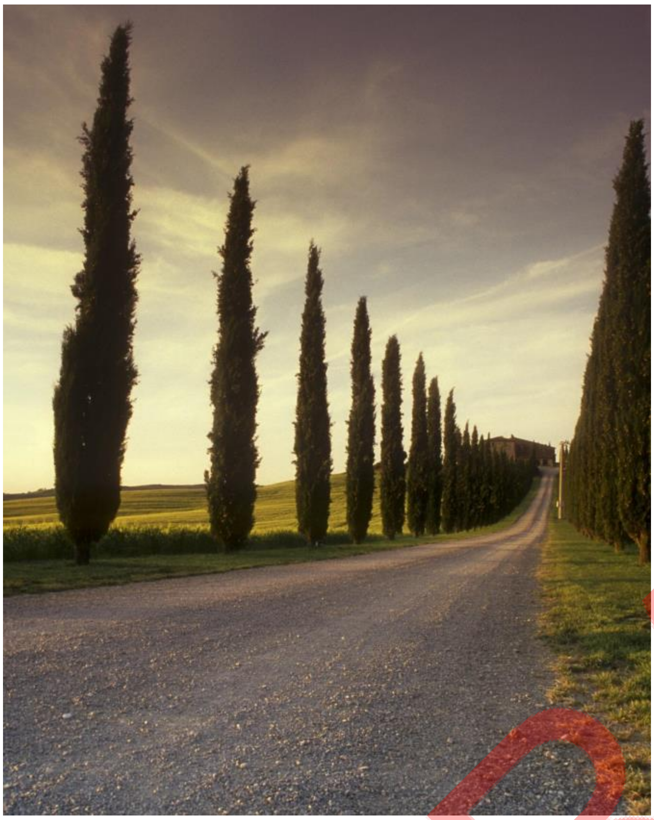

Analysis of Availability of Climate and Socioeconomic Information, Including Climate Data, Data on Risks and Impact Assessments, and Information on Adaptation Measures

REPORT 1

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List of Abbreviations

GHG	Greenhouse gases
HPC	High Performance Computing
RHMS	Republic Hydrometeorological Service
MPGs	Decision 18/CMA.1 on Modalities, Procedures and Guidelines
UNFCCC	United Nations Framework Convention on Climate Change
CMA	Conference of the Parties serving as the meeting of the Parties to the Paris Agreement
INC	Initial National Communication of the Republic of Serbia under the UNFCCC
IPCC	Intergovernmental Panel on Climate Change
M&E	Monitoring and Evaluation
SNC	Second National Communication of the Republic of Serbia under the UNFCCC
SPEI6	Standardized Precipitation-Evapotranspiration Index
RCM	Regional Climate Models
RCP	Relative Concentration Pathways
TNC	Third National Communication of the Republic of Serbia under the UNFCCC
WMO	World Meteorological Organization

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1. INTRODUCTION

A significant number of analyses confirm the sensitivity of the European continent to climate change, which will become more pronounced over time, especially in the absence of adaptation. Thus, the increase in the average global temperature results in a decrease in working capacity, but also a change in the length of ripening, the flowering period of plants, the water content in the soil and groundwater levels, i.e. through negative consequences for agricultural production. Energy needs for heating are decreasing, and for cooling, they are increasing with the increase of the average global temperature. At the same time, changes in the amount of precipitation can jeopardize the production of energy that depends on surface water-cooling (which raises the temperature) and hydropower.

According to the same analysis, the southern parts of Europe, including a part of Serbia, can be affected by a significant loss of water resources, and the European soil as a whole by an increase in the risk of floods. Floods on the other hand, especially in the coastal areas of Europe, are threatening traffic and other critical infrastructure. Increasingly pronounced and frequent drying of vegetation and drying of land in the southern parts of Europe leads to an increase in the risk of fire, and heat waves to an increase in the number of deaths.

In general, countries in southern Europe will be more exposed to the negative effects of climate change than those in the north[1].

By the way, the consequences of global warming are already visible above the European mainland. The rise in global temperatures has also affected the warming of Europe in the last 50, and especially the last 30 years. It is important that European soil warms significantly faster than the global average. Climate projections indicate a further rise in temperatures between 1.0 ° C and 2.5 ° C in the period 2021-2050, and between 2.5 ° C and 4.0 ° C in the period 2071-2100. The warmest year recorded so far in Europe was 2019, and 11 of the 12 warmest years were registered after 2000.

According to the official data of the Republic Hydrometeorological Service, 2019 has been the warmest year for the territory of the Republic of Serbia since 1951, whith the average annual air temperature of 12.3°C[2]. In Belgrade, 2019 has been the warmest year since 1888, when measurements at the Karadjordjev Park meteorological station started. Moreover, thirteen out of fifteen warmest years in Belgrade were recorded after 2000.

The first half of the summer of 2019 was characterized by the frequent occurrence of torrential floods. At the end of June, floods in Belgrade led to a collapse in traffic and significant damage, especially to residential buildings. In 2019, the warmest autumn ever was recorded, followed by the longest recorded October heatwave (17 days) and extreme drought, which brought many farmers into trouble with fieldwork. For eight months, the monthly average temperature was above normal, in January and July it was normal, and only in May it was below normal, in relation to the average values for the period 1981-2010.

[1] Climate impacts in Europe, Final report of the Joint Research Center PESETA III project, 2018 / Impacts of climate change in Europe, Final report of the PESETA III project of the Joint Research Center

[2] http://www.hidmet.gov.rs/podaci/meteorologija/ciril/2019.pdf

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In the last two decades, numerous hydrological and meteorological extremes (floods, frosts, heat waves, droughts ...) have been recorded in Serbia, where the following can be especially emphasized: 2007 with exceeded absolute maximum temperatures, 2002, 2005, 2006, 2009, 2010 and 2014 with the occurrence of floods and extreme rainfall, 2012, 2015 and 2017 with heat waves and 2000, 2003, 2007, 2011, 2012, 2013, 2015 and 2017 as extremely dry years.

Analyses for the territory of Serbia[3] also show that the average annual temperatures from 1998 to 2017 increased by 0.5 – 1.5°C (in some parts up to 2°C, compared to the values for the period 1961 - 1990. A particularly pronounced warming trend is observed from 2008 to 2017. In the last decade, the number of summer days (highest daily temperature higher than 25 degrees) increased by 25 days, while the number of cold and frosty days decreased significantly, showing evolving trends in climate change. Climate change has also led to changes in seasonal rainfall redistribution and intensity. The number of days with extreme rainfall in recent years has more than doubled, compared to the average values of the mid-twentieth century. The disturbed rainfall regime causes an increased risk of flooding during the spring and autumn months and an increased risk of drought during the summer.

If the increase in the concentration of greenhouse gases (GHG) in the atmosphere is not stopped, a further rise in temperature, frequent record-breaking temperatures, more frequent, longer and more intense heatwaves, more frequent and more intense extreme precipitation and floods associated with them can be expected. Specifically, by the end of the 21st century in Serbia, we can expect an increase in the average annual temperature by 4.3°C, compared to the period from 1961 to 1990, and this change accompanied by changes in the precipitation regime can lead to:

- Higher frequency and duration of heatwaves and dry periods,
- Higher risk of floods and loss of water resources,
- Reductions in the availability and quality of drinking water,
- Reductions in agricultural crop yields,
- Higher energy consumption during the summer months,
- Damage and destruction of infrastructure and disruption of production and provision of services,
- Increased frequency of forest fires,
- Loss of biodiversity,
- Higher risks to human health.

These data and information indicate the importance of including aspects of climate change in strategic planning and investments. At the same time, in order to reduce the risk and losses that occur as a result of climate change, an efficient and transparent system of monitoring and reporting on climate change and its impacts, consequences, and losses for the society and economy of Serbia is necessary.

Planning and reporting on adaptation is also a requirement of the Paris Agreement and, in particular, Decision 18/CMA.1 (Decision 18/CMA.1 on Modalities, Procedures and Guidelines (MPGs) for the transparency framework for action and support), as well as EU relevant legislation, primarily requirements of Regulation 2018/1999 and the European

[3] Observed climate change in Serbia and climate change projections, https://www.klimatskepromene.rs/wp-content/uploads/2019/04/Osmotrene-promene-klime-Final_compressed.pdf

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Climate Law (REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 – European Climate Law) published by the European Commission on 3 March 2020.

Otherwise, the main goal of the monitoring and reporting system is to improve policies and adaptation measures, ie to provide the necessary information, above all, to decision-makers. The essence of this system is in:

- Systematic and comprehensive collection of data and information relevant to climate change, their exchange and availability to the public, as well as
- the capacity of target groups to recognize the importance and essence of data on climate change and include them in the planning of activities in the field of their activities.

Data and information and their availability ie identified needs, are the subject of this report. The report presents the current situation, together with a list of identified needs, in order to make an analysis and/or implement the given recommendations. The report also includes information based on analyzes and assessments made at the EU level. The report is divided by sectors and for each sector, except for the chapter Observed and expected climate change, it contains information related to:

1) Impact assessment - a chapter that presents the basic characteristics of the sector, done so far in the sector from the aspect of impact assessment at the international, EU and national level, including used methodologies, data and data sources, identified problems and shortcomings;

2) Adaptation measures - the chapter presents measures identified/proposed so far and actions adaptation to changed climatic conditions, national and experiences at the international and EU level;

3) Conclusions and recommendations - which define the list of needs and especially proposals for further analyzes and improvements in sectors that will contribute to more efficient adaptation, including methodologies, methods and approaches, in accordance with available information that would be implemented within the Project.

Certain recommendations are based on the needs and international experiences and good practices, but their implementation depends, to a large extent, on the availability of the necessary data, as well as the capacity of national institutions.

In case of changes and deviations from the recommendations for the implementation of activities within this project, they will be explained in the final report.

The report is mainly based on experiences in drafting National Reports under the UN Framework Convention on Climate Change (UNFCCC), the first draft of the National Adaptation Plan, sectoral strategic and planning documents, as well as research and scientific work of the report. It takes into account the requirements of the Paris Agreement, Decision 18/CMA.1 and EU relevant legislation, as well as examples of good practice globally.

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2. OBSERVED CLIMATE CHANGE AND CLIMATE SCENARIOS

2.1. Previous analyzes

The observed climate change on the territory of the Republic of Serbia was analyzed through all three National Communications of the Republic of Serbia under the United Nations Framework Convention on Climate Change (UNFCCC).

The First Communication (INC, 2010) analyses the trends of average annual and seasonal temperatures and precipitation from the network of stations of the Republic Hydrometeorological Service of Serbia (RHMS) for the period 1950-2004, as well as anomalies of the same parameters for the periods 1971-2000 and 1961-1990. In the Second Communication (SNC, 2017), at the points of 25 meteorological stations of the RHMS network, the observed trends of average annual and seasonal temperatures and precipitation were analyzed, as well as 17 indices that are important for the analysis of climate and extreme weather events and recommended by the World Meteorological Organization (WMO)[4]. These analyses were performed by RHMS using its database of observed meteorological data.

For the analysis of observed climate changes on the territory of Serbia, the Third Communication (Draft TNC, 2020) uses daily gridded temperature and precipitation datasets on the 10km resolution network from the E-OBS[5] and DanubeClim[6] databases. E-OBS is a database of gridded observed meteorological data collected from operational meteorological services in Europe within the European Climate Assessment & Dataset – ECA&D project, which is regularly updated. DanubeClim (Climate of the Danube Region) is an atlas of observed meteorological data in the Danube basin, which includes daily gridded observed meteorological data for the period from 1961 to 2010, and is the result of the CARPATCLIM[7] (Climate of the Carpathian Region) project. DanubeClim and CARPATCLIM are projects within which an atlas of grid observed meteorological data has been prepared. The from the state network of synoptic, climatological and precipitation stations under the jurisdiction of RHMS[8] were used for the territory of the Republic of Serbia. Based on these data, the average climatological annual and seasonal values of average, minimum and maximum temperatures and precipitation, 15 climate indices for the period March-August, for the periods 1998-2017 and 2008-2017 were calculated. The frequency of drought was analyzed using the annual values of the SPEI6 (Standardized Precipitation-Evapotranspiration Index) drought index for

[4] WMO, 2009, Guidelines on Analysis of extremes in a changing climate in support of informed decisions for adaptation

[5] https://www.ecad.eu/download/ensembles/download.php#datafiles

[6] http://www.carpatclim-eu.org/danubeclim/PagesAspx/Download/default.aspx

[7] http://www.carpatclim-eu.org

[8] The Republic Hydrometeorological Institute, as a member of the working group, participated in the preparation of the Disaster Risk Assessment in the Republic of Serbia (adopted at the session of the Government of the Republic of Serbia on March 14, 2019), according to the Methodology for Risk Assessment RHMS, as the coordinator and executor of the Assessment of the vulnerability of the Republic of Serbia to weather disasters, prepared a risk assessment for extreme weather events (large amounts of precipitation, hail, stormy winds, snowstorms and precipitation, ice, heat and cold waves and drought). The assessment of the risk of natural disasters at the municipal level is in progress, as well as the preparation of protection and rescue plans in emergency situations.
The occurrence of drought and heat waves was one of the 4 groups of hazards for which a risk assessment was performed. The frequency and intensity of drought was determined using a quarterly STI index and the overall risk level and risk map were done for two scenarios (most likely adverse event and adverse event with the most severe possible consequences).

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the period from March to August, from 1890-2017 for Belgrade and 1950-2017 averaged for other stations over the territory of Serbia. This index is calculated on the basis of data on the amount of precipitation and evapotranspiration of temperature and represents the difference between the sum of precipitation and evapotranspiration, which is presented through the appropriate statistical distribution. The values of the difference between the sum of precipitation and evapotranspiration can be accumulated for different time periods. The advantage of SPEI over other drought indices is that it easily identifies the role of evapotranspiration and temperature variability in drought analysis.

Future climate change in all three communications was analyzed based on the results of regional climate model (RCM) simulations under the current IPCC greenhouse gas emission scenarios. The First and Second Communications analyze the results of the related (atmosphere-ocean) regional model EBU-POM (ETA Belgrade University – Princeton Ocean Model) under SRES (Special Report on Emissions Scenarios) scenarios A1B and A2 of the Intergovernmental Panel on Climate Change (IPCC). The horizontal resolution of the data used was about 25km. The reference period was 1961-1990 (standard climate period), and climate change was analyzed by the end of the 21st century.

In the First Communication, only changes in annual and seasonal temperatures and precipitation in the future in relation to the reference period were analyzed, while in the Second Communication, the model results were statistically corrected to reduce the systematic error common in numerical climate models (BIAS). Namely, all numerical climate models contain errors due to insufficient quality of input data, ways of parameterization of complex physical processes in the climate system and applied numerical methods. Therefore, it is especially important how the results of climate simulations are interpreted. The simplest way is to show the change in meteorological parameters for a certain future period in relation to the selected reference period in the past (the so-called delta approach). However, this approach can only show monthly, seasonal and annual changes in average temperatures and precipitation. In order for the simulation results to be used to calculate different indices and as input data to climate change impact models in different sectors of the economy (e.g. hydrological models, water management models, time-plant models (so-called CROP models) and the like), it is necessary to statistically correct them on a daily basis by comparing them with the meteorological parameters observed during the reference period. That is why it is extremely important to have as many long series of daily observations at meteorological stations across the country as possible.

Using the corrected results, changes in 17 climate indices in the future were calculated, and daily temperature and precipitation values were then used in various impact models on the basis of which vulnerability assessments were performed in individual sectors. The corrected model simulation data and the results of these analyses are publicly available in the database[9]. The change in average annual and seasonal temperatures and precipitation shown in the Second Communication was compared with an ensemble of 16 other RCMs, publicly available through the ENSAMBLES project database, to determine whether the results of the climate model used are in the most likely range of changes given by the ensemble of several different models.

In the Third Communication, future climate change was analyzed based on the results of an ensemble of 9 RCMs from the EURO-CORDEX database under RCP4.5 and RCP8.5 (Relative Concentration Pathways) IPCC scenarios for greenhouse gas emissions, at a horizontal resolution of about 12km. The analysis of the results of the ensemble of several

[9] http://haos.ff.bg.ac.rs/climatedb-srb/

models instead of only one, as was the case in the first two reports, also enabled the assessment of the uncertainty of the results of simulations of the future climate. This is especially important for assessing precipitation change, as Serbia is in a transition area between increased rainfall in the north and decreased rainfall in the south of Europe. The better resolution of the simulations used in relation to the previous two reports enabled a more detailed spatial analysis of the projected climate changes, which is especially important in areas with pronounced orography (hilly and mountainous areas). The selected reference period (1986-2005) is aligned with the Fifth IPCC Communication. Changes in average annual and seasonal temperatures, precipitation and 17 climate indices were analyzed, and statistically corrected model results were used in impact models to assess vulnerability to climate change in certain sectors of the economy.

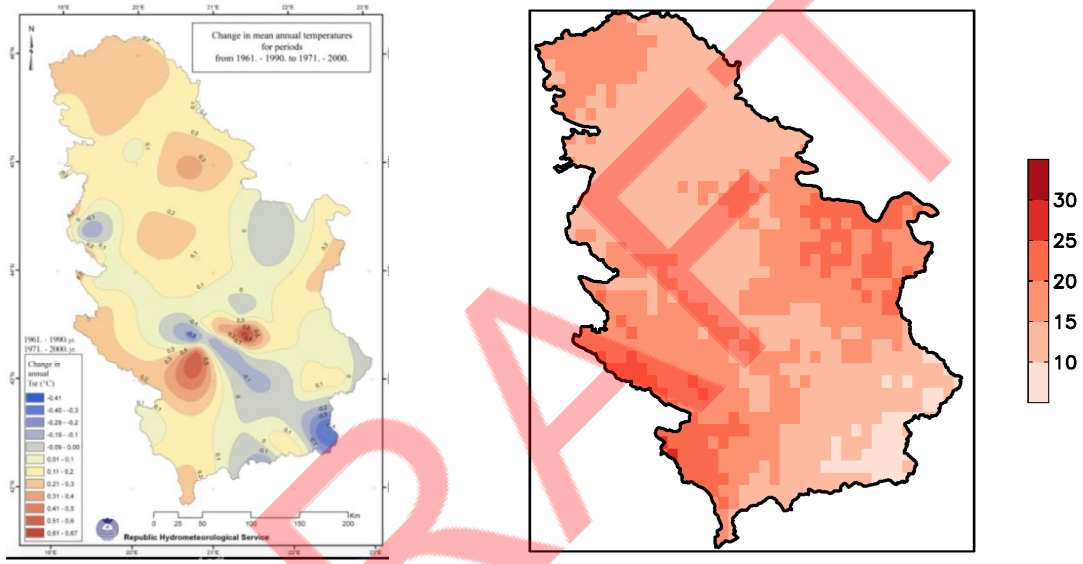

Figure 1. *Example of the results of the observed changes in the average annual temperature from the First (left) and the Draft Third Communication (right) of the RS under the UNFCCC*

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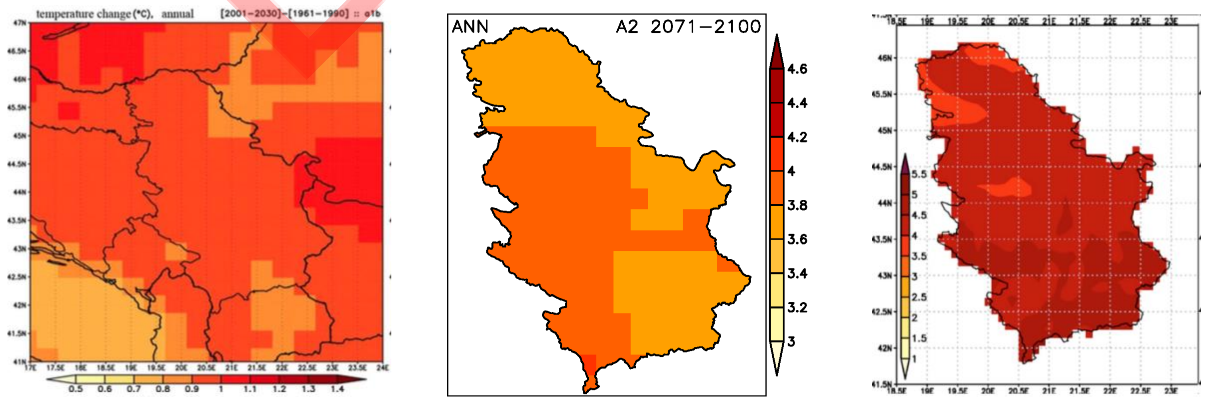

Figure 2. *Example of the results of the projections of the future change in the average annual temperature from the First (left), Second (middle) and the Draft Third Communication (right) of the RS under the UNFCCC*

An overview of the observed and simulated meteorological data used in the First (INC), Second (SNC) and Draft Third (TNC) Communication of the Republic of Serbia under UNFCC is shown in Table 1, below.

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Table 1. *Overview of the observed and simulated meteorological data used in the First (INC), Second (SNC) and Draft Third (TNC) Communication of the Republic of Serbia under UNFCCC*

	OBSERVATIONS	SIMULATIONS FOR THE FUTURE
INC	**Data:** observed average monthly precipitation and average monthly temperatures from the network of RHMS stations for the period 1950-2014 **Source:** RHMS internal database **Results:** trends, anomalies, climatological normals 1971-2000 and 1961-1990	**Data:** daily Tmin, Tmax, Taverage, precipitation (RR) from RCM EBU-POM, resolution 25 km, IPCC SRES scenarios A1B, A2, reference period 1961-1990, future periods 2001-2030 and 2071-2100 **Source:** Institute of Meteorology, University of Belgrade – Faculty of Physics (available on request) **Results:** anomalies of average annual and seasonal temperature and precipitation values on the 25km resolution network
SNC	**Data:** observed daily Tmin, Tmax, Taverage, RR from 25 stations of the RHMS network **Source:** RHMS internal database **Results:** trends of average annual and seasonal values and 17 climate indices at stations	**Data:** daily Tmin, Tmax, Taverage, RR from RCM EBU-POM, resolution 25km, IPCC SRES scenarios A1B, A2, reference period 1961-1990, future periods 2011-2040, 2041-2070, 2071-2100 and daily Tmin, Tmax, Taverage, RR from 20 RCM from the ENSEMBLE project for the same periods and scenarios **Source:** Institute of Meteorology, University of Belgrade – Faculty of Physics (available on request) ENSEMBLE project (http://ensemblesrt3.dmi.dk/) **Results:** average annual and seasonal T and precipitation values and 17 climate indices and on the 25km resolution network Publicly available database (http://haos.ff.bg.ac.rs/climatedb-srb/)
Draft TNC	**Data:** daily data Tmin, Tmax, Taverage, RR gridded at 10km and average monthly data on T and precipitation at the Belgrade station **Source:** E-OBS and DanubeClim databases **Results:** anomalies of average climatological annual and seasonal values of average, minimum and maximum T and precipitation, 15 climate indices, for the periods 1998-2017 and 2008-2017 in relation to the reference period 1961-1990, on the 10km resolution network; annual values of the SPEI6 drought index for the period 1890-2017 for Belgrade and 1950-2017 averaged over the entire territory of Serbia	**Data:** daily Tmin, Tmax, Taverage, RR from 9 RCM from EURO-CORDEX project, resolutions around 12km, IPCC scenarios RCP4.5 and RCP8.5, reference period 1986-2005, and future periods 2016-2035, 2046-2065, 2081-2100 **Source:** publicly available EURO-CORDEX project database (http://ensemblesrt3.dmi.dk/) **Results:** average annual and seasonal T and precipitation values and 17 climate indices and on the 12km resolution network

In addition, DanubeClim (Climate of the Danube Region) and CARPATCLIM (Climate of the Carpathian Region) are projects within which an atlas of gridded observed meteorological data has been prepared. As RHMS participated in the projects, the data from the state network of synoptic, climatological and precipitation stations under the jurisdiction of RHMS were used for the territory of the Republic of Serbia.

2.2. Data collection and availability

According to the Law on Meteorological and Hydrological Activity ("Official Gazette of the Republic of Serbia", No. 88/2010), the Republic Hydrometeorological Service of Serbia is, among other things, responsible for planning, establishing, maintaining and developing the state network of meteorological and hydrological stations as well as conducting systematic meteorological and hydrological measurements and observations within that network. The data collected from the station network undergo quality control and are then distributed, exchanged, archived and stored. Archived data make up the fund of official meteorological and hydrological data and information.

Meteorological and hydrological data and information are publicly available on the RHMS website and are submitted to the competent institutions in the form of periodic reports that may contain various forms of presentation, text, graph, table, map. The publicity of meteorological and hydrological data and information obtained by performing meteorological and hydrological activities of importance to the Republic of Serbia is defined by Article 30 of the Law on Meteorological and Hydrological Activity ("Official Gazette of RS", No. 88/2010). Thus, part of the collected meteorological data is publicly available within the yearbooks, which are published on the RHMS[10] website in the middle of the year for the previous calendar year. These yearbooks contain daily observed values of meteorological parameters for 6 main (synoptic) stations and average monthly observed values for other network stations. This yearbook does not include data from precipitation stations, but only from main and ordinary meteorological stations. Given the greater spatial variability of precipitation, precipitation analysis requires a larger number of observed data, i.e. measuring stations. The data are presented in a table, and the document is in PDF format, which makes it difficult to automatically download data. For the period from 1949 to 1991, only scanned yearbooks are available, and the visibility of data in some cases is very poor.

Observed daily (and term) data are stored in the RHMS internal database and access to this information is charged. The fee is charged in accordance withIt is important to note that data from all meteorological stations from the RHMS network, including precipitation data that met the required criteria for the availability of the required time series, were used to create the last two mentioned grid databases of monitored daily meteorological parameters. the Law on Meteorological and Hydrological Activities ("Official Gazette of RS", No. 88/2010) when additional information is issued at the request of the user. The amount of the fee is determined by the Decree on determining the fee for the provision of services in the field of meteorological and hydrological activities ("Official Gazette" No. 37/13). The situation is similar with hydrological data that are published in hydrological yearbooks. On the other hand, most EU Member States and the EU itself have this type of data publicly available.

In addition to meteorological and climatological observations, agrometeorological and phenological observations are also carried out at some stations. Historical phenological data have been partially digitized and are in the RHMS internal database, which is not publicly available.

[10] http://www.hidmet.gov.rs/latin/meteorologija/klimatologija_godisnjaci.php

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On the other hand, there are several publicly available grid databases of daily meteorological observations (E-OBS, DanubeClim, CarpathClim) which generally have a resolution of about 10km. It is important to note that data from all meteorological stations from the RHMS network, including precipitation data that met the required criteria for the availability of the required time series, were used to create the last two mentioned grid databases of monitored daily meteorological parameters. This is often not enough for research purposes, especially those covering areas at higher altitudes (temperature and precipitation estimates are not satisfactory). Handling these data requires some knowledge of certain software packages and can be a problem for researchers in scientific fields in which the format used is not common. In addition, of the listed databases, only E-OBS is regularly updated, while the other two were made by the end of 2010.

Additionally, RHMS, in cooperation with the Institute of Meteorology, Faculty of Physics, University of Belgrade, developed climate simulations RCM EBU-POM (horizontal resolution 25 km) under the IPCC name RCM NMMB (non-hydrostatic multiscale model on the B network) under the IPCC scenario RCP8. 5 at a horizontal resolution of about 8km. The results of all simulations are available on request and have been used in several studies in different sectors.

An additional problem for future research and analysis is the reduction of the number of measuring stations on the territory of the Republic of Serbia. From 2011 until today[11], the total number of main meteorological and ordinary climatological stations has decreased from about 100 to about 65[12], precipitation from about 550 to about 250, the number of stations where agrometeorological and phenological measurements are performed from about 50 to about 30, while soil moisture is measured at 9 meteorological stations.[13]

The reasons for these changes are not known.

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[11] http://www.hidmet.gov.rs/podaci/download/RHMSSrbije_Godisnjak_2011.pdf

[12] http://www.hidmet.gov.rs/podaci/meteo_godisnjaci/Meteoroloski%20godisnjak%201%20-%20klimatoloski%20podaci%20-%202018.pdf

[13] State network of meteorological and hydrological stations are regulated by the "Decree on determining the locations of meteorological and hydrological stations of state networks and protective zones in the vicinity of those stations, as well as the types of restrictions that can be introduced in protective zones" ("Official Gazette of RS", No. 34/ 13) and the "Decree on determination of the state network of meteorological stations, work programs and reporting methods of the state network of meteorological stations" ("Official Gazette of the RS", no. 123/12), and consist of: 32 stations that work according to the synoptic observation program (hourly measurements), 65 meteorological stations that work according to the climatological program (measurements are made three times a day), 316 locations where measurements are made according to the precipitation station program (daily), 13 meteorological radars, 2 radiosonde stations, 46 automatic meteorological stations, 47 automotive rain gauges. Within the national network of meteorological stations, there are stations that work in accordance with the program of agrometeorological measurements and observations: 9 automatic stations for soil moisture measurement, 16 stations for soil temperature measurements, 1 station for measuring evapotranspiration using a weight lysimeter, 30 phenological stations and 5 stations that measure evaporation from the free water surface. The hydrological observation system consists of 183 surface water hydrological stations, 343 groundwater stations (three main ones with 12 piezometers, 168 stations of the first order and 160 stations of the second order) and 113 automatic hydrological stations of surface water and 58 stations for measuring the level of underground water.

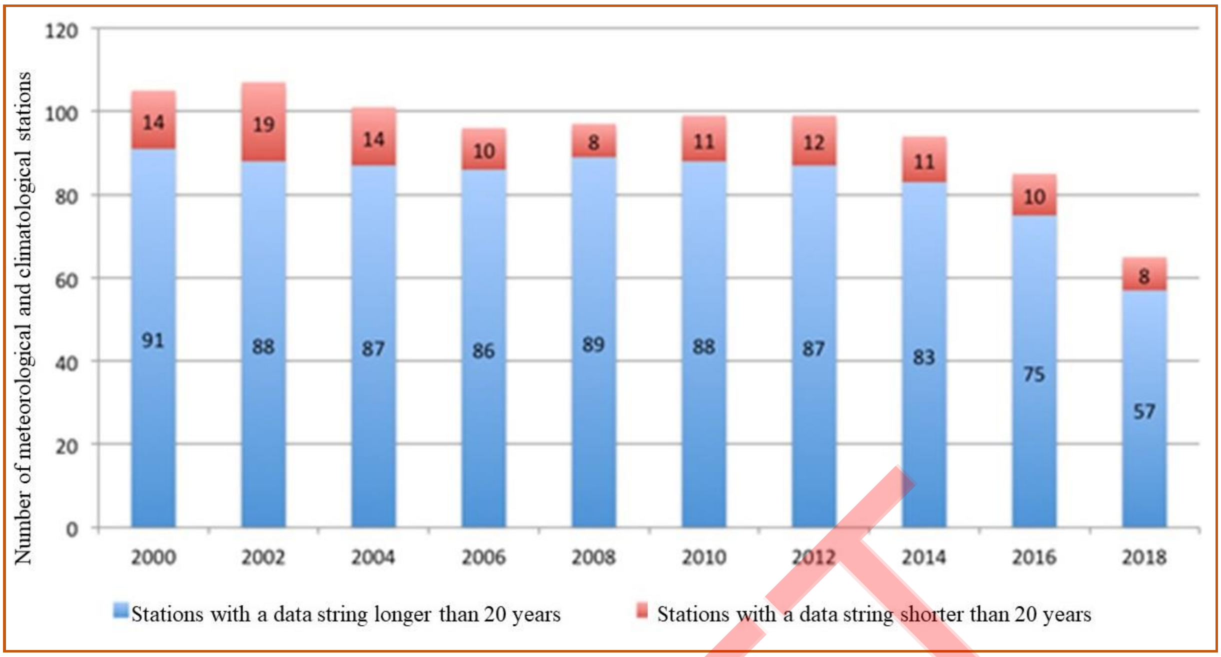

Figure 3. *Number of main and ordinary climatological stations in the RHMS network by years (analysis of Meteorological Yearbooks, http://www.hidmet.gov.rs/podaci/meteo_godisnjaci/)*

From the aspect of EEA (European Environment Agency) indicators, for indicators:

1. Average air temperature
2. Intense precipitation
3. Hail
4. Strong wind

There are the necessary data, because continuous measurements of air temperature, precipitation, wind, snow cover and hail are performed through the meteorological monitoring system of RHMS. Data on the appearance of the city are recorded at meteorological stations. Considering that anti-hail protection functions on the territory of Serbia, areas with damage from the city are also monitored, but these data are not publicly available.

5. Soil moisture

Within the national network of meteorological stations, during 2019, a network of automatic stations for measuring soil moisture was established. So far, 9 stations have been set up and are in the testing phase. 6. Snow cover

Although there are measurements of snow cover, they need to be improved, primarily by more frequent measurements of snow density.

6. Meteorological drought

As part of the hydrometeorological system for early warning and warning RHMS, a national operational system for monitoring, early warning and drought risk assessment has been developed, which enables constant monitoring of humidity conditions and issuance of analysis, forecasts and warnings on the occurrence, spatial extent and intensity of drought in Serbia. The RHMS Drought Risk Monitoring and Assessment System is the basis of the National Drought Management Plan, which contains three basic components: monitoring and early warning, risk assessment and mitigation and response.

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Operational procedures for monitoring humidity conditions include the calculation of various drought indices and humidity parameters, as well as various measurements: Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration Index (SPEI) for the period from 1 to 12 months and more, is calculated at the end of each month, while the calculation for periods of 30, 60 and 90 days is done on a daily basis; Palmer's Z index, which is a measure of the monthly moisture anomaly; soil moisture obtained by measurement; available soil moisture determined by calculating water balance, current and forecasted values of reference evapotranspiration.

RHMS issues a forecast of humidity conditions based on a one-month STI with 10-day forecast precipitation values, and a two-month SPI with monthly forecast precipitation values. Predicted precipitation values are obtained from the ECMWF and RHMS forecasting systems.RHMSProjections of the mentioned indicators are not made officially within the institutions of the Government, but they are made by a team of experts from the Institute of Meteorology of the Faculty of Physics in Belgrade.

2.3. Key issues

For the analysis of the observed climate change and impacts on different sectors, it is necessary to have as many long series of daily meteorological data on the entire territory of Serbia as possible. These data are observed at the main meteorological, ordinary climatological, agrometeorological and phenological stations, hydrological and groundwater stations, collected in the RHMS internal database and are not publicly available. In addition, without financial compensation and for the purpose of research, daily observed meteorological data from one site can be obtained in two years, which further complicates the study of the impact of climate change on sectors.

Available meteorological and climatological data, such as daily observed meteorological data, are not in easy-to-handle formats.

With the shutdown of stations, the continuity of multi-year climate monitoring in one place is lost, which is unfavorable from the point of view of the analysis of climate change, but also the assessment of their impact on systems and sectors. The situation is similar in the case of hydrological stations.

The development of such climate simulations requires appropriate computer resources, which is why it is necessary constant to invest in such HPC systems (high-performance computing) and their maintenance, which is not the case in RHMS. In addition, it should be borne in mind the lack of sufficiently trained staff in RHMS who would independently develop climate scenarios.

2.4. Recommendations

Analyzes of climate change and its impact on sectors and systems largely depend on the availability of data and their quality. It is also crucial that the same database of meteorological, climatological, hydrological, phenological and agrometeorological data (including those from the stations of the Agricultural Advisory Services) of the observed and projected data is used for different research on the effects of climate change. For this reason, it is essential that RHMS data be publicly available, in representative series and formats.

It is recommended to arrange a publicly available database at the national, but also at the level of the region (administrative) and region (sectoral depending on climatic and other conditions) as well as cities and municipalities and an accompanying electronic visual platform of

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publicly available data. The platform would also play a significant role in the monitoring and evaluation (M&E) system at the national level. If there is no possibility of forming such a database using RHMS data, it could be created using some of the publicly available databases that were used in the draft of the Third Report. The database and platform should also contain data from climate scenarios up to the level of local governments

In principle, the most efficient would be the existence of a gridded network of observed data at a resolution of 1km, which would provide data for the business community, i.e. for analysis at the level of agricultural or forestry farm, protected natural asset, river basin, regions, towns and settlements and alike. However, this is a demanding job and cannot be the subject of this contract within the project.

Data that do not exist or exist insufficiently, and would be useful for research on the impacts of climate change are:

- soil moisture measurements (establishment of soil moisture measurements in the areas most affected by drought and precipitation deficit, where agricultural production is represented)
- Phenological data (increase in the number of phenological cells, improvement of the quality of phenological observations, complete digitization of the phenological database)
- Groundwater measurements (increase in the number of stations where groundwater measurements are performed, especially in the areas most affected by drought)
- Making the database on the occurrence of hail and damage from hail public
- Improving the measurement of snow cover density.

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2.5. Activity proposal

Considering that for the needs of the Third Report of the RS according to the UN Framework Convention on Climate Change, analyzes of observed and projections of expected climate changes were made in accordance with the latest reports of the International Panel on Climate Change, there is no need to improve them.

The project could also provide support in the preparation of a publicly available database and platform.

In addition, the project could prepare a recommendation for the desired number of stations in the network, from the aspect of studying climate change and improving the availability of observed data.

3. AGRICULTURE

3.1. Current situation

The share of agriculture in the gross national income together with forestry and fishing is between 6-6.8% 2018[14]) where 40.6% of the population lives in rural areas and is engaged in some areas of agriculture (Statistical Office of the Republic of Serbia, 2018[15]). Most often,

[14] https://publikacije.stat.gov.rs/G2018/Pdf/G20182051.pdf
[15] https://publikacije.stat.gov.rs/G2018/Pdf/G20182051.pdf

these occupations are performed in the following sectors of activity: “Manufacturing” (17.2%), “Agriculture, forestry and fishing” (14.8%), “Wholesale and retail trade; repair of motor vehicles and motorcycles” (14.7%). Observed by regions, the Region of Vojvodina (31.0%) and the Region of Šumadija and Western Serbia (31.9%) have the most employees in the processing industry/manufacturing. Almost half (46.4%) of all employees in the sector “Agriculture, Forestry and Fisheries” are recorded in the region of Šumadija and Western Serbia, while most employees in the sector “Wholesale and retail trade” are in the Belgrade region (32.2%) (Census of Agriculture, 2012).

Data of importance for agricultural production for 2018 (Statistical Yearbook, 2019[16]) are shown in Table 2.

Table 2. *Agricultural production in the Republic of Serbia*

TOTAL AREA OF LAND USED FOR AGRICULTURE (2018. год) 3.765.847 hectares

PLANT PRODUCTION **66,3%**			LIVESTOCK PRODUCTION 33,7%	
ARABLE LAND AND GARDENS **74,1%**	MEADOWS AND PASTURES 19,4%	ORCHARDS 5,3%	VINEYARDS 0,6%	OTHER 0,6%

Of the crop plants, the most common are corn, wheat, sunflower and soya beans, and of vegetables, potatoes, peppers and beans. The orchards are dominated by the production of plums, apples, raspberries and sour cherries, which occupy about 75% of the area under fruit, while other orchards occupy the remaining 25% of the area. A large number of new plantations use drip irrigation systems and anti-hail nets, i.e. adaptation measures that have become necessary to achieve high and stable yields over a longer period.

Based on the available data, organic food production increased from 218 to 6,154 farms in the period from 2011 to 2017[17]. The total arable land under organic production is 7,540 ha, and in the process of transition to organic production, there are another 5,919 ha. According to the latest data (FAOSTAT), the total area under organic farming is 19,200 hectares

The number of cattle in organic cattle production dropped from 283 to 87, while the number of sheep (4665), goat (248) and poultry (4415) is stable. Livestock production is carried out in all regions, and is predominant in mountainous areas. Poultry production is dominant, with a number of over 16.6 million, then pigs with over 3 million, followed by sheep and cattle breeding. It should be noted that the volume of livestock production decreased in terms of the number of poultry, goat, horses and pigs, and remained at almost the same level in terms of the number of cattle, horses and sheep in relation to the number according to the 2012 Census of Agriculture. Expressed in the livestock units, there was a decrease of about 9%. Only an increase in the number of hives was recorded (by about 22%).

The average yields of different crops for the period 2016-2018 based on the available data from the 2019 Statistical Yearbook[18] and from the FAOSTAT database[19] are shown in Figure 4.

[16] https://publikacije.stat.gov.rs/G2019/Pdf/G20192052.pdf
[17] https://serbiaorganica.info/organska-poljoprivreda
[18] https://publikacije.stat.gov.rs/G2019/Pdf/G20192052.pdf
[19] http://www.fao.org/faostat/

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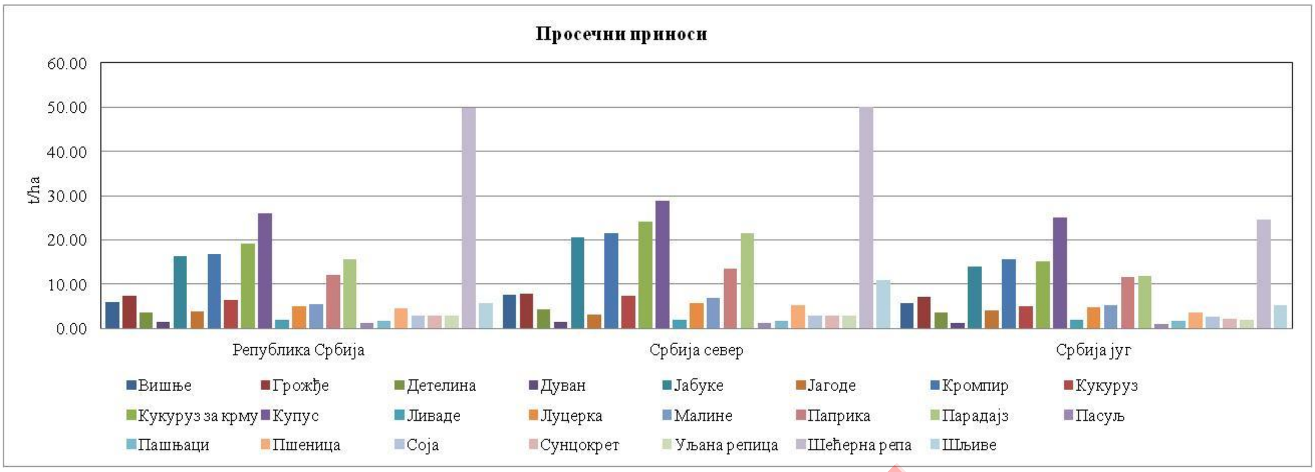

Figure 4. *Average yields of different crops*

The method of downloading and processing data being much simpler when using FAOSTAT compared to yearbooks of the Statistical Office of the Republic of Serbia. The advantages of using data from the Statistical Office of the Republic of Serbia yearbook databases are that all data are presented both on the national and regional level. Data at the level of local self-governments are not available in any database, with the exception of 2012, when the Census of Agriculture was made and these data are publicly available (in the Statistical Office of the Republic of Serbia database). In addition, it often happens that the Statistical Office of the Republic of Serbia data are inconsistent in displaying.

