a minimum daily temperature lower than -2°C. In Figure A2.2, the results shown for group 3 fruit species (third row) are appropriate for frost risk assessment for the grapevine, which is shown in Figure A2.10.

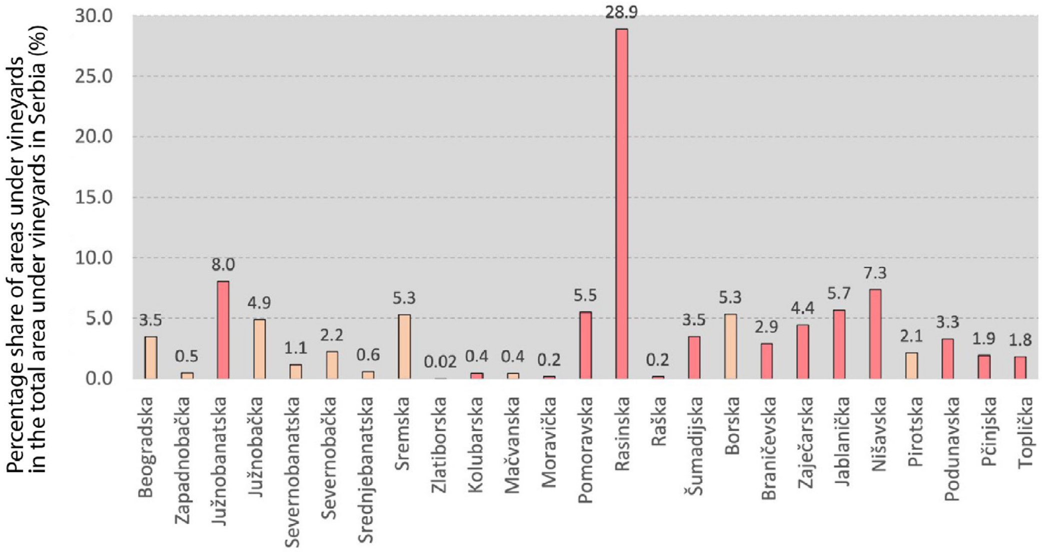

Figure A2.10. **Risk of frost in the grapevine growing season (in colors) and the distribution of areas under vineyards by administrative regions. The risk level is explained in Table A2.3.**

The assessment of the risk in growing season for the grapevine indicates level 1 and 2 risks (Table A2.3). Level 2 risk occurs in the administrative regions with the large share of vineyards relative to the total vineyard area in the Republic of Serbia (for example, in Rasinski, Pomoravljski, Nišavski, Južnobanatski district, etc.; Figure A2.10). This implies moderate level of risk, i.e. it can be assumed that this risk does not cause significant damage, but that it will increase in the future (by the middle of the 21st century) to a level that could be considered a risk for stable production.

The presented assessment for risk of frost in growing season for the grapevine indicate a potential increase of the problems related to the occurrence of frost growing season. As this risk assessment is sensitive to the spatial distribution of vineyards (that information was not available here) and may vary at a higher spatial resolution than the data resolution used here. If necessary, this risk assessment should be done at a higher spatial resolution and it should be included in the viticulture production decision-making (selection of the location, variety, rootstock, etc.).

A2.2.3. Analysis of the climate change impacts on the changes in the risk of low winter temperatures in grapevine growing

Temperature increase reduces the risk of low winter temperatures (*Appendix A1.2.5.*), and the risk of low winter temperatures decreases due to climate change. However, due to the slower increase in low temperatures compared to the increase in high temperatures and the increased climate variability (*Appendix A1.2.4.*), this risk should not be ignored in deciding on the selection of location, variety and rootstock, etc.

Low winter temperatures can occur in the locations with the local climate conditions that do not make them "visible" in the used climate data. The most resilient varieties include the Western European ecological-geographical group (convarietas occidentalis, subconvarietas galica), and the most sensitive include the oriental table varieties (convarietas orientalis, subconvarietas antasiatica). However, the varieties that belong to the same ecological-geographical group are not all equally resilient, as it also depends on the microclimatic conditions, protection, grapevine nutrition, etc. Table varieties are less resilient than wine varieties. Based on the freezing tolerance limits, grape varieties are divided into three groups: 1) varieties that freeze at temperatures from -15°C to -18°C (table grapes: Cardinal, Afus Ali, Drenak Rouge, etc.); 2) varieties that freeze at temperatures from -20°C to -24°C (wine and table grapes: Frankovka, Muscat Hamburg, Merlot, etc.); and 3) varieties that freeze at temperatures below -24°C (Pinot Noir, Italian Riesling, Traminac, etc.). While for group 2 and 3 varieties the risk is significantly lower, group 1 varieties may still be at a risk of frequent occurrence of this climate hazard.

According to the existing data, winegrowing regions located at low altitudes (below 200 m) are at high risk of low winter temperatures. Parts of Vojvodina are particularly vulnerable (Sremski Karlovci, Temerin, Banoštor, Čoka, Vršac, Bela Crkva, etc.; Korać, 2012). The grapevine is particularly vulnerable to low temperatures in February, especially due to the increased weather variability, i.e. the shifts between significantly warmer and colder periods, which has become more probable due to climate change.

A2.2.4. Analysis of the climate change impacts on the changes in the risk of high summer temperatures in grapevine growing

As already confirmed by various papers and project results, high temperatures during the ripening period have an adverse effect on the grape yield and quality (for example, Ranković-Vasić, 2013). The climate change assessment shows an observed increase in the number of heat waves and the number of days with high summer temperatures (*Chapter A1.2.*).

The frequency of periods with dangerously high temperatures in the future climate conditions is shown in Figure A2.11. The high temperature risk levels were assessed by administrative districts in the Republic of Serbia taking into account those results and the results for the vegetation period and the "hot period" overlapping (for the group 4 fruit species, which in terms of the duration of the vegetation period corresponds to the grapevine vegetation period, Figure A2.5 bottom row).

The high temperature risk levels for grapevine growing by administrative regions in the Republic of Serbia were assessed taking into account the projected duration of the "hot period" (period between the first and the last occurrence of maximum daily temperature above 35°C) and its frequency in the future climate conditions (Figure A2.3), as well as the growing season and the "hot period" overlapping results (for group 4 fruit species, which in terms of the growing season length corresponds to the grapevine growing season, Figure A2.5 bottom row). The results of the assessment by administrative regions are shown in Figure A2.11.

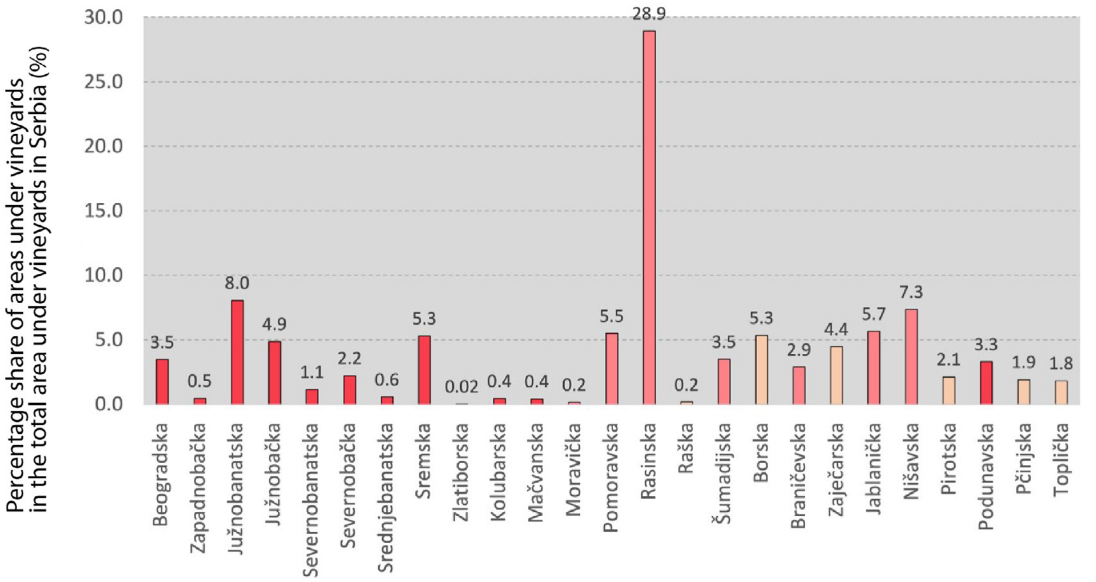

Figure A2.11. **The distribution of areas under vineyards with marked levels for risk of extremely high temperatures (the greatest vegetation period and "hot period" overlapping and increased frequency of "hot period" events). The level of risk is assessed depending on the spatial representation of increased risk in the administrative district and its change by the middle of the 21st century. The risk level meaning is explained in Table A2.3, with the highest level of risk (level 3) meaning that in a large part of the region there is or will be in the near future an overlap of the vegetation and hot period of at least three months (its occurrence has already been observed or increases to a significant level by the middle of the century) and a high frequency of occurrence of this climate hazard; level 2 means that in a large part of the region there is or will be an overlap of at least 60 days and a high frequency of occurrence in a large part of the region; and level 1 means non-existent or lower representation of this risk in the area, spatially or by intensity.**

In the administrative regions dominated by lower altitudes, the risk of extremely high temperatures is higher, considering that, due to rising temperatures, these areas are the first to have the temperatures exceeding the limit values of 35°C. These areas are at the highest level of risk (level 3, in red). The districts with parts of area under the increased risk levels, which will intensify significantly in the future, by the middle of the century, represent level 2 risk. These two risk level categories indicate a growing climate threat from extremely high temperatures for the grapevine cultivation. It is important to understand that an assessment at the level of administrative districts can underestimate the high risks that may exist in certain locations within these districts.

A2.3. Hail risk assessment for fruit and grapevine growing

According to the assessments of the climate change impact on the increase in the hail risk (*Appendix A1.4.*), this climate hazard will increase in intensity and prevalence in the future. As the observed hail damage estimates, which indicate the spread of hail events across the territory of the Republic of Serbia, were not available, as well as due to the local character of this phenomenon, which is conditioned by the factors that influence relatively short-duration intense hail storms, it is not possible to determine the locations with increased risk with high reliability. However, the hail risk assessment, taking into account the available estimates presented in the Chapter on the climatic impact-drivers related to storms and the accompanying extreme weather events (*Appendix A1.4.*) and orchards and vineyards distribution by administrative regions in the Republic of Serbia, is presented in Figure A2.12. The risk level is divided into two groups: level 1 - moderate risk (this climate hazard is not significant in the observed period or due to a lack of data it has not been recognized as a risk, but there is a probability that the hail risk will increase), and level 2 - high risk (this climate hazard has been recognized as significant in the observed period and it is estimated that its frequency and intensity will increase). The low risk level was not taken into account as the estimates obtained from future projections indicate a a high prevalence of the risk of intense precipitation that can manifest in the form of hail, depending on the time of year when it occurs. That is also confirmed by a study conducted to assess changes in the hail incidence and size at the European level (Radler et al., 2019).

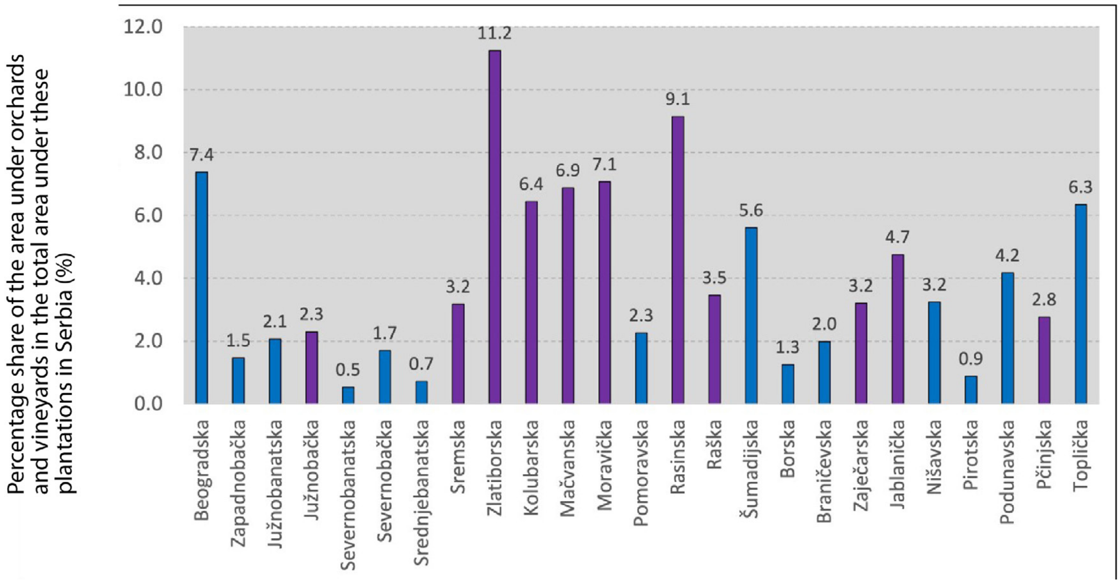

Figure A2.12. **Assessment of hail risk by administrative reagions (level 1 - moderate risk, shown in blue, level 2 - high risk, shown in purple), and distribution of areas and vineyards by districts in the Republic of Serbia. The above assessment is based on the available data and the assessments provided in Chapter A1.4.**

A2.4. Impact of climate change on crop farming

The assessment of the climate change impacts on crop farming takes into account the impact assessment for the following species: maize, wheat, soybean and sugar beet. The distribution of growing areas by administrative regions in Serbia and the distribution of growing by species are shown in Figure A2.13. The data was provided by the Serbian Statistical Office, for the categories “wheat and buckwheat” and “durum wheat” (the total value was taken as the representation for “wheat”), “maize grain” (under “maize”), as well as the sunflower, soybean and sugar beet croplands. The largest representation of these agricultural croplands is in the Vojvodina region, and the most represented cultivated species, of the above, are maize and wheat.

