Report on the impact of climate change on the AGRICULTURE sector, with proposed adaptation measures*

ACTIVITY 1:
Risk and vulnerability assessment – observed: occurrences, impacts, and levels of affectedness within

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*Note:
The assessment of the impact of climate change on the agricultural sector in the future with the proposal of adaptation measures will be realized through Activities 2 and 3.

List of Abbreviations

E-OBS	Daily gridded observational dataset for precipitation, temperature and sea level pressure in Europe
FAO	Food and Agriculture Organization of the United Nations
IDP	Irrigation and Drainage Paper
IPCC	Intergovernmental Panel on Climate Change
NIWR	Net Irrigation Water Requirement
RCP	Relative Concentration Pathway
RH	Relative Humidity
THI	Temperature HumidityIndex
UNDP	United Nations Development Programme

CONTENTS

1. Introduction

Since the 2015 Paris Agreement, the world has experienced its five warmest years. The Food and Agriculture Organization (FAO) has warned that food production is extremely sensitive to climate change[1]. It is a known fact that between 1950 and 2017, nine of the ten warmest years were registered after 2000. On the other hand, it is important to estimate that the global population will increase to more than nine billion by 2050. FAO predicts that food production will have to increase by about 70 percent[2].

The situation in the Republic of Serbia is also for observation, monitoring, and reaction. Data from the EM-DAT database show that the largest number of natural disasters in Serbia for the period 2010-2015 was due to extreme temperatures, floods, and earthquakes[3].

The minimum drought loss in 2007 was about 600 mil. EUR, and for the three episodes in 2003, 2012, and 2017, the losses were probably higher than EUR 1 billion. This leads to the conclusion that the average annual loss since 2000 can be estimated at several hundred million euros. Available data[4] [5], lead to a very similar large amount of losses due to droughts in the economy in the Republic of Serbia.

The appearance of increased yields in a larger number of crops, thanks to significant progress in the field of breeding and application of agrotechnical measures, has caused problems in terms of soil degradation and the environment in general, which negatively affects the long-term sustainability of agriculture, and on the other hand, negative impacts increase due to the effects of climate change. Therefore, it is necessary to ensure a higher degree of sustainability of agriculture, and one of the preconditions for this is to assess the risks and vulnerability to climate change.

The assessment of the risk and vulnerability of the agricultural sector to climate change was done using the Adaptation Planning Framework[6] developed in the process of drafting the Low Carbon Development Strategy with the Action Plan of the Republic of Serbia, as well as the Methodological Guidelines for Risk Assessment in the Agricultural Sector of the World Bank[7].

1 http://www.fao.org/3/aq191e/aq191e.pdf

2 http://www.fao.org/land-water/water/drought/en/

3 http://www.emdat.be/country_profile/index.html

4 Serbia'S first national adaptation plan: http://www.klimatskepromene.rs/wpcontent/uploads/2017/04/NAP-UNDP-2015.pdf

5 https://knowledge.unccd.int/sites/default/files/country_profile_documents/NDP_SERBIA_2020.pdf%20

6 Adaptation Planning Framework, Climate Change Strategy with the Action Plan of the Republic of Serbia, project No. EuropeAid/1365966/DH/SER/RS, 2018.

7 Agricultural Sector Risk Assessment: Methodological Guidance for Practitioners, World Bank, 2016.

2. Methodology

The vulnerability of the agricultural sector to climate change is based on the Adaptation Planning Framework[8] which was proposed in the preparation of the Proposal of the Climate Change Strategy with the Action Plan of the Republic of Serbia, as well as the Methodological Guidelines for Risk Assessment in the Agricultural Sector of the World Bank[9].

Step 1: Defining potentially dangerous meteorological phenomena

Based on the literature and expert knowledge, it is necessary to single out meteorological phenomena that can potentially cause significant damage and losses, i.e. which in the past led to a greater reduction in quality and/or yield of relevant crops, or negatively affect (directly or indirectly) the health state of the cattle. In addition to extreme meteorological events, these can be slow onset changes caused by climate change, such as an increase in the average seasonal and annual air temperature and the intra-annual redistribution of precipitation. Dangerous events related to climate change and extreme meteorological phenomena highlighted in this Study, as well as their potential impacts are shown in Table 1.

Table 1. Isolated potentially dangerous events related to climate change and extreme meteorological events and their impacts on agricultural production

Slow onset changes	**Impacts**
Increase in the average seasonal and annual air temperature	Warming during all seasons leads to an earlier start and later end of vegetation, acceleration of certain phenophases and affects the quality of yield. Early onset of vegetation increases the risk of spring frosts.
Precipitation redistribution	Changes in the intra-annual precipitation regime can lead to a deficit or excess of rainfall during the critical stages of plant development.
Extreme events	**Impacts**
High summer temperatures	Air temperatures above 35°C bring plants and animals into a state of temperature stress. They can cause burns on plants and fruits, especially if they occur during the ripening period. They often occur in the combination with a lack of precipitation, which puts plants in a state of temperature and water stress.
Low winter temperatures	Air temperatures below-17°C, especially if they occur without the snow cover, can negatively affect grapevines, grasses and winter crops.
Spring frost	Low temperatures during the spring negatively affect fruit trees, grapevines and field crops. The temperature limit, as well as the period in which the plants are sensitive to frost, differs from plant to plant.

8 Adaptation Planning Framework, Climate Change Strategy with the Action Plan of the Republic of Serbia, project No. EuropeAid/1365966/DH/SER/RS, 2018.

9 Agricultural Sector Risk Assessment: Methodological Guidance for Practitioners, World Bank, 2016.

Drought	Drought puts plants in a state of water stress and causes a decrease in yield and quality of almost all field crops.
Intense precipitation	Intense precipitation leads to waterlogging of the soil, which creates unfavorable conditions for the germination and root development. If they occur at the time of pollination, they can reduce fertilization, and thus the yield. They accelerate soil erosion. Increased humidity favors the development of plant diseases.
Floods	Floods can completely destroy field crop yields, cause animal deaths and damage agricultural infrastructure
Hail and storms	Hail and storms accompanied by strong winds can physically damage plants and fruits.

Step 2: Analysis of data on observed and projected climate change

The analysis of observed and projected climate change implies a spatial analysis of the frequency of occurrence of potentially dangerous phenomena defined in step 1 during the defined periods in the past and future.

Due to the drastically reduced number of active climatological stations in the observation network of the Republic Hydrometeorological Institute of Serbia (from a total of 99 synoptic and climatological stations in 2010 to a total of 66 stations in 2019[10]) and public unavailability of daily observed data for most stations, in this Study an alternative source of meteorological observations was used – spatially interpolated fields of daily minimum and maximum temperatures and daily precipitation at a resolution of about 10 km from the E-OBS database[11]. The reference period is the period of the last 20 years for which data were available, i.e. 2000-2019.

For the analysis of climate change in the future, it is important to choose state-of-the-art and relevant results of climate projections, which means an adequate selection of one or more scenarios of greenhouse gases and appropriate integration of climate models with the highest possible spatial resolution. In this Study, the RCP8.5 scenario was chosen (*Relative Concentration Pathway*) from the Fifth Assessment Report[12] of the Intergovernmental Panel on Climate Change (IPCC). Although this scenario does not envisage the application of mitigation measures, and can be considered the "worst option", Serbia has already reached the values of temperature change that the scenario predicts over the next 20 years, so the choice of milder scenarios, in this case, would be inadequate.

The choice of the integration of climate models is taken from the "Development of Internet application and platform for vulnerability assessment to climate change and adaptation" Project

10 http://www.hidmet.gov.rs/ciril/meteorologija/klimatologija_godisnjaci.php

11 https://www.ecad.eu/download/ensembles/download.php

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

which is implemented within the UNDP project "Improvement of medium and long-term adaptation planning in the Republic of Serbia"[13] and includes an ensemble of 8 regional climate models with a spatial resolution of 0.1° (about 12 km) from the EURO-CORDEX project database[14] (Table 2). In accordance with the mentioned project, the reference period 1986-2005 and three twenty-year future periods, 2021-2040, 2041-2060 and 2081-2100, were selected.

Table 2. Selected combinations of global and regional climate models

Regional climate model	Global climate model
CCLM4-8-17	ICHEC-EC-EARTH
CCLM4-8-17	MOHC-HadGEM2-ES.rcp85
CCLM4-8-17	MPI-M-MPI-ESM-LR
HIRHAM5	ICHEC-EC-EARTH
RACMO22E	ICHEC-EC-EARTH
RACMO22E	MOHC-HadGEM2-ES
REMO2009	MPI-M-MPI-ESM-LR
REMO2009	MPI-M-MPI-ESM-LR

Based on the selected potentially dangerous phenomena, bioclimatic indices have been formulated, the calculation of which in the past and in the future can be performed using daily values of minimum and maximum temperatures and precipitation. A list of these indexes with explanations is provided in Table 3. For those dangerous phenomena for which it was not possible to formulate bioclimatic indices, such as the occurrence of hail and floods, data from the published scientific and professional literature will be used.

13 Djurdjevic et al., Data collected and database prepared for the country, region and local level, Project: Development of web-based application and platform for Climate Change Vulnerability Assessments and Adaptation, within the project "Advancing medium and long-term adaptation planning in the Republic of Serbia" (RPF 668), 2021.

14 https://www.euro-cordex.net/

Table 3. Bioclimatic indices

	FRUIT GROWING
Vegetation start date	Sixth day after the first occurrence for five consecutive days with a mean daily temperature higher than the baseline temperature (Tb, biological minimum). The following baseline temperatures were selected for different fruit species: 9°C (almond and apricot), 10°C (peach, walnut, hazel, strawberry, currant), 11°C (plum, sour cherry, cherry, raspberry), 12°C (apple, pear, quince, blackberry)
Late spring frost	The percentage of years in which the minimum daily temperature (Tn) below-2°C occurred in the period after the start of vegetation.
High summer temperatures	The number of days of overlapping of the warm period and the end of the fruit harvest. The beginning of the climatologically warm period is determined as the average date of the first occurrence of maximum daily temperatures higher than 35, in those points where such temperatures occur in more than 10 years (50% of the total 20 years). The climatological date of fruit harvest is calculated by adding 150 (almond, apricot, peach, cherry, plum, sour cherry) or 180 (apple, pear) days to the previously calculated date of the vegetation start, which is determined based on the baseline temperature.
	VITICULTURE
Mean temperature during the vegetation period Tveg (AWEG)	Average mean daily temperature for the standard vegetation period from 1 April to 31 October <13oC Very cold 13-15oC Cold 15-17oC Moderate 17-19 C Warm 18-21oC Hot 21-24oC Very hot >24oC Extremely hot
Mean amount of precipitation during the vegetation period (Rveg)	Average precipitation for the standard vegetation period from 1 April to 31 October
Winkler Index (WIN)	The sum of effective temperatures for the standard vegetation period from 1 April to 31 October. Region I ⍰<1389 Region II ⍰1389-1667 Region III ⍰1668-1944 Region IV 451945-2222 Region V ⍰2223-2700
Huglin's heliothermal index (HI)	Huglin's heliothermal index for the standard vegetation period from 1 April to 31 October.[1] >3000 Very warm (HI+3) 2400-3000 Warm (HI+2) 2100-2400 Moderately warm (HI+1) 1800-2100 Moderate (HI-1) 1500-1800 Cold (HI-2) <1500 Very cold (HI-3)
Cool night index (CI)	Average minimum temperature in September. <12 very cold nights 12-14 cold nights 14-18 moderate nights > 18 warm nights
Dryness index (DI)	The amount of available moisture in the soil at the end of September.[2] <100- very dry (DI+2) 100-50 – dry (DI+1) 50-150 – subhumid (DI-1) >150 – humid (DI-2)

1 Huglin, M.P. (1978). Nouveau mode d'évaluation des possibilités héliothermiques d'un milieu viticole. Comptes Rendus de l'Académie d'Agriculture de France 64:1117–1126.

2 Tonietto, J., Carbonneau, A. (2004). A multicriteria climatic classification system for grape-growing regions worldwide. Agric For Meteorol 124:81–97.

Mean date of the start of vegetation	The date of the sixth day after the first occurrence for five consecutive days with a mean daily temperature higher than 10°C since the beginning of the year.
Mean date of the end of vegetation	The date of the sixth day after the first occurrence for five consecutive days with a mean daily temperature below 10°C in the second half of the year.
Mean length of the vegetation duration	Number of days from the start to the end of the vegetation.
Sum of effective temperatures (GDD)	The sum of effective temperatures from the calculated start date to the end date of vegetation.
Mean date of ripening of early and late grape cultivars	The date by which the sum of active temperatures 2800°C for early and 3500°C for late grape cultivars was collected.
Late spring frost	The percentage of years in which the minimum daily temperature (Tn) below-2°C occurred in the period after five consecutive days with an average daily temperature higher than 11°C.
Low winter temperatures (NTN15)	Number of days with a minimum daily temperature below-15°C.
High summer temperatures (NTX35)	Number of days with a maximum daily temperature higher than 35°C.
	ARABLE FARMING
Optimal sowing date	Maize: the first date from the beginning of the year after one day with a minimum daily temperature above 10°C and the following three days with an average daily temperature above 10°C. Sunflower: the first date from the beginning of the year after five consecutive days with a mean daily temperature above 10°C. Winter crops: the first date in the second half of the year in which the conditions were met that the average daily average temperature during the previous 10 days was lower than 15°C, that the amount of precipitation during the previous 20 days was higher than 10 mm and that in the previous three days there was no more than 3 mm of precipitation per day. Sugar beet: the first date from the beginning of the year after 4 consecutive days with a minimum daily temperature higher than 5 Soybean: the first date from the beginning of the year after three consecutive days with a minimum daily temperature above 10°C and the fourth day when the average daily temperature is higher than 10°C.
Sum of effective temperatures	The sum of effective temperatures for baseline temperature 10°C (maize, sunflower, soybean) and 3°C (winter crops and sugar beet)
Spring frost in critical phenophases	The percentage of years in which, after the optimal sowing date, a minimum temperature lower than-3°C occurred for 2 days (maize),-3°C for two days (sugar beet), -4°C for more than one day (soybeans).
High summer temperatures and drought in critical phenophases	The percentage of years in which a certain number of days with high daily temperatures occurred in defined critical phenophases, with possibly an additional condition on the amount of precipitation. The beginning and end of the critical phenophase are determined based on the sum of effective temperatures calculated from the optimal sowing date. Winter crops – more than 2 days with maximum daily temperatures over 35°C in the period before full ripening (sum of effective temperatures less than 1700°C) maize- Seljaninov heliothermal index, in the period when the sum of effective temperatures is between 430 and 1170°C Sunflower – more than 5 days with maximum daily temperatures above 35°C and precipitation amount less than 100 mm when the sum of effective temperatures is between 850 and 1450°C

Shortage of water in critical phenophases	The percentage of years in which the amount of precipitation below the defined threshold occurred in the defined critical phenophases. The beginning and end of the critical phenophase are determined based on the sum of effective temperatures calculated from the optimal sowing date. Winter crops – the sum of precipitation less than 50 mm when the sum of effective temperatures is less than 388°C, and the sum of precipitation less than 70 mm when the sum of effective temperatures is between 650 and 1250°C. Sunflower – the sum of precipitation is less than 100 mm when the sum of effective temperatures is between 150 and 1000°C Sugar beet – precipitation amount less than 50 mm when the sum of effective temperatures is between 1300 and 2000°C Soybean – precipitation amount less than 100 mm when the sum of effective temperatures is between 400 and 1300°C
	MEADOWS AND PASTURES
Occurrence of frostbite with very low temperatures	The percentage of years in which it occurred during the winter for at least three days with a minimum daily temperature lower than-17 after 5 consecutive days without precipitation.
Critically low rainfall during the summer season	The percentage of years in which the total amount of precipitation during the summer months (June, July, August) is lower than 150 mm.
	SOIL
Intense precipitation	The number of days with precipitation over 20 mm total precipitation during such episodes.

To analyze the water needs of agricultural crops data from the locations of 27 meteorological stations within each administrative district of the Republic of Serbia were used. Table 4 shows the list of locations with the percentage of total agricultural land per district covered by the analysis.

Table 4. Meteorological stations and the share of agricultural land included in the analysis

Region	Administrative district	Location	Longitude	Altitude (m)	Agricultural land covered by the analysis (%)
Vojvodina Region	North Banat	Kikinda	45° 51′ N	81	96
	Central Banat	Zrenjanin	45° 24′ N	80	98
	North Bačka	Palić	46° 06′ N	102	89
	South Banat	Banatski Karlovac	45° 03′ N	90	94
	West Bačka	Sombor	45° 46′ N	87	92
	South Bačka (North Srem)	Novi Sad	45° 19′ N	86	89
	Srem	Sremska Mitrovica	45° 01′ N	81	91

Belgrade Region	City of Belgrade	Surčin	44° 49′ N	99	90
		Sopot*	44° 31′ N	214	
Region of eastern and southern Serbia	Danube River Basin District	Smederevska Palanka	44° 22′ N	121	86
	Braničevo	Veliko Gradište	44° 45′ N	80	86
	Bor	Negotin	44° 14′ N	42	93
	Zaječar	Zaječar	43° 53′ N	144	95
	Nišava	Niš	43° 20′ N	202	86
	Pirot	Dimirovgrad	43° 01′ N	448	88
	Toplica	Kuršumlija	43° 08′ N	384	89
	Jablanica	Leskovac	42° 59′ N	231	94
	Pčinja	Vranje	42° 33′ N	433	88
Region of Šumadija, central and western Serbia	Šumadija	Kragujevac	44° 02′ N	185	90
	Pomoravlje	Ćuprija	43° 56′ N	123	81
	Raška	Kraljevo	43° 43′ N	219	90
	Rasina	Kruševac	43° 34′ N	163	95
	Mačva	Loznica	44° 32′ N	121	83
	Kolubara	Valjevo	44° 17′ N	174	92
	Moravica	Požega	43° 51′ N	311	97
	Zlatibor	Užice	43° 53′ N	822	91
		Zlatibor*	43° 53′ N	1029	

**Data for Zlatibor were used to analyze the water needs of meadows and pastures that are dominant crops in hilly and mountainous areas, while the location of Užice was used to analyze the water needs of field and fruit crops whose production is more dominant and more successful at lower altitudes. Two locations were also used for the Belgrade Region; Surčin, for the analysis of the needs of field crops, meadows and pastures, while the location of Sopot was used for the analysis of the water needs of orchards.*

Based on the values of temperatures and precipitation at selected locations, water deficits that occur in crop production and hydromodules of irrigation systems were determined. Effective precipitation is adopted as 90% of the daily precipitation (Pe[15]). Using FAO IDP (*Irrigation and Drainage Paper*) 56 Methodology[16] reference evapotranspiration and evapotranspiration of crops that are most represented in the analyzed administrative districts were calculated.

15 Effective precipitation is the amount of water that is absorbed and retained in the zone of the active rhizosphere, the rest flows on the surface or goes into deeper layers through percolation.

16 Allen, R.G., Pereira, L.S., Raes, D., Smith, M. (1998). Crop Evapotranspiration. Guidelines for computing crop water requirements. *Irrigation and drainage paper,* No. 56, FAO Rome.

As a difference between the reference evapotranspiration and effective precipitation, a water deficit was obtained in each district. By analyzing the structure of plant production of the mentioned administrative districts, a crop rotation was made in the irrigation system, which consists of the most important field crops, meadows and pastures, grapevines and orchards. Data on the area of used agricultural land and the structure of crop production are taken from the statistical yearbooks of the Republic Statistical Office of the Republic of Serbia[17].

Table 4 shows the percentage of total agricultural land covered by the analysis. The percentage of plant production coverage by analysis ranges from 81% (in the North Banat District) to 98% in the Central Banat District.

The evapotranspiration of the crop was determined as the product of the reference evapotranspiration and crop coefficient. The difference between the crop evapotranspiration and effective precipitation provides a net water deficit for the given plant species (crop) (In). To determine the irrigation hydromodule, it is necessary to determine the gross water deficit (Ib) in the period of peak consumption, which depends on the efficiency of the irrigation system. The efficiency is highest in drip systems and lowest in gravity systems[18]. In our climate conditions, the period of peak consumption usually occurs in July.

The hydromodule of the irrigation system is calculated using the following equation:

$$q_s = \frac{Ib \cdot 10000 \cdot 24 \cdot 30}{86400 \cdot t \cdot n}$$

Where: qs-hydromodule of the system (l•s-1•ha-1); Ib - gross water deficit (mm); 10000 number m2 in one hectare; 24 - number of hours per day; 30 - number of days in the month; 86400 - number of seconds in the day; t - operating hours of the system during the day (determined by the designer); h - number of operating days of the system during the month (determined by the designer).

The level of exposure to heat stress of domestic animals was estimated using the temperature-humid index (THI[19]) which is calculated on 10 selected farms where there are multi-year measured data on ambient temperature and humidity. The farms were selected to cover the largest number of production conditions and applied technologies for milk production[20]. The formula for calculating the THI index is:

$$THI = 1.8 \times AT - (1 - RH) \times (AT - 14.3) + 32$$

17 Statistical Office of the Republic of Serbia Statistical Yearbook (2018). https://publikacije.stat.gov.rs/G2018/Pdf/G20182051.pdf
Statistical Office of the Republic of Serbia Census of Agriculture, Book 1, (2012). https://pod2.stat.gov.rs/ObjavljenePublikacije/Popis2012/PP-knjiga1.pdf
Statistical Office of the Republic of Serbia Statistical Yearbook (2019). https://publikacije.stat.gov.rs/G2019/Pdf/G20192052.pdf
Statistical Office of the Republic of Serbia Survey on the structure of farms, (2018). http://publikacije.stat.gov.rs/G2019/pdf/G20196003.pdf

18 Stričević, R. (2000). Designing in land reclamation Practicum. Faculty of Agriculture, University of Belgrade.

19 Kibler H.H. (1964). Thermal effects of various temperature-humiditycombinations on Holstein cattle as measured by eight physiologicalresponses. Environmental physiology and shelter engineering. LXVII.

20 Optimization of technological procedures and zootechnical resources on farms in order to improve the sustainability of milk production (TR- 31086)" Ministry of Education, Science and Technological Development Republic of Serbia.

Where the average daily ambient temperature was measured - AT expressed in °C, and RH - relative humidity expressed as a percentage. Depending on the THI value, intervals are formed which characterize the exposure of dairy cows to heat stress: comfort zone (THI <72), low heat stress (72 <THI <78), moderate (79 <THI <88), strong (89 <THI < 98) and very strong heat stress (THI> 98).

Due to the impossibility of projecting the values of ambient temperature and humidity inside the farm, it is not possible to calculate projections of the future value of this index.

Step 3: Exposure assessment

Exposure assessment means estimating the frequency, i.e. how often the defined potential hazards occur related to climate change and extreme weather events in the past and future. The scale of probability and frequency of occurrence of hazards is provided in Table 5.

Table 5. Scale of the probability and frequency of occurrence of hazards

Probability of event	Frequency of occurrence
Small	once in 20 years
Moderate	once in 10 years
High	once in 4 years
Very high	once in 2 years

Step 4: Vulnerability assessment

Vulnerability assessment involves assessing the severity of the socio-economic consequences that defined hazards may have according to the scale provided in Table 6.

Table 6. The scale of the degree of the consequence of hazards

Vulnerability	Degree of consequence
Small	with little or no negative consequences
Moderate	with negative consequences that can lead to smaller economic losses
High	with negative consequences that may lead to significant economic losses and/or may affect certain social categories
Very high	severe negative consequences that can lead to large economic losses and/or social instability

Step 5: Risk assessment

The risk quantification is performed based on assessments of exposure levels and vulnerabilities in the previous two steps. According to the risk matrix given in Table 7, low risk are those events that occur with low or moderate probability and cause small or moderate consequences. Moderate risk are those events that occur with low or moderate probability and cause large or critical consequences, as well as those that occur with high or very high frequency, and cause small or moderate consequences. High risk are those events that occur with a high or very high probability and cause great or critical consequences.

Table 7. Risk category quantification

Exposure/ Vulnerability	Small	Moderate	High	Critical
Small	LOW	LOW	MODERATE	MODERATE
Moderate	LOW	LOW	MODERATE	MODERATE
High	MODERATE	MODERATE	HIGH	HIGH
Very high	MODERATE	MODERATE	HIGH	HIGH

Step 6. Proposing adaptation measures and their prioritization

For the risks that were assessed as moderate or high in the previous step, based on the literature and expert knowledge, appropriate adaptation measures are proposed, which are then prioritized by the method of multi-criteria analysis. To apply this method, the criteria and scoring system are defined from 1 to 5, where 1 is weakest and 5 strongest. After prioritization, for measures with the highest scores, it is necessary to assess the necessary resources, define indicators that can monitor their implementation, and identify responsible institutions.

Table 8. Criteria for prioritizing adaptation measures

Criterion	Explanation
Efficacy	How effective is the proposed measure to reduce the impact
Cost-effectiveness	Are the benefits of implementing the proposed measure greater than the estimated costs of its implementation
Applicability	Is the proposed measure in accordance with applicable laws, programs, strategies, etc.
Urgency	Are damages and losses already being suffered from the occurrence to which the proposed measure refers
Multifunctionality	Does the proposed measure have other benefits (e.g. adaptation in other sectors, reduction of greenhouse gas emissions, preservation of the environment, etc.)

3. General risks, vulnerabilities and different levels of damage in agriculture

3.1 Water related risks and water needs in agriculture

3.1.1 Uneven precipitation and dry periods

In the area of Serbia, there are periodic dry periods and periods with excess water. There is an uneven occurrence of precipitation (waterlogging) in the winter-spring period and drought in the summer-autumn period, which leads to the need to regulate the water-air regime of the soil in order to provide conditions for stable agricultural production. About 2.6 million ha of agricultural land are permanently or occasionally endangered by waterlogging, while about 955,000 ha can be used without the application of drainage systems[21]. These data show that there is a need for the good arrangement and maintenance of reclamation systems, primarily a drainage system.