The impacts of climate change on the agricultural sector are analyzed in the First, Second and draft Third report. The first report mainly presents the results for AP Vojvodina, the second analyzes the changes in the yield of the most common field crops and the vegetation period, and the third includes vegetable and fruit crops. So far, the occurrence of pests and diseases has not been analyzed, nor have the trends of observed changes been presented.[20]

The first National Report to the United Nations Framework Convention on Climate Change states that the changed climatic conditions and their greater variability will affect the situation in agriculture in the Republic of Serbia in the future. Rising temperatures and a higher frequency of extreme weather events can lead to reduced yields and increased year-on-year fluctuations in yields if adequate adaptation measures are not taken in time.

Climate change will have the greatest impact on maize yields. If no adaptation measures are applied, by 2030, a reduction in corn yield in non-irrigated conditions of 58% is expected.

The potential reduction in wheat yields will be up to 16% in the period until 2030, depending on the region. It is expected that the production of sugar per hectare of sugar beet will decrease, and by 2100, the production of soybeans and vines will also decrease. The increase in temperatures caused by climate change will prolong the growing season of winter wheat and shorten the growing season of soybeans and corn, moving the beginning of the growing season forward (on average between 20 and 30 days until 2100), which will affect the timing of agricultural work. In the conditions of climate change, numerous changes are observed and expected in terms of the occurrence of diseases and pests. Fungal diseases and the occurrence of pests (and related viral diseases) will be a challenge to which future crop protection measures will have to respond.

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[20] http://www.klimatskepromene.rs/publikacije/

Long-term effects of extreme weather events can lead to a decrease in the productive fertility (yield potential) of certain types of soil and disrupt their essential functions. It is especially necessary to keep in mind erosion due to the effects of heavy rainfall and bare soil on the slopes on sloping terrain (hilly and mountainous soils).

Timely adaptation measures, however, of which the most important one is the increase of irrigation capacity, can for certain crops lead to the increase in yield, and also two harvests in a year (by the year 2100).

According to the Second Report of the Republic of Serbia to the Convention, an increase in vulnerability of agricultural production is expected due to the increase in the growth rate of plants. Changes in flowering dates for the period 2001-2030 for corn, soybeans and winter wheat are a few days. The change in the date of full ripening, which ranges from 7 to 13 days on average, indicates earlier ripening of corn, while no significant changes are expected in winter wheat and soybeans. For the period 2071-2100 earlier flowering of corn and soybeans is expected more than two weeks. For corn, the time of full ripening can be up to two months earlier, which can significantly affect the quantity and quality of yield. For soybeans, the time of full ripening can be about two weeks earlier, so a similar shift in the date of flowering and ripening should contribute to maintaining the usual length of vegetation. In principle, changes in vegetation dynamics can significantly affect the yield of these crops and the organization of fieldwork. At the same time, earlier sowing can be a significant factor in the adaptation of these crops to expected climate change. Estimates of changes in expected winter wheat yield for the period 2001-2030 indicate relative yield changes of approximately -16% in the north-western and northern regions, to 21% in the south-eastern region of the country. However, for the period 2071-2100 altered regional vulnerability is expected: the largest relative change in yield in the central region (6%) and a decrease in yield in southern Serbia (-10%). Expected changes in corn yield for the period 2001-2030 have a variable sign depending on the region, with the largest possible reduction of -6%. For the period 2071-2100 the expected decrease in yield ranges from -52 to -22% for the entire territory of Serbia. The obtained results are in accordance with the results obtained for the conditions without irrigation. Analyses show that, with irrigation, the loss of corn yield by the middle of the 21st century can be reduced by up to 31%. Changes in soybean yields vary from 31% (northern region) to 41% (southern region) for the period 2001-2030 and from -14% to 20% for the period 2071-2100, with the expected increase in the northern and southeastern regions of Serbia.

Agricultural Development Strategy for the period 2014-2024 states:

Yields of most crops are relatively lower compared to more developed countries and record significant oscillations. The analysis of the dynamics of changes in yields, expressed by ten-year averages over the last three decades, indicates that only industrial plants and some types of fruit (plums and raspberries) have permanent yield growth. Grain yields still do not reach the level of the ten-year average from the pre-transition period (1980-1989). Wheat and corn are the two leading products in terms of share in sown areas, with a long tradition, good domestic and available foreign assortment, and this development of yield and production can be attributed to insufficient training of producers, outdated technology and insufficient adaptation to climate change.

Furthermore, the Strategy points to the data from the report of the Republic of Serbia to the United Nations Framework Convention on Climate Change and states the need to adapt to changed climate conditions. However, it does not define adaptation measures and does not make them a priority.

Of the indicators directly relevant for assessing the impact of climate change on the agricultural sector, the EEA monitors trends and prepares projections for the following:

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1) Crop yield depending on water availability;
2) Agrophenology (flowering of winter wheat);
3) Crop water needs (deficit during corn growth);
4) Crop growth season;
5) Organic carbon (CO_2) content in the soil (in the surface layer); as well as
6) Economic damage from natural disasters.

Although the projections for indicators 1) - 4) and for a larger number of crops are presented in the First, Second and draft of the Third Report, and trends can be obtained from the Statistical Office of the Republic of Serbia database. There is no systematic monitoring of changes in these values, nor are they part of any publicly available databases. Data at the level of local self-governments are not available, nor is it known that there are any.

Indicator 5) is monitored by SEPA (Environmental Protection Agency) – http://indicator.sepa.gov.rs/pretraga/indikatori/allfind/629f8ac8c0a546818e78e466357d1de3) and 2013 values are available. It is necessary to harmonize with the EEA method of monitoring and displaying.

Economic damage from natural disasters Indicator 6) although related to other sectors, is certainly of great importance for the agricultural sector, which suffers large losses due to natural disasters, especially drought. Projections of climate change, as well as yield losses, etc. certainly conclude that these damages will be even greater in the future, with an increase in the number, frequency and intensity of droughts. Data on damages and losses in agriculture are an integral part of the database managed by the Ministry of Interior (https://www.desinventar.net/DesInventar/profiletab.jsp?countrycode=srb&continue=y). However, a methodology for assessing damages and losses in the agricultural sector is not available, nor is there data specifically for the agricultural sector. The development of methodology and systematization of data in this regard is among the key priorities in the field in general.

3.1.1. Fruit growing

In Serbia, 16 types of fruit are grown commercially: apple, pear, quince, plum, sour cherry, cherry, peach and nectarine, apricot, strawberry, raspberry, blackberry, currant, blueberry, walnut, hazelnut and almond. Other fruit species are less represented and have no greater economic significance.

Official data on the production, yields and areas of different types of fruit trees can be found on the website of the FAO organization and on the website of the Statistical Office of the Republic of Serbia. In 2018, the Statistical Office of the Republic of Serbia, based on a survey conducted on a sample of selected family farms and entrepreneurs during 2017, published the document "Statistics of fruit production - Results of research on orchards 2017". From that document, it can be seen that the total area under orchards in 2017 was 183,602ha. The structure of fruit production is shown in Figure 5.

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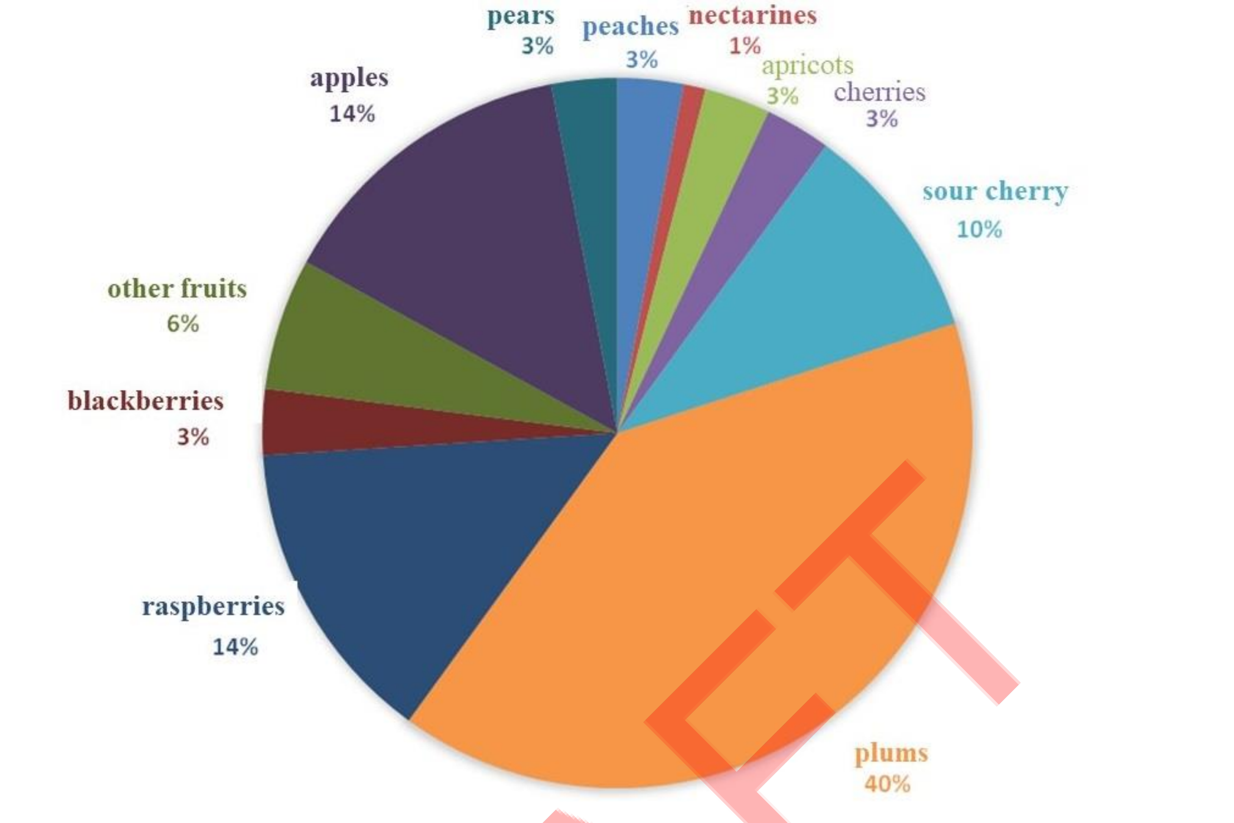

Figure 5. *Share of fruit species in total areas under orchards*

This research is the first of its kind in our country, and in addition to the area, total production, yield, it also included the structure of the assortment, the age of the plantations, as well as the planting density. The next such research is planned to be done in 2022. The main disadvantage of such research is the representativeness of the sampling frequency (lack of data for each year), so it is not possible to monitor the oscillations in production and their dependence on climatic conditions.

On the other hand, in the FAO database (http://www.fao.org/faostat) annual values for a multi-year period are available (Table 3), but not the data for many years. Data for 2019 are not yet available on this site.

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Table 3. *Area, production and yield of the most important fruit species*

Type	Year	Area (ha)	Production (t)	Yield (t/ha)	Type	Year	Area (ha)	Productoin (t)	Yield (t/ha)
Apple	2014	23.737	336.313	14,2	peach and nectarine	2014	8.012	91.348	11,4
	2015	24.703	431.759	17,5		2015	7.501	98.119	13,1
	2016	24.818	400.473	16,1		2016	7.244	82.795	11,4
	2017	25.134	378.644	15,1		2017	7.132	80.578	11,3
	2018	25.917	460.404	17,8		2018	7.068	73.657	10,4
	Average	*24.862*	*401.519*	*16,2*		*Average*	*7.391*	*85.299*	*11,5*
Plum	2014	77.949	401.452	5,2	Pear	2014	7.343	63.744	8,7
	2015	74.172	354.890	4,8		2015	6.082	71.895	11,8
	2016	73.319	471.442	6,4		2016	5.949	60.799	10,2
	2017	72.024	330.582	4,6		2017	5.703	52.291	9,2
	2018	72.224	430.199	6,0		2018	4.982	53.905	10,8

	Average	*73.938*	*397.713*	*5,4*		*Average*	*6.012*	*60.527*	*10,1*
Raspberry	2014	11.041	61.715	5,6	Apricot	2014	5.290	29.655	5,6
	2015	16.211	97.165	6,0		2015	5.471	27.611	5,0
	2016	20.194	113.172	5,6		2016	5.670	25.617	4,5
	2017	21.861	109.742	5,0		2017	5.707	41.320	7,2
	2018	22.654	127.010	5,6		2018	5.860	25.414	4,3
	Average	*18.392*	*101.761*	*5,5*		*Average*	*5.600*	*29.923*	*5,3*
Sour cherry	2014	13.990	93.905	6,7	Strawberry	2014	4.977	23.307	4,7
	2015	16.034	105.150	6,6		2015	5.077	26.036	5,1
	2016	16.797	96.769	5,8		2016	5.806	22.938	4,0
	2017	17.566	91.659	5,2		2017	7.054	30.106	4,3
	2018	18.841	128.023	6,8		2018	6.892	21.735	3,2
	Average	*16.646*	*103.101*	*6,2*		*Average*	*5.961*	*24.824*	*4,2*

The data referring to 2017 are identical to the data published by the Statistical Office in the document "Statistics of fruit production - Results of the survey on orchards 2017". It is not known from which sources FAO publishes data for other years. What can be noticed are the small average yields per hectare, which are calculated from the ratio of total production and total area, in relation to professional practice. In professional practice, it is known that the minimum yields achieved in apple orchards are 30-40 t/ha, plums 15 t/ha, raspberries 10 t/ha, peaches and nectarines 20-30 t/ha, pears 20 t/ha, strawberries 15-20 t/ha.

In order for the data to be more precise, greater coordination of state institutions is needed, which can provide various data. Some of these sources of data can be: realized subsidies at annual level for raising perennial crops (Ministry of Agriculture, Forestry and Water Management), data on the amount of produced and sold planting material, as well as the amount of imported planting material (Plant Protection Directorate), data on the amount of exported fresh fruit, data on the quantity of imported fruit, data on processing capacities, data on the quantity of exported frozen fruit (Ministry of Trade).

In addition, to yield data, data on change in yield due to climate change are not publicly available or systematized. There are also no systematized databases on the damage and losses due to climate change.

Analysis of the occurrence of diseases and pests as a consequence of climate change for fruit and agricultural production in a systematic and systematized way has not been done so far and is one of the challenges.

Recognizing the importance of regionalizations (defining the boundaries of regions that are more or less suitable for growing a certain type of fruit tree), certain analyses were made in this context. The model of thermal favourableness as an indicator of the general favourableness of the region contains basic and corrective thermal indicators. Among the basic thermal indicators (indicators of sufficiency or insufficiency of the available amount of thermal energy) in a specific area for the organization of economically justified fruit production are:

- Base temperature of vegetation movement
- Average annual air temperature determined by types of fruit trees
- Average vegetation air temperature is also determined by species
- Length of vegetation.

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The values of these thermal indicators are obtained on the basis of daily observations of air temperature at RHMS stations and are calculated for the 1997 – 2016 period (Figures 6 and 7).

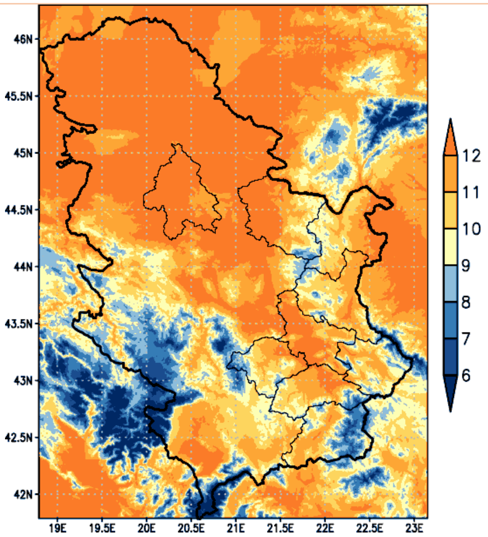

Figure 6. *Average annual air temperatures (1997-2016)*

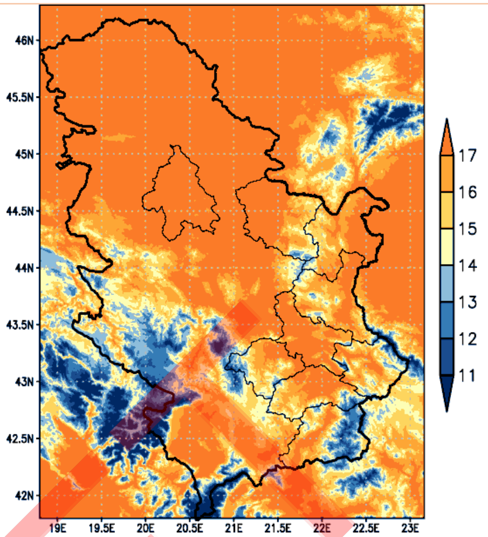

Figure 7. *Average vegetation air temperatures (1997-2016)*

A satisfactory amount of thermal energy on an annual level does not automatically imply a satisfactory amount of that energy in all phases of the annual cycle of fruit growth and development. Therefore, the given model of regionalization must include, as corrective factors, factors and indicators of heat stress of fruit trees: frost, as a stress deficit of heat energy in the initial stages of vegetation, and for most types of fruit trees heat waves, as a stress surplus of energy in the critical (summer) vegetation period. The values of the minimum thermal parameters depending on the species or g
groups of varieties are shown in Table 4.

Table 4. *Values of minimum thermal parameters by species*

TYPE	Base temperature of vegetation movement °C	Length of vegetation Days	Annual air T °C	Vegetation air T °C
Early-season apple	12.0	150	9	15
Late-season apple	12.0	170	9	15
Early-season pear	12.0	150	10	16
Late-season pear	12.0	170	10	16
Quince	12.0	180	10	16
Medlar	12.0	180	10	16
European plum	11.0	150	9	15
Peach	10.5	150	11	17
Apricot	10.0	180	11	17
Cherry	11.0	150	10	16
Sour cherry	11.5	150	9	15

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Early-season walnut	10.5	150	10	16
Late-season walnut	11.5	150	10	16
Hazel	10.5	180	10	16
Early-season almond	9.0	180	11	17
Late-season almond	10.0	180	11	17
Early-season strawberry	10.5	90	8	14
Raspberry	11.0	120	8	14
Blackberry	12.0	120	9	15
Currant	10.5	140	7	13
Blueberry	12.0	110	8	14
Gooseberry	11.5	100	7	13

Out of the corrective indicators of heat stress of fruit trees, the model includes the probability of spring frost in the initial phases of vegetation with an intensity higher than -2.0°C. If this probability is lower than 20.0% (or if the frost after the fruit enters the active period occurred in 4 out of 20 years), the risk of this environmental stress factor is treated as minimal, and the area that this probability characterizes, as favorable for organizing fruit production. The occurrence of spring frost with a probability between 20.0 and 40.0% is treated as moderately risky, and the area with a probability of over 40.0% is unfavorable. A similar favourability ratio is reflected when it comes to the probability of heat waves (the number of days with temperatures above 35°C that can significantly reduce fruit production).

Based on these thermal indicators, especially for each type of fruit, the regions can be divided into favorable (probability of stress factor occurrence less than 20%), moderately favorable (probability of stress factor occurrence 20 to 40%) and unfavorable (probability of stress factor occurrence more than 40%) for organizing fruit production. Figure 8 shows favorable and less favorable areas for peach cultivation in the Belgrade district.

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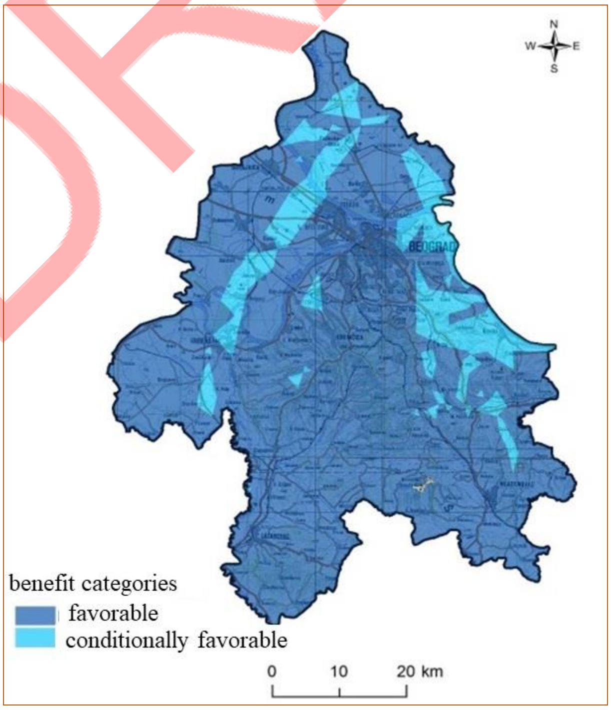

Figure 8. *Thermal conditions for peach cultivation in the Belgrade District*

Elements of material resources of agricultural habitats, and above all water and biogenic elements, also appear as a limiting factor in organizing economically justified fruit production. If there are available water sources in a certain region that is favorable for the cultivation of a certain fruit species from the aspect of thermal indications, this problem will be solved by irrigation. However, in many parts of Serbia, the availability of water for irrigation is very limiting, and according to projections, it will be decreasing. For that reason, alternative methods must be applied that will solve the water deficit in certain phenophases of fruit development (choice of resistant varieties, choice of substrate, choice of cultivation form, choice of type of pruning, methods of soil maintenance).

3.1.2. Viticulture

The Republic of Serbia has about 25,000 ha under vines, of which 22,150 ha are statistically listed in Central Serbia and Vojvodina. Wine varieties are grown on 17,483 ha, which is 75.7% of the total area under vineyards, Varieties whose grapes are intended for fresh consumption (table grapes) are grown on a total of 4667 ha, or 24.3% of the total area under vineyards (Census of Agriculture, 2012).

In the region of Central Serbia, vines are grown on 17,118 ha, and in the region of Vojvodina on 5032 ha. Of the areas under vines covered by the 2012 Census, 77.3% are located in the region of Central Serbia, and 22.7% in the region of Vojvodina. Most vineyards are located within the Tri Morave region, and at the municipal level, most vineyards are located in the municipality of Trstenik. In Central Serbia, table varieties are grown on as much as 30.1% of the area under vineyards, while in Vojvodina, table varieties are grown on 16% of the area under vineyards.

80,341 agricultural holdings are engaged in grape production, which is 12.7% of the total number of farms in the Republic of Serbia (Table 5).

***Table 5.** Census of Agriculture, 2012 (Source: Vineyard Atlas, 2015)*

	WINE-GROWING REGION CENTRAL SERBIA	**Total number of farms**	**Number of holdings with vineyards**	**Vineyards (ha)**	**Wine varieties (ha)**	**Table varieties (ha)**
1	Pocer-Valjevo region	60608	1153	190,62	96,77	93,85
2	Negotinska Krajina region	6836	3555104	978,04	890,12	87,92
3	Knjaževac region	17733	6473	1.076,47	958,24	118,23
4	Mlava region	30557	6848	814,37	499,22	315,15
5	Toplički region	19856	5910	764,73	590,22	174,51
6	Niš region	25381	8415	1.311,85	1.064,86	246,99
7	Nišava region	11873	3598	470,88	433,10	37,78

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8	Leskovac region	11873	10863	1.459,27	1.282,49	176,78
9	Vranje region	22159	2613	421,31	317,73	103,58
10	Čačak-Kraljevo region	31935	397	64,88	44,24	20,64
11	Region Tri Morave	54663	18129	7.528,76	6.161,22	1.367,54
12	Belgrade region	37246	4421	1.129,55	426,26	703,29
13	Šumadija region	38954	5000	1.119,79	534,21	585,58
WINE-GROWING REGION VOJVODINA						
1	Srem region	31371	2200	2.215,55	1.882,30	333,25
2	Subotica region	10270	447	312,18	295,39	16,79
3	Area Telečka	16817	334	115,23	75,16	40,07
4	Potisje region	25651	437	227,37	173,78	53,59
5	Banat region	11900	800	132,03	84,19	47,84
6	Južni Banat region	12091	786	1,730,69	1.567,07	163,62

There are also more recent data on areas and production of grapes and wine than those obtained by the 2012 Census of Agriculture, but they are not publicly available. The Ministry of Agriculture, Forestry and Water Management, based on competition in accordance with the Law on Wine ("Official Gazette of RS", no. 41/09 and 93/12), entrusted the work related to the Viticulture Register to the Center for Viticulture and Oenology from Nis (https://cevvin.rs/). Pursuant to the Law on Wine and bylaws, all grape producers who produce grapes on plots larger than 10 acres (as well as on smaller ones if they sell grapes on the market) are obliged to register in the Viticulture Register. This register contains updated data on areas, varieties, cultivation systems, etc. The data can be obtained from the Ministry upon request.

Based on the Study of Analysis of the Grape Production and Wine Production Sector "Viticulture and Oenology of Serbia“[21] prepared by the Center for Viticulture and Oenology in 2019, it can be concluded that the number of registered agricultural holdings engaged in viticulture is lower than determined by the 2012 Census of Agriculture. In this study, one can find data from the Directorate for Agrarian Payments of the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia from 2018 on the total number of 47,120 registered agricultural farms that own and cultivate vineyards. The average area of vineyards per registered agricultural holding is slightly less than 0.30 hectares, which is approximately the average area determined by the Census of Agriculture in 2012 (0.28 hectares).

In this study, data are also available that the total number of areas of vineyard plots kept in the Viticulture Register is 6,490.95 hectares. Within all these vineyard plots that are kept in the Viticulture Register, as many as 88.79% are vineyards with wine varieties. This is a higher percentage than that determined by the 2012 Census of Agriculture (75.7%). This data is

[21] „Виноградарство и винарство Србије“(2019): Студија анализе сектора производње грожђа и производње вина „Виноградарство и винарство Србије. Центар за виноградарство и винарство, Ниш. Уредник: Дарко Јакшић

different because vineyards with table varieties are grown primarily in backyards, areas are small and grapes are mostly produced for their own needs, so producers do not enter such vineyards with table varieties in the Viticultural Register.

Out of a total of about 200 grape varieties recorded in the vineyards kept in the Viticulture Register, ten varieties make up as much as 69.85% of all commercial vineyards. Based on the areas in 2019, the leading wine variety in the vineyards kept in the Register is the regional variety Graševina (909.35 ha), and other leading varieties are predominantly international (Riesling, Merlot, Cabernet Sauvignon, Sauvignon White, Chardonnay, Frankovka). The only autochthonous variety that is in the first ten most widespread varieties is Prokupac, which is represented by 4.27% (277.30 ha), and the only domestic newly created widespread variety is Župljanka with 3.83% (248.85 ha). The most common table variety is Muscat Hamburg (5.42%).

Viticulture production in the Republic of Serbia is characterized by a number of specifics. A large number of grape producers have small areas. About 34% of the holdings covered by the 2012 Census of Agriculture are holdings with vineyards with an area of less than 0.1 hectare. According to the 2012 Census of Agriculture, only six wineries in Serbia had vineyard areas of 100 and more hectares, with a total census area for these large grape producers of about 2,800 hectares. The data from the Viticulture Register, which were published in 2019 in the above-mentioned Study, show certain differences in the structure of registered grape producers, which is understandable since within this register are mostly market-oriented grape producers. The average area of vineyards kept within the Viticulture Register per grape producer at the level of the Republic of Serbia is 1.51 hectares.

Regionalization of wine-growing geographical production areas of the Republic of Serbia was completed in 2015, within the Twinning project (*Capacity Building and Technical Support for the renewal of Viticulture Zoning and for the System of Designation for Wine with Geographical Indications*). Wine-growing regions of Serbia cover the territory of the entire Republic of Serbia at an altitude of up to 800 m, as well as areas above this altitude if they are on the list of regionalized. With the viticulture zoning, the territory of Serbia is divided into three wine-growing regions:

1) the region of Central Serbia,
2) the region of Vojvodina,
3) the region of Kosovo and Metohija.

Within these regions, there are 22 areas, 77 vineyards and a large number of wine-growing oases (Figure 9). The document called Vineyard Atlas, in which the data can be found, was published in 2015.

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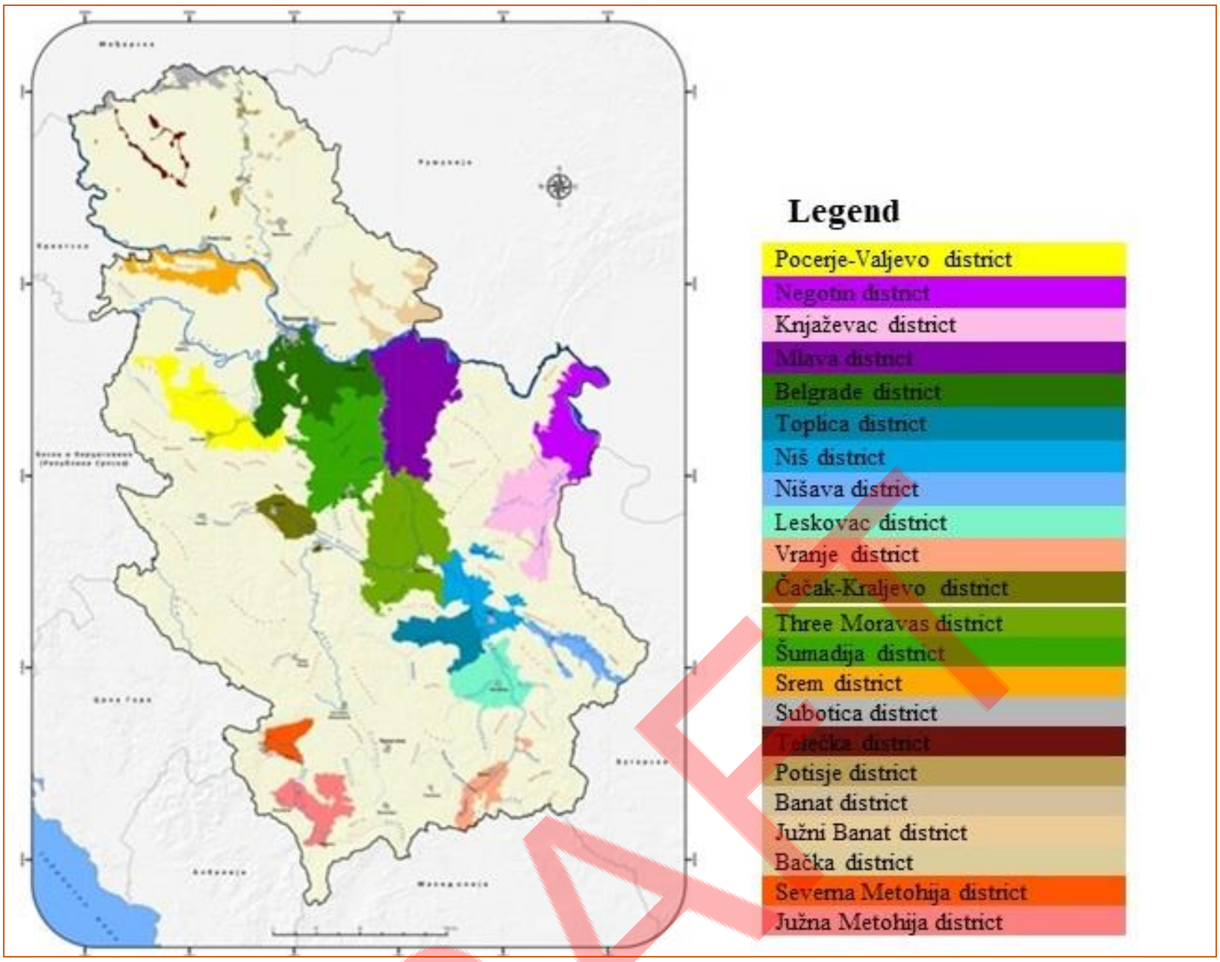

Figure 9. *Wine-growing regions of Serbia (Vineyard Atlas, 2015)*

The basis for regionalization was the analysis of factors of grapevine cultivation sites (analysis of climatic and soil factors), based on which lists of permitted and recommended varieties, yields, substrates, cultivation systems, etc. were made.

Based on the analysis of the most important viticulture indices used to assess the favourability of a particular region for growing vines, maps were made such as an example for the Winkler index of the Pocer-Valjevo wine-growing region (Figure 10).

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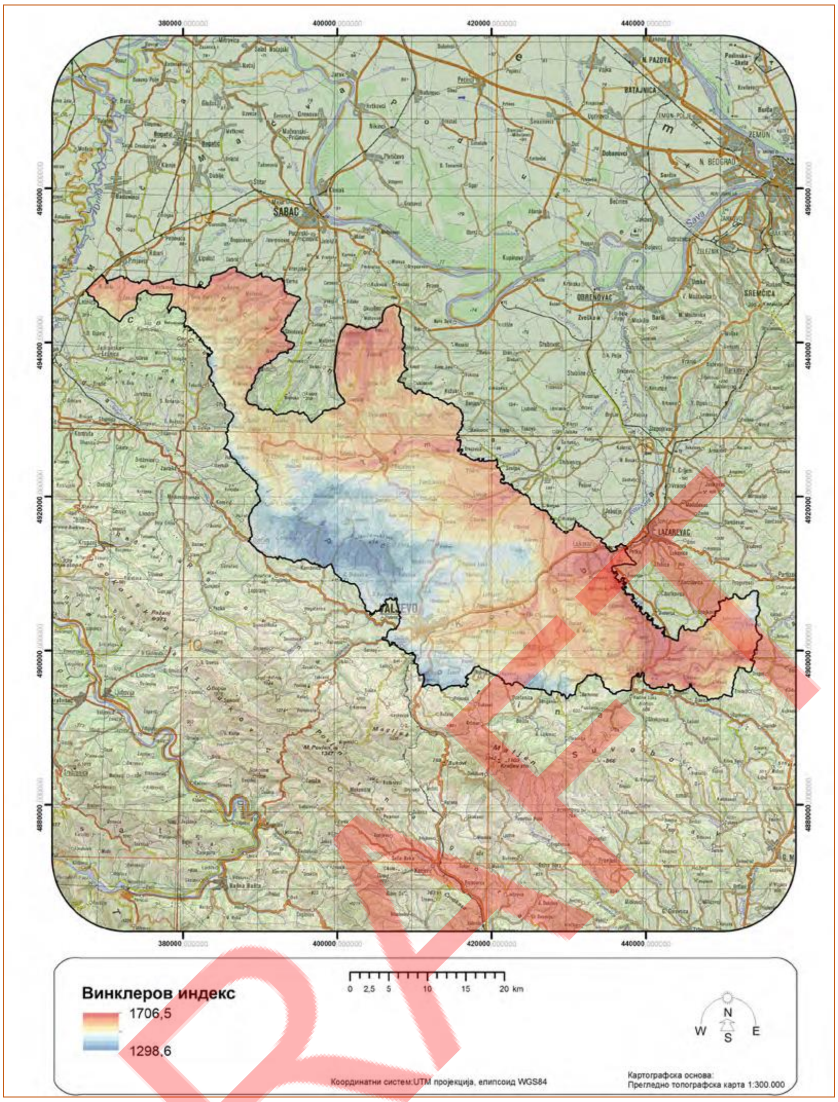

Figure 10. *Winkler index of the Pocer-Valjevo wine-growing region (Vineyard Atlas, 2015)*

Climate change on the territory of Serbia significantly changes the thermal conditions for growing vines. The years that were dry and caused damage in agriculture, such as 2012 and 2017, proved to be extremely favorable for the production of high-quality wine. In other words, the values of climatic parameters and wine quality assessments show that in contrast to other branches of agriculture, climate change can have a positive impact on viticulture. However, very high temperatures (over 30ºC) in a longer interval can adversely affect the content of phenol substances, which negatively affects the quality of grapes and wine. (Ranković-Vasić, 2013[22]).

There is a significant danger in some vineyards (north and northeast) from low winter temperatures and low temperatures during March, which can cause various kinds of damage to the vines. (freezing of vines in 2012 in some localities in Vojvodina[23]).

Climatic factors have different influences on certain varieties and clones of vines that are grown both in the same and in different growing sites (Ranković-Vasić et al., 2015 a[24],b[25]).

[22] Rankovic-Vasic, Z. (2013): Uticaj ekološkog potencijala lokaliteta na biološka i antioksidativna svojstva sorte vinove loze Burgundac crni (*Vitis vinifera* L.). Univerzitet u Beogradu. Poljoprivredni fakultet. Doktorska disertacija.

[23] Nada Korać (2012): „Štete na vinovoj lozi u Vojvodini nastale smrzavanjem i mogućnost regenreracije čokota". Savetovanje voćara i vinogradara. Poljoprivredni fakultet, Novi Sad. Predavanje, mart 2012.

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Large amounts of precipitation (May-July) can adversely affect certain phenological stages of development (e.g. flowering, berry sprouting, berry growth) and intensify the development of the disease. However, the greatest danger is posed by hail, which occurs due to the appearance of strong storm clouds, the frequency and intensity of which are increasing. Anti-hail nets are not commonly used in viticulture in the Republic of Serbia, which is why the vine is extremely vulnerable to these phenomena.

Future projections of climatic conditions on the territory of Serbia show that this trend of change will continue (Vujadinović et al., 2016[26]; Muždalo et al., 2019[27]), but also intensify in the case of global greenhouse gas emissions without the implementation of global mitigation measures (IPCC, 2013[28]; Ministry of Environmental Protection, 2017[29]; Vuković et al., 2018[30]) which can cause negative consequences for viticultural production. Based on all the above, the importance of the analysis of viticultural production in the function of climate change is clear.

Climatic factors and meteorological factors have different influences on different wine-growing regions and vineyards in a given year.

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Biological zero (base temperature) for grapevines is set to 10°C.

In 2019, an analysis of the impact of climate change on the Niš wine-growing region was made during the implementation of the project: *“Adaptation of autochthonous gene pool of fruit trees and grapevine to changed climatic conditions in order to achieve sustainable production”*, funded by the Ministry of Environmental Protection of the Republic of Serbia. The methodology is based on the analysis of climatic viticultural indices, which are important for assessing the suitability of thermal conditions for grape and wine production.

The most important viticultural indices are:

- ***TVEG - Average vegetation temperature*** (average temperature for the period 1 April - 31 October)

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[24] Rankovic-Vasic, Z., Nikolic, D., Atanacković, Z., Sivčev, B., Ruml, M. (2015б): Characterization and adaptation of some 'Pinot Noir' clones to the environmental conditions of Serbian grape growing regions. Vitis (Special issue) 54:147-149.

[25] Ranković-Vasić, Z., Sivčev, B., Vuković, A., Vujadinović, M., Pajić, V., Ruml, M., Radovanović, B. (2015a): Influence of meteorological factors on the quality of 'Pinot Noir' grapevine grown in two wine-growing regions in Serbia. 11th International Conference on grapevine Breeding and Genetics. Acta Horticulturae (ISHS) (pp. 1082, 389-396). 29 July - 02 August, 2014, Yanging-Bejing, China.

[26] Vujadinović, M., Vuković, A., Jakšić, D., Đurđević, V., Ruml, M., Ranković-Vasić, Z., Pržić, Z., Sivčev, B., Marković, N., Cvetković, B., La Notte, P. (2016): Climate change projections in Serbian wine-growing regions, Proceedings of the XI Terroir Congress (pp. 65-70). 10-14 July, 2016, Willamette Valley, Oregon, USA.

[27] Muždalo, S., Vujadinović, M., Vuković, A., Ranković-Vasić, Z., Mircov, V.D., Dobrei, A. (2019): Climate cnahge in vineyards of Serbian-Romanian Banat, Research Journal of Agriculture Science, 50: 3-8.

[28] IPCC, Climate Change (2013): The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York, USA.

[29] MZŽS (2017): Drugi izveštaj Republike Srbije prema Okvirnoj konvenciji Ujedinjenih nacija o promeni klime. Ministarstvo zaštite životne sredine, ISBN: 978-86-87159-15-1.

[30] Vuković, A., Vujadinović Mandić, M. (2018): Study on the climate change in the Western Balkans region. Regional Cooperation Council, Sarajevo, Bosnia and Herzegovina, ISBN: 978-9926-402-09-9, pp. 76.

- ***Winkler index (WIN)*** - the sum of active temperatures during the growing season. It represents the thermal potential of the locality and categorizes the climate of the wine-growing regions into seven classes (Winkler et al., 1974[31]).
- ***Huglin's heliothermal index (HI)*** - expresses the heliothermic potential of the locality, taking into account the temperature during the vegetation period, but also the length of the day at a certain latitude (Huglin, 1978[32]).
- ***Night freshness index (CI)*** - average value of minimum temperature during the month of ripening (September). Low night temperatures during ripening are of great importance for the accumulation of polyphenols and aromas, so using this index it is possible to assess the potential of the wine-growing region for the production of high-quality wines (Tonietto and Carbonneau, 2004[33]).
- ***Drought index (DI)*** - is an estimate of the amount of water in the soil available to the grapevine during the growing season. This index is used to determine the degree of humidity, i.e. dryness of the climate (Riou et al., 1994[34]).
- ***N35 - Number of days with extremely high temperatures*** (average number of days per year with Tx≥35°C), indicates a potential risk of high temperatures for growing some varieties
- ***TXAPS - Absolute maximum temperature*** (highest maximum daily temperature observed during the climatic period)
- ***TNAPS - Absolute minimum temperature*** (lowest minimum temperature observed during the climatic period)

All selected indices are important for climate characterization in viticultural practice and **are often used in assortment selection**. The HI, CI and DI indices together form the Multicriteria Classification System (Tonietto and Carbonneau, 2004[35]) which allows uniform categorization of vineyards around the world, as well as mutual comparison of climatic conditions in them. These indices were used in the development of a new regionalization of wine-growing production areas in the Republic of Serbia, to assess the suitability of the region, vineyards and cultivation sites. The observed data from the stations of the Republic Hydrometeorological Service of Serbia were used for their calculation.

In various researches (scientific papers, master's theses, projects, etc.) in the last two years, significant changes in the values of viticultural indices have been established for certain wine-growing regions. Analyses were performed for Banat, Pocer-Valjevo wine-growing region, Niš region, Župa vineyards, etc.

Analysis of the impact of climate change in the Niš wine-growing region

[31] Winkler, A.J., Cook, J.A., Kuwe, W.M., Lider, L.A. (1974): General viticulture, University of California Press, California, USA.

[32] Huglin, P. (1978): Novaue mode d'evalutaion des possibiliteheliothemiques d'un milieu viticole. Proceedings of the Symposium International sur l'ecologie de la Vigne. Ministere de l'Agriculutre et de l'IndustrieAlimentarie, Contanca.

[33] Tonietto, J., Carbonneau, A. (2004): A multicriteria climatic classification system for grape-growing regions worldwide. Agricultural and Forest Meteorology, 124(1/2):81-97.

[34] Riou, C. (1994): The effect of climate on grape ripening: application to the zoning of sugar content in the European community (European Commission: Luxembourg), 319.

[35] Tonietto, J., Carbonneau, A. (2004): A multicriteria climatic classification system for grape-growing regions worldwide. Agricultural and Forest Meteorology, 124(1/2):81-97.