Due to temperature rise, increase in the frequency of critically high temperatures, droughts, changes in the annual precipitation distribution and intensity and the increased climate variability (Chapter 2), there is a significant climate change impact on the agricultural crops cultivation. Due to different levels of sensitivity to climate change, the climate change impact assessment was prepared and the specific climate hazards were identified for each crop species separately. Table A2.5 shows the climatic parameters used to assess the climate change impact in crop farming. The criteria were identified and verified based on the available data on the timing of specific phenological stages and the climatic data for the locations where the data was available.

The obtained data indicates the need for climate adaptation measures in crop production (for example, Stričević et al. 2019; Dolijanović, 2022), including the development of recommendations and education, through zoning, development of training materials, and ensuring effective access to information for agricultural producers.

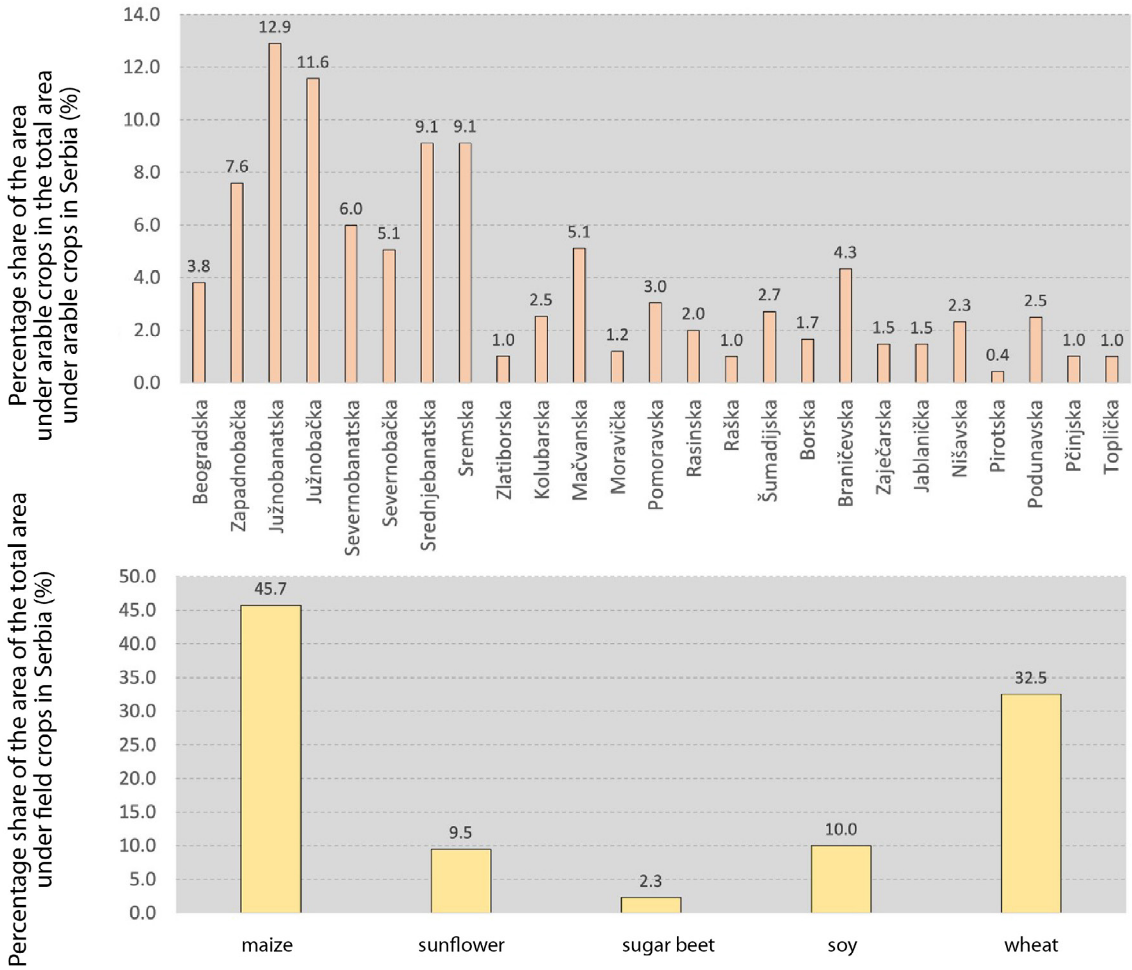

Figure A2.13. The distribution of areas under crop cultivation (maize, sunflower, sugar beet, soybean and wheat) by administrative regions in the Republic of Serbia (% of total cropland area, upper panel), and the percentage share of areas under specific crops in relation to the total area under crop cultivation (lower panel). Source: Serbian Statistical Office (Note: the total area with the categories “wheat and buckwheat” and “durum wheat” is taken for the representation for “wheat”; “maize grain” is taken for the representation for “maize”).

Table A2.5. **Climatic parameters used in the climate change impact and risk assessment for crop farming and the method of calculation, i.e., definition. The listed criteria are determined based on the observed impact indicators and the limit values (particularly for precipitation) may be sensitive to the choice of meteorological data sources.**

Parameter	Definition
Optimal sowing date	Maize: the first date from the beginning of the year after one day with minimum daily temperature above 10°C and three subsequent days with mean daily temperature above 10°C. Sunflower: the first date from the beginning of the year after five consecutive days with mean daily temperature above 10°C. Winter crops: the first date in the second half of the year meeting the following conditions: average mean daily temperature in the previous 10 days lower than 15°C, the precipitation sum in the previous 20 days greater than 10 mm, and in the previous three days, the precipitation not exceeding 3 mm per day. Sugar beet: the first date from the beginning of the year after 4 consecutive days with minimum daily temperature above 5°C. Soybean: the first date from the beginning of the year after three consecutive days with minimum daily temperature above 10°C and the fourth day with mean daily temperature above 10°C.
Effective temperature sum	Effective temperature sum for the base temperature of 10°C (maize, sunflower, soybean) and 3°C (winter crops and sugar beet)
Frost during critical phenological stages	The percentage of years in which, after the optimal sowing date, minimum temperature was lower than -3°C for 2 days (maize), -3°C for two days (sugar beet), -4°C for more than one day (soybean).
High summer temperatures and drought during critical phenological stages	The percentage of years in which a certain number of days with high daily temperatures occurred during the identified critical phenological stages with possibly an additional condition relating to precipitation rate. The beginning and the end of the critical phenological stage is determined based on the effective temperature sum calculated from the optimal sowing date. Winter crops: more than 2 days with maximum daily temperatures over 35°C in the period before full ripening (effective temperature sum less than 1700°C). Maize: Seljaninov heliothermic index, in the period when effective temperature sum is between 430°C and 1170°C; frequency of values lower than 0.7. Sunflower: more than 5 days with maximum daily temperatures above 35°C and precipitation sum less than 100 mm when effective temperature sum is between 850 and 1450°C
Water deficit during critical phenological stages	The percentage of years in which precipitation amount during the identified critical phenological stages is under the specified threshold. The beginning and the end of the critical phenological stage is determined based on the effective temperature sum calculated from the optimal sowing date. Winter crops: precipitation sum less than 50 mm when effective temperature sum is less than 388°C, and precipitation sum less than 70 mm when effective temperature sum is between 650 and 1250°C. Sunflower: precipitation sum less than 100 mm when effective temperature sum is between 150 and 1000°C Sugar beet: precipitation sum less than 50 mm when effective temperature sum is between 1300 and 2000°C. Soybean: precipitation sum less than 100 mm when effective temperature sum is between 400 and 1300°C

In the assessment of the risk of adverse climate change impacts on agricultural crops, the priority was to assess the adverse impact of high temperatures and precipitation deficit in periods when crops are most susceptible to these adverse weather events. Precipitation deficit is most damaging in the critical vegetation period for certain crops (Dolijanović et al., 2020).

These climate hazards have been identified as the major current hazards by agricultural producers (Vuković Vimić et al., 2022). However, the increased climate variability in terms of heat and precipitation conditions may cause other risks, such as excess precipitation during vulnerable periods, risks of sudden changes in weather conditions, unfavourable conditions during harvest that may prevent timely harvesting and storage, etc. As it is emphasized in the following part, there is a need for additional research and assessments of the climate change risk in crop farming, including the development of the methodology that would take into account the observed climate hazards and their impacts on different agricultural crops.

A2.4.1. Analysis of the climate change impacts on maize

The analyses of climate parameter/hazard that were taken into account in the assessment of the climate change impacts on maize cultivation include: optimal sowing date, temperature sum indicating the heat required for normal plant development to maturity for different FAO groups, high temperatures and water (precipitation) deficit risks that indicate heat stress and drought stress (Table A2.4).

The optimal sowing date for maize, when the favourable heat conditions have been reached, in the observed period, from the second half of the 20th century, in the largest part of the territory, shifts between 5 and 10 days. The optimal sowing date is expected to continue shifting in the future. Figure A2.14 shows the optimal sowing dates in future periods. The obtained results indicate a tendency of the optimal sowing date shifting by the mid- 21st century period to the beginning of April in the largest part of the territory, and in some areas to March. By the end of the 21st century, a significant disturbance in heat conditions is expected, which is not considered in this document for the adaptation measures developing purposes.

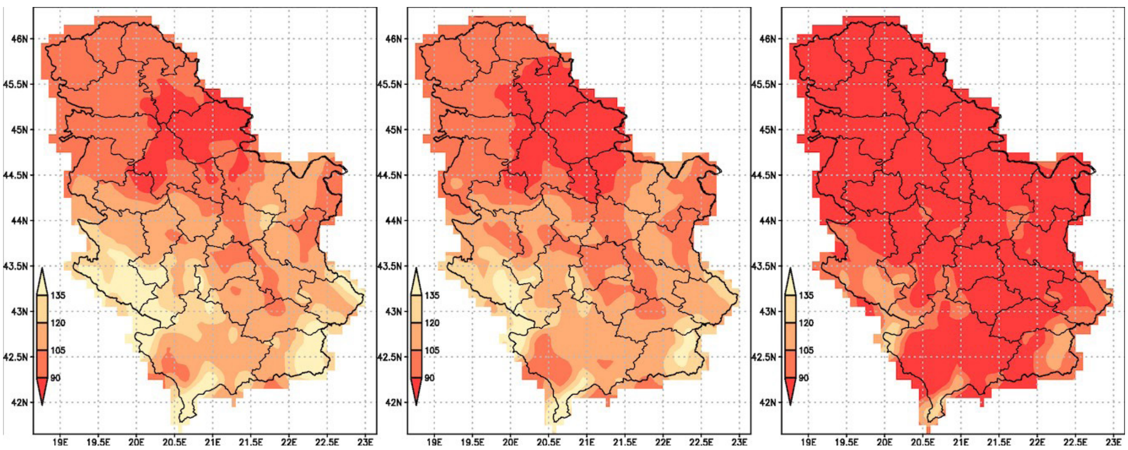

Figure A2.14. **Optimal sowing date for maize (in units: number of days from the beginning of the year) in the near-future climate period 2021-2040 (left side panel), in the mid-century period 2041-2060 (middle panel), and in the end-of- century period 2081-2100 according to the RCP8.5 scenario (right side panel).**

Due to the increased climate variability (*Appendix A1.2.4.*), the sowing date shift can cause an increased frost risk, if it occurs after sowing has been completed on the optimal sowing date. However, at the climate period level, this risk is not significant in any of the periods, i.e., the probability of occurrence is at most once in 10 years.

Figure A2.15 shows the heat conditions suitability for growing different FAO group hybrids, according to specific temperature sums for each group. The criteria for temperature sums for specific FAO groups are shown in Table A2.6. The heat conditions for the FAO group with the highest heat requirement, i.e. the longest period of development before ripening, are met in a large part of the territory of Serbia, with the tendency of further expansion. According to these results, the heat conditions for the development of maize with a high heat requirement in the Republic of Serbia are becoming more favourable.

Table A2.6. **Minimum effective temperature sums required during the growing season for specific maize hybrid FAO groups.**

FAO group	Temperature sum
FAO 100	940°
FAO 200	1050°C
FAO 300	1170°C
FAO 400	1280°C
FAO 500	1390°C
FAO 600	1500°C
FAO 600	1610°C

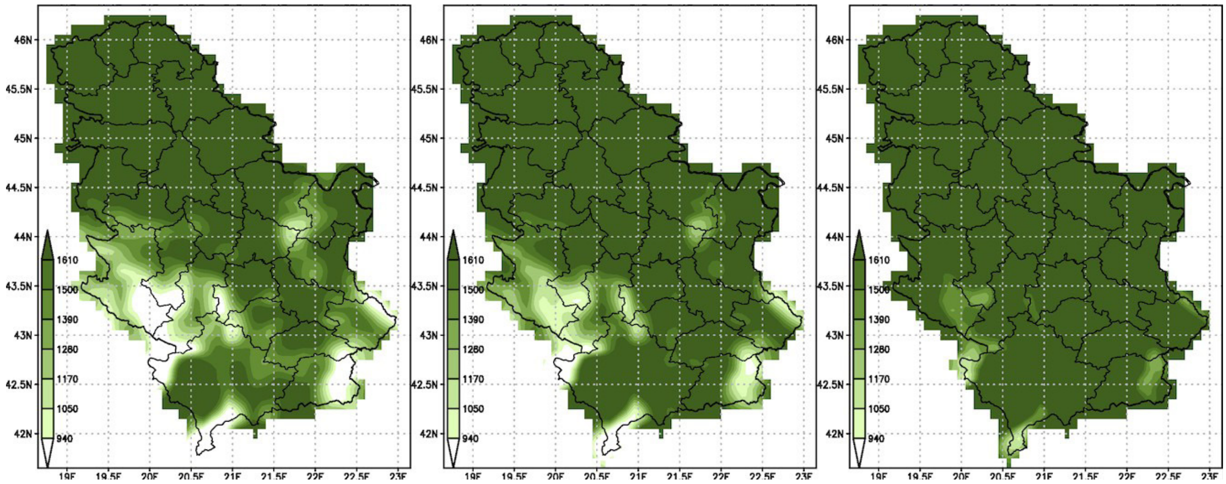

Figure A2.15. **Spatial distribution of heat conditions suitability according to FAO group criteria listed in Table A2.6 in the near-future climate period 2021-2040 (left side panel), mid-century period 2041-2060 (middle panel) and in the end-of-century period 2081-2100 according to the RCP8.5 scenario (right side panel).**

Precipitation deficit has an extremely adverse impact on maize cultivation, particularly in the late ripening FAO groups due to periods of overlapping of low precipitation, which has a tendency to decrease due to climate change, and high temperatures, whose risk also increases in the same period. In other words, drought and extremely high temperatures are an obstacle for a good yield. The SPEI6a drought index value, which corresponds to the change in maize yield (*Appendix A1.3.3.*; Đurđević, 2020), indicates a significant increase in this risk in the future climate periods.