Damage from waterlogging is most often reflected in an indirect way as opposed to drought damage. If waterlogging, i.e. excess water occurs in a longer period (especially in the spring), the timely application of agro-technical measures (tillage and soil preparation) is prevented. Therefore, sowing, planting and transplanting are delayed which significantly affects the delay of plant vegetation, which can enter a sensitive phenophase in an unfavourable part of the year (drought occurrence when most crops are most sensitive - flowering and fruiting period), which later affects the quantity and quality of yields. If plant production is organized on an uneven terrain, in the depressions that are most prevalent in the lowest parts of the field, water retention occurs, plants suffocate due to the lack of air, which additionally affects the reduction of yield. On soils which are constantly and occasionally prone to waterlogging, the application of irrigation is disabled and thus the possibility of second sowing is excluded, which significantly affects the economy of agricultural production. Also, sowing of crops sensitive to waterlogging, such as perennial grasses (alfalfa) and winter wheat crops, is impossible, which introduces only summer crops into the production system. This method of plant production is also unfavourable from the ecological aspect and the fact that due to climate change there is a high risk of endangerment due to increasing temperatures and frequent droughts.

Damages in yields/revenues are compared in relation to the years in which the good or usual yields were achieved, so-called "good years". It is especially important to emphasize the risk for the production of strategic crops – the most important field crops (maize, wheat, sunflower and soybeans) and vegetable plants (peppers, tomatoes, potatoes, cabbage and beans), because the risk of production could affect the instability of the population and endanger the economy in the Republic of Serbia. Based on the analysis conducted within the United Nations Development Program 2019[22] there is an

21 Water Management Strategy in the territory of the Republic of Serbia, Draft, Institute of Water Management "Jaroslav Černi, (2015): http://www.rdvode.gov.rs/javne-rasprave.php

22 Stričević, R., Prodanović, S, Đurović, N., Petrović Obradović, O., Đurović, D. (2019). Impacts of climate change on Serbian agriculture. United Nations Development Program https://www.klimatskepromene.rs/wp-content/uploads/2019/11/e-pub_Uticaji-promene-klime-na-srpsku-poljoprivredu.pdf

increase in the frequency of "bad years", with a significant decrease in the average yields of the mentioned field and vegetable plants (Table 9).

Table 9. Damages from adverse effects of climate on crop yields in arable farming and vegetables, loss at the level of the Republic of Serbia[23]

Year	Plant species (crop)	Decrease in yield (t/ha) compared to the average*	Sowing area (ha)	Producer price per kg**	Estimated damage (in millions of dinars) at the RS level
2010	Barley	0.6	89,937	16.06	867
2012	Maize	2.2	976,020	16.19	34764
2012	Sugar beet	11.6.	69,069	4.24	3397
2012	Sunflower	0.4	185,918	33.22	2470
2012	Potatoes	2.1	52,035	22.78	2489
2012	Peppers	1.2	11,906	54.34	776
2012	Soybeans	1.0	162,714	45.02	7325
2014	Potatoes	2.0.	51,987	22.78	2369
2015	Wheat	1.2	589,922	16.77	11872
2015	Alfalfa	1.0	109,230	11.51	1257
2015	Clover	1.2	76,625	11.60	1067
2017	Wheat	1.1	556,115	16.77	10259
2017	maize	2.1	1,002,319	16.19	34078
2018	Tobacco	0.4	5,762	205.15	473

**Deviation of yield in the mentioned year from the regression line of average yields in RS for the period 1947-2018, according to the SO of RS.*
***Producer prices in 2017, according to the SO of RS data.*

Based on the planned unit prices, analysis of the condition of facilities and the need to ensure the functioning of water facilities where this is not achieved by regular maintenance, a program of works on investment maintenance of water facilities in public ownership is being prepared. Funds provided in 2017 by the water management program for the regulation of watercourses and protection against the harmful effects of water in the amount of 1,220,333,000 dinars are insufficient for the rehabilitation of the newly damaged ones and they cannot provide efficient financing of flood defense measures. Although significant rehabilitation works were carried out after the floods in 2014, by reducing the volume of regular maintenance in 2016, the condition of protection and regulation facilities does not provide the necessary reliability of protection in

23 https://www.klimatskepromene.rs/wp-content/uploads/2019/11/e-pub_Uticaji-promene-klime-na-srpsku-poljoprivredu.pdf

high water conditions. Despite the evident and urgent needs, the development plans were completely suspended due to the lack of technical documentation. This will affect the readiness to use significant funds from foreign sources of financing, the amount of which would enable the realization of the construction of capital protection facilities. Therefore, for the above reasons, it is clear that the risk of new floods and other types of harmful effects of water is increasing.

3.1.2 Consequences of drought - Mycotoxins in the light of climate change

Another mechanism through which climate change can negatively affect the health of animals and humans is presented so that high temperatures and humidity can have a positive effect on the growth of fungi producing mycotoxins, which is the case in almost all countries, including Serbia. The growth of these fungi and the production of mycotoxins are closely related to the ambient temperature and the degree of humidity, which depend on the weather conditions in the harvest and the technique of drying and storing grains. Mycotoxins can cause episodes of acute disease when animals consume critical amounts of infested feed.

Recently, changing climatic conditions have provided more and more opportunities for aflatoxin contamination of maize in Serbia and other European countries[24]. *Aspergillus flavus* and related species produce aflatoxins, which are secondary metabolites with a negative impact on human health and food safety in areas of agricultural production with a warm climate[25] [26]. *Aflatoxins* are potent naturally occurring carcinogens that can suppress the immune system, causing hepatocellular carcinoma, with fatal outcomes in humans and livestock[27] [28].

Environmental and biological factors, such as increased temperatures, droughts, damage caused by various pests, susceptibility of the host to infection and the potential of aflatoxin-producing fungi, together raised the level of aflatoxin pollution above the prescribed limits[29] [30]. Aflatoxin contamination can occur after crop maturation when crops are exposed to high temperatures and humidity levels, which favors fungal infections and may result in increased aflatoxin accumulation[31]. Therefore, aflatoxin contamination can begin and continue after cultivation, but also during storage, transport, processing and handling[32].

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32 Cotty, P.J., Mellon, J.E. (2006). Ecology of aflatoxin-producing fungi and biocontrol of aflatoxin contamination. Mycotoxin Res. 22, 110–117.

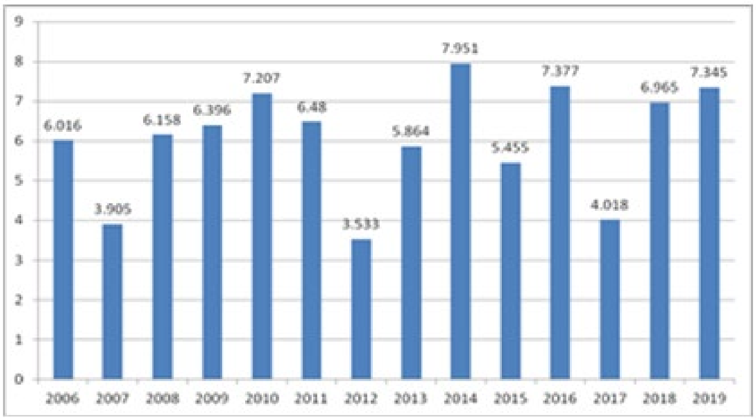

Chart 1. Maize production in Serbia during the last 15 years (000 t)

In the Republic of Serbia during the summer of 2012 the occurrence of *A. flavus* (AFB1) in maize was the result of extremely stressful environmental conditions that included high air temperatures and low precipitation and was reported as a new hazard to humans and animal feed (Chart 4). There is more than a double variation in the production of the most important crop in Serbia, where maize in 2012 barely produced 3.5 million tons, and in favorable years the production is almost 8 million tons. With the price around 200 dollars per ton on world stock markets in recent years, it can be seen that weather conditions can make a difference of 900 million dollars, between a favorable and an unfavorable year for growing maize.

As a consequence of the occurrence of aflatoxin AFB1 in the silage of the whole plant and maize kernel in the spring of 2013, there was a problem with the concentration of aflatoxin AFM1 (metabolite AFB1) in the milk of cows fed with these nutrients. The study found that of the 281 feed samples, 67 (23.8%) had an AFB1 concentration above the maximum allowable limit, primarily due to contamination of maize, because this mycotoxin was not found in other nutrients analyzed[33]. In the same study, the authors examined the concentration of aflatoxin AFM1 in the milk of cows fed with these nutrients and found that of 2045 tested milk samples, 934 (45.7%) had a concentration of this mycotoxin above the maximum allowable value. All this led to a serious crisis in milk supply and milk consumption due to consumer distrust, which has led to a crisis in the dairy industry from which the entire sector was recovering for the next few years.

In a very favorable 2020, the production of maize was over 8 million tons, which was about 10% more than the production achieved in the previous year.

Natural occurrences of aflatoxins are uncommon in typical climatic conditions of Serbia, but since the occurrence of mycotoxins is climate-dependent[34], recent climate change has become a significant cause for human and animal safety issues[35 36].

33 Spirić, D.M., Stefanović, S.M., Radičević, T.M., Stojanović, J.M.Đ., Janković, V.V., Velebit, B.M., Janković, S.D. (2015). Study on the finding of aflatoxins in animal feed and raw milk in Serbia during 2013. Chemical Industry, 69 (6), 651–656.

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3.1.3 Water needs in the agricultural sector

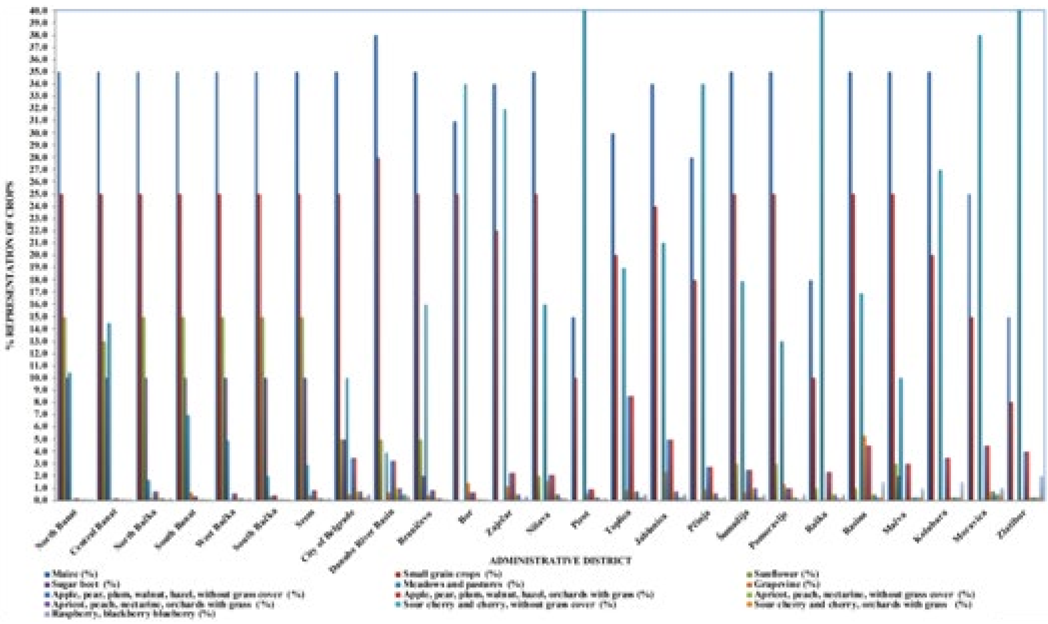
In order to determine the impact of climate change on the agricultural sector (droughts, floods ...), an analysis of the need for water was performed.

There is no doubt that the current climatic conditions will reduce the quality and yield. Namely, as we are witnessing more and more frequent droughts, it is necessary to perform a detailed analysis of the need for water in crop production, to assess its vulnerability in the agricultural sector. The precise needs of crops for water will contribute to the proper development of a strategy in combating climate change. Good water resources management is of immeasurable importance for the sustainability of the agricultural sector.

The performed analysis shows the need for water at the level of the Administrative Districts of the Republic of Serbia, which are integral parts of the Region. The territory of the Republic of Serbia is divided into 25 administrative districts without Kosovo and Metohija.

Chart 2. shows a graphical representation of the representation of agricultural crops by districts.

Chart 2. Percentage representation of agricultural crops by Administrative Districts



Figures 1, 2, 3, 4, 5 and 6 show the average monthly values of reference evapotranspiration, effective precipitation and water deficit in the Administrative Districts of the Republic of Serbia during the vegetation (April, May, June, July, August and September) and off-vegetation periods (October, November, December, January, February, March).

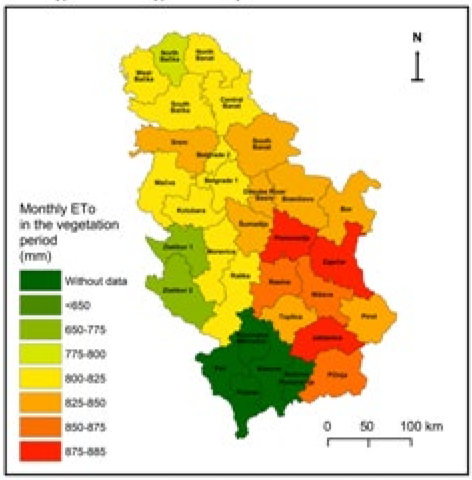


Figure 1. Reference evapotranspiration in the vegetatio

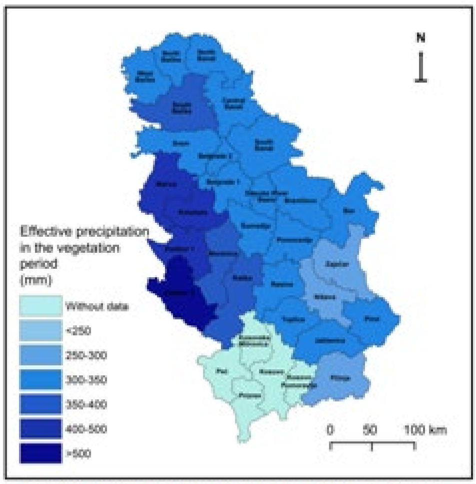


Figure 2. Effective precipitation in the vegetation period

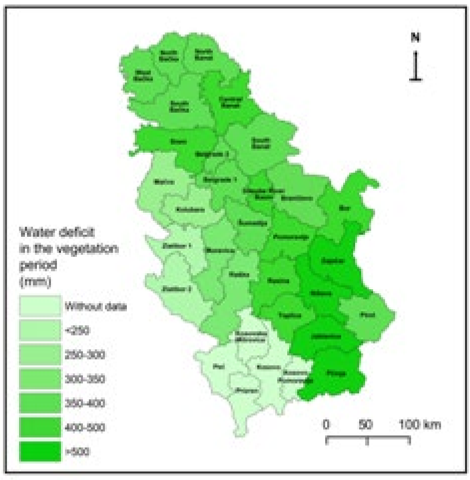


Figure 3. Net irrigation water requirements in the vegetation period

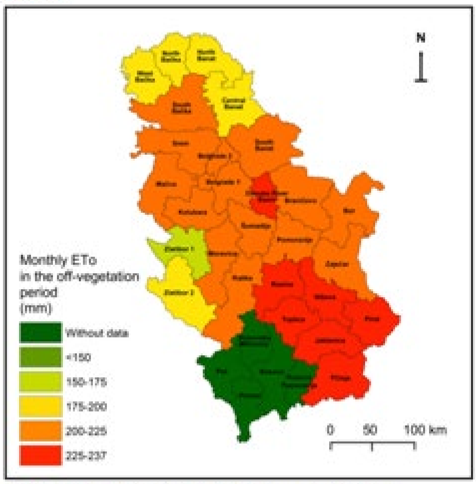


Figure 4. Reference evapotranspiration in the off-vegetation period

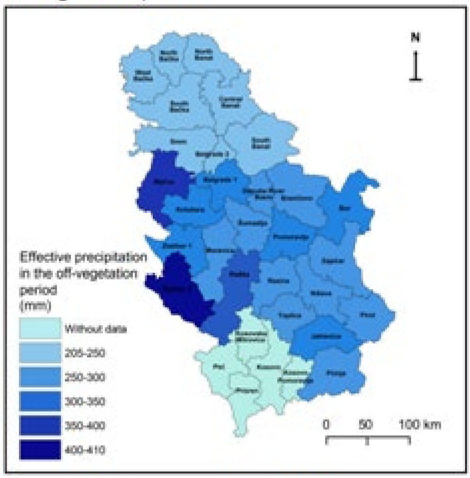


Figure 5. Effective precipitation in the off-vegetation period

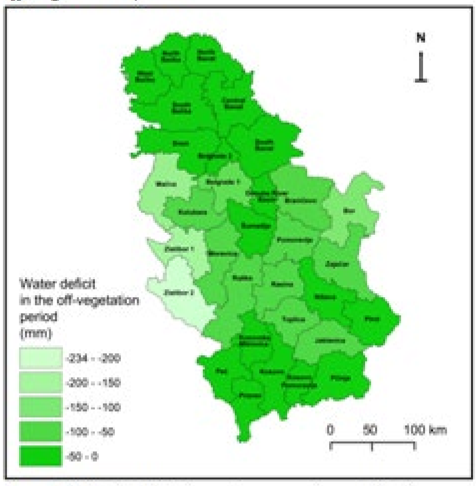


Figure 6. Net irrigation water requirement in the off-vegetation period

The average annual value of the reference evapotranspiration in the territory of the Republic of Serbia is 1031 mm. In the vegetation period, the average value of the reference evapotranspiration is about 820 mm (highest in Jablanica District 885 mm, lowest in Zlatibor District 658 mm), while values in the off-vegetation period are on average 212 mm (highest in Jablanica 237 mm, lowest in Zlatibor District 172 mm). The average annual effective precipitation is 624 mm. In the vegetation period, it is on average 349 mm (highest in the Zlatibor District 526 mm, and the lowest in the Pčinja Administrative District 282 mm), and the average values of effective precipitation in the off-vegetation period are 275 mm (highest in the Zlatibor District 410 mm, and lowest in the North Banat Administrative District 206 mm). The value of the average annual net water deficit is 425 mm. The average value of the net water deficit during the vegetation period is 482 mm (highest deficit occurs in the Bor District 832 mm, and the lowest in the Zlatibor District 131 mm). In the off-vegetation period, the net water deficit varies from -72 mm in the Bor District to -234 mm in the Zlatibor District, on average -57 mm.

Figure 7 a, b, c shows the values of specific discharge for surface, sprinkler and drip irrigation systems in the period of peak water consumption.

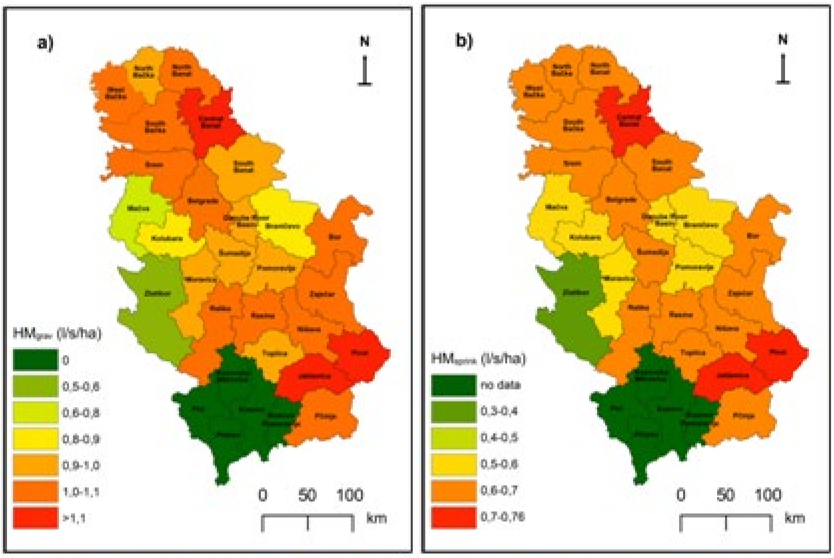


Figure 7. Hydromodulesofirrigationsystems a) surfacesystem; б) sprinklersystem for the period 2000-2019

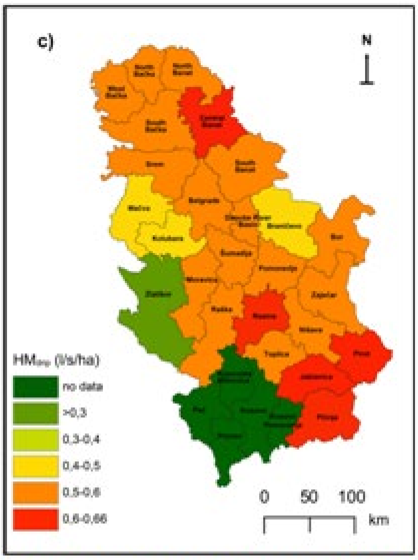


Figure 7c. Hydromodulesofdrip irrigationsystem for the period2000-2019

In the observed period, the greatest water needs are in July, except in the Zlatibor, Raška, Bor and Pirot districts, where the period of peak water consumption is in August. The average value of the specific discharge of the surface irrigation system is 0.98 $l \cdot s^{-1} \cdot ha^{-1}$ (from 0.52 $l \cdot s^{-1} \cdot ha^{-1}$ in the Zlatibor District up to 1.18 $l \cdot s^{-1} \cdot ha^{-1}$ in the Jablanica District). The specific discharge of the sprinkler irrigation system varies from 0.33 $l \cdot s^{-1} \cdot ha^{-1}$ in Zlatibor up to 0.76 $l \cdot s^{-1} \cdot ha^{-1}$ in the Jablanica District, with an average value at the level of the Republic of Serbia of 0.63 $l \cdot s^{-1} \cdot ha^{-1}$. The average value of the specific discharge of the drip irrigation system is 0.55 $l \cdot s^{-1} \cdot ha^{-1}$ and ranges from 0.29 $l \cdot s^{-1} \cdot ha^{-1}$ in the Zlatibor District up to 0.66 $l \cdot s^{-1} \cdot ha^{-1}$ in the Jablanica District.

Figures 8 and 9 show net irrigation requirements for the vegetation and off-vegetation period calculated at 10 km^2.

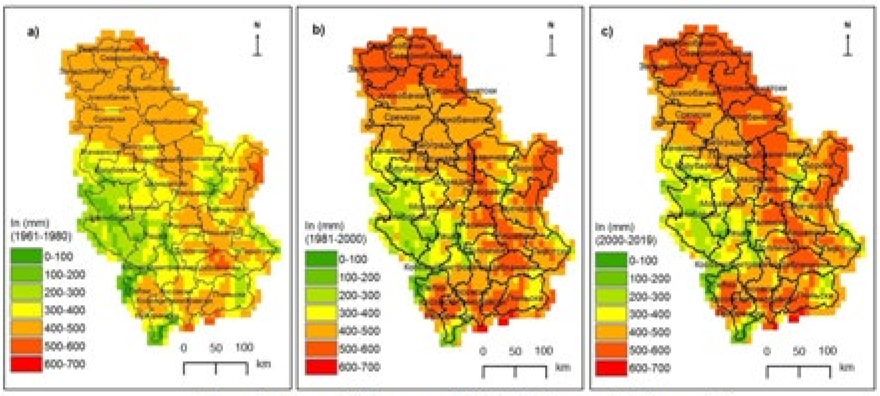


Figure 8 Figure 8. Average NIWR in the vegetation period
a) 1961-1980; b) 1981-2000; c) 2000-2019

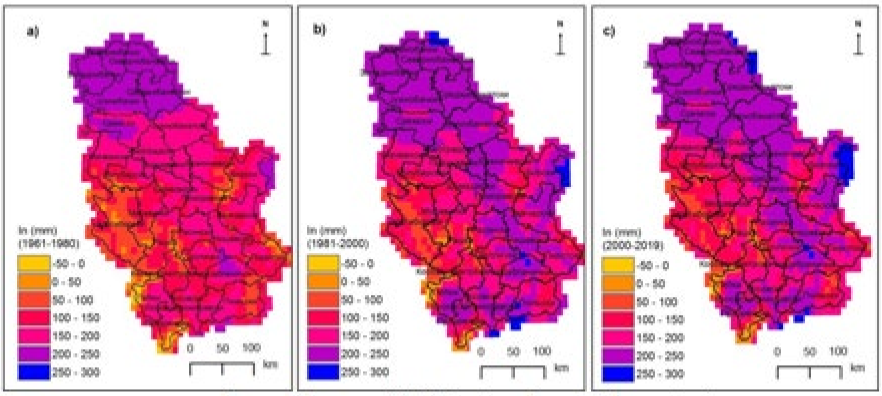


Figure 9. Average NIWR for the off-vegetation period
a) 1961-1980; b) 1981-2000; c) 2000-2019

Net deficits are presented and compared for the period 1961-1980, 1981-2000, 2000-2019. It is noticed that there is an increase in water deficit, especially in the vegetation period for the period 2000-2019 compared to the period 1981-2000 and 1961-1980.

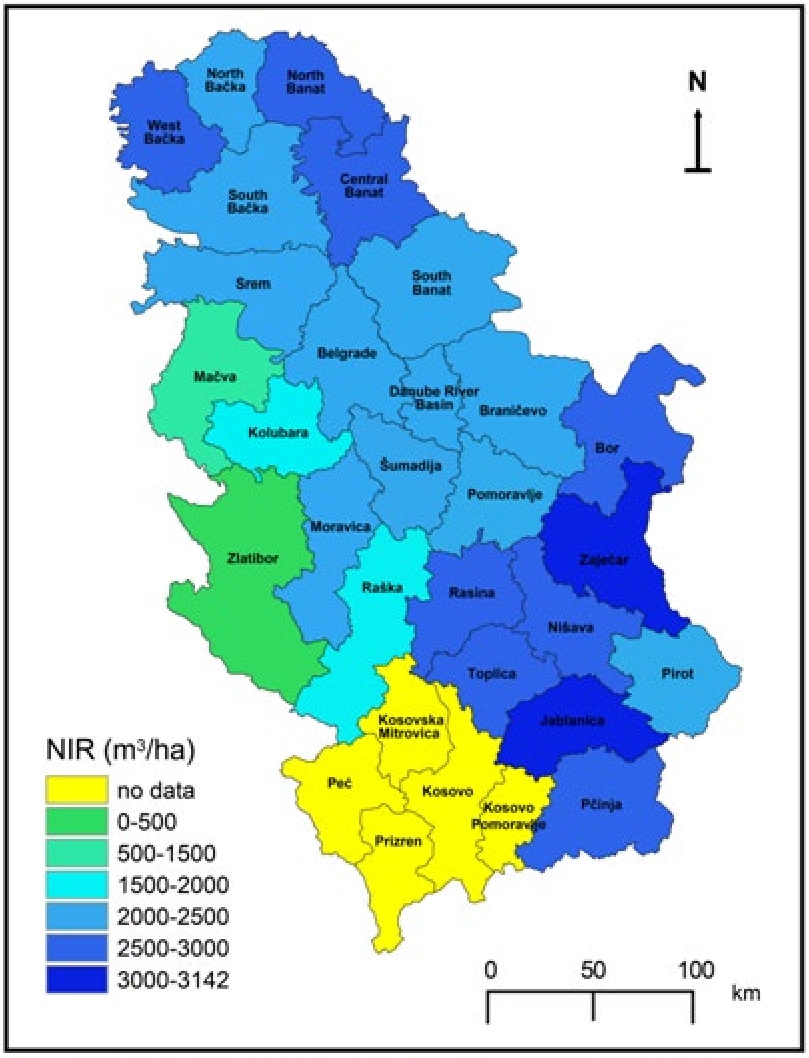
Table 10 shows the net and gross irrigation water requirements depending on the choice of irrigation methods by administrative districts for the observed period (2000-2019).