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The analysis in the Niš wine-growing region included the analysis of the index and the assessment of the risk of extreme weather events. Data from the Niš station, which belongs to one of the main observation stations of the Republic Hydrometeorological Service, were used for the analysis of climate change. Climate periods for which climate change analysis was performed are 1961-1990 (reference period in relation to which climate change is analyzed) and 1998-2017 (climate period that reflects the characteristics of the current climate). Table 6 shows the values of selected climate indices for the periods 1961-1990 and 1998-2017 in Niš, and Table 7 the meanings of the obtained values

Table 6. *Values of climate indices for the climate periods 1961-1990 and 1998-2017 in Niš and values of the index for Niš for the period 1961-2010*[36]

	TANNUAL	TVEG	WI	HI	N35	CI	TXAPS	TNAPS
1961-1990	11,8	17,4	1625,3	2291,1	4,2	11,1	42,3	-23,7
1998-2017	13,1	18,9	1923,5	2613,0	16,2	12,4	44,2	-19,0
1961-2010		17,8	1713,8	2259,7	7,7	11,3		

Table 7. *Meanings of the obtained values of the selected indices for the two climate periods for the Niš wine-growing region*[37]

	1961-1990	1998-2017
T ANNUAL		Average temperature increased by 1,3°C
TVEG	warm	warm (upper limit)
WI	Region II (upper limit)	Region III (upper limit)
HI	moderately warm	warm
N35		Average occurrence per year increased by 12 (4 times)
CI	very cold nights	cold nights
TXAPS		increased heat extremes
TNAPS		decreased low-temperature extremes

The average temperature in this region changed by 1.3°C, the maximum temperature extreme increased, and the minimum temperature extreme decreased. The increase in the value of the heliothermal index, as well as the increase in the number of extremely warm days, indicates an increased risk of high temperatures, which is why it is necessary to consider implementing some of the proposed measures of adaptation to climatic conditions (shading, irrigation, selection of more favourable micro-localities when raising new plantations). In the analysis of the impact on viticulture, it was obtained that the climatic group did not change in terms of the

[36] Project: Adaptation of the autochthonous gene pool of fruit trees and grapevine to the changed climatic conditions with the aim of achieving sustainable production. Ministry of Environmental Protection of the Republic of Serbia, 2019

[37] Project: Adaptation of the autochthonous gene pool of fruit trees and grapevine to the changed climatic conditions with the aim of achieving sustainable production. Ministry of Environmental Protection of the Republic of Serbia, 2019

value of the average vegetation temperature, but reached the values close to the category of "hot" climate. According to the value of the Winkler index, the characteristic of production has changed from Region II to Region III. Region III means good conditions for the high production of standard and quality wines. The number of days with very high temperatures increased from 4 to an average of 16 occurrences per year. The night freshness index indicates a change in ripening conditions from the category of "very cold nights" to "cold nights".

These changes in thermal conditions for viticulture indicate that the conditions have become more favourable for the production of quality wines. However, for some varieties, it should be borne in mind that the conditions may be too warm with risky high temperatures, because the values of the Winkler index indicate the transition to Region IV and the number of days with extremely high temperatures. In addition, the value of the absolute maximum temperature increased, which indicates the occurrence of thermal extremes, i.e. extremely hot waves that did not exist in the climate of the reference period. The risk of severe winter frosts is reduced.

Analysis of the impact of climate change in the Banat region

The results published in 2019 included an analysis of current and future climatic conditions for growing vines in the area of Serbian and Romanian Banat[38]. In this paper, the observed meteorological data on temperature and precipitation from the publicly available E-OBS database (www.ecad.eu) were used for the analysis of climatic conditions in the area of Banat in the past. These data are daily and are interpolated to a regular network of points with a spatial resolution of about 10 km. They were used to calculate the average climatological (normal) values of temperatures and precipitation during the year and the vegetation season, as well as the values of bioclimatic indices for the period of the last 20 years (1997-2018). The analysis of future climatic conditions in Banat vineyards was performed using the results of regional climate models (RCM) according to the scenario RCP8.5 (IPCC , 2013[39]) which are available within the Euro-CORDEX project (Jacob et al., 2014[40]). Period 1986-2005. year is defined as the base (reference) period for the current climate, while for the future are defined three periods, 2016-2035, 2046-2065 and 2081-2100, which respectively represent the near future, the middle and the end of the century.

In the present climate (base period 1986-2005), the vineyards in Bela Crkva and Vršac belong to region II according to WIN. The climate in other vineyards in the Serbian part of Banat, Kikinda, Zrenjanin and Banatski Karlovac, belongs to the WIN region III. According to HI, all Serbian vineyards in this area, except Bela Crkva and Vršac, fall into a warm temperate climate (Figure 11). **This conclusion does not agree with the regionalization** of viticultural production in the Republic of Serbia, according to which all Banat vineyards are in WIN region II (Vineyard Atlas, 2015). However, zoning was done on the basis of climatic norms for 50 years in the period from 1961-2010, and due to increasingly intense climate change over the last few decades, this average does not reflect the current climate conditions well enough. Due to the above, it is necessary to improve the existing regionalization, taking into account climate change in the future.

[38] Muždalo, S., Vujadinović, M., Vuković, A., Ranković-Vasić, Z., Mircov, V.D., Dobrei, A. (2019): Climate cnahge in vineyards of Serbian-Romanian Banat, Research Journal of Agriculture Science, 50: 3-8.

[39] IPCC, Climate Change (2013): The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York, USA.

[40] Jacob, D., Petersen, J., Eggert, B., Alias, A., Chtistensen, O.B., Bouwer, L.M., Braun, A., Colette, A., Deque, M., Et Al. (2014): EURO-CORDEX: New high-resolution climta change projections for European impact research. Regional Environmental Change, 14: 563-578.

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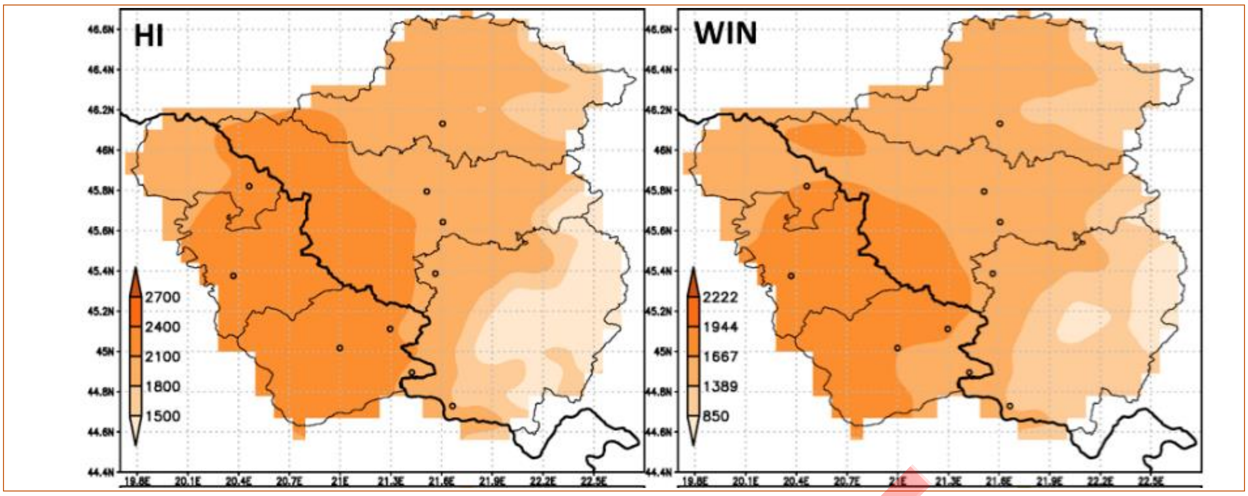

Figure 11. *Normal value of Winkler index (WIN) and Huglin index (HI) in Banat in the current climate (1986-2005)*[41]

If the trend of greenhouse gas emissions continues, Banat, like the rest of the world, will suffer from constant warming. In the near future it will be up to 1 ° C higher than the base period (1986-2005) throughout Banat, between 1.5 and 2.5 ° C higher in the middle of the century and from 3 to 4.5 ° C higher until the end (Figure 12).

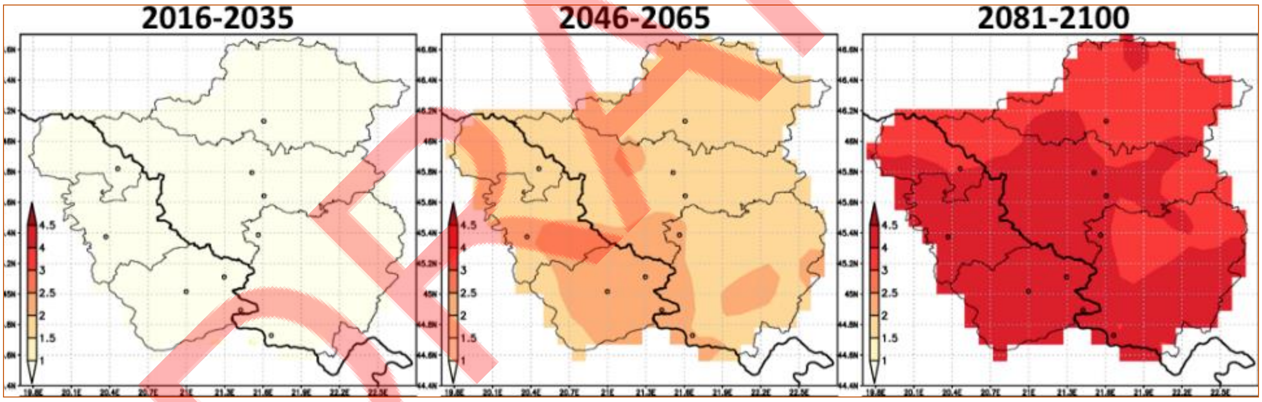

Figure 12. *Normal values of average annual air temperature in Banat in the future climate according to the scenario RCP8.5 compared to the base period (1986-2005)*[42]

In the middle of the century, all current vineyards of Serbian Banat will move to the WIN IV region, and by the end of the century to the WIN region V with a very warm climate (Figure 13).

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[41] Muždalo, S., Vujadinović, M., Vuković, A., Ranković-Vasić, Z., Mircov, V.D., Dobrei, A. (2019): Climate cnahge in vineyards of Serbian-Romanian Banat, Research Journal of Agriculture Science, 50: 3-8.

[42] Muždalo, S., Vujadinović, M., Vuković, A., Ranković-Vasić, Z., Mircov, V.D., Dobrei, A. (2019): Climate cnahge in vineyards of Serbian-Romanian Banat, Research Journal of Agriculture Science, 50: 3-8.

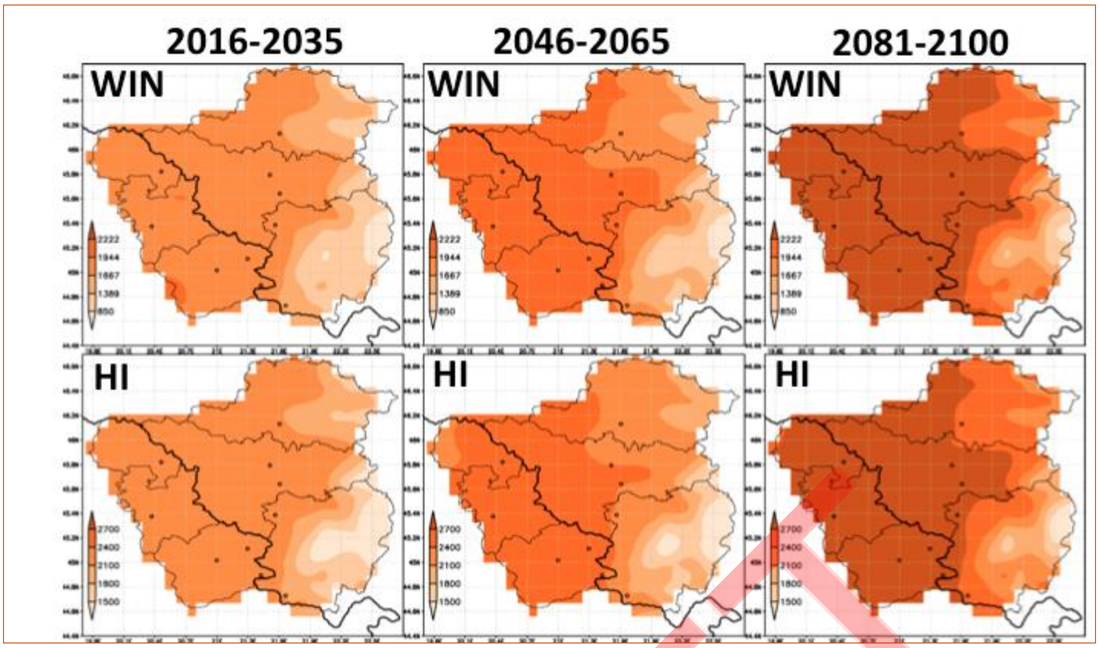

Figure 13. *Mean value of Winkler index (WIN) and Huglin index (HI), in Banat, in the future climate according to the RCP8.5 scenario*[43]

With the change of climatic conditions, there will be a change in the assortment for growing vines. As the region enters the WIN 5 index, it will no longer be optimal for growing grape varieties intended for the production of light white wines with a lower percentage of alcohol and fruit aromas and flavors. Black wine varieties with pronounced aromas and a higher amount of alcohol will be more accessible for the coming climate changes. Thus, varieties such as Frankovka, Prokupac and others will be grown in Banat.

3.1.3. Crop production

Farming as a part of plant production refers to the cultivation and production of cultivated plants in field conditions. According to the nature of the product used from them, field plants can be divided into:

1. **Cereals** (Cereal starchy plants): wheat, barley, oats, rye, triticale, corn, millet, sorghum, rice and buckwheat.

2. **Legumes:** soybeans, beans, peas, broad beans, chickpeas, green beans, lentils, peanuts, shells, etc.

3. **Plants for oil production:** sunflower, oilseed rape, sesame, poppy, castor, etc.

4. **Plants for the production of starch and sugar:** potatoes, sweet potatoes, sugar beet, etc.

5. **Fibre-producing plants:** cotton, flax, hemp, kenaf and abutilon.

6. **Medicinal and spice plants:** coriander, fennel, cumin, anise, myriad, chamomile, etc.

7. **Other plants for technical processing:** tobacco and hops.

8. **Fodder plants**:

   - root-tuber: fodder beet, fodder carrot, kale, borecole, chicory, etc.

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[43] Muždalo, S., Vujadinović, M., Vuković, A., Ranković-Vasić, Z., Mircov, V.D., Dobrei, A. (2019): Climate cnahge in vineyards of Serbian-Romanian Banat, Research Journal of Agriculture Science, 50: 3-8.

- other plants for feeding domestic animals: fodder kale, sorghum-sudangrass, corn silage, pumpkins, etc.

The production of the most important field crops, according to the data from 2018, is displayed in Table 8

Table 8. *The most important field crops, total production and average yield (Statistical Office of the Republic of Serbia, 2018[44])*

Crops	**Sown area (in thousands t)**	**Average yield (t/ha)**
Wheat	2942	4,6
Rye	13	2,8
Corn	6965	7,7
Sunflower	734	3,1
Tobacco	7	1,2
Sugar beet	2 325	48,3
Potatoes	488	17,3

The sown areas of autumn and spring field crops change, both by regions and by years (Table 9).

Table 9. *Sown areas in autumn and spring sowing*

Republic of Serbia

<table>
<tr><td rowspan="2"></td><td rowspan="2">total</td><td colspan="3">Serbia – North</td><td colspan="3">Serbia – South</td></tr>
<tr><td>total</td><td>Belgrade Region</td><td>Vojvodina Region</td><td>total</td><td>Šumadija and Western Serbia Region</td><td>Southern and Eastern Serbia Region</td></tr>
<tr><td colspan="8">Autumn sowing</td></tr>
<tr><td>Sown area, ha</td><td>774967</td><td>453801</td><td>42003</td><td>411798</td><td>321166</td><td>162438</td><td>158728</td></tr>
<tr><td colspan="8">Wheat</td></tr>
<tr><td>Sown area, ha</td><td>583319</td><td>357211</td><td>27018</td><td>330193</td><td>226108</td><td>110003</td><td>116105</td></tr>
<tr><td colspan="8">Barley</td></tr>
<tr><td>Sown area, ha</td><td>104183</td><td>50807</td><td>8399</td><td>42408</td><td>53376</td><td>29218</td><td>24158</td></tr>
<tr><td colspan="8">Oats</td></tr>
<tr><td>Sown area, ha</td><td>15691</td><td>3353</td><td>1401</td><td>1952</td><td>12338</td><td>7714</td><td>4624</td></tr>
<tr><td colspan="8">Rye</td></tr>
<tr><td>Sown area, ha</td><td>4637</td><td>1872</td><td>388</td><td>1484</td><td>2765</td><td>1289</td><td>1476</td></tr>
<tr><td colspan="8">Oilseed rape</td></tr>
</table>

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[44] https://publikacije.stat.gov.rs/G2019/Pdf/G20192052.pdf

Sown area, ha	24809	22716	983	21733	2093	798	*1295*
Other sown areas							
Sown area, ha	**42328**	**17842**	**3814**		**14028**	**24486**	***13416***

In the spring sowing, the total cultivated area of corn is between 980,000 and one million hectares, sugar beet about 60 thousand hectares, soybean about 250,000 hectares, sunflower about 220 thousand hectares, while the cultivated area of spring barley is about 20,000 hectares.

Looking at the regions, in 2018, corn was the most dominant crop in the Pomoravlje District, where between 40,000 and 45,000 hectares were sown, while soybeans were sown on only 200-250 hectares, in the Morava District, corn, both silage and mercantile corn, was sown on about 18,000 hectares, in the north of Vojvodina, in the area of Subotica, out of the total sown 80,000 hectares, the most of the area was under corn, followed by sunflower and soybeans, as well as in the region of Bečej, where 35,000 hectares were sown, of which 18,000 under corn, 6,000 under soybeans, 5,000 under sunflower and about 4,000 under sugar beet.

Estimates of the impact of expected climate change on agriculture in Serbia are not encouraging. Based on several models, a drop in yield was projected for almost all arable crops (RS national reports according to the UN Framework Convention on Climate Change, Ministry of Agriculture and Environmental Protection, 2008 and 2015). A slight increase is expected in corn yield only, but with the intensification of irrigation. This leads further to the issue of analysis of irrigation possibilities concerning the expected availability of water resources due to the expected impacts of climate change on water resources.

An increase in air temperature will shorten the period of crop growth, potentially reducing yields and thus threatening future global food security (Anwar et al., 2015[45]). The reason for the shortening of the growth period is the accelerated development in the conditions of increasing air temperatures followed by the lack of precipitation (Wu et al., 2019[46]). Fifteen-year results of these authors showed that the dates of the main phenological growth phases of corn, winter wheat and rice have changed, but they still conclude that the length of the growth period for these crops due to global warming is unlikely to be shortened as predicted by some simulation models. The shorter duration of the vegetation season, the smaller number of days required from sowing to flowering and the number of days from sowing to ripening is a consequence of the expected increase in air temperature during the year and the increase in temperature sums, as well as the sharp increase in summer and tropical days. For the territory of Vojvodina, it is projected that the increase in temperature and summer drought will generally endanger the spring crop more than the winter crop yields. The positive effects (extension of the vegetation season) in the winter crop yields are estimated to outweigh the indirect negative effects (Malešević et al., 2011[47]; Lalić et al., 2011[48]). Certainly, the effects of climate change will be manifested differently in different regions of Serbia, and it is still not possible to speak reliably about different regional scenarios. However, it should be noted

[45] Anwar, M.R., Liu, D.L., Farquharson, R.J., Macadam, I., Abadi, A., Finlayson, J. (2015): Climate change impacts on phenology and yields of five broadacre crops at four climatologically distinct locations in Australia. Agricultural Systems, 132: 133-144.

[46] Wu, D., Wang, P., Jiang, C., Yang, J., Huo, Zh., Yu, Q. (2019): Measured Phenology Response of Unchanged Crop Varieties to Long-Term Historical Climate Change. International Journal of Plant Production, 13: 47-58.

[47] Malešević, M., Jaćimović, G., Jevtić, R., Aćin, V. (2011): Iskorišćavanje genetskog potencijala pšenice u uslovima abiotičkih stresova. 45 savetovanja agronoma Srbije, Zbornik referata 3-14.

[48] Lalić, B., Mihailović, T.D., Podraščanin, Z. (2011): Buduće stanje klime u Vojvodini i očekivani uticaj na ratarsku proizvodnju. Ratar Povrt/Field Veg Crop Res 48: 403-418.

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that the most important field crop regions of Serbia are located in Vojvodina and in the valleys of larger rivers, and it is in these lower parts that the conditions of dry climate are expected which directly leads to the conclusion that these areas can be expected to be the most vulnerable.

Influence of meteorological conditions in the area of Belgrade on corn and wheat (1990-2012) – an example of analysis for the region

Based on decades of analysis of data from the Republic Hydrometeorological Service of Serbia for the area of Belgrade (Kovačević et al., 2012a[49]) it is stated that droughts in this area have been more frequent in the last twenty years. There are more and more years with extremely high temperatures in the summer months and frequent heat waves, which have a very unfavorable effect on the cultivated crops (Figure 14). The legend of the chart on the right shows the different periods from 1967 to 2012, which show that the largest number of years with temperatures in those summer months above 20°C is in the new century, from 2000 to 2012, even 11. In the first period from 1967 to 1969, (the lightest blue color), no year exceeded that value. These data clearly show increasingly warm summers. It is very important for agriculture when there is a dry period. **If the drought occurs during the critical period for moisture for a certain crop, or when the fruit is formed and the grain is poured, then the damage is greatest.** Spring crops, i.e. spring sowing crops, are especially susceptible to this.

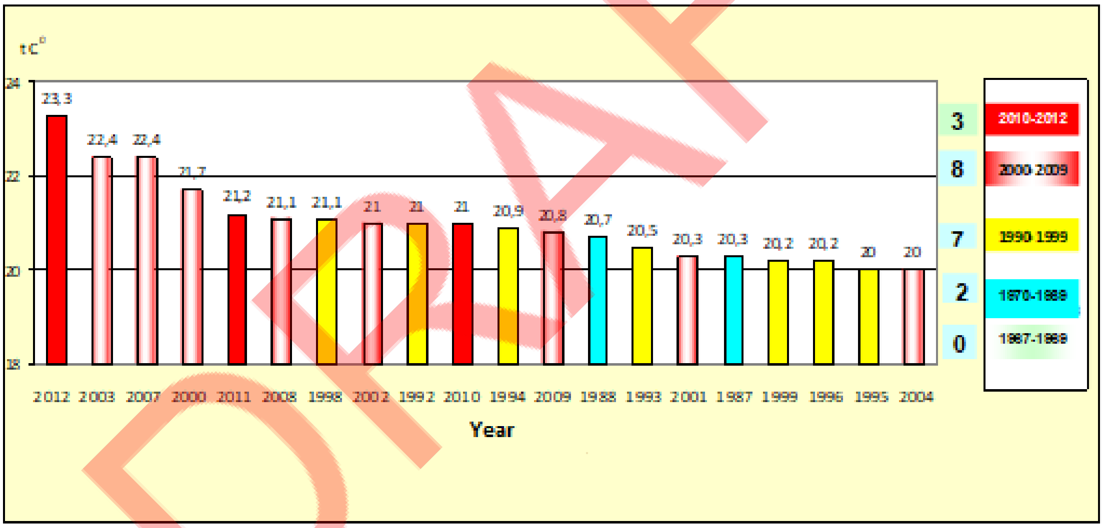

Figure 14. *Average monthly temperatures of three summer months in Serbia in the period (1967-2012) (Kovačević et al., 2012a)*

Kovačević et al. (2012a[50]; 2012b[51]) analyzed the meteorological conditions for the area of Belgrade in the period of 22 years (1991-2012) and concluded that 1992, 2000, 2003, 2007, 2011 and 2012 were extremely dry. In the above years, the drought was already in the spring, and very pronounced in the summer, so that the harmful consequences for most spring crops were great. In 2007, even higher temperatures were recorded than in 2012. These are the

[49] Kovačević, D., Oljača, S., Dolijanović, Ž., Milić, V. (2012a): Climate changes: Ecological and agronomic options for mitigating the consequences of drought in Serbia. In: Kovačević D (ed) Third International Scientific Symposium Agrosym, Jahorina pp 17-35.

[50] Kovačević, D., Oljača, S., Dolijanović, Ž., Milić, V. (2012a) Climate changes: Ecological and agronomic options for mitigating the consequences of drought in Serbia. In: Kovačević D (ed) Third International Scientific Symposium Agrosym, Jahorina pp 17-35.

[51] Kovačević, D., Dolijanović, Ž., Oljača, M., Oljača, J. (2010b): Produžno dejstvo meliorativne obrade na fizičke osobine zemljišta u usevu ozime pšenice. Poljoprivredna tehnika XXXV(2): 45-53.

highest temperatures recorded in this area, up to 45°C, when some historical previous highs were exceeded. The damage from the drought, which was reflected in the reduction of yields, was great. Compared to the previous year, lower corn yields were obtained by 32% and sunflower, as a more drought-resistant crop, by 23%. The spring drought was also in 2009, but it was overcome and does not belong to great droughts. During the corn vegetation period, the occurrence of heatwaves in the summer months is more and more frequent. Initially, those dry waves occurred in September, which contributed to the faster ripening of corn. However, in recent years, tropical heat waves, when the night temperature does not fall below 20°C, occur earlier - in August, and in 2012 there were some in the second half of July. These waves contributed to poorer fertilization, accelerated ripening and grain pouring. This is becoming more and more of a problem today. The best evidence for this claim is the weather conditions in 2017, which so far are very similar to the weather conditions that prevailed in 2012, characterized as very dry.

A special problem arises when the drought is transferred to the optimal deadlines for sowing winter crops (in Serbia, October and until the middle of November), which significantly hinders and prolongs their germination until winter. An example is the situation in 2011, when there was a drought during the entire vegetation period, and especially in August and September when it was the strongest. It continued into October and November, due to which the land was without any moisture for a long time, which had an impact on the wheat yield the following year.

The main feature of 2012 is significantly less precipitation than the average in June, July and August. In June, only 32% of the average, in July (only due to the rain at the end of the month) 86%. In August, only 5% of the average was recorded, which means that there was almost no precipitation. In these three months, the largest part of the territory of Serbia received 25-50% of the average precipitation. **This represents a strong drought that has an impact not only on agricultural crops but also on river water levels and on the reduction of groundwater quantities.**

In contrast to the dry years, in the analyzed period there were also those with more abundant precipitation, such as 1999, 2000, 2004, 2005, 2009 and especially 2010. In 2010, there was 80% more precipitation, and there were floods. The year 2005 was similar. It was the wet years with long periods of heavy rains that replaced the dry ones in Serbia and the region that contributed to a more favorable situation with the groundwater level, which is sometimes important as a source of water for cultivation, especially spring agricultural crops, which are more represented in the sowing structure of Serbia than winter ones. More abundant precipitation in winter caused great damage in some years, such as extreme 2010 and 2014, in the form of floods and lying waters on the entire territory, especially in Vojvodina (Malešević et al., 2011[52]).

3.1.4. Livestock production

The share of livestock production in total agricultural production is one of the important indicators of agricultural development in general. Countries with a higher share of livestock production in total agricultural production are considered economically developed. Livestock production in the Republic of Serbia in the last 10 years accounts for 35-40% of the value of total agricultural production, which is far less than countries with developed cattle breeding, such as the Netherlands, where cattle breeding has a share of over 60% in total agricultural production.

[52] Malešević, M., Jaćimović, G., Jevtić, R., Aćin, V. (2011): Iskorišćavanje genetskog potencijala pšenice u uslovima abiotičkih stresova. 45 savetovanja agronoma Srbije, Zbornik referata 3-14.

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In 2018, a total of 878,000 cattle of all categories were raised in Serbia, which is the level of 50% in relation to the number of cattle raised in the early 1990s. The number of pigs is around 2.8 million and is slightly declining compared to the five-year average. The number of poultry has been relatively stable over a long period of time and on the average, around 16 million heads are raised in the Republic of Serbia (Figure 15[53]). The increase in the number of heads is present only in sheep production, where the number of heads grows by about 2% annually. An increase in production is also present in beekeeping.

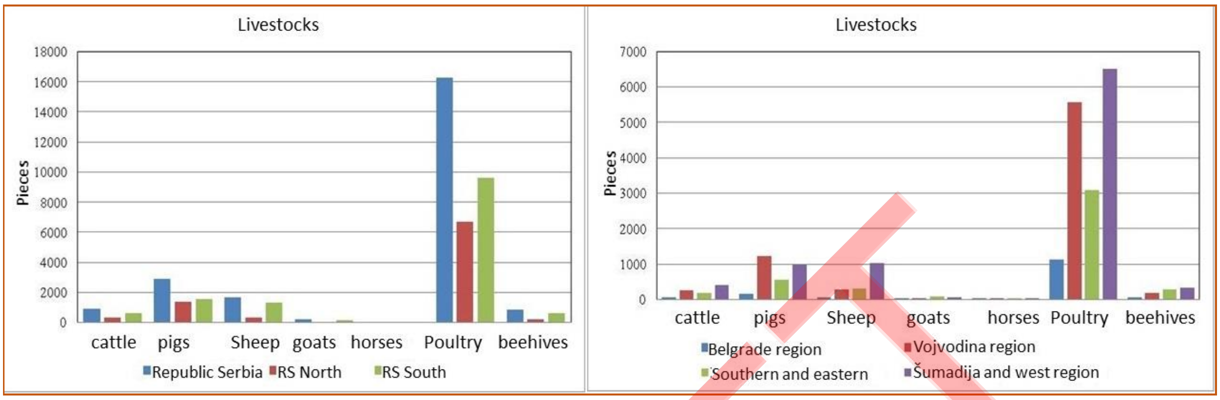

Figure 15. *Livestock for the period 2016 – 2018*

The number of conditional heads of livestock has been declining since the beginning of the 1990s, which is still present to this day. There are several reasons for this. First of all, these are economic reasons, which underlie the transition and change of market relations. Other reasons concern the demographic depopulation of the village, unfavorable structures of livestock farms, which was an obstacle to specialization, as an important prerequisite for increasing productivity and competitiveness of livestock farms. Despite the decrease in the number of heads, the production of all livestock products increased, as a result of the increase in the productivity of heads raised.

Livestock production is greatly influenced by climate change and the technology of all types of livestock production demands continuous adaptation. Adaptations to changed climatic conditions require greater material investment on the one hand, and growing losses on the other, which raise the profitability and sustainability of livestock production. As a result, the socio-economic conditions are changing in environments where livestock production is predominant, there is a demographic depopulation, and even the cessation of livestock production. This is especially true of marginal, hilly and mountainous areas, where this is traditionally the primary and dominant source of income.

The impact of climate change on livestock production can be observed in two ways:

- Direct (immediate) impact;
- Indirect (intermediary) impact.

The direct impact is seen through the negative impact of unfavorable values of temperature and air humidity on the heads, resulting in heat stress that reduces the resistance and productivity of the heads. We must not neglect the impact on reducing the quality of livestock products, such as reduced milk solids, which limits the use-value of milk. The direct impact on the animal is reflected through the combined influence of temperature and humidity. The combination of these two effects is called the temperature-humid index (THI index), which is under the direct impact of external climatic factors. For each species, there is a comfort zone, i.e. the optimal values of this index that have a favorable impact on production and health of

[53] Statistical Yearbook (2019): https://publikacije.stat.gov.rs/G2019/Pdf/G20192052.pdf

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the heads. For example, the optimal values of the THI index for dairy cow's comfort zone are up to 70, the negative effect occurs already at 72, and if the THI values exceed 90, serious disorders and even death of the heads occur.

There were no data in Serbia on the values of the microclimate in the facilities where animals are raised, but there were attempts to use the official data of the Republic Hydrometeorological Institute of Serbia from the station closest to the farm (otherwise very inaccessible and almost impossible to reach them). Still, it turned out that as quite imprecise due to the great impact of the type of building, the number of heads in the building as well as the impact of the microclimate where the building is located. Since 2014, this problem has been overcome, within the project “Optimization of technological procedures and zootechnical resources on farms in order to improve the sustainability of milk production“ (TR 31086) under the auspices of the Ministry of Education, Science and Technological Development.

Within the research, 8 farms of different capacity and applied technology and level of production were selected, where dairy cows are raised and dataloggers that measure the temperature and humidity of the air every hour (24 times during the day) are set. Based on these values, the values of the THI index were calculated and the actual impact on the head was determined. The assumption at the beginning of the research was that the negative impact was present during the summer months (June, July, August). Studies have shown that THI values that have a negative impact on productivity and health of the heads occur from the second half of April until the first half of October, which means that for almost 6 months in our climate there is a danger of the negative effect of climate factors on livestock production, primarily through reduced production and higher treatment costs, which significantly contributes to reduced production profitability (Figure 16).

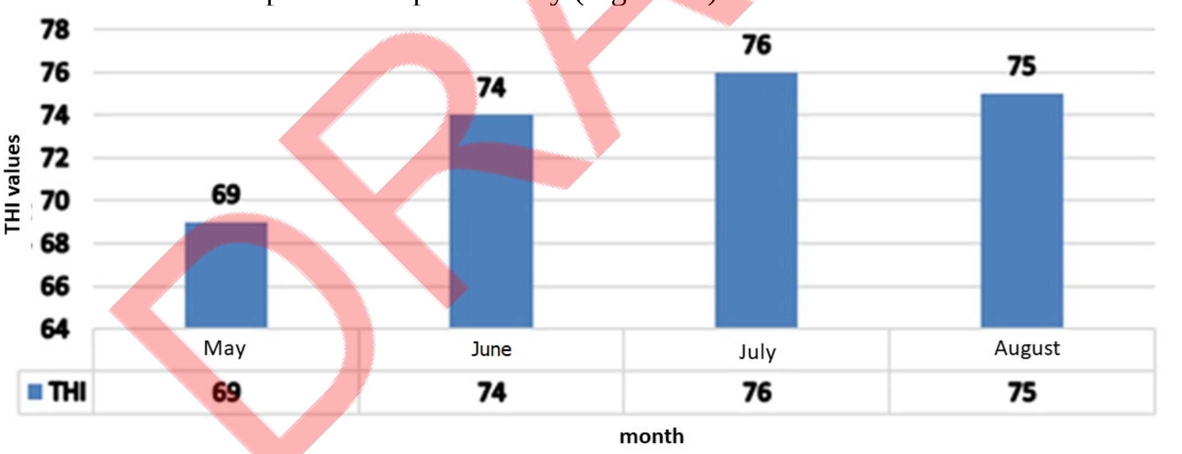

Figure 16. Average THI values in summer months

In the future, this period will expand, with climate change, and the negative effects on production will increase. Three summer months are a serious problem because the THI averages for these three months exceed 72, i.e. it can be considered that in these three months there is no day in which there is no negative effect of the microclimate effect on productivity and health in a certain period of the day. Underway is the development of a methodology that could estimate productivity losses, as well as economic losses due to these negative effects. The application of this methodology can be expected in the coming years, through the implementation of various projects, including this one.

The indirect impact is reflected in the impact of climate change on crop production, as an important segment in which animal feed production takes place. These effects are reflected in the quantity and quality of animal feed. Increasing the frequency of extreme climate events,

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such as droughts, floods, hail, reduces primarily the amount of animal feed that producers can store and such a situation is often reflected in the price, primarily through increasing the price of food that can be bought on the market, which negatively affects the economic sustainability of production itself. In addition to the quantity and price of food, an important segment is the quality of animal feed produced. In such stressful conditions for the plant, the quality of the prepared food itself can be questioned. This is supported by the appearance of aflatoxins in corn grain in 2012 as a result of drought and the action of some pests, which caused major disturbances in the dairy market.

Also, in extreme climatic conditions, it is possible to perform all procedures in a timely manner, such as harvesting crops in the optimal phenophase, as well as forced procedures in food preparation, which affects the quality and price of food produced in this way.

Also, we must not neglect the impact of new diseases that occur due to climate change and the expansion of the range of causes of these diseases. Thus, diseases such as African swine fever, contagious skin bumps in cattle, bluetongue disease appear in our country today, which cause great damage and pose a great threat to our livestock. Data on these diseases are collected and processed by the Veterinary Directorate within the Ministry of Agriculture, Forestry and Water Management, but these data are not available to the general professional public, which would certainly be necessary to assess the danger and spread of these diseases depending on climate change and timely reacting in case of outbreaks of local hotspots.

3.2. Adaptation measures

In agriculture, adaptation measures take place at different spatial scales, at the national, regional and agricultural producers level (farmers) (Smith and Skinner, 2002[54]). Among the significant adaptation measures is the establishment of the efficiency of the early warning system at the national/regional level and the risk management scheme and other technical measures at the level of agricultural holdings. The following (Table 10) lists potential adaptation measures at the national, regional and farm level, based on international good practices and experiences.

Table 10. *Potential adaptation measures to changed climatic conditions*

National/Regional level	**Early warning and weather conditions warning** **Insurance systems against natural disasters and natural catastrophes** **Improving the efficiency of irrigation infrastructure** **Flood management and prevention**	
- *On-farm level:* - *Agricultural crops* - *Livestock* - *Viticulture* - *Horticulture (plant production)*	- Drainage - Improving irrigation efficiency - Precise agriculture - Ecological or organic agriculture - Modification of the crop calendar - Cover crops - Use of adapted	- Variety and crop rotation - Livestock breeding with higher tolerance and productivity - Improving pasture and grazing management (meadows and pastures) - Improving animal husbandry conditions - Prevention of livestock diseases caused by climate change - Modification of application of

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[54] Smith, B., Skinner, M. (2002): Adaptation options in agriculture to climate change: A topology, Mitigation and Adaptation Strategies for Global. Climate Change, 7: 85-114.

	(tolerant) crops - Adjustment of terms and types of works	fertilization and spraying in annual and perennial plantations - Fruit thinning and ampelotechnical measures in orchards and vineyards - Setting up greenhouses - Protection and monitoring equipment - Diversification of agricultural activities

On the other hand, the analyzes of the impact of climate change on the agricultural sector in the First and Second National Reports are the basis for a list of recommended measures for adaptation to changed climate conditions (Table 11).

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Table 11. Proposed adaptation measures at the national level

Risk reduction	-Changing the time of work in the field; -Timely tillage and sowing, optimal sowing density, the introduction of minimum plowing and/or reduced tillage; -Selection and introduction into production of varieties resistant to drought and high temperatures; -Cultivation of early ripening varieties in regions with pronounced dry summer and without irrigation; -Growing varieties with better yield (such as C-4 plants); -Increasing the presence of winter crops; -Provide more crops per year by rotation in order to take advantage of the extension of the vegetation period; -Rational and efficient use of fertilizers; -Increasing the organic content in the soil, especially in some parts of Vojvodina; -Plowing plant residues in the soil; -Improvement of efficient use of water resources; -Improving the efficiency of irrigation and water use to obtain adequate yields by optimizing irrigation techniques and methods: -More significant use of anti-hail nets; -Introduction of alternative, early and table varieties, especially in western Serbia; -More efficient application of techniques for protection of vines from early autumn and late spring frosts; -Forming terraces for production on the slopes; -Improvement of methods of protection against water erosion by improving techniques for water accumulation in the soil; -Improvement by afforestation to protect the soil from erosion
Policies	-Providing legal frameworks for the implementation of adaptation measures and mitigation of the effects of climate change in agriculture; -Strengthening institutional measures to successfully establish links between different participants and experts (eg by providing the necessary capacities in agricultural research and advisory services, establishing monitoring and warning systems for agricultural purposes; -Providing subsidies for the implementation of adaptation and/or mitigation measures; -Implementation of adopted legal measures for specific environmental problems, such as protection of the quality of water resources by limiting fertilization or restrictive land use; -Supporting the education of producers in various ways, which includes financial

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	support; -Sustainable use of agricultural land, organic production, agro-ecological measures, good agricultural practice.
Monitoring and research	-Monitoring: development of capacities for implementation of adaptation measures to climate change, financial efficiency of applied measures, changes in the agricultural insurance policy, time and place of occurrence of harmful organisms, improvement of producers' awareness, education of all participants in the implementation of adaptation measures, work of agricultural advisory services; -Research: selection of varieties resistant to stress and drought, development and improvement of techniques to reduce evapotranspiration, water conservation in soil and increased irrigation efficiency, more efficient use of modeling results (eg use of numerical weather forecast in combination with already developed agronomic models to predict harmful occurrence and mitigation of their effects).
Capacity and awareness development	-Education of farmers related to new technologies and management; -Support and advice for direct marketing producers; -Ensuring the availability of counseling services for all; -Providing attractive educational opportunities for younger producers; -Connection of small farms into medium and large farms; forming cooperatives wherever possible; -Maintaining a balance between crop and livestock production in order to avoid increasing the content of greenhouse gases at the local and then at the global level.
Small grains	-Development of new genotypes with adaptability to abiotic and biotic factors or adaptation of existing genotypes to future conditions; -Detailed risk assessment based on meteorological and biological observations in a wide region is necessary for the prevention of diseases and epiphytosis.
Corn	-Changing the date of sowing, selection of tolerant hybrids and irrigation in order to reduce the total stress (in the future it will be necessary to consume more water for irrigation on larger areas than before); -Replacement of current hybrids with those that mature later and that are resistant to higher temperatures; -Rotation of crops to reduce pest attacks; -Monitoring the occurrence of diseases and pests and prognosis (not only for corn) strengthen effective crop protection and reduce the risk of decay.
Sugar beet	-Irrigation; -Early sowing; - Delaying the extraction of beets, which is an extension of production and exposure of the plant to external conditions for at least another month; -Selection of tolerant hybrids and identification of regions with favorable growing conditions.

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Grapes and wine	-Taking into account the expected agro-climatic conditions when raising new orchards and vineyards; -Timely fertilization, irrigation, installation of anti-hail nets, weed control, cultivation system, regular pruning, removal of fallen leaves.

The proposed adaptation measures do not define priority needs, nor optimal solutions for certain regions/areas, local self-governments, etc., but are, in accordance with the nature of the document (national reports), a list of possibilities and potential solutions. Therefore, it is necessary to define adaptation measures at a level lower than the national. In that context, it is necessary to determine the impact of agricultural production at levels lower than the national ones, which again requires systematic and continuous monitoring of the basic parameters of agricultural production, monitoring of diseases and pests, etc.

Fruit production

Meteorological phenomena that negatively affect fruit trees, the consequences they cause and the optimal measure of adaptation for a specific cause and effect on fruit trees are shown in Table 12. It is clear that the most commonly proposed measure of adaptation to changed climatic conditions is: **the correct choice of terrain, species, varieties and substrate**. In other words **regionalization is a key adaptation measure to changed climatic conditions**, which will be increasingly pronounced in the future (Đurđević et al., 2018[55]). For that reason, it is necessary to prepare regionalization taking into account the expected changes in climate, ie climate projections.