Figure A2.16 (upper panel) shows the observed yield values in the 2011-2020 period, when in one half of the years there was a drought in the territory of the Republic of Serbia according to the SPEI6a index. The drought years, on average, in the territory of the Republic of Serbia according to the SPEI6a index, by intensity, are: 2012 with the most intense drought, followed by 2017, 2015, 2011, 2013. In all these years, the average yield in t/ha was lower than the average, particularly in 2012 and 2017. In these years, the highest temperatures were recorded in the observed period of March-August, along with a precipitation deficit.

Variations in weather conditions during this period can have a significant impact on crop development, which is why a special climate parameter (climate hazard) has been specified for the impact of periods of high temperatures in combination with a precipitation deficit, as shown in Table A2.5, with the results for the future periods shown in Figure A2.16 (bottom panel). This parameter calculation takes into account the change in the phenological development dynamics in the warmer future conditions and the sowing date adjustments. In other words, the assumption is that crops are sown at the optimal sowing date, i.e., in accordance with the shift to earlier date due to the increased temperatures. The phenological stage shift in time due to future warming was taken into account in order to assess the risks in the period when the plant is sensitive to high temperatures more reliably (Note: if these future climate changes are not taken into account, the risks would be higher).

In accordance with the presented results, if the assumption is that the acceptable risk is up to 30% (occurring in three out of ten years), a large part of the territory is at risk of this climatic hazard, and in the eastern and southern Serbia, even more than 50% . By the mid-century period, high levels of risks will be present in almost the entire territory where the heat conditions according to FAO criteria for growing maize are present. It should also be noted that the identified risk, according to the observed data, indicates that the potential damage could mean the reduction in yield by more than 40% compared to the multi-year average.

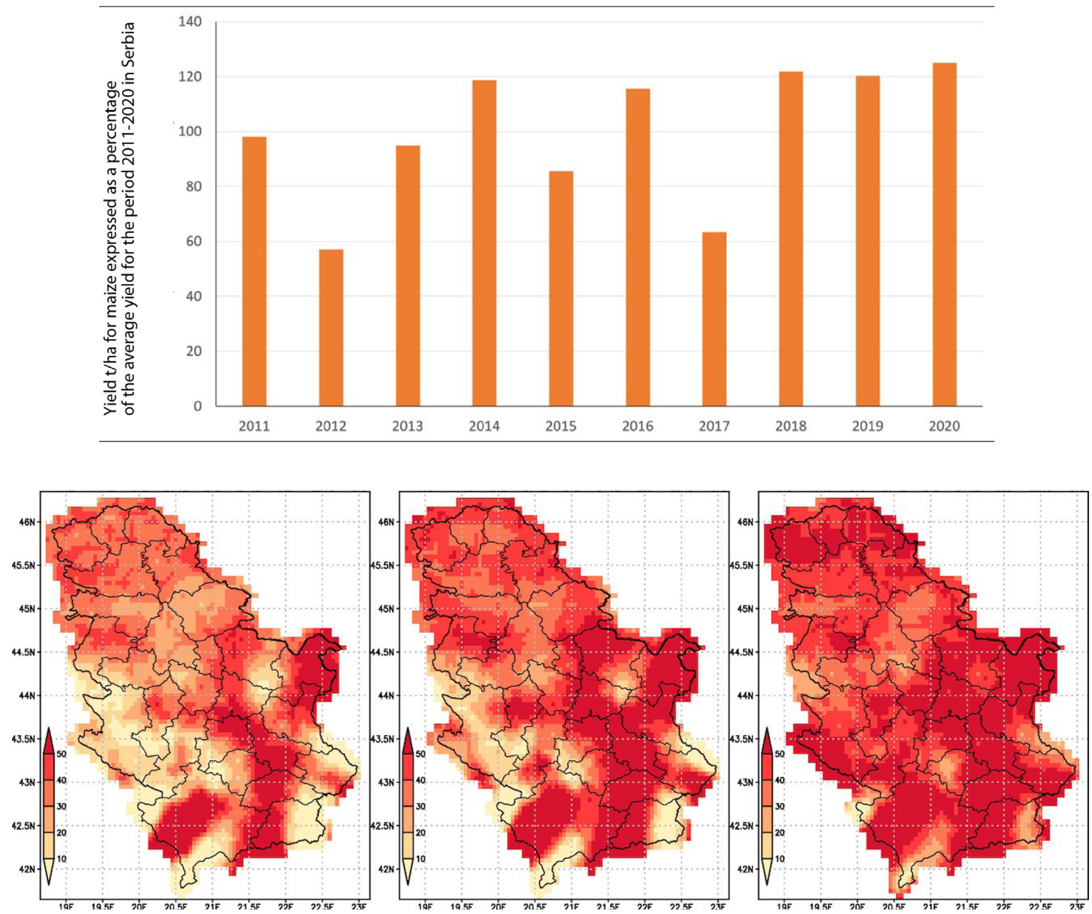

Figure A2.16. **Percentage of average maize yield in t/ha in the territory of the Republic of Serbia in the 2011-2020 period by years (upper panel). The frequency of years with a high risk of high temperatures and precipitation deficit in the sensitive stage of maize development, under assumption that crop is sown at the optimal sowing date, as defined in Table A2.5, in the near-future climate period 2021-2040 (left side panel), mid-century period 2041-2060 (middle panel) and in end-of-century period 2081-2100 according to the RCP8.5 scenario (right side panel).**

The presented climate change impact analyses indicate an expansion of the area with heat conditions for growing FAO group hybrids with high heat requirements. However, due to the high risk of high temperatures and drought in these hybrids, a stable yield quality cannot be expected. In order to reduce the risk of high temperatures and drought, sowing should be done at the optimal sowing date (preferably earlier) and in areas with a high risk for growing higher FAO groups hybrids, those hybrids should be avoided. Figure A2.17 shows the risk distribution by administrative districts in the Republic of Serbia, with the maize growing area representation. The results show that maize is at the highest risk of high temperatures and drought of all the cultivated crops, due to its high sensitivity to these weather conditions at the time of their occurrence. Due to climate change, by the middle of the century, the risks will reach the highest level, i.e., the adverse impacts of the risks are expected to be more frequent than once in every two years.

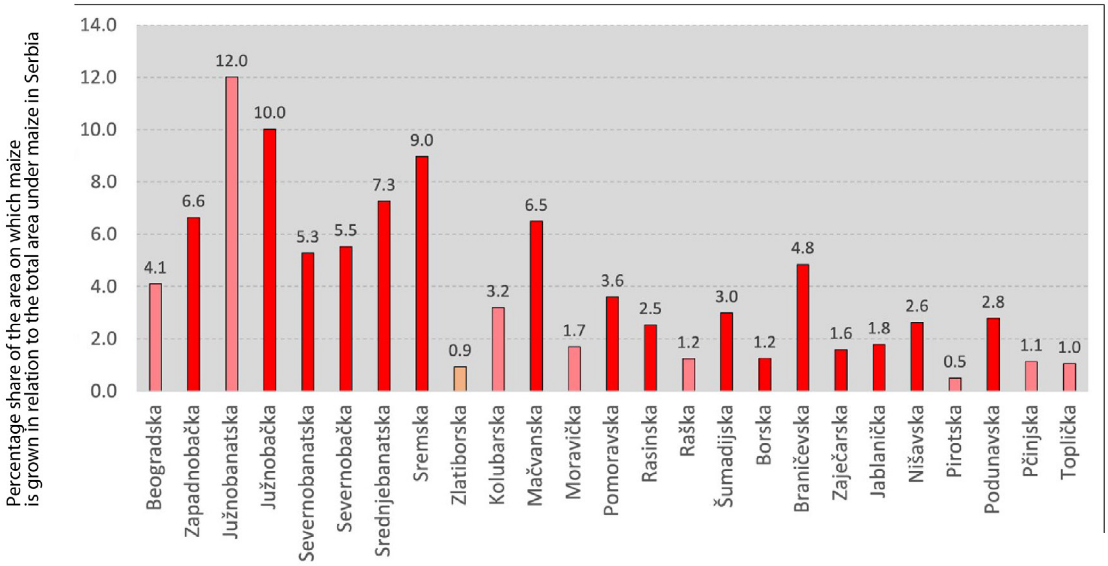

Figure A2.17. **Assessment of the high temperatures and drought risk level for growing maize and maize growing areas distribution by administrative regions in the Republic of Serbia. The highest risk level (red colour) reflects the districts where the risk exceeds 30%, with an increase in a large part of the region above 40% in the future, by mid-century period; the medium risk level (light red) reflects the regions where the risk is partially represented and is lower than 30%, but has a tendency to rise above 40%; the lowest risk level (orange) reflects the regions where there is mostly no significant risk (over 30%) until the mid- 21st century period. The regions with significant areas with risk exceeding 50% are also considered to be at the highest risk. It should be noted that in the regions with the risk values above 50%, these risks increase significantly above 50% by the mid-century period (not shown in the Figure).**

According to the yield data for 2021 and 2022, the years with extremely warm summers in the Republic of Serbia, lower than average yields were recorded, and in 2022, the yield was more than 20% lower according to preliminary data.

The above conclusions are confirmed by the analysis of the drought incidence and increased drought intensity due to climate change (Appendix A1.3.3.), which predicts that in the territory of the Republic of Serbia a severe droughts will occur in 3-4 years per decade, while a moderate drought can be expected almost every year during the mid-21st century climate period.

A2.4.2. Analysis of the climate change impacts on sunflower

The analysis of the climate change impacts on sunflower took into account the optimal sowing date shift, the risk of the occurrence of periods with high temperatures combined with precipitation deficit from flowering to ripening stage and the occurrence of the precipitation deficit in the period of vegetative growth and flowering (Table A2.5).

The average optimum sowing date has shifted to an earlier period (the results are not shown here), as expected due to the rise in temperatures, and by the middle of the century, in a large part of the territory, it will shift to March. Sunflower is significantly more resilient to frost than maize, which is why this risk does not have a significant value.

Figure A2.18 shows the sunflower yield in the 2011-2020 period by years (based on the data on yields in t/ha provided by the Serbian Statistical Office) in relation to the average yield value for this period in the Republic of Serbia. The yield reduction compared to the average yield was recorded in the identified years with drought in the territory of the Republic of Serbia (Đurđević, 2020; Vuković Vimić et al., 2022), similarly as for maize. The preliminary 2022 data also indicates reduced yield compared to the average. However, the reduction in yield compared to the average yield is not as significant as in maize. For example, in 2012, the yield was lower by approximately 30% compared to the average yield, and in 2017 it was approximately 10% lower. Sunflower is more resilient to these adverse weather conditions. However, climate hazards have been identified for sunflower specifically, as previously indicated, in accordance with this crop's sensitivity to high temperatures and precipitation deficit. In the assessment, it should be taken into account that the identified risks do not necessarily have to cause a reduction in yield as in the case of maize.

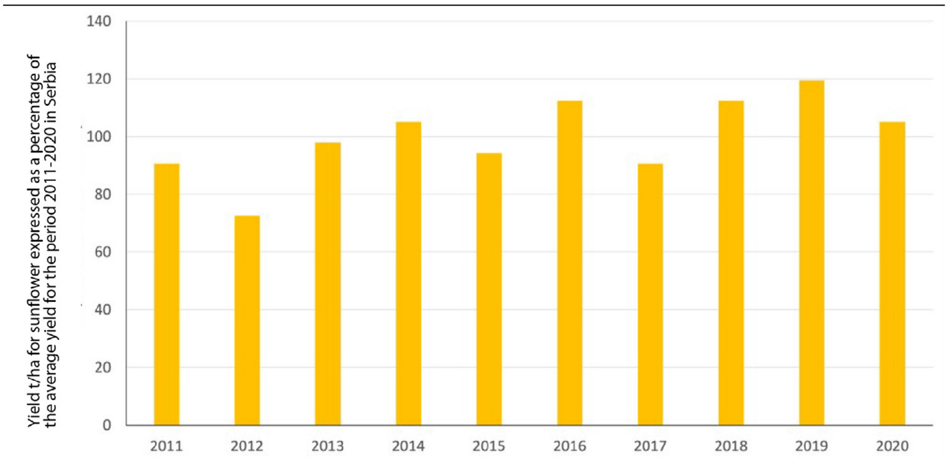

Figure A2.18. Percentage of the average sunflower yield in t/ha in the territory of the Republic of Serbia in the 2011-2020 period by years.

For the normal sunflower development, the risk of occurrence of the climate change-induced periods of high temperatures combined with a precipitation deficit from flowering to ripening stage (hereinafter - R1) has been identified. The incidence of such periods in the end-of-20th century period was not significant, i.e., it had a frequency below 30% in the largest part of the Republic of Serbia where the climatic conditions for growing sunflower exist (the results are not shown here). The frequency of occurrence of years with this climatic hazard for sunflower in the future climate periods is shown in Figure A2.19 - upper panels. This risk increases significantly primarily due to the increased frequency of extremely high temperatures. Precipitation deficit is also a risk in the period of vegetative development and flowering (hereafter - R2), and its frequency is shown in Figure A2.19 - bottom panels. The risk assessment calculations take into account the optimal sowing date shift and the change in the phenological development dynamics in the future heat conditions. The results for the these climatic hazard risks indicate that sunflower will be exposed to an increased climate risk in terms of insufficient precipitation in the period when it is necessary for the normal crop development and the frequent occurrence of high temperatures. The results show that R1 is dominant over R2 in terms of its frequency in most regions. However, in some regions, R2 is more significant in terms of its distribution and intensity. That is why the risk assessment by regions takes into account both these risks.