Administrative district	Period	Net irrigation water requirement (ΣIn mm·m-2)	Net irrigation rate water requirement (ΣIn m3·ha-1)	Gross irrigation water requirement (ΣIb mm·m-2) surface irrigation system	Gross irrigation water requirement (ΣIb m3·ha-1) surface irrigation system	Gross irrigation water requirement (ΣIb mm·m-2) sprinkler irrigation system	Gross irrigation water requirement (ΣIb m3·ha-1) sprinkler irrigation system	Gross irrigation water requirement (ΣIb mm·m-2) drip irrigation system	Gross irrigation rate (ΣIb m3·ha-1) dripping	Total agricultural land covered by the analysis (ha)
Vojvodina Region										
North Banat	2000-2019	265.7	2656.7	531.3	5313.5	379.5	3795.3	332.1	3321.1	169633
Central Banat	2000-2019	270.1	2700.5	540.1	5401.1	385.8	3857.9	337.6	3375.7	257234
North Bačka	2000-2019	218.0	2180.0	436.0	4359.9	311.4	3114.2	272.5	2725.0	123967
South Banat	2000-2019	247.5	2475.1	495.0	4950.1	353.6	3535.8	309.4	3093.8	295704
West Bačka	2000-2019	253.9	2538.6	507.7	5077.2	362.7	3626.6	317.3	3173.3	164049
South Bačka	2000-2019	203.9	2038.5	407.7	4077.0	291.2	2912.2	254.8	2548.2	243619
Srem	2000-2019	246.2	2462.0	492.4	4924.0	351.7	3517.1	307.8	3077.5	208636
Average	2000-2019	244	2436	487	4872	348	3480	305	2627	208977
City of Belgrade										
City of Belgrade	2000-2019	235.2	2351.7	470.3	4703.4	336.0	3359.6	294.0	2939.6	130980
Region of Eastern and Southern Serbia										
Danube River Basin District	2000-2019	219.5	2194.6	438.9	4389.2	313.5	3135.1	274.3	2743.3	72364
Braničevo	2000-2019	218.3	2183.0	436.6	4366.0	311.9	3118.6	272.9	2728.8	129163
Bor	2000-2019	271.6	2716.3	543.3	5432.6	388.0	3880.4	339.5	3395.4	73108
Zaječar	2000-2019	314.2	3141.9	628.4	6283.8	448.8	4488.4	392.7	3927.4	85686
Nišava	2000-2019	262.6	2626.3	525.3	5252.5	375.2	3751.8	328.3	3282.8	70887
Pirot	2000-2019	236.0	2359.9	472.0	4719.8	337.1	3371.3	295.0	2949.9	41004
Toplica	2000-2019	272.9	2729.4	545.9	5458.7	389.9	3899.1	341.2	3411.7	48490
Jablanica	2000-2019	303.8	3037.7	607.5	6075.3	434.0	4339.5	379.7	3797.1	61019
Pčinja	2000-2019	289.3	2893.1	578.6	5786.1	413.3	4132.9	361.6	3616.3	59398
Average	2000-2019	265	2654	531	5307	379	3791	332	3317	71235
Region of Šumadija, Central and Western Serbia										
Šumadija	2000-2019	238.2	2381.7	476.3	4763.3	340.2	3402.4	297.7	2977.1	109205
Pomoravlje	2000-2019	221.2	2211.8	442.4	4423.5	316.0	3159.7	316.0	3159.7	83414
Raška	2000-2019	184.9	1849.0	369.8	3697.9	264.1	2641.4	231.1	2311.2	93945
Rasina	2000-2019	266.9	2668.5	533.7	5337.0	381.2	3812.2	333.6	3335.6	91128
Mačva	2000-2019	134.2	1341.6	268.3	2683.1	191.7	1916.5	167.7	1677.0	139322
Kolubara	2000-2019	165.5	1654.7	330.9	3309.3	236.4	2363.8	206.8	2068.3	121533
Moravica	2000-2019	217.7	2176.8	435.4	4353.6	311.0	3109.7	272.1	2721.0	106079
Zlatibor	2000-2019	32.6	326.0	65.2	652.0	46.6	465.7	40.7	407.5	183866
Average	2000-2019	183	1826	365	3652	261	2609	233	2332	116062
Average of the Republic of Serbia	2000-2019	232	2316	463	4632	331	3308	291	2793	126537

Table 10. Net and gross irrigation water requirement in mm·m-2 and m3· ha-1 by administrative districts of the Republic of Serbia

The average net irrigation water requirement (NIWR) in the Republic of Serbia for the observed period is 232 mm·m-2 (2320 m3·ha-1), the highest NIWR in the area of the Zaječar District, 314 mm·m-2 and least in the Zlatibor District, only 33 mm·m-2.

Figure 10 below shows the spatial distribution of NIWR.



without data

Figure 10. Net irrigation water requirement by administrative districts of the Republic of Serbia 2000-2019

For the Region of Vojvodina, NIWR is 244 mm·m-2, highest in Central Banat (270 mm·m-2) and least in the South Bačka District (204 mm·m-2). In the region of eastern and southern Serbia, NIWR varies from 218 mm·m-2 in the Braničevo District up to 314 mm·m-2 in the Zaječar District, with an average of 265 mm·m-2 for the whole region. In the region of Šumadija, central and western Serbia, the average NIWR is 183 mm·m-2, from 33 mm·m-2 in the Zlatibor District up to 267 mm·m-2 in the Rasina District. Taking into account NIWR and the area of used agricultural land, the greatest irrigation water needs occur in the area of the South Banat District (731896970 m3), while the least needs occur in the area of the Zlatibor District (59940316 m3). The obtained data on the net and gross irrigation water requirements are following the results presented in the Water Management Strategy in the territory of the Republic of Serbia by 2034[37]. However, what remains a major problem is the amount of water abstracted and the available water resources for irrigation. Where there is enough water, irrigation systems are non-rationally

37 Water management strategy in the territory of the Republic of Serbia by 2034. Official Gazette of the Republic of Serbia, No. 3 of 18. January 2017

handled, leading to soil degradation, groundwater pollution, and excessive water consumption. The Water Management Strategy in the territory of the Republic of Serbia does not contain clear data on available water quantities for the agricultural sector, as well as data on how much water is used for irrigation, so there is no clear data on whether there are sufficient resources based on the calculated needs. There is no data for the system of publicly owned water quantities in the Lower Danube water area. Irrigated areas are presented by Regions, not by Administrative Districts. It is necessary to perform an analysis of available water resources as well as the current state of irrigated areas in communication with water management companies and agricultural professional services at the level of local self-government. It is very important to point out the (un)availability of data from the Agricultural Advisory Services and the Statistical Office of the Republic of Serbia on the structure of plant production. Knowledge of the structure of plant production is very important for the analysis of the impact of climate change and the proposal of adaptation measures because not all crops have the same demands and are not equally endangered by the stress factors of climate change. The official Republic institutions provide data that are primarily at the level of the Region, which is insufficient, they also classify all crops into four groups (arable land and gardens (where all are field, vegetable, medicinal and aromatic plants), meadows, and pastures, orchards and vineyards). For example, only within orchards, there are at least seven groups that differ in the duration of vegetation as well as sensitivity and needs. To apply adequate adaptation measures, these problems must be addressed, which can be easily resolved with the establishment of a clear work methodology.

Table 11 shows NIWR (calculation methodology provided in Chapter 2) of crops included in the analysis for the observed period (2000-2019).

Table 11. Net Irrigation Water Requirement of crops included in the analysis

Period	Net Irrigation Water Requirement	Crops													
		Maize	Winter Wheat	Sunflower	Sugar beet	Meadows and pastures	Vineyards	Apple, pear, plum, walnut and hazel orchard without grass cover	Apple, pear, plum, walnut and hazel orchard with grass	Apricot, peach, nectarine orchard without grass cover	Apricot, peach, nectarine orchard with grass	Sour cherry, cherry orchard without grass cover	Sour cherry, cherry orchard with grass	Raspberry, blackberry, blueberry	Average
North Banat															
2000-2019	ΣNI-WR(mm)	360.9	40.9	218.5	495.5	168.5	237.7	392.4	579.9	191.5	308.5	160.5	255.2	241.2	280.9
Central Banat															
2000-2019	ΣNI-WR(mm)	360.1	34.2	228.1	500.8	179.3	240.7	397.2	586.4	204.8	322.6	168.1	263.7	254.9	287.8
North Bačka															
2000-2019	ΣNI-WR(mm)	324.1	2.8	195.5	450.8	145.2	201.8	351.0	532.1	175.0	288.3	143.3	235.2	225.6	251.6
South Banat															
2000-2019	ΣNI-WR(mm)	349.3	22.7	217.6	490.9	162.7	223.7	383.4	576.6	205.0	325.0	169.1	266.3	252.5	280.4

West Bačka															
2000-2019	ΣNI-WR(mm)	369.0	24.7	209.3	511.2	161.7	227.8	391.9	588.9	177.8	298.7	149.6	247.3	228.6	272.1
South Bačka															
2000-2019	ΣNI-WR(mm)	310.8	-17.7	178.7	446.9	131.4	187.2	343.1	531.1	154.1	270.8	128.1	222.7	202.2	237.7
Srem															
2000-2019	ΣNI-WR(mm)	356.5	20.6	216.9	499.3	169.7	232.6	392.9	586.0	194.7	315.0	158.5	256.0	244.8	280.3
Belgrade															
2000-2019	ΣNI-WR(mm)	337.4	4.7	200.5	471.6	154.9	181.3	337.3	525.9	151.7	269.7	114.9	210.6	200.2	243.1
Danube River Basin District															
2000-2019	ΣNI-WR(mm)	359.1	-17.6	212.2		157.4	217.1	381.3	579.0	180.1	302.3	145.8	244.8	233.3	249.6
Braničevo															
2000-2019	ΣNI-WR(mm)	357.8	-19.8	206.4	499.9	150.6	218.9	381.6	578.8	187.6	309.9	153.0	251.7	238.9	270.4
Bor															
2000-2019	ΣNI-WR(mm)	396.2	-33.6			197.2	262.7	424.0	619.4	214.6	335.5	178.2	276.0	263.8	307.9
Zaječar															
2000-2019	ΣNI-WR(mm)	423.9	21.8			209.1	294.4	463.9	668.7	232.7	359.0	195.4	297.3	285.6	313.8
Nišava															
2000-2019	ΣNI-WR(mm)	414.0	6.7	251.7		201.3	284.0	452.5	655.0	213.1	337.2	174.1	274.5	268.0	294.3
Pirot															
2000-2019	ΣNI-WR(mm)	357.4	-12.9			156.8	223.3	387.7	584.7	174.6	295.0	142.7	240.1	287.0	257.9
Toplica															
2000-2019	ΣNI-WR(mm)	369.0	24.7			161.7	227.8	391.9	588.9	177.8	298.7	149.6	247.3	228.6	256.1
Jablanica															
2000-2019	ΣNI-WR(mm)	415.2	-17.2			193.2	279.4	451.2	657.0	204.1	329.9	166.4	268.2	260.8	291.6
Pčinja															
2000-2019	ΣNI-WR(mm)	420.4	8.3			205.0	291.2	457.8	657.4	219.2	340.6	179.5	277.6	270.1	302.5
Šumadija															
2000-2019	ΣNI-WR(mm)	350.9	1.6	209.8		160.1	213.0	374.2	568.2	178.8	298.7	147.1	244.3	228.2	247.9
Pomoravlje															
2000-2019	ΣNI-WR(mm)	383.2	-38.5	217.1		163.7	241.7	411.3	615.4	181.8	307.6	148.2	249.9	236.1	259.8
Raška															
2000-2019	ΣNI-WR(mm)	276.3	-81.6	141.5		89.7	124.9	281.0	468.9	106.3	222.3	80.6	174.4	154.5	169.9

Rasina															
2000-2019	ΣNI-WR(mm)	369.7	-19.2	213.3		161.6	234.2	399.4	597.8	180.6	302.8	145.5	244.5	234.3	255.4
Mačva															
2000-2019	ΣNI-WR(mm)	238.2	-149.7	118.4	362.5	68.2	77.4	232.5	419.1	85.5	202.2	61.2	156.1	132.1	154.1
Kolubara															
2000-2019	ΣNI-WR(mm)	248.8	-86.1			75.4	98.5	253.8	440.2	98.3	214.4	74.8	169.1	143.1	157.3
Moravica															
2000-2019	ΣNI-WR(mm)	297.6	-38.7			116.8	154.4	313.9	505.5	139.2	258.6	118.5	215.5	188.1	206.3
Zlatibor															
2000-2019	ΣNI-WR(mm)	154.0	-166.4			-77.8	3.3	131.0	285.3	30.4	126.3	18.7	96.4	68.6	60.9

The average seasonal In of the Bor District is 60.9 mm, while the highest In, 313.8 mm, is observed in the Zaječar District. The highest In was calculated for orchards (apple, pear, plum) in grassed orchards of about 560 mm, while in small grain crops a water surplus of -23 mm is observed on average. Although In is highest in orchards with grass covers, it should be noted that grassing has a positive effect on the microclimatic conditions in orchards, which has a positive effect on fruit quality and also protects the soil from erosion and degradation.

3.2 Use of mineral and organic fertilizers in agricultural production and greenhouse gases

Mineral fertilizers are nutrients that are introduced into the soil in the form of inorganic salts, and are obtained by extraction, physical and/or chemical industrial processes.

According to the data of the Statistical Office of the Republic of Serbia[38], the total production of mineral fertilizers in 2019 amounted to 550 thousand tons and was 14% higher than the production in 2017. In 2017 and 2018, 40% of the total production of fertilizers were other nitrogen fertilizers, 51-56% were complex fertilizers, while other types of fertilizers had a marginal share in the production. In 2019, complex fertilizers accounted for 75% of the total fertilizer production, 15% for ammonium phosphates, and 10% for other nitrogen fertilizers. About 75% of the fertilizers is used for the four most important field crops: maize, wheat, sugar beet and soybeans. Mineral fertilizers are mostly imported from Russia (about 60%), while far smaller quantities are imported from the European Union, mainly from Croatia, Austria, Hungary and Romania. In the observed three-year period, imports from these five countries accounted for 92% of the total imports of mineral fertilizers. By years, in 2017, 800 thousand tons were imported, in 2018, slightly over 500 thousand tons, and in 2019, over a thousand ton were imported. According to data more than a decade old, which has not changed significantly today, Serbia has an average

38 Report on the analysis of the state of competition on the wholesale market of artificial fertilizers in the territory of the Republic of Serbia in the period 2017-2019 (2020).- http://www.kzk.gov.rs/kzk/wp-content/uploads/2020/12/Izve%C5%A1taj-o-sektorskoj-analizi-na-tr%C5%BEi%C5%A1tu-mineralnog-%C4%91ubriva.pdf.

use of fertilizers on our arable agricultural land below 80 kg/ha of active NPK matter, which is about three times lower than in developed agricultural countries and about 1/3 in relation to the period before 1990 in Serbia[39]. Owing to this, it can be seen why the yields of many cultivated crops, especially cereals, are at the lower limit of profitability.

Organic fertilizers are a product of organic origin, plant and animal, in which nutrients are part of organic compounds, and are obtained by fermentation of plant and animal residues. The most famous and most used one is manure. Its quantity in Serbia can be calculated according to the conditional head (UG), and its composition and quality depend primarily on the animal species from which it originates. Also, the composition of manure can be affected by food consumption, amount of urine, as well as the type and amount of the mat used. Liquid manure, as well as solid manure, has its specific value as a fertilizer. Based on the number of heads raized at the end of 2020 and their conversion into conditional heads of the body weight of 500 kilograms and daily production of liquid manure by type[40] the amount of manure produced was estimated and is provided in Table 12.

Table 12. Estimation of the manure produced in 2018 in the Republic of Serbia based on the number of heads raised during 2020

Species	Number of heads	No. of conditional heads	Amount of liquid manure in t
Cattle	886 127	886 127	14421150
Pigs	2 983 102	596 620	6132000
Sheep	1 684 613	168 461	2187080
Goats	202 325	16 186	200312
Poultry	15 248 808	60 995	1168000
Horses	15000	12000	175200
Total		1740390	24283742

According to this estimate, 24.3 million liquid tons of manure are produced in our country annually. If 50 tons per hectare are used, the amount produced is sufficient to fertilize about 485,600 hectares of arable land. The value of the obtained manure for the production of field crops, as well as for meadows and pastures, is limited, because it does not contain all the necessary nutrients in adequate quantities, manipulation is difficult and it is unevenly distributed in areas, i.e. the places of intensive manure production do not always coincide with places of intensive application. An improper method of the preparation and application of manure can lead to water and soil pollution, and on the other hand, manure is a soil improver if used properly, increases fertility and has a beneficial effect on the flora and fauna of agrophytocenosis.

39 Stevanović, D., Kresović, M., Stojanović, M., Grubišić, M. (2009). The state of production and problems of application of mineral fertilizers in Serbia. Conferences of agronomists, veterinarians, technologists and agroeconomists, Institute PKB Agroekonomik, 15, pp. 169-175.

40 Radivojević, D., Topisirović, G., Stanimirović, N. (2004). Mechanization of livestock production, University textbook, Faculty of Agriculture, Belgrade

The ratio of the use of mineral and organic fertilizers in 2012 was as follows: area on which mineral fertilizer is used was 2,298,574 hectares, or 67% of the total area of used agricultural land. Solid manure was used by 49% of farms on the area of 373,871 hectares, which is 11% of the total area of used agricultural land[41].

The agricultural sector is one of the largest sources of greenhouse gas emissions which in EU countries in 2015 amounted to 10%[42]. Emissions of carbon dioxide, methane and nitrogen suboxide from the agricultural sector account for almost a fifth of the total greenhouse gas emissions. If the change in land use, including biomass combustion and land degradation, is taken into account, the total share of these gases increases up to one-third. One of the greenhouse gases is N2O which is released into the atmosphere most often as a result of microbial transformation of nitrogen fertilizers in the soil. The formation of N2O in agriculture represents more than half of the total emissions from agriculture. The total consumption of mineral fertilizers in Serbia is increasing from year to year, which shows that agricultural production is intensifying. In 2012, a total of about 400,000 tons of mineral fertilizers were consumed in Serbia, while in 2019 the consumption was twice as high. This fact, from the aspect of agricultural prosperity, seems good, but from the point of view of environmental protection, it is worrying. In particular, it should be borne in mind that plant nutrition, especially on smaller production areas, is carried out without proof that it is necessary and to what extent (without chemical analysis of the soil).

Animal husbandry and climate change are strongly interlinked, with both climate change affecting livestock production and livestock production affecting climate change through greenhouse gas emissions such as carbon dioxide, methane and nitrogen oxides. It is estimated that 14.5% of anthropogenic greenhouse gas production comes from livestock production[43]. The same authors state that 44% of methane emissions come from livestock production, primarily from the cattle sector (fattening and dairy) as a result of the fermentation of plant food in the rumen. In the case of greenhouse gas emissions, the disposal and manipulation of manure should not be neglected, as they participate with 25.9% in the total emissions of livestock production. The indirect emission of greenhouse gases is a consequence of the preparation of fodder, as well as the conversion of land that did not have that purpose and forests into agricultural land.

41 Census of Agriculture, 2012 Agriculture in the Republic of Serbia https://publikacije.stat.gov.rs/G2013/Pdf/G201314002.pdf https://ec.europa.eu/eurostat/statistics-explained/pdfscache/16817.pdf.

42 https://ec.europa.eu/eurostat/statistics-explained/pdfscache/16817.pdf.

43 Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A., Tempio, G. (2013). Tackling Climate Change Through Livestock: A Global Assessment of Emissions and Mitigation Opportunities FAO, Rome.

4 Specific risks and vulnerability in plant production

4.1Risk assessment and vulnerability in 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. In the first place in terms of total annual production is the apple, followed by plums, raspberries and sour cherries[44]. Based on the area under the orchards, plums are in the first place, followed by apples and raspberries (Table 13).

Plums are grown in the territory of the whole of Serbia, but the areas of western Serbia, Šumadija and a part of southern Serbia around Prokuplje stand out. The leading municipalities by area are Valjevo (4006 ha), Kraljevo (2351 ha), Kragujevac (2330 ha), Osečina (2265 ha) and Prokuplje (2049 ha). The largest areas under apples are located in the municipalities of Subotica (1596 ha), Smederevo (1340 ha), Grocka (1219 ha), Čačak (831 ha) and Arilje (778 ha). Significant areas are also in Srem, parts of Šumadija and southern Banat. Raspberry production is concentrated in western Serbia and in some parts of southern Serbia. The largest areas under raspberries are in the municipalities of Ivanjica (1249 ha), Arilje (1226 ha), Krupanj (759 ha), Brus (705 ha) and Bajina Bašta (694 ha)[45].

Table 13. Area, production and yield of the most important fruit species in Serbia 2014-2018

Species	Year	Area (ha)	Production (t)	Yield (t/ha)	Species	Year	Area (ha)	Production (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**
Rasp-berry	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**

44 http://www.fao.org/faostat/en/#data/QC

45 Keserović, Z., Magazin, N., Kurjakov, A., Dorić, M., Gošić, J. (2012). Census of Agriculture 2012 AGRICULTURE IN THE REPUBLIC OF SERBIA- FRUIT GROWING. Statistical Office of the RS, 1-94.

As perennial crops, fruit trees are more sensitive to climatological factors than other plant species. The most significant factors influencing yield oscillations are large temperature oscillations in spring (occurrence of late spring frosts), high temperatures during vegetation and drought. In addition to these factors, the sudden appearance of storms (strong wind and hail) has a significant impact on fruit species, which can cause great damage to orchards.

Fruit species differ from each other. From the aspect of resilience to climatic conditions, these differences are primarily reflected in the necessary temperatures for the start of vegetation (base temperature or biological minimum - TB), vegetation length, fruit ripening moment, etc.

All fruit species, depending on the moment of the start of vegetation, can be divided into four groups:

- Species that start with vegetation at average daily temperatures of 9°C (almonds and apricots).
- Species that start with vegetation at average daily temperatures of 10°C (peach, walnut, hazel, strawberry, currant).
- Species that start with vegetation at average daily temperatures of 11°C (plum, cherry, sour cherry, raspberry).
- Species that start with vegetation at average daily temperatures of 12°C (apple, pear, quince, blackberry).

In species that start with vegetation at lower temperatures, the probability of damage by late spring frost is higher.

In addition to frost, the limiting factor for successful and economically viable cultivation of certain species in certain localities in Serbia is the length of the vegetation period (DV), i.e. the period from the start of vegetation to fruit ripening[46]. According to this criterion, the shortest period of fruit development is in strawberries (90 days), and the longest in some cultivars of apples, pears, quinces, almonds, hazelnuts and walnuts (180 days). The period of fruit development in plums and peaches is 150 days. In localities in Serbia where the period of duration of temperatures that are lower than base temperatures is longer than the period of vegetation (DV), the fruits cannot ripen and these species are unsuitable for cultivation in this area. This usually happens on terrains with higher altitude.

Figure 11a, b, c, d shows the probability of frost occurrence (Tn <-2°C) after vegetation start at different localities in Serbia. After the start of vegetation, fruit trees become resistant to frost, i.e. to temperatures below -2°C. If frost occurs frequently in a certain locality in the period after flowering (more than three years in a ten-year period), that locality is not suitable for growing certain types of fruit trees.

46 Project: Regionalization of the fruit growing area in Belgrade, Southern and EasternSerbia. Ministry of Agriculture, Forestry and Water Management of the Republic ofSerbia, 2018-2020.