Table 12. *Climate change factors that cause damage to fruit trees and potential adaptation measures*

Meteorological phenomena	**Consequences on the fruit tree**	**Adaptation measures**
Occurrence of extremely low temperatures during the winter period	Freezing of parts or whole plants	Selection of varieties and substrates, site selection
Temperature variations during the winter period (change of hot and cold periods)	Increased sensitivity of certain fruit organs to frost	Selection of varieties and substrates, site selection
Lack of snow cover formation	Freezing of the root or root collar in fruit trees	Selection of varieties and substrates, site selection
Large temperature oscillations in spring (occurrence of late spring frosts)	Freezing of flowers and newly formed fruits	Selection of varieties that bloom later, site selection, installation of "anti- frost" system, orchard insurance
Snow cover formation after leafing	Breaking branches	Selection of varieties that start later with vegetation
Heavy rainfall during fruit ripening	Fruit cracking, fruit rot	Selection of resistant varieties, installation of

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[55] Đurđević, V., Vuković, A., Vujadinović Mandić, M. (2018): Izveštaj o osmotrenim promenama klime u Srbiji i projekcijama buduće klime na osnovu različitih scenarija budućih emisija, Treća nacionalna komunikacija o klimatskim promenama, Beograd.

		"rain cap" system
Raising groundwater levels (flooding)	Drying of whole trees	Substrate selection, soil drainage, terrain selection
Drought	Decreased yield, poorer fruit quality, absence of fruit in the next year	Irrigation, selection of variety and substrate
High temperatures during the growing season	Occurrence of burns on fruits, reduced photosynthesis, the appearance of double fruits next year	Selection of varieties, placement of shade nets, proper pruning
Strong wind	Breaking trees, falling fruits, falling leaves	Planting a windbreak or shelterbelt, proper arrangement of fruit trees, choice of position
Occurrence of hail storms	Damage to trees, leaves and fruits	Installation of anti-hail nets, use of anti-hail rockets, orchard insurance

In addition, it should be borne in mind that some of the mentioned meteorological phenomena (hail and floods) are registered at the level of local self-governments, and when a state of emergency is declared, the damages caused as a consequence of the occurrence are assessed. However, as stated, there is no integrated damage assessment methodology, nor a fully publicly available systematic collection of data on natural disasters.

Viticulture production

Potential adaptation measures in viticulture are shown in Table 13.

Table 13. *Potential adaptation measures in viticulture*

Adaptation measures in viticulture
Proper selection of cultivation sites and moving the vineyards to higher altitudes
Natural shading of vineyards (cultivation on north-oriented sides)
Adequate defense against diseases and pests due to more frequent adverse weather conditions (spring-summer)
Adequate defence against extreme events (drought, floods)
Insurance of vineyards
Installation of anti - hail nets
Adequate selection of assortment
Application of appropriate agro and ampelotechnical measures (soil maintenance, cultivation system, pruning, etc.)
Provision of subsidies including climatic factors
Creation of new vines varieties that are tolerant to various biotic and abiotic stressors

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Crop production

Significant adaptation measures in field production include **agro-technical measures by which moisture is retained and moisture losses are prevented while encouraging its more efficient and economical use**. Agromeliorative tillage creates a layer in the soil that is able to receive and conduct, i.e. accumulate sufficient moisture reserves from the period when there is more, as well as to make them available to plants in their critical periods for moisture (Kovačević et al., 2010[56]). Hence the **invaluable importance of autumn deep plowing** for everyone, especially spring crops. All **pre-sowing treatment measures,** as well as **care measures** aimed at cutting capillaries and preserving moisture, are welcome for these purposes (harrowing, inter-row cultivation and hoeing). To eliminate various adverse abiotic influences that leave their direct effects on the soil and create favorable conditions for cultivated plants, various crop care measures are used, primarily of mechanical nature: harrowing, rolling and inter-row cultivation with hoeing and covering (Kovačević et al., 2017[57]).

When it comes to sowing, one should take into account **the choice of varieties/hybrids**, drought-adaptable for a known area, predetermined technology (*high* or *low input*), expected meteorological conditions in the year as far as can be predicted in advance based on some indicators, plant density and sowing depth, i.e. seed quantity (Simić et al., 2018[58]).

Reduction of damage from the consequences of drought on the largest areas under corn can be achieved by certain **agro-technical measures**, selection of hybrids and sowing in the recommended densities per unit area. The number of plants per unit area has the greatest effect on the yield of corn in years with favorable weather. However, in years with reduced rainfall or their unfavorable distribution, it is very risky to grow hybrids in high densities because barren plants (plants without cobs) appear. Maize hybrids created in our country are better adapted to drought in these parts. In addition, our hybrids have the ability to give high yields in conditions of a smaller number of plants per unit area in favorable weather conditions, while in dry years they tolerate drought better. In order to make the best use of soil moisture reserves and to prevent evaporation as much as possible, it is being worked on creating hybrids suitable for very early sowing, as early as the beginning of April in our climate.

Land under broad-leaved crops has been unprotected for a long time. By applying inter-row cultivation, with cultivators intended only for such purposes, the soil is cut and scattered between the rows. **Mulching** (spreading soil) reduces evaporation in such a way that a smaller area is exposed to the sun and wind. The sun's rays are more reflected from the brighter surface (mulch is brighter than the soil), which affects the temperature reduction. Chopped materials or smaller substances used for mulch absorb water better and prevent it from draining or evaporating. The surface under the mulch is more porous without the crust and can absorb more moisture. For these reasons, the land is more supplied with moisture.

[56] Kovačević, D., Dolijanović, Ž., Jovanović, Ž., Kolčar, D. (2010): Uticaj produžnog dejstva meliorativne obrade zemljišta na razvoj korenovog sistema, morfološke i produktivne osobine ozime pšenice. Poljoprivredna tehnika XXXV(2): 37-44.

[57] Kovačević, D., Momirović, N., Dolijanović, Ž., Poštić, D. (2017): Modern approach to soil tillage in Serbia: from productivity and energy efficiency towards agroecosystems resilience and sustainability. 3rd International Scientific Conference Sustainability challenges in agroecosystems, Osijek, Croatia p 29.

[58] Simić, M., Kresović, B., Dragičević, V., Tolimir, M., Brankov, M. (2018): Improved maize cropping technology to reduce the impact of climate changes. Proceedings of the IX International Agricultural Symposium "Agrosym 2018", Jahorina pp 263-270. http://www.agrosym.unssa.rs.ba.

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In addition, significant adaptive capacities can also have measures of crop thinning, fertilization, irrigation, crop rotation (two-field: winter wheat – corn, but increasingly three-field composition, in addition to winter wheat and corn, includes soybeans). When it comes to the plants themselves, it should be mentioned that in addition to the choice of species, one should also look at the varieties (hybrids) of one of the species. Some are more drought tolerant and more adaptable to such circumstances, and some are again very intensive, with very high requirements for all factors, from nutrients to water (Dolijanović et al., 2014[59]).

In other words, in adaptation to drought, regular and special agro-technical measures are used along with an adequate assortment of cultivated plants with greater drought tolerance. Regular measures include **tillage, fertilization, sowing, crop care measures, crop rotation**, and special measures include **snow retention, mulching and anti-evaporation**. All those agro-technical measures that retain moisture and prevent moisture losses, while encouraging its more efficient and economical use are applied (Kovačević et al., 2013b[60]). In addition to the mentioned measures, there is also **irrigation as the most direct measure** for field crops. However, irrigation essentially changes all the conditions in one system of plant production, so that in itself it represents a special measure with a far-reaching impact, which should be taken into account. All of the above are also potential adaptation measures, and their effectiveness depends on the inclusion of climate change (observed and expected) in the planning process. Drought-sensitive plants should not be sown behind pre-crops that have consumed a lot of moisture in previous years. Sunflower, sugar beet, alfalfa are exactly such crops.

Contrary to drought, in years with more precipitation, problems of another type occur, especially on heavier soils. Hydromorphic soils are characterized by excess water, either occasionally or throughout the year (Kovačević et al., 2010[61]). Heavier soils require agro-ameliorative tillage for better permeability, especially in wetter years. This is very important so that water does not lie on the same impermeable surface for a longer period and does not create water retention that would soon suffocate the crop. In this case, the required measures that can be treated at the same time as adaptation measures are:

- **Properly placed crop rotations** with greater crop diversification provide better tolerance with regard to extreme moisture conditions, which is especially in the case of wheat ie. the proper arrangement of crops in the crop rotation can significantly reduce the extreme effects of heat and precipitation.

- **Creating new varieties of cultivated plants** that are more tolerant to water and other stressful conditions (in the meantime use varieties or hybrids that are most adapted so far on the basis of previous experience).

- **Increasing the number of crops,** in order to use better the moisture reserves in the soil and which will be in the field during autumn and winter and will not interfere with the sowing of spring crops.

- **Raising of field protection belts** in order to reduce the wind speed, and then mulching the soil.

[59] Dolijanović, Ž., Kovačević, D., Momirović, N., Oljača, S., Jovović, Z. (2014): Effects of crop rotations on weed infestation in winter wheat. Bulgarian Journal of Agricultural Science 20(2): 416-420.

[60] Kovačević, V., Kovačević, D., Pepo, P., Marković, M. (2013б): Klimatske promjene u Hrvatskoj, Srbiji, Mađarskoj i Bosni i Hercegovini: Usporedba vegetacije kukuruza 2010. i 2012. godine. Poljoprivreda 19(2): 16-23.

[61] Kovačević, D., Dolijanović, Ž., Jovanović, Ž., Kolčar, D. (2010): Uticaj produžnog dejstva meliorativne obrade zemljišta na razvoj korenovog sistema, morfološke i produktivne osobine ozime pšenice. Poljoprivredna tehnika XXXV(2): 37-44.

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Sustainable agriculture is an important element of the overall effort to make humanity compatible with the requirements of the soil ecosystem.

Livestock production

Intensive livestock production, primarily pig and poultry, will be quite under the negative direct and indirect impact of climate change in the Republic of Serbia. Planning and implementation of adaptation in the livestock sector is related to measures of importance for crop production, but also to direct adaptation measures. Significant adaptation measures for livestock include:

- In poultry and pig breeding, in intensive production that takes place in closed facilities, it is possible to partially control microclimatic conditions and their negative impact on these types of livestock production.
- Milk production, primarily cow's milk, is potentially the most endangered activity within livestock production. In this segment of livestock production, it is necessary to **adjust the production technology (diet, meal composition ...), as well as the installation of ventilation and sprinkling equipment inside the facility**. For farms that are being built, it is necessary to take into account when designing facilities, their volume, orientation, as well as the materials of which they are built. A good adaptation measure is to use a drain with shade and sprinklers.
- When it comes to sheep production, it must be adjusted primarily to the **amount of available pasture**, for the sake of economic sustainability, as well as the possibility of using by-products of crop production for sheep feeding, in the most intensive crop production regions
- In all species of domestic animals, it is **necessary to carry out a selection** in order to obtain genotypes with increased resistance to heat stress, i.e. to create genotypes that can successfully produce in changed climatic conditions.
- **The transition of one part of livestock production into the framework of ecological and organic production**, in which genotypes are grown that are more resistant to the negative effects of climatic factors and get products of higher biological value.
- **Animal feed production**, as an important segment of successful livestock production, should be based on traditional crops such as corn, barley and other crops, whose technology must adapt to climate change (earlier sowing, use of irrigation ...). New crops should also be introduced or areas under crops such as cattle sorghum and sudangrass should be expanded, which can be an excellent source of quality food for domestic animals and can withstand changed climatic conditions well.
- **Harmonization with the regionalization of crop production**, as an important prerequisite for sustainable livestock production.

In general, for the complete sector of agricultural production, but also other sectors and adaptation measures to changed climatic conditions, there are two key shortcomings for which it is necessary to propose solutions:

(1) identification of activities and measures at levels lower than national (regions, areas, local self-governments) and

(2) monitoring and reporting on implementation, problems and barriers to

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implementation.

3.3. Conclusions and recommendations

Based on the previous analysis, it is clear that effective planning and implementation of adaptation in the agricultural sector requires:

- Establishment of a system for monitoring the relevant indicators (EEA indicators) and displaying them on a common platform (which can be an integral part of the MPB national system);
- Establishment of systematic and continuous collection of data on production, yield, etc. (at the annual and local self-government level) and their availability to stakeholders;
- Harmonization of publicly available data and improvement of data quality (especially yield data), eg, FAOSTAT and Statistical Office of the Republic of Serbia data;
- Providing publicly available data on observed and expected climate changes, but also other data available, primarily, to the Ministry of Agriculture, Forestry and Water Management and public companies, ie other institutions entrusted with tasks within the scope of competence. Especially at the level of the region or area and local self-governments and in easy-to-use forms;
- Preparation of a methodology for assessing damage and losses due to natural disasters and natural catastrophes caused by climate change. Especially at the level of the region or area and local self-governments;
- Development of guides and recommendations for local self-governments on the issue of collecting and systematizing data and information, because the assessment of the impact, and above all the planning of adaptation depends on the needs of cities and municipalities;
- Inclusion of climate projections (which is not the case in the national risk assessment of natural disasters and catastrophes) and socio-economic aspects in the assessment of the impact of the sector (which is not the case in the national reports) and planning adaptation measures;
- Monitoring and assessment of the impact of climate change on the occurrence of diseases and pests;
- Regionalization based on observed and expected changes in climate, topographic and soil characteristics;
- Popularization of regionalization results, through the production of publications, brochures, newsletters and the like for individual target groups and stakeholders, but also through the training of employees in the competent Ministry and experts, primarily agricultural professional services.

From the aspect of adaptation, it is important to analyze the benefits and possibilities for the application of certain agro-technical measures. The Ministry of Agriculture, Forestry and Water Management (Agricultural Land Administration) that in past years financed Study and Research works that dealt with **the suitability of land for irrigation in certain regions, the availability of this data** is important for agricultural production organizations.

In principle, evaluation is crucial for the adaptation of the agricultural sector and the possibilities of construction and maintenance of canals and dual-purpose accumulations (in seasons when large amounts of precipitation occur to serve for draining and retaining excess water, and for using that water for the purpose of irrigation in the irrigation season). It is

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necessary to analyse in detail the needs of crops for water and on that basis to determine the time and norms of watering in order to efficiently use water

So it is recommended to use the *AquaCrop* model for simulation of yield, duration of phenophases, movement of vegetation of strategic field, vegetable and fruit crops on the basis of observed (measured) data and their expected values in the future in different regions of the Republic of Serbia. The model can also simulate water needs, thus defining regions according to the possibilities for growing certain plant species. This model is used for drafting National Reports.

Required data for the model: Location, Latitude; Altitude; Climate data; T max, T min, wind speed, precipitation, duration of sunshine during the day (insolation of hours) – it would be ideal, daily values, if not at least monthly. The minimum required is T max, T min and precipitation;

Soil – Soil type, Water characteristics of the soil (FWC (field water capacity) and WM (wilting moisture) ρб (soil bulk density) this is the minimum, and if not any, than at least the type of soil and in which area;

Agrotechnics; Irrigation – Dates of irrigation and applied amount of water (time and standard of watering); Fertilization – Dates and standards of fertilization (type of nutrients);

Plant – Yields dry and fresh yield mass (fruits) ($t \cdot ha^{-1}$), total biomass (fresh and dry $t \cdot ha^{-1}$). A large number of models like this one predict (simulate) dry mass and dry biomass (if you do not have this data, you must know the percentage of water in the fruit, leaf... in order to recalculate), Dates and beginning and duration of individual phenophases (planting, transplanting (if planted) leafing, flowering, fruiting, ripening); Increase during individual phenophases (cover) as much as the plant covers the area in each phenophase, density of planting, sowing, transplanting (number of plants, seedlings per ha), Is it a C3 or C4 plant. This is the basic data that is needed. Of course, if other adequate measurements are made, they can be included in the model.

The approximate water demand during the vegetation period can be determined as the average water consumption per evapotranspiration process (Eto) multiplied by the number of days in the month. However, each culture has its own specificity (culture coefficient (k_c) which differs according to the phenophases of each culture), so the culture's need for water was obtained as a product of evapotranspiration and the culture coefficient (Table 14).

Table 14. *Water needs in the climatic conditions of Serbia during the vegetation period (April – October)*

Month	Average Eto (mm·day-1)	Monthly need for water (mm)
April	2-2,5	60-75
May	3	90
June	3,5-4	105-120
July	4,5-5	135-150
August	4-4,5	120-135
September	2,5-3	75-90

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In addition to water needs, investments in dual-use systems, especially when it comes to construction, also determine the availability of water to a particular area. It is recommended that the adaptation measures involved in these systems take into account the results of the assessment of the impact of climate change on the water resources and water availability. This aspect should, in accordance with the possibilities, be incorporated into the impact assessments.

Also, from the aspect of plant production planning, it is important to know the optimal temperatures for the beginning of individual plant phenophases, as well as the duration of each phenophase, which actually depends on the temperature sums.

Based on previous analyses, it is possible to assess the need for subsidies and prepare recommendations in that context (Subsidies of the Ministry of Agriculture, IPARD funds, etc.). On the other hand, it should be taken in the account that the planning of this adaptation measure depends on the availability of water, ie on integrated water management. Which is not the subject of this report, but it is crucial for the next phases.

Given that there is no systematic collection of data on the implementation and implemented adaptation measures, which is also a requirement of the draft Law on Climate Change, it is necessary to legally regulate this area.

3.3.1. Recommendations

The project recommends:

FRUIT GROWING

- To determine changes in the values of basic and corrective thermal indicators (based on scenarios on climate change for the next 100 years, Đurđević et al., 2018[62]) in relation to current values and based on these indicators to determine the favorable cultivation of certain fruit trees in the near and distant future.
- Based on these analyzes, give an assessment of the increase or decrease of areas in which fruit production can be successfully organized and the scope and types of different measures of adaptation of fruit trees in relation to the current situation.
- Determine in the future by regions what is the level of damage and which species would be grown, which varieties, which technology would be applied depending on climate change, water availability, the possibility of providing subsidies and the like.
- Draft maps of current and future regions of favorable cultivation of certain types of fruit trees will be made.

- **VITICULTURE**

- Identify changes in the values of viticultural indices for wine-growing regions in relation to those calculated and given in the current regionalization, which will take into account the projected climate change.

62 Ђурђевић, В., Вуковић, А., Вујадиновић Мандић, М. (2018): Извештај о осмотреним променама климе у Србији и пројекцијама будуће климе на основу различитих сценарија будућих емисија, Трећа ..национална комуникација о климатским променама, Београд.

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- In order to calculate the wine-growing indices and assess the suitability of a locality, appropriate data from Republic Hydrometeorological Institute of Serbia stations are necessary. Also, data on the characteristics of soil owned by the Administration for Agricultural Land as well as the Institute of Soil Science may be relevant. Data on areas, varietal representation, grape production, age of vineyards, applied agro and ampelotechnics, etc. are also necessary. available to the Center for Viticulture and Oenology from Niš (https://cevvin.rs/).

- CROP PRODUCTION

- Determine by regions what is the current and expected level of impact to crop production and which species would be grown, which varieties and hybrids, which technology would be applied depending on climate change, water availability, state possibilities to reduce the vulnerability of the sector to the changed climate conditions.
- This work requires appropriate data from Republic Hydrometeorological Institute of Serbia stations as well as the necessary data on the characteristics and condition of the land owned by the Agricultural Land Administration at the Ministry of Agriculture of the Republic of Serbia and the Institute for Soil.

-LIVESTOCK PRODUCTION

- Assessment of direct impacts of climate change, primarily on the quantity and quality of livestock products, as well as potential zoning in accordance with the zoning of crop production as an important prerequisite for economical livestock production.
- In order to make estimates of losses in livestock production, data from Republic Hydrometeorological Institute of Serbia stations are necessary, as well as climate projections for the same stations in order to connect with the location of the farm and calculate the temperature-humid index. It is also necessary to have data on agro-ecological conditions available, in order to rationally base the production of animal feed.
- Assessment of the danger of occurrence and speed of spread of new diseases in the field of livestock production and their connection with climate change, as a basis for timely response in case of outbreaks of local hotspots. Data on these diseases are collected and processed by the Veterinary Directorate within the Ministry of Agriculture, Forestry and Water Management

- GENERAL

- Prepare a database of publicly available data of importance for monitoring areas, yields of different agricultural crops, implementation and evaluation of adaptation measures with recommendations for cultivation. The platform can be used for production analysis, as well as recommendations for future agricultural production. The main feature that this platform should satisfy is easy access to agricultural producers. Connecting to a platform that will contain data on observed and expected climate change would ensure the availability of all relevant information in one place. It could also be a place of early warning and warning of phenomena that can cause negative consequences for

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agricultural production.

- Perform the analysis of the occurrence of diseases and pests, as a consequence of climate change, and the consequences for agricultural production in this regard, or prepare recommendations for the necessary monitoring and systematization of data, so that such an analysis be made.
- Prepare a list of adaptation measures and joint multisectoral adaptation measures for the sectors: water management, forest management and agriculture.
- Prepare a list of relevant models and methodologies for assessing the impact of climate change on the agricultural sector.
- Prepare recommendations for: lists of indicators, in line with EEA indicators; institutional competence and responsibility for data collection and indicators.
- Support in the preparation of a methodology for assessing damages and losses due to natural disasters and natural catastrophes.

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4. WATER MANAGEMEMT AND WATER RESOURCES

4.1. Impact assessment

4.1.1. International and EU context

The use of drinking water, hygiene, recreation, transport, agricultural, industrial and energy production, etc. significantly affects the availability and quality of water resources, and this pressure certainly increases with the intensification of climate change. The impacts of climate change on the global water management sector are presented in the 5th report of the International Panel on Climate Change and a special part, more precisely in the part of the report Climate change 2014 - Impacts, adaptation and impact[63], while a new report of this type is being prepared and expected. its publication in 2021.

On the one hand, climate change is increasing the need for water, and on the other hand, it is reducing its availability. Analyzes from 2018 for the Danube River Basin showed that the change in land use and water use contributes with only 10-20%, expected changes in the availability and quality of water resources, while climate change is responsible for 80-90% of these changes.

According to previous EU analyzes, a significant reduction in water availability can be expected as early as 2020, especially during the summer season in the southern and southeastern parts of Europe. By 2080, 14-38% of the Mediterranean population can be expected to live in regions with significant water scarcity. By the end of the century, droughts that occurred once in 100 years can be expected to occur once in 10-40 years in Greece. At the same time, in the countries of Central Europe, such as Hungary, a significant reduction in summer precipitation can be expected, with pronounced negative consequences for ecosystems and agriculture. In Eastern (winter) and northern (winter and spring) Europe, the increase in flood risk is among the greatest risks of climate change.

The latest EU analyzes confirm that climate change will increase the loss of water resources, in areas that are already exposed to water supply problems. In the EU + UK, around 51.9 million people and economic activities worth 995 billion euros are already exposed to problems with water supply, of which as many as 3.3 million people and businesses worth 75 billion euros are exposed to major problems with water supply.

At the same time, the occurrence of 100-year-old floods will occur more often in most of Europe (with the exception of northern Europe, the southern parts of Spain and Turkey), as well as floods caused by extreme rainfall. In fact, it is estimated that river floods are among the biggest causes of losses and damage in Europe. In the case of a rise in the global mean temperature above 20 C, the damage directly caused by floods due to climate change, without adaptation, can be tripled. It is realistic to expect similar scenarios for Serbia.

[63]Climate Change 2014 Impacts, Adaptation, and Vulnerability, https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf

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In the period 1980-2017. year, as of 2017, 83% of the total monetary losses of the EU (about 426 billion euros) are those caused by weather and climate extremes.

In principle, analyzes of the impact of climate change on water resources in Europe (mostly involving the EU) include assessments of the impact on:

• annual and seasonal flows and water availability;

• high (important for floods) and low waters;

• needs for and simultaneous availability of water;

• water-affected population;

• soil moisture;

• needs for irrigation, cooling, production;

• production of energy from hydro potential and cooling in the production of energy from coal (including the region of Serbia);

• underground waters; i

• water supply in urban areas.

In addition, EEA indicators of importance for monitoring the impact of climate change on water resources and the effectiveness of adaptation measures are:

(1) Hydrological drought

(2) River flow

Data for the observed trends are available to RHMS, while the projections in part are made in national reports, however, the data are not systematized or publicly available.

(3) Floods

(4) Economic damages and losses caused by natural disasters and natural disasters

Flood data are available to the RHMS, but also to the Ministry of the Interior (MUP), as an institution responsible for risk reduction and prevention in the event of natural disasters and natural disasters. For the same reason, the Ministry of the Interior has data on damages and losses, although a good database is incomplete (as stated in the chapter: Agriculture).

Finally, it should be borne in mind that the role of the water sector in climate change is reflected through direct consequences in this sector, but also indirect in other sectors, such as: agriculture, energy production, infrastructure, human health and ecosystems (e.g. increasing the frequency and intensity of floods, which reduces the quality of available water, but also the destruction of infrastructure by floods).

4.1.2. National context

Availability of domestic waters (which originate on the territory of the state) already classifies Serbia in the water of a poorer country in Europe. There are less than 1,500 m3 of domestic water per capita per year (minimum required for normal self-sufficient development, about 2,500 m3 per capita per year), and in the zone of large cities and zones in need of irrigation (Vojvodina, Sumadija, Kolubara basins, Sitnice, Pomoravlje) water has less than 500 m3 per capita per year.

The situation is much more unfavourable when the distribution of domestic waters in the territory is taken into account. Then there is a noticed "resource paradox" that water is most scarce where it is most needed (zones of the largest settlements and the highest quality lands that need to be irrigated). This is also expressed through specific runoff, (figure 17), which is on average about 5.7 $L/s \cdot km^2$, but varies from about 1 $L/s \cdot km^2$ and even less than that in parts of Vojvodina, and climbs to over 30 $L/s \cdot km^2$ in mountain areas (Mokra Gora, Prokletije, Šara). In some areas, the specific availability of domestic waters drops below 500 m^3 per capita per year (Vojvodina, Šumadija, the Sitnica, Kolubara and Pomoravlje basins). In these areas, water needs cannot be met without the use of transit water and/or the supply of water from greater distances.

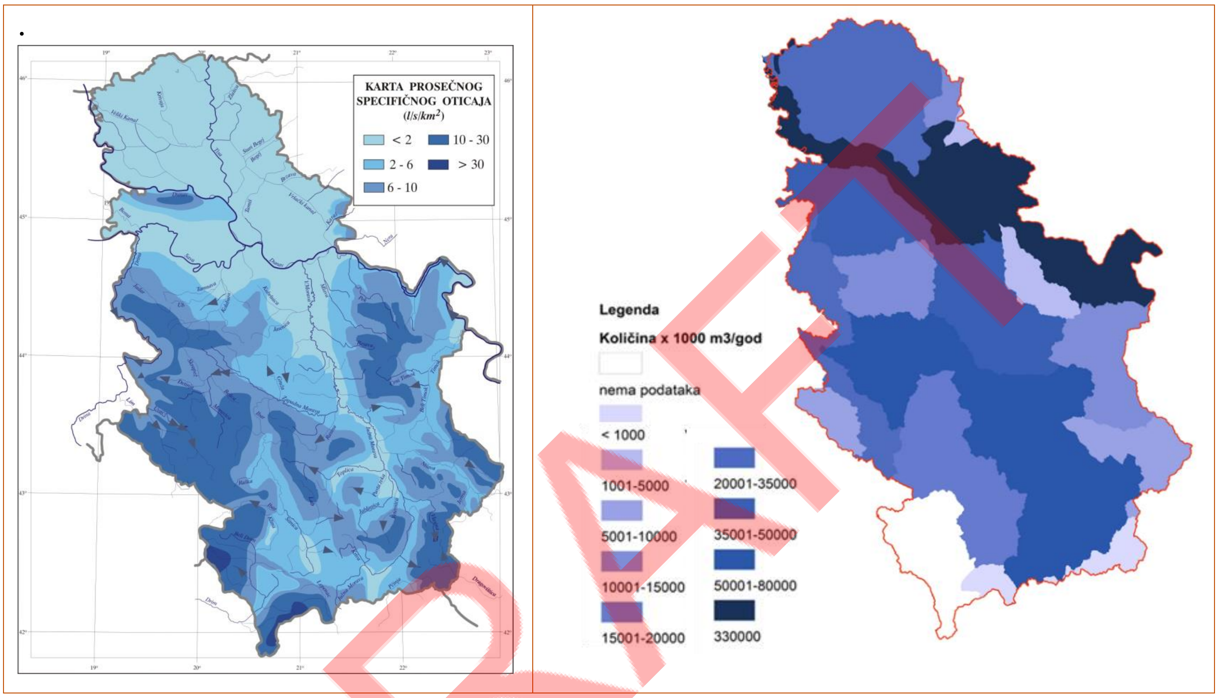

Figure 17. *Map of specific runoff (l/ s km2) of the territory of Serbia (left) and the amount of affected drinking water in Serbia by basins*[64] *(right)*

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The waters of Serbia are characterized by a large spatial and temporal unevenness and an increasingly pronounced decrease in flow in periods of low waters and an increase in wave peaks in periods of high waters.. Tendencies to increase the peaks of large water waves on larger transit rivers require constant review of the degree of protection from large waters on sections near cities and technological systems that are vulnerable to flooding (example: Mining-Energy Complex Kostolac, Mining-Energy-Industrial Complex Kolubara).

The quality of drinking water in a large part of Vojvodina (especially in Bačka and Banat), Pomoravlje, parts of Šumadija and numerous smaller municipalities is inadequate. The problem with inadequate water quality is more present in smaller environments, while inadequate protection of springs occurs regardless of the size of the system.

The situation with groundwater is similar and there is also a decrease in availability and quality. For example, in Vojvodina, there have already been large drops in groundwater levels, in some places over 50 to 60 m.

It is evident that the already bad situation is further aggravated by the impact of climate change. An assessment of the impact of climate change on the water management sector is

[64] http://www.sepa.gov.rs/download/Odrzivo_koriscenje_WEI.pdf

available in the First[65],, Second[66] and Draft Third RS Reports under the UN Framework Convention on Climate Change.

Estimates are mainly reduced to the effects of climate change on the flow of a certain number of flows. In order to assess the impact of climate change on water resources for the purposes of the Second Report, changes in river flow trends were analyzed, with 18 selected hydrological stations in central Serbia. The results of these analyzes showed that the average long-term trend on domestic rivers is around -30% / 100 years, while the spatial distribution varies. The long-term trend for the Danube and Sava rivers in Serbia is about -10% / 100 years and while the maximum daily values show a significant declining flow trend for almost all rivers (with the exception of the Danube and Tisa with a very slight increase), the minimum daily values are very variable trend.

For extremely small and large waters, larger rivers generally show a declining trend, while smaller rivers record very different results. Scenarios of future climatic conditions indicate a further decline in flow, especially in the period 2071-2100. In terms of the magnitude of the changes, the Kolubara basins in central Serbia and Toplice in southern Serbia will be most susceptible to change by up to -40% in the period 2071-2100. in relation to the period 1961-1990. Moderate changes can be expected for the two basins in western Serbia, the Drina and Lima rivers. For the near future, flow changes are within several estimates, and rarely exceed 10%.

For groundwater, a declining trend in availability was observed, but less than in the case of surface water. This is especially true of deep releases. It should be borne in mind that, when it comes to a detailed analysis of groundwater availability and the impact of climate change on them, there is a problem of lack of long data sets. This problem is also identified in Chapter 1: Observed Climate Change and Climate Scenarios, of this Report.

In the basins of Velika Morava, Južna Morava and Zapadna Morava, due to the increase in water temperature, especially during low waters, a negative trend of water quality is observed and can be expected in the future. The period of small waters can be especially critical for the quality of waters in basins, such as the Morava and Tisa basins, and on smaller watercourses in eastern Serbia, such as the rivers Nisava, Timok, Mlava.

The second report identifies significant pressure on water security in the future, especially in large cities and in the southeast, east, and central and northern parts of the country.

The draft of the Third Report shows the impact of climate change on the average annual, average monthly and average daily flows for the Danube, Sava, Drina, Kolubara, Velika Morava, South Morava - lower basin and upper basin, West Morava, Ibar, Timok, Tisza and Tamis expected flow changes for the periods 2011-2040 (2020), 2041-2070 (2050) and 2071-2100 (2080) compared to the period 1971-2000. years. Data from publicly available databases and platforms were used to display these results. The methodology for analyzing the impact of future climate change on this sector is based on the analysis of the results of a multimodel ensemble of climate models related to hydrological models. Two data sources were used: SWICCA (Service for Weather Indicators in Climate Change Adaptation; swicca.eu) and EDgE (End-to-End Demonstrator for improved decision-making in the weather sector in

[65] https://unfccc.int/resource/docs/natc/srbnc1.pdf
[66] https://www.klimatskepromene.rs/wp-content/uploads/2017/12/SNC-Eng_Serbia.pdf

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Europe; edge.climate.copernicus.eu) the Copernicus project of the European Union program. The results of the model cover the area of Europe, which means that the impact of climate change in the regions of entire basins of major rivers that partly pass through the Republic of Serbia is included. A summary of these analyzes is shown in Table 15

Table 15. *Changes in the mean annual flow (%) for selected river basins for the periods 2011-2040 (2020), 2041-2070 (2050) and 2071-2100 (2080) compared to the period 1971-2000 (Đurđević, 2019)*

	RCP4.5			RCP8.5		
	2020	2050	2080	2020	2050	2080
Danube	7	4	3	1	5	-1
Sava	8	7	3	-1	1	-9
Tisa	12	2	1	-2	2	-5
Tamiš	8	2	2	-2	1	-7
Drina	4	0	-1	-4	-4	-10
Kolubara	9	3	2	-1	1	-3
Velika Morava	2	-2	1	-2	-6	-11
West Morava	3	-2	0	-2	-6	-7
South Morava (lower course)	4	-4	-1	-3	-5	-13
South Morava (upper course)	4	-5	1	-3	-6	-13
Ibar	2	-3	-3	-5	-8	-17
Timok	9	-2	-3	-2	3	-8

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In addition, flows in the shallow and warm period of the year (for most rivers, the period June - October) are further reduced. Compared to the reference period, a decrease in mean monthly flows is expected in the period from April to October (Figure 18). On the other hand, during December, January, February, for some rivers and March, an increase in average monthly flow values is expected. So, the period with higher average monthly flow values moves towards the beginning of the year, towards the winter months. The situation is a consequence of the increase in temperature, a smaller number of cold days and shorter retention of the snow cover. According to the RCP8.5 scenario, a more pronounced intra-annual unevenness is expected, i.e. an increase in flow in the winter period and a decrease in flow in the spring and summer period. A reduction in the minimum daily flows for the Tamiš was particularly pronounced, ranging from 55% for RCP4.5 to almost 80% for RCP8.5.

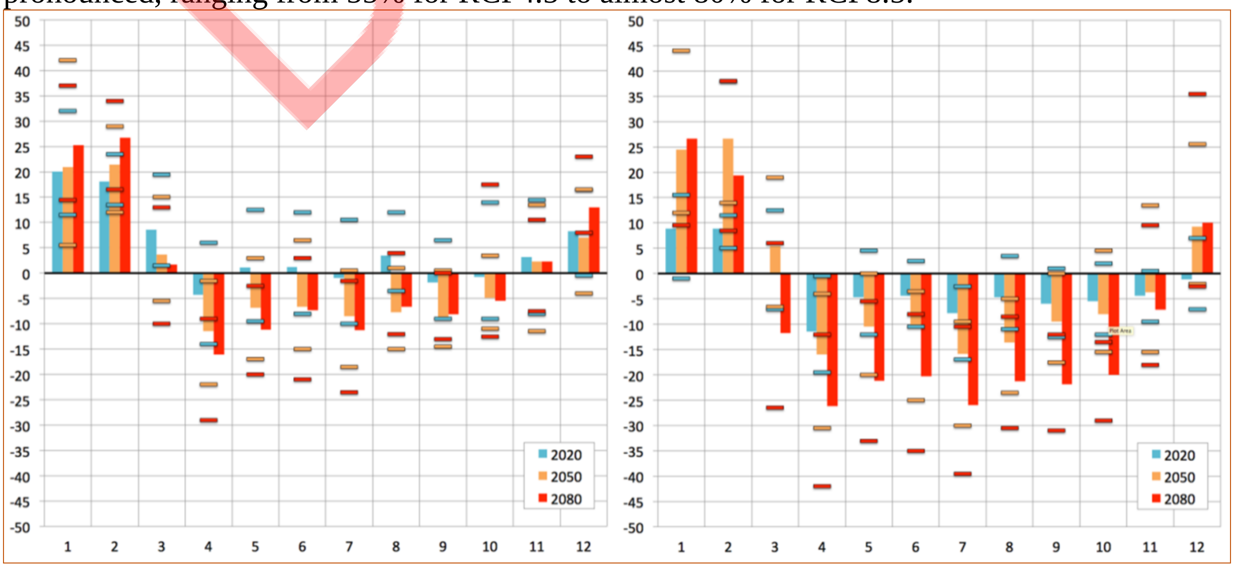

***Figure 18**. Mean value of change in mean monthly river flows in Serbia for the three future periods 2011-2040 (marked as 2020), 2041-2070 (2050) and 2071-2100 (2080) shown by histogram and the corresponding maximum and minimum values indicated by dashes; on the left graph are the results obtained according to the RCP4.5 scenario, and on the right according to the RCP8.5 scenario. Deviations are given in percentages in relation to the corresponding values of the reference period 1971-2000*[67]

The mean change in the distribution of daily flows according to the RCP4.5 scenario shows that in the period 2011-2040 there is a positive change (increase) in the largest daily flows, while in the future the gradient of these changes decreases. However, the decrease in daily flows below the 50th percentile, which is not so pronounced in the near future, increases significantly in the period beyond 2040, as much as over 20%. That is a very bad development of the process, even according to that milder scenario. According to the RCP8.5 scenario, no significant changes in the highest daily flows are expected during the period 2011-2040, but a decrease in the intensity of daily flows below the 70th percentile is expected, and for the lowest daily flows this decrease is up to 20%. In the period beyond 2040, the largest daily flows are expected to increase by about 15% and the smallest flows to decrease by about 25%. Such development of the process – increase of large waters, and thus drastic reduction of small flows (by 1/4) is very unfavorable for both classes of water management systems – regional systems for water supply of settlements and river systems, from which water is supplied to the largest consumers, agriculture and industry.

In terms of water management, from the point of view of planning reliable water management systems, the stated tendencies are very unfavorable. They indicate that **large water waves will increase** due to torrential regimes, large flows are realized in the form of large water waves, while **small waters will decrease and their duration will be significantly extended**. So, the already very unfavorable water regimes of rivers in Serbia will become even more uneven. Whereat, it is very important that these changes take place in the most unfavorable way from the point of view of consumption: the increase in flow occurs in winter, when there is no irrigation as the future largest consumer of water, and flows decrease significantly in the vegetation part of the year, whatsoever in the critical, warmest part (June-September), when the needs for water are the greatest in agriculture, but also in all other activities. The one and **only management response to such tendency are the reservoirs with annual regulation**, which are the only ones that can perform the necessary redistribution of water during the year, in a way that suits all users/consumers, but also all ecosystems, both aquatic and terrestrial.

From the aspect of groundwater, it is important that their quality ranges from waters of exceptional quality, to waters that require complex purification procedures. Water quality is mostly affected by pollution from untreated industrial and municipal wastewater, leachate and leachate from landfills, drainage water from agriculture, as well as thermal pollution from water from cooling systems of thermal power plants and pollution related to river navigation.

The expected climate change according to the RCP8.5 scenario will reduce the total amount of groundwater by about -10% in the near future and -50% by the end of the century. These changes will be more pronounced in the eastern and southeastern parts, and least pronounced in the western and south-western parts.

The impact of climate change on water resources, more precise adaptation measures that also contribute to the reduction of greenhouse gas (GHG) emissions, are also addressed in the

[67] Đurđević V., A. Вуковић, M. Vujadinović Mandić (2018): Report on observed climate change in Serbia and projections of future climate based on different scenarios of future emissions, Third National Communication on Climate Change, Belgrade

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National Low-Carbon Development Strategy with an Action Plan. Adaptation issues in the water sector are part of the Adaptation Planning Framework[68], but as they are based on the measures and activities already outlined in the Second Report to the Convention, they will not be elaborated here again.

In addition, within the scientific project of the Ministry of Science and Technological Development "Assessment of the impact of climate change on water resources of Serbia" (TR37005), a methodology for assessing changes in the hydrological regime due to climate change was developed. The project started in 2011 and has not yet been formally completed. Within the project, most of the work was done on research in two directions. The first direction focused on the analysis of the stochastic structure of hydrological time series for the purpose of identifying nonstationarity, ie. long-term trends and cyclicalities[69]. The second direction of research dealt with the methodology for making hydrological projections based on climate projections, where significant attention is paid to the adequate application of hydrological simulation models[70]. As a result of the work on the project, a large number of scientific papers were published, and the proposed methodology was applied to individual basins in Serbia (examples are the rivers Kolubara[71], Mlava, Toplica, Nišava[72], Crnica[73], Moravica, Timok[74]).

The results of these surveys according to scenario A1B generally showed a relatively small decrease in average flows on these rivers (up to about 20%) by the end of the 21st century with potentially larger variations in seasonal water distribution.

In the period 2009-2012, the international project CCWaters[75] dealt with the impact of climate and other changes on water resources in Southeast Europe, with an emphasis on drinking water resources. The results of this project ranged from minor changes to a significant reduction in drinking water resources of 50% by the end of the 21st century.

In 2013, the Republic Hydrometeorological Institute, in cooperation with the Norwegian Water and Energy Directorate (NVE), conducted an analysis of the impact of climate change on the waters of Kolubara and Toplice[76], where it is estimated that by both end of the 21st century flow by 30-40%. The results of this project are integrated into the National Disaster Risk Assessment.

The World Bank project WATCAP[77] (Water and climate adaptation plan for the Sava River Basin), implemented for the entire Sava River Basin in the period 2012-2014, was the first

[68] Projekat „Strategija klimatskih promena sa Akcionim planom“, http://www.klimatskastrategija.eu/

[69] Stojković, M., Ilić, A., Prohaska, S. and Plavšić, J. (2014) Multi-Temporal Analysis of Mean Annual and Seasonal Stream Flow Trends, Including Periodicity and Multiple Non-Linear Regression. *Water Resources Management*, 28(12): 4319–4335

[70] Todorović A., Plavšić J. (2016) The role of conceptual hydrologic model calibration in climate change impact on water resources assessment. *Journal of Water and Climate Change*, 7(1): 16-28.

[71] Todorović A., Plavšić J. (2015) Uticaj klimatskih promena na hidrološke režime Kolubare, Toplice i Mlave, 17. Savetovanje SDHI i SDH, str. 315-330.

[72] Prohaska S., Ilić A., Tripković V., Đurđević V. (2015) Preliminarna projekcija stanja vodnih resursa u slivu Nišave u uslovima promenjene klime. 17. savetovanje SDHI i SDH, str. 424-433.

[73] Tripković V., Ilić A., Prohaska S., Blagojević B. (2015) Poređenje različitih pristupa za sagledavanje uticaja klimatskih promena na vodne resurse u slivu reke Crnice, 17. savetovanje SDHI i SDH, str. 341-356

[74] Plavšić J., Muhić F., Petrović A., Todorović A. (2015) Problemi u proceni uticaja klimatskih promena hidrološkim modeliranjem: primeri slivova Moravice i Crnog Timoka, 17. Savetovanje SDHI i SDH, str. 303-314.

[75] www.southeast-europe.net/en/projects/approved_projects/?id=65

[76] Langsholt, E., Lawrence, D., Wong, W. K., Andjelic, M., Ivkovic, M., & Vujadinovic, M. (2013). *Effects of climate change in the Kolubara and Toplica catchments, Serbia*. Report No. 62, NVE, Oslo, Norway.

