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

ACTIVITY 2:
Assessing the impact of climate change on the agricultural sector in the future

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*Note:
The proposed adaptation measures will be implemented through Activity 3.

List of Abbreviations

CI	Cool night index
DI	Dryness Index
E-OBS	Daily gridded observational dataset for precipitation, temperature and sea level pressure in Europe
FAO	Food and Agriculture Organization of the United Nations
HMN	Median value of the irrigation hydromodule
HI	Huglin Index
IDP	Irrigation and Drainage Paper
IPCC	Intergovernmental Panel on Climate Change
NIWR	Net Irrigation Water Requirement
NNN	Net Irrigation Rate
RCP	Relative Concentration Pathway
RH	Relative Humidity
RP	Reference Period
TB	Base Temperature
THI	Temperature Humidity Index
UNDP	United Nations Development Programme
WIN	Winkler Index

CONTENTS

1. Water demand in the agricultural sector in the future climate

Using the water demand calculation methodology proposed in the first phase of the Report on the impact of climate change on the AGRICULTURE sector, with the proposed adaptation measures (Section 2) an analysis of water demand in the future climate was performed. A reference period (RF) was used for the analysis - 1986 - 2005) in relation to which all future periods were compared (P1 - 2021 - 2040; P2 - 2041 - 2060. and P3 - 2080 - 2100). The RCP8.5 scenario was chosen in this Study (Relative Concentration Pathway) as well as an ensemble of 8 regional climate models with a spatial resolution of 0.1° (about 12 km) from the EURO-CORDEX project database. In these studies, the median (it is considered that the median has already been reached) and the 75th percentile (stricter assessment) of the obtained results are presented.

Figures 1, 2, 3, 4, 5, 6, 7 and 8 show the values of irrigation hydromodules for gravity, irrigation and drip systems in the period of peak consumption for RF and three future periods P1, P2, P3.

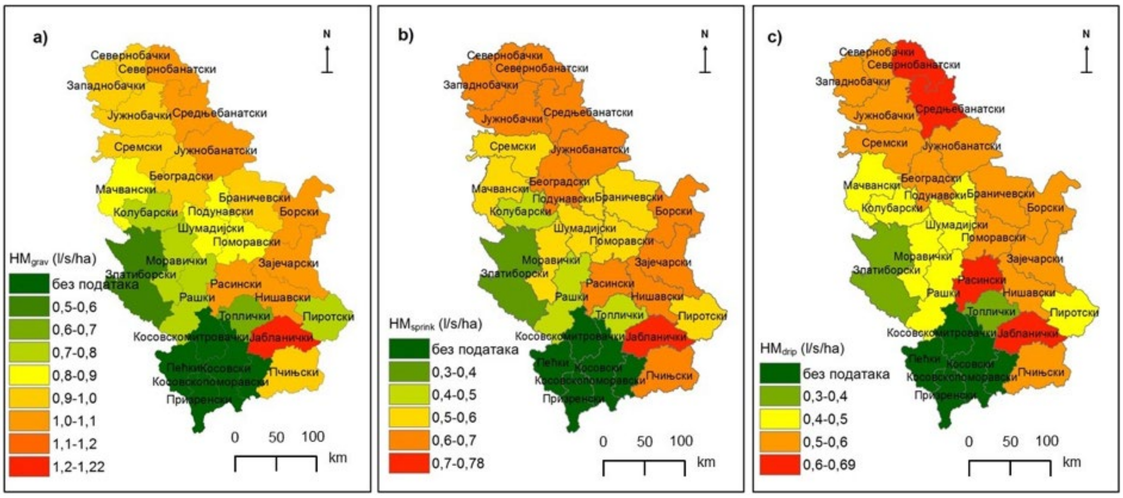


Figure 1 Hydromodule of a) gravity system, b) sprinkler system and c) drip system for the reference period 1986-2005.

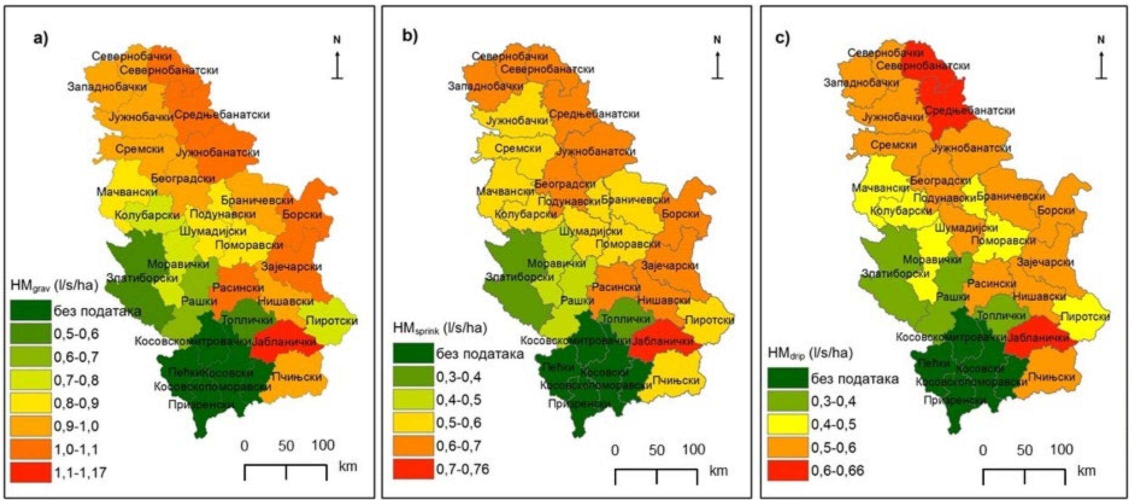


Figure 2 Hydromodule of a) gravity system, b) sprinkler system and c) drip system for the period 2021-2040.

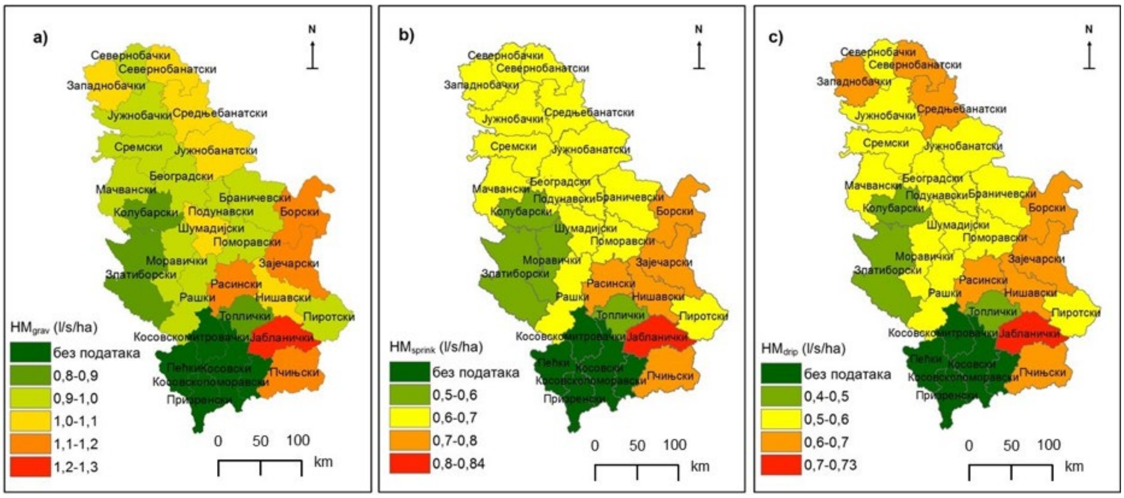


Figure 3 Hydromodule of a) gravity system, b) sprinkler system and c) drip system for the period 2041-2060.

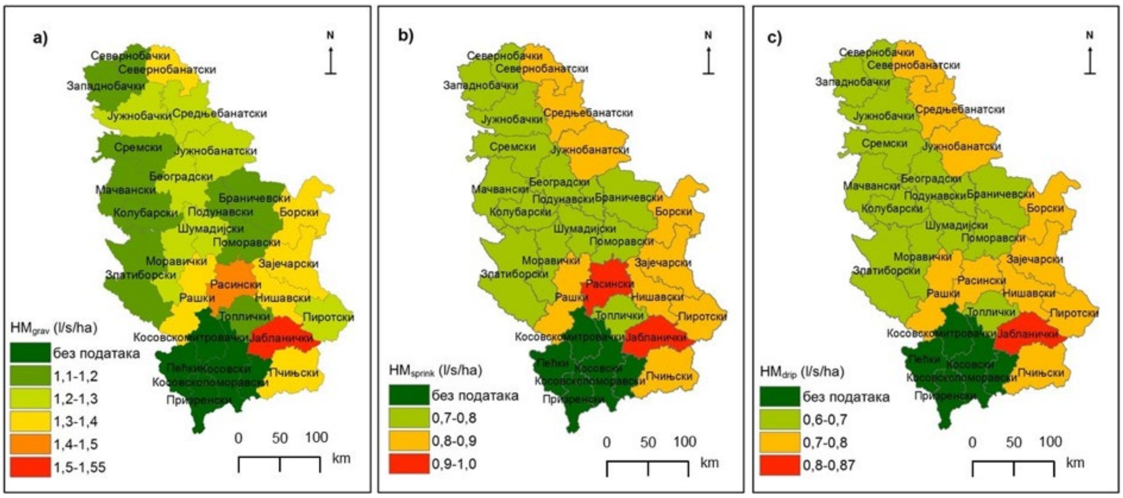


Figure 4 Hydromodule of a) gravity system, b) sprinkler system and c) drip system for the period 2080-2100.

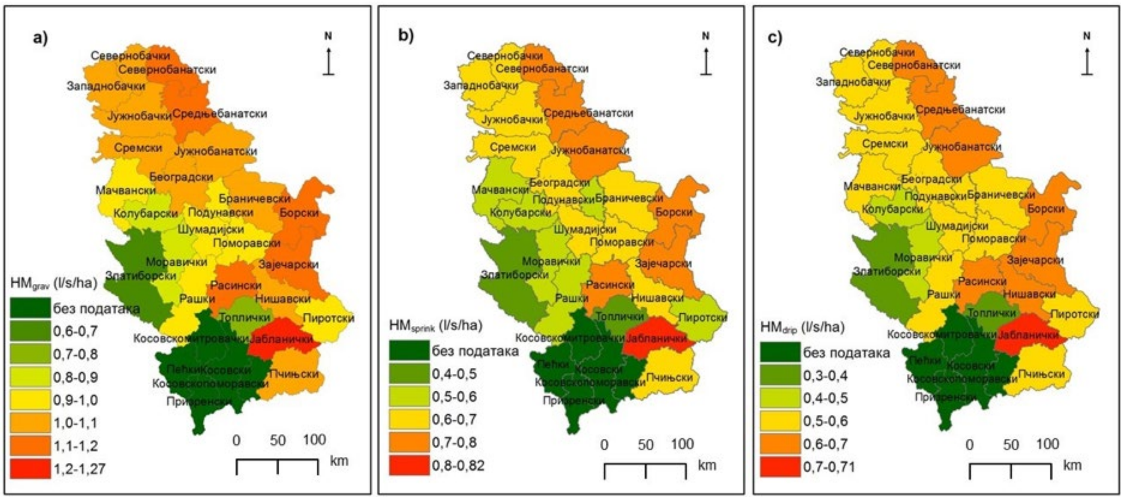


Figure 5 Hydromodule of a) gravity system, b) sprinkler system and c) drip system for the period 1986-2005.

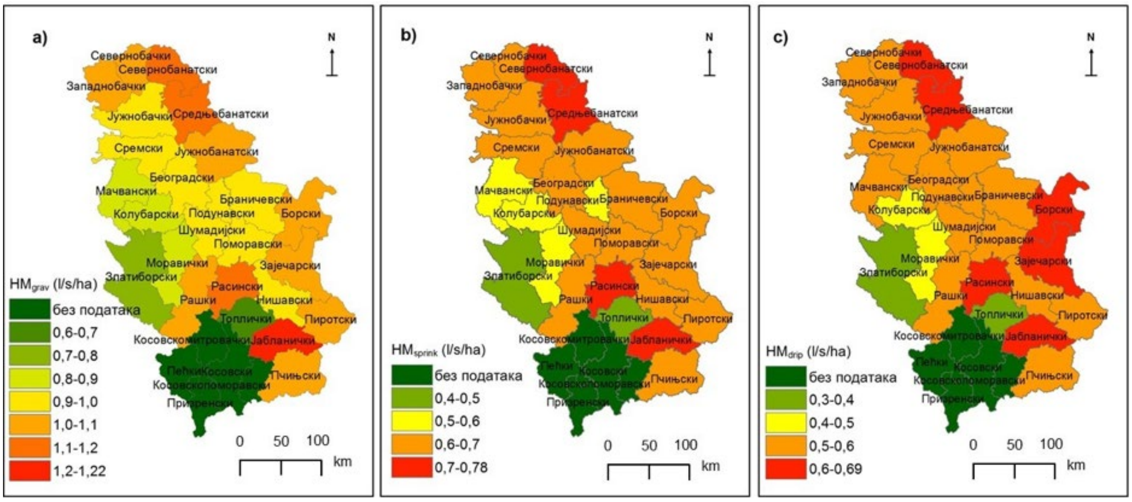


Figure 6 Hydromodule of a) gravity system, b) sprinkler system and c) drip system for the period 2021- 2040.

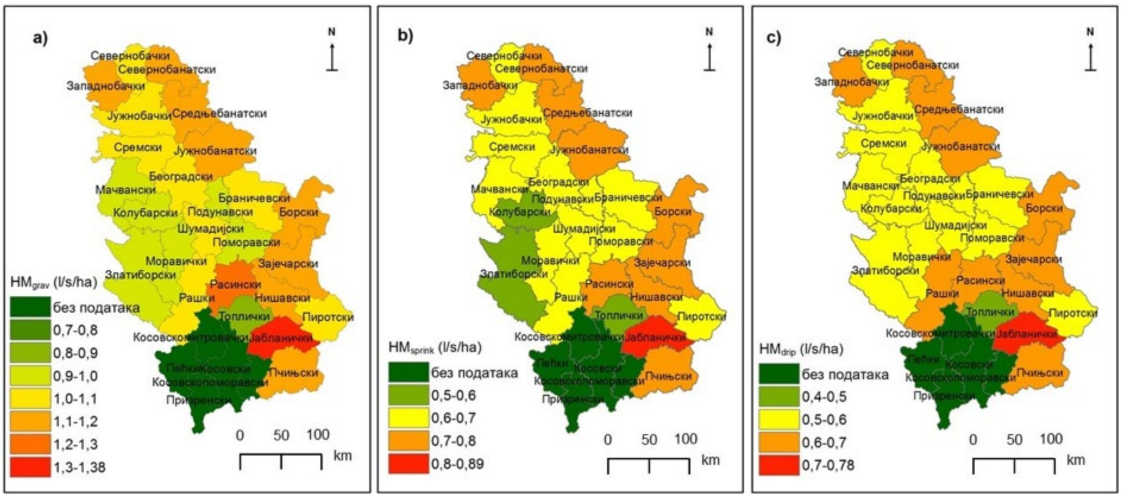


Figure 7 Hydromodule of a) gravity system, b) sprinkler system and c) drip system for the period 2041- 2060.

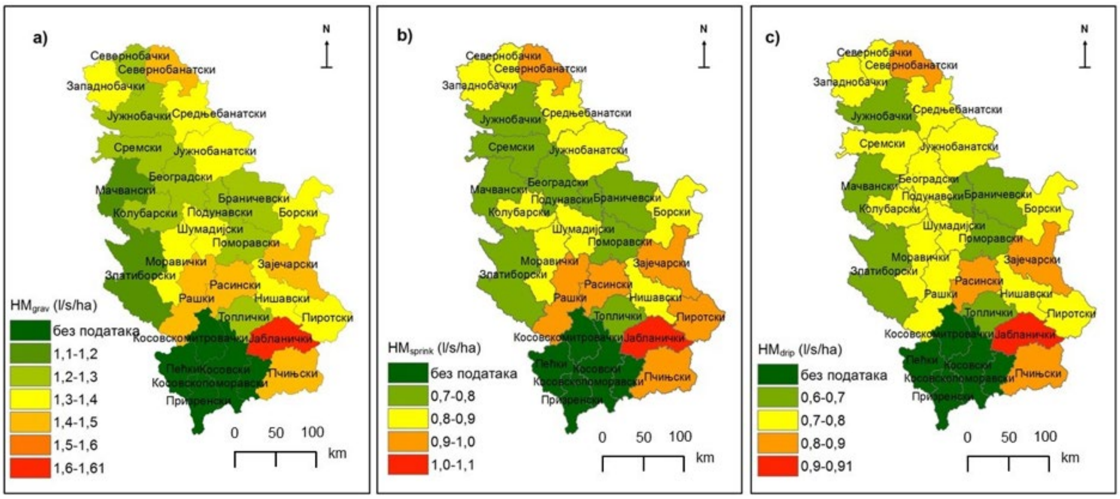


Figure 8 Hydromodule of a) gravity system, b) sprinkler system and c) drip system for the period 2080- 2100.

The obtained values of the irrigation hydromodule are shown through the median (Figures 1, 2, 3 and 4) and the 75th percentile (Figures 5, 6, 7 and 8). The median values of the hydromodules of gravity, irrigation and drip irrigation in the reference period vary from 0.55, 0.35, 0.31 $l \cdot s^{-1} \cdot ha^{-1}$, respectively in the Zlatibor District up to 1.22, 0.78, 0.69 $l \cdot s^{-1} \cdot ha^{-1}$, respectively in the Jablanica District. Average values for the entire territory of the Republic of Serbia are 0.93, 0.60, 0.52 $l \cdot s^{-1} \cdot ha^{-1}$, respectively. The values of the 75th percentile of the hydro module by gravity, dew and dripping in the reference period vary from 0.63, 0.40, 0.35 $l \cdot s^{-1} \cdot ha^{-1}$, respectively up to 1.27, 0.82, 0.71 $l \cdot s^{-1} \cdot ha^{-1}$, respectively in the same districts. Average values for the entire territory of the Republic of Serbia are 1.00, 0.64, 0.56 $l \cdot s^{-1} \cdot ha^{-1}$, respectively.

Chart 1 shows the percentage change in the median value of the irrigation hydromodule (HMN) by gravity, dew and dripping in the future climate in relation to RF . In the first period in the future, the percentage change of the irrigation hydromodule varies from -15.1% decrease in the value of the hydromodule in the Toplica District to 2.3% increase in HMN in the Šumadija District. The value of HMN in the 2021 - 2040 period decreases by -2.2%. The average percentage change in the value of HMN for the second period of the future indicates that there will be an increase in hydromodule by 11.8%. Values range from a -1.2% decrease in HMN in the Central Banat District to a 47.6% increase in the Zlatibor District. At the end of the century (2080 -2100 period) there is a significant increase in the value of HMN, of 38.6% on average, with the smallest increase of 17.9% in the Central Banat and the largest increase of 100% in the Zlatibor District, which indicates the risk of crop production without irrigation.

Chart 2 shows the percentage change in the value of the 75th percentile of the irrigation hydromodule by gravity, irrigation and dripping in the future climate compared to RF[1]. The average change is -0.7, 8.0 and 35.1% for the periods 2021 - 2040, 2041 - 2060, 2080 - 2100, respectively. Also, in this case, an increase in the value of the irrigation hydromodule at the end of the century is observed.

1 Ref. vs. P1- percentage change of irrigation hydromodules (HMN) in the 2021- 2040 period in relation to RF; Ref. vs. P2- percentage change of HMN in the 2041- 2060 period in relation to RF; Ref. vs. P3- percentage change of HMN in the 2080- 2100 period in relation to RF.