Figure A2.20 shows the risk assessment by regions in Serbia. As the risks are identified based on the observed data, i.e., when the yield reductions were at most around 30% (with a smaller decrease in other unfavourable years), less significant than in the case of maize, it can be assumed that they cause less damage, which is why the level of risk is lower in relation to maize despite the high frequency of the identified climate hazards. In the regions with the highest prevalence of sunflower cultivation (Vojvodina region), the risks increase significantly in the near-future period, and particularly in the mid-century period, when unfavourable periods will occur in more than half of the years during the climate period. In the regions with a lower risk, sunflower cultivation is not represented. It should be noted that in the future climate conditions (even in the mid-century period), the intensity of these climate hazards will also increase, i.e., weather conditions that have not previously been recorded in these areas will occur, particularly due to the increase in high temperatures and the precipitation distribution changes, and consequently more significant yield reductions can be expected.

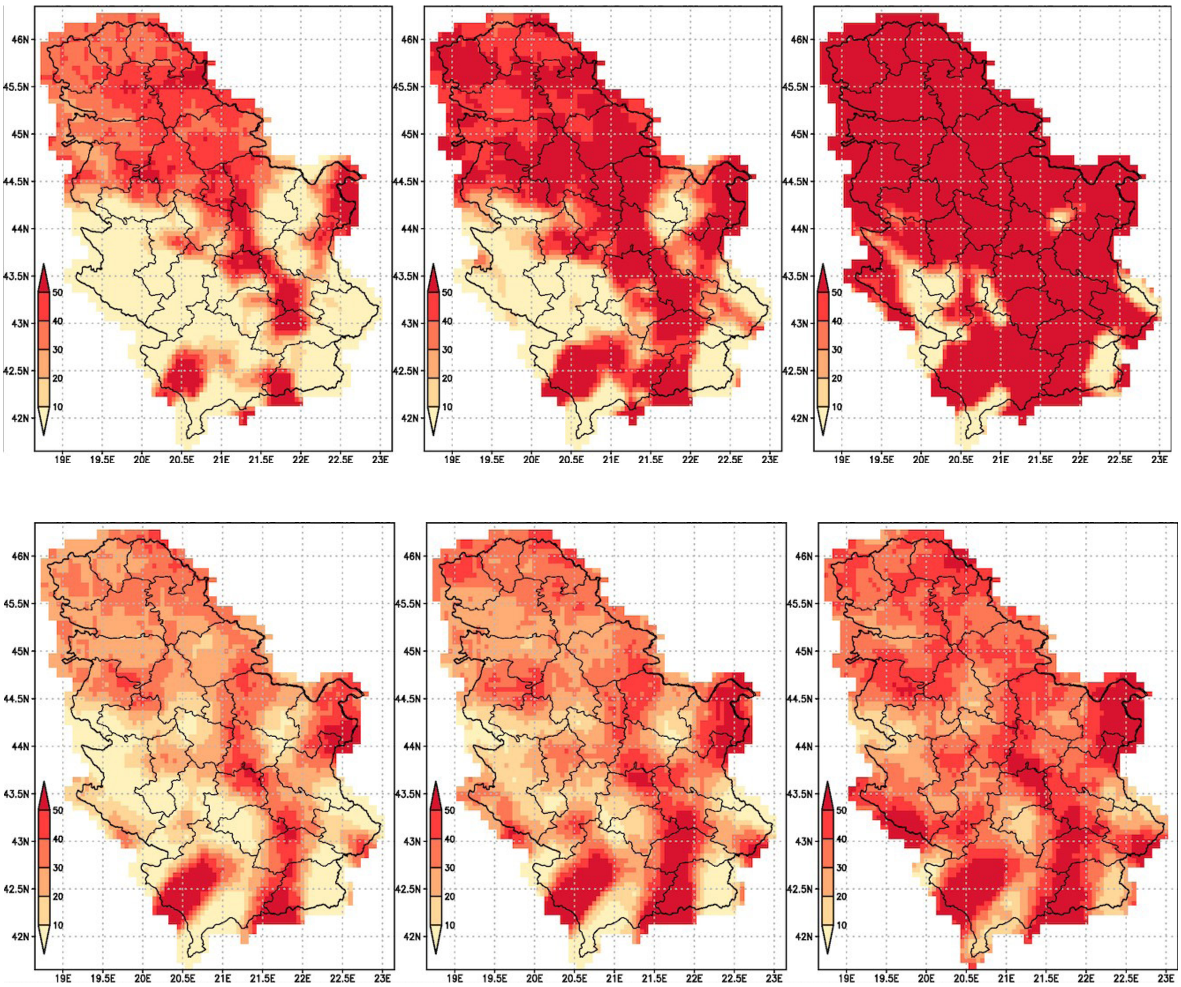

Figure A2.19. **The frequency of years with the occurrence of a period of high temperatures combined with a precipitation deficit from flowering to ripening stage for sunflower (upper panels) and with the occurrence of a period of a precipitation deficit in the period of vegetative growth and flowering (bottom panels), as specified in the Table A2.4, in the near-future climate period 2021-2040 (left side panel), mid-century period 2041-2060 (middle panel), and in end-of-century period 2081-2100 according to the RCP8.5 scenario (right side panel).**

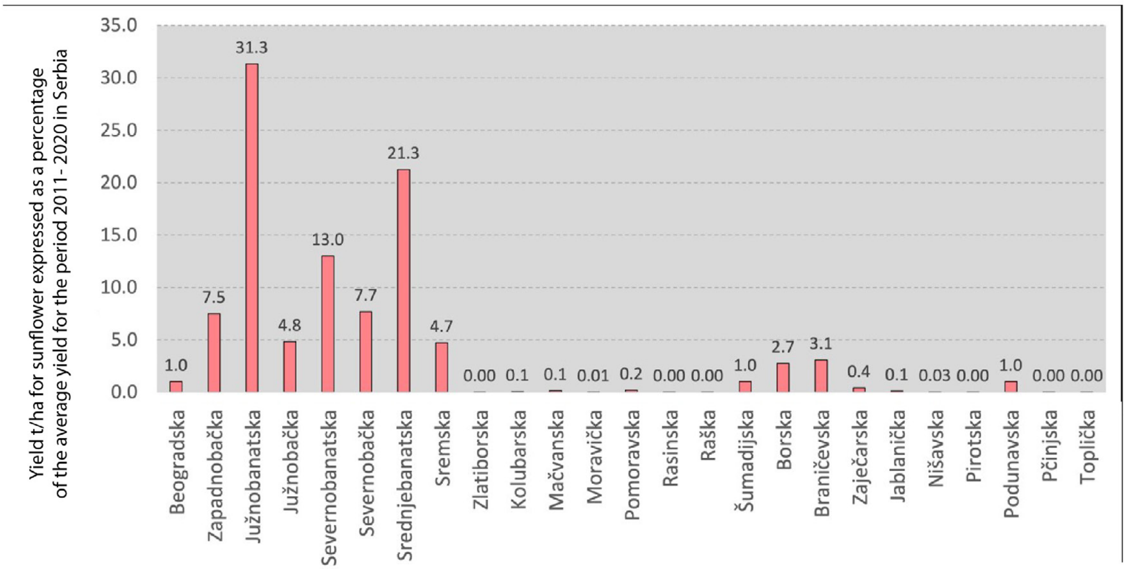

Figure A2.20. Assessment of the combined risk of high temperatures and precipitation deficit for sunflower cultivation (risks R1 and R2), shown in Figure A2.19 and specified in Table A2.5, and sunflower growing area representation by administrative districts in the Republic of Serbia. The risk level in all districts with sunflower cultivation is identified as level 2, i.e., moderate risk, considering a high risk frequency (particularly of R1), while the identified damages are currently in the range of 10% to 30%, but with a tendency of increase in frequency by the middle of the 21st century.

A2.4.3. Analysis of the climate change impacts on soybean

The analysis of the climate change impacts on soybean took into account the optimal sowing date shift and the risk of frost occurrence after the optimal sowing date, as well as the frequency of occurrence of periods of high temperatures combined with a precipitation deficit in the period from flowering to fruit setting, as specified in Table A2.5. Due to the increase in temperature, the optimal sowing date shifting trend will continue in the future, while the risk of frost occurring after the optimal sowing date is not significant in the future (results not shown here).

Figure A2.21 shows the soybean yields in the period 2011-2020 by years (based on the data on yields in t/ha provided by the Serbian Statistical Office) in relation to the average yield value for this period in the Republic of Serbia. The changes in yield indicate a sensitivity to high temperatures and drought, i.e. reduced yields were recorded in 2012, and also in 2017, 2013, 2015 and 2011, which were identified as the years with drought, on average, in the territory of the Republic of Serbia, but also with increased temperatures (Appendix A1.3.3.). The lowest yield (61% of the average yield for 2011-2020) was recorded in 2012, which was the year with the most intense drought and high summer temperatures during the growing season, particularly during the summer. In 2017, which is another extreme year for these weather conditions, the yield was 82% of the average yield.

Figure A2.22 shows the frequency of periods with severe high temperatures and a precipitation deficit during the development stages when the crop is sensitive, for future climate periods. It has to be noted that in calculating this risk, the optimal sowing date shift and changes in the phenological development dynamics due to changed heat conditions in the future were taken into account (Note: if the fixed dates of the risk periods had been taken into account, the risks values would have been higher). The increase in temperature, i.e. the increased frequency of high temperatures, contributes the most to this risk changing in the future. As unfavourable periods, according to the observed data, can cause a yield reduction of approximately 40%, and probably even more under the influence of future more intense unfavourable weather extremes, the criterion used for the assessment of the risk level is the frequency greater than 30% (on average, in three years in a decade). The risk is considered high if it reaches that frequency by the mid- 21st century period. At the level of regions, the higher risk frequency should be reflected in a significant part of the territory.

The results of the risk assessment by administrative regions of the Republic of Serbia are shown in Figure A2.22. The obtained risk distribution is similar to the risk distribution for the climate hazard of the unsuitable periods for maize growing. Abundance of cultivation indicates that in the three regions with over 70% of the total growing areas for this crop in the Republic of Serbia (the three districts with the highest representation of this crop growing areas), which are located in the Vojvodina region, have the highest level of this climate hazard risk.

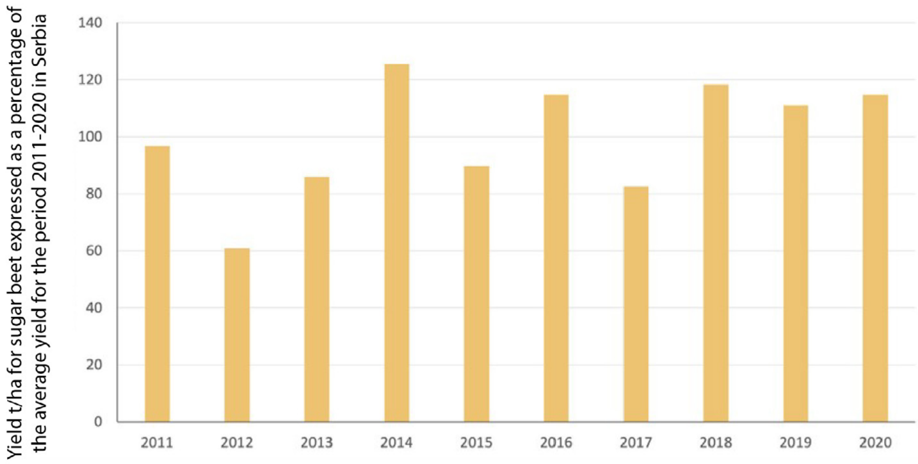

Figure A2.21. **Percentage of the average soybean yield in t/ha in the territory of the Republic of Serbia in the period 2011-2020 by years.**

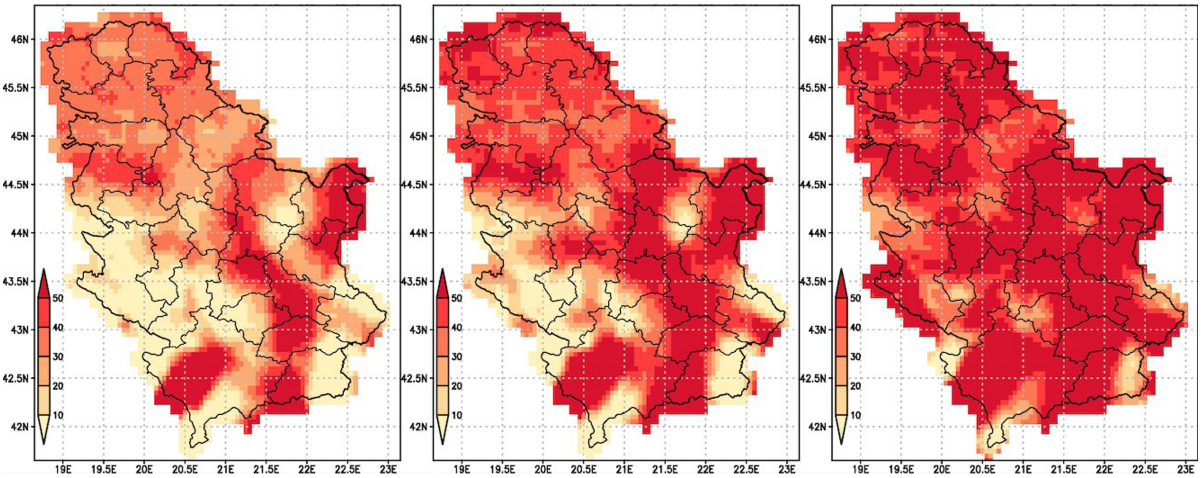

Figure A2.22. The frequency of years with the occurrence of unfavourable periods for soybean development, i.e. periods when damaging high temperatures and precipitation deficit occur in the period from flowering to fruit setting, as specified in Table A2.5. in the near-future climate period 2021-2040 (left side panel), mid-century period 2041-2060 (middle panel) and in end-of-century period 2081-2100 according to the RCP8.5 scenario (right side panel).