[77] www.savacommission.org/project_detail/18/1

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project in which the projections of the hydrological regime in the Sava River Basin were used to assess the impact of climate change on four (water) economic sectors: flood protection, navigation, hydropower and agriculture. Projections for the A1B climate scenario until 2070 have shown that changes in average flows are small, but that there could be a significant intra-annual redistribution of water, while it is estimated that intensification of floods can be expected both in terms of frequency and higher high waters. In that sense, the impact on the mentioned sectors was assessed and adaptation measures were proposed.

Within the World Bank project "Support to Integrated Water Resources Management in the Drina Basin[78] " in the period 2014-2017, a detailed hydrological model for the Drina Basin was formed, based on which hydrological projections to the end of the 21st century for climate scenarios RCP 4.5 and 8.5. For the purpose of an integrated view of the entire Drina basin as a complex water management system, a detailed water management model (in WEAP software) was formed in which the impact of climate change on the availability of water resources in hydropower, water supply, industry and agriculture, as well as opportunities to meet environmentally sustainable flows. All analyzes were performed for three basin development scenarios (no change, with moderate hydropower utilization and with maximum hydropower utilization). The impact of climate change on the considered water management branches in this study proved to be significant in the second half of the 21st century.

For the needs of the Water Directorate of the Ministry of Agriculture, Forestry and Water Management, in 2018 a preliminary water management model (also in WEAP software) was developed for the Velika Morava basin, but it did not consider the impact of climate change on water resources and water management in this basin.

In order to be able to analyze climate change and its impact on various areas of water management, it is necessary to have the longest possible series of daily hydrological and meteorological data on the entire territory of Serbia. These data are observed at over 200 surface water hydrological stations (of which over 150 stations are equipped with limnigraphs for continuous level monitoring) and over 400 groundwater stations. They are collected in the RHMS internal database and are not publicly available in a convenient form (certain data can be found in yearbooks, but are not available as easy-to-download databases). This is the biggest problem not only for operational management but also for system planning. In addition to data from hydrological measurements, for the operational management of water management systems (especially for defense against torrents and floods, as well as for agricultural purposes) and their planning, precipitation data are of great importance, whose measurement is the responsibility of the meteorological sector RHMS. These data are not publicly available for most measuring points. Other climatological data (air temperature, humidity, wind speed, etc.) are also important for the development and operational application of hydrological models, and are generally not available for most measurement sites. The problem with RHMS data is analyzed in detail in Chapter 1: Observed Climate Change and Climate Scenarios.

Water quality testing is performed by the Environmental Protection Agency (quality monitoring was once the responsibility of RHMS). This information is not publicly available. It is paradoxical that even data on water quality and emergency or other pollution, which are needed to make management decisions in a matter of minutes (disconnection of water intakes for water mains, order to discharge from reservoirs the required amount of water to repair environmental consequences), do not they can be obtained from the Agency or obtained after lengthy administrative procedures.

[78] www.wb-drinaproject.com/index.php/en/

Data on water use, water protection and water protection can be found in the databases of various institutions. Data on public water supply and other water supply facilities are not consolidated into a single database. Annual data on the work of public utility companies for water supply and sewerage are collected by the Ministry of Construction, Transport, and Infrastructure, as well as the Republic Bureau of Statistics. Data on water quality are mainly examined by public health institutes, and they are united by the Institute of Public Health of Serbia "Dr. Milan Jovanovic Batut ". Data on hydropower use of water are available to EPS, ie its business systems of the Hydroelectric Power Plant "Đerdap" and the Drina-Lim Hydroelectric Power Plant. These data are also completely inoperative, so they cannot be used even in periods of flood defense when some decisions on the management of hydroelectric dams (eg decisions on the dynamics of opening evacuation bodies) must be made with operability measured in just a few minutes.

The eventual public availability of the mentioned data is, in fact, a presentation of trends and extremes within the annual reports of the institutions that monitor or consolidate them. On the other hand, the measured databases are generally not or are publicly available in difficult-to-use formats. Therefore, these databases/information systems should be integrated into a single and publicly available database, which would also include indicators for monitoring the impact of climate change and adaptation relevant to the water management sector.

4.2. Adaptation measures

The use of water in the future and the preservation of its quality and quantity as a water resource, requires the urgent undertaking of appropriate measures and activities. Measures to adapt to expected climate change for the water sector presented in the Second Report are shown in Table 16.

Table 16. Potential adaptation measures

Reducing the risk	Water use	-Increasing the efficiency of water supply (reduction of losses to the optimal level, economic price of drinking water, organizational optimization of water supply); -Application of the best available irrigation techniques, cooperation with upstream countries; -Translation of waters from water-rich areas to water-deficient areas.
	Water quality	-Application of the best available techniques for bulk pollution, which mostly comes from agriculture; -Construction of protective green belts along rivers.
	Protection against the harmful effects of water	-Development of flood protection plans for international rivers and large river basins; -Preservation of existing flood zones; -Regular maintenance and reconstruction of infrastructure for flood protection and drainage systems; -Prohibition of construction of new facilities in flood zones; -Integral approach and harmonized activities of competent institutions and

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		organizations at the local, regional and national level.
	Multipurpose measures	-Increasing the capacity of reservoirs; -Translation of waters from water-rich areas to water-deficient areas.
Legislative framework		-Water management strategy; -Water management plans; -Other planning documents provided by the Law on Waters, water protection plans against pollution, flood protection plans, etc.
Monitoring and research		-Improvement of monitoring and other non-investment measures to combat drought; -Improvement of the hydrological monitoring network; -Improvement of the early warning system for extreme climate and weather events; -Improvement of research related to the impact of climate change on water resources; -Improvement of multidisciplinary research on climate change; -Improvement of research in the field of numerical modeling of hydrological processes.
Capacity building and awareness-raising		-Improvement of coordination and harmonization of activities of competent institutions and organizations at the local, regional and national level; -Strengthening the capacity of state institutions; -Strengthening the capacity of local communities; -Strengthening the capacity of research and educational institutions; -Improving cooperation between sectors

Adaptation measures are also discussed in detail in the Third Report and include:

1) **Construction of multipurpose reservoirs** as part of integrated water management systems. Reservoirs are elements that can redistribute water over time, and their significance and ability to mitigate the negative effects of climate change increases with increasing relative useful volume (the ratio of useful volume to an average annual inflow of water into the reservoir).

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2) **Reduction of losses in water supply systems** is a measure of adaptation in the area of water supply of settlements, which should certainly be implemented before or together with other measures. The implementation of this measure generally does not require such large investments, and due to more rational use and lower losses, water is saved as an important natural resource.
3) In the field of flood protection, it is necessary **to determine the actual levels of protection of the protected area**, especially in the zones of large cities and important technological systems, and where necessary apply appropriate active and passive protection measures to achieve the required levels of protection. The applied measures should be based on the principle of **providing sufficient space for receiving large waters** (cantilever embankment, deepening of riverbeds, widening of riverbeds for high water, removal of obstacles from riverbeds, formation of retention spaces and bypasses), and not on the principle of high water into downstream areas (which would become even more endangered with such measures).
4) **Construction of torrential barriers**, together with anti-erosion works in the basin can significantly reduce torrential floods, the amount of alluvium, and the backfilling of reservoirs.
5) **Increasing the capacity and efficiency of the drainage system** is significant in order to reduce flood damage to inland waters, which will be more frequent and intense due to the projected increase in rainfall intensity. For the same reasons, only for urban areas (populated areas) is there a significant increase in the capacity of sewage systems, especially rainwater drainage systems.
6) **Construction of medium and large hydropower facilities**, which would be part of integrated water use, water protection and water protection.
7) **Construction of small hydropower plants next to existing water management facilities (dams),** which could use the energy that must be discharged downstream from such facilities and the decline that is already concentrated in the existing facility.
8) The development and application of **operational mathematical models for the management of reservoirs** enable more flexible management of the useful volume of the reservoir, greater reliability of water supply to users and better protection of the downstream area from floods.
9) Hydrological **models for flow prediction and early warning systems for possible floods** have a significant role in the fight against floods and reduction of flood damage because their application gives a certain advantage over nature and the possibility of timely response.
10) **Construction of wastewater treatment plants** in order to protect water quality.
11) **Defining the methodology for determining the ecological flow** and the necessity of discharging appropriate amounts of water downstream from the dam is necessary to ensure the survival and development of aquatic systems, but also the undisturbed and undisturbed life of people in settlements along the river downstream.

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12) **Protection of reservoirs from eutrophication** is a very important task because reservoirs are irreplaceable objects that make the integral system manageable. Therefore, it is extremely important that all reservoirs are protected from eutrophication processes, which can lead to their ecological destruction, but also to a reduction in their usability for water management needs.

At the same time, the draft of the Third Report lists the measures shown in Table 17 as a priority and most significant.

Table 17. The most significant measures of adaptation to climate change

segments	Adaptation measures
Water use	Construction of multi-purpose reservoirs that provide water to various users of the system (population, industry, agriculture, hydropower, etc.) (Annex 1)
	Reduction of losses in water supply systems
	Reduction of specific water consumption for households, irrigation and industry
	Repeated recirculation use of purified water
	Construction of medium and large hydropower facilities
	Construction of small hydropower plants next to existing water management facilities (dams)
Water quality	Construction of wastewater treatment plants
	Improving water quality monitoring in rivers and lakes and protecting reservoirs from eutrophication
	Application of the best techniques for reducing pollution from agriculture, industry and urban areas
Protection against the adverse effects of water	Construction of torrent barriers, together with anti-erosion works in the basin
	Increasing the capacity and efficiency of drainage systems in order to reduce flood damage from inland waters
	Increasing the capacity of sewage systems in populated areas, especially rainwater sewerage systems, taking into account changes in precipitation intensities
	Determining the actual levels of protection of the protected area, especially in the zones of large cities and important technological systems, and where necessary to apply appropriate measures of active and passive protection in order to achieve the required levels of protection
	Providing enough space to accommodate increased high water (embankment overhang, deepening of the riverbed, widening of the high water riverbed, removal of obstacles from the riverbed, formation of retention spaces and bypasses), with the application of nature-based solutions
Water	Development and application of operational mathematical models for reservoir management that enable more flexible management of useful reservoir

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Management	volume, greater reliability of water supply to users and better protection of the downstream area from floods
	Development of hydrological models for flow prediction and early warning systems for possible floods
	Development of a methodology for determining ecological flow
	Protection of water land to enable occasional interventions in order to increase the level of protection of line protection systems
	Development of flood risk and risk maps and flood risk management plans (especially in the areas of large settlements, large industrial and other facilities, the largest thermal power plants)

Within the EU technical documents, the following potential adaptation measures can be found, which were not considered in any of the documents that dealt with adaptation to changed climatic conditions in Serbia:

- Improving the efficiency of irrigation systems (optimization of water consumption). An effective way to achieve this is to introduce special prices for the use of irrigation water;
- Use of treated wastewater for irrigation;
- Switching from conventional energy sources (coal) to renewable sources which would reduce water consumption for cooling the production system;
- Green cities (green roofs, walls, insulation and green areas, parks,) which reduce the need for cooling energy and increase evaporation, slow down surface runoff (reduces city floods).

4.3. Conclusions and recommendations

Starting from the analysis of observed and expected climate changes for the Republic of Serbia and performed analyzes, it is clear that there are impacts of climate change on the water management sector, which result in a significant reduction in flow on watercourses, especially in certain seasons.

The southern and eastern parts of the country (basin of all three Morava, Ibar, Drina, Timok), which have been scarce with water resources so far, will be most affected. In addition, an even more unfavorable intra-annual redistribution of precipitation and flow is expected, with the largest decrease in the vegetation part of the year, especially in the low-water months (July to October), while in winter there is even a certain increase compared to current values. I can expect more frequent and intense floods. This coincides with the results of the findings made for the needs and the area of the EU.

Due to the reduction of precipitation, a significant reduction in the intensity of groundwater renewal is expected (even over 50%, depending on the area of the country and the period), mostly in the southern and eastern parts of the country.

On the other hand, increased temperatures and evapotranspiration will increase water demand in all areas, especially in agriculture/irrigation.

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In order to be able to meet the water needs of all users in such conditions, their protection from the destructive effects of water and protection of water quality, it is necessary to take a number of measures to mitigate these negative impacts.

Based on the documents and reports prepared so far (First and Second Reports of the Republic of Serbia under the United Nations Framework Convention on Climate Change, Draft Third, Framework for Adaptation Planning), the impacts of climate change on watercourses and proposals for potential adaptation measures are mostly detailed. In order to achieve certain improvements in the assessment of the impact of climate change on water resources and water management, it is necessary to:

- Analyze other impacts of climate change on the water management and water management sector;
- Establishment of a system for monitoring the relevant indicators (EEA indicators) and displaying them on a common open platform (which can be an integral part of the MRV national system);
- Integration of existing databases and information systems and public availability of these data;
- Establishment of a database on irrigation systems and users, at the national and local government level;
- Improve the system for collecting data on damages and losses caused by floods and hydrological droughts, erosions and torrents;
- Data collection at the level of local self-government;
- Inclusion of climate projections (which is not the case in the national risk assessment of natural disasters and catastrophes) and socio-economic aspects in the assessment of the impact of the sector (which is not the case in the national reports) and planning adaptation measures;
- Improving adaptation measures and preparing proposals for multisectoral adaptation measures for the sectors: water management, forest management and agriculture;
- Development of appropriate control - simulation and optimization mathematical models (MM), without which it is impossible to imagine water management in conditions of deteriorating water regimes;
- Analysis of a drastic reduction in the intensity of groundwater recharge on the development of irrigation systems;
- Consideration and proposal of an approach for determining the reliability of delivery to consumers, which is of particular importance, bearing in mind that many systems (settlements, industries, energy) have increasingly stringent requirements regarding the required reliability of water supply without reduction;
- Proposed approach for determining ecological flows downstream of reservoirs and water intakes;

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- Consideration of methodological frameworks for optimizing long-term management of multipurpose reservoirs. In conditions of worsening hydrological conditions, long-term management of reservoirs becomes extremely important, as a measure for the most rational use and delivery of water, but also for the realization of other very important goals: mitigation of flood waves, improvement of water regimes in longer periods of low water, etc.

- Strengthening national capacities in the water management sector, including civil servants, but also the scientific and professional public, especially for the use of models that assess the impact of climate change on the sector and interpret the results they give.

4.3.1. Recommendations

The multisectoral nature of the water management sector and the indirect impacts of climate change on other sectors due to changes in the water sector require a number of activities in order to implement integrated water management in the conditions of changed climate and its expected changes. Starting from the needs and real possibilities within the project, and taking into account the available national capacities, it is proposed that within the project;

(1) Identify opportunities and prepare assessments of the impact of climate change on high (significant for floods) and low waters; needs for and simultaneous availability of water; water-scarce population; soil moisture; needs for irrigation, cooling, production; production of energy from hydro potential and cooling in the production of energy from coal (including the region of Serbia) [79]; underground waters; and water supply in urban areas or identify data gaps for the implementation of these analyzes.

(2) Within the assessment, the calculation of the water exploitation index (WEI) by seasons and for characteristic catchments is also proposed. One of the indicators of the water sector's impact on climate change is the WEI index. The WEI (Water Exploitation Index), ie the water exploitation index, is an indicator of pressure on the sustainable use of renewable water resources. It is determined as the ratio of the total annual amount of affected water resources and renewable water resources. The value of the WEI index indicates the severity of the water problem, ie the "water stress" of an area. In cases when this value exceeds 20%, it is considered that there is water stress, and in cases when it is above 40%, it is an area with extreme water stress. Although the value of this index for Serbia is relatively low (Figure 19), it should be noted that it is determined by the total available water quantities (together with transit waters), as well as the average annual values, not taking into account time irregularities. Clearly, significantly higher values of the WEI index would be obtained in the summer periods, given that these are periods with low flows and high water needs. Figure 8 shows the change in the WEI index for the period 1990-2017. After a significant decline in the value of the index in the 90s, there is a trend of gradual increase, so that the value of the index returned to the level of the 90s and continues to grow.

[79] Impact of a changing climate, land use, and water usage on Europe's water resources, A model simulation study, JRC Technical Report, 2018

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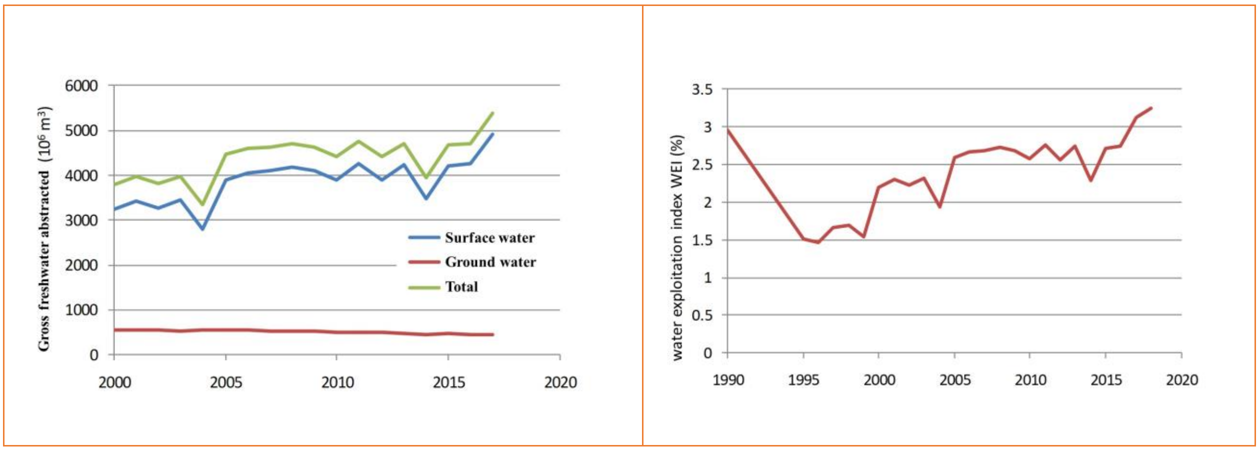

Figure 19. *Affected annual water quantities (left) and WEI index (right) based on data from the Republic Bureau of Statistics*

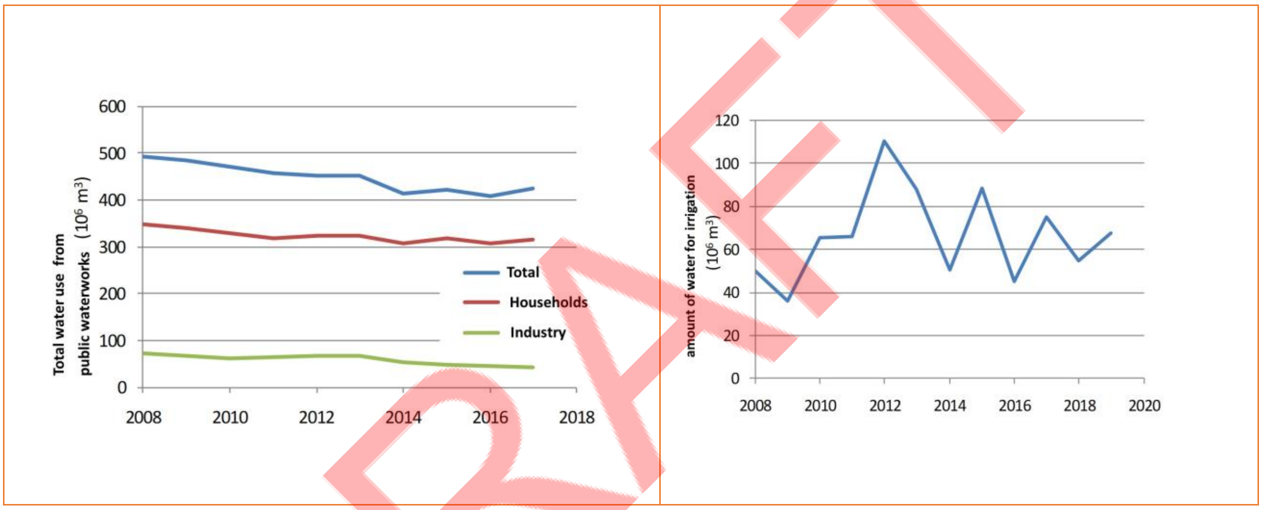

Figure 20. *Use of water from public water supply and use for irrigation (done on the basis of data from the Republic Bureau of Statistics)*

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(3) Preparation of recommendations for the establishment and improvement of a network of measurements of importance for groundwater.

(4) Preparation of a list of available and water management models which can be used to consider the impact of changes in the hydrological regime on individual water management branches, in case the necessary data are available.

(5) Preparation of a list of available methodologies of importance for the identification of impairments, but also planning and monitoring the success of adaptation measures in the sector.

(6) Preparation of recommendations for: lists of indicators, in accordance with EEA indicators; institutional competence and responsibility for data collection and indicators;

(7) Preparation of recommendations for integration of existing databases and information systems and inclusion of data from EPS, important for irrigation and on irrigation and users, data of local self-governments, etc.;

(8) Prepare a list of adaptation measures and joint multisectoral adaptation measures for the sectors: water management, forest management and agriculture.

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5. ENERGY PRODUCTION

5.1. Impact assessment

5.1.1. International and EU context

Changes in temperature, amount and intensity of precipitation, as well as the frequency and intensity of natural disasters affect the production and consumption of energy, which is a significant source of greenhouse gas emissions in Serbia.

Global analyzes show that climate change is already affecting and will continue to have a trend of increasing energy consumption for cooling in the summer season (consumption can be significantly higher than the average and during the winter months) and decreasing consumption of heating in the winter season. This redistribution of production/consumption will certainly affect additional investments in infrastructure, so that the supply, especially during heat waves, is possible and stable.

Climate change also affects energy production through the impact on water resources. Reducing availability and increasing water temperature, due to climate change, affects:

- Availability of water for energy production from the aspect of providing other needs;
- The unfavorable hydrological situation for energy production;
- Availability of reactor cooling water for energy production from nuclear and fossil fuels.

The specific impact on thermal energy (important for Serbia as well) is reflected in the reduction of thermal efficiency, due to rising temperatures, as well as the reduction of cooling efficiency, due to reduced availability and rising water temperatures in nearby rivers and lakes. Thus, energy production in thermal power plants will face new challenges, which will require structural and operational changes[80].

In 2016, the total share of energy produced globally from renewable energy sources (RES) was 24%, of which hydropower 16%, wind energy 4%, solar 1% and other RES 3%.[81] According to the projections of the International Energy Agency, in 2040, RES will make up 66% of globally produced energy, of which 19% from hydropower, 21% from wind energy, 17% from solar energy and 8% from other sources. It is clear that this share of RES in total global electricity production will largely depend on climatic conditions, and that investment in RES requires a serious analysis of expected climate change and the impact on energy production, in order to make investments sustainable and to avoid losses and damages.

Analysis of impacts and adaptation potentials at the global level and for the energy sector is given by the International Panel on Climate Change, in the report "Climate change 2014: impacts, adaptation, and vulnerability[82]", while a new report of this type is being prepared and is expected to be published in 2021. According to the latest available report, the impacts of climate change on the energy sector depend on the type of source (coal, water resources, solar energy), production process and location of production capacity (eg flood zone), but can certainly be expected to increase the risk to sustainable production and security of energy

[80] Adapting the energy sector to climae change, IEA, https://www-pub.iaea.org/MTCD/Publications/PDF/P1847_web.pdf

[81] INTERNATIONAL ENERGY AGENCY, World Energy Outlook 2018, IEA, Paris (2018).

[82]Climate Change 2014 Impacts, Adaptation, and Vulnerability, https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf

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supply. Diversification of energy sources is one of the significant measures of adaptation in the energy sector.

Climate change and extreme weather conditions are increasingly affecting all elements of the EU's energy system, including: energy sources, transformations, transmission, distribution, storage and energy consumption. These impacts vary depending on the element of the energy system and the EU region. The energy sector in the southern part of Europe is most endangered due to rising heat waves and declining water availability.

Mostly economically negative, individual impacts of climate change can result in economic benefits such as reduced heating energy costs. In principle, adaptation implies actions that lead to the reduction of the impact on the energy infrastructure and the functioning of the energy system.[83]

The impacts of climate change on the EU energy sector are mainly monitored and expressed through changes in the amount of energy needed for heating and cooling. It is estimated that, due to climate change, the total amount of energy for heating and cooling will decrease by 32% by 2100 compared to 2010, as a result of a significant increase in the use of energy for cooling (which will double in the same period) and a 37% reduction in heating energy use. Such a change in energy needs will affect the stability of energy production and will lead to a change in the distribution of production compared to the current ones. In general, increased energy efficiency of air conditining systems can have significant positive effects on energy consumption..

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Analyzes show that the number of days in which there is a need for heating (Heating degree days - HDDs) on an annual basis decreased by 6% in the period 1981-2017 comparing the value in the period 1950–1980, which corresponds to a decrease of 6.5 HDDs on average per year. The largest reductions are typical for northern Europe and Italy. The number of days in which there is a need for cooling (Cooling degree days - CDDs) increased by 33% in the period 1981-2017 in relation to the average value for the period 1950–1980 and averaged 0.9 HDDs per year. The largest increase is typical for the southern part of Europe. Projections indicate that this trend will continue until the end of the 21st century, and the increase in the number of CDDs will certainly increase costs many times, since electricity is used almost entirely for cooling. This scenario also indicates the possible instability of the electricity distribution network, especially during heat waves and in the absence of adaptation measures.[84]

The indicator monitored at the EU level, in the segment of adaptation to changed climatic conditions, and related to energy production (EEA indicator) is:

1) Change in the number of days in which there is a need for heating, ie cooling (Heating degree days - HDDs and Cooling degree days - CDDs).

EEA defines HDDs and CDDs comparing to the base temperature, ie. the outside temperature below which the space needs to be heated (HDDs), or above which the space needs to be

[83] Adaptation challenges and opportunities for the European energy system Building a climate-resilient low-carbon energy system, EEA Report No 01/2019

[84] Индикатори за адаптацију на климатске промене европске Агенције за животну средину, https://www.eea.europa.eu/data-and-maps/indicators/heating-degree-days-2/assessment

cooled (CDDs). The base temperature, which takes into account the minimum and maximum daily temperatures, is 15.5 °C for HDDs and 22 °C for CDDs.

RHMS performs hourly measurements and displays maximum and minimum daily temperatures, so that the necessary input data (maximum and minimum daily temperature) are available for monitoring this indicator.

2) Economic damage from natural disasters

Although related to other sectors, this indicator is certainly of great importance for the energy sector, which suffers significant losses and requires significant investments, primarily in infrastructure.

The availability of electricity is one of the key preconditions for the distribution and processing of water, while the availability of water resources is important for energy production, but also other sectors and needs. Therefore, there is an increasing number of analyzes for the territory of the EU and its Member States that link the availability of water resources and energy production.

According to these analyzes, in the period until 2050, as a result of decarbonization, water consumption in the energy sector is expected to decrease by 38%, from 74 billion m^3 in 2015 to 46 billion m^3. Energy transformation plants (refineries and energy production plants) will represent the largest energy consumers (76%), and the remaining part will be mainly used in coal mines and oil wells. The key reason for this reduction in water consumption is the closure of coal mines, as a consequence of decarbonization.

The connection between these two sectors and the need for joint action, ie the nexus approach, has been the subject of international study for almost a decade. Thus, within the special report of the International Energy Agency, in 2017, it was stated that policies and technologies for reducing the use of energy and water already exist and define issues of importance, as well as opportunities that lead to more efficient intermediate use. For that to happen, and to reduce the mutual negative impacts, it is necessary to start integrating energy and water management policies.[85]

The EU has recognized that achieving the ambitious decarbonization targets could be significantly undermined if there is a significant reduction in water availability, which requires a nexus approach to increase energy efficiency in the water sector and increase water efficiency in energy production. For these reasons, the Water Energy Food and Ecosystem Nexus (WEFE) project was initiated, which was implemented by the Joint Research Center. Within the project, the interdependence and interaction of water resources, energy, agriculture and the environment were analyzed integrally. Among other things, strategic and operational measures for the preparation of energy-water management of cross-sectoral policies are the results of this project.[86]

Finally, it should be borne in mind that key EU policies in the field of climate change and energy promote the inclusion of adaptation to changed climate conditions in energy policies. These policies include the EU Adaptation Strategy, Regulation on Energy Union and Climate Change Management Mechanisms ("Governance Regulation"), the long-term strategy "A

[85] https://www.iea.org/reports/water-energy-nexus

[86] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/water-energy-nexus-europe

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Clean Planet for All" and Regulation (EU) 2019/941 of the European Parliament and of the Council of 5 June 2019 on risk-preparedness in the electricity sector and repealing Directive 2005/89/EC. The Energy Union, and in particular the Regulation on Governance Mechanisms, requires the development of integrated national energy and climate plans (NECPs) for the period up to 2030 and long-term strategies for the period up to 2050, taking into account mitigation and adaptation. The component of adaptation, ie the impact of climate change on the sector, needs to be presented through the dimension: Security. A technical instruction that will elaborate this request in more detail (otherwise the request of Article 17 of the Regulation) is being prepared.

5.1.2. National context

Electrical energy

The total net installed capacity of power plants in Serbia is 8,274 MW[87]. PC Elektroprivreda Srbije (PC EPS), as the dominant producer of electricity, manages electricity generation capacities with a total capacity of 7,741 MW. The system of PC EPS consists of 6 lignite thermal power plants, with a total capacity of 4,429 MW, 3 thermal power plants-natural gas or fuel oil heating plants, with a total capacity of 330 MW and 16 hydropower plants, with a total capacity of 2,982 MW. The remaining electricity generation capacities include wind farms and small independent power plants.

In 2019, 34.83 TWh of electricity was produced in Serbia, while gross consumption was 33.8 TWh. End customers accounted for 85.8% of total consumption, while the rest was spent in the process of energy production and to compensate for losses in transmission and distribution networks. According to the data of the electricity supplier, 4.3 TWh were imported, and 3.9 TWh were exported in 2019.

As a consequence of the highest monthly consumption, lower production in thermal power plants and reduced hydrology, the largest imports were realized in January when 643 GWh of electricity was imported (about twice as much as in any other month). Electricity exports were expressed in March, when 932 GWh was exported, which was almost a quarter of the total exported electricity throughout the year. The highest daily gross consumption of 121,468 MWh was achieved on January 10, 2019, and on the same day at 6 pm, the maximum hourly load of 5,472 MW was achieved.

In the last ten years, PC EPS, as the dominant producer, reached the maximum electricity production of almost 37.5 TWh in 2013. In 2019, the production capacities of PC EPS produced slightly more than 33.5 TWh of electricity, of which 69% from coal-fired power plants. Due to the bad hydrological situation in the whole of 2019, the production of hydroelectric power plants was 10.4% lower than in 2018.

Although the electricity supply in 2019 was stable, the data indicate that the production of electricity in periods of high consumption was not enough to meet the electricity needs, but the shortfall was compensated by imports. Also, the capacity of hydropower plants is additionally sensitive to climate change, because the unfavorable hydrological situation already directly affects the reduction of production. Therefore, adaptation measures and

[87] http://www.aers.rs/Files/Izvestaji/Godisnji/Izvestaj%20Agencije%202019.pdf

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especially measures to increase energy efficiency, which lead to a reduction in energy consumption, are key to maintaining the stability of the electricity supply.

Thermal energy

In the Republic of Serbia, 57 cities/municipalities have district heating systems, with a total nominal installed capacity of 6,700 MW. The average age of boilers, substations and hot water distribution networks is about 30 years. In 2015, the entire district heating system used fossil fuels, namely: natural gas with a share of 48%, coal with a share of 23% and liquid fuels with a share of 29%[88]. An additional problem is the high losses in the distribution network and the flat-rate method of charging for thermal energy (per square meter of heated area). The Energy Development Strategy estimates the total costs for the modernization of the district heating system, including the production, distribution and billing of thermal energy per consumption, at 370 million euros by 2025 and 550 million euros by 2030. The estimated share of fuel in the district heating system for 2025 is 17 % liquid fuels, 53% natural gas, 18% coal and 12% biomass.

The Law on Energy ("Official Gazette of RS", No. 145/14 and 95/18 - other law) prescribes that the area of thermal energy is under the jurisdiction of local self-government units, ie the City of Belgrade. This means that their founders have jurisdiction over the operation of the district heating system, ie. cities and municipalities. The business association "Toplane Srbije", which brings together all district heating systems, serves as a platform for the exchange of information and coordination of activities and publishes an annual report on the operation of district heating systems in the Republic of Serbia.

According to the report for 2018[89], a quarter of households in Serbia were connected to the district heating system. The total heated area from the district heating system was about 43 million m^2, of which 80% was living space. The total average efficiency of the production system of all heating plants in Serbia was 88%, which is in the range of the European average. The actual share of energy sources for the production of thermal energy in 2018 was: 73.5% natural gas, 11% fuel oil, 15% coal and 0.5% biomass. About 27% of the total thermal energy needed for heating apartments in the Republic of Serbia is produced in district heating systems.

Based on the above data, it can be concluded that there is a lot of room for increasing the number of households connected to city heating plants, in terms of installing additional capacity, but also connecting more households to existing ones. For that, it is necessary to replace the oldest plants with coal and fuel oil, which would increase the efficiency of energy production, while reducing the emissions of pollutants and gases with the greenhouse effect. Also, the introduction of measures such as charging for thermal energy according to consumption and a comparatively lower price of district heating in relation to individual ways of heating the population would further increase the interest in connecting to the city heating system.

[88] Development Strategy 2015-2025, with projections until 2030, "Official Gazette of RS no. 101/2015 "

[89] Report on the operation of the district heating system in the Republic of Serbia for 2018, Toplane Srbije;https://www.toplanesrbije.org.rs/uploads/ck_editor/files/izvestaj%20o%20radu%20SDG%20u%20RS%20za%202018%20pdf.pdf

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It is significant that these, as well as measures to increase energy efficiency, in addition to the adaptation component, are also a measure to reduce GHG emissions, which is one of the most common in the RS Low-Carbon Development Strategy (in the draft).

Impacts of climate change on energy production

Although largely dependent on energy production from hydro and thermal plants, which are significantly affected and require detailed planning of functioning and improvement and construction of infrastructure, in order to reduce or avoid impacts, Serbia does not have analyzes of the impact of climate change on the energy sector.

The consequences of the impact of climate change on the energy sector can be seen from the example of the flood that occurred in Serbia in 2014. According to the official report of EPS "Realized electricity production of 32,014 GWh in 2014 is the lowest in the last 10 years, primarily due to reduced production of ES "TENT" and ES "TE-KO Kostolac" due to the catastrophic floods. Only the hydropower plants ES "Đerdap" exceeded the production from 2013. Coal production of 29.2 million tons in 2014 was lower by 26% than in the previous year. As the floods of May result, the mines "Veliki Crljeni", "Tamnava-Zapadno polje" and "Drmno" were flooded, and a temporary or permanent suspension of coal production in these mines. Revenue from coal for industry and consumer consumption was 54% lower than achieved in the previous year ".

At the same time, according to the report made for the needs of the Government[90], the total damage in the energy sector is estimated at 21,218.7 million dinars. Over 90% of the damage was caused to the coal mining and electricity production sectors, followed by the electricity supply sector. Some damage was also caused to the electricity and natural gas transmission and heating plants.

The same distribution of losses to subsectors, ie. 95% in the coal and electricity generation sector and 5% in supply systems. The total value of losses amounted to 35,670.70 million dinars. Of this figure, revenues lost by the end of 2014 amounted to about 70% (79.7 million dinars), and for others, it was expected to occur by mid-2015, when all sectors are expected to recover and reach the level that existed before the flood.

Moreover, immediately after the flood wave, more than 110,000 consumers (mostly households) were left without electricity. All large companies that were affected by the floods are 100% owned by the state. This situation should facilitate the improvement of work planning and investment in improvements, including infrastructure, in the energy sector.

One scientific paper[91] deals with the impact of climate change on the energy sector, through analyzes of expected changes in the number of HDD and CDD days (based on A1B and A2 scenarios). The results of this scientific work (which are not publicly available or part of the official databases) for the case of Serbia confirm, as in the case of the EU, the reduction of HDD from 2675 days in the period 1971-2000 year for 1 877 days in the period 2071–2100

[90] Поплаве у Србији 2014, Београд 2014, http://www.obnova.gov.rs/uploads/useruploads/Documents/Izvestaj-o-proceni-potreba-za-oporavak-i-obnovu-posledica-poplava.pdf

[91] Future climate change impacts on residential heating and cooling degree days in Serbia Aleksandar Jankoviц, Zorica Podrašцanin and Vladimir Djurdjevic, Quarterly Journal of the Hungarian Meteorological Service Vol. 123, No. 3, July – September, 2019, pp. 351–370

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years according to the A1B scenario. According to the A2 scenario, this decrease is to 1,743 days. The largest decrease is expected in the southern (mountainous) parts.

The number of CDD days increased from 365 in 1971–2000 year to 823 in the period 2071–2100 years according to A1B, or 894 days according to A2 scenario.

According to the same analysis, in the future (2041–2070 and 2071–2100), compared to the data in the reference period (1971–2000), the number of HDDs will decrease, and CDDs will increase in all months and according to both scenarios.

Serbia does not have the analysis that determines the interdependence of the energy and water production sectors, nor the influences of climate change on that connection.

The indicator monitored at the EU level (EEA indicator) is:

1) Change in the number of days in which there is a need for heating, ie cooling (Heating degree-days - HDDs and Cooling degree-days - CDDs).

The usual value is 15.5 °C for HDDs and 22 °C for CDDs. Given that RHMS performs hourly measurements and displays maximum and minimum daily temperatures, monitoring of this indicator could be easily achieved. In principle, the temperature values should be reviewed, taking into account national legislation that defines the lower temperature at the beginning of the heating season.

2) Economic damage from natural disasters

Although related to other sectors, this indicator is certainly of great importance for the energy sector, which suffers significant losses and requires significant investments, primarily in infrastructure (as can be seen from the 2014 flood).

As stated, data on damages and losses are presented in the database managed by the Ministry of Interior (https://www.desinventar.net/DesInventar/profiletab.jsp?countrycode=srb&continue=y), however, the methodology for assessing damages and losses. The development of methodology and systematization of data in this regard is among the key priorities in the field in general.

5.2. Adaptation measures

Given that, the analysis of climate change impact assessments on the energy sector of the Republic of Serbia is not an official work; the options for adaptation to changed climate conditions have not been developed or analyzed.

Globally identified adaptation measures include:

- Increasing energy efficiency/insulation of buildings and appliances (especially air conditioners);
- Diversification of energy sources;
- Planning the use of RES taking into account climate projections, in order to ensure the sustainability of production (eg selection of locations for hydropower plants based on changes in water availability due to climate change);
- Planning energy infrastructure in accordance with climate projections, including for energy production, distribution and storage;

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- Inclusion of climate change in production planning;
- Integration of policies and measures in the field of water management and energy;
- Inclusion of climate projections in the NECP and improvement of national legislation;
- Improving the efficiency of water resources use.

5.3. Conclusions and recommendations

Taking into account the energy mix in the Republic of Serbia and the goals of increasing the share of RES in total consumption, the vulnerability of the energy sector to climate change is clear. However, Serbia does not have an analysis of the impact of climate change on the energy sector.

Therefore, it is necessary to make these estimates and it is recommended to use:
(1) LISFLOOD hydrological model; i
(2) LISENGY model
because they were used in analyzes for the EU, and in some of them Serbia was included. Using these models would provide data complementary to EU data. On the other hand, it should be borne in mind that (1) is publicly available, which is not the case with (2). The models were developed within the Center for Joint Research at the EU level and, potentially, formal cooperation with this Center could ensure the use of these models.

In addition, the model results would indicate the availability of hydro potential for energy production depending on climate change, but also the availability of cooling water for coal-fired power plants. It is certainly necessary to determine the climate change effects, at least on, energy production and day changes with the necessary heating and cooling. These results would provide a basis for further assessments of economic needs and damage.

Moreover, basic integrated water management is still lacking at the national level, and the inclusion of expected climate change in sectoral policy planning is not on the agenda of line ministries.

Also:

1) The relationship between changes in energy production peaks and meteorological and hydrological parameters is not monitored;
2) Expected climate changes are not taken into account in the case of planning the construction of new plants or their location (eg thermal due to floods or the development of a cadastre of small hydropower plants) or production planning.

Proposed adaptation measures can only be made after assessing the impact of climate change on the energy sector, which is not the case now.

In addition, it should be borne in mind that the existing goals of increasing energy efficiency provide the basis for part of the adaptation actions. On the other hand, it is necessary to adjust the standards of construction and energy efficiency of buildings to the expected climate change, a good way can be the energy classification of buildings based on the final energy consumption for cooling.

Analyzes have shown that additional insulation can reduce the need for heating and cooling and provide energy savings of up to 40%. Therefore, it is recommended to prescribe ambitious requirements for insulation, which makes this sector much more resistant to climate change. Additional measures to improve energy efficiencies, such as increasing the energy

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efficiency of cooling systems, LEED certification of buildings and the introduction of tax incentives to improve the energy efficiency of buildings, can be mitigation measures since reducing consumption or energy production directly affects the reduction of greenhouse gas emissions.

Serbia has the necessary data to assess the impact of climate change on the energy sector (RHMS - average, minimum and maximum temperatures and precipitation, flows, water temperatures, EPS energy production, installed hydropower capacity, minimum and maximum turbine capacity, hydropower efficiency, etc.) they are not systematized, unified, or publicly available.

Indicators that would monitor the impact of climate change on the Serbian energy sector have not been developed, but monitoring the change in the number of days in which there is a need for heating, ie cooling (Heating degree-days - HDDs and Cooling degree days - CDDs) is easy to establish in direct cooperation with RHMS.

Although there is a basis, the scope of work and research primarily depends on the availability of relevant data.

5.3.1. Recommendations

Given that the assessment of the impact of climate change on the energy sector is in the initial phase, it is proposed to:

1. Develop an assessment of the impact of climate change on energy production, using the LISFLOOD hydrological and LISENGY model or some other available model. In this way, the impact of climate change on most energy sources (hydro and thermal plants) would be assessed;
2. Prepare of a list of available models that can consider the impact of climate change and energy;
3. Integrate scientific papers into official data and improve existing analyzes of the number of days requiring heating and cooling;
4. Prepare recommendations for lists of indicators, in accordance with the EEA indicators; institutional competence and responsibility for data collection and indicators;
5. Prepare recommendations for the integration of existing databases and information systems, including data from EPS, RHMS, etc;
6. Prepare a list of adaptation measures and joint multisectoral adaptation measures for the sectors: water management, food production and energy.

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6. TRANSPORT, INFRASTRUCTURE, AND DRR

6.1. TRANSPORT

6.1.1 Impact assessment

6.1.1.1 International and EU context

Extreme weather events most often result in damage to traffic infrastructure and slowing down or stopping the flow of traffic. Although the infrastructure is designed and built to withstand the various effects of weather disasters (based on data from a series of events in the past), increasing their intensity and frequency accelerates its deterioration. The essential problem with the impact of climate change on transport infrastructure (and infrastructure in general) lies in the fact that its design (planning and construction) is based on historical data (100-year event) which due to climate change are no longer reliable (100-year events are now much more common). For example, events such as Hurricane Katrina and Perfect Storm (which caused more than $ 200 million in damage and killed 13 people in 1991) are by definition 100-year-old events, and their occurrence now averages 7 years.