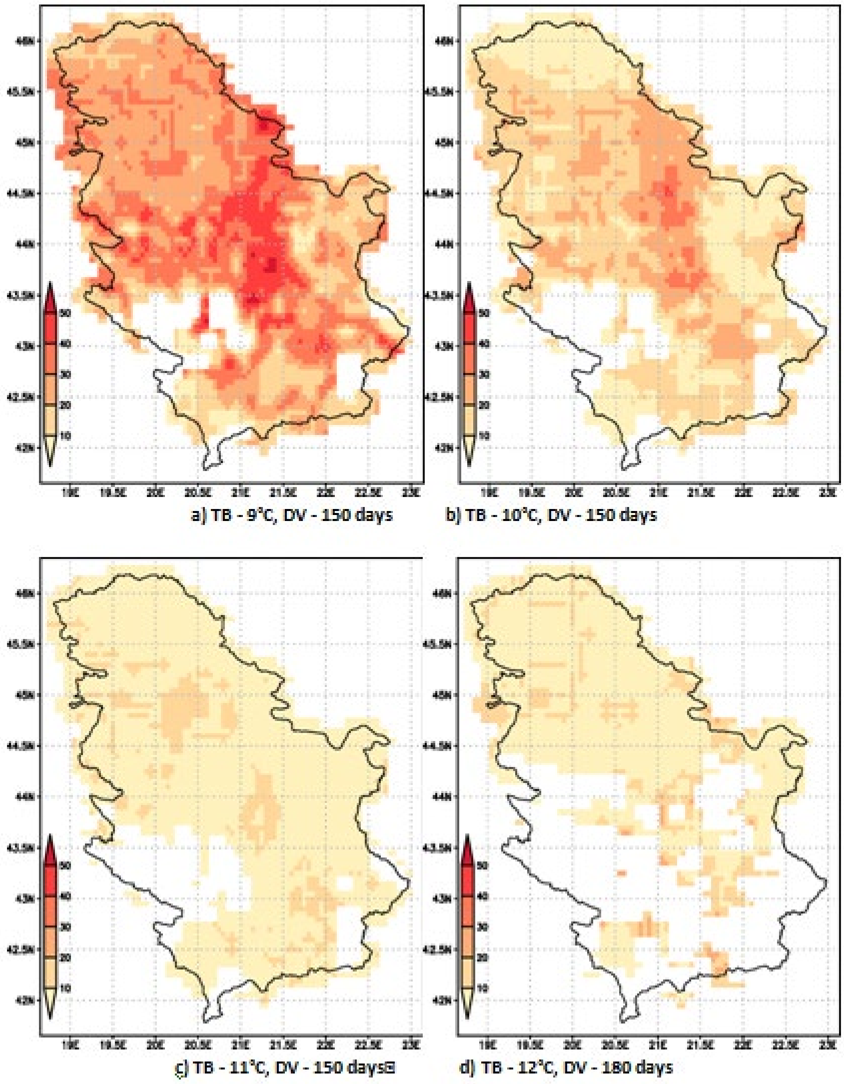


Figure 11 (a, b, c, d). Frequency of occurrence (Tn<-2°C) at the start of fruit vegetation depending on the baseline temperature (TB)

In addition, the same Figure shows the terrains where certain types of fruit trees cannot thrive due to the length of the vegetation (white color).

From the aspect of insufficiently long vegetation in 33.3% of the territory of Serbia or a third of the area, it is not possible to grow species that start later (TB - 12°C) and in which it takes 180 days for the fruits to ripen, such as apple, pear, quince, walnut, hazelnut. These localities are located in western, eastern and southern Serbia at altitudes higher than 700 m above sea level. Species in which TB is 11°C and where the vegetation lasts 150 days, cannot be grown in 11.7% of the territory of the Republic of Serbia. In species with TB 10°C and the vegetation of 150 days, they cannot be grown on 9.31% of the territory of Serbia. These localities are located at altitudes higher than 1000 m (Kopaonik, Pešter, Zlatibor, Golija, etc.). From the point of view of the sufficient length of vegetation, apricot and almonds can be grown most in the territory of Serbia (TB - 9°C, DV - 150 days). The limiting factor for the cultivation of these species is the high percentage of frost risk (probability of frost occurrence higher than 30% occurs in over 60% of the territory of Serbia) (Table 14). Territories of Serbia where the length of vegetation is insufficient, do not enter the % of the territory of Serbia where there is a different probability of frost.

Table 14. Percentages of the territory of the Republic of Serbia depending on the sufficiency of vegetation length and frost risk

Types of fruit trees	% of the territory of Serbia where the length of vegetation is insufficient	% of the territory of Serbia where there is a different probability of frost					
		<10%	<20%	<30%	<40%	<50%	<60%
TB- 9°C, DV – 150 (almond, apricot)	6.10	8.61	24.18	35.05	20.11	5.63	0.31
TB- 10°C, DV – 150 (peach, cherry)	9.31	39.98	36.15	13.07	1.49	0	0
TB- 11°C, DV – 150 (plum, sour cherry)	11.74	83.26	5.01	0	0	0	0
TB- 12°C, DV – 180 (apple, pear)	33.26	55.09	9.94	1.64	0.08	0	0

In addition to the above-mentioned limiting factors for the successful cultivation of various species in the territory of the Republic of Serbia according to the current climatic parameters, there is also the occurrence of hot periods, i.e. days with temperatures over 35°C. The greatest damage from extremely high temperatures occurs during fruit ripening.

Figure 12 shows the mean start date, end date and duration of the warm period in which Tx> 35°C occurs. High temperatures in the territory of the Republic of Serbia occur relatively often.

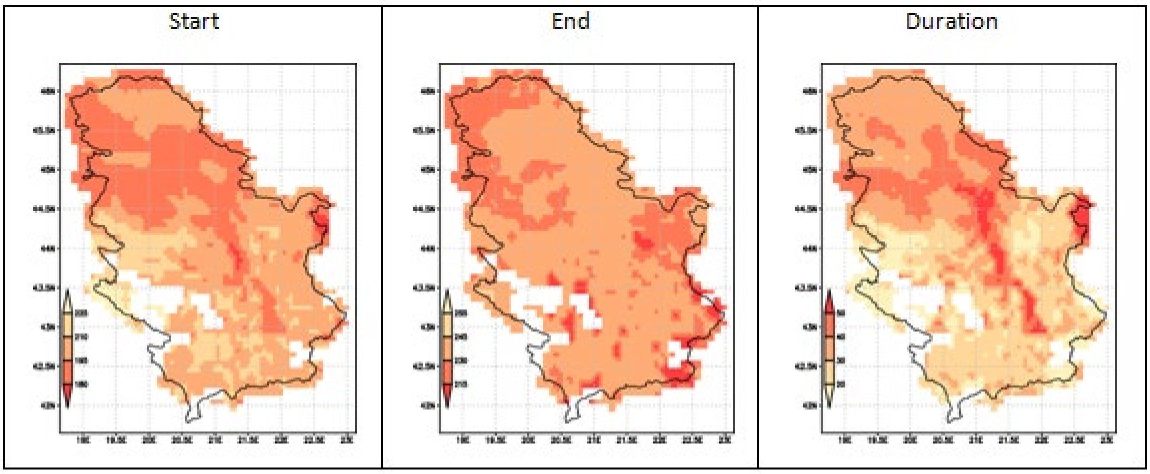


Figure 12. Mean start date, end date, and the duration of the warm period in which Tx> 35°C occur

Figure 13 shows the percentage of years in which Tx> 35oC appears at least once.

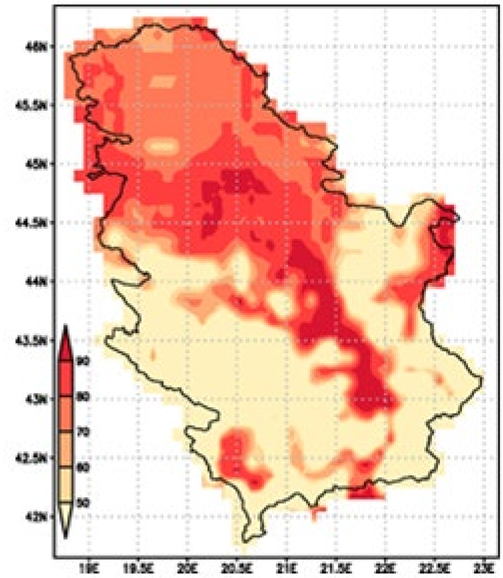


Figure 13. Percentage of years in which Tx> 35oC occurs at least once

High temperatures are especially harmful during the ripening period. Figure 14,showsthe number of days coinciding with the period of fruit ripening and the occurrence of the warm period in different localities for certain species. The higher the number, the more pronounced the problems with high temperatures.

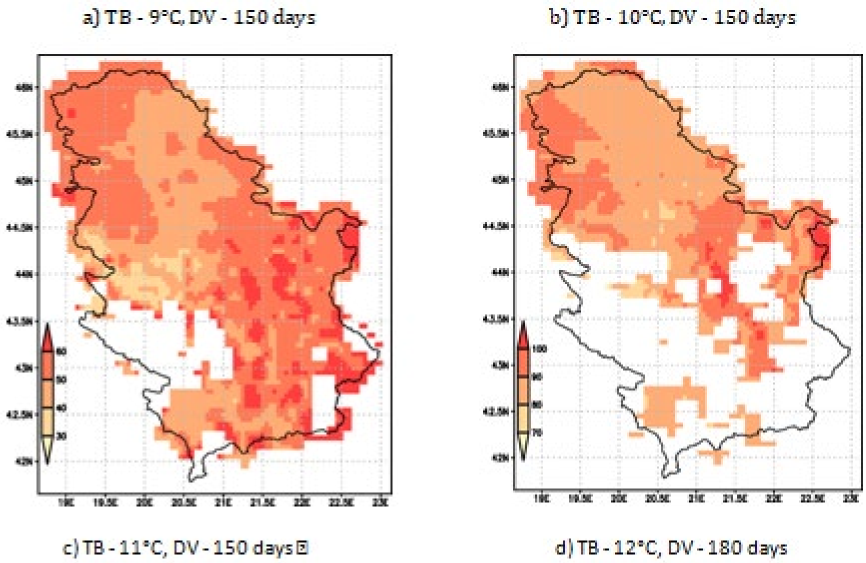


Figure 14 (a, b, c, d). Number of days of the coincidence of the period of ripening and the occurrence of the warm period depending on the baseline temperature and the length of vegetation

Table 15. Percentages of the territory of the Republic of Serbia, depending on the sufficiency of the length of vegetation and the number of days of overlapping of the warm period and the end of fruit harvest for areas in which it occurred at least in 10 years out of the observed 20 years.

Types of fruit trees	**1.**[1]	**The number of days of overlapping of the warm period and the end of the fruit harvest**										
		10%	**<20%**	**<30%**	**<40%**	**<50%**	**<60%**	**<70**	**<80**	**<90**	**<100**	**<110**
TB- 9°C, DV- 150 (almond, apricot	6.96	0.08	2.82	15.02	35.92	8.53	0.57	0	0	0	0	0
TB- 10°C, DV- 150 (peach, cherry)	9.70	0	0	2.19	18.31	36.15	6.18	0	0	0	0	0
TB- 11°C, DV- 150 (plum, sour cherry)	12.0	0	0	0	2.74	25.43	31.61	3.05	0	0	0	0
TB- 12°C, DV- 180 (apple, pear)	33.3	0	0	0	0	0	0	0.16	2.82	37.56	18.70	1.88

1 % of the territory of Serbia where the length of vegetation is insufficient + plus areas that do not have Tx>35o

In the case of fruit species which start later with vegetation (TB - 12°C) and with which it takes 180 days for the fruits to ripen (apple, pear, quince), the number of days of overlapping of the warm period and the end of fruit harvest greater than 90 occurs in 56,34% of the territory of Serbia (Table 5), which means that in more than half of the territory of Serbia, there are problems with high temperatures during fruit ripening (burns are created on fruits, fruits do not ripen properly, etc.). Species that start early with vegetation (TB - 9°C) and with which it takes 150 days for the fruits to ripen (almonds, apricots), the number of days of overlapping of the warm period and the end of fruit harvest greater than 50, occurs in 9.10% of Serbia.

The biggest problems with high temperatures in the period of fruit ripening are in the territory of Vojvodina and parts of southern Serbia (river valleys). Precisely on these terrains, especially in Vojvodina, one of the obligatory measures is the installation of shading nets in order to prevent the negative effect of high temperatures on fruit trees.

4.2Risk and vulnerability assessment in viticulture

The sector of grape production in Serbia is very specific because it is characterized by a large number of grape producers with small areas of vineyards. Based on the 2012 Census of Agriculture, 80,341 farms own vineyards, which is about 13% of the total number of listed farms (621,445 listed farms). Based on the Census of Agriculture (2012), the largest areas of vineyards (1,000 ha and more) are located in South Bačka (in the part that geographically belongs to Srem), Srem, South Banat, Bor, Pomoravlje, Rasina, Nišava and Jablanica districts (Figure 15)[47].

47 Viticulture and winemaking of Serbia. (2019). Study of the analysis of the grape production and wine production sectors. Center for Viticulture and Enology, Niš. Editor: Darko Jakšić.

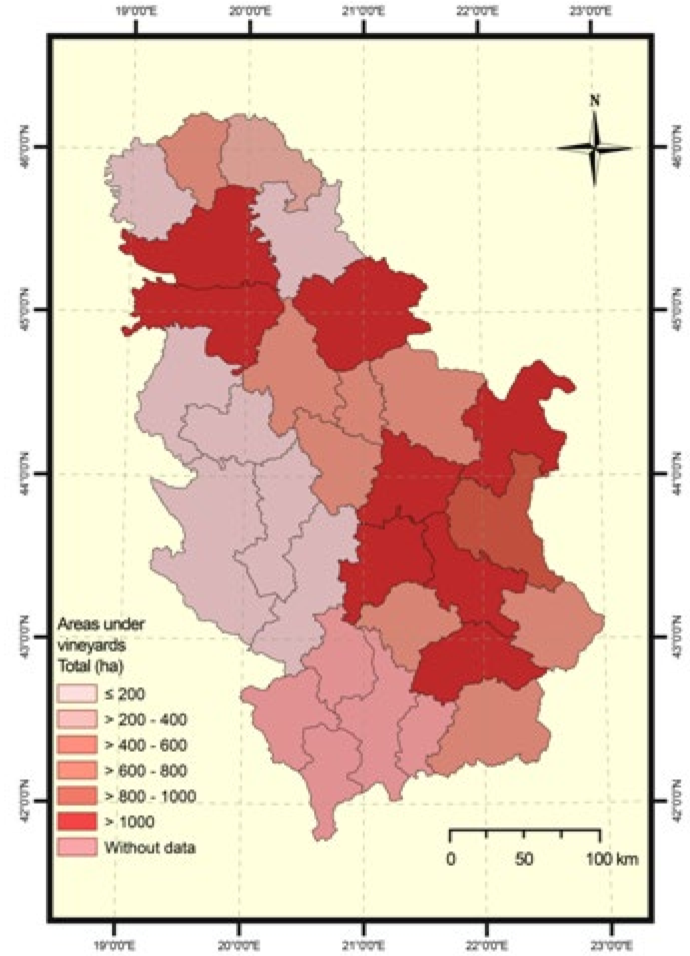


Figure 15. Distribution of vineyards by districts; 2012
Source: RSO, Census of Agriculture (Map: CEVVIN)[48]

In the Republic of Serbia, there are a total of about 25,000 ha under grapevines, of which 22,150 ha are statistically listed in central Serbia and Vojvodina. Wine cultivars are grown on 17,483 ha, which is 75.7% of the total area under vineyards. Cultivars whose grapes are intended for fresh consumption are grown on a total of 4667 ha, or 24.3% of the total area under vineyards (Census of Agriculture, 2012).

In the last five years (2015-2019), there was a slight decline in the area under grapevines and total grape production from 21,201 ha and 8049 t/ha (2015) to 20,501 ha 7976 t/ha (2019) (Chart 3)[49].

48 Viticulture and winemaking of Serbia. (2019). Study of the analysis of the grape production and wine production sectors. Center for Viticulture and Enology, Niš. Editor: Darko Jakšić.

49 http://www.fao.org/faostat/en/#data/QC

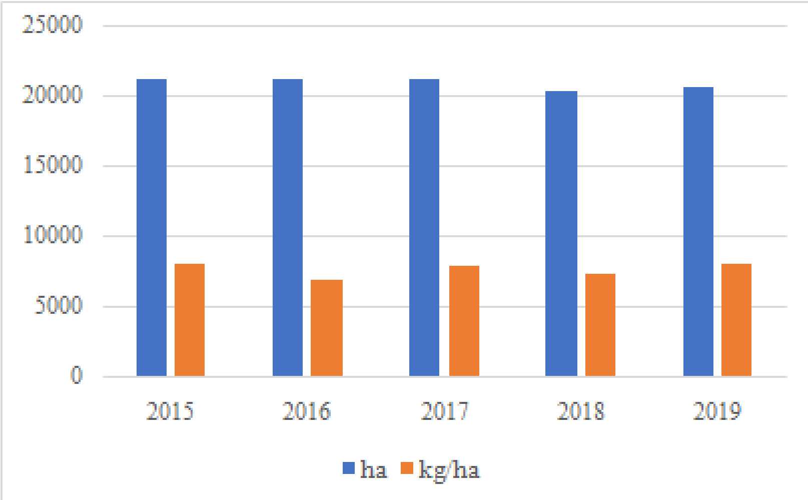


Chart 3. Vineyard areas and grape production in the Republic of Serbia in the period 2015-2019 (http://www.fao.org/faostat/en/#data/QC)

With the regionalization of vineyard geographical production areas, wine-growing Serbia covers the territory of the Republic of Serbia at an altitude of up to 800 m (Figure 16)[50], as well as areas above this altitude if they are on the list of regionalized areas with higher altitude. Within certain regions, there are parts of the territory with an altitude of more than 800 m (Figure 17)[51].

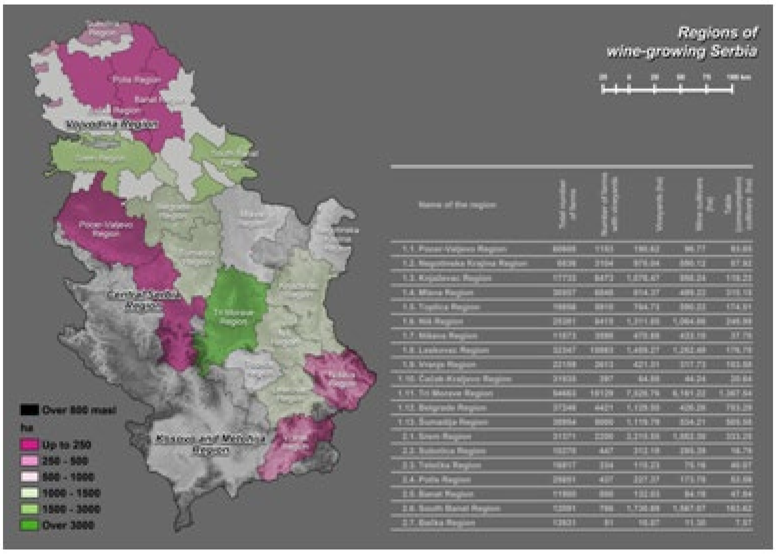


Figure 17. Regions of wine-growing Serbia[52]

The largest number of vineyard plots registered in the Viticultural Register is located at an altitude in the interval from more than 100 m to 200 m (39.54% of the total number of vineyard plots), and then in the interval from more than 200 m to 300 m (27.32%). Vineyards, located at

50 Viticulture and winemaking of Serbia (2019) Study of the analysis of the grape production and wine production sectors. Center for Viticulture and Enology, Niš. Editor: Darko Jakšić.

51 Dragoslav Ivanišević, Darko Jakšić (2014). Serbian viticulture through statistics and regionalization.

52 Dragoslav Ivanišević, Darko Jakšić (2014). Serbian viticulture through statistics and regionalization.

an altitude of over 300 m, represent 26.80% of the current vineyard plots entered in the Vineyard Register. A small number of vineyards are at higher altitudes (over 500 meters or more)[53].

Viticulture zoning divides the territory of Serbia into three wine-growing units (Vojvodina, central Serbia and Kosovo and Metohija) which comprise 22 regions, 77 wine-growing districts and a large number wine-growing oases, with their specific climatic and soil characteristics.

There are 13 wine growing regions within the wine-growing unit of Central Serbia (Figure 17):

1. Pocerje-Valjevo Region,
2. Negotinska Krajina Region,
3. Knjaževac Region,
4. Mlava Region,
5. Toplica Region,
6. Niš Region,
7. Nišava Region,
8. Leskovac Region,
9. Vranje Region,
10. Čačak - Kraljevo Region,
11. Tri MoraveRegion,
12. Belgrade Region,
13. Šumadija Region.

Within the region of Vojvodina there are 7 regions (Figure 17):

1. Srem Region,
2. Subotica Region,
3. Telečka Region,
4. Potisje Region,
5. Banat Region,
6. South Banat Region,
7. Bačka Region.

Figure 17 shows the data by region collected by the 2012 Census of Agriculture. The stated data refer to the number of farms that are engaged in grape production within a certain region, the total area of vineyards as well as the represented structure of cultivars. Most vineyards are located within the vineyard region of "Tri Morave" (7,528.76 ha, with 18,129 farms), and at the municipal level, most vineyards are listed in the Municipality of Trstenik. The fewest vineyards were recorded in the Bačka Region (18.87 ha; 51 farms with vineyards).

53 Viticulture and winemaking of Serbia (2019). Study of the analysis of the grape production and wine production sectors. Center for Viticulture and Enology, Niš. Editor: Darko Jakšić.

4.2.1 Climatic conditions in the regionalization of wine-growing Serbia

Climatic conditions and the appropriate choice of grape varieties are among the most important factors for the success of grape and wine production[54]. Changes in the phenological phases of many white and black grape cultivars have been observed in some vineyard regions in Serbia, mainly as a consequence of changes in thermal conditions. flowering, ripening and harvesting of grapes are significantly shifted, while a minor change was observed at budding[55].

The climate analysis for the purpose of the identification of homogeneous climate zones, and in order to regionalize wine-growing geographical production areas in the Republic of Serbia, was done on the basis of daily data from meteorological stations for a period of 50 years. Daily data for the 1961-2010 period were used from 103 stations. The indices were calculated for each year separately and then averaged over the number of years with available data[56].

Based on the analysis of the most important bioclimatic viticultural indices (AVG, WIN, HI, CI, DI, N0, N35, N15) an assessment of the suitability of the region for growing grapevines was performed (Chapter 2). In regionalization, the analysis of climate change was done for the 1961-2010 period, based on data obtained from RHMZ stations in Serbia[57]. Based on these processed data, the summary Table 16 shows the calculated viticultural indices for 20 regions of wine-growing Serbia, and the values of the Winkler index are shown through maps (Figures 18)[58].

Table16. Results for viticultural indices (1961-2010)

Station	AVG	WIN	HI	CI	DI	N0	N35	N15
Potcer-Valjevo region								
Šabac	17.4	1640.0	2183.9	10.9	187.1	3.6	4.5	1.9
Valjevo	17.0	1559.1	2092.6	10.8	246.2	4.6	3.3	2.2
RC Valjevo	17.4	1659.7	2051.0	13.1	221.4	2.4	3.0	0.4
Negotinska krajina region								
Negotin	17.8	1717.9	2278.1	11.5	127.5	3.8	4.6	2.8
Đerdap	18.0	1750.4	2198.2	13.5	159.9	0.6	1.1	0.4
Tekija	17.4	1624.2	2157.6	12.0	189.9	1.3	2.2	0.4
Donji Milanovac	16.8	1501.5	2044.2	11.7	124.9	1.4	1.8	0.6

54 Vujadinovic, M., Vukovic, A., Jaksic, D., Đurdjevic, V., Ruml, M., Rankovic-Vasic, Z., Przic, Z., Sivcev, B., Markovic, N., Cvetkovic, B., La Notte, P. (2020). Climate change projections in Serbian wine-growing regions. IVES- International viticulture and enology society, 65-70.

55 Ruml, M., Korać, N., Vujadinović, M., Vuković, A., Ivanišević, D. (2016). Response of grapevine fenology to recent temperature change and variability in the wine producing area of Sremski Karlovci, Serbia. Journal of Agriculture Science. 154(2):186-206.