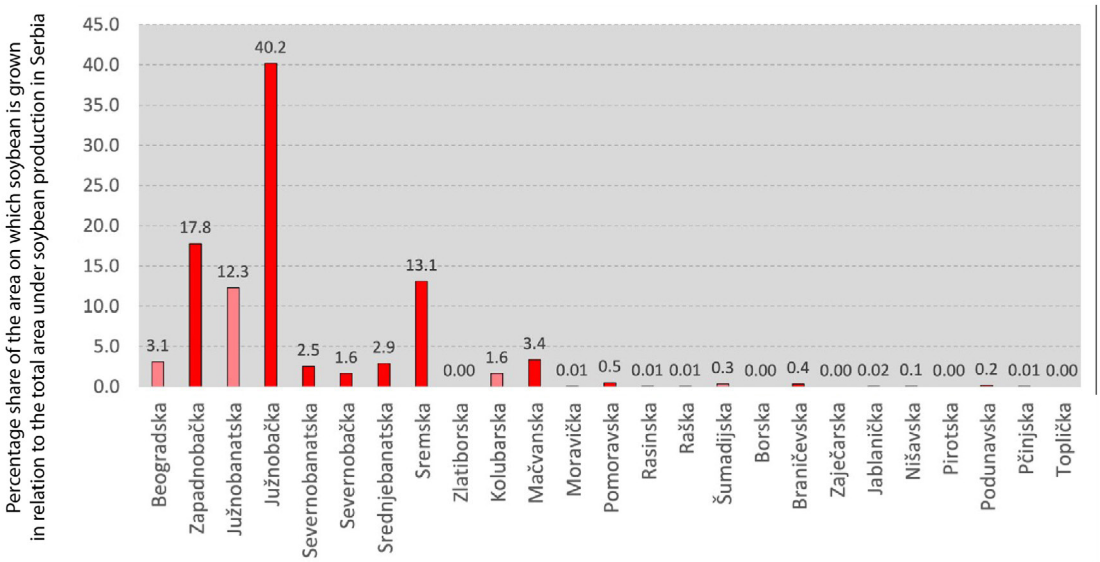

Figure A2.23. Assessment of the risk level for soybean due to the occurrence of a period with high temperatures combined with a precipitation deficit in the period from flowering to fruit setting, as specified in Table A2.5, and the soybean growing area representation by administrative regions in the Republic of Serbia. The risk level assessment criteria are those specified in Appendix A2.4.1, where level 3 (the highest level of risk) is marked in red, level 2 (moderate risk with a tendency to increase to high risk) is marked in light red, and level 1 in orange (here not visible).

A2.4.4. Analysis of the climate change impacts on sugar beet

The analysis of the climate change impacts on sugar beet cultivation took into account the optimal sowing date shift, the risk of frost occurrence after the optimal sowing date, and the risk of precipitation deficit in the critical development period, i.e., during the intensive leaf growth and secondary root thickening growth, as specified in Table A2.5.

The sowing date shift by the mid-century period is identified in almost all regions of the Republic of Serbia (not shown here). The shift in the beginning of growing season (in the case of annual plants, the optimal sowing date) for the species with lower heat requirements in this period, i.e., species that can begin their vegetative development at lower temperatures, is greater compared to the mean date shift for the species that begin their development at higher temperatures. In other words, the optimal sowing date shift for sugar beet in the near-future to mid-century period is greater than that for maize and sunflower. The identified potential risk is the occurrence of frost during the period of vegetative development of sugar beets, if the sowing is carried out when the heat conditions are reached (after the optimal sowing date). Since the optimal sowing date has shifted to the period when there is still a high probability of frost after that date, this risk needs to be taken into account when deciding on moving the sowing date. The risk in the future is in the range of 10%-30% in most parts of the territory.

The sugar beet yield, shown in Figure A2.24 - upper panel, shows sensitivity to drought, which were identified in the territory of the Republic of Serbia according to the SPEI6a index (Appendix A1.3.3), and the 2012 yield was approximately 70% of the 2011-2020 average yield in t/ha (Source: Serbian Statistical Office), while in the other years there was no significant decrease. This deviation in yield reduction in the later years with drought in the territory of the Republic of Serbia, such as 2017, 2015, 2013, 2011, compared to the yield reduction in maize and soybean, but also sunflower, which is more resilient than the two latter crops, is possibly due to the fact that the sugar beet growing areas are irrigated more and/or other impact mitigation measures are applied. Figure A2.24 - bottom panel shows the distribution of croplands with different agricultural crops by farm types (family farms and legal entities, while the share of entrepreneurs is under 1%). Unlike other crops, where the large majority of land is family farms (maize is almost 90%, and sunflower and soybeans are around 80% family farms), over 55% of the land on which sugar beet is grown is owned by legal entities. Based on that, as well as due to the fact that sugar beet is grown on a much smaller territory compared to other crops (Figure A2.13 - bottom panel), and in the absence of other data, it is assumed that the sugar beet growing areas are irrigated more, and as a consequence, smaller yield reduction has been recorded in the years with unfavourable conditions, even though the crop is sensitive in the period when the identified risk for this species is frequent.

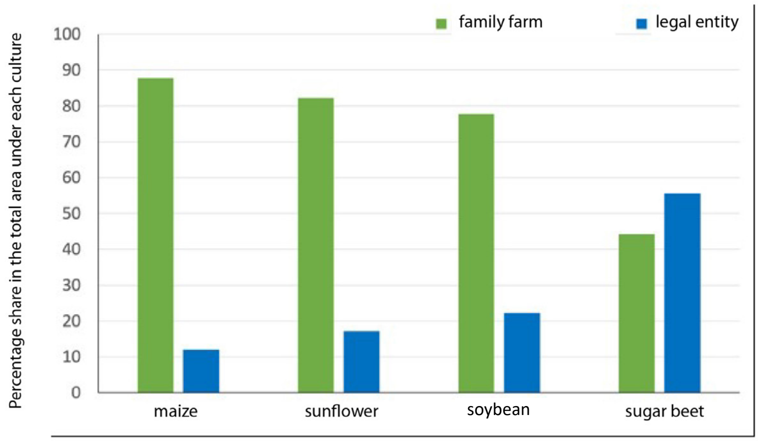

Figure A2.24. Percentage of the average sugar beet yield in t/ha in the territory of the Republic of Serbia in the 2011-2020 period by years (upper panel). Share of croplands with different crops by farm types (lower panel), based on the data updated in 2017.

The major risk identified for sugar beet development is precipitation deficit in the period when the crop is sensitive to moisture deficit, as previously indicated, in the period of intensive leaf growth and secondary root thickening growth. The frequency of the years with the occurrence of this climate hazard is shown in Figure A2.25. This risk was calculated based on the optimal sowing date shift and phenological development rate changes in the changed heat conditions in the future. High risks are spread in the largest part of the territory where there are optimal conditions for sugar beet cultivation. The frequency of this climate hazard is greater than 50% and this hazard is increasing in the future in terms of its spatial distribution and intensity (Note: the increase in intensity is not clearly visible on the maps as the values exceeding 50% are marked in the same colour, in order to maintain consistency with the frequency values for other crops).

If it is assumed that sugar beet is mostly grown on irrigated areas, and that in the absence of irrigation there would be significant yield reductions (as shown by the 2012 yield), it can be assumed that the areas with the frequency of occurrence of years with this climate hazard in a half or more years during the climate period have a high risk level (level 3). According to the risk assessments shown in Figure A2.26, there is a high level of risk of a precipitations deficit for the normal development of sugar beet in the entire area where it is grown (Vojvodina region), under the assumption that the crops are not irrigated.

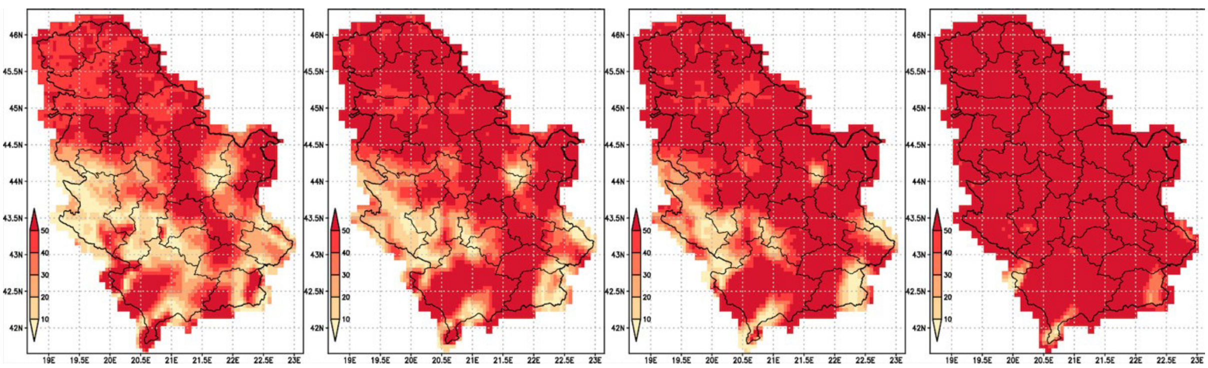

Figure A2.25. The frequency of years during the climate period with the occurrence of a period with a precipitation deficit disturbing the normal development of sugar beet (a period of intensive leaf growth secondary root thickening growth), as specified in Table A2.4 in the near-future period 2021-2040 (second panel), mid-century period 2041-2060 (third panel), and in end-of-century period 2081-2100 according to the RCP8.5 scenario (right side panel).

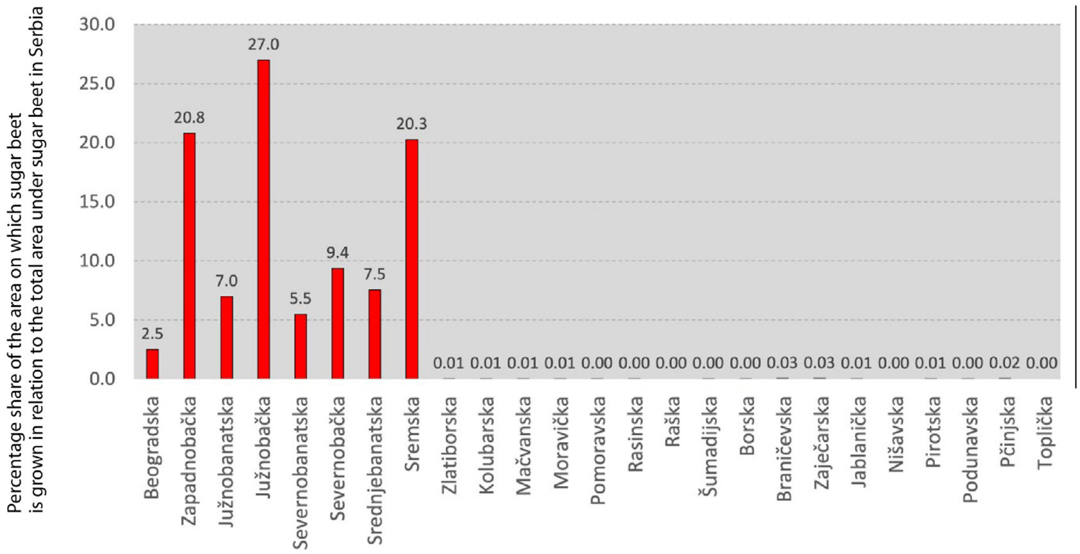

Figure A2.26. **Assessment of the risk level for sugar beet cultivation due to the occurrence of a period with a precipitation deficit which disturbs the normal development of sugar beet (a period of intensive leaf growth secondary root thickening growth), as specified in Table A2.5, with distribution of soybean growing areas by administrative regions in the Republic of Serbia. The regions where, in largest area, the frequency of the occurrence of this climatic hazard is in a half or more years (over 40%) during the climate period have a high risk level (level 3), while the regions where high risk is less represented, but where risk will increase by the mid-century period have level 2 risk (moderate), and the regions where the frequency is lower and is not considered a risk, without a significant increase in the future, have level 1 risk (low or non-existent, at the level of the area). Due to the low or zero abundance of sugar beet growing in the areas with lower risk level, they are not visible in this Figure.**

A2.4.5. Analysis of the climate change impacts on wheat and other winter crops

The analysis of the climate change impacts on winter crops cultivation took into account the optimal sowing date shift, the frequency of occurrence of high temperatures, the frequency of occurrence of the years with a precipitation deficit in the period from sprouting to the end of tillering and in the period from head differentiation to grain filling, as well as the frequency of occurrence of black frost. The calculations for these climate hazards for winter crops are explained in Table A2.5.

Due to the significant increase in temperature in all seasons (*Appendix A1.2.1*), the optimal sowing date shift towards a later period will continue in the future. The risk of black frost, i.e. the occurrence of days with low winter temperatures without snow cover is estimated with a high probability as low risk, due to the decrease in the number of days with low temperatures (*Appendix A1.2.5.*) and due to the unchanged or increased average amount of precipitation during the winter. However, due to the increased weather variability (*Appendix A1.2.4.*), the shifts between warmer and very cold weather can cause adverse impacts.

Figure A2.27 shows the yield of wheat, as the most cultivated winter crop species, for the period 2011-2020. There were no significant yield losses recorded in the years in which yield losses were recorded in spring crops (for example, 2012, 2017, etc., as discussed in previous chapters). High temperatures in the warm period of the year and precipitation deficit were not significant risks for winter crops.