Therefore, it is necessary to incorporate climate change projections into design and construction standards.

The reasons and needs for the analysis of the impact of climate change on transport infrastructure and its design in accordance with the expected climate change are clear from the average periods of "life" of the infrastructure:

Airports: 70 years;

Ports: 100 years;

Roads: 10-25 years.

Various risks associated with climate change affect airports, among which the greatest pressures are those caused by rising sea levels and changes in wind characteristics. Risks to ports are increased by rising sea levels, floods, extreme winds and storms, and water transport by droughts and floods. In principle, some of the potential climatic impacts on specific modes of transport are:

Air traffic: floods, rising sea levels, storms - which can lead to damage to facilities and slow down or stop functioning; extreme temperatures and heat waves - can lead to flight delays and cancellations and restrictions on the transport of goods.

Water transport: floods, rising sea levels and storms - may condition the need to raise and strengthen ports and infrastructure.

Railway traffic: high temperatures - can lead to widening and deformation of the railway, which would further condition the restrictions of speed and investment in repairs and replacements.

Roads: heat waves and high humidity can lead to construction interruptions, increased construction costs and maintenance of road infrastructure; floods and extreme snowfall - can significantly shorten the "lifespan" of roads and roads; extreme rainfall - can lead to complete destruction and disruption of traffic in rural and isolated, especially mountainous areas. Costs for repairs and rebuilding, especially in the case of rural areas, have increased dramatically in recent years, especially in the case of works without the inclusion of climate projections.

In addition, services in the transport sector must be organized in a way that takes into account possible delays and accidents due to natural disasters and natural disasters.

This can be especially important in urban and urban areas, both in the organization of work and provision of public transport services, and other public services (utilities, health services/ambulance, etc.), but also in the organization of private companies (especially delivery services).

In other words, transport as an area of interest in the context of adaptation to climate change has two perspectives: as an economic activity and as part of critical infrastructure.

Traffic is a derived activity, which results from other activities. Simply moving is not the purpose, but the purpose is to come to the location of interest. In that sense, the factors that affect its functioning (from extended travel time to extreme situations of inability to move) have a significant impact on the functioning of the economy and society (economic activities in the first place). Availability (safety) and safety of transport infrastructure are highly dependent on meteorological and climatic influences (such as floods and torrents, droughts, cold and hot waves, wind, forest fires).

The specificity of DRR and CCA in transport is the issue of two “multi” in one study, multi-modal (multiple modes of transport), and multi-hazard (multiple meteorological/climatic impacts). It should be borne in mind that when talking about the transport of an area, we talk about different types of transport (road, rail, water, air), but also multimodal/intermodal options (participation of two or more modes of transport in one transport flow). The same impact can be a greater threat to one mode of transport than another. According to the findings, for example, ports are *more sensitive* to the wind in relation to road or rail terminals, air. Furthermore, within one transport mode, the impacts differ depending on the elements of the system (roads, vehicles, terminals). The presence of different types of transport in one area determines its overall vulnerability, e.g. if there is an airport in the considered area, the roads that are the land connection of the airport with the service area gain in importance, i.e. *criticality*.

Table 18. *Sensitivity of different modes of transport to climate impacts in Europe (according to experts)*

	Hot waves	Cold waves	Droughts	Forest fires	Floods rivers	Wind gusts
Local roads	Medium	Medium	None	Medium	Medium	Low
Roads of national importance	Medium	Medium	None	Medium	Medium	Low
Highways	Medium	Medium	None	Medium	Medium	Low
Railways	Medium	Medium	None	Medium	High	Low
Inland waterways	Low	Medium	High	Low	High	Medium

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Ports	Low	Medium	Low	Low	High	Medium
Airports	Low	Medium	None	Low	Medium	Medium

Source: Forzieri, G., Bianchi, A., e Silva, F. B., Herrera, M. A. M., Leblois, A., Lavalle, C., ... & Feyen, L. (2018). Escalating impacts of climate extremes on critical infrastructures in Europe. Global environmental change, 48, 97-107. стр. 100

Therefore, the manner and intensity of the impact of climate change on the transport sector depend on the type of transport, but also on the region or area. In any case, climate change requires changes in planning, construction, organization and the way services are provided, mainly as a result of floods and storms, rather than as a result of changes in temperature and rainfall. Moreover, experience at the international level shows that the functioning of transport is much more sensitive to climate change than infrastructure.

Analyses of the effects of climate change on airports, ports and waterways made for the needs of the EU[92] confirm global analyzes showing that the impacts and consequences can be[93]:

(1) The rise in summer temperatures (designed for the whole territory of Europe):

- Affects aircraft performance, leads to restrictions on the transport of goods, changes in flight paths, delays and cancellations of flights;
- Leads to damage to traffic infrastructure / equipment / cargo;
- Increases energy consumption for cooling passengers and cargo;
- Reduces the water level by causing restrictions on navigation and increasing fuel consumption;
- Leads to an increase in the number of accidents;
- Reduces snow and ice cleaning costs.

(2) Increase in intensity and amount of precipitation:

- Causes flooding of airports, ports, roads;
- Leads to damage to infrastructure, facilities and equipment for cargo loading;
- Reduces the possibility of transport by rivers, lakes and the sea (during the summer season, the Nordic country expects a significant increase in precipitation and the southern parts of the drought).

(3) Increasing the frequency of extreme winds:

- Leads to damage to port and airport infrastructure (a significant increase is expected in northern and central parts of Europe, especially in the British Isles and the North Sea during periods typical of winds).

Analyses of the impact of climate change on road transport in the EU[94] show that the construction and repair of roads, taking into account climate projections, is a prerequisite for

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[92] Impacts of climate change on transport, A focus on airports, seaports and inland waterways, 2018, JCR Science for Policy Report

[93] Results of importance for Serbia are also presented

sustainability and the provision of necessary services. However, it should be borne in mind that investing in parts of the infrastructure, in this way, will not be economically justified or feasible.

Furthermore, the results of the analysis show that the costs of road infrastructure maintenance in Europe represent 30% -50% of the total maintenance costs (8 to 13 billion euros per year), of which 10% (~ 0.9 billion euros per year) are due to extreme weather events (primarily intense rainfall and floods). In addition, in the EU27 on average, an increase in the frequency of extreme rainfall and river and flooding within settlements will lead to additional costs in the period 2040-2100, for road infrastructure in the amount of 50-192 million euros per year. On the other hand, the mitigation of winter weather conditions will lead to a reduction in costs for road infrastructure from -170 to -508 million euros per year (in the case of climate change according to the A1B scenario).

Detailed analyzes of costs or economic losses in traffic that occur as a result of extreme weather conditions are shown in Table 19[95].

Table 19. *Annual costs of extreme weather conditions in Europe (in millions of euros)*

Extreme weather event		Infrastructure funds (m €)	Infrastructure repairs (m €)	Funds for vehicles (m€)	Vehicle repairs (m €)	User time (m €)	Health & life (m €)	Total (m €)
Storm	**Roads** (1)	76,10	22,60	5,10	1,40	63,00	5,90	174,10
	Railway (2)	0,07		12,05		6,28		18,39
	Marine (5)			2,10	17,98			20,08
	Intermodal (6) (7)	0,53					0,72	1,25
	Air (8)			53,80	34,30	38,40	28,30	154,80
Winter	**Roads** (1)	248,80	126,30	81,30	12,50	125,50	164,90	759,30
	Railway (2)(3)	0,04		3,38		1,60		5,02
	Intermodal (6) (7)	0,21					0,21	0,42
	Air (8)		11,20	12,00	57,70	64,60	1,90	147,40
The flood	**Roads** (1)	630,10	21,90	24,40	30,01	93,70	21,50	821,61
	Railway (2) (3)					4,87		4,87
	Intermodal (6) (7)	103,66		111,60		67,30		282,55

[94] Impacts of Climate Change on Transport, A focus on road and rail transport infrastructures, 2012, JRC Scientific and Policy Report

[95] WEATHER (2011). Deliverable 2 - *Vulnerability of Transport systems*, http://www.weather-project.eu/weather/downloads/Deliverables/WEATHER_Deliverable-2_main-report_20110614.pdf. стр. 93.

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	Air (8)			3,20	26,50	29,60	0,20	59,50
	Travel (1)	0,32					0,10	0,42
Heat and drought	**Roads** (1)						46,90	46,90
Total		1059,82	182,00	308,92	180,39	494,84	270,63	2496,60

(1) Average for the years 2000-2010; (2) Average annual data 1999-2010; (3) Avalanches, winter storms and extreme heat events are not included; (4) Average annual data 2003-2009, costs of service providers; (5) Hurricane Kyrill 2007 average case study, freight; (6) Average data 2009 freight transport without AT, CH, I, CZ, DE (already included in railway); (7) including extreme temperatures (heat) (8) Average annual data

Given the amount of additional costs, as well as the possible consequences of climate change on traffic infrastructure, there is an evident need to determine the so-called critical infrastructure in the future climate, including roads, bridges, tunnels, ports, etc. It is clear that the definition of critical infrastructure requires the existence of complete and publicly available databases of existing infrastructure and its characteristics.

The epithet critical in the context of transport infrastructure suggests that vulnerability assessment must take into account the importance of the link or node of the transport network for the economy and society. The 2013 WMO report, which assessed air traffic as more sensitive than road, water and rail, states that the higher sensitivity is a consequence of a combination of high dependence on meteorological influences and high economic importance of the sector (share in GDP).

More detailed analyzes on the issue of transport infrastructure are presented in the following chapters, while in this segment the focus is on the functioning of transport, which is more sensitive to climate change in the short term than infrastructure.

6.1.1.2. National context

The traffic system of the Republic of Serbia is characterized by the presence of various types of transport, the dominant representation of road traffic and insufficiently developed intermodal transport.

The primary road network of RS consists of about 15,000 km of state roads, of which 741 km are with a highway profile. The total value is estimated at around 13 billion dollars. In addition, the network consists of over 25,000 km of local roads. There are 2,921 bridges and 92 tunnels on the RS road network. According to the current legal framework (Law on Roads), state roads are managed by the Public Company "Roads of Serbia" (hereinafter JPPS), while the management of local roads is entrusted to local governments. Since 2009, the design and construction of highways has been under the jurisdiction of the company "Corridors of Serbia". Road maintenance in RS is realized through private-public partnership agreements. The last detailed assessment of the quality of infrastructure was made more than ten years ago. According to WEF data from 2017-18. According to the quality of roads, Serbia ranks

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100th out of 137 ranked countries in the world with a score of 3.6 (on a scale from 1 to 7) [96]. Bulgaria, Latvia, Malta and Romania have a slightly lower score than the EU countries.

The RS railway network consists of about 3,800 km of lines, of which 1,247 km are electrified. In the regional context, the most important part of the network is Corridor X with 827 km of lines. There are 690 stations/stops, 3,803 culverts, 334 tunnels, 981 bridges and 2,135 crossings on the line network. Although the system is designed for higher speeds, due to maintenance deficiencies over time, only 3-4% of the trains run at speeds over 100km/h. More than half (55%) of all railways were built in the 19th century, and the average age of the tracks is about 43 years, of electrical plants between 30 and 40 years. According to the data from 2017, Serbia ranks 71st out of 101 ranked countries in terms of the quality of railway infrastructure, while the countries of Europe and Central Asia are ranked above the 40th place (median)[97]. According to the valid legal framework, the management of the railway infrastructure is entrusted to the company "Infrastructure of the Serbian Railways", a.d.

The total length of waterways in RS is about 1500 km, of which 588 km is the Danube River, about 200 km is the Sava River, about 167 km is the Tisa River and about 600 km are navigable canals within the Danube-Tisa-Danube Hydrosystem (HDS DTD). There are six international ports on the Danube (Belgrade, Novi Sad, Apatin, Smederevo, Pancevo and Prahovo) and three more national ones (Beocin, Backa Palanka and Bogojevo). In addition to these, there are four other ports on the RS waterway network (on the Sava abac and Sremska Mitrovica, on the Tisa Senta and on the HDS DTD Sombor). Waterways in RS are part of the Rhine-Danube European Corridor, one of the corridors of the European TEN-T network. In addition to the relevant Ministry, the bearers of strategic planning in water transport of the Republic of Serbia are the State Water Directorate "Plov Put" and the Agency for Port Management, and in the regional context the International Sava River Basin Commission (Sava Commission) and the Danube Commission. The obsolescence of the fleet (on average over 35 years) and port infrastructure, sensitivity to hydrometeorological conditions as well as administrative problems are among the most important obstacles to the development of RS water transport.

The RS air traffic system consists of airports and heliports (two have the status of international airports: "Nikola Tesla" in Belgrade and "Constantine the Great" in Nis); airlines (predominantly Air Serbia), the Air Traffic Control Agency of Serbia and Montenegro (since 2005 a member of EUROCONTROL) and the Civil Aviation Directorate of Serbia. Both passenger and freight traffic is predominantly (over 90%) realized through the airport in Belgrade, but the capacity of the airport is not fully used. According to the data from 2017, Serbia ranks the 76th out of 137 ranked countries in terms of the quality of air traffic infrastructure, while the countries of Europe and Central Asia are ranked above 60th place (median). RS, compared to 2013, when it had a rank of 121, has significantly improved its position[98]

[96] https://reports.weforum.org/pdf/gci-2017-2018-scorecard/WEF_GCI_2017_2018_Scorecard_EOSQ057.pdf

[97] https://tcdata360.worldbank.org/indicators/h403e9361?country=SRB&indicator=540&viz=line_chart&years=2009,2017

[98] https://tcdata360.worldbank.org/indicators/hf15b0fde?country=SRB&indicator=544&viz=line_chart&years=2007,2017

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Intermodal transport in the Republic of Serbia is not developed. "Railway Integrated Transport" (*ŽIT*) l.t.d about. Belgrade and the Port "Belgrade" a.d. are equipped to serve standard container transport but cannot be characterized as intermodal terminals.

The strength of further development of transport in RS lies primarily in the favorable geographical position and integration of the trans-European transport network. The modernization of the RS transport system *is hampered* by the low quality of infrastructure as a consequence of decades of inadequate maintenance, non-renewal of the vehicle fleet, modest innovations (primarily in the field of intelligent transport systems), but also many others. A particular problem is the lack of integration and coordination of different modes of transport as well as integrated planning at all levels[99]. This is also reflected in the adaptation to climate change as an area of interest.

In the RS, there is still no umbrella sectoral document in the context of transport and adaptation to climate change. In some sub-sectors (railways), this is seen as one of the main reasons for the lack of activities and initiatives in this area[100]. The shift was made in water transport, where the current strategy (for the period from 2015-2025) emphasizes the problem of the dependence of navigation on hydrometeorological conditions and calls in the recommendations for the regular preparation of risk assessments from natural disasters. In addition, they give general proposals for adaptive measures (swimming pools, winter quarters, shelters, procurement of icebreakers, etc.).

In the existing cross-sectoral documents, traffic appears very modestly (for example, in the existing draft NAP from 2015, it appears sporadically in the context of: road infrastructure as a criterion for assessing vulnerability in forestry; within the flood impact assessment, etc.) [101]. The same is true for National Communications[102], where the transport sector is not included in *the vulnerability to climate change and adaptation measures.*

Although there are examples of studies that seek to provide an overall analysis taking into account all modes of transport (WEATHER project[103]) and even at the level of the overall critical infrastructure (ENHANCE[104]), in most analyses the focus is on: a specific mode of transport or road direction and multiple impacts (e.g. endangerment of navigation along the Sava due to climate change) or one impact for one mode of transport (e.g. impact of floods on roads). These conclusions can be transferred to Serbia as well (Table 20). Risk/threat assessments are focused on a specific type of transport or even a specific section and their setting depends on the client of this assessment, the region for which the assessment was

[99] Here, it is important to recall that climate change in traffic generates two fields of research: mitigation (primarily in the field of reducing greenhouse gas emissions) and adaptation (ensuring resilience to the effects of climate change through vulnerability and risk assessment). Unlike the adaptation in the part of mitigations, RS is largely in agreement with the EU in terms of transposition of legislation, primarily in the context of mandatory analyzes in the context of environmental impact within the planning process.

[100] Jeremić, M. (2017). Railway infrastructure in the Republic Of Serbia, PPP at the Workshop How to develop resilient infrastructure (Global SDG 9), Ljubljana Slovenia, https://transport.danube-region.eu/wp-content/uploads/sites/2/sites/2/2019/09/Experiences-M-Jeremic_Serbia_.pdf

[101] UNDP (2015). *Prvi nacionalni Plan adaptacije na izmenjene klimatske uslove za Republiku Srbiju - N a c r t*

[102] Second national communication of the Republic of Serbia under the United Nations framework convention on climate change, http://www.klimatskepromene.rs/wp-content/uploads/2017/09/SNC_eng.pdf

[103] WEATHER - Weather Extremes: Assessment of Impacts on Transport Systems and Hazards for European Regions, http://www.weather-project.eu/weather/index.php

[104]ENHANCE: "Enhancing risk management partnerships for catastrophic natural hazards in Europe" (2007-2013); http://enhanceproject.eu/

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made, and also the team which participated in its development (in terms of methodology selection).

Table 20. *The focus of analyzed studies in the field of Transport (client, time of realization)*

	One impact	**More impacts**
One mode of transport	Vulnerability of roads to floods (PEPS, 2017, 2018) Vulnerability of roads to snow deposits (PEPS, 2016)	Adaptation to climate change on the Sava River – Navigation section (2012-15, World Bank, Sava Commission) Adaptation to climate change in Belgrade (includes transport, 2015, GIZ and the City of Belgrade) Road vulnerability in the municipality of Valjevo (part of the project on the development of a methodology for multi-hazard road risk assessment, World Bank, 2017-18)
Multiple modes of transport	/	Adaptation to climate change in the part of the Orient/Eastern Mediterranean corridor and the part of the TEN-T Rhine-Danube corridor passing through Serbia (2016, REC, RCC, SEETO)∗
∗separate analysis of the mentioned corridors using the same methodology		

Bearing in mind that 15.8% of the surface of Serbia is prone to landslides, 20.72% droughts and 17.20% floods[105], as well as changes in the intensity and distribution of precipitation as a result of climate change (more precipitation during hot summer days, more days with extreme precipitation during years) [106] the vulnerability of the transport sector of Serbia to climate change can be assessed as very high. However, unlike European projects, studies of this type in Serbia are less comprehensive, ie they focus on either a specific hazard or a specific area (section), and both are usually valid (more in the review of studies or the next chapter). Table 21 gives only basic indications based on available data. Although this is only an illustrative summary, it is clear that, as at the European level, the impact differs depending on which type of transport we are talking about or which element of the subsystem.

[105] Novkovic, I., Dragicevic, S., & Manic, E. Natural Hazards and Vulnerability to Natural Disasters: The Case of Serbia. *Risk Measurement and Control in Insurance; Kocovic, J., Jovanovic Gavrilovic, B., Rajic, V., Eds*, 41-62.

[106] Second national communication of the Republic of Serbia under the United Nations framework convention on climate change, 2017, http://www.klimatskepromene.rs/wp-content/uploads/2017/09/SNC_eng.pdf

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Table 21 [107]*: Sensitivity of different modes of transport to climate impacts in Serbia (framework review based on the results of available studies)*

Type of transport / system element	**Sensitivity**
Local roads	here is no data except for Belgrade, but no assessment is given according to the type of roads
Roads of national importance	High: Torrential floods, landslides. Medium: floods, snow/ice, fires Low: wind gusts, droughts
Highways	Only for Corridor 10: High: Torrential floods, landslides, landslides; Medium: floods of rivers and lakes, snow/blizzard
Railways	No data
Inland waterways	Only for Sava and Danube: High: decrease of water level due to higher temperatures, drought, floods and changes in intensity and distribution of precipitation, medium: ice, extreme wind
Ports	High: extreme wind Medium: floods and torrential floods
Airports	No data
Source: Studies: CLIMACOR, Mainstreaming CCR in Road transport in Serbia, CCA and VA for Belgrade,	

The absence of an umbrella document and thus a comprehensive analysis at the sector level is best seen in the difference between Table 15 and Table 17. Unlike the European approach (Table 15), where we can comprehensively view and compare the vulnerability of individual transport options and/or system elements, in Serbia there is an inconsistency in approach (and even the situation that different methodology is used for the same type of threat assessment, an example of flood risk analysis in two different basins). Above all, there is a need to consider the action plan for adaptation.

European studies are more detailed in the analysis of costs or economic losses in traffic that occur as a result of extreme weather conditions (Table 18).

Data for Serbia are not systematized in this way. In some studies, sporadic data can be found:

- Losses in the transport sector caused by the floods in 2014 are estimated at 166 million euros[108], of which the total direct damage to road infrastructure is 96 million euros and 70 million euros are indirect losses[109]. In the Disaster Risk Assessment in RS, the consequences within certain areas (example Obrenovac), the total material damage

[107] Студије: CLIMACOR, Mainstreaming CCR in Road transport in Serbia, CCA and VA for Belgrade,
[108] GFDR&WB (2018). Mainstreaming climate resilience in the road transport management in Serbia.
[109] Радић, З., Радић, З., & Ђурић, У. (2017). Санација клизишта на путевима Србије средствима из Фонда солидарности ЕУ и буџета Републике Србије. *Пут и саобраћај*, 63(3), 13-20.

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from floods on critical infrastructure is characterized with the highest degree - catastrophic (> 5% of the budget).[110]

- The average annual economic losses in the road maintenance sector in RS, ie unfavorable weather phenomena (snowfall and ice) amount to about 3 million euros[111]. Comparisons are made in The American study[112], which was the methodological basis for the study in RS, discusses the effects on traffic safety - during snowfall, up to 25% of accidents occur in areas without protective fences, compared to 11% in areas where these fences exist[113]. Discussions of this type are not given in the road study in RS.
- in the Disaster Risk Assessment in RS[114], it appears in the section Facilities and other infrastructure of special importance (critical infrastructure). In some scenarios (example of floods) it appears as part of the risk by economic activity (public transport) and other categories (eg damage to the bus station). For example, in the section Impact on protected values for SPNMP Kolubara-Obrenovac, 12.5 million dinars of damage is estimated in the domain of Public and other transport during the event (based on 2014), but it is not clear to what extent it reflects losses of carriers due to traffic disruptions. and to what extent the rehabilitation of infrastructure. It should also be borne in mind here that the transport activities themselves pose a risk (eg. accidents in the transport of dangerous goods).

Taking into account the above, the existing methodology for disaster risk assessment[115] needs to be supplemented in part with the assessment of traffic damages and losses in order to have a consistent approach.

Starting from the list of studies given in Table 20, Annex 1 provides a more detailed overview of these studies, followed by a summary according to the following characteristics: the methodology used and implementation challenges; inclusion of socio-economic indicators; level of analysis (whether they were done at the regional and city and municipality level); adaptation measures and monitoring. These topics are then commented on in more detail in separate sub-chapters.

A summary of the studies is given in Table 22, while in the following sub-chapters some aspects are commented on in more detail.

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[110] *Процена ризика од катастрофа у Републици Србији, стр.270-271,* *http://prezentacije.mup.gov.rs/svs/HTML/licence/Procena%20rizika%20od%20katastrofa%20u%20RS.pdf*

[111] from the JPSS study on the impact of snow deposits and based on the findings of the World Bank study "Study on Economic Benefits of RHMS of Serbia" from 2005

[112] Tabler, R. D. (2003). Controlling blowing and drifting snow with snow fences and road design (No. NCHRP Project 20-7 (147)). https://sicop.transportation.org/wp-content/uploads/sites/36/2017/07/NCHRP-20-07147_Controlling-Blowing-Snow-Snow-Fence_Tabler_2003.pdf

[113] Tabler, R. D. (2003). *Controlling blowing and drifting snow with snow fences and road design* (No. NCHRP Project 20-7 (147)).

[114] Disaster risk assessment in the Republic of Serbia, http://prezentacije.mup.gov.rs/svs/HTML/licence/Procena%20rizika%20od%20katastrofa%20u%20RS.pdf

[115] PC(2019) *Uputstvo o Metodologiji izrade i sadržaju procene rizika od katastrofa i plana zaštite i spasavanja,* *https://www.pravno-informacioni-sistem.rs/SlGlasnikPortal/eli/rep/sgrs/ministarstva/uputstvo/2019/80/1/reg*

Table 22. Summary of realized studies in the Transport sector

	Hazard	Area of analysis	Methodology	Involvement of climate change projections	Vulnerability assessment	Involvement of socio-economic analysis	Adaptation measures	Monitoring
JPPS studies	Floods Torrential floods	State roads of the first and second order in the Kolubara Basin South Morava Basin Studies are underway for three more basins	Different depending on the basin. For example. FFI was used for the Kolubara Basin and not for the South Morava Basin	No	List and map of endangered sections	No	Yes	No
	Snow drifts	State roads in Serbia	Based on the American model (Tabler, 2003)[116]	No	List and map of endangered sections	No	Yes, with a recommendation to develop an action plan in the coming period	Partly in terms of proposing checklists for road maintenance companies
Climacor	40 climate-related threats under the EEA SEE scenario	Waterways (Sava and Danube through Serbia) and road-rail Corridor 10	Based on RoadAdapt (which is part of Climate-Adapt). It is an expert assessment.	Yes, until 2050.	List and map of threats with the highest degree of risk	Partly in terms of the impact on the availability and accessibility of the road	Yes	No
WATCAP	Changes in water and ice levels	The course of the Sava River (multisectoral analysis includes navigation)	Hydrological simulations	Yes	Based on the results of the hydrological model	Partly in the form of guidelines	Yes	/
Mainstreaming climate resilience in RTM of RS	Floods Torrential floods Landslides Forest fires Ice / snow	State roads in the municipality of Valjevo (pilot study)	Based on the IPCC AR5	Да до 2100 укључујући два периода пројекције (2020-2050 и 2040-2070)	Multi-hazard risk index per map section	Yes	Yes, along with the costs of rehabilitation and an action plan	Yes
CCAWB	Consequences of the influence of hot waves, drought, intense rainfall, extreme cold	Belgrade (multisectoral analysis includes city road transport)	*FUTURE CITIES Adaptation Compass*	Yes	Degree of threat for each climate impact	Yes	Yes	Yes

[116] Tabler, R. D. (2003). *Controlling blowing and drifting snow with snow fences and road design* (No. NCHRP Project 20-7 (147))

Based on the previous analysis, it is clear that methodological approaches vary from study to study, even in the case of the same type of study as flood risk.

The studies combined qualitative expert assessments and data from different databases. CLIMACOR has shown that when the involvement of experts is well thought out, the results can complement more serious models in terms of a quick preliminary assessment of the impact of climate change when the information base is unsatisfactory.

Climate change projections do not appear in all studies. For example, JPPS studies on road hazards are based only on observed values. The reason for non-inclusion was "not foreseen by the tender of the study commissioner", although there were capacities (data and competencies of team members) to include projections.

Methodologically closest to European and world practice is the study Mainstreaming climate resilience in road transport management in Serbia.

The problem of data gaps was identified in all studies. The MCRRTM, which referred to roads, points out that the problem is less that there is no data, but that they are not available, ie they are not systematized in one place and that they are of inconsistent quality (especially for roads and RAMS[117]). This study shows how the problems of missing data can be overcome with proxy indicators.

JPPS studies address data availability issues. An example is data collected from road maintenance companies that are inconsistent and for which a checklist recommendation is given.

Flood risk data are publicly available for two basins (and only in the form of final results, pdf file) although, according to the JPPS bulletin, studies have been conducted for other basins as well. There are GIS maps[118], for endangering state roads with snow, but they are not publicly available. Part of the MCRRTM study (on endangered sections of roads in the territory of Valjevo) is available through the academic network only in the form of a final map (pdf format).

Data on critical locations along the Sava and Danube and along the Orient/Eastern Mediterranean corridor (CLIMACOR II study) are available in tabular form. On *Google maps* for waterways, there are distance data (rkm) based on the "Plov Puta" database. Some of the data that could be useful in further analyzes are the BEWARE[119] landslide database in the context of risk and the JPPS road database[120], based on which, with the application of new methodologies[121], the extent of traffic disruption or deceleration could be modeled.

The level of detail of any future analysis will certainly depend on the data itself (eg whether existing analyzes in the field of traffic safety can be included) [122] as well as the possibility of combining different spatial data sources (eg GIS "Post of Serbia" for local roads).

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[117] Road Asset Management System

[118] Bilten JP Putevi Srbije vol 22/23, april 2019. https://www.putevi-srbije.rs/images/pdf/publikacije/bilten22-23.pdf

[119] http://geoliss.mre.gov.rs/beware/webgis/

[120] Annual tables of average annual daily traffic on I and II order roads available in excel format on the JPPS website for the period 2013-19.

[121] Ivanović, I. D. (2017). Modeliranje opterećenja ulične mreže za različite vremenske prilike (Doktorska disertacija, Univerzitet u Beogradu, Saobraćajni fakultet). http://uvidok.rcub.bg.ac.rs/bitstream/handle/123456789/1742/Doktorat.pdf?sequence=2

[122] In The World Bank study. (2005). Study on Economic Benefits of RHMS of Serbia. Belgrade. Serbia. It is stated that the annual loss of human lives on highways, regional and local roads caused by bad weather ranges from 105 to 131 per year, it can be assumed that there is some kind of information basis. The impact of weather

Consolidating or linking existing databases and their uniformity in presentation (publicly available information bases) is the first step in assessing the impact of climate change and planning adaptation to the transport sector.

A particular challenge in terms of information base is the lack of data on air[123] and rail traffic. According to current information, there are no studies on climate impacts or a plan for adaptation in railway traffic, but in 2017, the preparation of the Infrastructure Database (IDB) [124] was announced. In the field of air transport, the basis that needs to be further analyzed are the EUROCONTROL databases, which include the Air Traffic Control Agency of Serbia and Montenegro.

In addition, cocioeconomic data are necessary to assess the criticality of part of the infrastructure or part of the system, ie in terms of its importance for society and the economy. It comes down to demographic and economic indicators. It depends on the level at which the data is collected, ie on the extent to which they can be reduced to a section or element of the system being analyzed. As the databases on the elements of infrastructure are not monitored for the time being, it is difficult to assess their criticality. As an alternative (proposal in the MCRTM study) multicriteria analysis can be used. CLIMACOR is the only example of analysis that, in addition to availability, includes the impact on traffic safety (at the level of expert assessment) which is also a European practice, for which there are some information basis networks of road safety councils at the local level coordinated by the Traffic Safety Agency (state body). In the methodological sense, two studies are at the forefront: Mainstreaming climate resilience in road transport management in Serbia and CLIMACOR. The reason is that both were created by borrowing from recognized methodologies in the field, the first used for the basis of IPCC AR5, and the second RoadAdapt (which is a continuation of the European Climate-Adapt). The advantage of the first is that it is detailed, comprehensive in terms of the information base, but therefore demanding to apply. It is also narrowly focused only on roads. On the other hand, CLIMACOR directly overcomes the problem of methodological complexity, and can be extended to the level of the entire system. Still, it represents a pre-scanning assessment and as such can serve as a first guideline towards further and more detailed analyzes at the subsectoral level.

6.1.2. Adaptation measures

The impact of climate change on traffic largely depends on local characteristics, both climatic conditions and expected changes, as well as the characteristics of infrastructure and traffic organization. Therefore, the planning of adaptation to changed climatic conditions is largely determined by local needs and possibilities, but it is generally necessary:

(1) Include climate projections in defining technical requirements for rehabilitation and infrastructure construction, as well as the functioning and organization of services; that is

conditions on the occurrence of road accidents with fatalities, Paper presented at the 6th IRTAD Conference "Better road safety data for better safety outcomes" 10-12 October 2017, Marrakech, Morocco

Smailović, E., Pešić, D., Marković, N., (2018). Influence of weather conditions on the occurrence of traffic accidents with fatalities. 13th International Conference - Traffic Safety in the Local Community, Kopaonik.

[123] Similar to security in The World Bank study. (2005). Study on Economic Benefits of RHMS of Serbia. Belgrade. Serbia states that the average annual economic losses due to unfavorable hydrometeorological events in air traffic amount to 54 to 72 million dinars, so it can be assumed that there is some kind of information basis.

[124] Jeremić, M. (2017). Railway infrastructure in the Republic Of Serbia, PPP at the Workshop How to develop resilient infrastructure (Global SDG 9), Ljubljana Slovenia, https://transport.danube-region.eu/wp-content/uploads/sites/2/sites/2/2019/09/Experiences-M-Jeremic_Serbia_.pdf

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(2) Revise construction standards taking into account climate projections and risk assessments.

- In principle, adaptation to climate change requires:
- Establishment of backup services and ways of functioning;
- Construction of flood barriers in a way that takes into account climate projections;
- Increasing the thickness of layers during road construction and adjusting drainage/aliasing systems on roads; a
- in some cases relocation of road infrastructure.

Also, two approaches to planning adaptation to changed climatic conditions are proposed:

- Adaptation management - planning adaptation measures for a shorter period (eg 10 years). The advantage of this approach is the reduction of the risk of large infrastructure investments, given the accuracy of climate projections and the availability and accuracy of socio-economic data for the long term. commit to highly expensive investment which could tune out inadequate.
- One-time adaptation - planning adaptation measures for the long term.

6.1.3. Conclusions and recommendations

Given the complexity of the transport sector in terms of multiple modes of transport, different elements of infrastructure and consequently different levels of vulnerability, it is not possible to talk about adaptation measures in general. Especially if we take into account that no studies have been done at the sectoral level, ie that no adaptation measures have been identified for certain types (subsystems) such as railways and air transport in RS.

At this point, it is possible to refer to relevant sources on adaptation measures that would be the basis for this type of analysis in the RS.

At the sectoral level, it is a special report within the WEATHER project, and at the level of individual modes of transport: road traffic - RoadAdapt; Railway traffic- Mowe-it guidebook; Air Transport - EUROCONTROL (2013), Climate Change Risk and Resilience; Water transport - WATCAP and ECONET project.

Once a good information base is created and the capacities of the interested parties are strengthened, the possibilities of application of European solutions in the national framework can be furthermore concretely analyzed. The chance of RS in this context lies in its integration into trans-European networks and participation in European initiatives for adaptation to climate change, which alleviates the dependence of national capacities.

Defining adaptation measures while monitoring their implementation has not been consistently represented in previous analyzes. Many analyzes are more recent, so it is still early to talk about the effects of implementation. Where they exist (eg the action plan in the study for the city of Belgrade) are not directly related to adaptation but relate to the mitigation of climate change to which traffic undoubtedly contributes. Some studies provide guidelines (WATCAP), and some announce an action plan as a continuation of the threat analysis (example of the impact of snow on roads).

In this part, the study Mainstreaming climate resilience in road transport management in Serbia is in accordance with European and world practice. It ends with a chapter dedicated to

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monitoring and implementation of measures, and can be an example of good practice for adaptation planning.

At the same time, it should be borne in mind that the EU does not have special indicators for monitoring the impact of climate change on the transport sector, ie the success of adaptation measures. The only relevant EEA indicator would be:

(1) Economic damage from natural disasters,which will be elaborated in more detail through the following sub-chapters of this chapter.

Based on the review of realized studies in RS and European experiences, the conclusion is that in the methodological sense, two studies are in the forefront: Mainstreaming climate resilience in road transport management in Serbia (MCRRTM) and CLIMACOR. Their advantage is primarily that they are created by borrowing from recognized methodologies in the field, the first used for the basis of IPCC AR5, and the second RoadAdapt (derived from Climate-Adapt). The advantage of MCRTM is that it is detailed, comprehensive in terms of the information base, but therefore demanding to implement. It requires the engagement of a large number of team members, field observations, a long period of implementation and what is especially important to emphasize applies only to roads. On the other hand, the CLIMACOR approach has just been defined to overcome the problems of methodological complexity, and previous experience indicates that it can be applied to different modes of transport (an example is CLIMACOR II where access for roads is extended to rail and waterways). Although with the potential for comprehensiveness, CLIMACOR is a pre-scanning analysis that primarily provides guidelines for further and more detailed analyzes at the sub-sectoral level.

Bearing in mind that this project is aimed at planning adaptation at the national level, the proposal is to give priority to comprehensiveness over detail, in order to take into account the representation of different modes of transport in the territory of RS. In methodological terms, this implies that CLIMACOR II is used as a basis.

6.1.3.1. Recommendations

Based on previous analyzes and experiences at the international and EU level, it is recommended that within this project:

- Prepare recommendations for the integration of existing databases and information systems, relevant for impact assessment and adaptation planning;
- Identify the elements of the RS transport system for which the impact assessment and adaptation plan will be done by crossing two lines of analysis: elements of the transport system (transportation assets) and climate threats;
- Preparation of a list of possible threats, if possible (depending on the availability of data) for all elements of the system for which the implication of vulnerability has been previously determined;
- Assess the degree of risk of identified threats at the level of elements, subsystems and systems based on the probability of consequences for the availability and safety of traffic, taking into account two scenarios: current meteorological conditions and conditions expected as a result of climate change in current weather conditions and those which are expected to be possessed by climate change;
- Prioritization of threats with the highest degree of risk (with the possible inclusion of socio-economic data for criticality assessment) and their mapping on the transport network;
- Identifies critical infrastructure, as appropriate;
- Prepare a list of potential adaptation measures for the highest risk threats and/or more detailed analyzes;

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- Preparation of a list of available models that can consider the impact of climate change on the transport sector, based on international experience;
- Prepare recommendations for: lists of indicators, in line with EEA indicators; institutional competence and responsibility for data collection and indicators.

6. 2. INFRASTRUCTURE

6.2.1. Impact assessments and adaptation

Regardless of the measures taken and planned, mitigation and adaptation of climate change are already affecting, and expected climate change in the future may lead to significant disruption, damage and destruction of infrastructure, whether it is traffic, energy, housing or any other infrastructure. In general, the impact of climate change on infrastructure can be:

- Temporary - flooding of roads, railways, buildings, households, water supply, mines, faster deterioration of asphalt and the like; i
- Permanent - demolition of buildings and water supply systems, energy transmission systems and water supply, damage by strong winds in the long run, etc.
- The key threats to infrastructure are certainly natural disasters and natural disasters, the intensities and frequency of which increase with climate change, and some of the risks in this regard are vulnerability:
- Embankment safety performance - increasing rainfall intensity leads to rising water levels in rivers which can lead to this risk; or
- Stability of the energy network - due to more frequent storms.

At the same time, new research indicates the effects of other consequences of climate change (increase in temperature and humidity) on the sustainability of infrastructure in the long run.

Whatever the effects of climate change on infrastructure, key activities to reduce them can be classified as:

(1) Increasing the resilience of infrastructure and management systems;

(2) Inclusion of resilience in infrastructure construction and maintenance standards;

(3) Provision of funds for the rehabilitation of the existing and construction of new climate-adaptable infrastructure.

(1) and (3) are of an absolutely local character, while (2) it is primarily a question of international and EU standards and is the basis for increasing the resilience of infrastructure to changed climatic conditions.

Technical standards are used in all phases of infrastructure construction, rehabilitation and maintenance and have an impact on the resilience of products, processes and construction. Therefore, it is necessary to include aspects of observed and expected climate change in technical standards.

- ISO standards (left in their original names in English, to avoid improvisation) relevant to the field of climate change are:
- ISO 14030 Green Bonds - defines environmental performance for projects and activities;

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- ISO 14080 Greenhouse gas management and related activities - framework and principles of emission reduction methodologies;
- ISO 14090 Adaptation to climate change - basic principles of requirements and guidelines related to adaptation;
- ISO 14091 Adaptation to Climate Change - impact, impacts and risk assessment;
- ISO / TS 14092 Greenhouse gas management and related activities;
- ISO 14097 Investments, financing and climate change.

Of these standards, only ISO 14090 has a significant impact on investment in adaptation to changed climatic conditions.

For the EU, the priority sectors for which technical standards need to be adapted to climate change are:

- Traffic infrastructure;
- Energy infrastructure and
- Buildings / structures.

In this context, the standards EN 1990 - EN 1999, play a key role for construction and construction works and with them in relation to the map of thermal zones used in the EU are based on climatological data 10 to 15 years old and do not take into account climate change and potential impacts. European standards (Eurocodes) actually include 10 standards in the field of construction, which are being amended to integrate climate projections. EU standards of importance for construction and climate change are those from the group EN 1990 and EN 1991. Specifically by sectors:

(1) EU standards for the field of building/construction (as in the case of international standards, the names are left in the original in English) are:

- EN ISO 15927-4 Hygrothermal performance of buildings - Calculation and presentation of climatological data, in part 4: hourly data required for the calculation of annual energy consumption for heating and cooling;
- FprEN 16798-1 and -3; -2 and -4 Energy performance of buildings, part 1: Internal environmental parameters for design and assessment of energy performance of buildings - Module M1-6; and Part 3: Ventilation for non-residential buildings - performance requirements for room ventilation and cooling;
- EN 16309 Sustainability of construction works - assessment of the sociological performance of buildings - calculation methodology;
- EN ISO 52000-1 Energy performance of buildings - total energy consumption and definition of energy assessment;
- A standard for construction works in a climate-resistant manner is being prepared.

(2) Standards for the energy sector

- EN 16348 and EN 15399 Gas infrastructure - safety management system;
- EN 1473 Installation and Equipment for Liquefied natural gas (LNG) - design and installation.

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(3) Standards for the transport sector

- EN 206 Concrete Specification, performance, production and conformity;
- EN 15723 Closing and locking devices for payload protecting devices against environmental influences;
- EN 50125-1, -2 and -3 Railway applications;
- EN 1915-1 and -2 Aircraft ground support equipment.

It is recommended that instead of individual analyses of the direct impact of climate change on infrastructure in transport, energy, water management, agriculture, the focus should be on construction standards and legislation defining the latter, i.e. spatial planning, and to change them in a way that will ensure the reduction of losses and damages caused by acts of God and natural disasters, the intensity, and frequency of which change due to climate change.

In addition, it is recommended to identify opportunities and improve legislation related to 6.5. Conclusions and recommendations

There are not many concrete assessments of the impact of climate change on infrastructure, both at the international and EU level. The conclusions are based on previous experience with natural disasters and natural disasters. In addition, these analyzes and work in the field at the national level are completely absent in the field of adaptation to changed climatic conditions. Certain advances are visible both in research and in practice when it comes to reducing greenhouse gas emissions (mostly due to setting energy efficiency standards for new buildings).

Therefore, the basis for assessing the impact of climate change on infrastructure in Serbia, which is also proposed for implementation within this project:

(1) Identification of critical infrastructure by sectors (energy and transport in the first place) and potential hotspots;

(2) Verification of the application of standards EN 1990 - EN 1999, adopted in RS, and preparation for amendment/preparation of maps of thermal zones that would take into account current climatological data and climate projections at the national level.

Regarding the adaptation of infrastructure to changed climatic conditions, the priority is the inclusion of climate projections and the need for adaptation in existing capital investment programs.