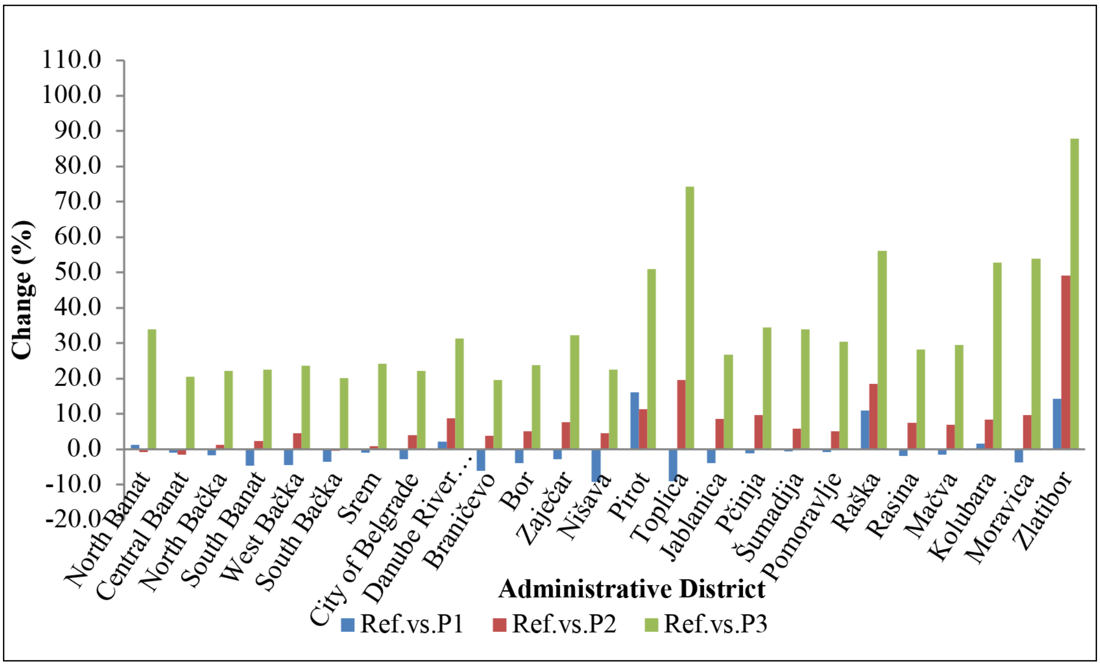


Chart 1. Percentage change in the value of the median of the irrigation hydromodule in the future climate (2021 - 2040; 2040 - 2060 and 2080 - 2100) of the median value of the hydromodule of the reference period (1986 - 2005).

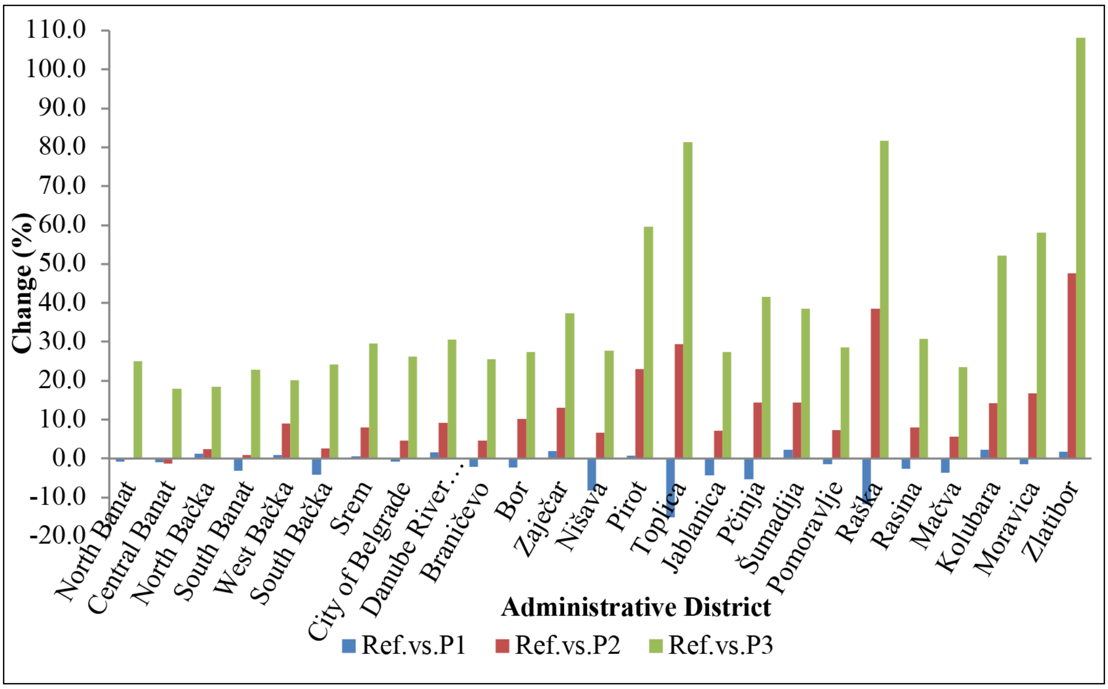


Chart 2. Percentage change in the value of the 75th percentile of the irrigation hydromodule in the future climate (2021 - 2040; 2040 - 2060 and 2080 - 2100) from the value of the 75th percentile of the hydromodule of the reference period (1986 - 2005)

Figures 9, 10, 11 and 12 show the values of the median net irrigation norms, and Figures 13, 14, 15 and 16 show the values of the 75th percentile of the net irrigation norms in $m^3 \cdot ha^{-1}$ by administrative districts of the Republic of Serbia for the reference period (1986 - 2005) and three future periods (2021 - 2040; 2040 - 2060 and 2080 - 2100). The values of the median and 75th percentile of net irrigation norms in the reference period vary from 19.7 and 50.0 mm, in the Toplica, to 312.0 and 326.4 mm in the Jablanica District, with average values of 214.7 and 227.1 mm for the Republic of Serbia.

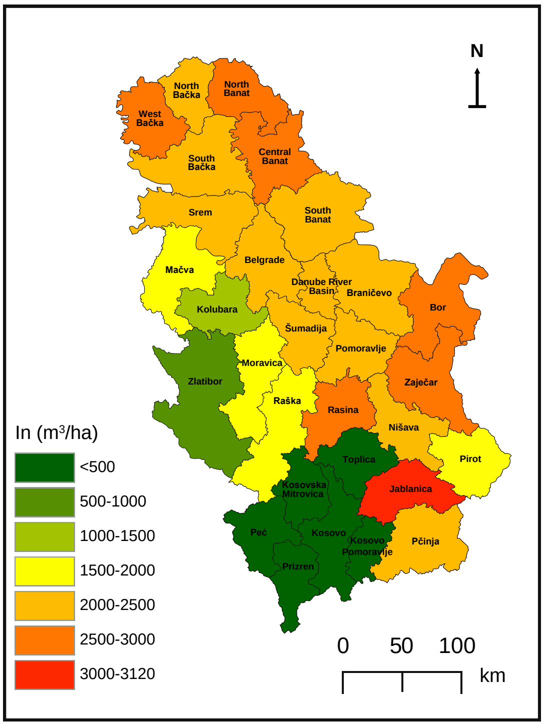


Figure 9. Net irrigation norm by administrative districts of the Republic of Serbia for the reference period 1986 - 2005

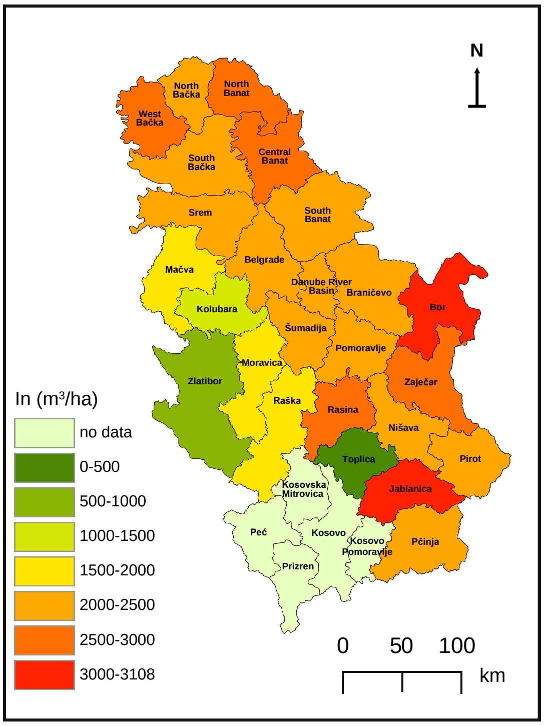


Figure 10. Net irrigation norm by administrative districts of the Republic of Serbia for the reference period 2021 - 2040.

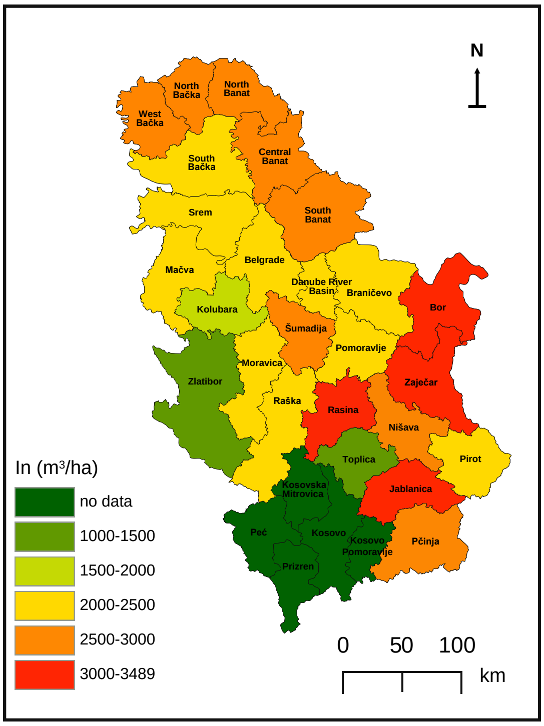


Figure 11. Net irrigation norm by administrative districts of the Republic of Serbia for the reference period 2041 - 2060

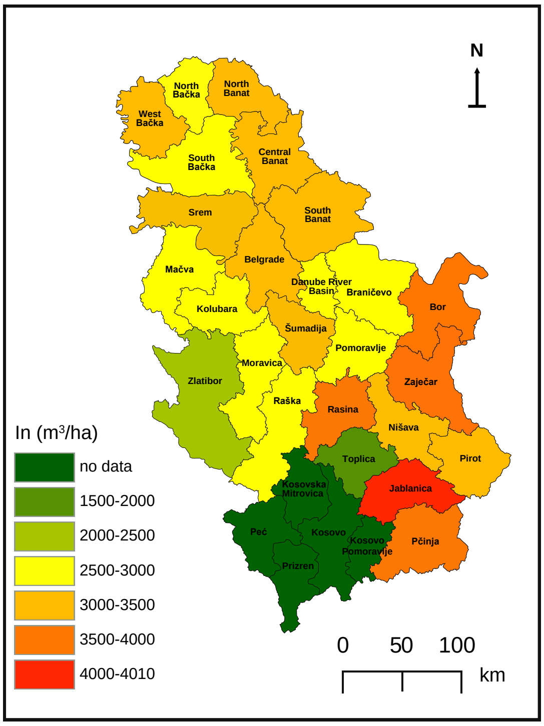


Figure 12. Net irrigation norm by administrative districts of the Republic of Serbia for the reference period 2080 - 2100

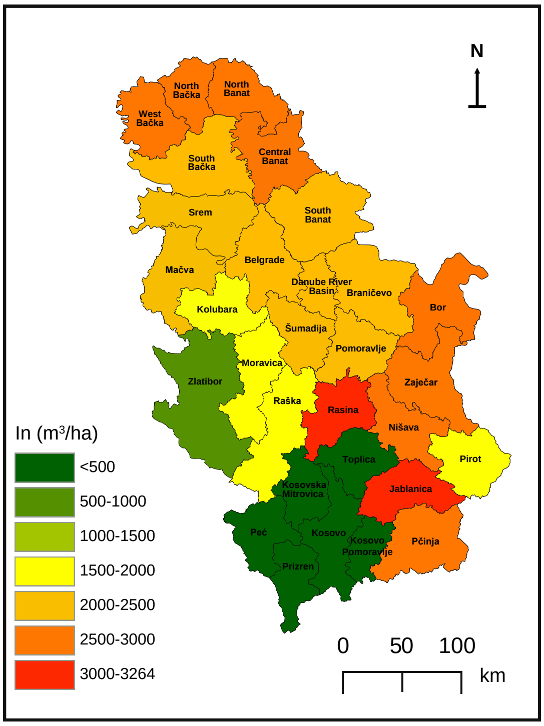


Figure 13. Net irrigation norm by administrative districts of the Republic of Serbia for the reference period 1986 - 2005

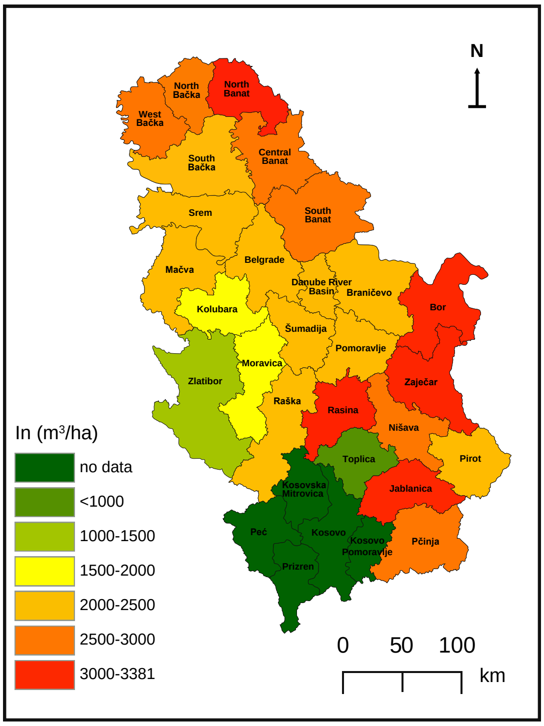


Figure 14. Net irrigation norm by administrative districts of the Republic of Serbia for the reference period 2021 - 2040.

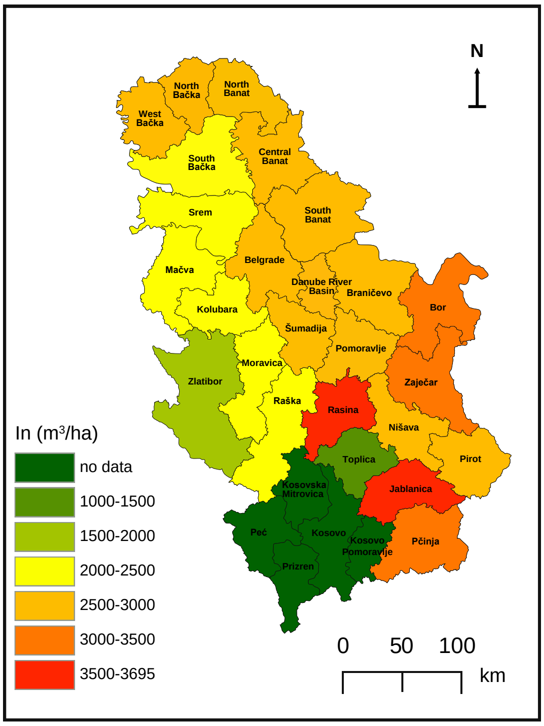


Figure 15. Net irrigation norm by administrative districts of the Republic of Serbia for the reference period 2041 - 2060.

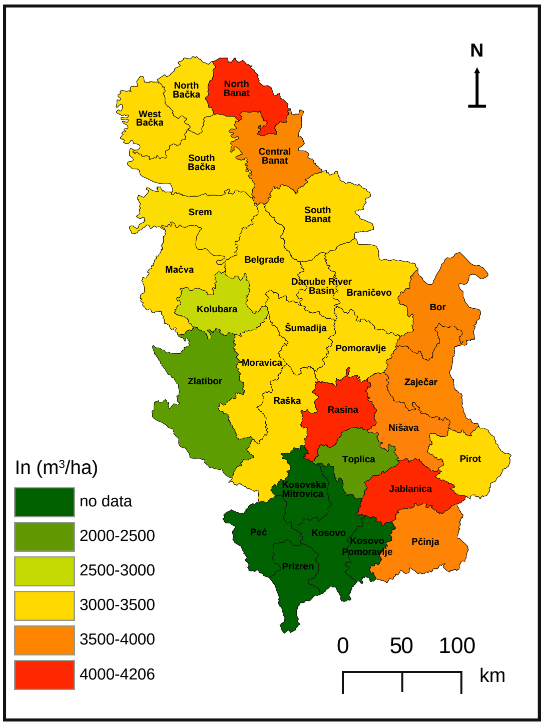


Figure 16. Net irrigation norm by administrative districts of the Republic of Serbia for the reference period 2080 - 2100.

Chart 3 shows the changes in the value of the median net irrigation rate (NNN) in relation to RF[2]. The average change in NNN in the P1 period compared to the RF period is 3.6 mm, which varies from -15.5 mm in North Banat to an increase of 32.6 mm in the Pirot District. The change of NNN in P2 varies from 1.2 mm in North Banat to 88.6 mm in the Toplica District, with an average value of 36.0 mm for RS. The average change of NNN in the P3 period is 93.8 mm and varies from 36.3 mm in the Central Banat District to 173.7 mm in the Toplica District. The obtained results for the middle and end of the century show that production without the application of irrigation will be risky and that the needs will increase by one to five average waterings per vegetation season.

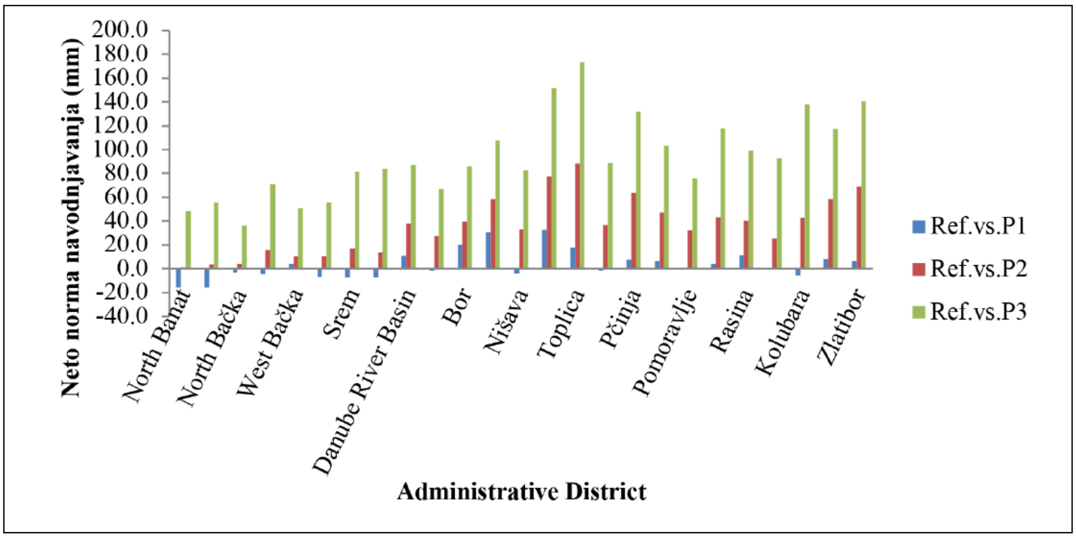


Chart 3. The change in the value of the median net irrigation norm in the future climate (2021 - 2040, 2040 - 2060 and 2080 - 2100) in relation to the values of the median net irrigation norm of the reference period (1986 - 2005).

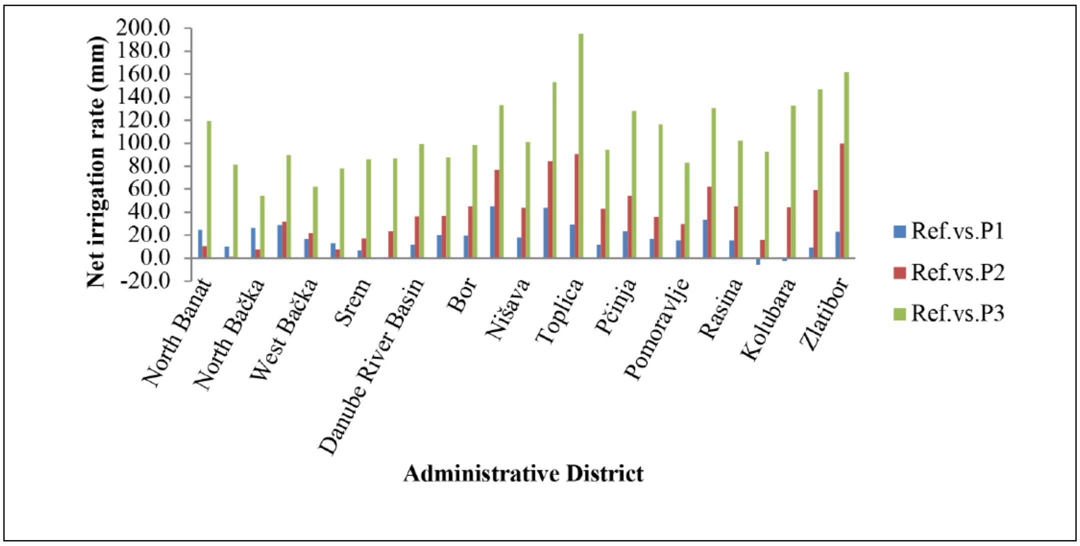


Chart 4. Changes in the value of the 75th percentile of the net irrigation norm in the future climate (2021 - 2040, 2040 - 2060 and 2080 - 2100) in relation to the values of the 75th percentile of the net irrigation norm of the reference period (1986 - 2005).