56 Viticultural Atlas, 2015

57 Viticultural Atlas, 2015

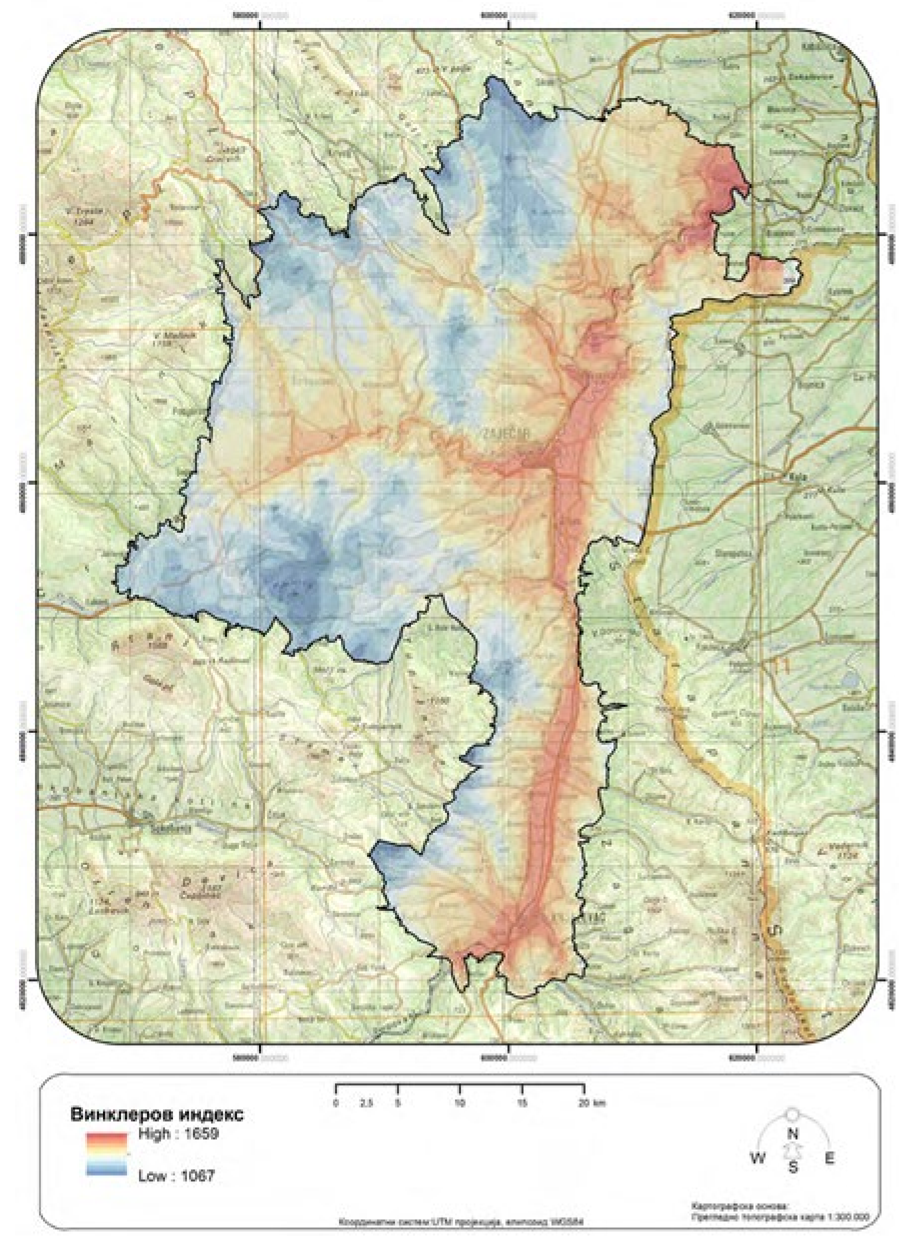
58 Viticultural Atlas, 2015

Station	AVG	WIN	HI	CI	DI	N0	N35	N15
Knjaževac region								
Knjaževac	16.8	1524.8	2167.1	9.3	150.7	9.2	7.0	2.2
Zaječar	16.8	1517.9	2142.3	9.7	151.8	8.1	5.1	3.1
Negotinska krajina region								
Mlava region	17.8	1717.9	2278.1	11.5	127.5	3.8	4.6	2.8
Đerdap	18.0	1750.4	2198.2	13.5	159.9	0.6	1.1	0.4
Tekija	17.4	1624.2	2157.6	12.0	189.9	1.3	2.2	0.4
Donji Milanovac	16.8	1501.5	2044.2	11.7	124.9	1.4	1.8	0.6
Toplički region								
Blace	16.0	1366.6	1912.2	9.7	185.5	6.7	2.2	2.0
Prokuple	17.0	1556.4	2151.7	10.2	138.0	5.8	7.0	2.4
Niš region								
Aleksinac	17.6	1676.4	2220.7	11.0	141.5	3.2	6.0	1.3
Niš	17.8	1713.8	2259.7	11.3	138.0	3.6	7.7	1.2
RC Niš	15.0	1208.8	1572.6	10.8	217.6	6.4	0.5	1.6
Sokobanja	16.2	1415.9	1993.7	9.5	180.3	7.3	3.2	2.3
Nišava region								
Babušnica	16.0	1363.7	1952.6	9.0	189.2	7.9	4.2	4.1
Bela Palanka	17.2	1596.1	2187.6	10.3	163.2	5.2	6.8	2.0
Dimitrovgrad	16.0	1357.3	1935.1	9.3	195.7	7.7	2.1	2.4
Pirot	16.5	1464.9	2042.2	9.7	170.1	6.9	4.1	2.0
Leskovac region								
Leskovac	17.0	1548.4	2143.8	9.9	153.8	6.8	5.8	3.1
Vlasotince	17.7	1703.0	2244.6	11.4	185.5	1.9	7.7	1.7
Vranje region								
Bujanovac	16.4	1432.1	2056.2	9.0	163.8	7.8	3.9	2.5
Vranje	16.8	1512.1	2064.1	10.4	154.0	4.7	3.3	1.4
Preševo	16.8	1511.4	2018.6	11.0	152.9	3.1	2.3	1.0

Station	AVG	WIN	HI	CI	DI	N0	N35	N15
Čačak-Kraljevo region								
Vrnjačka Banja	16.8	1523.2	2064.3	10.7	235.8	4.2	4.3	1.9
Kraljevo	17.1	1575.6	2108.4	10.8	220.5	4.1	3.4	1.7
Tri Morave region								
Aleksandrovac	16.8	1520.0	1990.5	11.0	166.3	2.7	1.5	2.0
Aleksinac	17.6	1676.4	2220.7	11.0	141.5	3.2	6.0	1.3
Brus	15.3	1232.8	1857.4	8.1	203.7	12.9	3.0	4.5
Ćuprija	17.0	1553.3	2140.5	10.1	183.9	7.9	5.9	2.5
Jagodina	17.6	1680.6	2229.0	11.0	149.2	3.3	6.3	1.9
RC Kruševac	17.1	1571.5	2130.0	10.4	173.5	5.5	4.9	2.9
Rekovac	16.8	1521.2	1899.7	12.0	180.7	2.7	1.4	0.6
Kruševac	17.1	1571.5	2130.0	10.4	173.5	5.5	4.9	2.9
Belgrade region								
Belgrade	18.3	1817.4	2252.3	13.2	174.9	1.0	3.6	0.3
Radmilovac	17.1	1571.2	2112.3	10.7	192.7	3.7	3.7	1.5
Surčin	17.6	1669.3	2163.0	11.9	182.7	2.7	3.6	1.4
Šumadija region								
Čumić	17.0	1564.9	1996.3	12.3	218.6	1.8	2.0	0.3
Kragujevac	17.2	1591.3	2133.2	11.0	181.8	4.0	4.3	2.2
Rudnik mountain	15.2	1263.9	1604.2	11.7	344.2	6.8	0.4	1.0
Smederevska Palanka	17.1	1580.4	2138.2	10.7	177.0	5.3	4.1	2.9
Bukovačka banja	16.7	1514.7	2010.0	11.3	209.0	3.9	2.7	1.3
RC Bešnjaja	16.1	1407.8	1758.6	11.9	253.7	4.1	1.2	0.9
RC Bukulja	14.9	1201.8	1542.2	11.7	282.0	7.0	0.0	1.3
Srem region								
Sremski Karlovci	17.8	1717.7	2150.7	12.8	148.9	1.4	2.7	0.5
Sremska Mitrovica	17.2	1591.8	2143.1	10.8	168.4	3.6	2.4	2.3
Subotica region								
Palić	17.1	1583.2	2102.5	11.2	151.2	3.6	1.8	2.2

Station	AVG	WIN	HI	CI	DI	N0	N35	N15
Telečka region								
Bačka Topola	17.1	1592.2	2118.2	11.3	145.8	4.2	2.8	1.6
Potiski region								
Bečej	17.4	1634.2	2167.0	11.2	160.9	4.7	2.6	2.6
Senta	17.7	1694.8	2228.8	11.4	140.9	3.2	5.2	1.7
Banat region								
Zrenjanin	17.4	1632.2	2153.8	11.4	152.9	4.2	2.7	2.5
Kikinda	17.3	1609.8	2133.2	11.2	147.7	4.0	2.2	2.2
South Banat region								
Vršac	17.3	1627.2	2140.7	11.4	192.6	6.3	2.5	3.3
Bela Crkva	17.4	1635.7	2163.5	11.4	199.4	5.4	3.6	1.8
Bačka region								
Sombor	17.0	1549.2	2102.8	10.4	169.2	5.4	2.5	2.7

Potcer-Valjevo region and Negotinska krajina region


Винклеров индекс
High : 1659
Low : 1067
0 2,5 5 10 15 20 km
N
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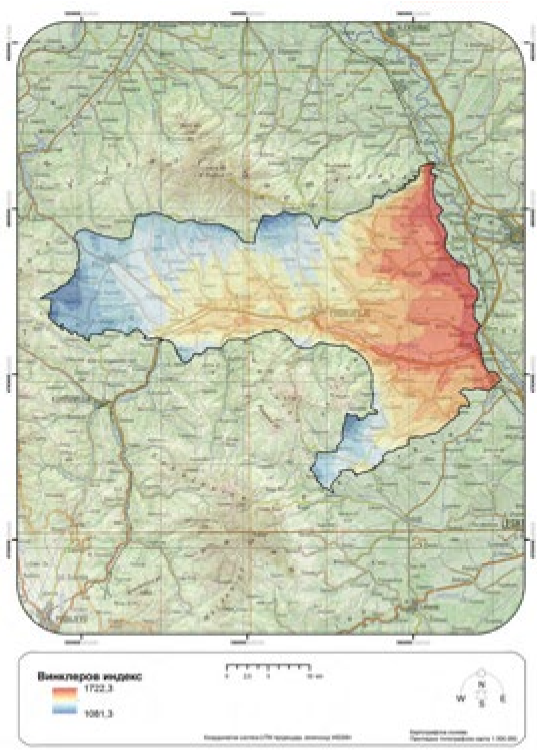
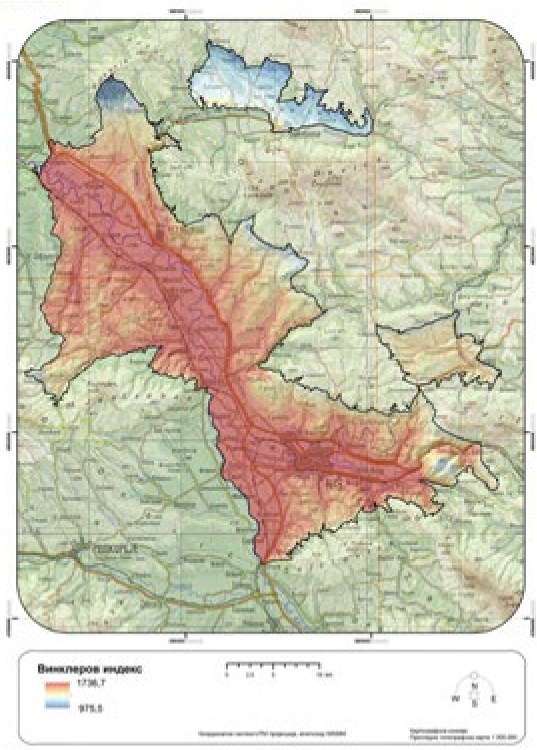
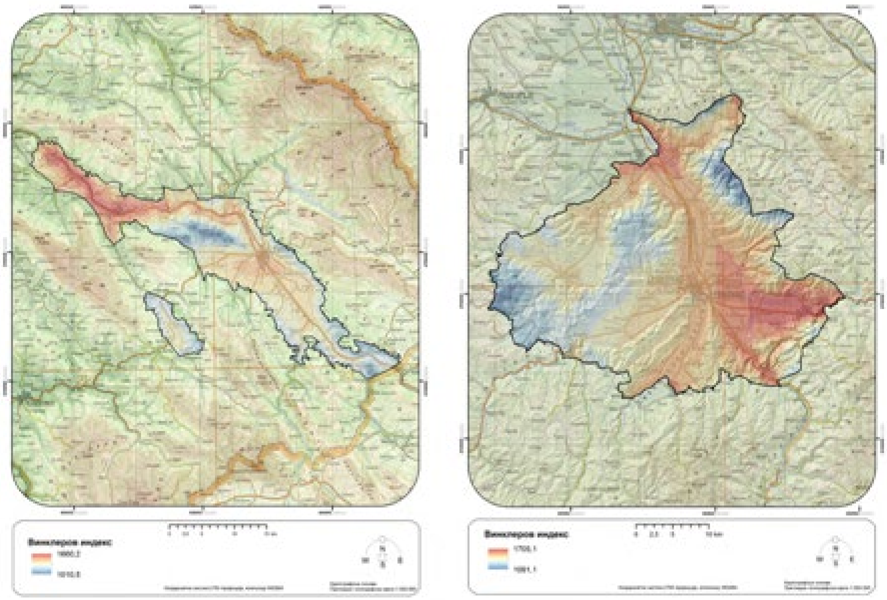
Координатни систем:UTM пројекција, елипсоид WGS84

Knjaževac and Mlava region

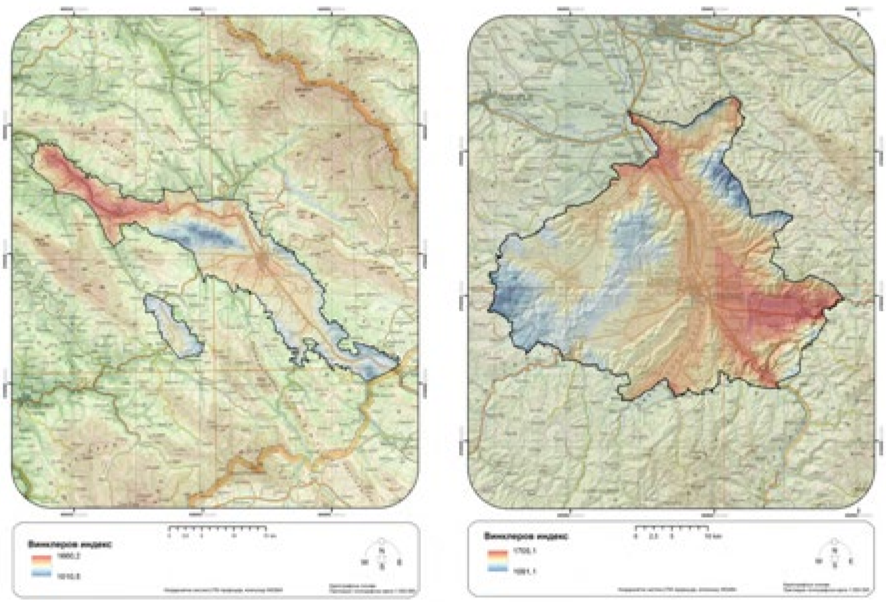




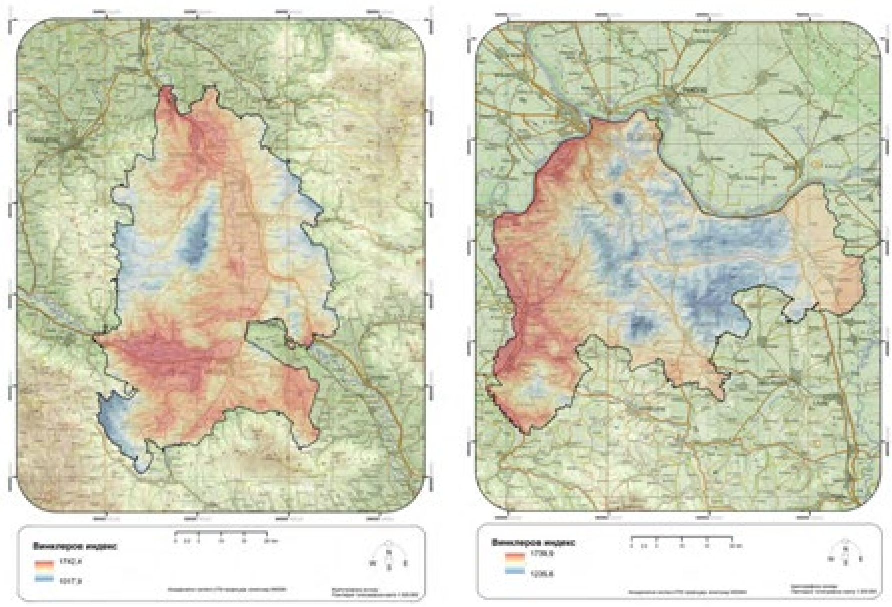
Toplički and Niš region



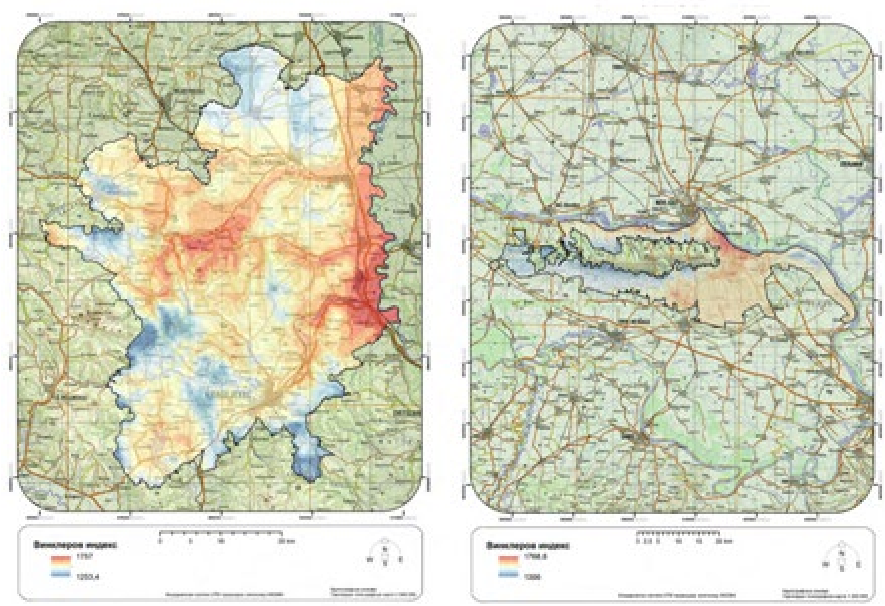
Nišava and Leskovac region



Vranje and Čačak-Kraljevo region

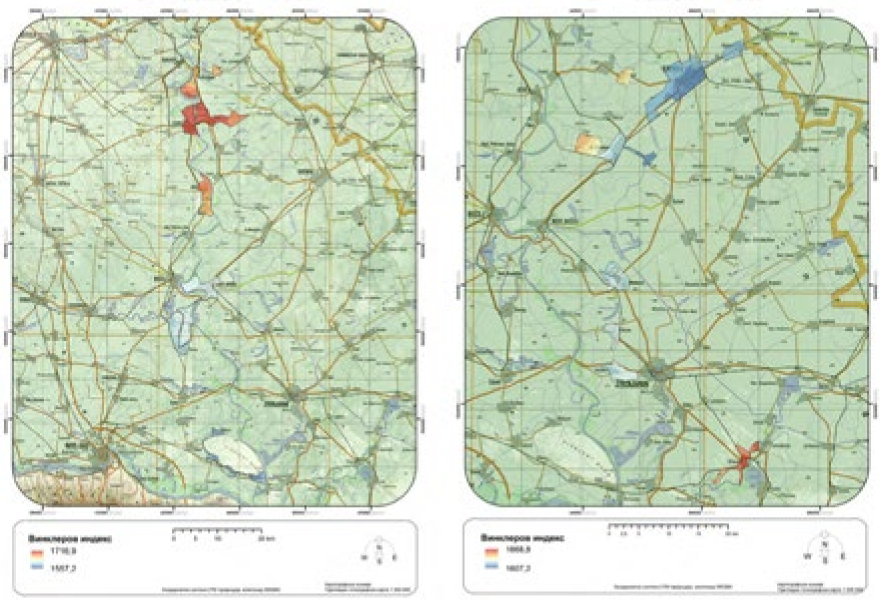


Tri Morave and Belgrade region

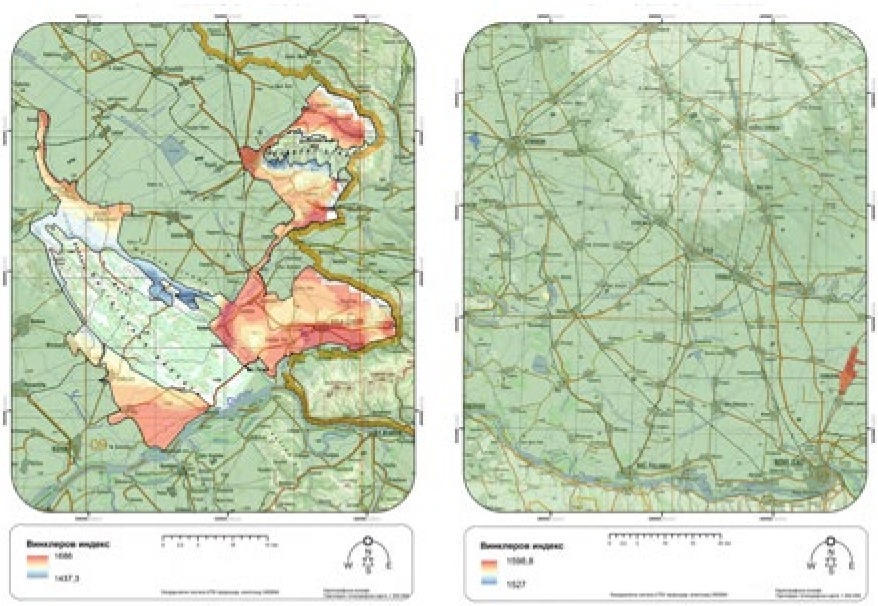


Šumadija and Srem region

Subotička and Telečka region



Potiski and Banat region



South Banat and Bačka region

Figure 18. Winkler index of wine-growing regions in Vojvodina and Central Serbia

(Source: Viticultural Atlas, 2015)

Based on the results shown in Table 16 and Figures 18, and According to the classification based on the AVG index, the vineyard regions of Serbia mostly fall into the warm category (17-19oC), which is suitable for ripening of a very large number of cultivars[59]. Vineyard regions of Serbia, on average (more than half) belong to the Winkler (WIN II) region (1389-1667oC).

Three viticultural climates, defined in the Multicriteria classification system (indices HI, CI and DI)[60], are present in Serbia: 1. moderately warm, humid with very cold nights (HI+1 DI-2 CI+2), examples are the regions of: Subotica, Bačka, Knjaževac; 2. moderately warm, sub-humid to humid, with very cold nights (HI+1 DI-1/DI-2 CI+2); South Banat, Banat, Potisje, Srem, Belgrade, Leskovac; 3. moderately warm, sub-humid with very cold nights (HI+1 DI-1 CI+2) (Telečka Region). Some regions (Šumadija, "Tri Morave", Nišava, Mlava...) partially have a temperate (HI-1), humid (DI-2) climate, and they also have very cold nights (CI+2).

In the moderately warm class, HI+1, there is practically no heliothermal restriction for the ripening of all cultivated varieties (with some exceptions such as seedless cultivars). Subhumid class DI-1 is characterized by the "absence of dryness", wet class DI-2 corresponds to the "absence of dryness" with a high level of water availability, which can negatively affect the quality of grapes and wine because the best quality is usually obtained in less humid years. Class CI+2, which is characterized by very cold nights, has a positive effect of low night temperatures on the color,

59 Jones, G.V. (2006). Climate and Terroir: Impacts of Climate Variability and Change on Wine. In Fine Wine and Terroir- The Geoscience Perspective. Macqueen R.W., and Meinert L.D. (eds.), Geoscience Canada Reprint Series Number 9, Geological Association of Canada, St. John's, Newfoundland, 247 p.

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

aroma and taste characteristics and depends on the heliothermal potential ensuring good ripening of grapes for a particular variety[61].

The largest number of days until 2010, based on the calculated data in the regionalization, in the vegetation period (April-October), with a minimum daily temperature of less than 0oC was in the region of Knjaževac (N0=8.1-9.2). This data indicates the danger of low temperatures that can cause damage to the grapevine, depending on how low the temperature is below 0ºC, how many days it lasted and in which phenophase it occurred. The lowest values of the N0 index were determined in Belgrade, Srem and the region of Negotinska Krajina.

The number of days in the vegetation period (April-October) with a maximum daily temperature greater than or equal to 35ºC indicates the risk of very warm days. In no vineyard region is the index (N35) less than 1, which means that very warm days occur every year. The exceptions are the Rudnik Planina station, RC Bukulja (Šumadija Region) and RC Niš (Niš Region), which do not even represent typical vineyard terrains for the given region. The highest number of days with a temperature higher than 35ºC was determined in the Niš (Niš station) and Leskovac (Vlasotince station) vineyard region and it was 7.7. High temperatures, if they occur during the ripening period of grapes (from the phenophase of veraison to the harvest), can affect the reduction of synthesis and degradation of anthocyanins, and thus the weaker color of grapes and produced wine[62].

In the region of Tri Morava (Brus station), the largest number of days in the dormant period was determined with a minimum daily temperature less than or equal to -15ºC, which was 4.5, which indicates the danger of low temperatures and damage that they can cause on the vines of certain cultivars. In the current climate, although the risk of severe winter frosts is reduced, it still exists in some localities (at higher altitudes or valleys possible occurrence of "cold air lakes" during the winter)[63]. It is important to consider the locality of cultivation, cultivar, in which part of the winter dormancy low temperatures occurred and what period of time they lasted. In other vineyard regions, the values of the H15 index are lower than the values for the Brus station (there is a certain number of days with such a low minimum daily temperature).

Table 6 shows the values of wine-growing indices in seven vineyard regions in different administrative regions of the Republic of Serbia for the periods of twenty (2000-2019) and ten (2010-2019) years, based on the processed data from RHMZ stations in Serbia. In relation to the results from the regionalization of wine-growing areas (Table 16 and Figures 18) changes in the values of the index are observed, which occurred both due to the calculation period and due to changes in the values of temperature and precipitation. The NTX35 index stands out in particular, wherein in some vineyard regions there was an increase in the number of days with temperatures higher than 35oC. In the Niš Region, in the last 10 years, there were 15.1 days with high temperatures, which is twice as much as in the period analyzed for the needs of regionalization (1961-

61 Ruml, M., Vuković, A., Vujadinović, M., Đurđević, V., Ranković-Vasić, Z., Atanacković, Z. (2012). Classification of Serbian winegrowing regions based on climate-viticulture indices. Proceedings 47th Croatian and 7th International Symposium on Agriculture (pp. 783-786). 13-17 February, 2012, Opatia, Croatia.

62 Rankovic-Vasic, Z. (2013). The impact of the ecological potential of the locality on the biological and antioxidant properties of the grapevine cultivar "Burgundac crni" (*Vitis vinifera* L.). University of Belgrade. Faculty of Agriculture. Doctoral dissertation.

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

2010). Other surveys also analyze vineyard indices or have already confirmed their changes[64] [65]. High temperatures during the ripening period of grapes can adversely affect the synthesis and content of phenolic substances, which leads to a decrease in the quality of grapes and wine[66].

Table 17. Values of wine-growing indices in seven vineyard regions (2000-2019 and 2010-2019)

Period	Region/ Station	Tveg	Rveg	NTN15	NTX35	NTN0	WIN	CI	HI	DI	VegStart	VegEnd	VegL	SF	AF
2000-2010	Negotinska krajina / Negotin	19.1	396.7	2.0	9.2	2.2	1968.4	12.9	2530.0	52.7	5.4.	2.11.	212.2	28.3.	1.11.
	Niš Region / Niš	19.0	382.8	1.0	14.7	2.5	1946.6	12.3	2499.1	53.7	6.4.	2.11.	210.9	2.4.	29.10.
	Subotica / Palić	18.3	406.2	1.2	4.3	1.9	1807.2	12.2	2331.4	82.3	8.4.	29.10.	204.6	28.3.	31.10.
	Tri Morave / RC Kruševac	17.7	430.5	0.6	2.8	1.3	1709.2	12.8	2113.1	93.0	13.4.	27.10.	198.5	26.3.	8.11.
	Vranje Region / Vranje	17.7	377.1	1.3	7.9	4.1	1686.5	10.8	2275.1	75.5	12.4.	2.11.	204.9	9.4.	25.10.
	South Banat / Vršac	18.5	441.4	2.3	6.8	4.7	1852.4	12.2	2388.1	91.9	7.4.	4.11.	211.9	9.4.	19.10.
	Pocerje-Valjevo / Valjevo	18.3	532.6	1.5	8.0	2.8	1802.8	12.0	2327.0	116.5	8.4.	3.11.	210.1	1.4.	29.10.
2010 - 2019	Negotinska krajina / Negotin	19.4	393.5	2.1	9.4	1.5	2035.8	13.5	2607.5	29.1	29.3	2.11.	219.2	21.3	2.11.
	Niš Region / Niš	19.2	371.7	0.7	15.1	1.8	1990.0	13.0	2537.9	32.8	7.4.	6.11.	213.9	28.3.	30.10.
	Subotica / Palić	18.4	408.3	1.0	5.7	1.1	1840.0	12.7	2371.4	75.8	4.4.	28.10.	208.1	24.3.	31.10.
	Tri Morave / RC Kruševac	18.0	443.5	0.6	2.8	0.5	1761.3	13.5	2174.0	77.4	11.4.	29.10.	201.9	24.3.	10.11.
	Vranje Region / Vranje	18.0	370.1	1.0	9.0	3.4	1750.7	11.4	2346.0	56.3	11.4.	6.11.	210.6	9.4.	25.10.
	South Banat / Vršac	18.7	460.9	1.7	8.0	4.2	1898.3	12.6	2444.0	89.7	4.4.	5.11.	215.2	6.4.	16.10.
	Pocerje-Valjevo / Valjevo	18.6	552.0	1.3	9.5	1.7	1873.4	12.7	2397.1	96.2	6.4.	4.11.	213.6	29.3	31.10.