Specifically in the case of Serbia, the priority and most efficient would be to include the effects of climate change and adaptation measures, ie the need to adapt to changed climatic conditions in the investment program "Serbia 2025".

At the same time, it should be borne in mind that adaptation measures and activities include:

(1) "hard" options, such as raising bridges, changing the content of asphalt, methods of construction of drainage and sewerage systems and the like and

(2) "soft" options, which include changes in infrastructure maintenance practices and practices, changes in flood zones including climate projections, etc.

Thus, for critical infrastructure, within the project, risk reduction and impact reduction measures could be prepared through both types of previously mentioned measures and activities.

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Moreover, a significant aspect of risk reduction for the energy sector would be the inclusion of climate projections and climate risk reduction in the NECP (as explained in the chapter of this report, which refers to the energy sector).

Consultations with line ministries (the ministry responsible for climate change and energy) are needed to examine the possibilities and options for providing support in this context and within the project.

For the area of transport infrastructure, within the project, it is necessary to define with the line Ministries (responsible for agriculture, rural development and construction) the possibilities of assessing the impact of climate change on rural infrastructure.

Aspects of the impact of climate change on construction, to a large extent, can also be regulated through inclusion in legislation related to strategic and environmental impact assessment. These aspects will be discussed in more detail in the next report under this Agreement.

The lack of analysis and activities related to the impact of climate change on infrastructure indicates the need to strengthen capacity in this regard, and certainly, a significant role in this context has the Capital Investment Commission, which was recently formed at the national level and is responsible for implementation. investment program "Serbia 2025".

6. 3. RISK REDUCTION

6.3.1. Basic information

Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) are two concepts and practices that address the increased risk of climate change disasters. Both concepts aim to increase the resilience of communities, so their coordination and joint action is necessary. However, it is still lacking, causing duplication of effort, resources and confusion, especially at the local level where activities are most needed.

In its publication: “Common Elements of the Paris Agreement and the Sendai Framework - Adapting and Disaster Risk Reduction” (2019), the OECD states that synergies require:

1. Political commitment and readiness of all levels of Government;
2. Creating centralized platforms that will generate data relevant to adaptation and risk reduction, in one place;
3. Identifying objectives and action plans including both concepts;
4. Establishment of joint financing mechanisms;
5. Establishment of a system for reporting on the effectiveness of the implementation of action plans.

6.3.2. Risks and adaptation

The Law on Disaster Risk Reduction and Emergency Management ("Official Gazette of RS", No. 87 of November 13, 2018) deviated from the previous definition of such laws on the basis of "protection and rescue" or "civil protection", so by including the phrase "disaster risk reduction", it has become more comprehensive. However, even in such a "broader" law, which, must be said to be "more advanced" than similar laws of countries in the region, aspects of climate change are omitted.

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Without going into the analysis of the legislation, which will be the subject of the next report, the niche for connecting the two concepts could be:

Improving national disaster and disaster risk assessment, by including climate projections, which is not currently the case;

Implementation of a pilot project that would ensure the connection of the two concepts at the level of local governments or the level of river basins. The possibility would be to make a risk assessment that would include climate projections.

Optionally, some local governments that have recognized the importance of climate change developed Local Adaptation Plans (with the help of UNDP), or acceded to the "Covenant of Mayors for Climate and Energy" could join the development program. These can also be included in the preparation of certain documents for the needs of participants in the initiative (Belgrade, Priboj, Sombor, Kula, Petrovac na Mlavi, Ivanjica, Vrbas, Zabalj, Varvarin, Titel, Temerin, Vranje, Nis and Zrenjanin). The proposal is to make a risk assessment for some of the mentioned municipalities and cities within the project, which will include climate projections.

Inclusion of climate change aspects in the National Platform for Disaster Risk Reduction. The National Platform is defined in Article 14 of the Law on Disaster Risk Reduction and Emergency Management as "a platform for considering and defining issues of the utmost importance for the disaster risk reduction and emergency management system, which provides exchange of opinions, knowledge, innovations and experiences from areas of risk reduction, proposes measures and policy activities for disaster risk reduction and emergency management, considers development strategies, plans and programs of interest for risk reduction and emergency management and strengthens mechanisms of cooperation and coordination at the national and international level. ".

The realization of some or all of the above possibilities within this project depends primarily on UNDP and the Ministry, as the project holder, because these are activities of national interest. Especially because, based on the content of the mentioned documents and the concept of activities related to them, there is an evident lack of understanding and capacity of institutions responsible for risk reduction issues (Ministry of Interior and Public Investment Management Office).

Experts engaged in the project can provide information relevant to capacity building, but not the willingness of institutions to participate in this process. In principle, the proposal is to prepare recommendations on issues (1) to (3) within the project.

In addition, a special opportunity to improve cooperation relevant to the two concepts and types of activities (risk reduction and adaptation) is the establishment of a system for data collection and reporting on economic damage from natural disasters, and as an EEA indicator in the field of adaptation to changed climatic conditions.

This EEA indicator is one of the few indicators relevant for monitoring the impact and success of adaptation measures in almost all sectors and segments of society.

Data on damages and losses are part of the database managed by the Ministry of the Interior (https://www.desinventar.net/DesInventar/profiletab.jsp?countrycode=srb&continue=y) and according to the requirements of the Sandei framework. A review of the database reveals a number of shortcomings in the quality, but also the quality of the data that needs to be overcome. This is, among other things, because the data on damages and losses are the basis for financial assistance from international funds earmarked for assistance to developing countries under the auspices of the UN Framework Convention on Climate Change (Green Climate Fund).

The reason for the incompleteness of the mentioned database may be the lack of a methodology for assessing damages and losses, as well as sectoral methodologies.

It is proposed to assist in the preparation of general or some of the sectoral methodologies in the framework of the project, following the needs.

All this would lead to a more efficient fight against climate, and thus reduce the need to allocate large funds in response to disasters, because through adequate use of adaptation actions, the need for recovery after disasters would be reduced.

From the aspect of developing methodologies, it is important that the topic of social vulnerability, as one of the key factors needed to determine and calculate the level of disaster risk, is not adequately addressed in the documentation concerning the field of civil protection in the Republic of Serbia.

In that sense, there is a need to develop a methodology of social vulnerability for the territory of the Republic of Serbia, which would be used as a tool in the development of risk assessments at the national level and local government levels. Finally, tools for assessing social vulnerability must be chosen for specific program or investment decisions and may therefore be different. It is proposed that this methodology be prepared within the project and prepared at the national level. The result of applying the methodology would be the identification of areas of different levels of social inclusion (example as in Figure 21)

However, it should be borne in mind that the methodology of social vulnerability will not be successful if it is not systematically integrated into the overall process of climate change and disaster risk management.

What usually happens is that many documents that should be "risk assessments" such as the Disaster Risk Assessment of the Republic of Serbia do not go beyond the "hazard assessment" because they lack standardized, comparable and measurable dimensions of social vulnerability.

Availability of data on social vulnerability (based on census, pre- and post-disaster surveys, public surveys, etc.) and sample size on which social vulnerability study is conducted (individuals, community, city, municipality, etc.) are key parameters that determine the success of the assessment social vulnerabilities for disaster adaptation and reduction programs.

Different communities and individuals are exposed to different dangers, even within the same area. Nevertheless, disaster statistics in recent years show an increased percentage of women, children and other socially vulnerable groups among disaster victims in the Republic of Serbia. Therefore, it is clear that socially vulnerable people are more exposed and affected by the effects of climate change.

The final data should be numerical and mapped (visual representation, as in Figure 21).

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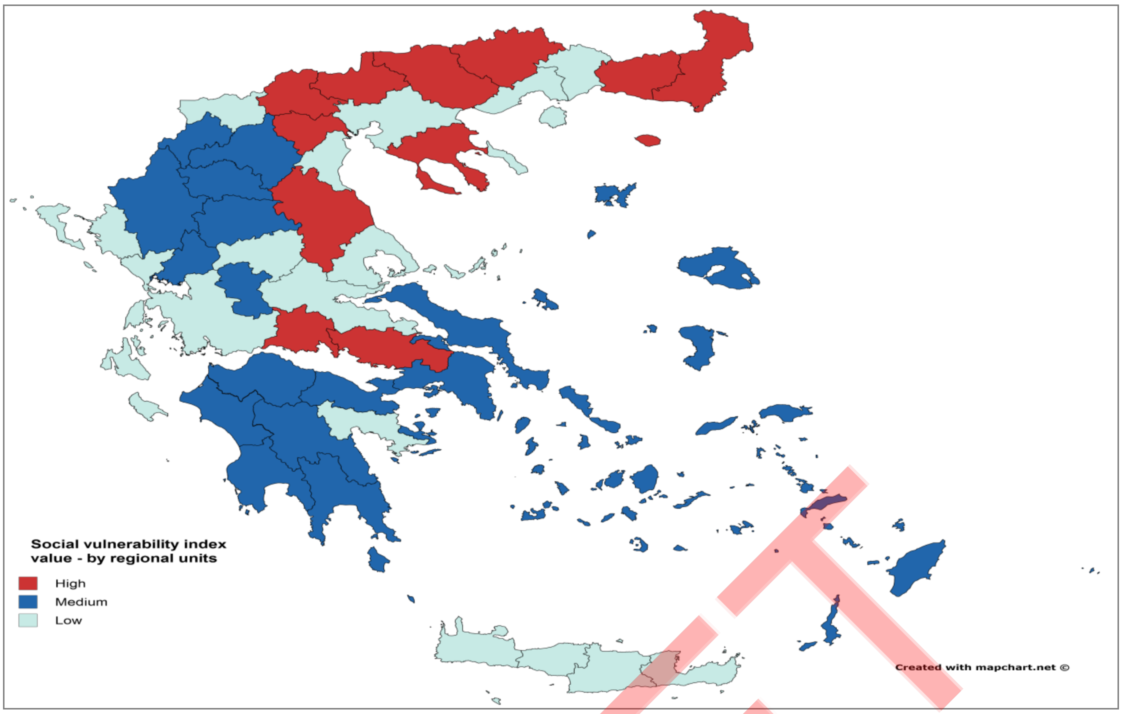

Figure 21. *Example of mapping - visual representation of social vulnerability by geographical levels (fictitious results taken from mapchart.net)*

From the aspect of risk reduction and adaptation to changed climate conditions, it is important that the existing legislation (Law on Risk Reduction and Emergency Management and the Law on Climate Change) obliges local governments to prepare risk reduction and protection and rescue plans and report on the consequences of natural disasters and natural disasters, ie on the implemented adaptation measures. It is also recommended to examine the possibilities of coordinating these activities of local governments and to unite them in the reporting package, as well as to include aspects of climate change in the plans at the level of local governments. A detailed proposal in this regard will be contained in the next report provided for in this Agreement.

In this context, it is necessary to prepare a database on observed and expected climate change, which would be publicly and easily accessible. On the other hand, it is necessary to make a list of possible adaptation measures, as guidelines for local self-government units.

Strengthening the capacity of target groups at the level of local communities is of key importance because both areas require actions at the level of local self-governments units as a precondition for better efficiency.

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ANNEX : Sectors that are not subject to ToR, but are proposed by the methodology (forests and forest management, public health)

Introduction

Although not initially envisaged by sectoral analyzes, recognizing the importance of adaptation in the forest management sector as well as in the public health sector, these sectors will be included and analyzed as far as possible given data availability and the need for optimal implementation of activities in the above sectors.

It is proposed that the forestry and forest management sector be involved, at least, in defining common adaptation measures for the water management sector, agriculture and forestry.

For the public health sector, it is possible to prepare a list of potential risks and a list of potential adaptation measures, based on international and EU experience.

7.1. FORESTS AND FOREST MANAGEMENT

Forestry is a sector that is heavily affected by climate change. Prolonged drought periods together with extreme events (floods, strong winds, late frosts, etc.) disrupt the stability of forest ecosystems. In this regard, there are disruptions in management plans, the expected cycle of forest regeneration is disturbed, which introduces uncertainty into the economic model of business of companies that manage forests in Serbia.

Public companies that are the largest entities entrusted with forest management (PE "Srbijašume", PE "Vojvodinašume", PE NP "Fruška gora", PE NP "Tara", PE NP "Djerdap", PE NP "Kopaonik") are in charge of the largest areas under forests or under some kind of protection. Small forest owners, despite being a significant factor in the forestry sector in Serbia in terms of the number and area of forests they own, they are not being mutually coordinated, and they mostly rely on the capacities of public companies and the private sector in terms of management.

A major factor in the forest-based industry is wood processing, which is predominantly privately owned.

In the past decade, which is considered to be the warmest one globally in the past 140 years, ever since the measurements are made, there has been a drying and declining vitality of oaks in Vojvodina due to long droughts, the devastation of forest areas due to ice breakage in Eastern Serbia, and drying of spruce in coniferous areas, following highly warm and dry years. Attacks of pests (bark beetles, gypsy moths, oak bugs, leaf defoliators, etc.) are also recorded, which are closely related to the decline in forest vitality caused by extreme events.

The issue of the trend of changing the degree of forest cover is of great importance for the strategic planning in forestry as well as for adaptation and mitigation in relation to future climate changes. Based on the research[125], the degree of forest cover decreased in the period 2000-2013 in Vojvodina and Kosovo and Metohija, while in Central Serbia it increased. A summary of the change in forest cover in Serbia is presented in Table 21. The largest relative reductions were recorded in Srem, Peć, West Bačka, and Kosovo-Moravian districts, while the largest increases were recorded in Zlatibor, Raška, the Pčinja, and the Moravica Districts.

[125] Stojanović, DB, Matović, B., Orlović, S. (2015): Trends in changes in the degree of forest cover in the Republic of Serbia. Forestry (3): 89-98

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Table 23*.The overview of area covered by forest trees and changes at the national level, the regions, and the administrative districts in the period 2000-2013. Districts in which a reduction of forest cover has been observed are highlighted in grey.*

District	**District area (ha)**	**Forest cover 2000 (%)**	**Increase (2000-2013) (%)**	**Reduction (2000-2013) (%)**	**Total change (2000-2013) (%)**	**Absolute change of cover (2000-2013) (ha)**
BOR	351733	38.618	0.002	0.004	-0.002	-789
BRANIČEVO	386780	38.410	0.003	0.002	0.001	481
BELGRADE CITY	323713	16.612	0.004	0.006	-0.002	-796
ZAJEČAR	363255	39.293	0.002	0.003	0.000	-88
WEST BAČKA	248456	6.555	0.002	0.006	-0.004	-1031
ZLATIBOR	616114	43.389	0.011	0.002	0.008	5165
THE JABLANICA	276826	42.601	0.006	0.004	0.002	656
SOUTH BANAT	424254	8.009	0.003	0.003	-0.001	-293
SOUTH BAČKA	402448	6.957	0.003	0.006	-0.003	-1273
THE KOLUBARA	247463	29.777	0.002	0.002	0.000	-14
KOSOVO	312447	29.033	0.004	0.007	-0.003	-797
KOSOVSKA MITROVICA	205430	35.979	0.006	0.005	0.001	192
KOSOVO-MORAVIAN	142930	26.562	0.009	0.012	-0.003	-484
MAČVA	326808	26.600	0.002	0.002	0.000	-22
THE MORAVICA	302495	46.162	0.008	0.002	0.006	1798
THE NIŠAVA	273459	32.558	0.003	0.003	0.000	70
PEĆ	255971	22.962	0.006	0.010	-0.004	-1140
PIROT	276296	41.139	0.005	0.003	0.001	334
THE DUNAV BASIN	124187	9.569	0.001	0.000	0.001	89
MORAVIAN	259805	37.019	0.002	0.002	0.001	152
PRIZREN	174889	21.568	0.002	0.004	-0.003	-442
THE PČINJA	351215	41.404	0.013	0.007	0.006	2246
THE RASINA	266537	40.048	0.007	0.001	0.005	1431
RAS	392680	48.732	0.011	0.003	0.008	3094
NORTH BANAT	233036	1.710	0.001	0.002	-0.001	-205
NORTH BAČKA	178148	1.790	0.001	0.001	0.000	-11
CENTRAL BANAT	326286	2.430	0.001	0.002	-0.001	-290
SREM	347827	15.011	0.003	0.009	-0.006	-2030
THE TOPLICA	220999	45.583	0.004	0.003	0.001	274
ŠUMADIJA	237925	28.843	0.001	0.001	0.000	-10
REPUBLIC OF SERBIA	8850414	28.454	0.005	0.004	0.001	6047
AP VOJVODINA	2160456	6,718	0.002	0.005	-0.002	-5123
CENTRAL SERBIA	5598291	37,277	0.005	0.003	0.002	13959
AP KOSOVO AND METOHIJA	1091667	27,411	0.005	0.008	-0.002	-2668

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In summary, the Republic of Serbia in the period 2000-2013 increased the area under forests by 6000 h. Nevertheless, when this is put in the context of 2.5 million ha, which is the degree of forest cover, the increase is only 0.001%. The fact that in 2/3 of the districts in our country there is a decrease in forest cover (grey fields in Table 21), including all districts in the AP

Vojvodina, is quite worrying. One of the main reasons for the reduction of forest cover is the increased number of sanitary felling caused by intensive drying. Forest drying is associated with the occurrence of extreme events, primarily extreme droughts (2000, 2003, 2007, 2011, and 2012), as well as windsnap, ice breakage, forest fire, and pest infestation and diseases. Data on sanitary felling in PE "Srbijašume" show that their increased intensity occurred two to three years after the great drought. Also, intense forest fires contributed significantly, especially from 2007 and 2012, which were also years of great droughts. In addition to drought conditions and fires, the gypsy moths (*Lymantria dispar L.*) caused great damage to forests in Serbia and contributed significantly to reducing the vitality of the forests and their subsequent drying. A rather massive infestation by gypsy moths was recorded in 2004, 2013, and 2014. Finally, as an illustration of economic losses due to forest drying and other adverse effects, there is a trend of increased operational loss in the PE "Vojvodinašume" (Figure 22) since 2000. The average annual loss in this period exceeded 50 million dinars[126]. The estimated direct and indirect damage from the fire in the PE "Srbijašume" in the period 2000-2009 amounted to 36,454,762,406.56 dinars. Given that, based on climate scenarios, longer droughts and more frequent extreme events are predicted, it is to be expected that the processes related to forest drying will intensify in the future.

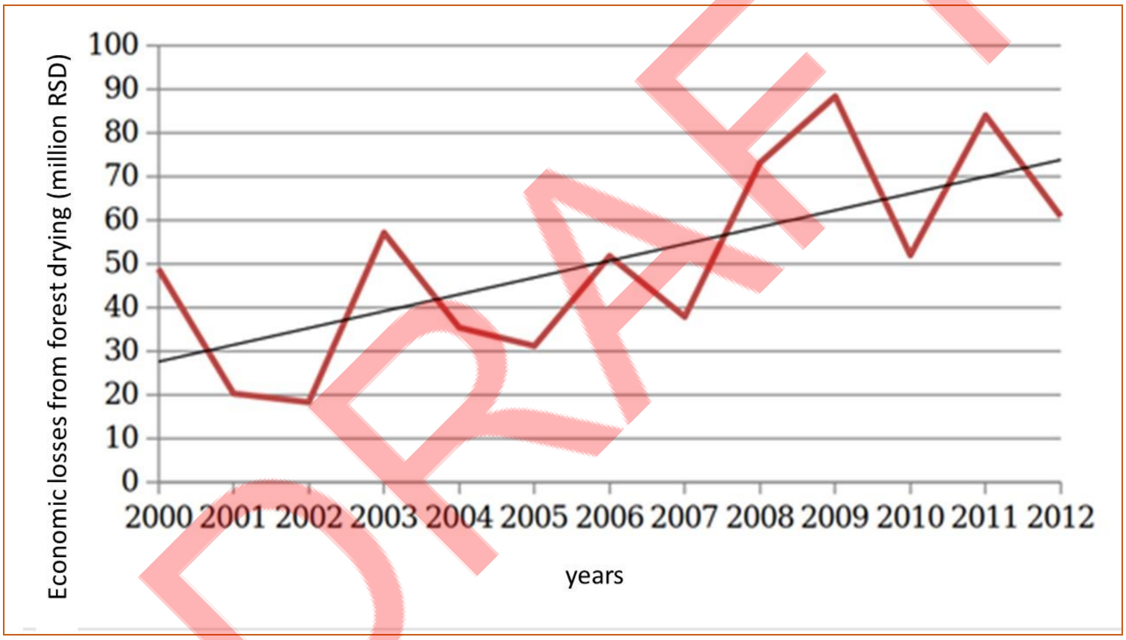

Figure 22. *Estimated operational loss caused by forest drying in the forests managed by the PE "Vojvodinašume" in the period **2000-2012**[127]*

Previous investments in the sector aimed at raising the adaptive capacity to climate change have been made in the segment of new afforestation, forest tending, construction of forest roads, production of seeds, planting stock, research, forest protection and other activities. The Forest Administration, Ministry of Agriculture and Environmental Protection, subsidized the protection and improvement of forests with approximately 33 million euros in the period 2004-2013 (Table 24).

[126] Aleksić, P., Jančić, G. (2011) Zaštita šuma od šumskih požara u Javnom preduzeću „Srbijašume". Šumarstvo, 95-109.
[127] Source: Forest Administration

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Table 24. Subsidies to forestry (funds for forest protection and improvement) in the period 2004 - 2013[128]

Year	Tree planting on state-owned land		Private afforestation		Forest tending		Construction of forest roads		Production of seeds	
	ha	€	ha	€	ha	€	km	€	ha	€
2013	33	31,512	801	260,085	0	0	114	1,264,288	16,838	10,482
2012	297	282,018	407	117,963	1,904	434,356	167	1,656,510	7,037	29,631
2011	472	516,46	767	267,548	2,270	564,847	171	1,424,676	6,577	22,486
2010	921	586,314	1,155	258,11	2,053	476,716	157	963,996	283,234	88,805
2009	785	549,463	1,318	358,323	870	144,044	140	1,184,382	256,059	84,867
2008	485	349,007	749	277,070	2,909	527,978	161	1,580,500	7,410	51,988
2007	1,571	1,448,133	1,441	477,888	3,087	501,334	127	1,165,581	38,750	44,985
2006	1,010	431,757	1,043	220,918	3,060	266,340	59	319,580	126,599	79,702
2005	961	319,188	1,036	213,016	2,958	236,935	76	241,792	4,229	35,185
2004	1,418	285,435	1,263	297,333	3,883	307,416	57	192,232	24,760	37,385
Σ	**7,951**	**4,799,287**	**9,981**	**2,748,256**	**22,994**	**3,459,993**	**1,230**	**9,993,536**	**771,493**	**485,516**

Year	Production of seedlings		Research & Development	Protection	Miscellaneous (ed.prog.)	Total
	kom	€	€	€	€	€
2013	0	0	163,388	450,920	520,014	2,700,689
2012	3,628,955	192,343	235,049	176,523	307,602	3,431,995
2011	4,692,690	242,230	198,550	159,197	168,767	3,564,787
2010	2,937,177	174,750	176,095	189,468	183,938	3,098,194
2009	3,157,357	182,407	196,591	258,502	35,025	2,993,604
2008	6,914,800	312,649	256,638	709,162	458,322	4,523,314
2007	7,360,384	303,224	252,906	112,673	309,087	4,615,811
2006	4,941,079	131,177	188,231	960,829	223,531	2,822,065
2005	4,981,732	134,385	96,735	1,627,530	169,287	3,074,053
2004	8,047,500	167,110	124,575	621,256	224,840	2,257,582
Σ	**44,661,674**	**1,840,275**	**1,888,758**	**5,266,060**	**2,600,413**	**33,082,094**

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The goals of sustainable development of forests and forestry in the Republic of Serbia are based on the strategic goals of the EU and include: supporting rural and urban communities, fostering competitiveness and sustainability of forest-based industries, bioenergy, preserving and strengthening forest capacity for resilience and adaptation to climate change, including forest fire prevention and other solutions to adapt to and mitigate climate change, protect biodiversity, protect forests and improve ecosystem services, combat deforestation and forest degradation in order to reduce the negative effects of climate change.

7.1.1. The impact of climate change on the forestry sector

[128] Source: Forest Administration

The First (Initial)[129] and the Second National Communication (2010, 2015), as well as the First National Plan for Adaptation to Changed Climatic Conditions for the Republic of Serbia, addressed the forestry sector.

The First National Communication states that the general condition of forests is unsatisfactory and that it is characterized by: insufficient production fund, unfavorable age structure, unsatisfactory cover and afforestation, unfavorable stand condition, and unsatisfactory health condition.

The Second National Communication confirms the findings from the First National Communication, especially emphasizing the vulnerability of the most important forest species: pedunculate oak, beech, sessile oak, European Turkey oak, fir and spruce, which by their economic and ecological significance, as well as spatial distribution represent the foundation of forestry in Serbia.

Existing research presented in the Second National Communication indicates that pedunculate oak is most exposed to the negative impact of climate change. Its vulnerability stems from the fact that it is also dependent on groundwater, which has experienced a general decline in the last few decades in oak habitats in Serbia (data from RHMS), but also that elevated temperatures negatively affect its growth. For sessile oak, European Turkey oak, fir, spruce, and beech we can say that most likely their distribution will be changed before the end of 21. Based on calculations obtained using drought index and data for the future climate in case of unfavorable future climate scenarios it can be concluded that the least favorable conditions for forests in the 20th century correspond to the most favourble ones in the period 2071-2100. European black pine and (Eastern) white pine, as well as pubescent oak, which are already present in arid areas, will be least affected by climate change.

The first national adaptation plan states that the main challenges that the forestry sector is facing are poor forest condition (large share of coppice forests, low volume growth, unfavourable age structure), uneven distribution of forest cover, poor road infrastructure important for forest exploitation and protection, and organizational management problems related to a large number of private forest owners.
Among the aforementioned challenges, of great importance for forestry, and at the same time important for the entire society, is the increase of forest cover and its optimization. Increasing the forest cover in the part concerning the protective function of forests is perhaps of the greatest importance. The establishment of new forests and belts that will protect against Aeolian and water erosion can contribute to the adaptation of several sectors of society at the same time. Establishing windbreaks contributes to reducing the negative impact of winds on agricultural crops on the one hand, on the other hand, it prevents burying of drainage and irrigation canals, while at the same time, and it raises the share of total forest cover, which is extremely low in some parts of Serbia. Newly established forests encourage general useful and economic functions in the regions in which they are growing, such as the development of local communities, development of hunting, rural, and ecotourism, improvement of the environment, creation of favourable conditions for human health, favourable impact on climate, and biodiversity conservation.

[129] UNDP (2015). Prvi nacionalni Plan adaptacije na izmenjene klimatske uslove za Republiku Srbiju - N a c r t

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7.1.2. Analysis of socio-economic aspects at the level of administrative districts

Rising temperatures and changes in the frequency and intensity of precipitation will have a direct or indirect impact on all segments of society. In the case of Serbia, it is expected to have an impact on forestry, agriculture, transport, public health, nature protection and the economy in general. Nevertheless, certain regions in Serbia may find themselves under greater pressure caused not only by future projected climate change. The main goal of the analysis of the proposed measures was the efficient adaptation to climate change through the assessment of regional features on the territory of Serbia. The analysis of the effectiveness of the measures is focused on the choice of regions concerning the criteria according to which the regions are ranked according to the degree of hazard from the standpoint of forestry. The criteria were selected in order to comprehend the broader context of vulnerability, in addition to vulnerability to potential future climate change, through the assessment of the current state of forests, economic and demographic characteristics, as well as additional benefits in other sectors, such as agriculture, water resources, and nature protection, concerning the proposed adaptation measures. Ten criteria based on which the regional prioritization was carried out are presented in Table 25. Each of the proposed criteria was accompanied by a geo-referenced map that quantifies the given criterion whether it's about the current situation or projected values for the future.

Table 25. *Criteria for determining priority regions for the implementation of adaptation measures in Serbia*

	Criteria	**Appropriate geo-referenced map for the territory of the Republic of Serbia**
1.	Area under forests	Status based on [4]
2.	The quality of forests (conversion of coppice forests to high forests)	Status based on the National Forest Inventory [2])
3.	Road infrastructure	Current status (road network based on the Digital Map of Serbia in vector format 1:300000 of the Military Geographical Institute)
4.	The population of the District	Status based on the 2011 Census of Population, Households, and Dwellings in the Republic of Serbia
5.	Unemployment rate	Current status
6.	Average salary	Current status
7.	Budget surplus/deficit	Current status
8.	Climate Change (temperature and precipitation)	Projected values
9.	Erosion (water and aeolian)	The map was not available
10.	Nature protection (ecological network)	Current status

Each of the criteria was assessed in relation to its current impact on the general situation in the forestry sector or through its impact on the adaptive capacity of the proposed measures concerning future climate change. To achieve robust results, the criteria were evaluated through surveys of experts from different fields (climatology, forestry, economics, agriculture,

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water management, and nature protection) and various organizations (ministries, institutes, public companies, university departments, and agencies) and the final ranking was done using the method of analytical-hierarchical processes. The result of the final ranking is presented in Table 26.

Table 26. *Ranking criteria by experts in order of importance for the regional adaptation to climate change*

Criteria	**Rank**	**Weight values**
Climate Change (temperature and precipitation)	1	14.9%
Nature protection (environmental network)	2	11.8%
Unemployment rate	3	11.3%
Erosion (water and aeolian)	4	10.1%
Average salary	5	9.9%
Budget surplus / deficit	6	9.7%
Area under forests	7	9.2%
Population of the District	8	8.7%
The quality of forests (conversion of coppice forests to high forests)	9	8.4%
Road infrastructure	10	6.0%

As a final result, a vulnerability map of individual regions was obtained as a difficult mean of the prepared maps, using the weighting factors obtained by the previous ranking of the criteria. Based on the results, we can conclude that the most vulnerable regions are as follows: West Bačka, North Bačka, North Banat, Central Banat, the Danube Basin, Šumadija, the Rasina, the Nišava, the Toplica, the Jablanica, and the Pčinja Districts (Figure 23). Although shown on the map, most of the data for the districts in the Autonomous Province of Kosovo and Metohija were not available.

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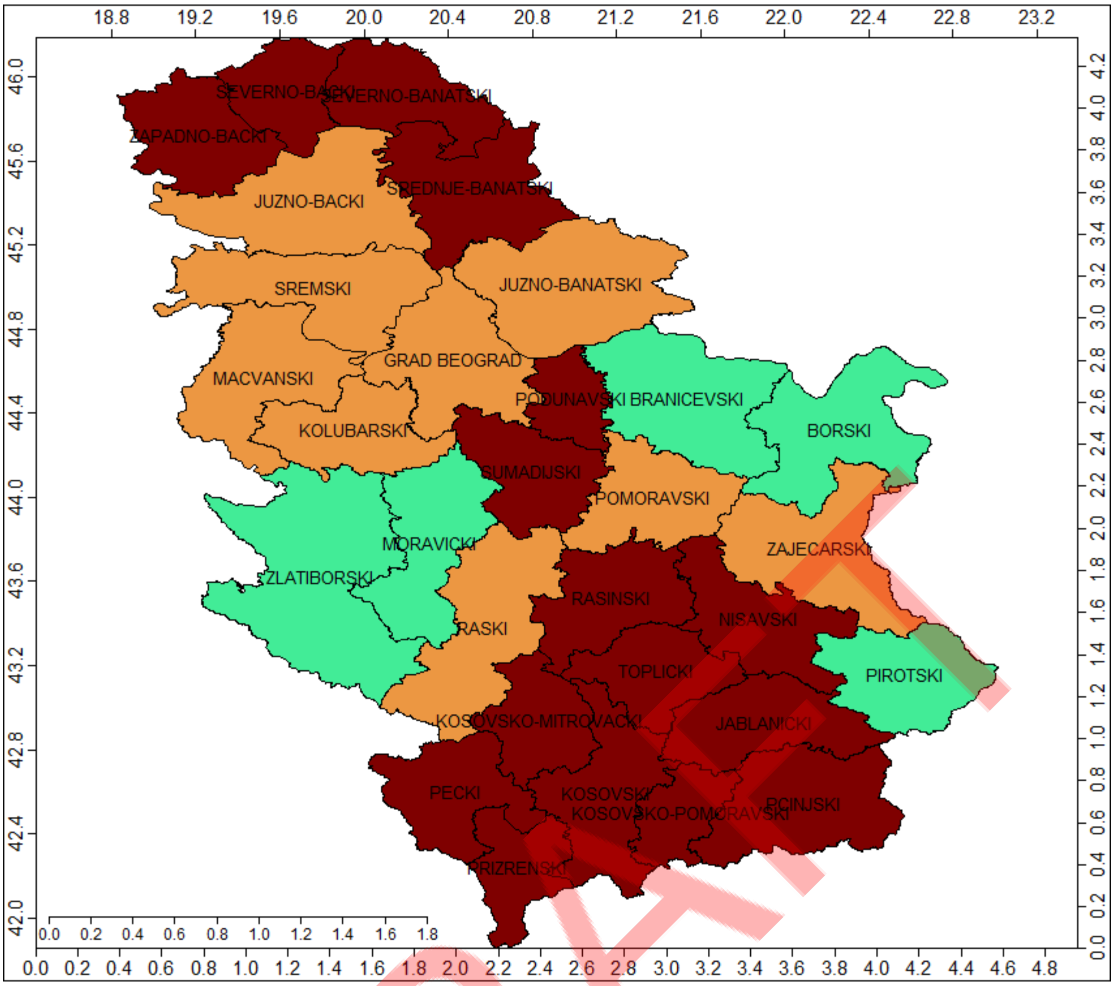

Figure 23. Vulnerability of the region in the Republic of Serbia based on nine criteria: area under forest cover, forest quality, road infrastructure, district population, unemployment rate, average salary, budget surplus/deficit, climate change, area of protected goods. The first ranking, being the most vulnerable - dark red, the second-ranking - orange, the third-ranking - green. Note: Not all data were available for the AP K&M.

The most vulnerable areas in terms of the impact of climate change according to the presented methodology are those that were highlighted as vulnerable according to several criteria. The biggest expected climate change in combination with poor economic indicators was crucial for highlighting 11 districts in dark red. The population of the district is considered in such a way that the more inhabitants a district has, the greater its vulnerability, because of the number of people who could potentially be vulnerable. Nevertheless, climate change and economic indicators had the greatest weight in this choice of criteria. The assumption was that economically developed districts and the citizens who have more money will also have more opportunities to adapt and mitigate the negative effects of climate. Also, since forests have a favorable effect on the microclimate, it was calculated that areas with more forests and with better quality forests are in a more favorable position compared to those that lag behind in this regard.

It is also important that the areas where climate change is expected to be the most pronounced are already vulnerable in terms of afforestation and exercising the benefits of ecosystem services that forests can provide. Therefore, increasing the forest cover and its optimization in terms of afforestation of deforested areas and establishing protective forests should be a priority in the adaptation of the entire society to climate change. Increased activity related to

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the establishment of new forests and the improvement of the existing ones will also lead to an increase in economic activity in the vulnerable areas.

Future expected climate changes will also affect forests in Serbia. At higher altitudes, this impact can be even positive, but in the lowlands, where the largest part of the population is located and where the largest part of economic and social activities take place, the expected changes are negative.

Elevation change projections for the most common forest species

Beech in Serbia is represented by approximately 30% of the area under forests (660,400 ha, Banković et al., 2009) and is the most represented and economically most important forest species. Previous research has determined that there is a possibility that approximately 50% of beech forests in Serbia are in a zone that will not favor the survival of existing forests until the end of the 21st century (Stojanović et al., 2013), and that the pedunculate oak, sessile oak, European Turkey oak, fir, and spruce forests can be significantly vulnerable (Stojanović et al., 2014), which is also suggested by and recorded in episodes of drying and loss of vitality of the aforementioned species in the past ten years. Recent research, which besides temperatures and precipitation took into account some orographic, pedological, and more complex bioclimatic indices, suggests that beech, as the most common woody species in Serbia, will be forced to reduce its distribution and potentially retreat to higher altitudes (Figure 4.) (Pavlović et al. 2017, 2018, 2019).

Today, the beech is predominantly located at altitudes in the interval from 500 to 1000 meters (x-axis, red line, Figure 24). At these altitudes, the conditions for beech growth were most favorable in the period 1961-1991. It is expected that in the period 2041-2070, according to the A2 scenario, there will be a shift of optimal habitats in such a way that the optimum for beech will be in the range of 750 to 1250 meters above the mean sea level, since in such a short periodbeech cannot migrate to higher altitudes, growth reduction, drying, and loss of beech habitat at lower altitudes are expected.

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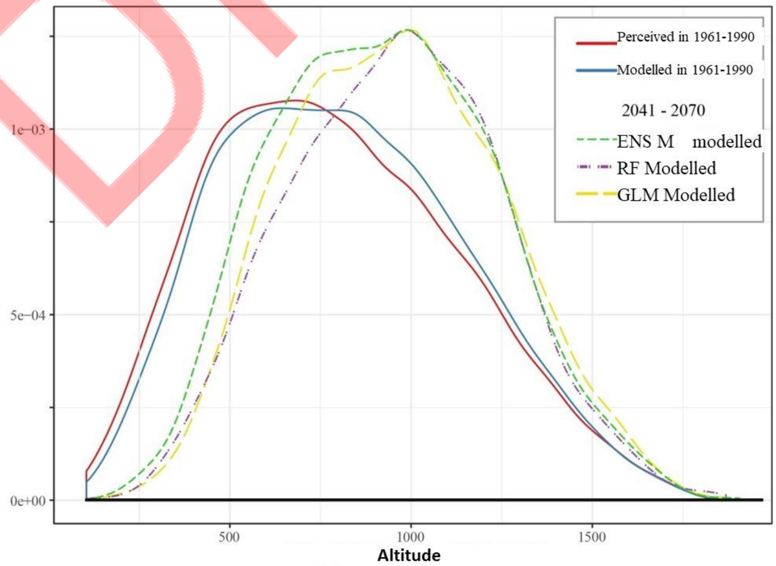

Figure 24. *The predicted loss of beech habitat at lower altitudes according to the model based on machine learning (see more in Pavlović et al., 2019)*

In addition to the climate that crucially affects the distribution and the vitality of forests, the orographic and pedological characteristics of habitats are a factor of great importance. Previous research in Serbia has not taken into account habitat characteristics except for climatic conditions.

It is necessary to complete the current predictions of potentially suitable conditions for the main tree species in the light of climate change by using advanced statistical tools that include machine learning methods, which will take into account factors such as altitude, exposure, slope, soil depth, physical and chemical properties of the soil at different depths, satellite observations in different parts of the spectrum, and enable decision-makers to review everything at the regional and local levels.

It is necessary to link the increment of forests and soil moisture, as one of the most important factors for the ecology of forest ecosystems, which can be obtained using remote detection methods.

In order for additional estimates to be made in this context, it is necessary to provide data from the National Forest Inventory, obtained by using a network of measured sites in the layout of 4 x 4 km.

The Statistical Office of the Republic of Serbia publishes the Forestry Bulletin in the Republic of Serbia on an annual basis. Although the data presented in the bulletins are very precise and comprehensive, for them to find their application in creating concrete measures to mitigate and adapt the impact of climate change on forest ecosystems, it is necessary to consider their spatial component. In particular, spatially defined data are needed to monitor forest statistics.

Currently, there is very useful information such as wood felled in forests, forest damage, etc. Nevertheless, the existing spatial determinant refers only to regions (Vojvodina, Southern, and Eastern Serbia, etc.), which is not enough for more precise analyses that are necessary given that these are regions that cover millions of hectares, a large number of forest types, ecological and administrative units.

Georeferenced stand management maps are needed for all forests in Serbia, which are consolidated by the Forest Administration using data from various legal entities (mostly public companies) that manage forests.

Maps are needed to cover forest statistics for the last 10 years. Such maps would make it possible to model the impact of climate change and other disturbances on forest drying, predict future risks, and adopt measures to mitigate them.

Investing in monitoring forest increment and their vitality using remote detection (multispectral imaging, lidar and radar monitoring data) can pay off many times over by contributing to better forest resource management and related savings.

It is necessary to support research pertaining to field measurements and monitoring of forest ecosystems, genetic and dendroecological research that contributes to understanding the impact of forest ecosystems.

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7.2. PUBLIC HEALTH

7.2.1. Introduction

The impact of climate change on the health sector is multiple and is reflected in:

- the impact on the health of the individual and the population
- the impact on medical systems and requirements for certain services
- the preparedness of the medical sector to adapt to the complex impacts of climate change.

If timely adaptation measures are not applied, the climatic conditions will affect public health directly and indirectly. Directly, through the impact of higher temperatures and extreme weather events on the disease rates of the risk groups, and indirectly, through the spreading of the so-called vector-borne infectious diseases. Therefore, the Republic of Serbia has taken a number of measures in this area aimed at monitoring and early notification. These measures should be coordinated and implemented, inter alia, by the Republic Hydrometeorological Service and the Institute of Public Health of Serbia, in cooperation with the network of local public health institutions.

Particular challenges in studying the impact of climate change on health relate to the systematic collection - records of medical data - which are of particular importance – and include the connection of primary, secondary, and tertiary levels of health care through appropriate protocols and mandatory recording of data relating to individuals - patients).

Another significant challenge is the planning of human resources in healthcare in relation to the needs for adaptation and increased needs for healthcare services that are a consequence of climate change (e.g. long-term heat waves).

In addition, the lack of connection between private and public healthcare has resulted in insufficiently accurate data on health and medical effects caused by the impact of various external factors, including climate change, insufficient preparedness for an adequate response.

It is recommended for this project to collect information on existing data relevant to the impact assessment of the public health sector, and the legislation that provides for their collection, as well as to identify needs in this regard. Optionally, the project could also help meet the objectives of the Health and Environmental Plan, which is currently under development.

It is also recommended to conduct research on the needs and possible tools for early warning of heat waves, which would make it effective in the health system.

One of the tools and recommendations is contributed by the World Health Organization in its documents. The aim is to provide basic and flexible guidance on conducting a national or sub-national assessment of current and future vulnerability (i.e. population or region vulnerability) to climate change health risks and policies and programs that could increase resilience, taking into account multiple determinants of health outcomes sensitive to climate

Strengthening the capacity of target groups in general on the connection between climate change and action planning in the healthcare system is a key prerequisite for a more detailed analysis of the impact of climate change in the sector.

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CONCLUSION

In the RS, there is still no umbrella document for adaptation to climate change that would define sectoral vulnerability and guidelines for sectors to adapt to it. The exceptions are the National Communications that provide them for the three most affected sectors. However, one should bear in mind that these documents are reports, i.e. they are not policy documents.

In some sectors, this is defined as one of the main reasons for the absence of activities and initiatives in the context of adaptation.

The draft Law on Climate Change prescribes the drafting of such a document, and the analyses within this project should also provide the document prescribed by the said Law.

With regard to the tasks under the contract concluded with DVOPER, analyses of the impact of climate change and its impact on the sector will be made in accordance with the proposals in the previous chapters and taking into account the available and accessible data. In the context of analyses of the current situation in each area, i.e. the impact and vulnerability, as well as analyses of political, institutional capacity per area, the project team will make proposals for updating at least 5 sectoral development plans and relevant policy documents with climate change adaptation components. The development of the knowledge base and the list of measures for adaptation to climate change (the basis for understanding, initiatives, decisions, future activities, etc.) will be upgraded throughout the project, given that the project is focused on proposals for document changes and the process of establishing an integration system for adaptation to climate change in sectoral legislation.