Chart 4 shows the changes in the values of the 75th percentile of NNN in relation to RF[2]. The average change of NNN in the P1 period in relation to RF is 18.3 mm, and varies from -5.7 mm in the Mačva District to an increase of 45.3 mm in the Zaječar District. The change of NNN in P2 varies from 1.3 mm in the Central Banat to 99.6 mm in the Zlatibor District, with an average value of 41.0 mm. The average change of NNN in the P3 period is 108.6 mm and varies from 54.2 mm

2 Ref. vs. P1 - change in net irrigation rate (NNN) in the 2021 – 2040 period in relation to RF; Ref. vs. P2 - change of NNN in the 2041 – 2060 period in relation to RF; Ref. vs. P3 - change of NNN in the 2080 – 2100 period in relation to RF.

in the Central Banat to 195.4 mm in the Toplica District. Also, the values of the 75th percentile of the change in the net irrigation norm indicate that the needs for water and irrigation will significantly increase in the middle and at the end of the century in relation to the reference period.

Table 1 shows the net irrigation norms in $m^3 \cdot ha^{-1}$ for all periods covered by the analysis.

Administrative district	PERIOD								Total agricultural land covered by the analysis (ha)
	1986-2005		2021-2040		2041-2060		2080-2100		
	median	75th percentile	median	75th percentile	median	75th percentile	median	75th percentile	
North Banat	2862,0	2892,3	2706,8	3140,0	2873,8	2995,3	3347,5	4085,5	169633
Central Banat	2710,1	2793,6	2554,9	2891,9	2748,8	2806,9	3267,8	3608,1	257234
North Bačka	2468,1	2521,4	2434,6	2781,8	2510,3	2594,3	2831,5	3062,9	123967
South Banat	2414,6	2465,3	2372,7	2754,2	2571,7	2786,2	3123,8	3362,2	295704
West Bačka	2583,2	2645,4	2623,1	2811,1	2687,2	2860,6	3093,4	3268,9	164049
South Bačka (North Srem)	2304,4	2355,0	2236,5	2486,0	2407,2	2427,6	2862,4	3135,0	243619
Srem	2258,8	2305,6	2186,6	2374,8	2429,4	2475,0	3070,3	3165,6	208636
City of Belgrade	2257,2	2346,8	2182,7	2355,9	2395,8	2583,0	3096,4	3214,5	130980
Danube River Basin	2042,8	2139,5	2149,8	2253,8	2425,5	2502,3	2914,6	3129,8	72364
Braničevo	2084,8	2191,3	2072,8	2393,7	2361,3	2559,8	2755,9	3065,9	129163
Bor	2832,6	2964,1	3036,0	3162,6	3231,5	3415,0	3691,2	3945,3	73108
Zaječar	2634,9	2650,3	2941,5	3103,0	3220,7	3421,6	3711,1	3985,3	85686
Nišava	2450,5	2545,5	2411,5	2727,5	2782,1	2984,3	3279,2	3552,9	70887
Pirot	1724,8	1819,7	2050,3	2260,4	2496,6	2664,3	3242,0	3351,5	41004
Toplica	196,5	499,6	374,3	794,0	1082,2	1404,3	1933,6	2453,2	48490
Jablanica	3120,0	3264,2	3108,1	3381,4	3488,7	3695,0	4010,3	4205,9	61019
Pčinja	2329,4	2516,1	2405,8	2752,4	2963,5	3056,8	3649,2	3795,8	59398
Šumadija	2106,5	2311,2	2173,2	2475,9	2581,5	2669,2	3135,9	3475,7	109205
Pomoravlje	2131,8	2240,9	2129,2	2398,4	2455,1	2541,2	2888,1	3072,4	83414
Raška	1583,6	1765,9	1623,9	2100,3	2013,6	2388,6	2761,4	3074,8	93945
Rasina	2833,1	3068,2	2947,8	3223,7	3233,6	3519,4	3825,5	4090,1	91128
Mačva	1975,1	2189,0	1979,4	2131,5	2231,4	2350,8	2903,3	3114,5	139322
Kolubara	1382,4	1583,1	1328,5	1559,3	1807,9	2025,9	2761,3	2912,1	121533
Moravica	1634,9	1865,9	1716,7	1959,2	2220,4	2460,1	2809,9	3335,2	106079
Zlatibor	756,4	829,0	824,9	1063,6	1446,8	1824,8	2164,0	2444,5	183866
Average	**2032,0**	**2172,5**	**2094,0**	**2347,9**	**2463,7**	**2648,4**	**3073,3**	**3326,0**	**107642**
Maximum	**3120,0**	**3264,2**	**3108,1**	**3381,4**	**3488,7**	**3695,0**	**4010,3**	**4205,9**	**295704**
Minimum	**196,5**	**499,6**	**374,3**	**794,0**	**1082,2**	**1404,3**	**1933,6**	**2444,5**	**41003**

Table 2 shows an assessment of the risk of water scarcity for crop production.

Production in conditions without irrigation Risk: lack of water for plant production								
Administrative district	Exposure				Vulnerability	Vulnerability[1]	Risk	
	Present time 2000-2019	Near future	Mid century 2041-2060	End of century 2081-2100	Present time	Future	Present time	Tendency
North Banat	2021-2040	Mid century	Large	Large	Moderate	Moderate	Moderate	0
Central Banat	2041-2060	End of century 2081-2100	Present time	Future	Present time	Tendency	Moderate	-
North Bačka	Large	Large	Large	Large	Moderate	Moderate	Moderate	0
South Banat	Large	Large	Large	Large	Moderate	Small	Moderate	-
West Bačka	Large	Large	Large	Large	Moderate	Moderate	Moderate	0
South Bačka	Large	Large	Large	Large	Moderate	Moderate	Moderate	0
Srem	Large	Large	Large	Large	Moderate	Small	Moderate	-
North Banat	Large	Large	Large	Large	Moderate	Moderate	Moderate	0
City of Belgrade	Large	Large	Large	Large	Small	Small	Moderate	-
Danube River Basin	Large	Large	Large	Large	Moderate	Moderate	Moderate	0
Braničevo	Large	Large	Large	Large	Moderate	Moderate	Moderate	0
Bor	Large	Large	Very large	Very large	Moderate	Moderate	Moderate	0
Zaječar	Large	Large	Large	Very large	Moderate	Moderate	Moderate	0
Nišava	Large	Large	Large	Large	Moderate	Small	Moderate	-
Pirot	Large	Large	Large	Large	Moderate	Moderate	Moderate	0
Toplica	Large	Small	Small	Small	Moderate	Small	Moderate	-
Jablanica	Large	Large	Large	Very large	Moderate	Moderate	Moderate	0
Pčinja	Large	Large	Large	Very large	Moderate	Small	Moderate	-
Šumadija	Moderate	Moderate	Large	Large	Moderate	Moderate	Low	+
Pomoravlje	Large	Large	Large	Large	Moderate	Moderate	Moderate	0
Raška	Moderate	Moderate	Moderate	Large	Moderate	Moderate	Low	0
Rasina	Large	Large	Large	Very large	Moderate	Large	Moderate	+
Mačva	Moderate	Large	Large	Large	Moderate	Very large	Moderate	+
Kolubara	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	+
Moravica	Moderate	Small	Moderate	Moderate	Moderate	Small	Moderate	0
Zlatibor	Small	Small	Small	Moderate	Moderate	Moderate	Moderate	+
National level	**Large to moderate**	**Large to moderate**	**Large to moderate**	**Large to moderate**	**Moderate**	**Moderate to large**	**Moderate to low**	**0**

1 This is an auxiliary column, a vulnerability based on reduced yields in the future; <3 small, 3-10% moderate, 10-15% large,> 15% very large

Exposure estimation categories (frequency of occurrence):

- small - once in 20 years (probability 5%)
- moderate - once in 10 years (probability 10%)
- large - once in 4 years (probability 25%)
- very large - once in 2 years (probability 50%)

Vulnerability assessment categories:

- small - with little or no negative consequences
- moderate - with negative consequences that can lead to smaller economic losses
- large - with negative consequences that can lead to significant economic losses and/or may affect certain social categories
- very large - severe negative consequences that can lead to large economic losses and/or social instability

Risk is assessed on the basis of current exposure, but the risk trend column indicates whether it is expected to increase (+), decrease (-), or remain the same in the future.

Table 3 shows the average seasonal water demand for the evapotranspiration process -ΣETc (mm), effective precipitation -ΣPe (mm) and water deficit -ΣIn (mm) during the vegetation period for the crops included in the analysis, by regions of the Republic of Serbia.

Table 3. Average seasonal water demand for the evapotranspiration process ΣETc (mm), effective precipitation -Pe (mm) and water deficit during the vegetation period ΣIn (mm) for the crops included in the analysis, by regions of the Republic of Serbia

Crop	Maize	Small grains	Sunflower	Sugar beet	Meadows and pastures	Vine	Apple, pear, plum, walnut, and hazelnut without grass cover	Apple, pear, plum, walnut, and hazelnut orchard with grass	Apricot, peach, nectarine without grass cover	Apricot, peach, nectarine orchard with grass	Cherries and sour cherries without grass cover	Cherries and sour cherries orchard with grass	Raspberry, blackberry, blueberry	Average
Vojvodina region														
Average 1986-2005 median														
ΣETc (mm)	605,6	371,0	437,1	779,1	404,6	566,5	717,7	901,5	414,6	529,3	359,1	452,6	470,6	538,9
ΣPe (mm)	255,6	347,7	215,3	295,5	229,0	337,1	337,1	337,1	217,2	217,2	186,1	186,1	225,8	260,1
ΣIn (mm)	349,8	24,1	221,7	483,5	175,6	229,5	380,6	564,5	197,0	311,6	173,2	266,6	244,5	278,6
Average 1986-2005 75th percentile														
ΣETc (mm)	609,8	373,0	438,3	783,4	406,3	568,2	719,6	904,0	415,7	530,8	359,8	453,3	471,7	540,3
ΣPe (mm)	262,3	357,8	223,8	302,5	236,4	342,6	342,6	342,6	225,5	225,5	193,5	193,5	234,2	267,5
ΣIn (mm)	356,9	28,1	229,3	491,6	182,6	235,2	386,3	570,2	204,6	319,5	179,9	273,4	252,2	284,7
Average 2000-2019														
ΣETc (mm)	625,1	381,7	448,3	803,7	414,7	584,1	741,3	931,2	425,9	543,9	367,4	463,0	483,3	554,9
ΣPe (mm)	277,9	370,4	239,1	318,6	254,9	362,5	362,5	362,5	239,8	239,8	213,6	213,6	247,6	284,8
ΣIn (mm)	347,2	11,2	209,2	485,0	159,8	221,7	378,8	568,7	186,1	304,1	153,9	249,5	235,7	270,1

Average 2021-2040 median														
ΣETc (mm)	614,5	388,9	451,1	795,4	417,0	575,8	729,6	916,6	430,2	548,9	373,7	470,6	487,4	557,2
ΣPe (mm)	268,4	363,2	227,8	310,6	241,3	349,7	349,7	349,7	231,9	231,9	196,9	196,9	239,3	275,4
ΣIn (mm)	343,8	47,0	226,3	481,2	177,3	225,0	379,0	566,6	205,6	324,5	182,4	280,2	255,7	281,6
Average 2021-2040 75th percentile														
ΣETc (mm)	621,2	414,4	469,9	801,8	430,9	582,0	738,0	926,9	450,2	574,3	392,3	494,1	509,4	572,0
ΣPe (mm)	282,4	399,1	241,1	327,2	253,7	367,5	367,5	367,5	241,7	241,7	210,5	210,5	249,7	286,6
ΣIn (mm)	376,2	66,5	251,0	511,7	198,8	260,3	414,7	601,5	227,2	352,8	196,0	298,9	280,0	308,2
Average 2041-2060 median														
ΣETc (mm)	626,8	392,4	454,4	805,2	421,3	588,5	743,1	932,6	432,4	552,0	374,4	471,6	490,4	564,1
ΣPe (mm)	257,8	384,4	224,0	297,3	241,3	340,1	340,1	340,1	232,0	232,0	199,3	199,3	238,0	272,0
ΣIn (mm)	371,9	13,1	230,6	509,2	180,7	245,5	402,9	593,7	201,2	320,6	174,0	271,3	252,2	292,1
Average 2041-2060 75th percentile														
ΣETc (mm)	633,6	420,7	466,7	814,6	430,9	593,7	752,4	945,1	449,1	572,7	392,6	494,3	507,3	573,1
ΣPe (mm)	268,5	397,4	231,1	308,6	248,9	354,3	354,3	354,3	238,6	238,6	205,6	205,6	245,9	279,6
ΣIn (mm)	383,5	42,7	246,6	526,5	195,4	264,1	423,8	616,5	223,7	345,4	195,8	295,5	273,4	305,6
Average 2080-2100 median														
ΣETc (mm)	672,7	416,3	481,7	867,8	445,5	630,3	800,1	1005,2	457,4	584,0	395,3	498,0	518,8	597,7
ΣPe (mm)	237,8	415,4	218,0	279,1	229,9	318,9	318,9	318,9	229,5	229,5	203,5	203,5	235,0	265,5
ΣIn (mm)	432,0	0,7	261,3	581,7	212,7	307,0	474,8	676,6	223,2	347,4	188,7	289,6	278,1	327,4
Average 2080-2100 75th percentile														
ΣETc (mm)	688,9	431,6	494,0	884,0	457,3	643,0	815,7	1024,5	470,2	600,0	408,3	514,2	532,7	612,2
ΣPe (mm)	256,3	440,8	233,0	294,7	249,3	337,8	337,8	337,8	247,2	247,2	215,6	215,6	253,5	281,5
ΣIn (mm)	466,3	18,9	290,5	624,5	239,6	343,1	515,7	725,3	250,3	380,9	213,9	320,6	308,2	360,9
City of Belgrade														
City of Belgrade 1986-2005 median														
ΣETc (mm)	598,3	369,6	431,5	770,6	399,8	558,1	708,4	889,8	409,0	521,8	354,9	447,0	463,2	532,8
ΣPe (mm)	264,8	372,5	226,7	309,9	240,7	450,2	450,2	450,2	302,1	302,1	264,7	264,7	315,5	326,6
ΣIn (mm)	332,6	-0,6	202,9	460,1	157,0	98,7	242,9	424,1	108,0	220,9	101,5	193,8	150,8	210,7
City of Belgrade 1986-2005 75th percentile														
ΣETc (mm)	602,8	371,9	434,0	774,3	402,9	561,4	712,4	894,7	412,2	526,1	356,6	449,1	466,8	536,7
ΣPe (mm)	272,4	381,5	232,4	315,6	246,3	472,5	472,5	472,5	319,4	319,4	277,8	277,8	326,4	335,2
ΣIn (mm)	353,2	0,9	227,1	485,3	179,6	125,9	276,9	459,3	129,1	243,0	110,7	202,9	176,1	225,9
City of Belgrade 2000-2019														
ΣETc (mm)	611,2	380,1	439,5	786,4	406,5	581,1	737,2	925,8	426,6	544,6	368,4	464,1	483,6	550,4
ΣPe (mm)	273,8	375,4	239,0	314,8	251,6	399,8	399,8	399,8	274,8	274,8	253,5	253,5	283,4	307,3
ΣIn (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
City of Belgrade 2021-2040 median														
ΣETc (mm)	607,3	388,3	443,7	783,3	410,8	575,5	727,0	911,9	424,3	541,2	369,7	465,3	479,9	549,8
ΣPe (mm)	279,6	390,2	248,6	326,7	261,1	454,7	454,7	454,7	307,9	307,9	265,3	265,3	317,5	331,8
ΣIn (mm)	321,9	11,1	187,9	451,0	143,3	120,7	276,1	463,3	112,7	228,5	104,4	201,4	158,0	214,3

City of Belgrade 2021-2040 75th percentile														
ΣETc (mm)	613,0	416,0	464,7	788,3	426,5	576,2	731,3	918,4	446,9	569,9	389,9	490,8	505,0	571,1
ΣPe (mm)	293,4	411,0	256,1	342,0	272,2	475,7	475,7	475,7	318,3	318,3	273,0	273,0	331,4	348,1
ΣIn (mm)	345,7	33,8	240,1	475,3	186,8	182,9	340,4	531,9	163,8	286,9	138,6	236,1	214,3	259,7
City of Belgrade 2041-2060 median														
ΣETc (mm)	621,3	391,3	451,4	798,1	418,5	589,0	748,3	938,3	431,9	551,0	374,6	471,7	489,0	563,2
ΣPe (mm)	264,2	400,0	236,8	308,5	254,5	439,4	439,4	439,4	300,6	300,6	258,9	258,9	308,0	322,8
ΣIn (mm)	354,8	-3,3	216,3	489,4	162,7	144,8	299,6	486,8	130,4	249,1	115,2	212,1	178,9	238,4
City of Belgrade 2041-2060 75th percentile														
ΣETc (mm)	628,8	420,3	463,6	809,6	427,8	597,4	753,3	945,4	446,7	569,3	391,4	492,4	504,1	571,5
ΣPe (mm)	272,6	415,9	239,5	310,8	258,3	454,1	454,1	454,1	310,8	310,8	265,8	265,8	320,1	331,0
ΣIn (mm)	377,7	27,0	250,5	515,8	203,1	185,4	347,5	542,1	161,4	283,8	142,2	242,7	210,3	268,8
City of Belgrade 2080-2100 median														
ΣETc (mm)	662,1	411,7	466,4	853,0	434,8	632,4	803,9	1010,0	454,9	580,3	393,0	494,8	515,1	596,1
ΣPe (mm)	223,3	436,7	214,4	269,4	228,8	392,6	392,6	392,6	290,9	290,9	267,7	267,7	302,0	304,8
ΣIn (mm)	436,5	-14,2	259,8	585,0	210,6	234,3	406,6	614,9	167,4	293,1	136,0	238,5	220,0	288,6
City of Belgrade 2080-2100 75th percentile														
ΣETc (mm)	677,4	421,8	487,6	874,4	450,8	646,5	821,8	1032,0	471,9	601,8	410,9	517,2	533,5	606,6
ΣPe (mm)	245,7	464,8	226,5	282,9	244,4	428,6	428,6	428,6	319,6	319,6	284,0	284,0	327,0	326,9
ΣIn (mm)	451,0	1,6	273,5	601,9	230,8	280,7	451,8	656,3	186,0	311,0	149,0	251,3	240,6	314,5
Southern and Eastern Serbia														
Average 1986-2005 median														
ΣETc (mm)	614,7	376,4	444,9	784,6	406,0	573,4	727,6	914,2	414,2	528,8	357,6	450,6	470,0	529,8
ΣPe (mm)	280,0	416,2	230,7	304,6	258,7	372,8	372,8	372,8	251,4	251,4	218,9	218,9	258,7	296,1
ΣIn (mm)	335,7	-39,8	213,3	477,0	146,3	200,7	354,9	541,4	162,1	276,7	138,5	231,5	210,7	233,0
Average 1986-2005 75th percentile														
ΣETc (mm)	619,7	381,5	225,4	262,1	410,2	577,6	732,7	920,5	418,5	534,4	360,6	454,3	474,8	534,4
ΣPe (mm)	294,6	427,0	119,7	104,7	270,1	387,0	387,0	387,0	263,7	263,7	229,3	229,3	270,5	308,2
ΣIn (mm)	353,0	-28,3	114,9	163,2	161,2	216,8	372,1	559,9	176,3	291,7	147,3	240,6	226,7	246,5
Average 2000-2019														
ΣETc (mm)	656,7	402,5	467,7	836,0	432,5	613,3	779,3	978,9	443,1	565,8	381,7	480,9	509,0	568,3
ΣPe (mm)	266,3	412,4	244,3	336,1	251,1	357,9	357,9	357,9	242,7	242,7	216,7	216,7	249,5	285,6
ΣIn (mm)	390,3	-9,9	223,4	499,9	181,4	255,4	421,3	621,0	200,4	323,1	165,0	264,2	259,6	282,7
Average 2021-2040 median														
ΣETc (mm)	625,9	394,3	458,5	792,5	419,0	587,0	742,7	932,5	430,3	549,1	372,7	469,4	487,8	549,4
ΣPe (mm)	275,6	415,0	236,2	310,8	262,1	369,4	369,4	369,4	252,1	252,1	221,8	221,5	259,6	295,7
ΣIn (mm)	347,0	-8,7	225,4	483,2	156,8	218,9	375,7	565,0	180,1	298,6	152,7	249,6	230,1	255,2
Average 2021-2040 75th percentile														
ΣETc (mm)	633,9	420,6	287,2	268,7	433,2	592,8	752,9	945,8	450,3	574,4	391,3	492,6	509,4	566,6
ΣPe (mm)	293,6	439,1	147,1	108,6	277,4	388,1	388,1	388,1	264,5	264,5	234,5	234,3	273,5	310,7
ΣIn (mm)	375,1	17,3	153,4	174,3	189,3	245,0	401,4	590,8	208,6	332,9	179,8	280,1	261,7	282,6