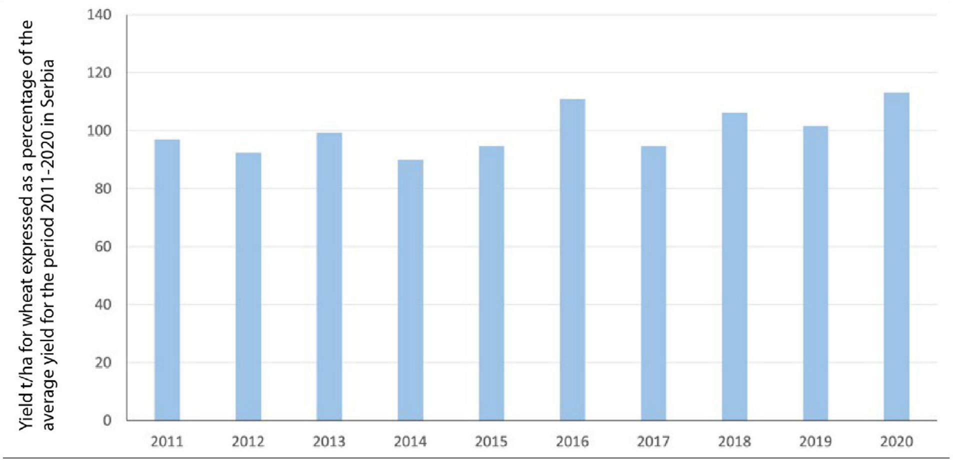

Figure A2.27. **The percentage of the average wheat yield in t/ha in the territory of the Republic of Serbia in the period 2011-2020 by years.**

The frequencies of unfavourable weather conditions in the periods critical for wheat development were calculated taking into account the optimal sowing date shift, and the potential change in the phenological development dynamics. The risk of extremely high temperatures (specified in Table A2.5) is significantly lower for winter crops, compared to spring crops for which the analysis was presented in the previous chapters. The obtained frequency of the years with unfavourable high temperature periods show that the frequency of the years with such periods is relatively low, up to 20% in the largest part of the territory of the Republic of Serbia. The frequency of this climatic hazard (results not shown here) for wheat by the mid- 21st century period is in the range of 20%-30%, while there is a probability that there will be a slightly higher risk in parts of the Pomoravski, Nišavski and Jablanički regions. The precipitation deficit risk in the period from sprouting to tillering (results not shown here) can also be considered relatively low, i.e. up to 30%. The greatest risks are reflected in the northern part of Serbia (in the range of 20%-30%), i.e. in the Vojvodina region, and in the later period the risks extend to the central and southern regions. In the territory of the Republic of Serbia, this risk remains in the range of up to 30% frequency even further into the future. The increased risk is due to a precipitation deficit in the period from germination to grain filling, as shown in Figure A2.28. Due to a large uncertainty of the change in precipitation in this period, the results are presented so that they include the most probable range of the ensemble, i.e. the range of the most probable values. The risk remains relatively similar in the future periods, due to a change in the dynamics of phenological development and a lower probability of precipitation deficit in this period compared to the later warmer season. As no significant yield reductions were recorded in the period 2011-2020 that can be correlated with the climate hazards, it is not possible to assess with confidence the impact of the aforementioned climate hazards on yield in the future.

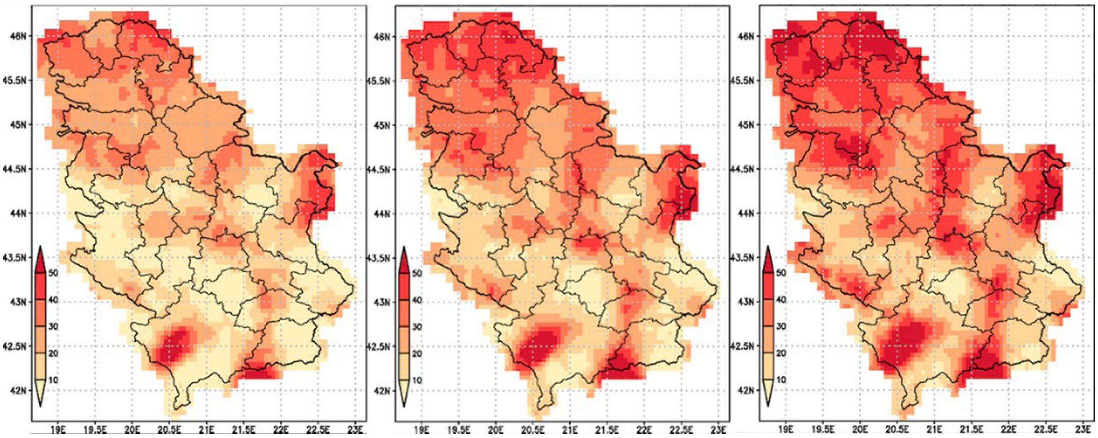

Figure A2.28. **The frequency of the occurrence of periods with a precipitation deficit in the period from head differentiation to grain filling in wheat, as specified in Table A2.5 in the mid-century climate period 2041-2060, for the most probable range of values, i.e. according to the climate model ensemble 25th percentiles (left side panel), median values (middle panel) and 75th percentiles (right side panel).**

Taking into account all the above potential climate hazard analyses for winter crops, it can be concluded that the precipitation deficit risk is most pronounced in the period from head differentiation to grain filling, but that in the observed period this risk did not cause significant yield reductions. As the frequency of this risk is up to 30% in the largest part of Serbia in the observed period (not shown here), this limit value will be considered as the threshold between a low risk level (level 1) and a moderate risk level (level 2), while in the areas with over 40% frequency (at least in a half of the years) in the future (Figure A2.28) according to the models' median value, are assigned the highest risk level – high risk (level 3). Figure A2.29 shows the risk level assessments by regions in Serbia with the distribution of wheat growing areas by regions. The presented risk levels indicate that the highest vulnerability is in the regions in the north of Serbia, while in other regions there is a probability of an increase in the risk that may cause damage in the future. As yield reductions were not significant and were not linked to climate hazards, it is expected that due to the climate hazard intensification, there will be an increase in the number of years with periods with higher risk and greater precipitation deficits due to the increased climate variability (*Appendix A1.3.4.*). However, for winter crops, due to the change in the dynamics of phenological development in future heat conditions and the completion of development before the period with the projected greatest decrease in precipitation, there is a high probability that the vulnerability to climate change due to the precipitation deficit will be moderate to low in the largest part of Serbia.

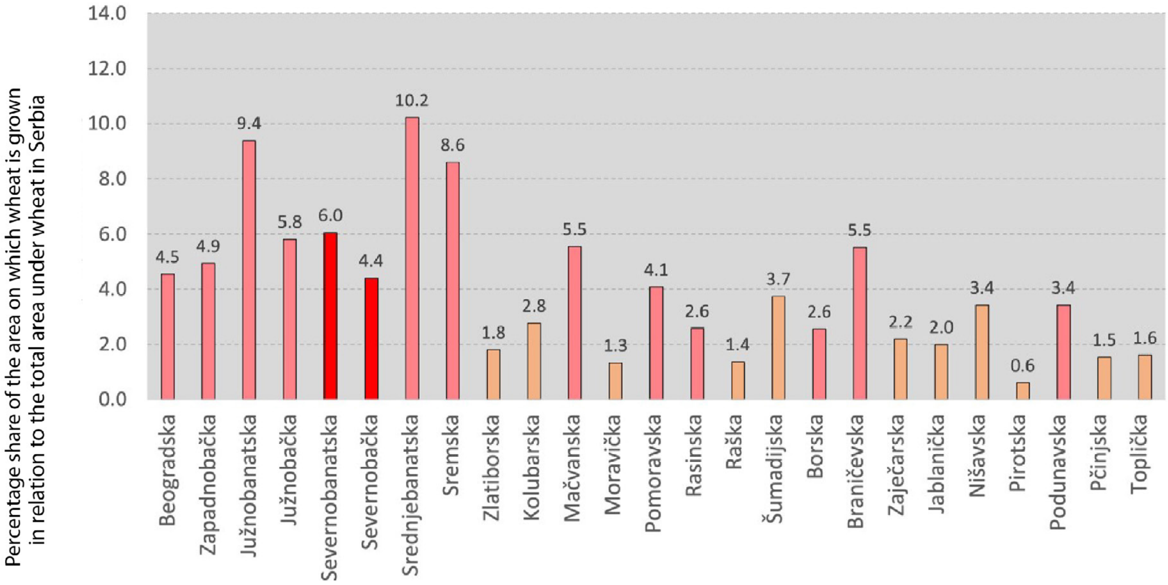

Figure A2.29. Risk assessment for the cultivation of wheat (and other winter crops) due to the occurrence of a period with a precipitation deficit during the period from head differentiation to grain filling, as specified in Table A2.5, and wheat growing areas distribution by administrative regions in the Republic of Serbia. Level 1 (low risk, orange colour) means that the risk of up to 30%, maintained in a large part of the region until the middle of the 21st century, level 2 (moderate risk, light red) means that the risk in a significant part of the region exceeds 30% by the middle of the 21 century, and level 3 (high risk, red colour) means that the risk in a significant part of the region exceeds 40% by the middle of the 21st century.

A2.5. Climate change impacts on meadows and pastures

The analysis of the climate change impacts on meadows and pastures was prepared as part of the impact assessment for the agricultural sector due to the indirect climate impact on livestock farming, through the availability of fodder. The climate hazards related to the sensitivity of meadows and pastures include increased drought frequency and intensity and increased dryness during the summer season (June-July-August, JJA) (Simić et al., 2022). In addition to the increased precipitation variability, the change in annual precipitation distribution and the precipitation decrease during the JJA season, the increased moisture deficit is also influenced by the temperature increase and the more frequent occurrence of extremely high temperatures (these climatic impact-divers are analysed in Appendices A1.2 and A1.3.). Grass species' drought tolerances varies significantly (Craine et al. 2013). Here, for the water scarcity climate risk assessment, the risk of insufficient precipitation amount during the JJA season is defined as the frequency of occurrence of the accumulated precipitation for this season below the specified limit value (150mm and 200mm). Figure A2.30 shows the frequency of occurrence of the accumulated precipitation below 150 mm during the JJA season in different climate periods. The values obtained for the occurrence frequency of the JJA season with the precipitation below 200 mm are not shown, because the risk values cover almost the entire area by the mid-century period, except at the highest altitudes, and mostly in the bordering western parts of the Republic of Serbia.

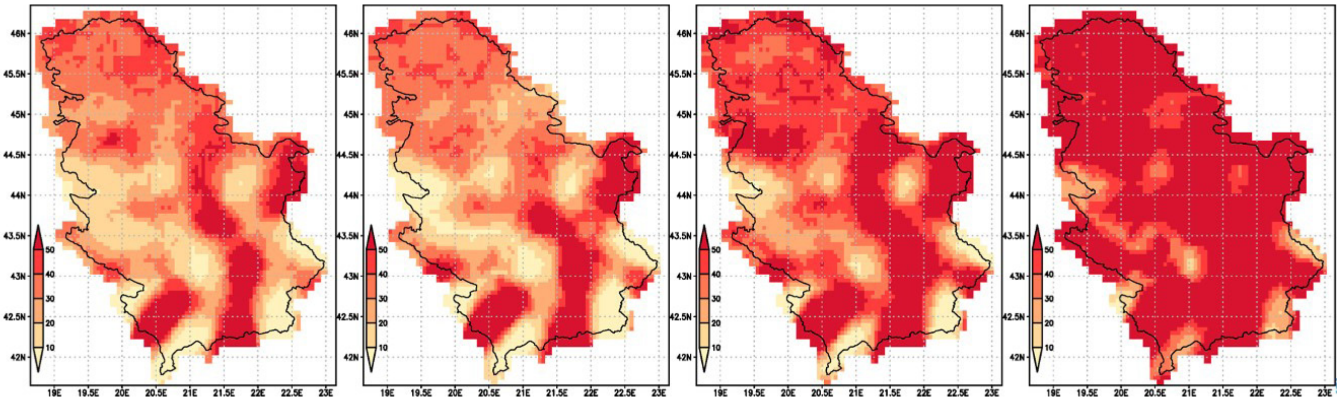

Figure A2.30. The frequency of occurrence of the JJA season precipitation sum below 150 mm in the climate periods: end-of -20th century (left side panel), the near-future period 2021-2040 (second panel), mid-century period 2041-2060 (third panel) and end-of-21st century 2081-2100 according to the RCP8.5 scenario (right side panel). The presented values are obtained based on the climate models ensemble 75th percentiles, which gives changes that are in line with the observed trend of change for this climate hazard.

Taking into account the changes in the identified climate hazards for meadows and pastures, the risk levels were identified as shown in Table A2.7. In addition, the risk assessments by administrative districts in the Republic of Serbia with meadows and pastures representation by district are provided in Figure A2.31.

Table A2.7. Criteria for identifying risk levels and their meaning, relating to risk of adverse climate change impacts of on meadows and pasture.