**VegStar – start of vegetation; VegEnd – end of vegetation; VegL – length of vegetation; SF – date of the last spring frost; AF – the date of the first autumn frost*

The last 7 years in the territory of wine-growing Serbia represent a record warmest 7 years, which means that the increase in temperature has been accelerating over the last decade and will continue to grow. These changes indicate the need to plan the adaptation of wine production and the entire wine sector in order to make the best use of the potential of *terroir*[67].

64 Project: Integrated system of agro-meteorological forecasts (IAPS). Science Fund of the Republic of Serbia. Promis Program, 2020-2022.

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

66 Rankovic-Vasic, Z. (2013). The impact of the ecological potential of the locality on the biological and antioxidant properties of the grapevine cultivar "Burgundac crni" (*Vitis vinifera* L.). University of Belgrade. Faculty of Agriculture. Doctoral dissertation.

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

4.2.2 Characteristics of thecurrent climate in vineyard regions

Based on climatological data from the E-OBS database[68] spatially interpolated meteorological data for Europe, vineyard indices were calculated for two multi-year periods (1961-2010 and 2010-2019) and maps were created. Figures 19 and 20 show differences in the mean vegetation temperature between the two periods.

Average vegetation air temperature (Tveg) in the wine - growing regions of wine - growing Serbia

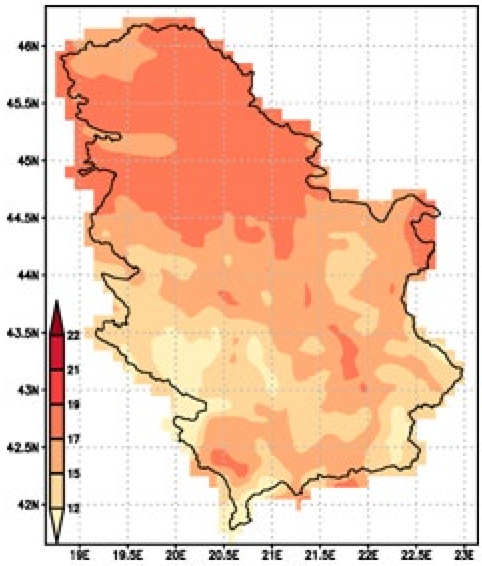


Figure 19. Mean vegetation air temperature for the period 1961-2010

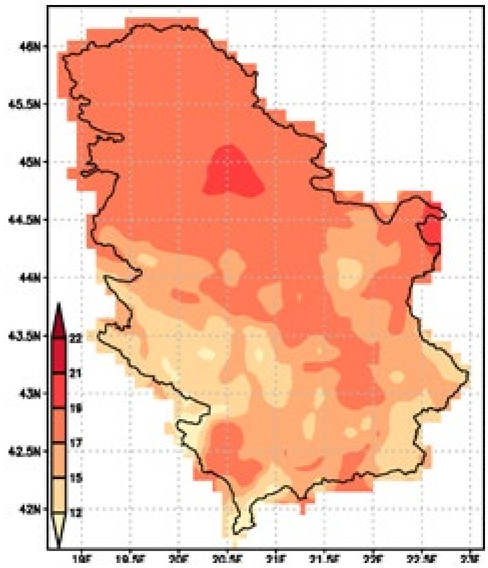


Figure 20. Mean vegetation air temperature for the period 2000-2019

Winkler's (WI) and Huglin's (HI) index in the wine-growing regions of wine-growing Serbia

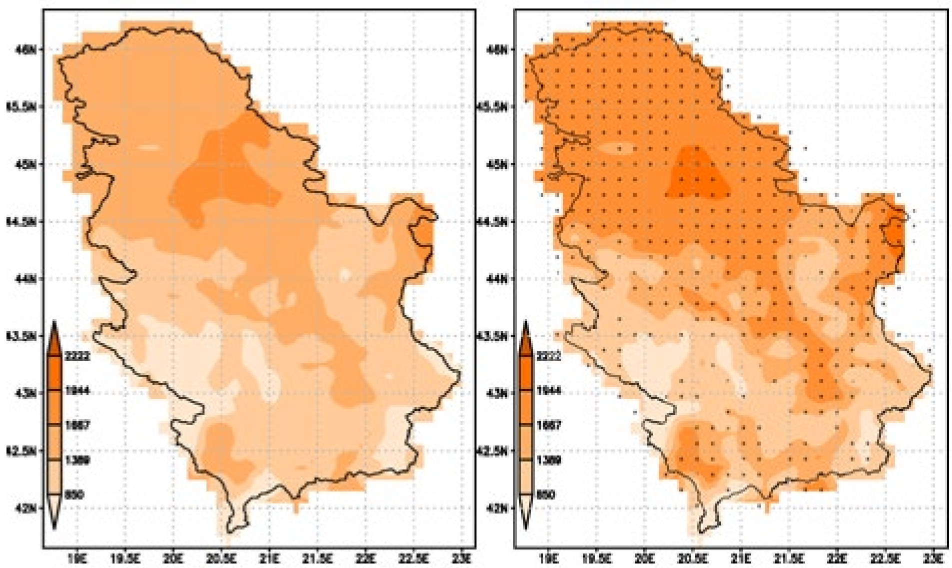


Figure 21. Winkler index a) 1961-2010; b) 2000-2019.

68 https://www.ecad.eu/download/ensembles/download.php

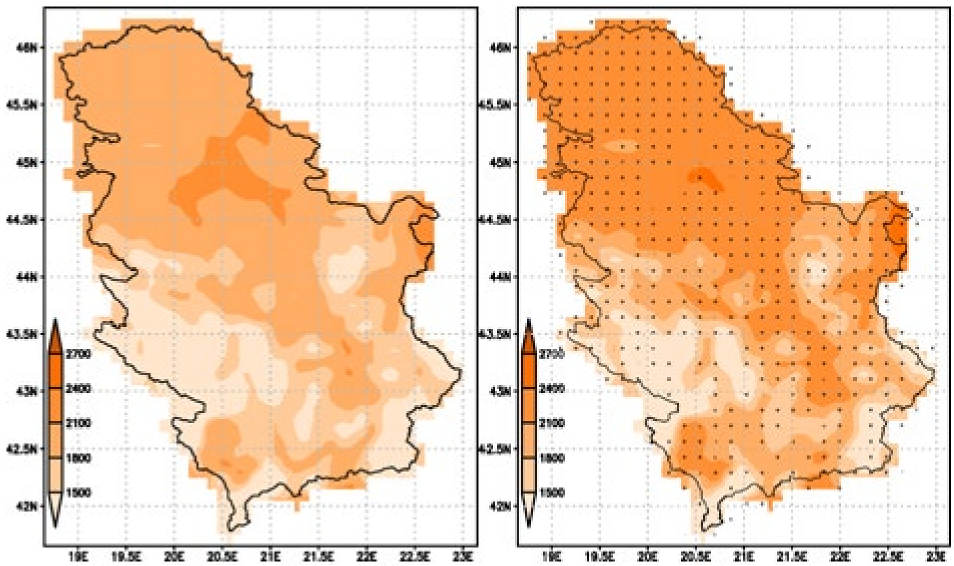


Figure 22. Huglin index a) 1961-2010.; b) 2000-2019.

From the WIN II category (1389-1667) some regions moved to the WIN III category (1668-1944) and some even to WIN IV (1945-2222). A large part of the territory is in the WIN III region, and Vojvodina, Srem, Mačva, Pocerina, the Morava valley, parts of eastern and southern Serbia are in the HI+1 category (moderately warm, 2100-2400).

Figure 23 b,indicates zones in Banat, Srem, the region of Belgrade, the valley of the three Moravas ("Tri Morave") where there were changes in the value of humid (DI-2) to the sub-humid climate and the category of index DI-1. Also, in the same annex, Figure 24 b shows changes in the value of the index of the freshness of the night from CI+2 (less than 12ºC - very cold nights) to CI+1 (12-14ºC - cold nights).

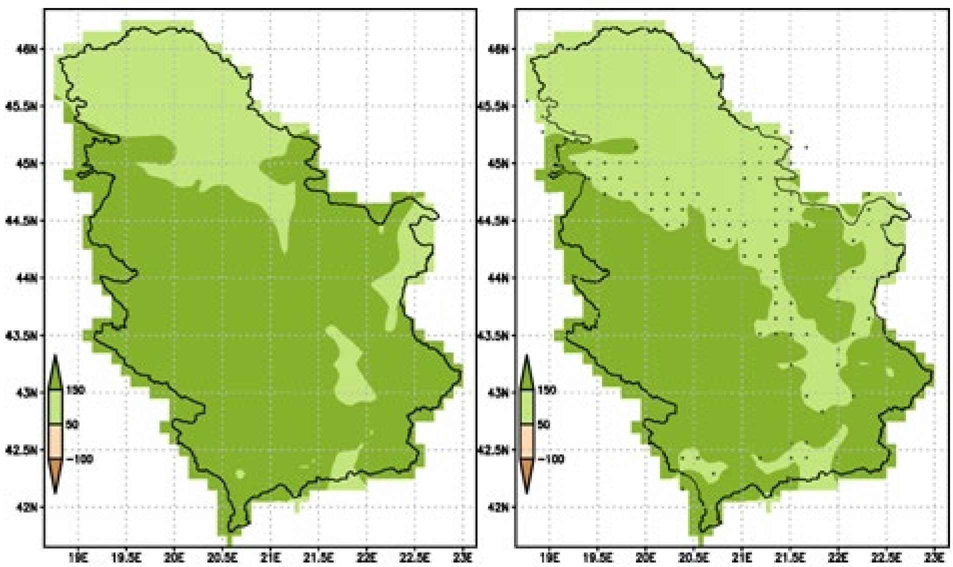


Figure 23. Drought index (DI): a): 1961-2010. b) 2000-2019.

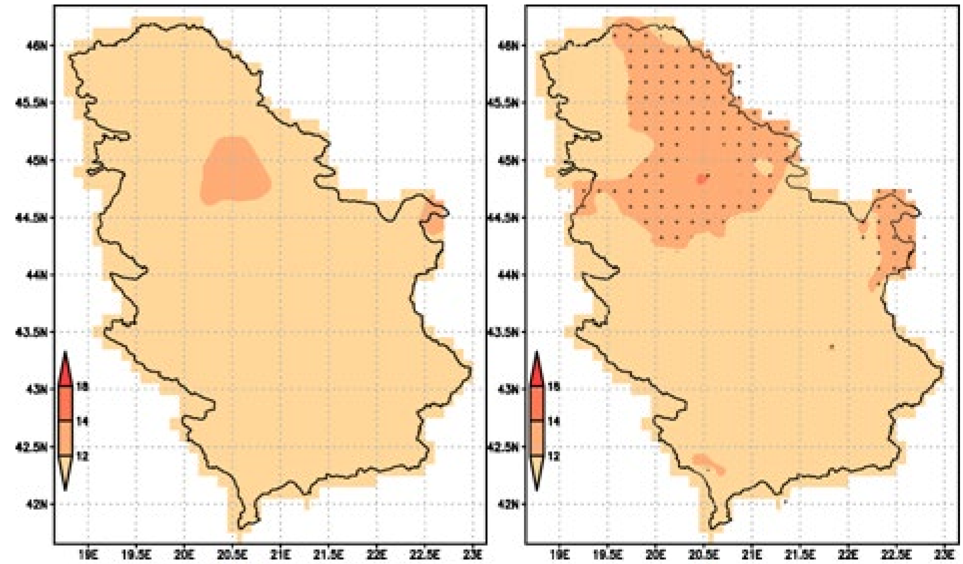


Figure 24. Night coolnes index (CI): a): 1961-2010; b) 2000-2019.

These changes have been identified in the last 10 years in the region of Belgrade, in Srem, Banat, and the eastern parts of Serbia.

The number of days in the vegetation period (April-October) with a maximum daily temperature greater than or equal to 35ºC is shown in Figures 25 a and b. In the multi-year period, the maximum number of days with 35ºC and higher degrees in the territory of Serbia was 2, while in the last decade this number has been higher than 10. i.e. 12 days in some regions.

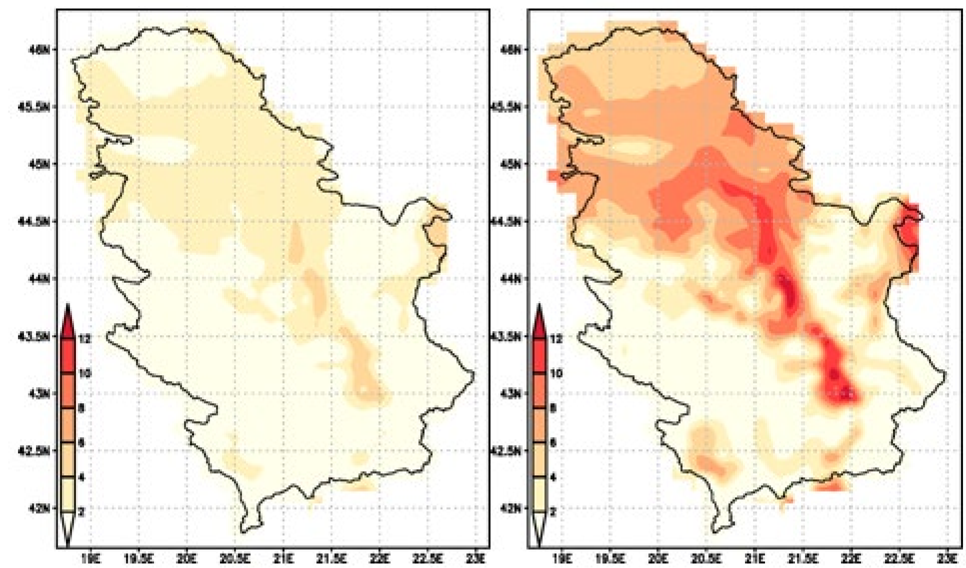


Figure 25. NTX35 index values: a) 1961-2010; b) 2000-2019.

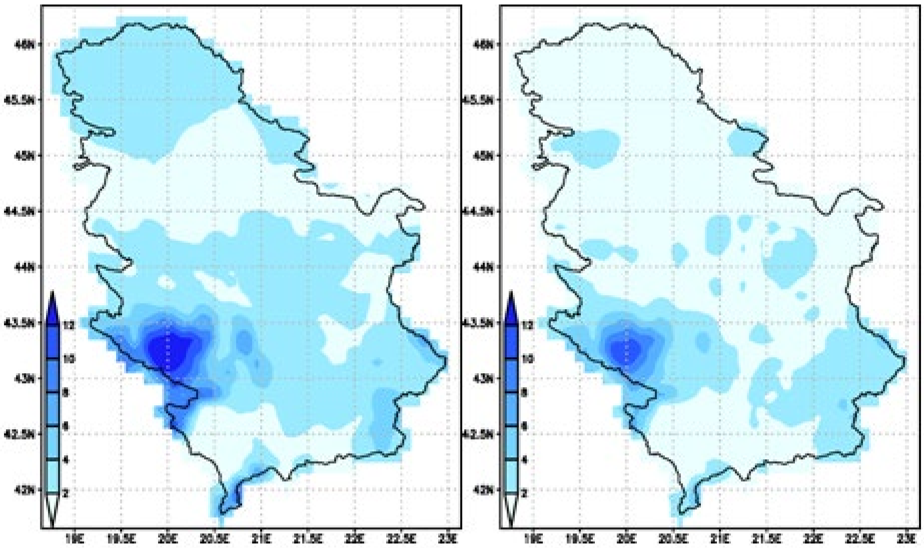


Figure 26. NTN15 index values: a) 1961-2010; b) 2000-2019.

A significant part of the territory of Serbia (northern Vojvodina, parts of the South Banat Region, central and southern Serbia) which in the first analyzed multiannual period (1961-2010) had up to 4 days with a minimum daily temperature of less than or equal to -15ºC, in the last decade no longer has days with such a low temperature (Figures 26 a and b).

Figures 27 a and b show the increase in the amount of precipitation (Rveg) in the vegetation period (April-October), especially in those parts of Serbia with the amount of precipitation from 300 to 450 mm.

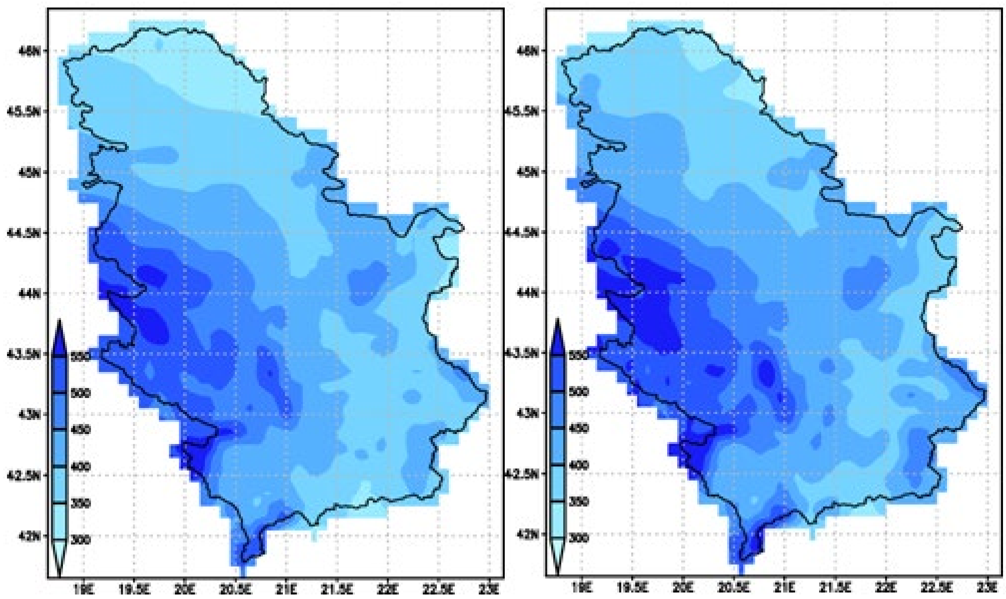


Figure 27. Total vegetation amount of precipitation: a) 1961-2010; b) 2000-2019

Large amounts of precipitation, especially in the period May-July, can adversely affect certain phenological stages of development (e.g. flowering, berry germination, berry growth) and intensify the development of the disease. The occurrence of hail is a special threat[69]. All this can negatively affect the yield and quality of the produced grapes.

Comparing the obtained values with the values for the period 1961-2010, which was used as a representative climatic period for the regionalization of wine-growing areas of Serbia, it can be seen that in relation to that period, the climatic conditions have changed significantly. This variability and change of the most important bioclimatic indices important for viticultural production indicate the necessity of projections for future years and the need to adopt various adaptation measures that would maintain or improve the quality of grapes and increase vineyard areas.

4.3 Impact of climate change on crop production - observed phenomena and levels of affectedness

Unlike animal husbandry, field crop production has not had a significant decline in the area represented since the beginning of the 21st century. When it comes to yield, they are increased in most crops, owing to significant progress in the field of breeding and the application of agro-technical measures. The supply of plants with heat and moisture both before sowing and during the vegetation period (from sowing to collection/ harvesting /extraction) also significantly affects the yield. For each crop species, there is a critical period for water and heat, with some shorter and some longer duration, and if in those periods unfavorable conditions of either humidity or heat are present, the yield will inevitably be reduced, both in quantity and quality, without considering the supply of crops with these conditions in the rest of the vegetation period.

Yield losses from the drought that hit Serbia in 2012 among field crops were extremely high and compared to the average, yields were reduced by 55% (maize), 50-70% (soybeans), 30% (sunflower). The drought, especially during the summer months of 2017, caused great damage, especially to soybeans, which amounted to about 200 million dollars. In the last decade, beans have been constantly reducing yields, which affects the price increase, as well as potatoes, whose yields have been significantly reduced in the last ten years.

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 temperatures during the year and an increase in temperatures, as well as a sharp increase in summer and tropical days. In the conditions of climate change, numerous changes are observed in terms of the occurrence of diseases and pests. Recently, as a consequence of hot summers, especially during the month of August, we have had a pest-potato moth (*Phthorimae operculella*) originating in the tropics, as well as tomato pests (*Tuta absoluta*) and others[70]. The

69 Project: "Improvement of medium-term and long-term planning of adaptation measures to changed climatic conditions in the Republic of Serbia- NAP" (2019-2022). Funded by the Green Climate Fund, and implemented by the United Nations Development Program (UNDP), in cooperation with the Ministry of Agriculture, Forestry and Water Management. Report 1: "Analysis of the availability of climate and socio-economic information, including climate data, data on risks and impact assessments and information on adaptation measures".

70 Dolijanović, Ž., Kovačević, D., Oljača, S., Simić, M. (2020). Adaptation of agrotechnical measures in arable farming to climate change. Scientific conference "The importance of development research and innovation in the function of improving agriculture and forestry in Serbia" Faculty of Forestry, University of Belgrade, November 4, 2020. Academy of Engineering Sciences of Serbia- AINS, Department of Biotechnical Sciences, Belgrade. Proceedings, 60-71.

results show that the total potential of the yield of maize has increased by 0.15 million tons per year over the last five decades due to the increase of the cultivated area. The reason for the increase in the area under maize is the strengthening of the intensity of climate change. The main meteorological factors that influenced the yield potential of maize are solar radiation with 47%, while the share of temperature changes was 16%[71].

The average long-term air temperatures and precipitation for the territory of the Republic of Serbia in the period 1921-1940 and 1961-1990 were (10.2 and 10.1°C) and the precipitation was 721 and 734 mm, which can be stated to be approximate values[72]. However, for the period 1991-2019, the situation is different, both in terms of air temperatures and in terms of precipitation. By analysing the data of RHMZ of Serbia (Figure 28) we notice that there is a trend of increasing temperatures during the winter months, but the most significant change in this period compared to the previous one is the increase in air temperatures during the summer months (June, July and August).

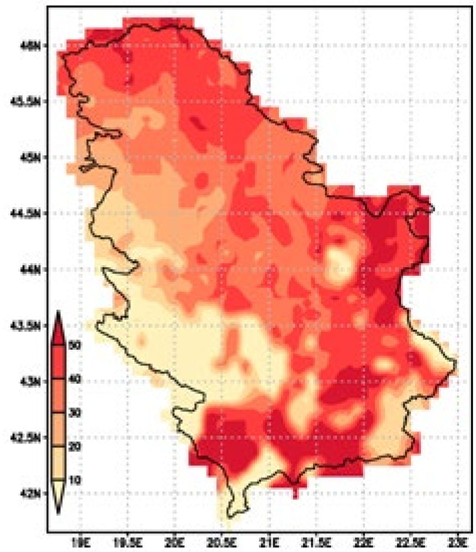


Figure 28. Change in the frequency of high temperatures and drought period 2000-2019 compared to 1961-2010 (%)

The increase of air temperatures during the winter has a negative effect on winter crops (wheat), interfering with the process of plant hardening and the accumulation of osmotically active substances, while sudden and short-term cooling leads to the weakening of crops. The increase in air temperatures during the summer is especially negative for spring crops, because most of these crops in those months are in a critical period, i.e. very sensitive to temperatures above the optimal ones. This is especially pronounced if the heat waves last longer, and such waves were recorded in 2000, 2007, 2012 and 2017.

71 Xu, X., Wang, L., Sun, D., Liu, L., Banson, K.E. (2017). The Impact of Climate Change on Yield Potential of Maize across China. International Journal of Plant Production, 11 (1): 47-64.

72 Dolijanović, Ž., Kovačević, D., Oljača, S., Simić, M. (2020). Adaptation of agrotechnical measures in arable farming to climate change. Scientific conference "The importance of development research and innovation in the function of improving agriculture and forestry in Serbia" Faculty of Forestry, University of Belgrade, November 4, 2020. Academy of Engineering Sciences of Serbia- AINS, Department of Biotechnical Sciences, Belgrade. Proceedings, 60-71.

Since the main plant production takes place in the conditions of temperate-continental climate in the plains and hilly areas, it is important to point out that the temperature rises quite sharply in the spring, and such is, only reversed, the temperature drop in the fall. The length of the period with medium temperatures above 10°C, which are the temperatures for the vegetation of spring crops (maize, sunflower, sugar beet, potatoes, etc.), is about 200 days. Mean temperatures above 20°C last for three summer months, somewhere around 80 days. The frost-free period lasts, on average, from April 1 to November 15 - about 230 days. The annual amount of precipitation is 600–750 mm. The ratio between the precipitation of the warm (April 1 - November 30) and cold part of the year is 55-60% to 40-45%. In other words, although there is more precipitation during the growing season for spring crops, there is often a problem of its lack during the months of July and August. The maximum precipitation is in June, and the lowest is in January and February. The lack of precipitation in January and February is unfavorable for winter crops because it affects the reduction of flowering intensity and preparation for the intensive growth and absorption of nutrients. On the other hand, this precipitation is the basis of winter moisture reserves which are necessary for the optimal tillage for spring crops and their supply in the initial stages of growth and development. High air temperatures during July and August, followed by a lack of precipitation, are the most important reason for the decline in spring crop yields, not only in quantity but also in quality. Namely, the increased level of aflatoxins in maize grain in 2012 occurred due to the fall of "*plant immunity*" caused by drought, because in any other case, fungal diseases are more present in wetter conditions. High temperatures during the summer, after the harvest of small grain crops, are unfavorable from the aspect of water evaporation from the surface layer of the soil, which negatively affects the basic cultivation (plowing) for sowing winter crops. Based on the geographical position of Serbia, it can be said that the conditions for agricultural production of important field plants are largely favorable. The higher areas have the characteristics of a mountain climate, but it is not so important for crop production, but for livestock production[73]. The relief affects cultivated plants, by influencing the climate and the soil. The most important factors in the relief are altitude, slope and exposure.