Average 2041-2060 median														
ΣETc (mm)	644,9	405,0	469,5	813,3	430,3	606,3	766,0	961,3	440,4	562,2	380,3	479,1	499,6	565,1
ΣPe (mm)	245,5	437,8	220,4	278,6	243,3	343,7	343,7	343,7	240,0	240,0	214,9	214,9	245,0	281,3
ΣIn (mm)	401,1	-17,4	248,8	527,9	189,0	258,0	418,1	613,6	202,8	324,5	169,2	268,0	256,7	288,6
Average 2041-2060 75th percentile														
ΣETc (mm)	655,2	435,6	480,7	823,9	443,5	612,1	776,9	976,1	460,4	587,0	402,0	505,9	520,2	579,6
ΣPe (mm)	264,7	459,0	233,7	315,7	259,2	370,2	370,2	370,2	258,1	258,1	230,8	230,8	262,9	301,4
ΣIn (mm)	425,1	25,3	271,9	549,6	213,9	299,5	464,8	662,5	237,7	363,7	204,9	308,1	291,6	314,6
Average 2080-2100 median														
ΣETc (mm)	702,2	436,8	493,7	866,6	459,3	655,7	833,2	1046,8	468,6	598,1	403,4	508,0	531,2	603,1
ΣPe (mm)	218,3	448,4	214,8	274,4	231,4	308,6	308,6	308,6	235,5	235,5	216,0	216,0	240,4	267,4
ΣIn (mm)	479,9	-12,7	282,4	602,2	229,4	342,3	519,0	730,6	232,0	361,3	187,3	292,5	290,9	332,1
Average 2080-2100 75th percentile														
ΣETc (mm)	714,5	449,0	218,8	224,9	472,4	667,4	847,6	1064,5	484,5	618,2	419,2	527,8	548,7	714,5
ΣPe (mm)	247,2	485,2	99,6	71,5	250,0	353,7	353,7	353,7	255,4	255,4	234,7	234,7	261,3	247,2
ΣIn (mm)	509,9	6,5	133,0	161,4	257,3	382,1	560,1	774,8	259,8	392,1	208,4	314,2	320,2	509,9
Šumadija, Central and Western Serbia														
Average 1986-2005 median														
ΣETc (mm)	594,3	373,9	439,4	783,2	393,5	557,0	706,7	887,6	419,4	517,5	352,0	443,4	459,6	515,8
ΣPe (mm)	307,7	448,7	240,3	325,2	283,3	413,2	413,2	413,2	274,9	274,9	235,8	235,8	283,8	324,1
ΣIn (mm)	286,2	-72,0	199,1	460,0	110,4	143,5	293,2	473,9	144,3	242,4	116,9	208,3	175,6	191,2
Average 1986-2005 75th percentile														
ΣETc (mm)	598,0	379,7	442,7	787,3	397,0	558,9	708,9	890,5	423,9	523,1	355,0	447,0	464,1	519,1
ΣPe (mm)	322,5	458,9	248,1	342,8	291,6	424,7	424,7	424,7	283,2	283,2	247,2	247,2	292,0	332,0
ΣIn (mm)	307,8	-60,8	217,7	474,2	127,3	164,3	313,9	495,1	163,8	262,9	127,5	219,7	196,5	209,8
Average 2000-2019														
ΣETc (mm)	617,0	386,8	456,5	787,9	409,2	578,1	734,2	922,2	421,3	537,8	363,9	458,3	477,5	534,3
ΣPe (mm)	327,2	459,1	276,5	425,4	314,5	434,6	434,6	434,6	296,2	296,2	264,5	264,5	304,4	345,4
ΣIn (mm)	289,8	-72,3	180,0	362,5	94,7	143,4	299,6	487,6	125,1	241,6	99,3	193,8	173,1	189,0
Average 2021-2040 median														
ΣETc (mm)	602,0	390,4	452,6	791,7	404,8	568,0	718,9	902,0	420,2	536,0	365,4	460,0	477,1	531,3
ΣPe (mm)	311,0	453,9	249,4	344,6	293,9	416,8	416,8	416,8	281,3	281,3	245,1	245,1	288,3	328,6
ΣIn (mm)	289,9	-53,4	200,8	450,9	108,4	148,9	300,1	482,9	140,9	256,5	121,8	216,5	191,9	202,8
Average 2021-2040 75th percentile														
ΣETc (mm)	611,9	419,0	474,2	399,4	421,4	573,8	727,2	913,2	442,9	564,8	386,2	486,1	500,3	550,8
ΣPe (mm)	326,3	474,9	262,1	176,1	304,3	434,8	434,8	434,8	293,0	292,6	252,5	252,5	301,6	342,3
ΣIn (mm)	321,5	-22,5	238,9	236,7	148,3	182,3	336,3	522,4	175,2	297,2	152,9	252,0	223,9	234,4
Average 2041-2060 median														
ΣETc (mm)	620,3	401,2	464,5	810,2	417,2	587,0	743,3	932,3	445,3	549,3	373,1	469,9	487,6	548,4
ΣPe (mm)	283,6	465,7	237,2	315,6	277,2	388,5	388,5	388,5	271,2	271,2	236,3	236,3	278,4	315,0
ΣIn (mm)	342,8	-55,1	227,3	491,8	143,4	197,4	355,9	546,3	177,1	280,7	139,6	235,9	212,7	236,8

Average 2041-2060 75th percentile													
ΣETc (mm)	630,6	438,0	479,9	823,7	430,9	592,7	750,2	941,9	468,6	576,0	396,9	499,3	509,4	562,1
ΣPe (mm)	299,6	490,6	247,8	324,8	289,4	406,7	406,7	406,7	281,7	281,7	249,9	249,9	290,3	329,7
ΣIn (mm)	369,2	-16,6	257,6	522,5	168,3	226,2	386,3	578,2	208,8	315,5	168,7	270,7	242,9	256,2
Average 2080-2100 median														
ΣETc (mm)	678,2	431,3	493,8	882,2	445,4	635,7	807,3	1013,9	474,0	584,8	395,5	498,0	519,0	586,7
ΣPe (mm)	245,9	491,2	222,7	275,9	255,4	348,4	348,4	348,4	266,0	266,0	241,9	241,9	272,8	300,1
ΣIn (mm)	427,3	-58,8	271,6	600,0	188,4	278,5	448,5	652,5	212,4	324,8	158,8	263,0	250,8	283,4
Average 2080-2100 75th percentile														
ΣETc (mm)	687,3	447,4	509,2	446,5	457,2	645,6	818,9	1028,3	490,9	605,2	413,4	520,3	536,5	601,1
ΣPe (mm)	279,7	532,4	239,2	151,4	282,9	400,6	400,6	400,6	292,0	292,0	262,4	262,4	300,3	332,2
ΣIn (mm)	463,6	-38,9	296,5	315,8	221,8	326,5	497,4	702,3	240,1	351,9	179,8	283,6	280,8	319,1
Average for the Republic of Serbia 1986-2005 median														
ΣETc (mm)	605,0	373,8	439,0	779,2	401,4	565,6	717,4	901,2	415,8	525,0	356,1	448,7	466,6	528,0
ΣPe (mm)	281,4	405,7	226,7	300,8	257,5	378,8	378,8	378,8	251,4	251,4	217,0	217,0	259,8	296,2
ΣIn (mm)	323,7	-30,6	211,9	478,2	143,5	186,4	337,9	521,6	164,0	273,3	139,8	232,4	206,5	231,5
Average for the Republic of Serbia 1986-2005 75th percentile														
ΣETc (mm)	609,3	378,1	372,0	652,6	404,6	568,3	720,6	905,3	419,2	529,4	358,4	451,5	470,2	531,2
ΣPe (mm)	293,6	416,0	197,8	257,5	266,6	390,1	390,1	390,1	261,5	261,5	227,0	227,0	269,5	305,5
ΣIn (mm)	339,6	-21,7	190,0	407,5	157,0	201,5	353,7	538,0	178,3	288,3	148,6	241,6	222,1	244,6
Average for the Republic of Serbia 2000-2019														
ΣETc (mm)	633,3	390,8	454,0	803,6	419,0	592,6	752,5	945,3	430,7	549,9	371,5	468,0	490,7	553,0
ΣPe (mm)	289,3	414,1	251,7	330,7	272,5	385,4	385,4	385,4	260,3	260,3	232,6	232,6	267,9	305,4
ΣIn (mm)	344,0	-23,4	202,2	472,9	146,5	207,2	367,1	559,9	170,4	289,6	138,9	235,4	222,8	247,6
Average for the Republic of Serbia 2021-2040 median														
ΣETc (mm)	614,3	391,3	452,5	793,5	413,6	577,3	730,8	917,5	426,8	544,6	370,5	466,6	484,0	545,8
ΣPe (mm)	285,1	412,0	237,4	315,7	266,4	382,5	382,5	382,5	258,0	258,0	224,0	223,9	265,4	302,0
ΣIn (mm)	326,8	-6,6	215,8	475,3	146,5	194,3	348,4	535,1	172,0	289,6	149,2	245,7	222,1	244,2
Average for the Republic of Serbia 2021-2040 75th percentile														
ΣETc (mm)	622,5	418,2	420,0	615,8	428,5	583,0	739,7	929,0	447,8	571,1	389,9	490,9	506,3	563,2
ΣPe (mm)	300,9	438,3	221,7	254,6	279,2	400,8	400,8	400,8	269,4	269,2	235,1	235,0	278,1	315,5
ΣIn (mm)	357,1	19,0	219,9	388,7	178,8	226,7	381,9	569,5	201,3	325,2	174,1	274,6	252,8	273,4
Average Републике Србије 2041-2060 median														
ΣETc (mm)	631,0	399,7	460,2	805,8	423,1	594,4	751,6	943,0	439,4	554,7	376,1	473,8	492,7	559,4
ΣPe (mm)	261,9	430,3	228,3	298,4	254,0	360,8	360,8	360,8	250,2	250,2	219,1	219,1	256,2	291,1
ΣIn (mm)	372,4	-20,3	232,1	507,3	171,1	230,6	389,2	581,4	191,2	306,4	158,9	256,4	238,3	271,0
Average for the Republic of Serbia 2041-2060 75th percentile														
ΣETc (mm)	640,2	431,6	473,2	815,9	435,3	600,1	760,5	955,3	459,3	578,8	397,3	500,0	512,5	571,9
ΣPe (mm)	277,2	450,2	237,3	311,1	265,9	380,8	380,8	380,8	262,3	262,3	231,3	231,3	269,2	305,5
ΣIn (mm)	393,7	16,8	255,1	527,3	193,7	261,6	423,5	617,8	221,4	340,0	188,3	290,0	267,6	291,6

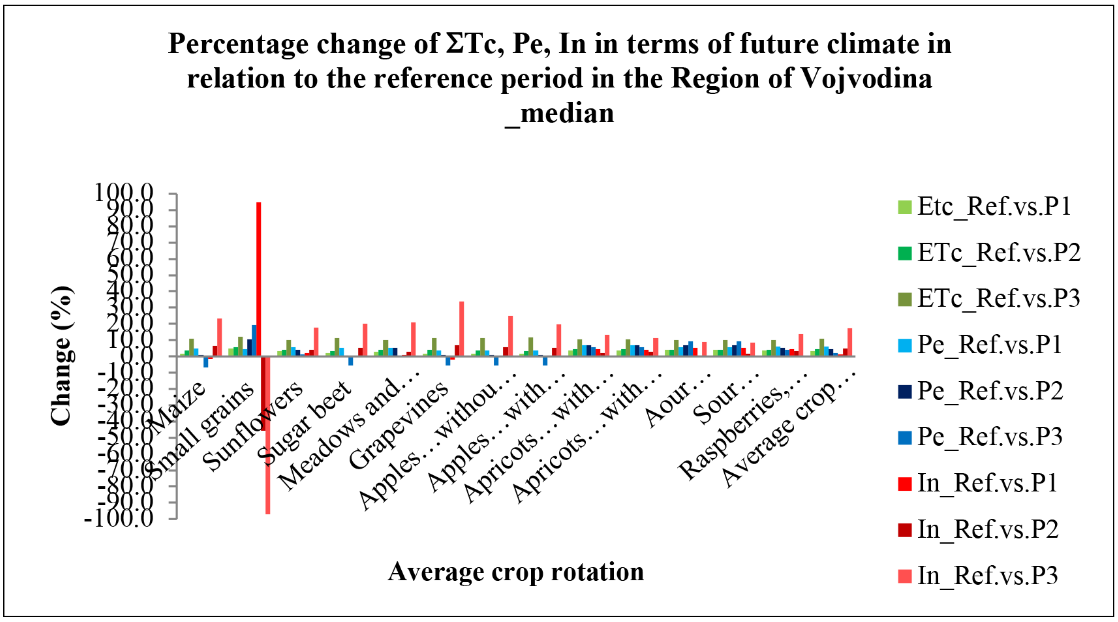
Average for the Republic of Serbia 2080-2100 median														
ΣETc (mm)	684,7	428,3	486,8	867,6	450,0	641,2	814,5	1023,1	466,6	589,2	398,2	501,5	523,2	596,1
ΣPe (mm)	232,8	452,4	218,7	277,3	238,6	327,6	327,6	327,6	245,8	245,8	222,8	222,8	251,7	278,8
ΣIn (mm)	447,9	-23,8	268,4	585,9	210,8	307,7	479,6	685,9	220,7	343,0	176,5	280,1	271,7	313,4
Average for the Republic of Serbia 2080-2100 75th percentile														
ΣETc (mm)	697,1	442,5	401,2	632,5	462,5	652,7	828,4	1040,4	482,1	608,3	413,9	521,2	539,7	611,0
ΣPe (mm)	260,1	487,1	187,5	209,6	260,1	367,2	367,2	367,2	267,4	267,4	240,2	240,2	274,2	305,3
ΣIn (mm)	480,5	-4,8	236,0	446,5	239,9	349,3	523,3	733,0	247,9	372,9	198,4	303,7	301,0	346,3

Vojvodina Region

The median and 75th percentile of RF for mean evapotranspiration values (ΣETc), effective precipitation (ΣPe) and water deficit ΣIn, during the vegetation period of the crops represented in the crop rotation are 532.2 mm, 541 mm, 260.5 mm, 267.9 mm and 278.6 mm, 285.3 mm, respectively. Values of ΣETc range from 359.1 mm, 359.8 mm for cherries and sour cherries without grass cover to 901.5 mm, 904.0 mm for apples, pears when the orchard is grassed. Effective precipitation is lowest for cherries and sour cherries without grass cover 186.1 mm, 193.5 mm, and the highest values were obtained for small grains 347.7 mm, 357.8 mm. The results of ΣIn show that the lowest values are for small grains 24.1 and 28.1 mm, and the highest ones for apples, pears ... with grass cover 564.5 and 570.2 mm.

Chart 5 shows the percentage change in average values ΣETc, ΣPe and ΣIn during the vegetation period in the future climate (P1, P2, P3 respectively) in relation to RF for the Region of Vojvodina. The median for the average percentage change of ΣETc for the P1, P2 and P3 period, respectively in relation to RF are 3.0%, 4.1% and 10.8%. It varies in the R1 period from 1.5% in maize to 4.8% in small grains. In the second period of the future (P2) in relation to the reference period it ranges from 3.3% for sugar beet to 5.8% for small grains, while in the P3 period it varies from 10.0% in grassed orchards of sour cherries and cherries to 12, 2% for small grains. The 75th percentile values for the average percentage change of ΣETc for the P1, P2 and P3 period, respectively in relation to RF are 6.0%, 6.8% and 13.3%. It varies in the P1 period from 1.9% in maize to 11.1% in small grains. In the second period of the future (P2) in relation to the reference period it ranges from 3.9% in maize to 12.8% in small grains, while in the P3 period it varies from 12.6% in meadows and pastures to 15.7% in small grains.

The median for the average percentage change of ΣPe for the P1, P2 and P3 period, respectively in relation to RF are 5.3%, 4.4% and 2.0%. It varies in the P1 period from 3.7% during the vegetation period of apple, pear orchards ... in grassed and orchards without grass cover to 6.8% in apricot and peach orchards with and without grass cover. In the second period of the future (P2) in relation to the reference period it ranges from 0.6% in sugar beet to 10.6% in small grains, while in the P3 period it varies from a decrease of -7.0% in maize to an increase of 19, 5% for small grains. The percentile values for the average percentage change of ΣPe for the P1, P2 and P3 period, respectively in relation to RF is 7.9%, 4.8% and 5.7%. It varies in the P1 period from 6.6% for raspberries, blackberries ... to 11.5% for small grains. In the second period of the future (P2) in relation to the reference period it ranges from 2.0% for sugar beet to 11.1% for small grains, while in the P3 period it varies from -2.6% for sugar beet to 23.2% in small grains.



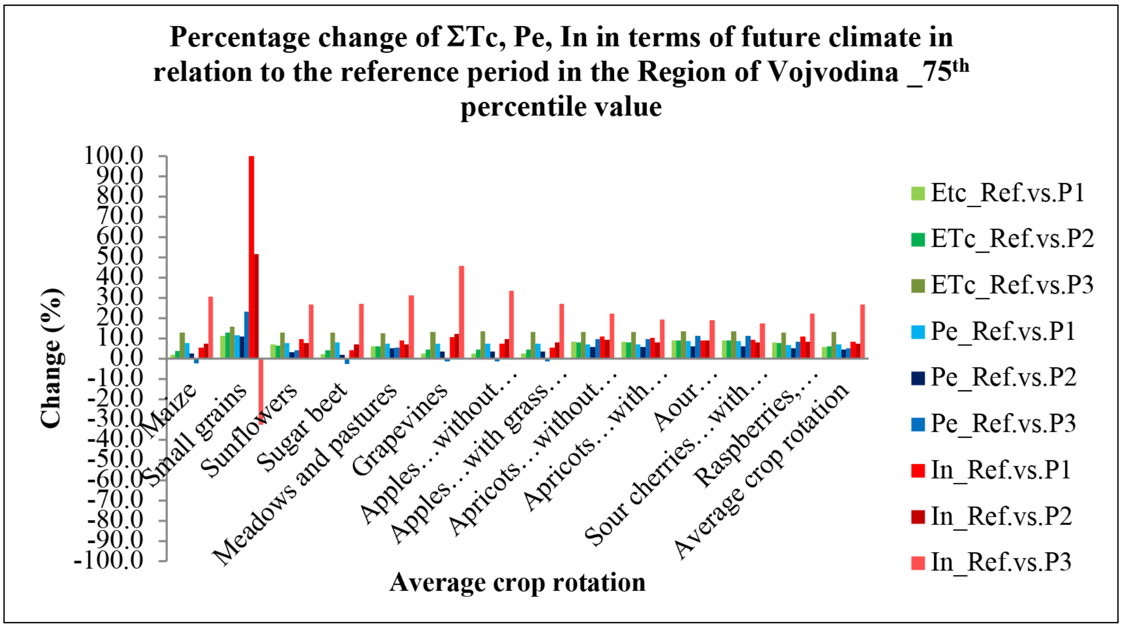


Chart 5. Percentage change in water consumption on the process of evapotranspiration of crops represented in crop rotation (ΣETc mm), effective precipitation ΣPe mm) and water deficit ΣIn mm) during the vegetation period in the future climate (P1 period: 2021 - 2040, P2 period: 2041 - 2060 and P3 period: 2080 - 2100) in relation to the reference period (ref. period: 1986 - 2005) for the Region of Vojvodina.

The median for the average percentage change of ΣIn for the P1, P2 and P3 period, respectively in relation to RF are 8.4%, 0.4% and 9.8%. It varies in the P1 period from -2.0% in grapevines to 94.7% in small grains. In the second period of the future (P2) in relation to the reference period, it ranges from -45.6% for small grains to 6.9% for grapevines, while in the P3 period it varies from a decrease of -97.1% for small grains to 33, 8% for grapevines. The 75th percentile values for the average percentage change of ΣIn for the P1, P2 and P3 period, respectively in relation to RF is 17.6%, 11.5% and 22.6%. It varies in the P1 period from 4.1% in sugar beet to 100% in small grains. In the second period of the future (P2) in relation to the reference period it ranges from 7.0% for meadows and pastures to 51.7% for small grains, while in the P3 period it varies from -32.8% for small grains to 45.9 % in grapevine.