As the definition phase follows, and the report submission phase is forthcoming (Report on the Review and Assessment of the Existing Political, Regulatory and Institutional Framework for Climate Change Adaptation with Recommendations for Development / Improvement of Specific Policy and Regulatory Framework), there is a possibility that this report will be finalized in accordance with the elements that will be defined for the purposes of report 3. In that case, a new version of the report with explanations of the reasons for amendments and supplements will be prepared during the next phase of the project (report on segment 3.1. in LOT 1. upon its completion, planned for September 2020)

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ADDENDUM 1 - **Review of studies in the transport sector - One mode of transport one impact - study examples**

As the operator of the state road infrastructure and the company responsible for the construction and reconstruction of roads on the territory of RS, PE "Roads of Serbia", according to their bulletin[130], conclusive of 2018, carried out five studies of the threat to state roads from floods and torrents, for the basins of the Sava, Kolubara, Ibar, West Morava and parts of the South Morava. Two are available on the website of PE "Roads of Serbia": *Study of threats to roads of I and II order from the occurrence of floods and torrents in the Kolubara basin* (of 2017) and the *Study of threats to roads of I and II order from the occurrence of floods and torrents in the South Morava basin* (2018)[131]. A study that is likely to have emerged from a similar study for the Ibar River Basin is publicly available[132]. In addition to the impact of floods, PEPS also has a 2016 study on the impact of snow deposits.
In the RS areas potentially endangered by floods, there is 680 km of railway lines and about 4,000 km of roads.[133] Roads are endangered by two types of floods: floods from larger (alluvial) watercourses (rivers and their tributaries) and torrential floods. The PEPS study for the Kolubara basin[134] explains that torrential floods pose a greater risk to transport because they come abruptly after heavy rains and do not leave enough time for defense, but the reaction comes down to rescue. What further increases this risk are the effects of climate change in terms of precipitation trends, their spatial and temporal distribution as well as the occurrence of extreme precipitation[135]. Unlike torrential floods, floods of large rivers occur less frequently and with the timely announcement of meteorological services. Also, reducing the risk of torrential floods contributes to reducing the risk of river overflows. In addition to unfavorable climatic trends, the endangerment of roads is high due to the condition of road structures as well as due to poor maintenance of culverts (e.g. 42% of culverts in the Kolubara basin are highly endangered[136]).

Considering that the studies were done for PE "Putevi Srbije", it is clear that they are aimed at reducing damages (financial losses) in the field of maintenance. For example, 20.2 billion dinars were invested in the maintenance of state roads of the first and second order in 2016, of

[130]Bulletin of Public Enterprise "Roads of Serbia" Vol 22/23, April 2019 https://www.putevi-srbije.rs/images/pdf/publikacije/bilten22-23.pdf, p. 13.

[131]PEPS (2017). *Study of endangerment of roads of the I and II order from the occurrence of floods and torrents in the Kolubara basin.* *https://www.putevi-srbije.rs/images/pdf/strategija/studija_ugrozenost_dp_I_II_reda_od_poplava_sliv_Kolubare.pdf*
PEPS (2018). *Study of endangerment of the I and II order roads from the occurrence of floods and torrents in the basin of South Morava.* *https://www.putevi-srbije.rs/images/pdf/strategija/studija_ugrozenost_puteva_J_Morava.pdf*

[132]Dragićević, S., Kostadinov, S., Novković, I., Momirović, N., Stefanović, T., Radović, M., & Jeličić, M. (2019). Torrential floods as a risk factor for the road network in the Ibar basin. Tenth scientific-professional conference with international participation Planning and normative protection of space and environment, Palić-Subotica, 9-11 May. 2019, pp. 261-266, available at https://www.researchgate.net/publication/333079617_BUJICNE_POPLAVE_KAO_FAKTOR_RIZIKA_ZA_PUTNU_MREZU_U_SLIVU_IBRA

[133]Disaster risk assessment in the Republic of Serbia, http://prezentacije.mup.gov.rs/svs/HTML/licence/Procena%20rizika%20od% 20catastrophe%20u% 20RS.pdf

[134]PEPS (2017). *Study of endangerment of roads of the I and II order from the occurrence of floods and torrents in the Kolubara basin.* *https://www.putevi-srbije.rs/images/pdf/strategija/studija_ugrozenost_dp_I_II_reda_od_poplava_sliv_Kolubare.pdf*

[135] Unkašević, M., Tošić, I. (2011): A statistical analysis of the daily precipitation over Serbia: trends and indices. Theoretical and Applied Climatology, 106:69–78

[136]PEPS (2017). *Study of endangerment of roads of the I and II order from the occurrence of floods and torrents in the Kolubara basin.* *https://www.putevi-srbije.rs/images/pdf/strategija/studija_ugrozenost_dp_I_II_reda_od_poplava_sliv_Kolubare.pdf*

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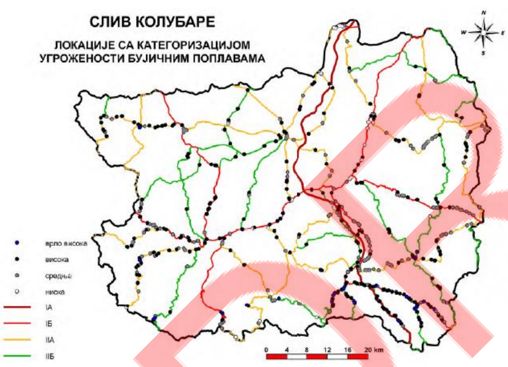
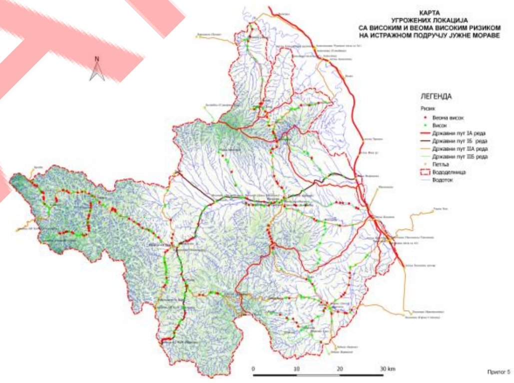
which 1.3 billion dinars were invested in the rehabilitation of 60 sections of roads and facilities damaged during the floods of 2014 and 2015.[137]

Endangerment of state roads from floods and torrents in the Kolubara and South Morava basins

Client: PEPS, Realization: Institute of Forestry, Belgrade (for the Kolubara basin), Institute of Water Management "Jaroslav Černi" (for the South Morava basin)
Purpose: optimization of investments in road maintenance
Publications: available on the PEPS website in pdf format[138]
Scope of analysis: 1155.93 km of I and II order roads in the Kolubara basin); 792 km in the South Morava basin
Methodology: Kolubara Basin - Places endangered by floods of larger rivers based on flood zones for maximum flows of watercourses with a return period of 100 and 1000 years[139]. Torrential flood risk assessment based on the Flash Flood Potential Index - FFPI, defined four classes of susceptibility very high, high, medium and low. South Morava Basin - four categories of flood risk correspond to four levels of risk quantitatively expressed through the number of points (0-100). To obtain the category of vulnerability, three criteria were used, where each has a defined contribution to the total number of points. The criteria are 1) hydrological analysis of high waters[140] (10-35 points); analysis of the capacity of culverts and openings of bridges on roads[141] (10-30 points); 2) amount of sediment, vegetation and waste in the zone of intersection of roads with watercourses[142] (5-30 points).
Results: Increase in the volume of flood risk of large rivers in the Kolubara basin from 28.04 km of flooded roads in the case of 100-year water to 36.67 in the case of thousand-year water. Torrential floods higher risk for roads, 304 out of 523 analyzed locations in the Kolubara basin very high and highly endangered by torrential floods, presentation of results in tables and on a map separately for floods and torrential floods. In the South Morava basin, 425 locations out of 449 analyzed are very high and highly endangered by floods and torrential floods (one map). In both studies, the vulnerability of culverts is presented in tables.

Locations on the I and II order roads with flood risk categorization in the Kolubara basin (left) and the South Morava basin (right)





Source: Study of endangerment of I and II order roads from the occurrence of torrents and floods in the Kolubara basin, PE "Putevi Srbije", 2017, p.200-201 (figure on the left), Study of endangerment of I and II order roads from the occurrence of floods and torrents in the South Morava basin, PE "Putevi Srbije", 2018, p.138 (figure on the right)

Proposed measures: In addition to general measures (e.g. in the field of erosion, retention works) for the Kolubara Basin, special measures are given to protect roads from the effects of water during the construction and exploitation phases, as well as a conceptual design for the protection for the Obnica River Basin. Five different measures were defined for the South Morava basin, and then a risk reduction measure was assigned in a table and on a map for each location.

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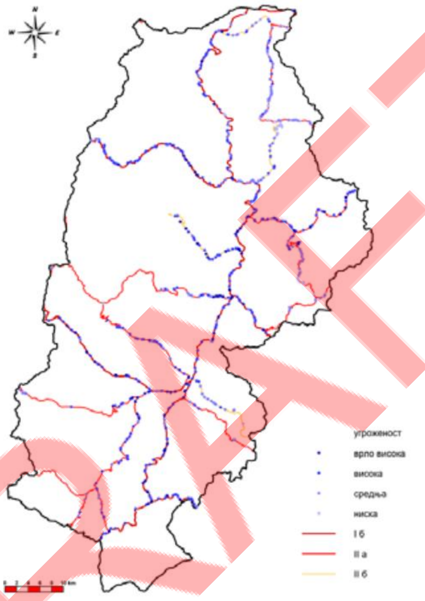
[137]Bulletin of Public Enterprise "Roads of Serbia", Volume 16/17. February 2017. Available at: https://www.putevi-srbije.rs/images/pdf/publikacije/bilten16-17.pdf
[138]*https://www.putevi-srbije.rs/images/pdf/strategija/studija_ugrozenosti_dp_I_II_reda_od_poplava_sliv_Kolubare.pdf* , *https://www.putevi-srbije.rs/images/pdf/strategija/studija_ugrozenosti_puteva_J_Morava.pdf*
[139]Source of data PWME "Srbijavoda", "Study of improving protection from water in the Kolubara River basin", Institute "Jaroslav Černi", 2016.
[140]Probability of occurrence of Qmax (1%) or return period of 100 years
[141]Assessment based on the cross-sectional area of the openings of culverts and bridges, which was assessed in the field and classified into three categories
[142]Based on field research

The results indicate that in the category of very high and high risk of torrents there are close to 60% of locations (intersections of watercourses and roads) in the Kolubara basin, and over 90% of locations in the South Morava basin from floods and torrential floods. An important note is that this does not mean that the South Morava basin is more endangered because these two studies do not use the same methodology and manner of presenting the results. In the mentioned paper dealing with the endangerment of I and II order roads in the Ibar river basin, the methodology was used as in the study for the Kolubara basin (flood zones and the Method of index of potential torrential floods - FFI). The findings indicate that 12.52% of the Ibar river basin is very highly susceptible to torrential floods, and about 62.09% of the intersections of watercourses and roads are in the class of very high and high risk,[143] which is a similar percentage as for the Kolubara basin.

Endangerment of the I and II order roads by torrential floods in the Ibar basin
(locations according to the category of endangerment)



Source: Dragićević, S., Kostadinov, S., Novković, I., Momirović, N., Stefanović, T., Radović, M., & Jeličić, M. (2019). Torrential floods as a risk factor for the road network in the Ibar basin, Tenth scientific-professional conference with international participation Planning and normative protection of space and environment, Palić-Subotica, 9-11 May. 2019, p. 265.

The study of the impact of snow deposits is conceived in a similar manner and aimed at optimizing road maintenance in the winter. This study was seen as an introduction to defining an Action Plan for potentially critical sections with snow on the basis of which PE "Roads of Serbia" would plan to finance appropriate protection measures. During the preparation of the study on snow deposits, shortcomings in the collection and recording of data were noticed, and accordingly, checklists were proposed for the assessment of problematic locations that should be used by road maintenance companies in the future. Missing data, which were not submitted by some road maintenance companies, are also cited as a problem.

Endangerment of state roads from snow deposits
Client: PEPS, Realization: Highway Institute, Institute of Transportation CIP
Purpose: optimization of investments in road maintenance in the winter

[143] Dragićević et al. (2019), p. 261.

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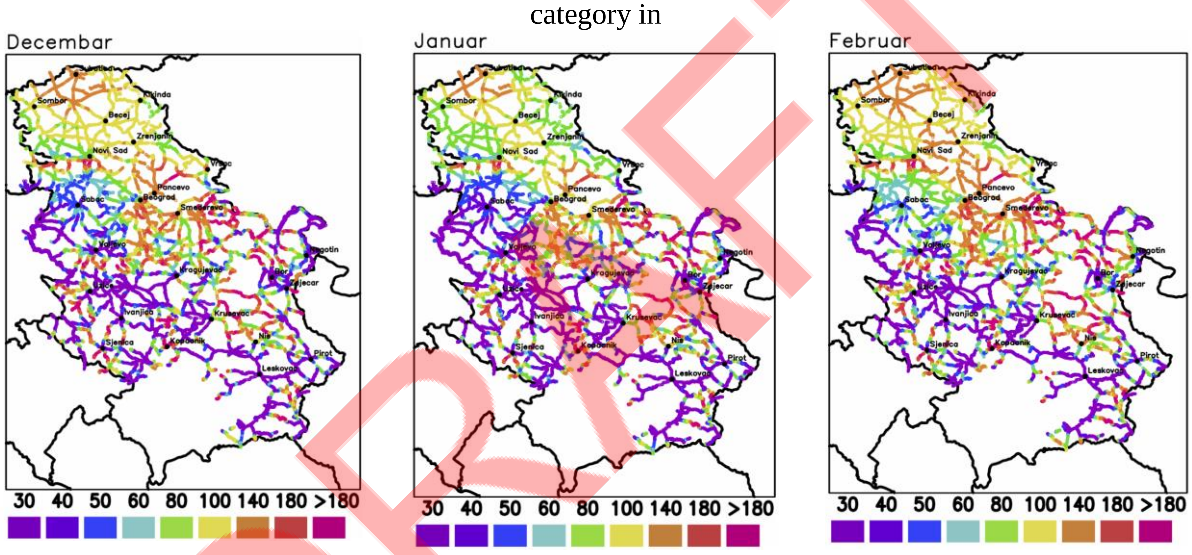
Publication: available on the PEPS website in pdf format[144]
Scope of analysis: 4,802.38 km of I order roads
Methodology: With the help of existing data (observed values) and purposefully created software for modelling snow deposits, depending on the appearance of the cross-section of the road, the spatial and temporal distribution of places with the appearance of snow deposits was defined. Data on the occurrence of snow deposits were collected from companies that were engaged in road maintenance in the winter. Wind speed value from the Wind Atlas Balkan database (http://balkan.wind-index.com), road map of the first and second category from the Open Street Map database (http://download.geofabrik.de). Data modeled based on the approach developed within the American Association of State Highway and Transportation Officials (AASHTO) Project[145.] Predictions of snow formation based on terrain characteristics (slope, etc.)
Results: total length of snow deposits on state roads of I order is 678.082 km. Results in the form of tabular reviews of sections on the road network where snowfall is frequent and maps with marked places where snowfall occurs for the winter months (November-March), at the RS level, and at the level of the area maintained by the engaged company. High and very high transport of snow by wind is considered to be valued above 140 and 180 kg/day/m, respectively (from the orange color on the maps), on the basis of which areas and sections of roads with higher risk can be identified. Similar representations are given for snow transport by relocation and values indicating high and very high snow relocation are 270 kg/day/m and 330 kg/day/m respectively.

Possible transport of snow by the wind in kg/day/m on the roads of the first and second category in



Source: Study of snow deposits on state roads of I order, PE "Roads of Serbia", 2016, pp.104-105

Proposed measures: Guidelines for road design are given, based on which the possibility of snow formation is reduced (including the conceptual solution for standard protection measures - fences and vegetation).

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Mentioned PEPS studies including the paper related to the Ibar basin **are based on the registered frequency (data from the past) and do not include climate projections.** Also, socio-economic factors are not included in the vulnerability assessment. Criticality of road routes and severity of consequences for availability (traffic disruptions of several hours or more than a month) and road safety (casualties, material damage) were not considered. The study for the Kolubara basin gives the length of roads endangered by floods, but it is stated that it was not possible to show the length of endangered roads in case of torrential floods. The same problem was mentioned in the study for the South Morava basin. No explanation was given in both studies.

[144] https://www.putevisrbije.rs/images/pdf/strategija/studija_istrazivanja_sneznih_nanosa_na_drzavnim_putevima_i_reda_finalno.pdf
[145] Tabler, R. D., (2003), Controlling blowing and drifting snow with snow fences and road design. National Cooperative Highway Research Program Project.

1.2. One mode of transport, multiple impacts - examples of studies

These studies aim to examine the impact of multiple climate threats on one mode of transport or a specific road route. They can be part of a study of the overall impacts of climate change in a region and therefore include transport accordingly. An example of such an analysis in which Serbia also participated is the "*Water and climate adaptation plan for the Sava river basin - WATCAP" Project* led by the Sava Commission and financed by the World Bank (2012-15)[146]. The result is the Sava River Basin Hydrological Model, the Impact Report and the Guidelines for Adaptation to Climate Change for Navigation, Hydropower, Agriculture and Flood Protection, as well as the Guidelines on the Economic Assessment of the Impact of Climate Change in the Basin. The project is geographically limited to the Sava River. In the part of navigation, it is methodologically related to hydrological simulations (water level levels – low, high and ice). The conclusion is that low water level is the biggest problem and that it is expected that in the future (as opposed to high water level) it will be one of the causes of disruption of navigation (an increase of 2-3 days in the near future (2011-2040) and about 13 days further in the future (2041-20170). The current strategy for the development of water transport recognizes the problem of low water levels as a basic problem of navigation which will intensify under the impact of climate change[147]. The situation is somewhat different in the context of ice. In the WATCAP[148] Report, it is concluded that given the general trend of rising temperatures, a decrease in ice formation can be expected along the entire navigable part of the Sava. Consequently, on an annual level, this would lead to the reduction in the number of days of suspension of navigation on the Sava River due to ice (in Serbia, this conclusion was demonstrated for Sremska Mitrovica). On the other hand, the Strategy for the Development of Water Transport in RS 2015-25 states that…"frequent unpredictable climatic phenomena require the purchase of new icebreakers."[149] It should be borne in mind that the WATCAP analysis is limited to the flow of the Sava. In addition to ice, which has been identified as an impact that needs to be further investigated in the proposed measures fog also appears. WATCAP relies on the large ECCONET project,[150] and was preceded by a Pilot Project on Climate Change, which did not include transport or navigation. The WATCAP Project contains a special guide for adaptation in the field of navigation (Annex 4). Measures are specifically defined for waterway infrastructure and for vessels. Seven stakeholders participated in the prioritization of measures, assessing the priority of each measure (1, 2, and 3, respectively, high, medium and low priority). Measures are ranked according to the mean value of the assigned priorities. The most important are: Better monitoring of water levels as well as meteorological parameters related to ice and fog and further improvement of RIS in the context of forecasting. In this study, the impact of the wind

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[146] World Bank, (2015). *Water and climate adaptation plan for the Sava river basin (Vol. 6): Annex four - guidance note on adaptation to climate change for navigation.* http://documents.worldbank.org/curated/en/42287146 8180255819/pdf/100525-v-6-WP-P113303-PUBLICBox393236B-Sava-Navigation-Guidance-Note-annex-4.pdf

[147] in the part related to the respect of the principles of the Luxembourg Declaration - Declaration on the efficient maintenance of infrastructure on the Danube and its navigable tributaries" signed by the EU countries in 2012.

[148] http://www.savacommission.org/dms/docs/dokumenti/public/projects/watcap/endorsed_version.rar

[149] Quote from the strategy "Given the extremely poor condition of domestic vessels – icebreakers on the overall and dense network of waterways, and taking into account the frequent unforeseen climatic events in the Republic of Serbia and the region, the new fleet procurement program should provide an adequate number of icebreakers to protect waterways and facilities on them".

[150] https://www.tmleuven.be/en/project/ecconet

was not specifically analyzed, although it appears in the list of priorities. In later studies (CLIMACOR) this impact was identified as important especially for ports.

Another cross-sectoral study came from the Climate Change Adaptation in the Western Balkans (CCAWB) Project[151]. One of the reports from 2015 refers to Belgrade[152], and the transport was analyzed in the critical infrastructure section. The *FUTURE CITIES Adaptaton Compass* approach was used[153]. The vulnerability was assessed on the basis of a matrix crossing the exposure to impacts and the capacity to adapt. Traffic in Belgrade was rated as highly vulnerable to intense rainfall and floods, cold waves, moderately vulnerable to heatwaves and storms, and low vulnerable to droughts. The results of the analysis refer to road city traffic. The inclusion of railway and air traffic was considered, but it was omitted due to lack of data. Based on the expert assessment of the representatives of the city secretariat for traffic, the representatives of Public Transit Company GSP Belgrade and statistical data (traffic intensity, etc.), the most endangered road routes have been determined. Based on the analysis of the vulnerability, an adaptation plan for Belgrade was proposed, i.e. a set of measures that are, in addition to the general elements, also characterized by the level of priority. In these measures, traffic is more in the domain of mitigation than adaptation to climate change. Consequently, the activities that resulted from this plan are directed towards mitigation[154].

One of the recent studies is "*Mainstream Climate Resilience in the Road Transport Management in Serbia*" (2016/17, World Bank[155]). The aim of this project is to develop a methodology for assessing the vulnerability of roads to climate risks that will increase the capacity to plan adaptation to climate change and risk response plans. A specific risk assessment was done for roads in the municipality of Valjevo (pilot study) and included the impact of floods, torrents and landslides on 43 sections of state roads (250 km). GIS maps of the area exposure to natural hazards were used[156] which overlap with the road map to identify sections passing through endangered areas. A combination of statistical and qualitative assessments and the multi-criteria AHP approach was used to assess the level of exposure.[157] Within this project, further steps are envisaged: including the importance of roads in the socio-economic sense, engineering vulnerability assessment, remediation costs and, finally, multi-criteria prioritization and investment plan. The project description states that the methodology is universal and applicable to each road network.

Multi-hazard assessment of road endangerment on the territory of the municipality of Valjevo

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[151]https://www.giz.de/en/worldwide/29000.html

[152]City of Belgrade, Secretariat for Environmental Protection, (2015). Climate Change Adaptation Action Plan and Vulnerability Assessment, available at: https://www.giz.de/en/downloads/Report%20%e2% 80% 93% 20Climate% 20Change% 20Adaptation% 20Action% 20Plan% 20and% 20Vulnerability% 20Assessment%20for% 20Belgrade% 20Serbia% 20 (2015) .pdf

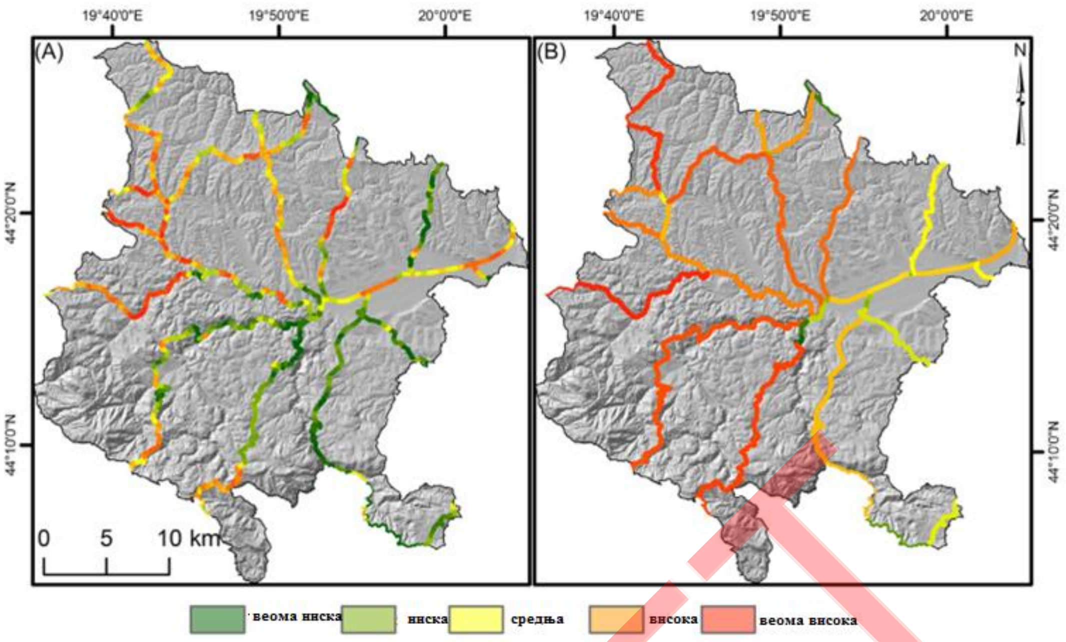
[153] This approach is mentioned as a recommendation in the "Manual for planning adaptation to changed climatic conditions in local communities in Serbia", Standing Conference of Towns and Municipalities, 2018. http://www.skgo.org/storage/app/uploads/public/157/071/948/1570719485_Planiranje%20prilagodjavanja%20na%20izmenjene%20klimatske%20uslove-web.pdf

[154]one of such activities is the procurement of electric buses for which the effects of exploitation are monitored (more in Mišanović, S., Živanović, P., Savković, D., Krstić, P., Ivanov, S., Stević, S., & Since, S. (2019). Two-year successful exploitation of the electric buses in Belgrade. Mobility & Vehicle Mechanics, Vol. 45, No. 1, pp 17-27)

[155]World Bank: Mainstreaming Climate Resilience in road Transport Management in Serbia (# 1233872). More at: http://documents.worldbank.org/curated/en/368251527152815053/pdf/126556-23-5-2018-15-26-58-FINALResilientTransportBelgradeTKXReportFinalDPforWebsite.pdf

[156]BEWARE base used for landslides http://geoliss.mre.gov.rs/beware/ . Contains missing data

[157]Analytical Hierarchical Process



Source: Marjanović, M., Abolmasov, B., Milenković, S., Đurić, U., Krušić, J., & Samardžić-Petrović, M. (2019). Multihazard Exposure Assessment on the Valjevo City Road Network. In *Spatial Modeling in GIS and R for Earth and Environmental Sciences* (pp. 671-688). Elsevier.

1.3. More modes of transport, more impact

An example of a multi-hazard study focused only on transport, but on two modes of transport, came from a regional project CLIMACOR (Assessment of *Climate* Impacts on Transport Corridors) II[158] which was realized in the second half of 2016 by RCC, SEETO and REC[159]. This project started after the Western Balkans Summit in Paris (July 2016) when a joint action plan of these countries was launched, which includes, among other things, the development of the *Network Resilience plans and the Identification of interventions for climate mitigation and increased network efficiency, and preparation of draft plans for their implementation* (SEETO coordinator, WB support). The project is related to the SEE 2020 Strategy activities, Transport section. Countries included in the analysis: Serbia (Kosovo analyzed separately), Croatia, Bosnia and Herzegovina and North Macedonia. CLIMACOR II[160] separately analyses the impact of climate change on the sections of the TEN-T Rhine-Danube corridor (the watercourse of the Sava and the Danube) and the sections of the Orient/Eastern Mediterranean road-railway corridor. The results are given separately without crossing.
Within the project, the CLIMACOR methodology was applied, which refers to scanning the impact of climate change on the mentioned corridors in the context of: identification of the most important threats, assessment of the degree of risk they have on the safety and availability of existing routes, mapping threats along the corridor and the proposal of measures for the reduction of risks/consequence. What makes this approach special is the fact that the climatic impacts were *translated* into threats to the road, rail transport and waterways (initial list of 40 threats). The methodology is defined so that for each threat it takes into

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[158] Reports available at http://documents.rec.org/projects/Annex1_OrientEast-MedCorridorAssessment.pdf и http://documents.rec.org/projects/Annex2_Rhine-DanubeInternationalWaterwayAssessment.pdf. More details on the methodology in Petrović, M. (2017). Pre-scanning climate change impacts on transport corridors -the case of Serbian waterways, In Proceedings of the 6th International Conference Transport and Logistics „TIL 2017“, 25th-26th May, 2017, Faculty of Mechanical Engineering, University of Niš, Serbia, pp. 197-204.
[159] Regional Cooperation Council, South East Europe Transport Observatory, Regional Environmental Centre
[160] II (two/second) because it relies on the first CLIMACOR initiative of 2016 Kiev, Chisinau, Lisbon and Madrid

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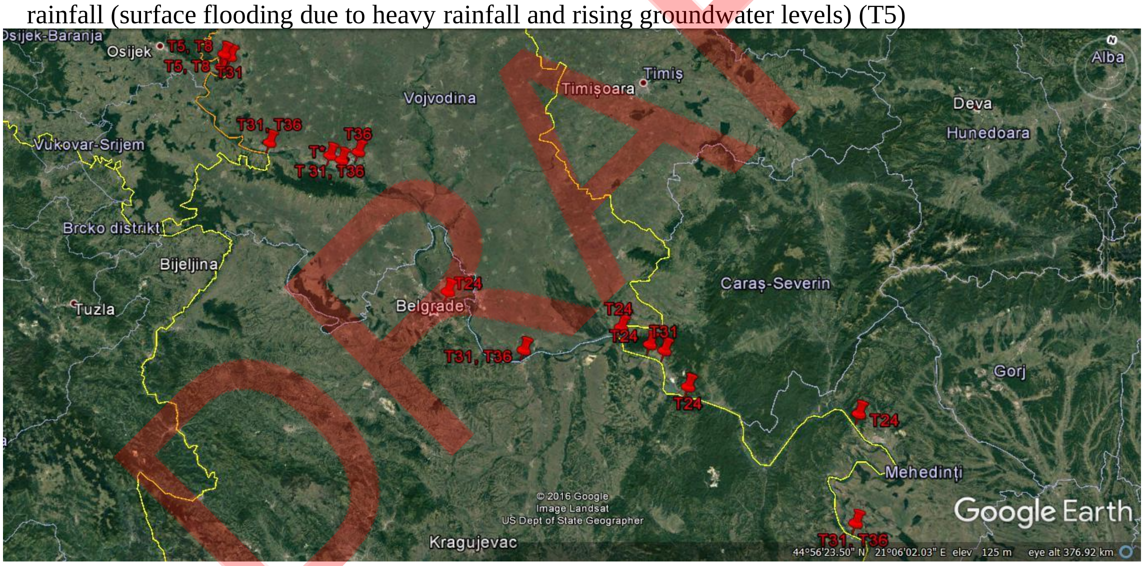
account the level of impact/consequences (on the availability and safety of the road) and the probability of consequences under current meteorological conditions and climate change conditions (taking into account the climate change scenarios until 2050, given by EEA). The input data for the calculation were the assessments of 12 experts (six from the field of transport and 6 from the field of meteorology and climate change) and included representatives of decision-makers (representatives of the ministry and the city, etc.), infrastructure operators (e.g port directorate, Roads of Serbia), executive parties (such as ship captains), representatives of the scientific community and representatives of civil society organizations. Data were collected through dedicated questionnaires with a previous interview of project experts with respondents. This interview included explanations about the project and the questionnaire itself. Based on the collected data, risk indices were calculated.

Threats (climate impacts) with the highest degree of risk in the field of navigation along the Sava and Danube in RS with a map of critical locations

1. Reduction of water levels due to climate change (higher temperatures, droughts, floods and changes in the intensity and distribution of precipitation) (T∗).
2. Damage to power supply systems, traffic communication networks, traffic disruption due to the extreme wind (T24)
3. Decrease in free volume under the bridge due to increase in average seasonal precipitation (T12)
4. Failure of flood protection systems on rivers and lakes due to prolonged rains in the basin area (T8)
5. Sedimentation processes in port/navigation canals; inability to dock in port due to storm surges (T36); Damage to cranes, warehouses and terminals due to the extreme wind (T31); Flooding of rivers due to heavy rainfall (surface flooding due to heavy rainfall and rising groundwater levels) (T5)



Source: REC (2016) Sub-corridor assessment on Rhine-Danube International Waterway (Serbia) available at: http://documents.rec.org/projects/Annex2_Rhine-DanubeInternationalWaterwayAssessment.pdf.

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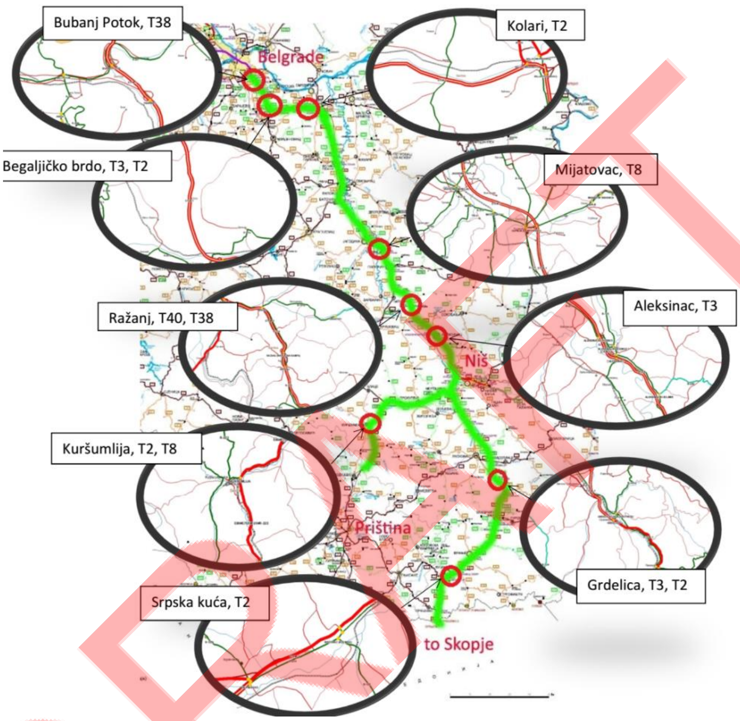
At the validation workshop, the results were analyzed in order to eliminate the effects of averaging and reach a consensus on the most important threats. Adaptation measures have been proposed for the five impacts/consequences with the highest assessed risk level. Threats are given hierarchically from the highest to the lowest calculated risk. An important note is that the first threat to waterways (T∗) was not part of the initial set of analyzed threats but was later included after the validation workshop, where it was determined by consensus of experts that the methodological shortcoming is that based on the universal initial list of threats common to land (road and rail) and waterways, neglected inclusion of the most important threat in the field of navigation on inland waterways (UPPP). The ones that previous projects already pointed out as the most important (WATCAP) and which also stands out within the strategy of water transport development.

Threats (climate impacts) with the highest degree of risk for sections of the Orient/Eastern Mediterranean corridor in RS with a map of critical locations

1. Increased soil subsidence, rockfall, landslides, or collapses on transport infrastructure due to heavy rainfall (T3)
2. Loss of driving ability due to reduced vehicle control due to snow and blizzard (T40)
3. Erosion and embankment sliding due to heavy rainfall (T2)
4. Failure of flood protection systems on rivers and lakes due to prolonged rains in the basin area (T8)
5. Reduced general maintenance due to snow and blizzards (snow and ice removal) (T38)



Source: REC (2016) Sub-corridor assessment on Orient/East-Med Corridor (Serbia) available at: http://documents.rec.org/projects/Annex1_OrientEast-MedCorridorAssessment.pdf

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The results also indicate that depending on the type of transport (in this particular case, waterways vs. roads), different climatic impacts stand out. The failure of the flood defense system on rivers and lakes due to prolonged rains in the basin area (T8) is the only threat common to both corridors and once again confirms the impact of floods as the most critical. As for the difference, the waterways are sensitive to wind and the road corridor to snow. The impact of the wind is related to ports and docks, as well as to the effect of skid and curvature of vessels. It should be added here that this project has shown that the threats differ depending on the country, i.e. the section of the corridor. What is a bigger threat in RS does not have to be a threat for a section of the same corridor in another country. The CLIMACOR methodology has both advantages and disadvantages. The advantage is a quick assessment and involvement of all stakeholders. One of the conclusions of the project workshop was that the opportunities that bring together representatives of all instances of meteorology and transport who should act together in the analysis of climate change are of invaluable importance. The important inputs given by those who directly influence the transport process should be added here. For example, in the case of waterways, those were ship captains and port workers with 20 years of experience. The disadvantage of the approach is that certain aspects of the assessment do not correspond to the knowledge of experts. The questionnaire was the same for meteorologists and transport representatives. During the filling training, transport representatives could not give good enough assessments in the domain of the probability of occurrence of some consequences due to the impact of climate change, just as meteorologists could not be precise enough in assessing the consequences of these changes on transport.

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ADDENDUM 2

Projects (implemented and currently implemented) of importance for impact assessment and adaptation planning

Analyses of the current climate and projections of the future:

2011-2019 Research on Climate Change and its Impact on the Environment - Impact Monitoring, Adaptation and Mitigation, III 43007, Ministry of Education, Science and Technological Development of the Republic of Serbia

2011-2019 Assessment of the Impact of Climate Change on Water Resources of Serbia, TR37005, Ministry of Education, Science and Technological Development of the Republic of Serbia

2017 Study on Environmental and Climate Challenges for West Balkan Countries, Regional Cooperation Council

2016 – 2017 Analysis of Climate Risks to Road Transport Infrastructure in the Western Balkans, EBRD

2014-2017 Support to Water Resources Management in the Drina River Basin, World Bank

2014-2015 Climate change adaptation in the Western Balkans - Integrating climate change adaptation strategies in urban planning for Belgrade, German Fed. M. for Economic Cooperation and Development, GIZ

2012-2014 Vegetation modeling in forest ecosystems under climate change scenarios, project financed by the Ministry of Agriculture, Forestry and Water Resources of the Republic of Serbia.

2012-2014 SEERISK – Joint Disaster Management risk assessment and preparedness in the Danube macro-region, EU

2011-2014 DRIHM – Distributed research infrastructure for hydrometeorology study, European Commission under the 7th Framework Programme (FP7).

2010-2013 CARPATHCLIM – Climate of Carpathian Region, Joint Research Center, European Commission.

2009 – 2012 Drought Management Center for South East Europe, EU

2009-2012 Water and Adaptation Plan for the Sava River Basin, World Bank,

2006-2008 SINTA - Simulations of climate change in the Mediterranean Area, financed by the Italian Ministry for the Environment, Land and Sea.

2005-2010 Weather and climate forecast in Serbia, Ministry of Education, Science and Technology of the Republic of Serbia

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Impacts of climate change on agricultural production:

1. "Formation of sustainable development indicators", Ministry of Science and Environmental Protection. Responsible institutions: Faculty of Agriculture, Belgrade-Zemun (2004);
2. Support and education of agricultural producers in the Municipality of Ljig. Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. Faculty of Agriculture, Belgrade-Zemun (2005);
3. "*Land reclamation in Lazarevac-Kolubara services*". Responsible institutions: Faculty of Agriculture, Belgrade-Zemun (2005-2006);
4. Education of the fruit and vineyard advisory service of the Republic of Serbia. Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. Faculty of Agriculture, Belgrade-Zemun (2005-2006);
5. Education of the fruit and vineyard advisory service of the Republic of Serbia - continuation of the project. Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. Faculty of Agriculture, Belgrade-Zemun (2006-2007);
6. Support and education of agricultural producers in the municipalities of Central Serbia. Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia, Faculty of Agriculture, Belgrade-Zemun (2006-2007);
7. Formation of experimental orchards and vineyards within the territory of the Municipality of Smederevo for the needs of the advisory service of the Republic of Serbia. Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. Faculty of Agriculture, Belgrade-Zemun (2006-2007);
8. Education of members of cooperatives and associations of fruit and vegetable growers of Serbia. Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. Faculty of Agriculture, Belgrade-Zemun (2007-2008);
9. Strengthening the capacity of the fruit and vineyard advisory service of the Republic of Serbia through the use of demonstration orchards and vineyards. Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. Faculty of Agriculture, Belgrade-Zemun (2007-2008);
10. Education of fruit producers within the territory of the City of Belgrade. Faculty of Agriculture, Belgrade-Zemun (2008-2009);
11. "Introduction of integral and organic plant production and good agricultural practice - education programme for agricultural producers". Ministry of Agriculture, Forestry and Water Management: Responsible institutions: Faculty of Agriculture, Belgrade-Zemun (2006);
12. "Possibilities of using the hilly and mountainous area of Serbia for organic field production". Technological development project financed by the Ministry of Science and Technology of the Republic of Serbia. BTR 20069 Responsible institution: Faculty of Agriculture, Belgrade-Zemun (2008-2010);
13. "Improvement of organic field production in hilly and mountainous regions within Serbia". Transitional Agriculture Reform (STAR) Project. Responsible institutions: Faculty of Agriculture, Belgrade-Zemun (2010-2011);
14. "Regionalization of wine-growing geographical production areas. "*Capacity Building and Technical Support for the renewal of Viticulture Zoning and for the System of Designation for Wine with Geographical Indication*". The EU Ministry of Agriculture, Forestry and Water Resources of the Republic of Serbia (2010-2015);

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15. “Research on climate change and its impact on the environment - impact monitoring, adaptation and mitigation”. Ministry of Education, Science and Technological Development of the Republic of Serbia (2011-);
16. ”Optimization of technological procedures and zootechnical resources on farms in order to improve the sustainability of milk production”. Ministry of Education, Science and Technological Development of the Republic of Serbia (TR31086) (2011-);
17. “Modern breeding of small grains for present and future needs” managed by the Scientific Institute of Field and Vegetable Crops, Institute for Small Grains - Novi Sad. Technological development project financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia. Project number BTR 31066 (2011-);
18. “Assessment of the impact of climate change on Serbia's water resources”. TR37005 (2011-);
19. “Integral systems for growing field crops: conservation of biodiversity and soil fertility”, managed by the Maize Research Institute “Zemun Polje”. Technological development project financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia. Project number BTR 31037 (2011-);
20. “Knowledge transfer from the Faculty of Agriculture to agricultural producers - together to safe and competitive products - Open Doors”. Ministry of Agriculture, Forestry and Water Management Resources of the Republic of Serbia (2017-2018);
21. “Adaptation of the autochthonous gene pool of fruit trees and vines to changed climatic conditions with the aim of achieving sustainable production”. Ministry of Environmental Protection of the Republic of Serbia (2019);
22. “Reports on the impact of observed climate change on agriculture in Serbia and projections of the impact of climate in the future on the basis of different future emissions scenarios”. Stričević, R., Prodanović, S., Đurović, N., Petrović-Obradović, O., Đurović, D. United Nations Development Programme (2019);
23. “Sustainable Development” Ministry of Education, Science and Technological Development of the Republic of Serbia (2020);
24. Regionalization of the fruit area in Belgrade, Southern and Eastern Serbia - managed by the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. Faculty of Agriculture, Belgrade-Zemun (2018-2020);
25. PROMIS Project. “Integrated system for agrometeorological forecasts”. Science Fund. Responsible institutions: Faculty of Agriculture, Belgrade-Zemun (2020-2022);
26. Rehabilitation and phytoremediation project in the production complex “EcoMet Recycling” KO ZAJAČA, Loznica (in the preparation phase).

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