Annual precipitation amounts, on average, increase with the altitude. In the lower regions, the annual precipitation ranges from 540 to 820 mm. Based on this, it could be said that there is enough of it for growing most field and vegetable crops. Also, in different parts of central Serbia, the amount is generally satisfactory, although there are extreme years with a lack of precipitation (dry periods), which affect a significant reduction in yield. The distribution of precipitation in the cultivation of plants under the natural regime of wetting in our country often has a decisive influence on the occurrence of shorter or longer dry periods. A favorable distribution of precipitation during the year could be the one providing a relatively large number of rainy days, as well as equal intervals between rainy and rainless periods, especially during the vegetation period of plants. The occurrence of longer rain-free periods in spring and autumn, especially in years with a dry summer when the drought transfers into autumn, regularly affects small grain crops due to uneven and long germination. In the conditions of a favorable

73 Project: "Improvement of medium-term and long-term planning of adaptation measures to changed climatic conditions in the Republic of Serbia- NAP" (2019-2022). Funded by the Green Climate Fund, and implemented by the United Nations Development Program (UNDP), in cooperation with the Ministry of Agriculture, Forestry and Water Management. Report 1: "Analysis of the availability of climate and socio-economic information, including climate data, data on risks and impact assessments and information on adaptation measures".

distribution of precipitation during the months of the vegetation period, it is not necessary for their total annual value to be large[74].

The Republic of Serbia has a total of close to 3.5 million hectares of arable agricultural land (Table 18). The most representative region for the field production is the region of Vojvodina, and the largest areas are connected to it.

Table 18. Total used agricultural land (KPZ) in ha (FSS, 2018)

Region/District	Total KPZ
REPUBLIC OF SERBIA	**3,475,894**
SERBIA – NORTH	**1,719,899**
Belgrade Region	145,533
Belgrade Region (City of Belgrade)	145,533
Vojvodina Region	**1,574,366**
West Bačka Region	178,314
South Banat Region	314,579
South Bačka Region	273,729
North Banat Region	176,701
North Bačka Region	139,289
Central Banat Region	262,483
Srem Region	229,270
SERBIA – SOUTH	**1,755,995**
Region of Šumadija and Western Serbia	**1,035,998**
Zlatibor Region	202,051
Kolubara Region	132,101
Mačva Region	167,858
Moravica Region	109,360
Pomoravlje Region	102,981
Rasina Region	95,924
Raška Region	104,384
Šumadija Region	121,339

74 Kovačević, D., Oljača, S., Momirović, N., Broćić, Z., Dolijanović, Ž., Milić, V. (2020). Potential impact of climate change on the production of cultivated plants. In: Janjić V, Pržulj N (editors) Limitations and challenges in plant production. Academy of Sciences and Arts of Republika Srpska, Banja Luka, Monograph LXII: 45-87.

Region of Southern and Eastern Serbia	**719,997**
Bor Region	78,611
Braničevo Region	150,190
Zaječar Region	90,195
Jablanica Region	64,913
Nišava Region	83,396
Pirot Region	46,595
Danube Region	84,114
Pčinja Region	67,498
Toplica Region	54,484

The largest areas are under maize, and of the total 56% are in the Region of Vojvodina (about one million hectares). After 2010, however, there has been an evident decline in the area under maize, which at the beginning of the 21st century amounted to over 1.2 million hectares.

Areas under wheat have remained largely unchanged for the last three decades and are in the range of 550-650 thousand hectares. Increasing the area under alternative types of grain (groats, durum wheat, etc.) is certainly encouraging because it is an indicator of the spread of alternative paths in agriculture, one of the key links to increase biodiversity, an important measure in mitigating climate change.

Areas under sunflower (about 240,000 hectares), soybeans (about 200,000 hectares) and sugar beet (about 45,000 hectares) should be increased in the future, not only in Vojvodina, but also in other regions/areas. Increasing the area under these crops means increasing the number of crops within the crop rotation, i.e. the introduction of multi-field crop rotations, as one of the cheapest, biological measures that have a phytosanitary, organizational and economic and agro-technical role in combating climate change.

Different plant species begin to grow and develop at different temperatures, and also individual phases take place at different temperatures. This lower limit at which plants enter a certain stage of development is called the biological temperature minimum (Table 19).

Table 19. Biological air temperature minimum[75]

Species	Germination and formation of vegetative organs	Formation of reproductive organs
Maize	10- 13	12- 15
Winter wheat ⍰	4- 5	10- 12
Barley	4- 5	10- 12
Oat	4- 5	10- 12
Winter rye	4- 5	10- 12
Sunflower ⍰	7- 8	12- 15
Soybeans	10- 11	15- 18

A drop in temperature below the biological minimum leads to a delay in the growth and development of plants, and with a later increase in temperature, the plant begins to grow and develop again. Temperatures above the biological minimum for a particular stage of development are active temperatures. The biological temperature minimum is the most important indicator of the sowing time of field species

Maize: It is considered that maize cannot be successfully grown in an area where average summer temperatures (June, July, August) are below 19°C, or if night temperatures in those months are lower than 12.8°C. In addition, in our agro-ecological conditions, there should be more than 200 mm of precipitation in the summer months. Total water needs in the vegetation period are about 500 mm, by months: April 50, May 75, June 90, July 100, August 95, September 80 mm. The critical period for water is long and lasts from the end of June to the second half of August (tree growth, panicling, silking and fruit setting). Optimal conditions for maize are in agricultural regions with summer temperatures of 20 - 22°C and the amount of precipitation (correct distribution) 75 - 150 mm for each mentioned month and the length of the frost-free period of 110 - 140 days.

The heat sum for medium-sized maize hybrids, which is most often grown in our country, is 2500-2700°C (Figures 29, 30, 31, 32).

75 Oljača Snežana, Dolijanović Ž. (2010). Practicum in Agroecology. Second, unmodified edition. Faculty of Agriculture, Zemun. 101 pp.

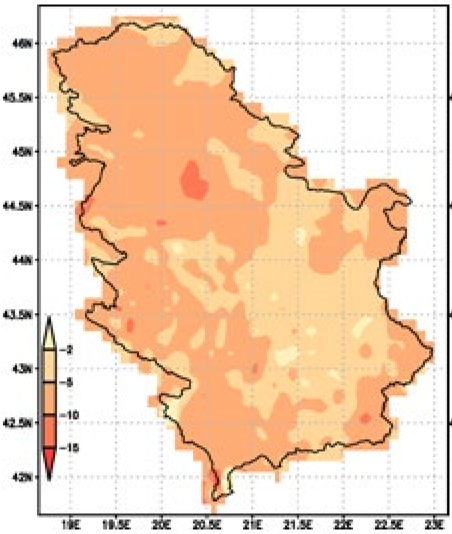


Figure 29. Average sum of temperatures from the optimal sowing date by FAO ripening groups for maize (FAO100 to FAO700) for the period 2000-2019

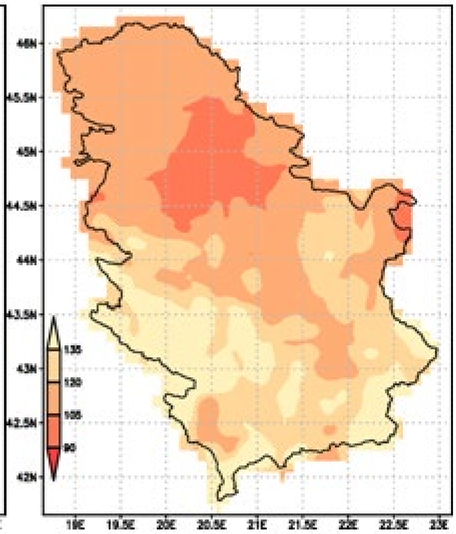


Figure 30. Average date of sowing corn in the Republic of Serbia

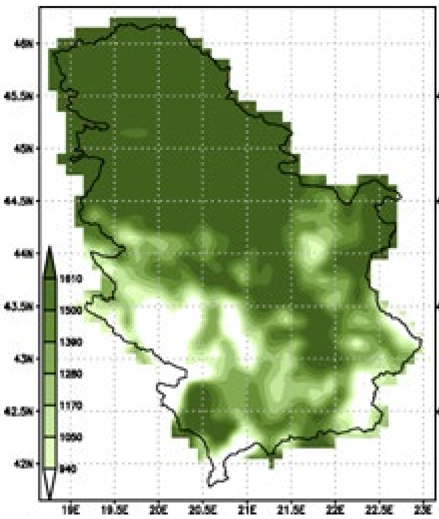


Figure 31. Frequency of high temperatures and drought in the period from phase V12 to phase R3 in the period 2000-2019

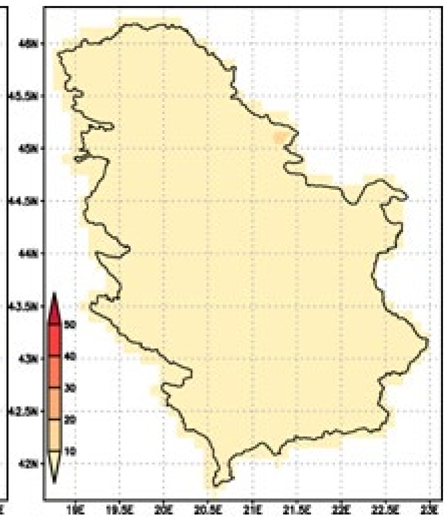


Figure 32. Frequency of low temperatures in vegetative phases in the period 2000-2019

A lower heat sum causes poorer fertilization of maize and thus lower yields. The minimum temperatures for sprouting and germination are 8-10, for the growth of vegetative organs 15 and for fruit ripening 10°C. High temperatures during silking (30 - 35°C and above) affect silk drying and pollen abortigenicity, which prevents fertilization and germination. In the period from fertilization to ripening, especially in self-fertilizing lines, and maize seed crops, low temperatures and frosts can cause enormous damage. The value of heat sums from germination to fertilization (silking) or to physiological maturity is very important for determining the time of maize ripening. The difference in heat sums in hybrids of different lengths of the vegetation period (early, middle and late hybrids) is the largest in the germination - panicling phase, while in other phases of vegetation the heat sums are more uniform. Studies have shown that in the same hybrid sown on the same date in 3 different years, the difference in the day of physiological maturity between the coldest and warmest year is 18 days.

Average optimal sowing date of maize in the period 2000-2019 (Figure 30) (the scale is the number of days from the beginning of the year, 90-105 is the first half of April, 105-120 is the second half of April, 120-135 is the first half of May).

The change in the average optimal date of sowing maize in the period 2000-2019 compared to 1961-2010 is extremely important from the aspect of earlier sowing, because maize enters the critical period for water and heat earlier, and in the last 20 years the warmest months are the second half of July and August. Moving the sowing date fifteen days earlier, to 5 April, gave a higher yield than under the usual sowing date of 20 April[76].

The frequency of high temperatures and drought in the period from the beginning of the silking phase to the fertilization phase in the period 2000-2019 (given in percentages, 10% means that it occurs in two years out of a total of 20 years, 20% that it occurs in 4 years over 20 years, 30% in 6 years over 20 years, etc.) (Figure 31). In the examined period, the exposure assessment is the highest in the territory of Vojvodina and western Serbia. These are also the most important areas for growing maize in Serbia, and in such conditions, the germination of cobs and the formation of grains are weaker, and thus the yield is lower. Thus, from January to the end of September 2020, four heatwaves were recorded, i.e. periods during which the lowest daily temperature was very or extremely warm for more than five days. From the beginning of 2013 to the end of September 2020, there were a total of 49 heat waves in different places in Serbia – almost three times more than cold ones.

The frequency of low temperatures in the vegetative phases in the period 2000-2019 is given in percentages, 10% - occurs in two years out of a total of 20 years, 20% - occurs in 4 years over 20 years, 30% - in 6 years over 20 years, etc. (Figure 32). In addition to high temperatures, significant damage was caused by spring frosts, as in Vojvodina in 2002, where 14,000 ha were endangered by spring frosts, and in 2003 40,000 ha. The impact of low air temperatures in the spring (late spring frosts), in addition to maize, is unfavorable for other spring field crops, because they lead to stagnation in growth, a general weakening of the plant and regular reduction of yield. Some producers sow maize as early as the end of March, with the risk that the period from sowing to germination will last for more than 20 days. Seeds that stand for a long time in cold and wet soil are susceptible to rot and attack by wireworms, which reduces the composition of plants and thins the crop.

Wheat requires a favorable precipitation distribution with a total amount of 650-750 mm in the vegetation period. From October to April (rooting, tillering) wheat consumes 30% of the required amount of water. During this period, the water supply is generally good and the reason for the decline in yield is mainly the lack of precipitation in the growing period when drought

76 Jančić, M. (2015). Impact of climate change on crop production. Doctoral dissertation. University of Novi Sad, Faculty of Agriculture. pp 189.

can affect the reduction of yield by 50%. Unlike maize, wheat is also sensitive to excess water. Large amounts of precipitation in June lead to an increased intensity of fungal diseases and a decrease in the quantity and quality of grain yields of winter wheat. The needs of wheat in heat are less, until the growth into the tree, the optimal temperatures are 10-15, for growth and development 18-25 and for heading, flowering and grain filling 20-25°C. In some years since the beginning of the 21st century, high temperatures at the time of flowering and fertilization have caused a decrease in the yield of wheat and other types of winter wheat. High air temperatures (30-35°C) are much more dangerous if they are accompanied by low relative soil moisture, and if a longer period of time followed by dry wind occurs, heat stroke or premature maturation of plants occurs.

Rye has fewer water needs than wheat, it is sensitive to drought in the autumn until it forms a root system, and the greatest needs are in the phase of intensive growth, heading and flowering. The lack of water at the time of germination affects weaker rooting, which causes poorer growth and grain yield. According to its biological properties, in relation to wheat, rye grows faster, with a stronger root system, it tolerates drought better, low temperatures has better tillering and it is a somewhat earlier crop than wheat (10 days). In most parts of Serbia, air temperatures are favorable for growing rye. It is grown at higher altitudes than wheat and high temperatures in these areas at the time of heading and fertilization are less frequent than in the lowlands. Rye is sensitive to frost, especially if the soil is too wet.

Triticale is less sensitive to autumn drought than rye. The lack of water and minerals in the period before the heading of triticale leads to poor graininess of the ears (top part). This period is a critical period for the water for triticale. If there is not enough moisture in the soil during this period, the yield is regularly reduced. The heat needs are almost identical to those for rye.

Barley requires a heat sum of1900-2000°C. Optimal temperatures during barley vegetation are 14-15°C and for the generative phase 20-24°C. Sudden changes in temperature are not desirable, especially in the phase of tillering, grain forming and grain filling. It falls in May and June, and in some years there are sudden changes in temperature during June. However, barley has a weaker reaction to high air temperatures (38-40°C) at the time of grain filling compared to other types of grain. The largest decrease in yield due to high air temperatures is with barley, compared to other types of winter wheat crops. For successful production of barley, it is necessary to provide, for winter barley 550 mm of precipitation, and for spring barley 450 to 650 mm, with the correct distribution during the vegetation. In the Republic of Serbia, mostly in the regions of barley cultivation, the condition of the amount of precipitation is fulfilled, but it often happens that the distribution is unfavorable, especially in the period of greatest needs, and those are the phases of tillering and heading.

Oat is a crop that does not have high heat needs, the optimal temperature of germination is 6 - 12°C, of the formation of generative organs and flowering 16-20°C, and for fruiting and maturation, the optimal temperature is 16-22°C. In the milk phase of maturation, the oat crop can withstand frosts up to - 5°C, which enables the cultivation of this crop in high mountain regions. Oat is sensitive to "heat stroke". Oats need more water than other small grain crops. In the germination phase they are larger, during rooting and tillering are smaller, and the greatest needs are in the stages of stem extension to panicling. At higher altitudes, there are generally higher amounts of precipitation, which suits oats and on the other hand there is no danger of extremely high temperatures in the critical phases.

Risk of frost for the period 2000-2019 (%), (minimum daily temperature less than -17°C, without snow cover; if there are more than 3 such days during the growing season, the year is marked as risky) (Figure 33). The number of days with such temperatures without snow is not as frequent during one year, as it was in February 2012, the whole of Serbia was hit by a cold wave that lasted from 29 January to 15 February, but with a snow cover. Owing to the presence of snow, there was no damage to plants and a reduction in the grain yield of winter wheat crops.

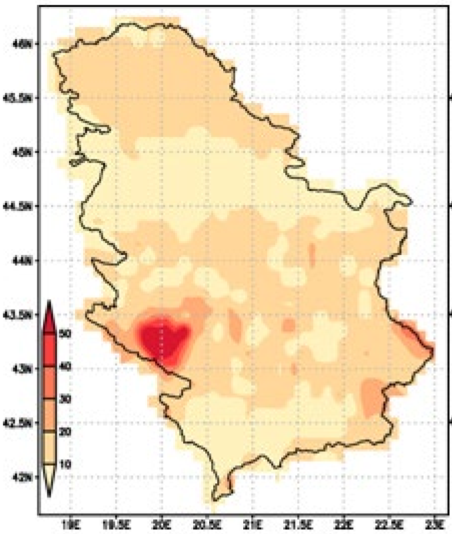


Figure 33. Frequency of frostbite i n the period 2000-2019

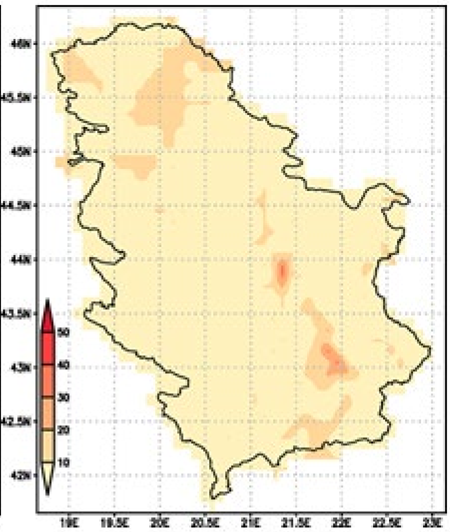


Figure 34. Frequency of high temperatures during flowering and fertilization

Flowering is best in quiet and moderately warm weather (16 to 18oC) with no precipitation. High temperatures (30 to 35oC) adversely affect fertilization, especially with low relative humidity (less than 25%) and soil. The risk of high temperatures for the period 2000-2019 (%) is when the maximum daily temperature is higher than 35°C and if there are more than 2 such days before full ripening (Figure 34). Extremely high air temperatures for a longer period of two days affected the reduction of grain yield in 2007, 2012 and 2017.

Exposure from the shortage of water from germination to the end of tillering (Figure 35)is much lower than the exposure to water shortage in the critical period – from heading to stem extension (Figure 36). The required amount of precipitation in the first period is over 50 mm, while in the second period this amount is over 70 mm. Research by a group of authors has shown that the dependence of wheat yield on moisture is greater in the spring period (from heading to stem extension), which are often lacking[77].

77 Kovačević, D., Dolijanović, Ž., Jovanović, Ž., Milić Vesna (2012). Climate change in Serbia: Depedence of winter wheat yield on temperatures and precipitation. Third International Scientific Symposium "Agrosym Jahorina 2012", Jahorina, November 15-17, 2012. Proceedings, 270-276.

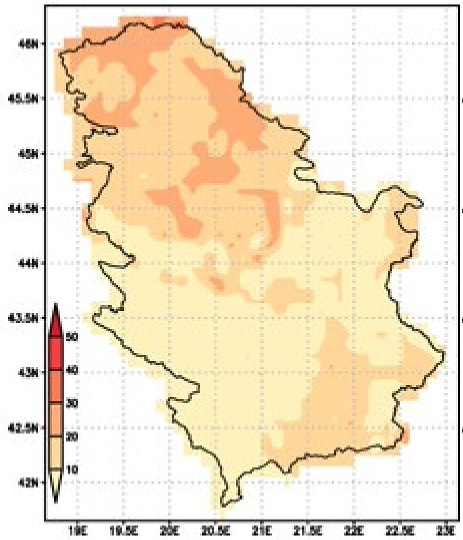


Figure 35. Frequency of moisture deficiency in vegetative phases in the period 2000-2019

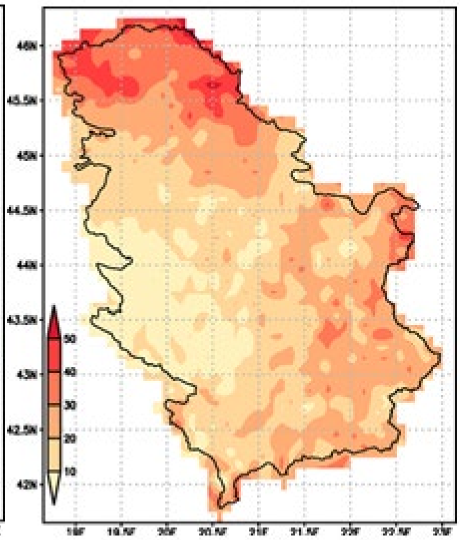


Figure 36. Frequency of water shortage in the critical period in the period 2000-2019

Unlike spring crops, with winter crops positive effects are expected (extension of the growing season) to outweigh indirect negative effects[78].

Soy has great needs in water, during the vegetation period they amount to 450 - 500 mm. The optimal sowing time is from 20 April to 10 May. Already in the germination phase (during the month of May), unlike wheat, soybeans require a lot of water, and in case of the shortage of water, sprouting and germination are uneven and slowed down, and the activity of nodule bacteria is weaker. There are frequent years with a shortage of water in this period, and this is one of the reasons why agricultural producers give up growing soybeans. Until flowering, the need for water is less. In the period of flowering and fruit setting (second half of June, July and August), plants consume 60-90% of water and this is a critical period for water. Given the increasing frequency of water shortages in these months, especially July and August, this is the second and key reason for reduced cultivation of this crop without the use of irrigation. During the ripening period (second half of August and September) there is less need for water. In the period of flowering – ripening, soybeans react to the lack of water in the air, the optimal humidity is about 75% and should not fall below 65%.

Soybean is a thermophilic plant, the sum of active temperatures during the vegetation period is from 2800 to 3000°C, up to 30% are needed until flowering, the greatest needs are during flowering and at the time of flowering and fruit setting the optimal temperatures are 22-25°C. In the period of flowering and germination of soybean fruits, temperatures in the main growing regions are mostly at or above the level of optimal temperatures, and soybeans have a low tolerance to high (35-38) and very high temperatures (above 38°C).

After sowing, low temperatures (below -4°C) can adversely affect growth and development, even for a short period of one day (Figure 37). Low temperatures in May are rare in the plains,

78 Lalić, B., Mihailović, T.D., Podraščanin, Z. (2011): The future state of the climate in Vojvodina andexpected impact on field crop production. Ratar Povrt/Field Veg Crop Res 48: 403-418.

but when some producers sow earlier (first half of April), the risk of low temperatures is higher, some years frosts in this month are not uncommon, as was the case in 2021 after all.

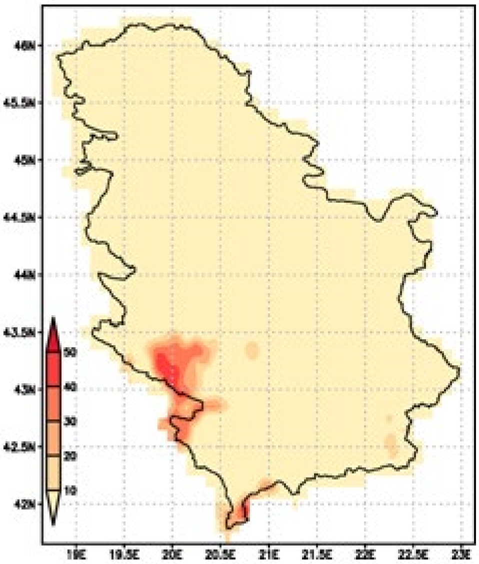


Figure 37. Frequency of low temperatures at the time of germination in the period 2000-2019

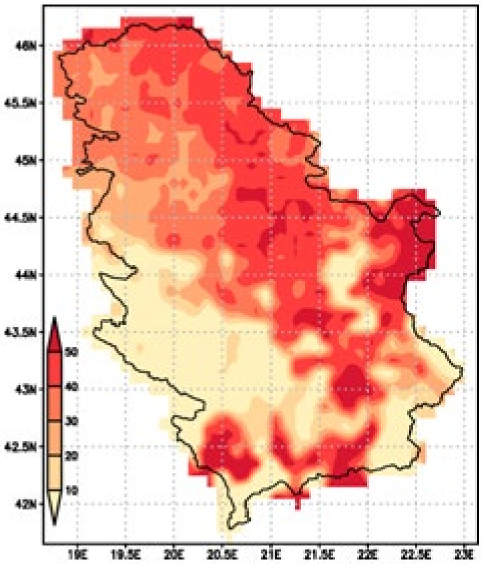


Figure 38. Frequency of lack of precipitation and occurrence of high temperatures during flowering and fertilization in the period 2000-2019

The risk of high temperatures and lack of precipitation (drought) during flowering and fruit setting is the highest one in soybean production. The required amount of precipitation in this period is >100 mm (Figure 38). The average monthly temperatures in June, July and August, the amount and distribution of precipitation in these months in recent years are mostly of such a character (therefore, unfavorable) that the soybean grain yield is significantly reduced[79].