In the Region of Vojvodina, the largest variations of water deficit in small grains are observed, while a significant increase in water deficit at the end of the century is predicted in grapevines.

Belgrade Region

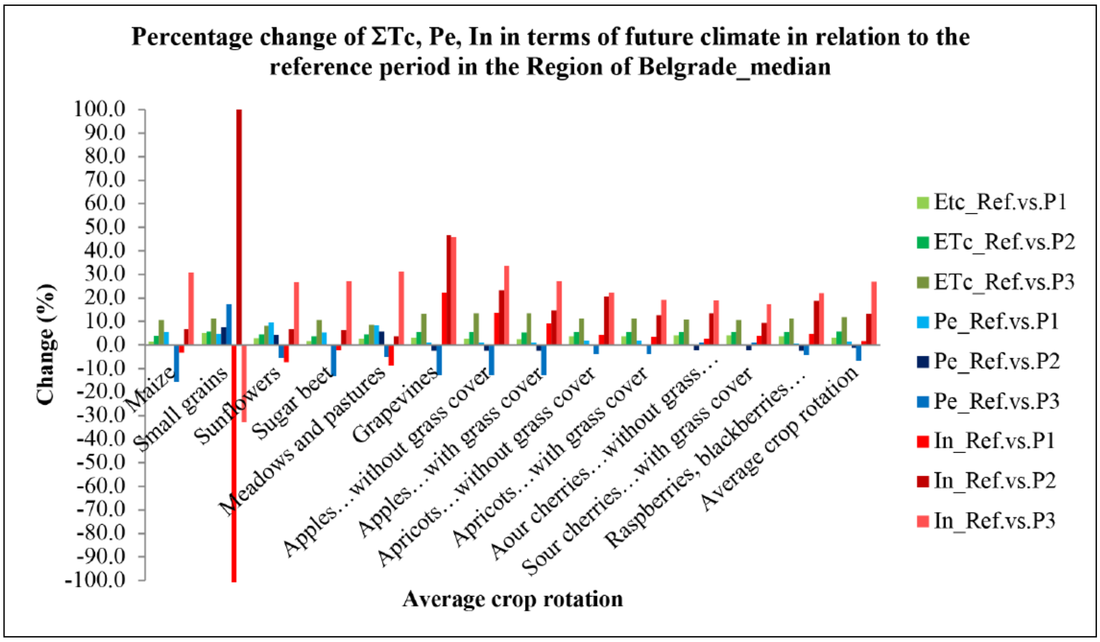
The median and 75th percentile of RF for mean evapotranspiration values (ΣETc), effective precipitation (ΣPe) and water deficit ΣIn), during the vegetation period of the crops represented in the crop rotation are 532.5 mm, 535.0 mm, 324.3 mm, 337.3 mm and 207.4 mm, 228.3 mm, respectively. The values of ΣETc range from 354.9 mm, 356.6 mm for cherries and sour cherries without grass cover, to 889.8 mm, 894.7 mm for apples, pears ... when the orchard is grassed. Effective precipitation is the lowest for sunflowers, 226.7 mm, 232.4 mm, and the highest values were obtained for grapevines and apple and pear orchards with and without grass cover of 450.2 and 472.5 mm. The results of ΣIn show that the lowest values are for small grains, -0.6 and 0.9 mm, and the highest for sugar beet 460.1 and 485.3 mm.

Chart 5 shows the percentage change in average values of ΣETc, ΣPe and ΣIn during the vegetation period in the future climate (P1, P2, P3 respectively) in relation to RF for the Belgrade Region. The median for the average percentage change of ΣETc for the P1, P2 and P3 period, respectively in relation to RF are 3.2%, 5.2% and 11.2%. It varies in the P1 period from 1.5% in maize to 5.1% in small grains. In the second period of the future (P2) in relation to the reference period it ranges from 3.6% in sugar beet to 5.9% in small grains, while in the P3 period it varies from 8.1% in sunflower to 13.5% in orchards of apples, pears with and without grass cover. The 75th percentile values for the average percentage change of ETc for the P1, P2 and P3 period, respectively in relation to RF are 6.2%, 6.2% and 14.0%. Values vary in the P1 and P2 period from 1.7% for maize to 11.9% for small grains. In the P3 period, they vary from 11.9% in meadows and pastures to 15.4% in non-grass orchards of apples and pears.

The median for the average percentage change of ΣPe for the P1, P2 and P3 period, respectively in relation to RF are 3.1%, 0.1% and -5.5%. It varies in the P1 period from 0.2% during the vegetation period of cherries and sour cherries in orchards with and without grass cover, up to 9.7% in sunflowers. In the second period of the future (P2) in relation to the reference period it ranges from -2.4% in apple and pear orchards, with and without grass cover and grapevines to 7.4% in small grains, while in the P3 period it varies from a decrease of -15.7% in maize, to an increase of 17.2% in small grains. The 75th percentile values for the average percentage change of ΣPe for the P1, P2 and P3 period, respectively in relation to RF is 3.4%, 3.4% and -1.9%. It varies in the P1 and P2 period from -1.7% in grassed and non-grassed orchards of sour cherries, cherries to 10.5% in meadows and pastures. In the P3 period, the values vary from -10.4% in sugar beet to 21.8% in small grains.

The median for the average percentage change of ΣIn for the P1, P2 and P3 period, respectively in relation to RF is > -100%, 44.0% and > 100%. It varies in the P1 period from a large decrease in small grains to an increase of 22.0% in grapevines. In the second period of the future (P2) compared to the reference period it ranges from 3.6% in meadows and pastures to a large increase in small grains, while in the P3 period it varies from 23.1% in grassed orchards of sour cherries and cherries, to an increase in small grains. The 75th percentile values for the average percentage change of ΣIn for the P1, P2 and P3 period, respectively in relation to RF are > 100%, > 100% and 43.8%. They vary in the P1 and P2 period from -2.1% in sugar beet to the maximum increase in small grains. In the P3 period, they vary from 20.4% in sunflowers to the maximum increase in grapevines.

Maximum increases do not mean the largest amount of water, but the largest oscillations in relation to the reference period. This is most often observed in small grains, which are mostly with small deficits (very often also surpluses), so even the smallest change leads to large values of percentage changes.



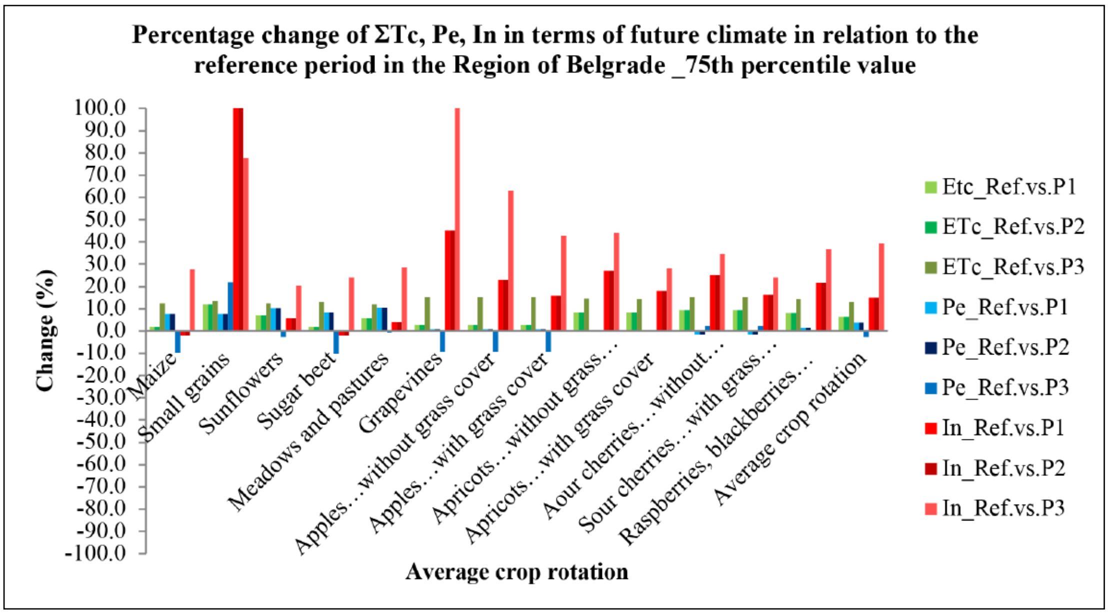
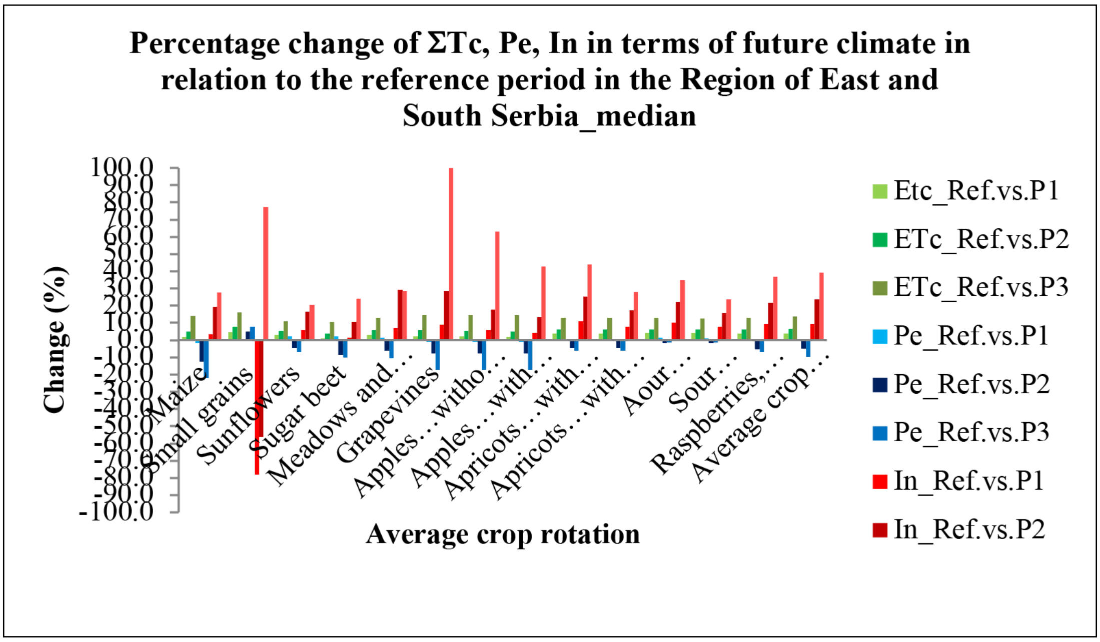


Chart 6 Percentage change in water consumption on the process of evapotranspiration of crops represented in crop rotation (ΣETc mm), effective precipitation ΣPe mm) and water deficit ΣIn mm) during the vegetation period in the future climate (P1 period: 2021 - 2040, P2 period: 2041 - 2060 and P3 period: 2080 - 2100) in relation to the reference period (ref. period: 1986 - 2005) for the Belgrade Region

Region of Eastern and Southern Serbia

The median and 75th percentile of RF for mean evapotranspiration values of (ΣETc), effective precipitation (ΣPe) and water deficit ΣIn), during the vegetation period of the crops represented in the crop rotation are 542.4 mm, 493.0 mm, 293.1 mm, 281.6 mm and 248.7 mm, 231.6 mm, respectively. The values of ΣETc ranges from 357.6 mm in non-grassed cherry and sour cherry orchards, 356.6 mm in sunflowers to 914.2 mm, 920.5 mm in apples, pears when the orchard is grassed. Effective precipitation is lowest in orchards with and without grass cover of sour cherries and cherries 218.9 mm and 104.7 mm in sunflower, and the highest values were obtained in small grains 416.2 mm, 427.0 mm. The results of ΣIn show that the lowest values are for small grains -39.8 and -28.3 mm, and the highest for grassed apple orchards, pears in the amount of 541.4 and 559.9 mm.



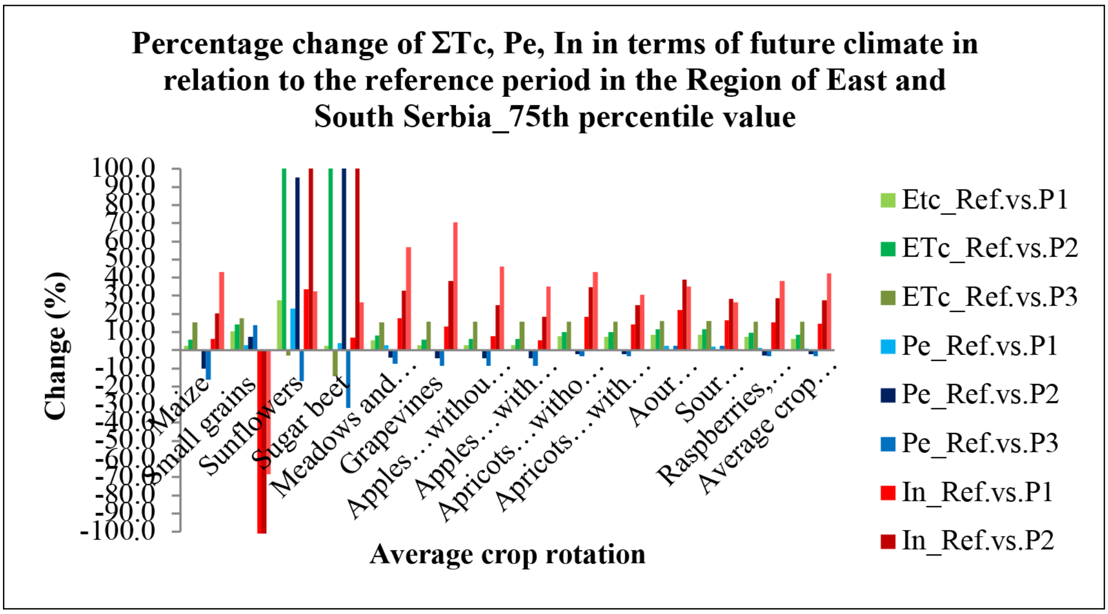


Chart 7. Percentage change in water consumption on the process of evapotranspiration of crops represented in crop rotation (ΣETc mm), effective precipitation SPe mm) and water deficit SIn mm) during the vegetation period in the future climate (P1 period: 2021 - 2040, P2 period: 2041 - 2060 and P3 period: 2080 - 2100) in relation to the reference period (ref. period: 1986 - 2005) for Region of Eastern and Southern Serbia.

Chart 7 shows the percentage change in average values of ΣETc, ΣPe and ΣIn during the vegetation period in the future climate (P1, P2, P3 respectively) in relation to RF for the Region of Eastern and Southern Serbia. The median for the average percentage change of ΣETc for the P1, P2 and P3 period, respectively in relation to RF are 3.1%, 5.9% and 13.3%. They vary in the P1, P2 and P3 period, respectively from 1.0%, 3.7%, 10.5% in sugar beet to 4.8%, 7.6% and 16.0% in small grains. The 75th percentile values for the average percentage change of ΣETc for the P1, P2 and P3 period, respectively in relation to RF are 7.3%, 32.0% and 12.4%. They vary in the P1 period from 2.3% in maize, to 27.4% in sunflower. In the second period of the future they vary from 5.7% in maize to the maximum increase in sugar beet, while in the P3 period they vary from -14.2% in sugar beet to 17.7% in small grains.

The median for the average percentage change of ΣPe for the P1, P2 and P3 period, respectively in relation to RF are 0.3%, -5.2% and -9.0%. It varies in the P1, P2 and P3 period, respectively from 1.6%, -12.3% and -22.0% in maize, up to 2.4% in sunflower, and 5.2% and 7.7% in small cereals. The 75th percentile values for the average percentage change of ΣPe for the P1, P2 and P3 period, respectively in relation to RF are 2.8%, 19.2% and -6.6%. They vary in the P1, P2 and P3 period, respectively from -0.3%, -10.1% and -16.1 in maize to 22.9% in sunflower, with the maximum increase in sugar beet and 13.6% in small grains.

The median for the average percentage change of ΣIn for the P1, P2 and P3 period, respectively in relation to RF is 1.0%, 14.7% and 32.7%. They vary in the P1 period from -78.1 in small grains to an increase of 11.1% in non-grassed apricot orchards. In the second period of the future (P2) in relation to the reference period it ranges from -56.4% for small grains to 29.2% for meadows and pastures, while in the P3 period it varies -68.2% for small grains to an increase of 70.5% in grapevines. The 75th percentile values for the average percentage change of ΣIn for the P1, P2 and P3 period, respectively in relation to RF are 2.2%, 35.8% and 28.8%. They vary in the P1, P2 and P3 period, respectively from the maximum decrease in small grains to 33.5% in sunflower, with the maximum increase in sugar beet and 76.0% in grapevines in the P1, P2 and P3 period, respectively.

Region of Šumadija, Central and Western Serbia

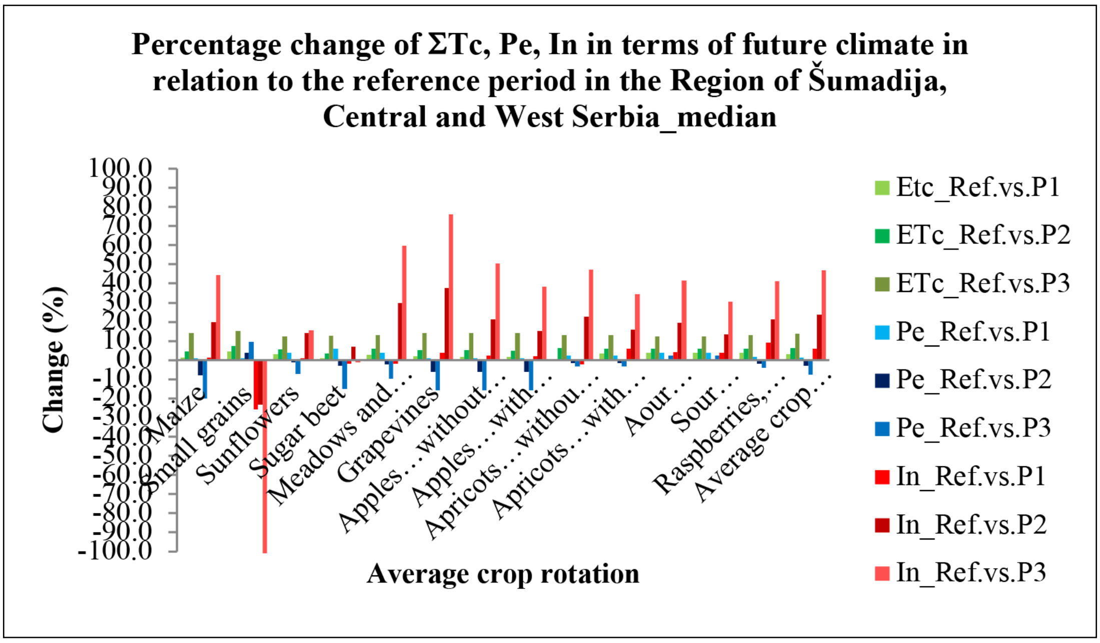
The median and the 75th percentile of RF for mean evapotranspiration values (ΣETc), effective precipitation (ΣPe) and water deficit (ΣIn), during the vegetation period of the crops represented in the crop rotation are 531.7 mm, 535.4 mm, 319.6 mm, 330.2 mm and 212.4 mm, 230.0 mm, respectively. Values of ΣETc range from 352.0 mm, 355 mm in non-grassed cherry and sour cherry orchards, to 887.6 mm, 890.5 in apples, pears when the orchard is grassed. Effective precipitation is the lowest in orchards with and without grass cover of sour cherries and cherries 235.8 and 247.2 mm, and the highest values were obtained for small grains 448.7 and 458.8 mm. The results of ΣIn show that the lowest values are for small grains -72.0 and -60.8 mm, and the highest for grassed apple orchards, pear orchards in the amount of 473.9 and 495.1 mm.

Chart 8 shows the percentage change in average values of ΣETc mm, ΣPe mm and ΣIn mm during the vegetation period in the future climate (P1, P2, P3 respectively) in relation to RF for the Region of Šumadija, Central and Western Serbia. The median for the average percentage change of ΣETc for the P1, P2 and P3 period, respectively in relation to RF are 2.6%, 5.7% and 13.4%. It varies in the P1, P2 and P3 period, respectively 0.2% in the non-grassed apricot orchard, 3.4% in sugar beet, 12.3% in grassed sour cherry and cherry orchards up to 4.4%, 7.3% and 15.4% in small grains. The 75th percentile values for the average percentage change of ΣETc for the P1, P2 and P3 period, respectively in relation to RF are 2.0%, 8.7% and 11.6%. It varies in the P1, P2 and P3 period, respectively -49.3%, 4.6% and -43.3% in sugar beet to 10.4%, 15.4% and 17.9% in the P1, P2 and P3 period, respectively for small grains.