Risk level	Risk level meaning	Value in terms of data
level 1	low, acceptable, inconclusive, no significant change projected by the middle of the 21st century	the region is dominated by risk lower than 50%, and in the largest part of the region, it is not projected to reach the higher risk category in the future
level 2	moderate, an increase in the future projected by the middle of the 21st century	the region is dominated by risk lower than 50%, but the risk exceeds minimum 40% in the largest part of the region in the future
level 3	high, an increase in the future projected by the middle of the 21st century	in a significant part of the region has risk exceeding 50% and it is projected to increase in terms of spatial coverage and intensity in the future

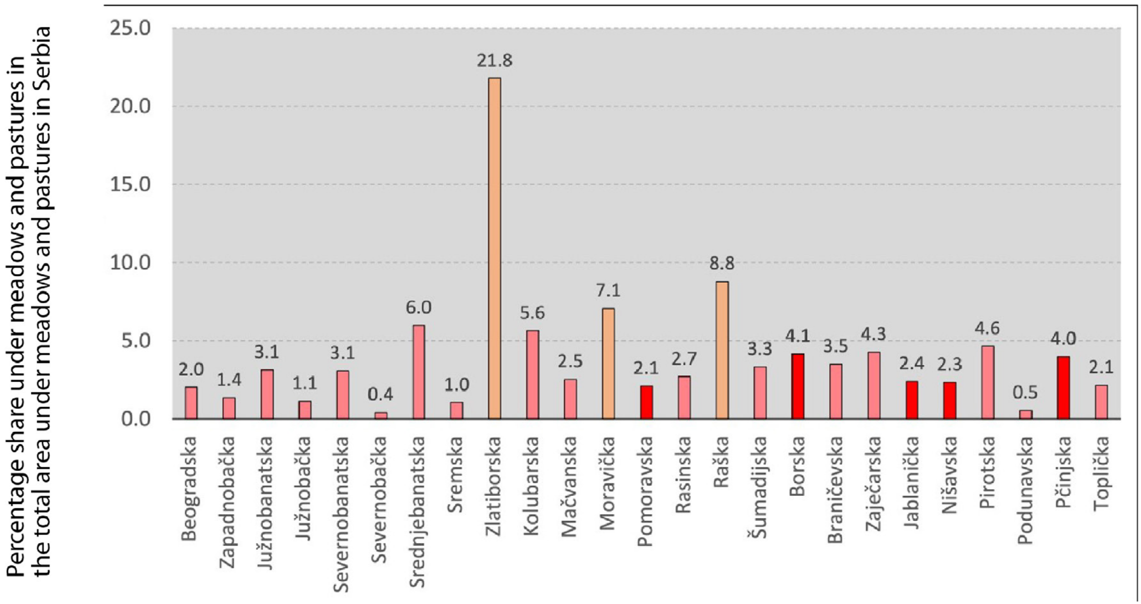

Figure A2.31. Precipitation deficit risk for meadows and pastures and meadows and pastures distribution by administrative regions in Serbia. The risk levels are identified in accordance with Table A2.7.

In the observed period, the areas at the greatest precipitation deficit risk are the areas in eastern Serbia, up to the border with North Macedonia. Even in the past, these areas had no conditions for intensive agricultural production or the production of fodder and livestock farming. Based on that, as well as the terrain configuration, which is generally unsuitable for land use and intensive cultivation, these areas have hillside and high-mountain pastures with a modest grass biomass yield, and are not considered particularly vulnerable. The highest JJA season precipitation amounts are present in the western areas of Serbia, from the area of Loznica in the north to the Pešter Plateau in the south. These areas are predominantly used for cattle and sheep breeding, and the majority of the sown meadows and pastures in Serbia are located in these areas. The most favourable areas for the further livestock farming development and thus pastures and meadows are: areas of western and southwestern Serbia, around the Drina river basin, Valjevo mountains, Tara and Zlatibor mountains, all the way to the border with Montenegro. In addition, in the east, there are areas around mountains Mučanj, Goč and Željin to Kopaonik. In principle, lower altitude grasslands are located in the northern part of Serbia, and have more favourable conditions for development due to different climate, soil and socioeconomic conditions. The soil has better agrochemical properties, it is more suitable for application of agro-technical measures (mowing, fertilizing, control of undesirable species), and the rural population is preserved and has a slightly better age structure than that in the hilly-mountainous areas. On the other hand, the grasslands located in the central part of Serbia, at higher altitudes, are in many ways in an unfavourable position. The natural conditions are less favourable for intensive production, the terrain is steeper, and the soil has poor agrochemical properties. In terms of climate, snow retention period in this area is longer, the winds easily dry out the shallow topsoil layer, even if slightly higher precipitation amounts and lower average temperatures have a favourable effect on the development of meadows and pastures. The grasslands at higher altitudes are frequently unmowed or rarely grazed.

The assessemnt of risk from precipitation deficit results indicate a growing risk in a large part of Serbia, especially in some central, eastern and southern regions, but also in other areas depending on the moisture requirements (Figure A2.31). The increase in the spatial distribution of risk and its intensification indicate the need for a more detailed analysis of this problem, taking into account the meadow and pasture locations and higher spatial resolution data, in order to better map the risks spatially and identify optimal adaptation measures and areas where these measures are urgently needed. In addition to livestock feeding, meadows and pastures conservation is important also for ensuring the provision of other ecosystem services, such as soil erosion protection, biodiversity conservation, etc.

In addition to the precipitation deficit, other risks, like already mentioned heat stress, but also the risk of intensification of precipitation need to be taken into account. Also, there is a need for further analysis to determine if there are significant risks of the appearance of invasive species of weeds, diseases and pests, etc. Certainly, by determining climate conditions and climate changes, identifying climate hazards and the associated risks, it is possible to apply measures that would ensure the conservation of these areas and the services they provide. For example, sowing high-quality grass varieties resilient to climate hazards and legumes, using varietal seeds, would ensure the hay or high-quality livestock grazing needs, contributing also to the suppression of weedy vegetation, which is undesirable in terms of the livestock nutrition.

A2.6. Climate change impacts on livestock breeding

In addition to the assessment of the climate change risk on the availability of livestock fodder, the direct climate change impact on livestock breeding includes the increased frequency of heat waves, i.e. the periods with high temperatures that stress living organisms. These climate hazards have also been recognized in the health, forestry, and agricultural plant production sectors. Other climate hazards for livestock farming, which will increase according to the climate change projections, include floods, wildfires, and droughts (*Appendix A1.6.*).

Figure A2.32 shows distribution the livestock headage share compared to the total number and the distribution by regions in the Republic of Serbia (Source: Serbian Statistical Office, data updated in 2021; distribution by regions is not available on the Serbian Statistical Office public website). The species taken into account are: pigs (a total of 2868 thousand livestock units), sheep (1695), cattle (860), and goats (195). The number of horses is significantly lower (13 thousand in total). The livestock is mostly pigs (51%), followed by sheep (about 30%), cattle (15%) and goats (3%). The largest share of pig farming is in the Vojvodina region (42%), followed by the Šumadija and western Serbia regions (34%), while the eastern and southern Serbia regions have the largest remaining share (19%). Sheep breeding is most prevalent in the Šumadija and western Serbia regions (62%). The highest number of cattle is in the Šumadija and western Serbia regions (46%), followed by the Vojvodina region (30%) and the eastern and southern Serbia (19%). The goat farming is somewhat more evenly represented across the regions. The Belgrade region has the lowest representation of all species (up to 5%).

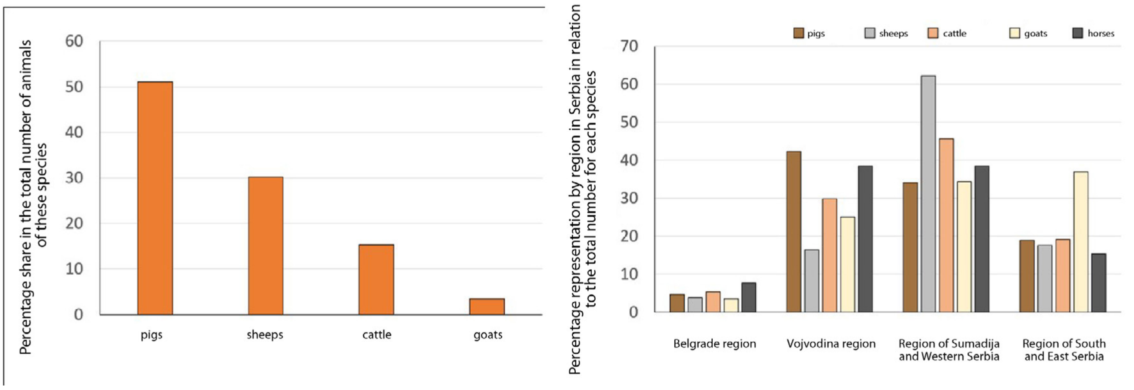

Figure A2.32. Percentege distribution by species in the total number of animals taken into account here, and the distribution by regions in the Republic of Serbia. Source: Serbian Statistical Office (2021).

The heat stress on livestock was analysed based on the Temperature Humidity Index (THI), which was found to correlate well with the observed heat stress on two farms (case studies: a farm in Vojvodina, Južnobački district, Municipality of Bečej, altitude 80m above sea level - representative for lowland areas; a farm in Mačvnski district, Municipality of Loznica, altitude 214m - representative for hilly lowland and upland areas). Taking into account the mean THI value calculated for these two locations, it is assumed that the risk assessment included most hilly lowland and upland areas where livestock farming is most prevalent. The average THI value (calculated for the warm period of the year, April-September) for the near-past period shows that in the last decade of the analysed observed period, which is also the warmest decade on the record in the Republic of Serbia (*Appendix A1.2.1.*), it is 72.1, i.e., it exceeds the critical value for this index. By the mid- 21st century period, it rises above 75, and by the end of the century almost to 80. The duration of the period with the increased risk of heat stress is extending, which is in line with the temperature rise (*Appendix A1.2.*). These results confirm that the temperature increase impact on livestock will be significant. Additionally, extremely warm periods, i.e. the increased frequency of heat waves and extremely high temperatures, show that the heat stress frequency, intensity and duration will be greater in the future. The consequences of the climate change impact on livestock are reflected in the reduced productivity, health deterioration, and reduced reproductive ability, and may cause an increase in the production costs.

As the livestock breeding representation is widespread in the territory of Serbia (Figure A2.32), there is a need to assess the spatial distribution of the heat stress risk, and specify other climate change risk factors for livestock production for different species.

A2.7. Climate change impacts on irrigation needs

The impact of climate change on the change in irrigation needs in the future was assessed taking into account the impact of climate change on the change in the irrigation amount and irrigation net rate (Stričević et al. 2019; Ćosić et al. 2022). This includes the impact of evapotranspiration and precipitation, which are changing due to climate change. The temperature increase significantly affects the increase in evapotranspiration, especially in the warmer part of the year, when there is also a decrease in precipitation during the JJA season (June-July-August). In order to roughly determine the changes in the irrigation needs, considering that the precipitation deficit has been identified as a high risk for a large number of cultivated species, representative points were identified for each administrative district and the net irrigation requirement calculated for the period from April to September.

The estimated net irrigation requirements for the near-past period (2000-2019) are shown in Figure A2.33 (this is the last climate period for which data were available at the time of the assessment and can be considered representative for the 2001-2020 period, which is used in the climate change assessment, *Chapter 2*).

Figure A2.34 - upper left panel, shows the distribution of areas by administrative regions taken into account in this analysis, which are used for growing specific crops (maize, small grain crops, sunflower, sugar beet, grapevine, fruit species with and without grass cover) and as meadows and pastures. For each group, water requirements were determined by districts, and the average is shown in Figure A2.34 - upper right panel. Due to the long growing season that covers the drier summer seasons, the apple, pear and plum fruit species have the highest water requirements, which is 50% higher in the grass covered orchards compared to those without grass cover. Apricot, peach and nectarine have significantly lower water requirements. In terms of field crops, sugar beet and corn have the highest water requirements. Considering that there has not been a significant sugar beet yield reduction recorded after 2012, and that most plantations are owned by legal entities (Figure A2.24), it is assumed that the cultivation of this species has adapted to weather conditions and other unfavourable influences, i.e. that irrigation and agro-technical measures are applied and have reduced the damage to the yields. For maize, the precipitation deficit and increasing temperature impact is pronounced, and the yield is sensitive to such extreme years (*Chapter 2.4.1.*). The presented results confirm the high water requirements of this crop. Small grain crops have the lowest water requirement, which is on average a surplus, i.e., sufficient water is available for their needs.

Taking into account the area coverage under cultivated crops and meadows and pastures by regions and their characteristics concerning water requirements , water requirements have been assessed, i.e. net irrigation requirement, by regions in Serbia (Figure A2.33) and the values by *regions per hectare* in relation to the average for the Republic of Serbia (Figure A2.34 – lower left panel). The highest requirements per hectare are in the following regions (in descending order): Zaječarski, Pčinjski, Nišavski, Jablanički, Srednjebanatski, Borski, Severnobanatski, Južnobanatski, Sremski, Zapadnobački, Braničevski, Toplički, Pomoravski and Pirotski. In these regions , the values per hectare exceed the average for Serbia. The lowest (23% of the average) is that in the Zlatiborski region.

The water requirement estimates by regions were obtained taking into account the growing areas with the above crops in the regions in the Republic of Serbia and the estimates per hectare. The distribution of water requirements in relation to the total value in the Republic of Serbia is shown in Figure A2.34 - lower right panel. According to those values, the regions with the highest water requirements are: Južnobanatski and Srednjebanatski (each about 10% of the total), followed by Sremski, Južnobanatski, Severnobanatski, Zapadnobački (in the range of 5%-8%), etc., and the districts with the lowest water requirements are (in order of increasing values): Pirotski, Zlatiborski and Toplički (below 2%).