Sunflower is an annual plant whose vegetation period is 90-130 days and goes through the following vegetative (V) and generative (R) phases of growth and development: sprouting and germination, leaf development, inflorescence (budding), phases of elongation of the flower bud above the peak leaf, bud opening, flowering phase and ripening phase. Sunflower is a large consumer of water, in addition to 250 mm of winter reserves (in our area), it needs about 300 mm of precipitation during the vegetation period. The greatest needs in water are during the intensive growth and flowering (about 65%) of the total water intake. The lack of precipitation in this period (less than 100 mm) is a criterion for the risky year (Figure 39).In general, the situation in some years is such that insufficient rainfall causes poorer flowering and reduced grain yield.

79 Nožinić, M., Pržulj, N., Đorđević, V., Lakić, Ž., Suljkanović, Š., Spremo, D. (2015). Soybean yield in extreme years. Annals of Scientific Papers, Year 39, Number 1, page 7.

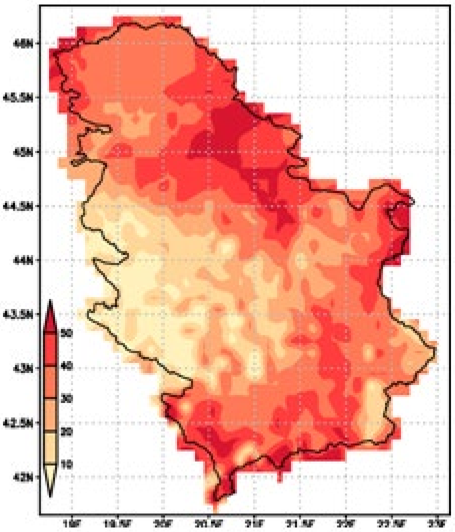


Figure 39. Frequency of occurrence of lack of precipitation during growth and flowering

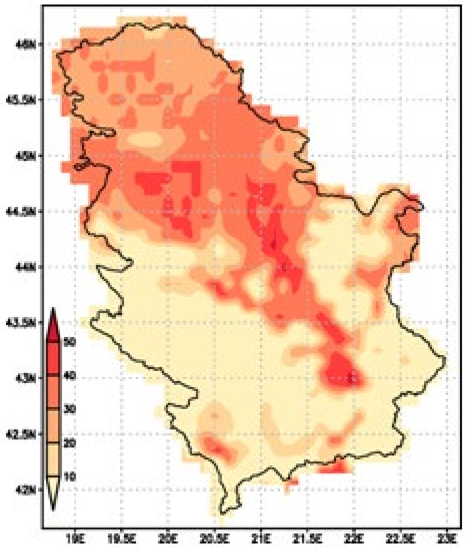


Figure 40. Frequency of lack of precipitation and high temperatures at the time of flowering and ripening

The sum of active temperatures (over 10°C) required for the growth and development of sunflower is 2500-3000oC. Newly emerged plants can withstand frosts down to -6°C. Optimal temperatures for flowering, seed formation and watering are 20-25°C. Very high temperatures (> 35°C), especially with a lack of precipitation from flowering to ripening, adversely affect seed and oil yield. The greatest risk of declining sunflower yields is the occurrence of high temperatures combined with a lack of precipitation in the period from flowering to ripening (Figure 40).

Sugar beet for the production of sugar (from the root) is an annual plant and the vegetation period lasts 160-200 days. In addition to 250 mm of winter reserves (in our area), about 350 mm of precipitation is needed during the vegetation period. The greatest needs for water are during the intensive increase of aboveground mass and the secondary thickening of roots (from the end of June to the middle of August) - a critical period for water (Figure 41). The minimum amount of precipitation in this period is 50 mm. The regression and correlation analysis determined that the yield of sugar beetroots and sugar grown in the area of Vojvodina mostly depends on this precipitation[80].

80 Marković, T. (2011). Production-related basis risk of sugar beet as deficiency of using weather derivatives. Annals of scientific papers, vol. 35, iss. 1, pp. 24-31.

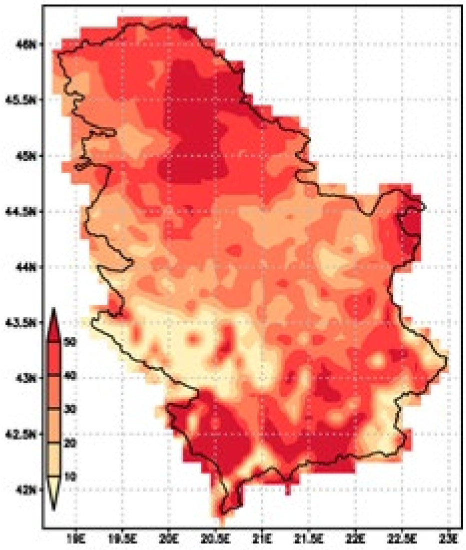


Figure 41. Frequency of occurrence of lack of precipitation at the time of increase aboveground masses and root thickening

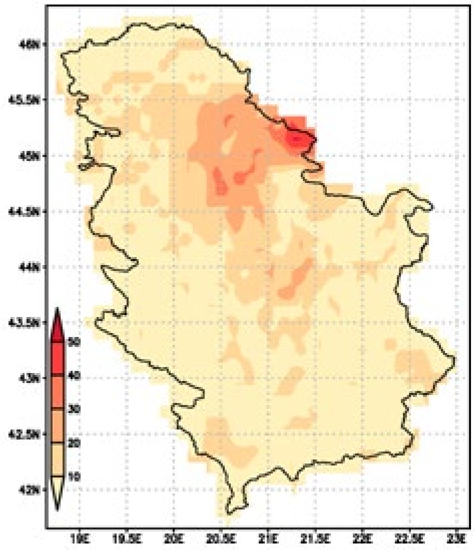


Figure 42. Frequency of low temperatures occurrence in the period after sowing

The sum of active temperatures for the vegetation period is 2800-3200°C, the minimum for sprouting is 4-5 and for germination 6-8°C. Spring frosts up to -3 can damage young seedlings, which happens in some years, especially in the territory of western Serbia. In addition to the effect on root and oil yield, in the period after sowing, low temperatures are one of the causes of root rotting (Figure 42). The greatest needs for heat are at the time of root thickening – a critical period for heat that coincides with a critical period for water. During the autumn period, the plants can withstand up to -7, but the beetroot extracted from the soil freezes at -2°C. In our conditions, it very rarely happens that this factor leads to a negative impact on the yield of sugar beetroots.

4.4 Meadows and pastures - risk assessment and levels of affectedness

Grasslands are the most common type of land use in many European countries, especially in Western Europe or in the mountainous countries of Central and Southern Europe, occupying 30-40% of the European agricultural area[81]. Grasslands cover less productive lands in the central Balkans, which represent a large share of total agricultural land in Serbia (19.5%). According to long-term statistical data, out of the total used agricultural area in Serbia, meadows and pastures were represented with 29.0%, i.e. they occupied 1.45 million hectares. However, according to valid statistical data from 2019, the situation has changed significantly. Namely, permanent grasslands in Serbia cover only 19.5% of the total utilized agricultural area, i.e. only 676.36 thousand hectares (meadows are located on 350, and pastures on 326 thousand hectares), while the areas under sown meadows are estimated at about 50,000 ha[82 83].

81 Simić, A., Bjelić, Z., Mandić, V., Sokolović, D., Babić, S. (2019). Permanent and sown grasslands in Serbia: Current state and trends. Analele Universităţii din Craiova, seria Agricultură – Montanologie – Cadastru (Annals of the University of Craiova- Agriculture, Montanology, Cadastre Series) Vol. XLIX/2019, 244-253.

82 Sokolović, D., Simić, A., Babić, S. (2018). Perennial forage grasses and their biodiversity. Organic production and biodiversity, Proceedings of the VI Open Days of Biodiversity, 20. June 2016, Pančevo, 43-66.

83 Statistical Office of the Republic of Serbia (2019). Statistical yearbook of Serbia Belgrade.

According to available statistical data, the meadow production at the level of Serbia is on average only 2.3 tha-1 of dry matter, and of pastures about 2 tha-1. If we look at the trends of grassland areas and their production over time, we can see a constant decrease in grassland areas in Serbia with very low forage yields, which is greatly influenced, in addition to socio-economic reasons, by climate change, i.e. the reduction and change in the regularity of precipitation distribution during the vegetation season.

Grasslands are extremely important for preserving the quality of soil and water. Perennial grasses form a dense cover with a fibrous root system that improves the infiltration rate more than other cultivated field crops, and reduces nitrogen leaching by efficient consumption. Also, with its dense composition, the grass cover reduces water loss by evaporation and surface swelling, and thus prevents the occurrence of water and wind erosion.

In general, grassland production, including pastures and meadows, is limited by solar radiation, temperature, water stress, nutrient availability, and grazing/mowing management. Most of the limitations on water, nutrients and management can be improved - although it is not always economically viable - but solar radiation and outside temperatures cannot, which are very important aspects of climate change[84]. The temperature affects the work of enzymes, which control all plant metabolic processes, from photosynthesis and respiration, to growth and development, through cell division, cell growth and cell wall formation. An increase of about 8°C generally doubles the effect of the enzyme[85]. Cool season grasses (C3) have optimal growth at about 20°C, and are metabolically active at 2°C. In contrast, warm season grasses have an optimal growth at 32°C, while they grow poorly below 15°C.

Climate change is causing a chain of problems, which require an integrated approach to identifying factors that limit yields, and which are likely to have a major impact on overall agricultural production in the future. There is almost no doubt that climate change will require short-term and long-term adaptation of land use and water management[86]. All this points to the need to study the impact of climate change on current natural grasslands[87]. This is supported by the results of research in which it was found that heat waves and droughts have a very negative impact on natural grasslands in the continental climate in the Pannonian Plain, which includes Hungary, Serbia, Bulgaria and Romania. Therefore, increasing biomass production while maintaining or reducing the amount of water used, i.e. increasing water efficiency (EKV) is of the greatest interest. Combining grass species with different functional groups and with different functional characteristics could play a key role in this regard[88].

84 Hutchinson, G.K., Richards, K., Risk, W.H. (2000). Aspects of accumulated heat patterns (growing degree-days) and pasture growth in Southland. In Proceedings of the New Zealand Grassland Association (Vol. 62, pp. 81-85). New Zealand Grassland Association.

85 Volenec, J.J., Nelson, C.J. (2017). Environmental aspects of forage management. In: Collins, M., Nelson, C.J., Moore, K.J., Barnes, R.F. (Eds.). Forages, Volume 1: An Introduction to Grassland Agriculture, 1, 71.

86 Hansen, J.W., Challinor, A., Ines, A., Wheeler, T., Moron, T. (2006). Translating climate forecasts into agricultural: advances and challenges. Climate Research 33, 27–41.

87 Olesen, J.E., Trnka, M., Kersebaum, K.C., Skjelvåg, A.O., Seguin, B., Peltonen-Sainio, P., Rossi, F., Kozyra, J., Micale, F. (2011). Impacts and adaptation of European crop production systems to climate change. European Journal of Agronomy 34, 96-11.

88 Hofer, D., Suter, M., Haughey, E., Finn, J.A., Hoekstra, N.J., Buchmann, N., Lüscher, A. (2016). Yield of temperate forage grassland species is either largely resistant or resilient to experimental summer drought. Journal of Applied Ecology 53, 1023-1034.

Physiological drought tolerance varies tenfold among 426 grass species[89]. Grasses are well distributed both climatically and phylogenetically, which indicates that most natural grasslands probably contain a great variety of drought tolerance. Consequently, local species can help maintain ecosystem functioning in response to changing drought regimes without requiring long-distance grass species migration. Furthermore, physiologically drought-tolerant species had higher rates of water and carbon dioxide exchange than intolerant species, indicating that severe and prolonged droughts may alter the floristic composition of natural grasslands. This fits in the mechanism of survival of natural grasslands to stressful abiotic conditions, such as high temperatures or drought. Due to the increase in air temperature, the longer vegetation period and the variable amounts of precipitation over the last two decades, grasslands such as meadows and pastures are increasingly left without enough water to a level that prevents them from regenerating.

Based on Figure 33, a very low probability of frostbite is observed (**Section 2**), with extremely low temperatures, which can damage the grass cover during the winter, except in the area of Pešter in southwestern Serbia. The Sjenica-Pešter plateau is an area of uninterrupted natural meadows and pastures at over 1000 m above sea level, which cover 726 square kilometers, which represents almost 90% of the agricultural land in the area[90]. The ecological conditions of this area are distinguished by certain specific edaphic conditions (mostly less suitable soils) and a harsh climate, with long and harsh winters and short dry summers. All this is conditioned by a short vegetation period, with the insufficient amount of and poor precipitation distribution. The choice of cultivated plants, even forage plants, which can thrive here, is limited. On the Sjenica-Pešter plateau, the species are adapted to extreme conditions on natural grasslands, with few representatives of legumes and low grasses, with narrow leaves and of a modest quality for animal husbandry. Such a plant cover is adapted to extreme growing conditions and is generally well prepared for long periods of low temperatures.

Precipitation is the predominant factor for the successful development of grass cover on meadows and pastures in Serbia, as well as for the regeneration of grasslands after grazing or mowing. The highest biomass production is formed and obtained in the spring months, until the beginning of summer, in most hilly and mountainous areas of importance for animal husbandry and nutrition with bulky nutrients.

The critical months are June, July and August, which are characterized by a jump in temperatures, with uncertain precipitation, necessary for the regeneration of mowed or grazed biomass. Based on Figure 43, the highest amount of precipitation is observed during 3 critical months in the western areas of Serbia, from the area of Loznica in the north to the south of the Pešterska plateau. The driest areas of Serbia in this period are from eastern Serbia to the border with Macedonia and most of Kosovo. These areas did not have conditions for intensive field production in the past, and consequently for the production of forage and livestock. The relief configuration is generally unsuitable for land use and intensive cultivation, with hilly and mountain pastures of a modest grass biomass yield. In recent decades, they have been exposed to large-

89 Craine, J.M., Ocheltree, T.W., Nippert, J.B., Towne, E.G., Skibbe, A.M., Kembel, S.W., Fargione, J.E. (2013). Global diversity of drought tolerance and grassland climate-change resilience. Nature Climate Change, 3(1), 63-67.

90 Pavlović, M.A., Šabić, D.S. (2003). Perspectives and problems of animal production in the Sjenica's region. Proceedings-Faculty of Geography, University of Belgrade, (51), 161-174.

scale depopulation, declining rural population, which reduces the capacity to use the existing meadows and pastures.

Areas of western Serbia with more intense precipitation are predominantly turned to cattle and sheep, and the majority of sown meadows and pastures of Serbia are present there. Without sowing high-quality types of grasses and legumes using varietal seeds, neither the need for hay or quality grazing can be adequately provided. The spread of sown grasslands in this area also helps to control weed vegetation, which is undesirable in animal nutrition.

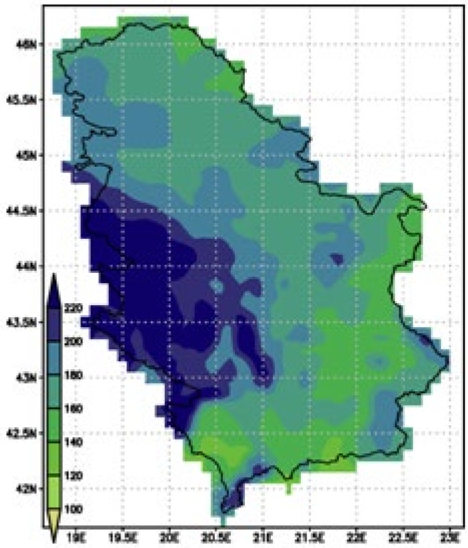


Figure 43. Average precipitation during June, July and AugustJuly and August

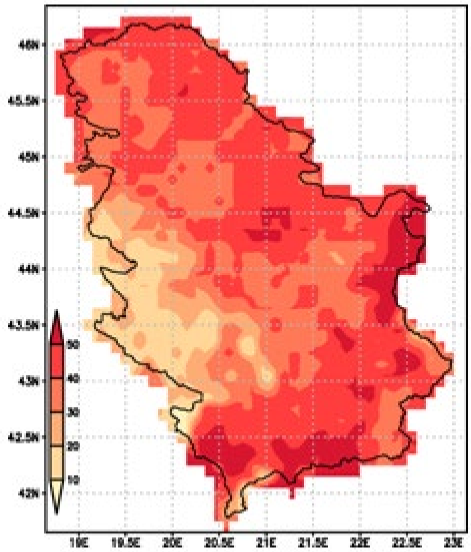


Figure 44. Frequency of small amounts of precipitation during the summer "Criteria for occurrence in the period after sowing the risk year - if the amount of precipitation during June, July and August less than 150 mm)

Figure 44 highlights lighter areas with a lower frequency of summer drought, and dark red areas, in which there are three summer months with total precipitation below 150 mm. which indicates a certain lack of moisture for lawns during the months when daily temperatures exceed 30°C. On such days, grass surfaces suffer from a combined heat and water stress, which leads them to forced dormancy or temporary wilting, which reduces the capacity for use by grazing or mowing. Grass regrowth or the occurrence of grass biomass regeneration can be expected only by September, with increased precipitation and lowered daily temperatures.

The distribution of risk from a small amount of precipitation during the summer fits into the previous schedule with the distribution of precipitation and due to the importance of precipitation for the development of grasslands, it indicates the most favorable areas for their exploitation. These areas are concentrated in the west and southwest of Serbia, encompassing the Drina River Basin in Serbia, as well as the area from the Valjevo Mountains, through Tara, Zlatibor, all the way to the border with Montenegro, and then east, through Mučanj, Goč and Željin to Kopaonik. Moderate temperatures in this area, with a lower risk of a dry summer period, provide a potential for further animal husbandry development.

5. Specific risks and vulnerabilities in animal husbandry

Healthy and in the production stable cattle are the basis of economical livestock production. Health problems contribute to financial losses in production. The impact of climate change and microclimatic conditions on animal health and productivity can be direct or indirect and is primarily a consequence of changes in the environment, which include air temperature, relative humidity, precipitation and frequency, i.e. the intensity of extreme events (sudden heat waves, severe droughts, floods).

The immediate direct effects of climate change on health occur primarily and firstly due to increased temperatures and the frequency and intensity of heatwaves. These effects are an indication of the occurrence of heat stress conditions. Depending on the intensity and duration, heat stress can negatively affect the health of animals, causing metabolic changes, oxidative stress, immune suppression and eventually the death of the animal. Also, weakened metabolic and immune responses of animals lead to the worsened health of the animal. Animals can respond to particular stress either by changing the behavior, physiologically, or with the combination of both, and the animal's responses to particular stress may vary based on the animal's previous experience with stressors, their duration and intensity, and the animal's physiological status. Metabolic stress is generally an imbalance between nutrient intake and distribution, with the genetic basis of highly productive cows stimulated to maximize nutrient conversion to milk, reducing their availability for other biological functions - weight maintenance, reproductive efficiency and health. The lying syndrome in cows is mentioned as a reliable indicator of metabolic disorders.
Due to the increase in average temperatures and the frequency of occurrence of extreme atmospheric events, cows are increasingly exposed to heat stress. Heat stress in dairy cows occurs as a consequence of the adaptation of the organism to the action of several related factors in combination with the high ambient temperature that causes the adaptation, in order to prevent the physiological dysfunction of the organism.

To assess the level of heat stress in domestic animals, mathematical indicators are used, the most common of which is the application of THI (Temperature Humidity Index- THI) indicator (Section 2). Most THI formulas are calculated using two factors, i.e. ambient temperature and relative humidity, because the most important thing is that both variables are easily measurable and/or are often publicly available through meteorological services.

Since 2014, microclimatic conditions have been monitored on farms in our country where dairy cows are raised and produced. The highest values of THI index[91] are evident during the summer months (June, July and August). However, the established unfavorable values of THI (THI> 72) in our country appear from April until October. If we take only the warm period of the year (from 1 April to 1 October), the average value of THI in the examined period (6 years) was 71.7, i.e. it was very close to the limit of heat stress. The number of days in this period when the average daily values were above the limit for heat stress (THI>72) was 44%, i.e. half of the days in the warmer

91 Kibler, H.H. (1964). Thermal effects of various temperature-humiditycombinations on Holstein cattle as measured by eight physiologicalresponses. Environmental physiology and shelter engineering. LXVII.

part of the year cattle heads were exposed to heat stress. The maximum determined value of THI in the given period was 86.25. The estimated average loss in milk production, as a consequence of heat stress, in the given period was 0.4 kilograms per day. When we multiply by the number of days in a given period and the number of cows (250,000) in our country, we get 18 million kilograms of lost milk just due to heat stress. This loss, estimated in money, is around 5,400,000 euros. This is an estimate of direct production losses. Indirect losses such as deteriorating health, reproduction and increased production costs are much more difficult to estimate. From Chart 3, it can be concluded that there is a complete correlation between the exposure of cattle heads to heat stress and losses in milk production.

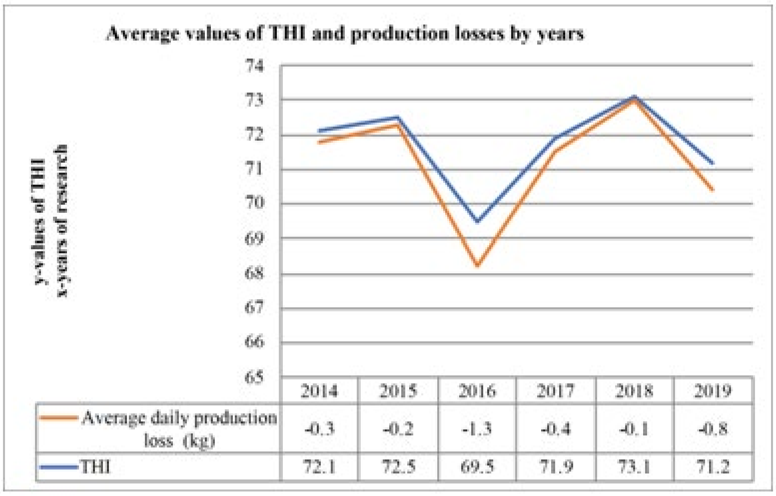


Chart 4. THI index values in the period from 1 April to 1 October, and the average decline in production as a result of exposure of the cattle head to heat stress

The indirect impact of climate change on livestock production is reflected in the quantity and quality of available animal feed. The increased frequency of extreme meteorological phenomena such as droughts, floods, storms and hail, reduce the yield of crops used in the nutrition of domestic animals, as well as changed conditions for the preparation of animal feed, which further reduces the quality of animal feed. The greatest impact of climate change is present on spring crops where the largest part of vegetation takes place in the warmest part of the year, when the cited meteorological phenomena are present, which occur as a consequence of climate change and are most pronounced.

The required areas of the most important forage crops that are grown for the purpose of feeding domestic animals are obtained through the needs of animals in nutrients, namely the share of certain nutrients in the meal by individual species.

Table 20. Number of animals by certain species and regions in the Republic of Serbia in December 2020[92]

	Republic of Serbia						
	total	Serbia – north			Serbia – south		
		total	Belgrade Region	Vojvodina Region	total	Region of Šumadija and Western Serbia	Region of Southern and Eastern Serbia
Cattle, number	886 127	305 634	46 107	259 527	580 493	410 827	169 666
Pigs, number	2 983 102	1 404 755	143 785	1 260 970	1 578 347	1 029 451	548 896
Sheep, number	1 684 613	346 837	69 595	277 242	1 337 776	1 042 176	295 600
Goats, number	202 325	56 692	7 115	49 577	145 633	70 422	75 211
Poultry, number	15 248 808	6 167 282	704 841	5 462 441	9 081 526	6 552 782	2 528 744

Table 21. Average meal by species according to breeding habits of breeders and average production of cattle of a certain species in Serbia (kg/average head)

Species of domestic animals				
Nutrient	Cattle	Pigs	Sheep and goats	Poultry
Maize silage	10	-	1	-
Maize kernel	3	1	0.5	0.15
Barley	1	0.5	-	-
Alfalfa hay	3	-	-	-
Grass hay	3	-	1	-
Green food from pastures	10	-	4	-

Based on the needs and number of animals bred during 2020 in the Republic of Serbia (Tables 12 and 13), the required amounts of food for animal nutrition for one calendar year were calculated. Table 14 shows the annual needs expressed in tons for each nutrient used in the nutrition of domestic animals in our country. The quantities of nutrients obtained in this way can be compared with the data on the number of animals by certain species and regions in the Republic of Serbia and we can determine that with the produced quantities of animal feed Serbia meets its needs and it remains for export in years with favorable weather conditions.

92 Republic Statistical Office (2020): https://publikacije.stat.gov.rs/G2020/Pdf/G20201029.pdf

Table 22. Required quantities of food for domestic animals (in tons)

Nutrient	Region				
	Entire country	Belgrade	Vojvodina	Šumadija and WesternSerbia	Eastern and Southern Serbia
Maize silage	3 923 096	196 290	1 066 562	1 905 617	754 627
Maize kernel	3 238 380	155 558	1 103 149	1 387 419	592 253
Barley	867 852	43 070	324 855	337 826	162 102
Alfalfa hay	970 309	50 487	284 182	449 856	185 784
Grass hay	1 659 041	78 486	403 471	855 954	321 130
Green food from pastures	5 989 293	280 287	1 424 429	3 123 912	1 160 665

New diseases are appearing in Serbia due to climate change and the spread of vectors transmitting these diseases. Thus, diseases such as nodular dermatitis in cattle and bluetongue occur, which cause great economic damage and pose a great threat to our livestock. Nodular dermatitis is a viral disease of cattle and Asian water buffalo causing enormous damage to cattle production. Direct contact between animals poses minimal risk for disease transmission, while the main vectors for the spread are insects, primarily the flycatcher (*Stomoxys calcitrans*), yellow fever mosquito (*Aedes aegypti*) and some species of African ticks (*Rhipicephalus and Amblyomma spp*.). With climate change, the area of distribution of these insects and the possibility of spreading the disease is expanding. 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 public, which would certainly be necessary to assess the danger and the speed of spread of these diseases depending on climate change as well as to the timely response in case of outbreaks of local hotspots. As the data are not publicly available, it is necessary to obtain data from the Administration on the incidence of these diseases in the last 10 years, as well as the volume of heads by species vaccinated in this period in order to assess the trend of these diseases and make a correlation analysis with climatic factors in the analyzed years, as well as the economic effects of these diseases.

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