The median for the average percentage change of ΣPe for the P1, P2 and P3 period, respectively in relation to RF are 2.4%, -2.5% and -7.3%. It varies in the P1, P2 and P3 period, respectively

0.9% for grapevines and apple and pear orchards with and without grass cover, -7.8% and -20.1% for maize up to 6.0% for sugar beets, 3.8% and 9.5% in small grains. The 75th percentile values for the average percentage change of ΣPe for the P1, P2 and P3 period, respectively in relation to RF is -0.7%, -1.4% and -4.0%. They vary in the P1, P2 and P3 period, respectively -48.6%, -5.2% and -55.8 in sugar beet to 5.7% in sunflower, 6.9% and 16.0% in small grains .

The median for the average percentage change of ΣIn for the P1, P2 and P3 period, respectively in relation to RF is 0.5%, 17.0% and 42.0%. It varies in the P1, P2 and P3 period, respectively from -25.8% -23.4% and -18.2% in small grains to an increase of 9.3% in raspberry, blackberry orchards, 37.5% and 94.0 % in grapevine. The 75th percentile values for the average percentage change of ΣIn for the P1, P2 and P3 period, respectively in relation to RF is 1.6%, 16.7% and 38.3%. They vary in the P1, P2 and P3 period, respectively from -62.9%, -72.6% and -36.0% decrease in small grains to 19.9% in non-grassed sour cherry and cherry orchards, 37.6% and 98, 7% in grapevine.



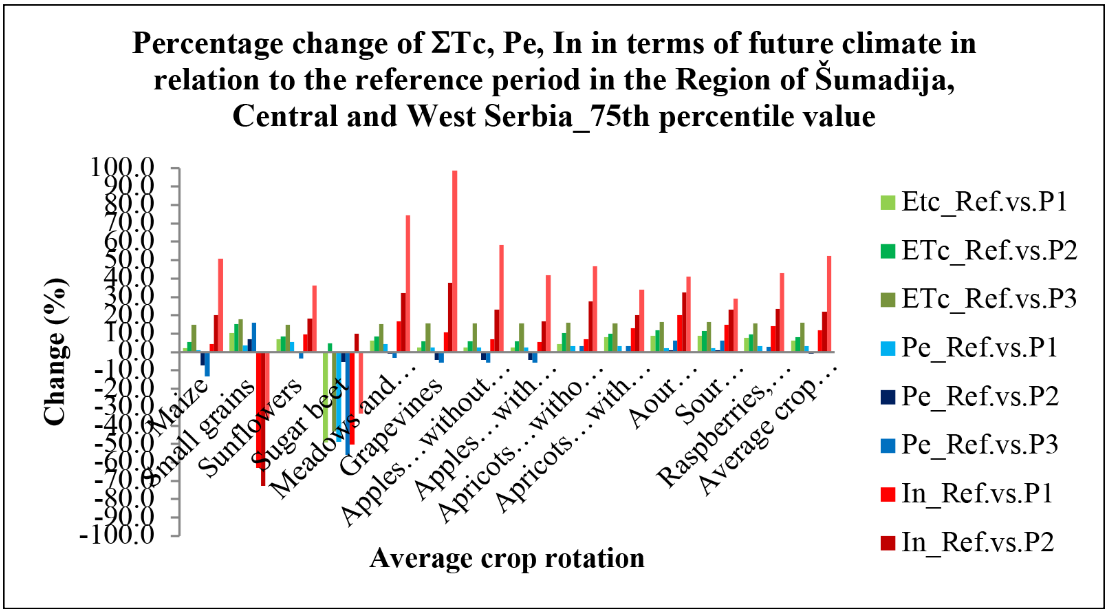


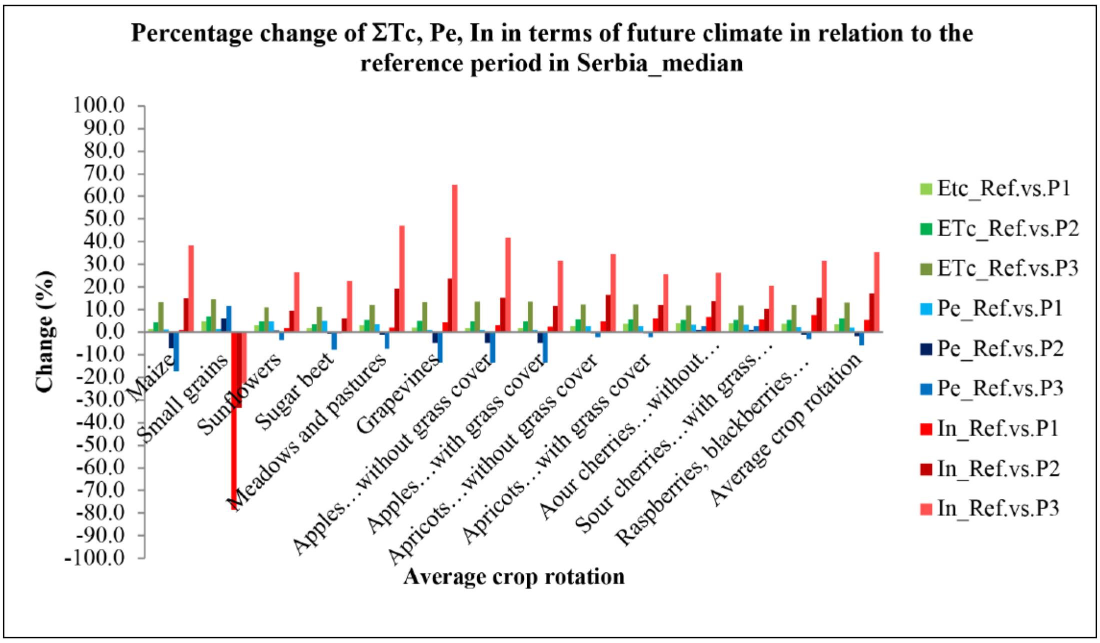
Chart 8. Percentage change in water consumption on the process of evapotranspiration of crops represented in crop rotation (ΣSETc mm), effective precipitation SPe mm) and water deficit ΣIn mm) during the vegetation period in the future climate (P1 period: 2021 - 2040, P2 period: 2041 - 2060 and P3 period: 2080 - 2100) in relation to the reference period (ref. period: 1986 2005) for the Region of Šumadija, Central and Western Serbia.

Republic of Serbia

The median and the 75th percentile of RF for mean evapotranspiration values (ΣETc), effective precipitation (ΣPe) and water deficit (ΣIn), during the vegetation period of the crops represented in the crop rotation are 537.3 mm, 526.5 mm, 293.0 mm, 296.7 mm and 244.3 mm, 249.2 mm, respectively. Values of ΣETc range from 356.1 mm, 358.4 mm in non-grassed sour cherry and cherry orchards, to 901.2 mm, 905.3 mm in apples, pears when the orchard is grassed. Effective precipitation is lowest in sour cherry and cherry orchards with and without grass cover of 217.0 mm, as well as 197.8 mm in sunflower, and the highest values were obtained in small grains 405.7 mm, 416.0 mm. The results of ΣIn show that the lowest values are for small grains -30.6 and -21.7 mm, and the highest for grassed apple orchards, pears in the amount of 521.6 and 538.0 mm.

Chart 9 shows the percentage change in average values of ΣETc, ΣPe and ΣIn during the vegetation period in the future climate (P1, P2, P3 respectively) in relation to RF for the Republic of Serbia. The median for the average percentage change of ΣETc for the P1, P2 and P3 period, respectively in relation to RF are 3.0%, 5.3% and 12.5%. It varies in the P1, P2 and P3 period, respectively from 1.5% in maize, 3.4% in sugar beet and 10.9% in sunflower, to 4.7%, 6.9% and 14.6% in small cereals. The 75th percentile values for the average percentage change of ΣETc for the P1, P2 and P3 period, respectively in relation to RF are 5.7%, 10.9% and 13.3%. They vary in the P1, P2 and P3 periods, respectively -5.6% in sugar beet, 5.1% in maize and -3.1% in sugar beet, to 12.9%, 27.2% in sunflower, and 17.0% for small grains.

The median for the average percentage change of ΣPe for the P1, P2 and P3 period, respectively in relation to RF are 2.5%, -1.3% and -5.2%. It varies in the P1, P2 and P3 period, respectively 1.0% for grapevines and apple and pear orchards with and without grass cover, -7.0% and -17.3% for maize up to 4.9% for sugar beets, 6.1% and 11.5% in small grains. The 75th percentile values for the average percentage change of ΣPe for the P1, P2 and P3 period, respectively in relation to RF is -3.7%, -2.9% and -1.4%. They vary in the P1, P2 and P3 period, respectively from -1.1% in sugar beet, -5.6% in maize and -18.6 in sugar beet, to 12.1% in sunflower, 20.8% in sugar beet and 17.1% in small grains.



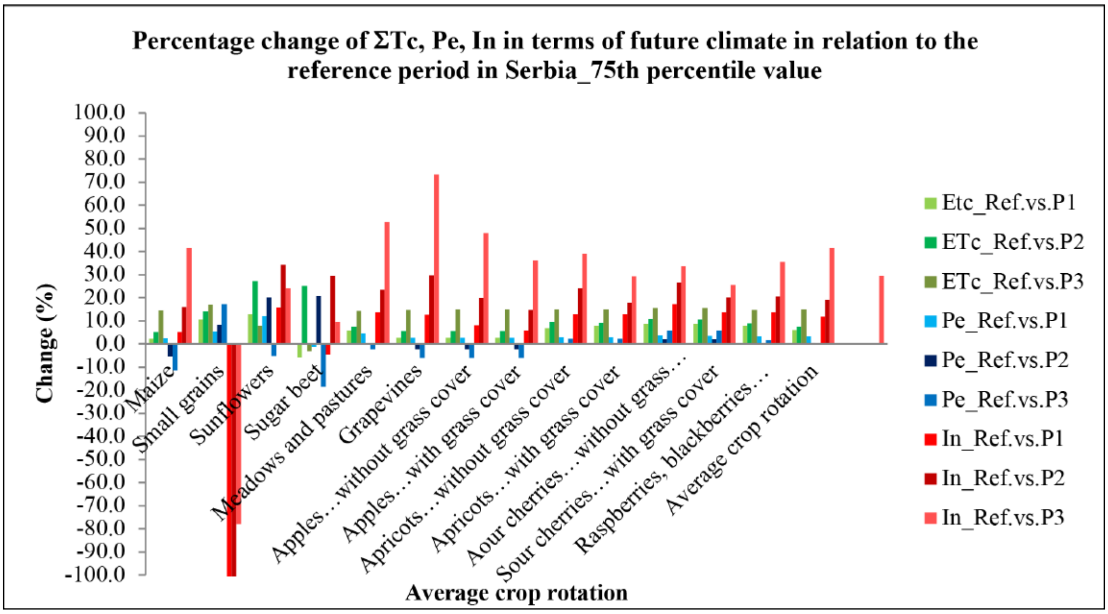


Chart 9. Percentage change in water consumption on the process of evapotranspiration of crops represented in crop rotation (ΣETc mm), effective precipitation (ΣPe mm) and water deficit (ΣIn mm) during the vegetation period in the future period (P1 period: 2021 - 2040, P2 period: 2041 - 2060 and P3 period: 2080 - 2100) in relation to reference period (ref. period: 1986 - 2005) for the Republic of Serbia.

The median for the average percentage change of ΣIn for the P1, P2 and P3 period, respectively in relation to RF are -2.0%, 10.8% and 30.3%. It varies in the P1, P2 and P3 period, respectively from -78.4%, -33.6% and -22.4% decrease in small grains to 7.6% increase in raspberry, blackberry orchards, and 23.7% and 65.0% in grapevines. The 75th percentile values for the average percentage change of ΣIn for the P1, P2 and P3 period, respectively in relation to RF is -3.5%, 8.5% and 29.4%. They vary with a maximum decrease in the P1 and P2 period and -78.1% decrease in the P3 period in small grains, up to 17.1% in sour cherry and cherry orchards without grass cover, 34.2% in sunflower and 73.4% increase in grapevine in the P1, P2 and P3 period, respectively.

2. Availability of water resources in the future climate

In the *Report on the impact of observed climate change on water resources in Serbia and projections of the impact of the future climate based on different scenarios of future emissions,* the analysis of the impact of climate change on water resources in Serbia was performed. Research has indicated a change in the distribution and intensity of the precipitation. During the June, July and August seasons, the amount of precipitation is expected to decrease, which is very unfavorable from the aspect of agricultural production. In other months, an increase in the amount of precipitation is expected, which can lead to problems such as untimely performance of agro-technical operations, increase in soil erosion, increase in surface runoff, etc. The obtained results of the distribution and amount of precipitation are in line with the results of this study. Changes in the precipitation regime, increase in temperature and evapotranspiration will adversely affect the hydrological regime in Serbia. Based on the analysis of the average annual and monthly river flow according to the RCP 8.5 scenario, it was established that there would be a decrease in river flows of about 8% in the basins in Serbia. The most endangered are the watercourses of Eastern, Southern and Central Serbia, where domicile waters dominate. Flow reductions range from 7 to 17% compared to the observed period.

The results of this study indicate that the largest increase in water deficit in crop production is expected in the above areas, which further increases the risks in agricultural production. Lack of water, increased temperatures, uneven rainfall distribution and declining river flows will significantly undermine the stability of the agricultural sector in the future climate.

Figures 17, 18, 19 and 20 provide a spatial representation of the number of days with precipitation greater than 20 mm, as well as the sum of the latter, during the vegetation and non-vegetation period in the future climate (comparison of RF with P1, P2, P3). The results of the 25th percentile, median, and 75th percentile obtained on the basis of an ensemble of 8 climate models according to the RCP8.5 scenario are presented.

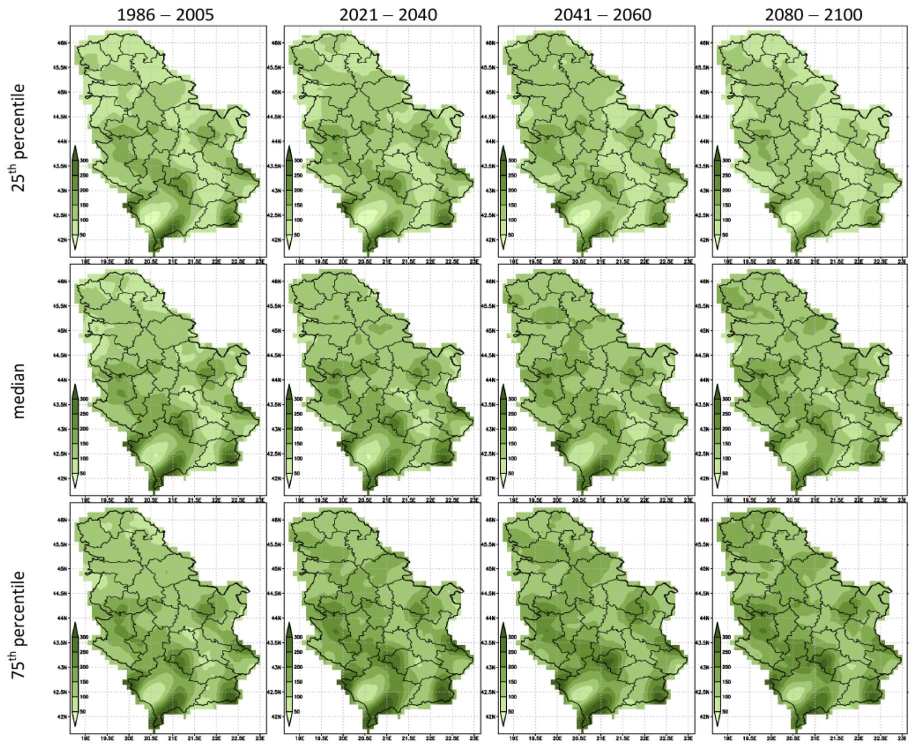


Figure 17. The amount of precipitation greater than 20 mm during the vegetation period

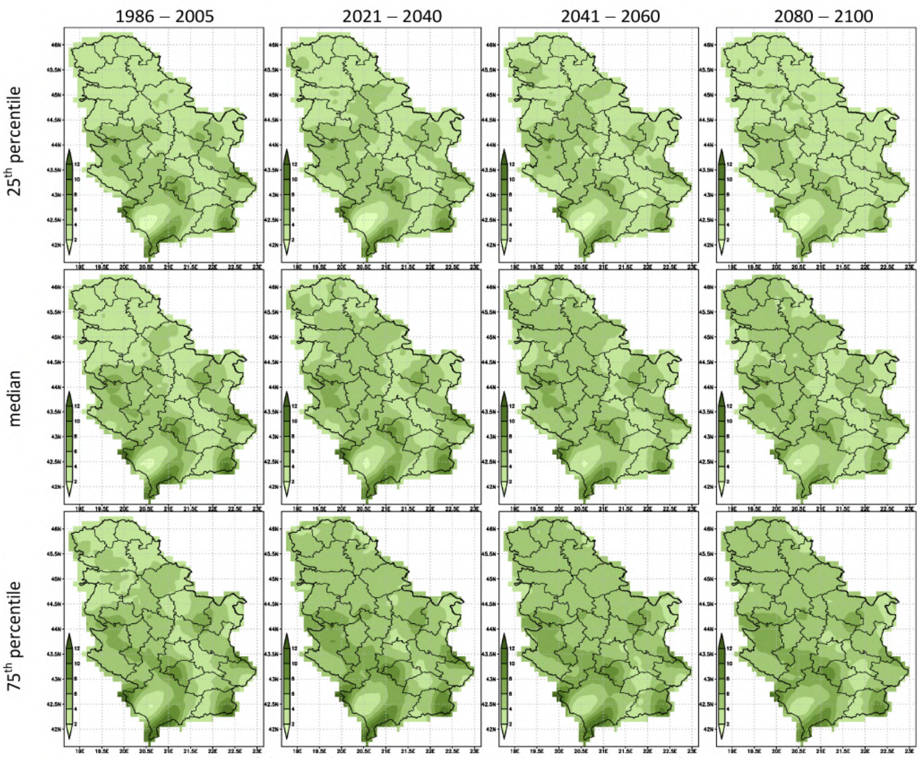


Figure 18. Number of days with precipitation greater than 20 mm during the vegetation period

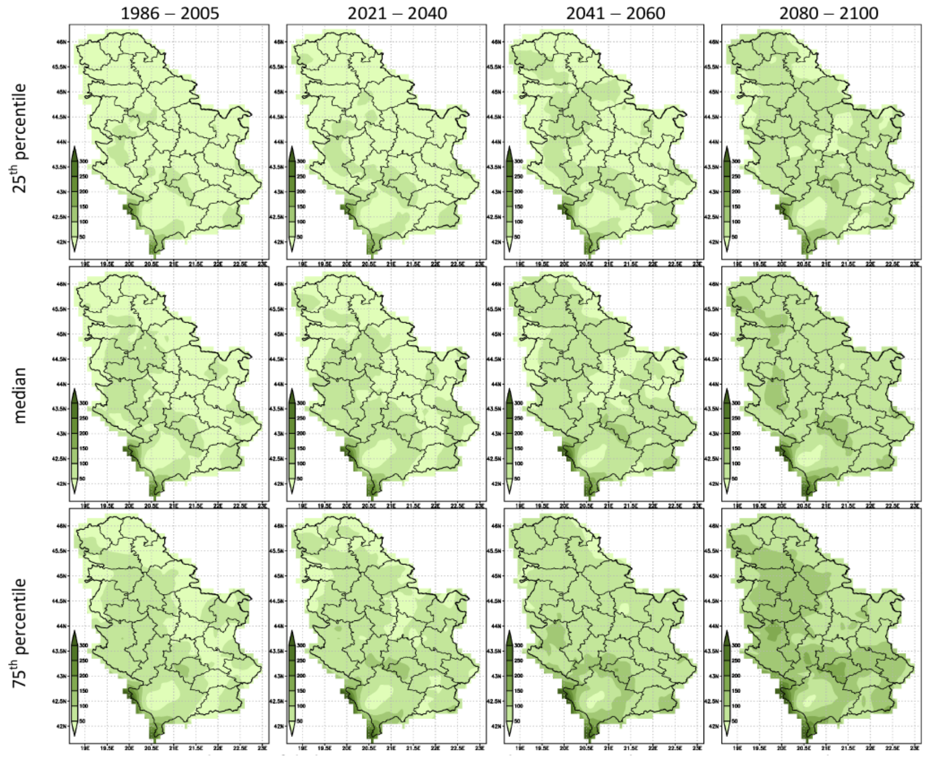


Figure 19. The sum of daily precipitation greater than 20 mm in the non-vegetation period

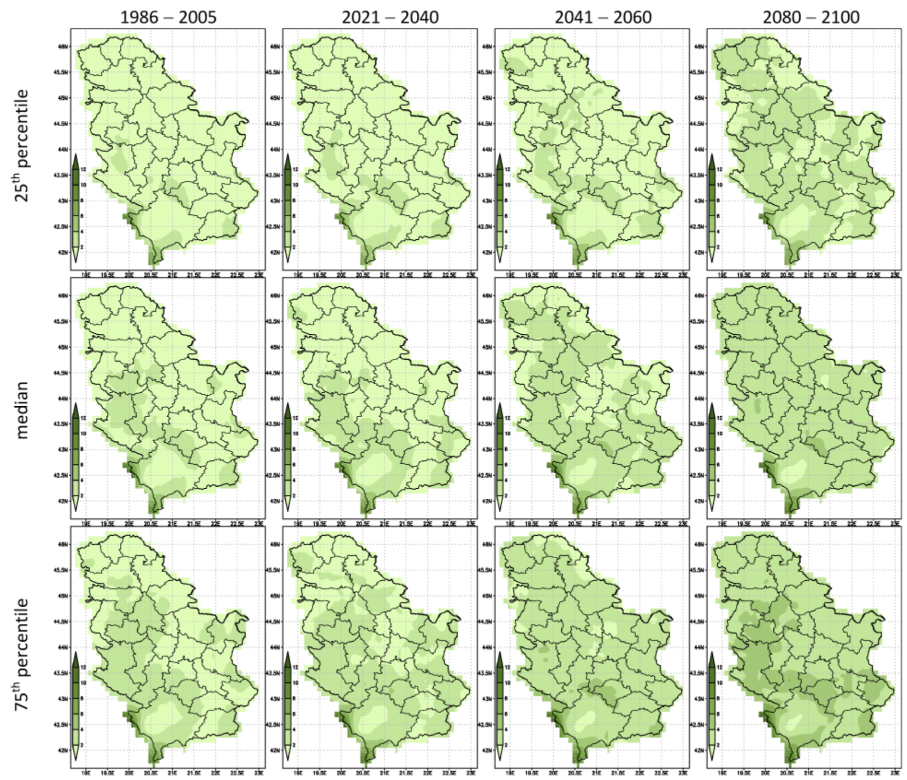


Figure 20. Number of days with precipitation greater than 20 mm in the non-vegetation period

Changes in the precipitation regime, in terms of increasing the intensity of precipitation in the summer, will increase the risk of torrential floods on small watercourses. That is why the analysis of the occurrence of days with extreme precipitation, greater than 20 mm, was performed. Such events can be one of the main causes of increased torrential floods.