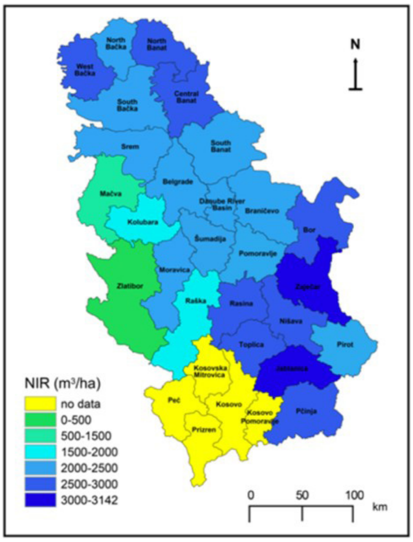

Figure A2.33. **Estimated net irrigation requirements by administrative regions in Serbia, based on meteorological parameters for one representative location in each district. The estimated values are the average for the near-past climate period 2000-2019 (the most recent period for which the data was available at the time of the assessment).**

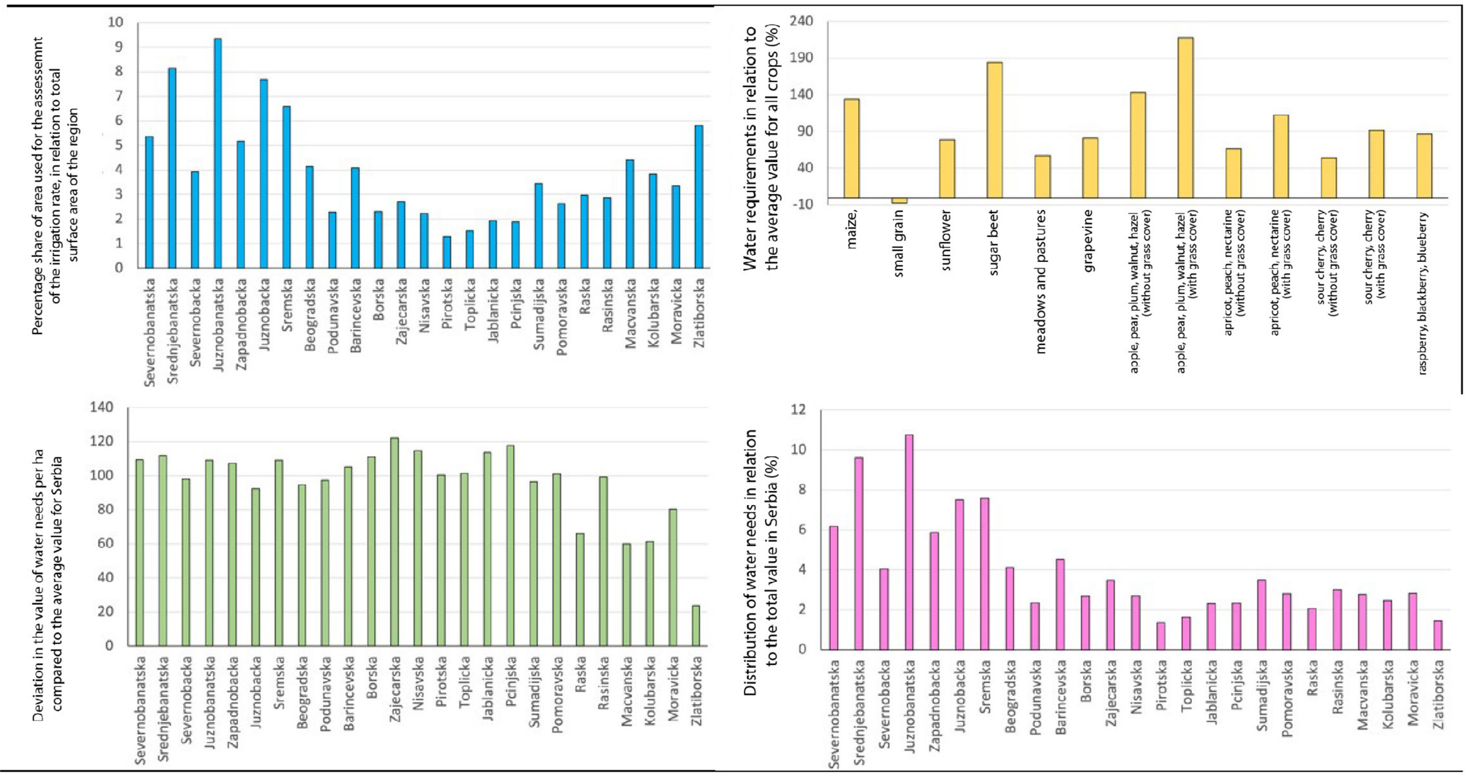

Figure A2.34. The percentage share of areas by administrative regions that were taken into account in the assessment of the net irrigation requirement in relation to the total area taken into account in this assessment in the Republic of Serbia (upper left panel). Average water requirement in the territory of the Republic of Serbia for specific groups of crops and for meadows and pastures (upper right panel). The percentage share of water requirement by regions per hectare in relation to the average requirement per hectare for the considered crops grown in the territory of the Republic of Serbia (lower left panel). The percentage share of water requirements by regions in relation to the total requirement in the territory of the Republic of Serbia (bottom right panel). The estimates are made for the climate period 2000-2019, where the only time-varying data are meteorological values.

The net irrigation requirement was assessed under the assumption that in the future the distribution of growing areas with specific crops, and the representation of those areas by districts will be unchanged, and taking into account future climate data for the same representative points by regions. In this case, the 1986-2005 period was taken as the base period (the last climate period before the greenhouse gas emission estimates using climate models, as done for IPCC, 2013). The estimated changes in the average net irrigation requirement values (per hectare) in the territory of the Republic of Serbia in future climate conditions (Table A2.8) show a significant increase in the average water requirement per hectare in the mid-century period 2041-2060 in the range of 17%-18%, and in the end-of-century period according to the RCP8.5 scenario, even by 44%-48%. The least significant changes are expected in the Vojvodina region, while in other parts of Serbia more significant changes are expected.

Table A2.8. **Change in the average net irrigation requirement for different climate periods (near-future period 2021-2040, mid-century period 2041-2060, end-of-century period 2081-2100 according to the RCP8.5 scenario) in relation to the end of the 20th century value. The range of change was determined based on the climate models ensemble median values and 75th percentiles.**

Period	Change relative to end of 20th century
2021-2040	2%-8%
2041-2060	17%-18%
2081-2100 (RCP8.5)	44%-48%

The presented estimates do not take into account the changes in the optimal sowing date, the plant phenological development dynamics, and the precipitation distribution during the period of the estimates. The changes in annual precipitation distribution and precipitation intensity due to future climate changes (*Appendix A1.3.*) could mean a greater water scarcity risk or greater water requirement than estimated here. It has to be noted that the assessment was made using one representative location for each district, i.e. the spatial variability of meteorological parameters within districts was not taken into account. In addition, the precise data on the distribution of cultivated crops and land cover species for the purposes of this assessment, as well as data on irrigated areas, were not available. However, the above estimates are in line with the previously mentioned crop vulnerability analyses and risk assessments and confirm the increased precipitation deficit risk and the increase in irrigation needs in order to preserve a relatively stable and high-quality yield.

Due to the growing irrigation needs and the increased threat to water resources used to meet those needs (*Appendix A1.5.1.*), it is important to ensure the irrigation system sustainability, i.e adaptation of the irrigation system to climate change.

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Appendix 3: Contribution to the assessment of climate change impacts on forests and forestry

In the process of developing the Programme, a study has been prepared to assess the climate change impacts on climate conditions favourable for the survival of the most represented types of trees in the Republic of Serbia in accordance with the National Forest Inventory (2009), i.e. tree species with sufficient abundance to estimate with confidence the future impact at the national level based on the available data.

The estimates were made in accordance with the RCP4.5 and RCP8.5 scenarios, for the 2041-2070 and 2071-2100 future periods. The period 1990-2019 was used as the base climate period and the estimates were made based on the E-OBS dataset. The data sources are described further in Appendix 1. The indicative estimates were calculated in accordance with the Forestry Aridity Index (FAI) and the Ellenberg Quotient (EQ) (the indices are explained in the Digital Climate Atlas: atlas-klime.eko.gov.rs), which proved to be adequate tools for understanding the current forest distribution. The FAI index takes into account July and August temperature and May to August precipitation, while the Ellenberg Quotient takes into account annual accumulated precipitation and temperature in the hottest month of a year (July).

The study results were published in Miletić et al. (2021; reference provided in Chapter 5.3), including the maps of projected changes in favourable climate conditions and the species distribution information. As an addition to these results, the here are given additional general estimates by administrative regions in the Republic of Serbia, shown in Figures A3.1 and A3.2.

The models based on FAI and the Ellenberg Quotient, which have been successfully used in the surrounding countries (Central Europe, Hungary), showed a good predictivity for fir, spruce, white and black pine and beech in the case of Serbia. For other forest species, these results do not have high confidence, but they can be taken into account as an rough estimates. It can be highlighted that the conditions for the main oak types (pedunculate oak, sessile oak, and turkey oak) also will be less favourable in the 21st century (Miletić et al., 2021).

The climate change analyses provided in Appendix 1 show that the estimates for the middle of the 21st century are known with high confidence, and that no significant differences are expected in the results obtained under these two scenarios, but that they are more intense than the previously estimated expected impacts. In addition, to select the most likely outcome in the future climate conditions, i.e. to select a representative value of the models ensemble results, changes in the relevant climatic parameters need to be analysed and observed. Furthermore, in addition to changes in the general climate characteristics shown by the indices selected here, the frequency of extreme conditions and other climate hazards that can cause greater and earlier appearance of negative impacts also has to be taken into account. Consequently, a more comprehensive climate analysis is recommended for the forestry sector decision-making purposes.

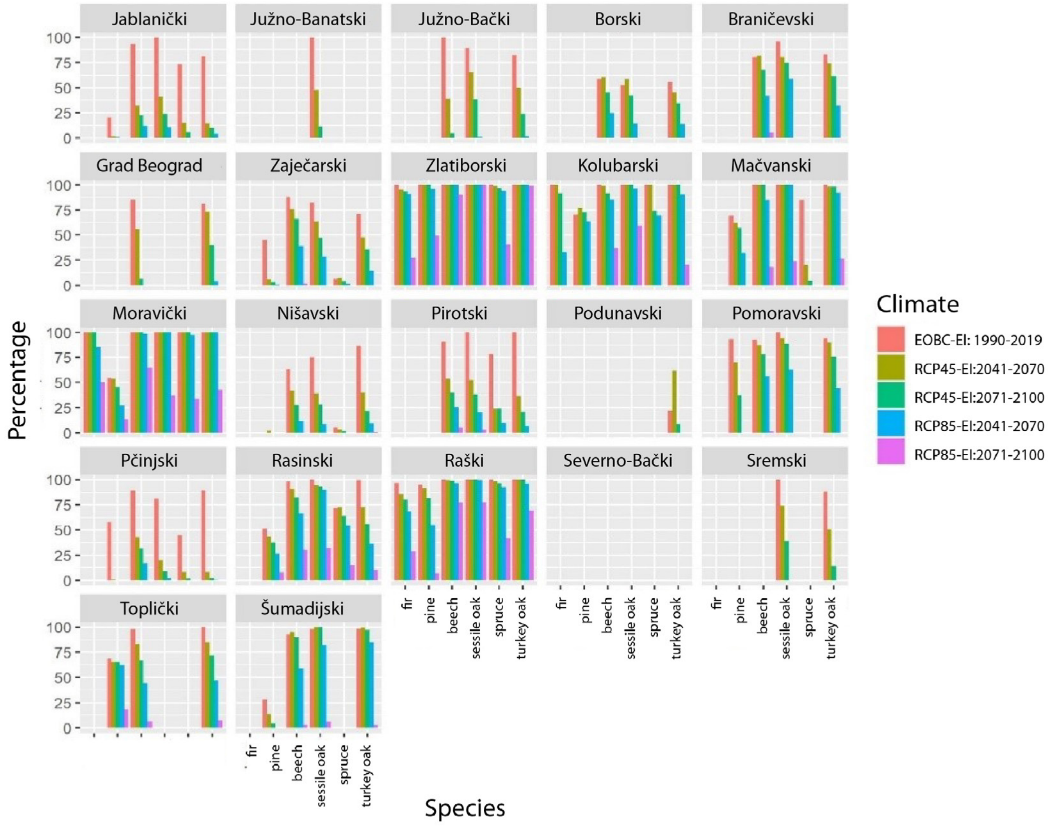

Figure A3.1. **The percentage share of suitable habitats for fir, pine, beech, sessile oak, spruce, and turkey oak by administrative regions in the Republic of Serbia. The estimates are obtained in accordance with Ellenberg Quotient.**

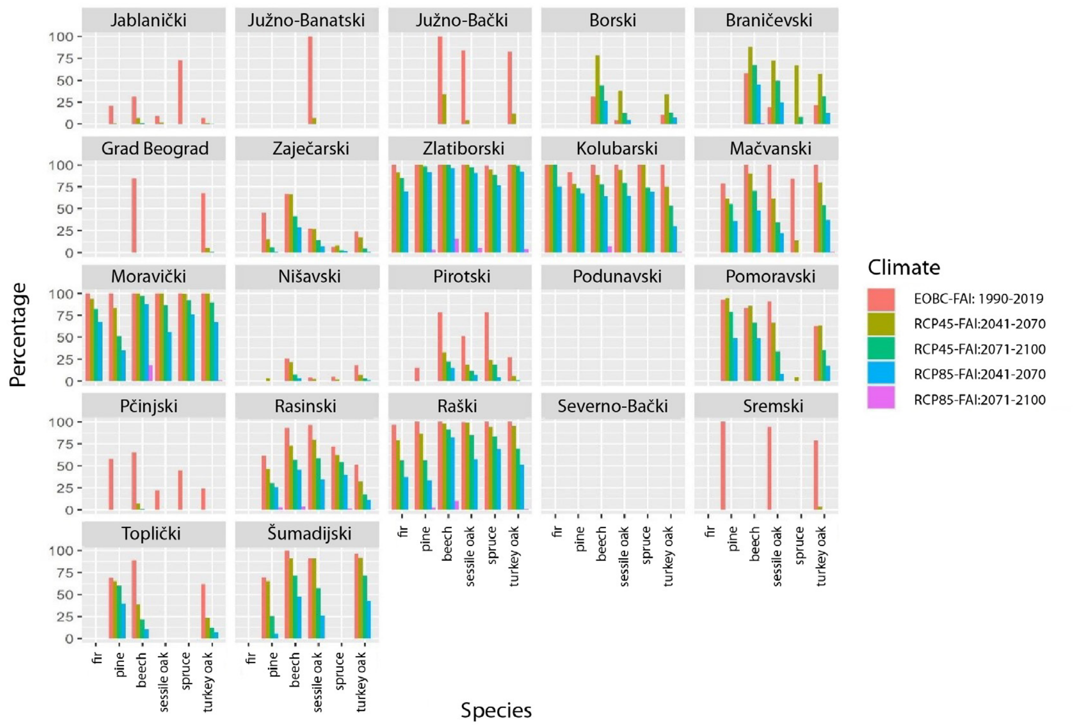

Figure A3.2. **The percentage share of favourable habitats for fir, pine, beech, sessile oak, spruce, and turkey oak by administrative regions in the Republic of Serbia. The estimates are obtained in accordance with FAI index.**