In addition to the fact that the analyses found a decrease in precipitation in the future during the summer period, there is an increase in the number of days with precipitation over 20 mm in the area of Serbia. In the area of Vojvodina, this trend will not cause floods to a large extent, because there are no torrents in this area, but the occurrence of high-intensity precipitation will certainly have a negative impact on soil and crop production.

Regarding the Southeastern and Central parts of Serbia, where the greatest decrease in precipitation is expected in the summer, with a slight increase in the number of days with precipitation greater than 20 mm, we can expect greater exposure to torrential floods, soil erosion and damage to cultivated plants. Indirectly, torrents will further worsen working conditions in plant production by damaging the road infrastructure.

The risk of torrential floods in the summer will be affected by the intensity of precipitation greater than 20 mm. Rains of moderate and weak intensity will not cause torrents and floods and will compensate for the lack of moisture in the soil in the critical period of the year. However, the observed data indicate that the occurrence of large amounts of heavy rainfall is more frequent, which results in torrents, floods and erosion[3].

3 Đurđević, V., Vuković, A., Vujadinović Mandić, M. (2019). Report on the impact of observed climate change on water resources in Serbia and projections of the impact of the future climate based on different scenarios of future emissions. United Nations Development Program.

3. Risk and vulnerability assessment in the future climate - fruit growing

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 length of vegetation, necessary temperatures for the start of vegetation (base temperature or biological minimum - TB), fruit ripening moment, etc.

Length of the vegetation period

One of the important limiting factors 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. 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 altitudes[4].

According to the observed data (1997-2016), from the aspect of insufficiently long vegetation on 33.3% of the territory of Serbia or a third of the area, species that start later (TB – 12°C) and which take 180 days for the fruits to ripen cannot be grown, which are apple, pear, quince, walnut, hazelnut (Table 4, observed data)[5].

Table 4. Percentages of the territory of the Republic of Serbia depending on the sufficiency of vegetation length (observed data)

Types of fruit trees	% of the territory of Serbia where the length of vegetation is insufficient
TB- 9°C, DV – 150 (almond, apricot)	6.10
TB- 10°C, DV – 150 (peach, cherry)	9.31
TB- 11°C, DV – 150 (plum, cherry)	11.74
TB- 12°C, DV – 180 (apple, pear)	33.26

4 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.

5 Project: Regionalization of the fruit growing area in Belgrade, Southern and Eastern Serbia. Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia, 2018-2020.

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 mostly in the territory of Serbia (TB - 9°C, DV - 150 days).

According to the "median ensemble model", for the period 1986-2005, the percentage of the territory where species that start later (TB - 12°C) and which take 180 days for the fruits to ripen (apple, pear, quince, walnut, hazelnut) cannot to be grown on 54% of the territory of Serbia (Table 4a).

Table 4a. Percentages of the territory of the Republic of Serbia depending on the sufficiency of the length of vegetation (according to the model - median)

Types of fruit trees	Period	% of the territory of Serbia where the length of vegetation is insufficient
TB - 9°C, DV – 150 (almond, apricot)	1986-2005	8.5
	2021-2040	5.7
	2041-2060	2.0
	2081-2100	0.0
TB - 10°C, DV – 150 (peach, cherry)	1986-2005	11.6
	2021-2040	8.6
	2041-2060	3.2
	2081-2100	0.1
TB - 11°C, DV – 150 (plum, cherry)	1986-2005	15.3
	2021-2040	11.6
	2041-2060	4.9
	2081-2100	0.6
TB - 12°C, DV – 180 (apple, pear)	1986-2005	54.0
	2021-2040	44.4
	2041-2060	22.3
	2081-2100	9.2

In the near future (2021-2040), it will not be possible to grow these species on 44.4% of the territory of Serbia, in the 2041-2060 period on 22.3% of the territory of Serbia, while in the distant future (2081-2100), on only 10% of the territory of the Republic of Serbia it will not be possible to grow these species, taking into account this limiting factor. Other species show a similar tendency. Due to the increase of the average annual temperature, the cultivation area on the territories of Serbia will permanently increase, if only the factor of the length of the vegetation period is observed.

Risk of late spring frost

All fruit species, depending on 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 , walnut, hazel, strawberry, currant), species starting with vegetation at average daily temperatures of 11°C (plum, cherry, cherry, raspberry), and species starting 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.

According to the "median model ensemble" for the period 1986-2005 (Table 2b) in species that start early with vegetation (almonds and apricots) in 3.9% of the territory of Serbia, the probability of frost after the start of vegetation is higher than 30% (Figures 21 a, b, c, d).

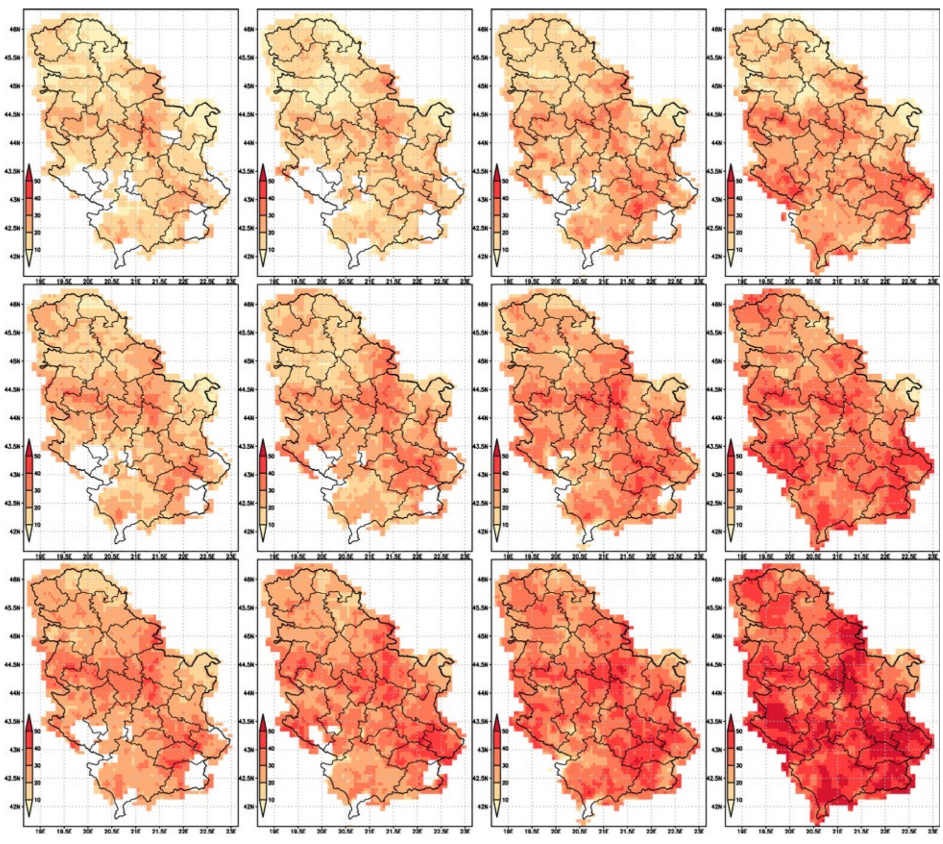


Figure 21a. Probability of frost occurrence b9

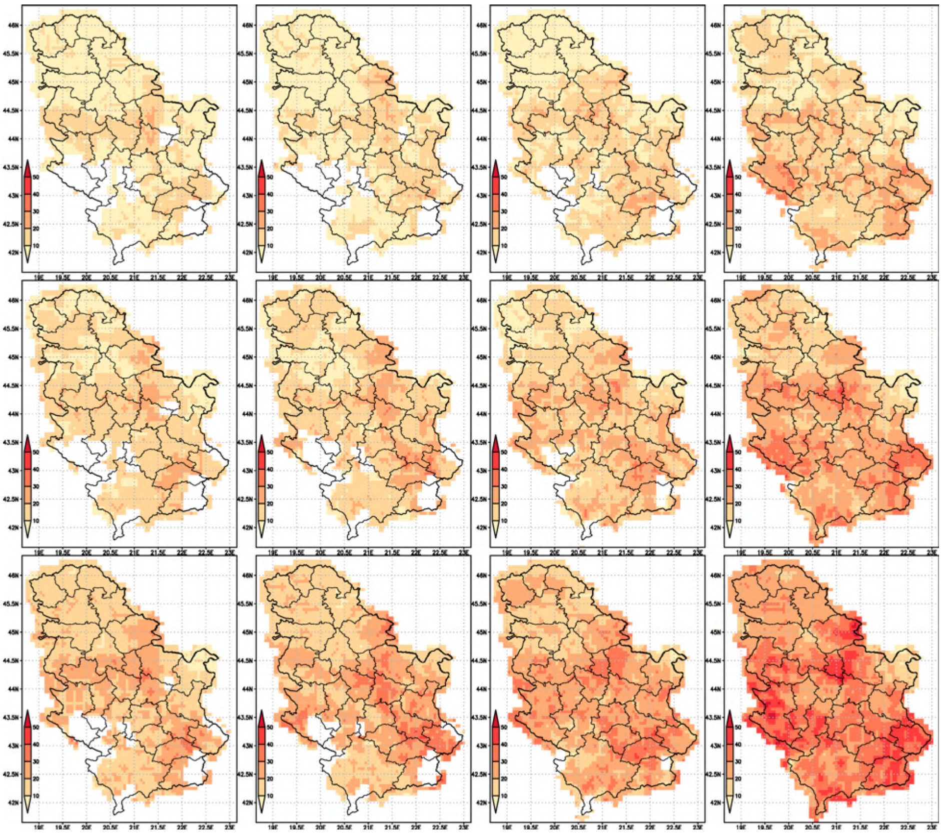


Figure 21b. Probability of frost occurrence b10

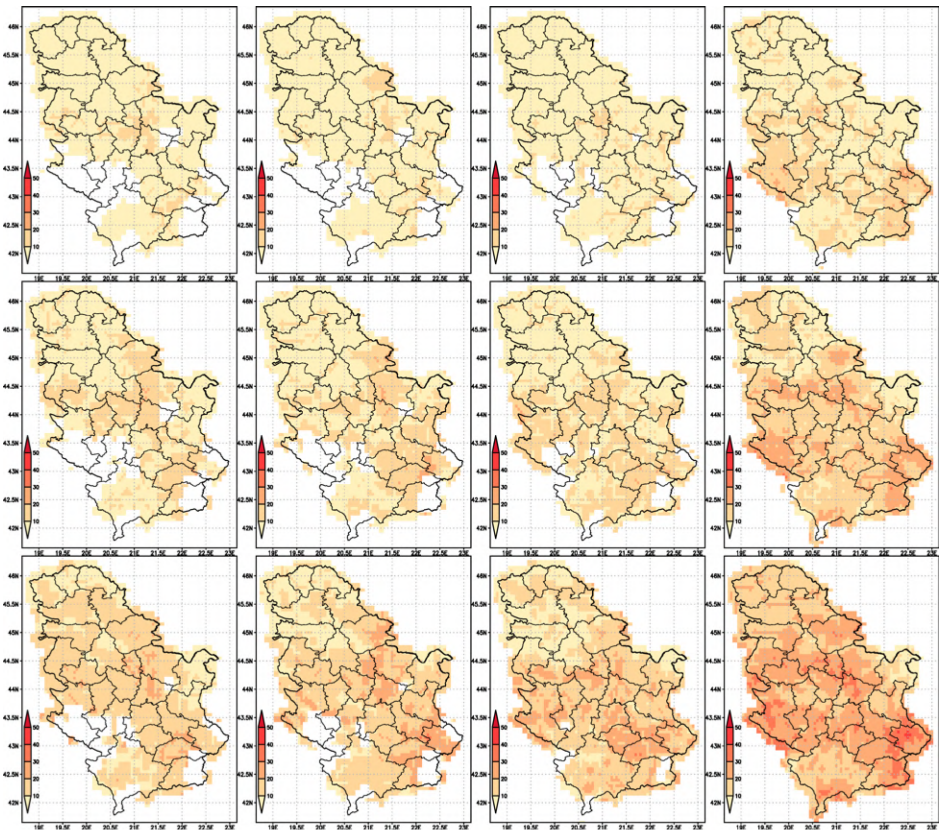


Figure 21c. Probability of fros occurrence b11

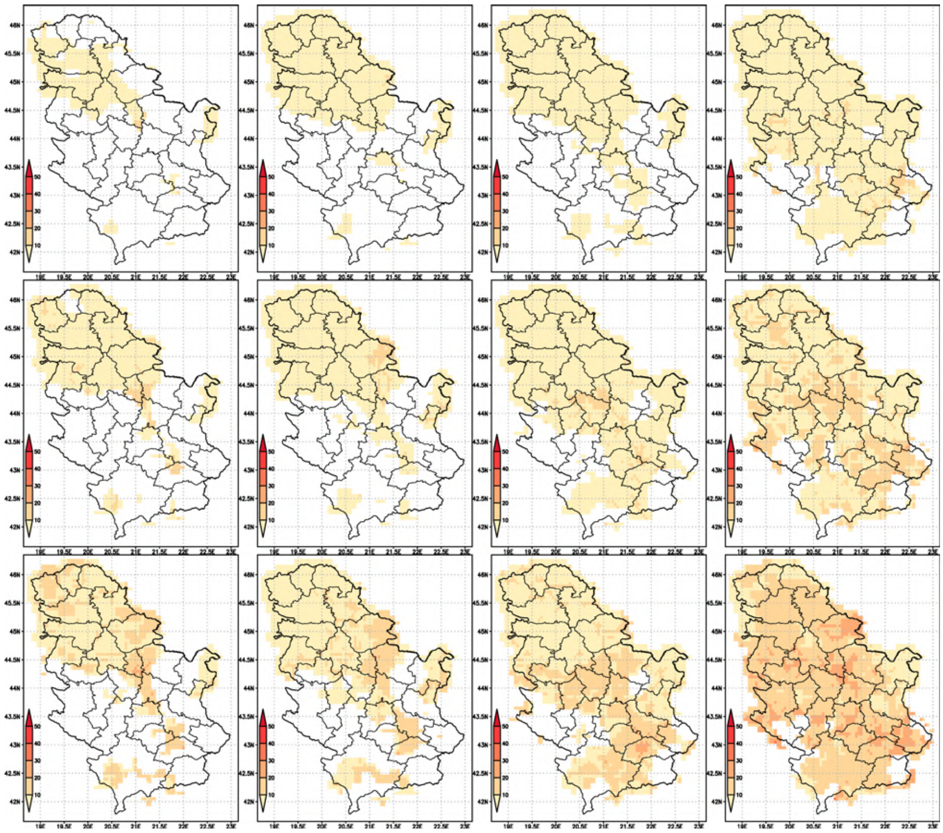


Figure 21d. Probability of frost occurrence b12

Table 4b. Percentages of the territory of the Republic of Serbia depending on the risk of frost (according to the model - median)

Types of fruit trees	Period	% 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)	1986-2005	8.5	5.4	44.7	37.6	3.8	0.1	0.0
	2021-2040	5.7	2.8	38.3	40.0	13.1	0.1	0.0
	2041-2060	2.0	1.8	17.8	48.1	28.5	1.8	0.0
	2081-2100	0.0	1.6	6.0	34.1	45.3	12.8	0.3
TB- 10°C, DV – 150 (peach, cherry	1986-2005	11.6	28.7	56.0	3.7	0.0	0.0	0.0
	2021-2040	8.6	25.0	54.0	12.3	0.2	0.0	0.0
	2041-2060	3.2	21.0	55.5	20.0	0.4	0.0	0.0
	2081-2100	0.1	7.8	35.9	45.2	11.0	0.1	0.0
TB- 11°C, DV – 150 (plum, sour cherry)	1986-2005	15.3	64.8	19.9	0.0	0.0	0.0	0.0
	2021-2040	11.6	63.2	24.8	0.4	0.0	0.0	0.0
	2041-2060	4.9	66.5	28.6	0.0	0.0	0.0	0.0
	2081-2100	0.6	31.8	54.0	13.5	0.1	0.0	0.0
TB- 12°C, DV – 180 (apple, pear)	1986-2005	54.0	44.2	1.8	0.0	0.0	0.0	0.0
	2021-2040	44.4	54.6	0.9	0.0	0.0	0.0	0.0
	2041-2060	22.3	76.2	1.5	0.0	0.0	0.0	0.0
	2081-2100	9.2	72.9	17.8	0.1	0.0	0.0	0.0

According to the observed data (Table 5), in 26% of the territory of Serbia the probability of frost after vegetation start is higher than 30%, which means that the model – median shows milder values than observed, so the 75th percentile of this model should be taken into account for this limiting factor (Figure 21a), where the probability of frost occurrence higher than 30% occurs in 21% of the territory of Serbia (Table 6).

Table 5. Percentages of the territory of the Republic of Serbia depending on the risk of frost (observed data)

Types of fruit trees	% 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)	8.61	24.18	35.05	20.11	5.63	0.31
TB- 10°C, DV – 150 (peach, cherry)	39.98	36.15	13.07	1.49	0	0
TB- 11°C, DV – 150 (plum, cherry)	83.26	5.01	0	0	0	0
TB- 12°C, DV – 180 (apple, pear)	55.09	9.94	1.64	0.08	0	0

Table 6. Percentages of the territory of the Republic of Serbia depending on the risk of frost (according to the model - 75th percentile)

Types of fruit trees	Period	% 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)	1986-2005	0.9	16.3	55.4	20.3	0.8	0.0
	2021-2040	1.3	8.4	45.5	35.5	6.1	0.1
	2041-2060	0.5	4.3	29.4	49.1	15.6	0.3
	2081-2100	0.0	0.8	8.7	35.1	39.1	15.5
TB- 10°C, DV – 150 (peach, cherry)	1986-2005	6.6	59.6	24.3	0.5	0.0	0.0
	2021-2040	3.1	50.7	34.0	6.0	0.1	0.0
	2041-2060	2.2	35.8	50.6	10.1	0.0	0.0
	2081-2100	1.3	8.1	45.3	35.5	9.6	0.3
TB- 11°C, DV – 150 (plum, sour cherry)	1986-2005	29.8	57.0	1.3	0.0	0.0	0.0
	2021-2040	31.2	50.9	9.0	0.1	0.0	0.0
	2041-2060	30.9	56.2	10.8	0.0	0.0	0.0
	2081-2100	5.9	47.1	42.2	4.9	0.0	0.0
TB- 12°C, DV – 180 (apple, pear)	1986-2005	40.7	13.3	0.0	0.0	0.0	0.0
	2021-2040	52.0	12.1	0.0	0.0	0.0	0.0
	2041-2060	62.5	21.0	0.2	0.0	0.0	0.0
	2081-2100	25.6	61.6	6.8	0.1	0.0	0.0

According to this model, in the future, the probability of frost occurrence of more than 30% will occur in an increasing part of the territory of Serbia. In the 2021-2040 period in 41.6% of Serbia, in the 2041-2060 period in 65%, and at the end of the century (2081-2100) in almost 90% of the territory of the Republic of Serbia the cultivation of these species will not be economically viable, because late spring frosts which can completely destroy production will occur every three years. This is particularly the case in Southern and Central Serbia.

For species that start with vegetation at average daily temperatures of 10°C (peach, walnut, hazel, strawberry, currant) the situation is somewhat better (Figure 21b).

According to the "75th percentile of the model ensemble" (Table 5) in these species in only 0.5% of the territory of Serbia, the probability of frost after the start of vegetation is higher than 30%. In the 2021-2040 period in 6% of Serbia, in the 2041-2060 period in 10%, and at the end of the century (2081-2100) in 45% of the territory of the Republic of Serbia. For species that start with vegetation at average daily temperatures of 11°C (plum, sour cherry, cherry, raspberry), or 12°C (apple, pear, quince, blackberry), the probability of frost is higher than 30% in the territory of Serbia now and will not exist in the future (Figures 19 c and d).

In the case of plums and sour cherries in the largest part of the territory of Serbia, late spring frost will occur once in five years, and in the case of apples and pears, once in ten years. At the end of the century and with apples and pears, frost damage can occur every five years. These species will also be most endangered in Southern, Western and Central Serbia. The smallest changes in endangerment will be in the area of Vojvodina, which is currently most endangered by frost (Table 7).

Table 7. Risk assessment of late spring frost by regions

Admin. district	Crop: Almond, apricot Risk: Late spring frost					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present	Tendency
North Banat	Moderate	Large	Large	Moderate	Moderate	+
Central Banat	Large	Large	Large	Moderate	Moderate	0
South Banat	Large	Large	Very large	Large	High	+
North Bačka	Large	Large	Large	Moderate	Moderate	0
West Bačka	Large	Large	Very large	Moderate	Moderate	+
South Bačka	Large	Large	Very large	Large	High	+
Srem	Large	Large	Large	Moderate	Moderate	0
City of Belgrade	Large	Large	Large	Moderate	Moderate	0
Danube River Basin	Very large	Very large	Very large	Large	High	+
Braničevo	Large	Very large	Very large	Very large	High	+
Bor	Moderate	Large	Very large	Large	Moderate	+
Zaječar	Large	Large	Very large	Large	High	+
Nišava	Large	Large	Very large	Very large	High	+
Pirot	Large	Very large	Very large	Very large	High	+
Toplica	Large	Large	Very large	Large	High	+
Jablanica	Large	Very large	Very large	Very large	High	+
Pčinja	Large	Large	Very large	Moderate	High	+
Šumadija	Very large	Very large	Very large	Large	High	0
Pomoravlje	Very large	Very large	Very large	Large	High	0

Raška	Large	Large	Very large	Moderate	High	+
Rasina	Large	Large	Very large	Moderate	High	+
Mačva	Very large	Very large	Very large	Large	High	+
Kolubara	Very large	Very large	Very large	Large	High	+
Moravica	Large	Large	Very large	Moderate	High	+
Zlatibor	Large	Large	Very large	Moderate	High	+
National level	**Large**	**Large**	**Very large**	**Large**	**High**	**+**

Admin. district	Crop: Crop: peach, cherry Risk: Late spring frost					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present	Tendency
North Banat	Large	Large	Large	Moderate	Moderate	0
Central Banat	Large	Large	Large	Moderate	Moderate	0
South Banat	Large	Very large	Very large	Large	High	0
North Bačka	Large	Large	Large	Moderate	Moderate	0
West Bačka	Large	Large	Large	Moderate	Moderate	0
South Bačka	Large	Large	Large	Large	High	0
Srem	Large	Large	Large	Moderate	Moderate	0
City of Belgrade	Large	Large	Large	Moderate	Moderate	0
Danube River Basin	Very large	Very large	Very large	Large	High	0
Braničevo	Large	Very large	Very large	Very large	High	+
Bor	Moderate	Very large	Very large	Large	High	+
Zaječar	Large	Very large	Very large	Large	High	+
Nišava	Very large	Very large	Very large	Very large	High	0
Pirot	Large	Very large	Very large	Very large	High	+
Toplica	Large	Very large	Very large	Large	High	+
Jablanica	Very large	Very large	Very large	Very large	High	0
Pčinja	Large	Very large	Very large	Moderate	High	+
Šumadija	Large	Very large	Very large	Large	High	+
Pomoravlje	Large	Very large	Very large	Large	High	+
Raška	Moderate	Very large	Very large	Moderate	High	+
Rasina	Large	Very large	Very large	Moderate	High	+
Mačva	Large	Very large	Very large	Large	High	+
Kolubara	Very large	Very large	Very large	Large	High	0
Moravica	Large	Very large	Very large	Moderate	High	+
Zlatibor	Large	Very large	Very large	Moderate	High	+
National level	**Large**	**Very large**	**Very large**	**Large**	**High**	**+**

Crop: Crop: plum, sour cherry Risk: Late spring frost						
Admin. district	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present	Tendency
North Banat	Moderate	Moderate	Moderate	Moderate	Low	0
Central Banat	Large	Large	Large	Moderate	Moderate	0
South Banat	Large	Large	Large	Large	High	0
North Bačka	Moderate	Moderate	Large	Moderate	Moderate	+
West Bačka	Moderate	Moderate	Large	Moderate	Moderate	+
South Bačka	Large	Moderate	Moderate	Large	High	-
Srem	Large	Moderate	Moderate	Moderate	Moderate	-
City of Belgrade	Moderate	Moderate	Moderate	Moderate	Moderate	0
Danube River Basin	Large	Large	Large	Large	High	0
Braničevo	Large	Large	Large	Very large	High	0
Bor	Moderate	Large	Large	Large	High	+
Zaječar	Large	Large	Large	Large	High	0
Nišava	Large	Large	Large	Very large	High	0
Pirot	Large	Large	Large	Very large	High	0
Toplica	Large	Large	Very large	Large	High	+
Jablanica	Large	Large	Large	Very large	High	0
Pčinja	Moderate	Large	Very large	Moderate	Moderate	+
Šumadija	Large	Large	Very large	Large	High	+
Pomoravlje	Large	Large	Large	Large	High	0
Raška	Moderate	Large	Large	Moderate	Moderate	+
Rasina	Large	Large	Very large	Moderate	Moderate	+
Mačva	Large	Large	Large	Large	High	0
Kolubara	Large	Large	Large	Large	High	0
Moravica	Large	Large	Large	Moderate	High	0
Zlatibor	Moderate	Moderate	Large	Moderate	Moderate	+
National level	**Moderate, large**	**Large, moderate**	**Large**	**Large**	**High**	

Crop: Crop: apple, pear Risk: Late spring frost						
Admin. district	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present	Tendency
North Banat	Moderate	Moderate	Moderate	Moderate	Moderate	0
Central Banat	Moderate	Moderate	Moderate	Moderate	Moderate	0
South Banat	Moderate	Moderate	Moderate	Moderate	Moderate	0
North Bačka	Moderate	Moderate	Moderate	Moderate	Moderate	0
West Bačka	Moderate	Moderate	Moderate	Moderate	Moderate	0

South Bačka	Moderate	Moderate	Moderate	Moderate	Moderate	0
Srem	Moderate	Moderate	Moderate	Moderate	Moderate	0
City of Belgrade	Moderate	Moderate	Moderate	Moderate	Moderate	0
Danube River Basin	Moderate	Moderate	Moderate	Moderate	Moderate	0
Braničevo	Small	Moderate	Moderate	Moderate	Moderate	+
Bor	Small	Moderate	Moderate	Moderate	Low	+
Zaječar	Small	Small	Moderate	Small	Low	+
Nišava	Small	Moderate	Moderate	Moderate	Moderate	+
Pirot	Small	Small	Moderate	Small	Low	+
Toplica	Small	Small	Moderate	Small	Low	+
Jablanica	Small	Moderate	Moderate	Moderate	Moderate	+
Pčinja	Small	Small	Small	Small	Low	0
Šumadija	Small	Moderate	Moderate	Moderate	Moderate	+
Pomoravlje	Small	Moderate	Moderate	Moderate	Moderate	+
Raška	Small	Small	Small	Small	Low	0
Rasina	Small	Moderate	Moderate	Moderate	Moderate	+
Mačva	Moderate	Moderate	Moderate	Moderate	Moderate	0
Kolubara	Moderate	Moderate	Moderate	Moderate	Moderate	0
Moravica	Small	Small	Moderate	Small	Low	+
Zlatibor	Small	Small	Small	Small	Low	0
National level	**Small**	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**+**

Risk of high temperatures

In addition to the above-mentioned limiting factors for the successful cultivation of various fruit species in the territory of the Republic of Serbia according to the current observed 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.

Table 8. Percentages of the territory of the Republic of Serbia depending on the number of days

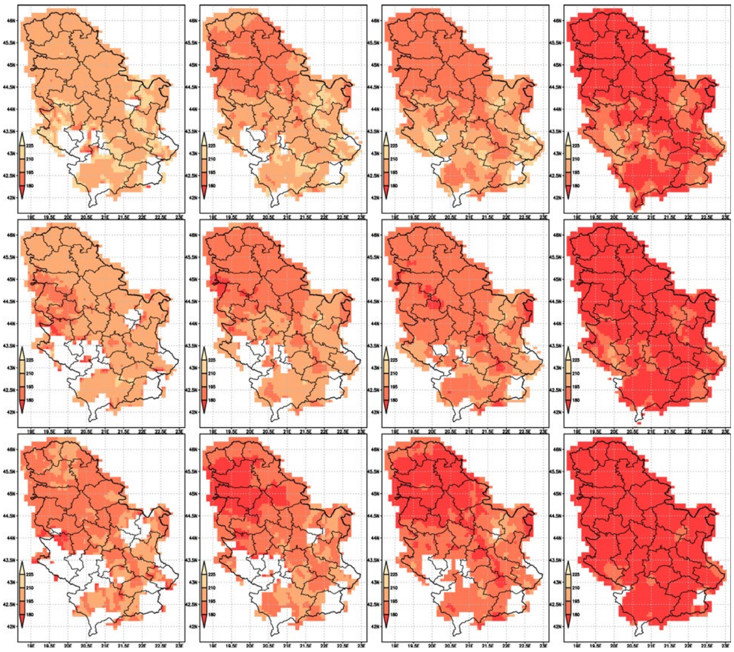
Types of fruit trees	1.[1]	The number of days of overlapping of the warm period and the end of the fruit harvest										
		<10	<20	<30	<40	<50	<60	<70	<80	<90	<100	<110
TB- 9°C, DV- 150 (almond, apricot)	6.96	0.08	2.82	15.02	35.92	8.53	0.57	0	0	0	0	0
TB- 10°C, DV – 150 (peach, cherry)	9.70	0	0	2.19	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

of overlap of the warm period and the end of the fruit harvest, according to the observed data

High temperatures are especially harmful during the ripening period. 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 6), 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.).

Figures 22 a, b and c show the mean start date, end date and duration of the warm period in which Tx> 35°C occur according to the model for the 1986-2005 period, as well as for future



periods (2021-2040, 2041-2060 and 2081-2100).

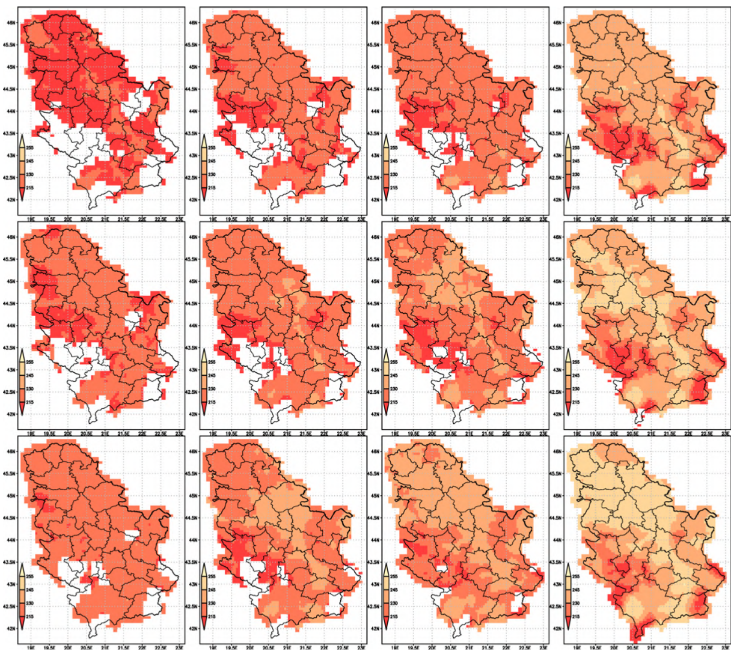


Figure 22a. Start of the warm period

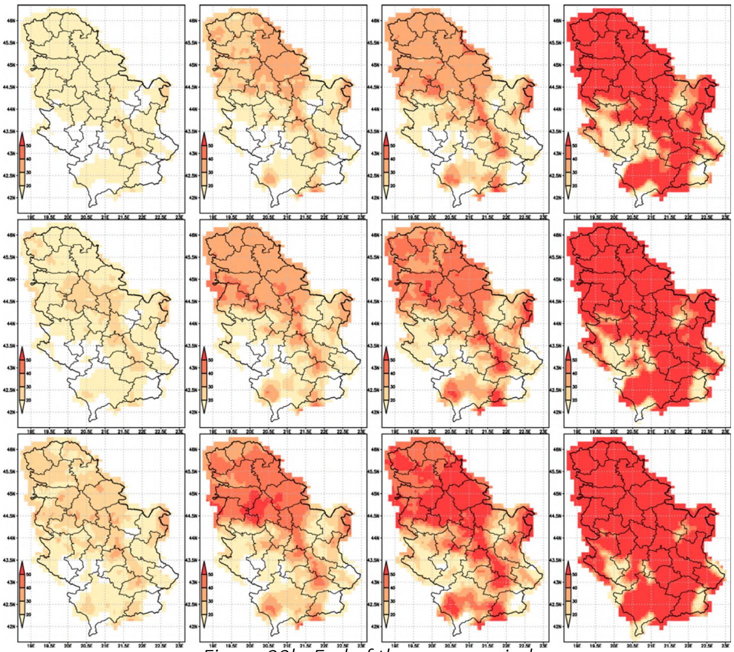


Figure 22b. End of the warm period

Figure 22c. Duration of the warm period

According to the "median model" (Table 9) for the 1986-2005 period, in these types of fruit trees (apple, pear, quince), the number of days of the overlap of the warm period and the end of fruit harvest greater than 90, occurs in 43.3% of Serbia.

Table 9. Percentages of the territory of the Republic of Serbia depending on the number of days

Types of fruit trees	Period	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)	1986-2005	12.1	0.0	0.0	0.9	26.0	54.0	6.6	0.4	0.0	0.0	0.0	0.0
	2021-2040	9.5	0.0	0.2	2.2	31.1	54.6	2.4	0.0	0.0	0.0	0.0	0.0
	2041-2060	5.6	0.0	0.1	1.4	24.0	66.0	2.9	0.0	0.0	0.0	0.0	0.0
	2081-2100	0.6	0.0	0.1	1.6	25.9	67.4	4.2	0.2	0.1	0.0	0.0	0.0
TB- 10°C, DV – 150 (peach, cherry)	1986-2005	13.5	0.0	0.0	0.0	2.0	50.2	32.2	2.0	0.1	0.0	0.0	0.0
	2021-2040	11.1	0.0	0.0	0.2	5.4	41.7	41.2	0.3	0.0	0.0	0.0	0.0
	2041-2060	6.1	0.0	0.0	0.1	3.4	35.8	53.9	0.8	0.0	0.0	0.0	0.0
	2081-2100	0.7	0.0	0.0	0.1	1.6	29.9	63.4	4.1	0.2	0.0	0.0	0.0
TB- 11°C, DV – 150 (plum, sour cherry)	1986-2005	16.0	0.0	0.0	0.1	0.0	11.0	64.0	8.5	0.5	0.0	0.0	0.0
	2021-2040	12.6	0.0	0.0	0.0	0.1	16.3	58.1	12.9	0.0	0.0	0.0	0.0
	2041-2060	6.8	0.0	0.0	0.0	0.4	6.0	56.7	30.1	0.0	0.0	0.0	0.0
	2081-2100	1.0	0.0	0.0	0.0	0.0	2.2	36.6	59.1	1.0	0.1	0.0	0.0
TB- 12°C, DV – 180 (apple, pear)	1986-2005	54.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	33.5	9	0.2
	2021-2040	44.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.1	15.8	35.3	2.3
	2041-2060	22.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.9	14.9	53.8	7.1
	2081-2100	9.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	4.6	57.0	28.7

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

of overlap of the warm period and the end of the fruit harvest, according to the median model

According to the 75th percentile model in 53.3% of the territory (Table 8), so a stricter model would be taken for analyzing the future, whose data are more similar to the observed data.

According to this model, towards the future, the length of the overlap of the warm period and the end of the fruit harvest is increasing in ever-larger areas of the Republic of Serbia. In species that have long vegetation (apple, pear, quince) in the near future (2021-2040) the number of days of the overlap of the warm period and the end of the harvest higher than 90 will be in 62.4% of the territory of Serbia (Figure 23).

In the mid-future (2041-2060), in 82.5% of the territory, and at the end of the century (2081-2100) in as much as 94% of the territory of the Republic of Serbia problems will occur causing extremely high temperatures (reduced yields, burns on fruits, poorer quality) .

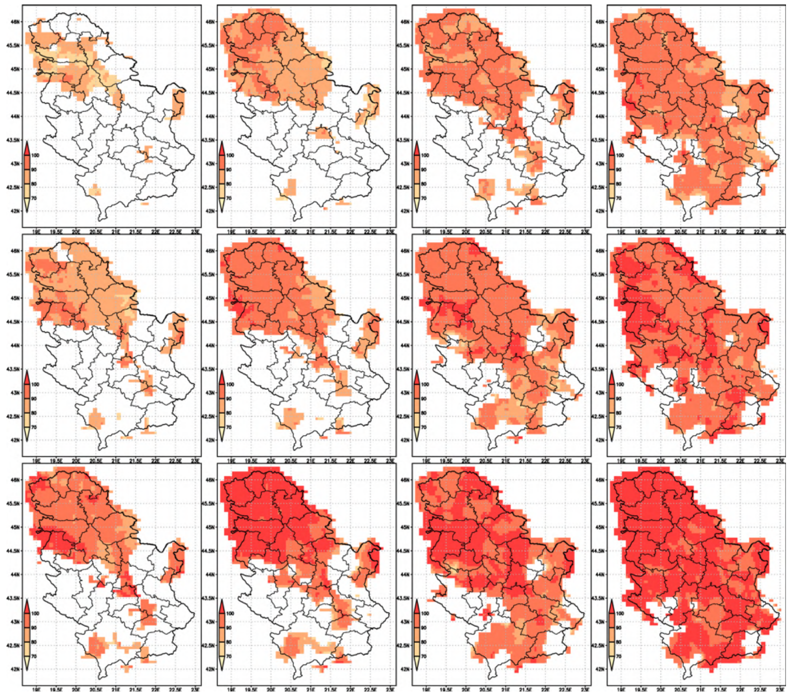


Figure 23. Number of days of the overlap of the warm period and the end of the harvest for species that have long vegetation (apple, pear, quince)

For species that start vegetation earlier and whose fruits ripen earlier, the problems with high temperatures will be less pronounced. Apricots and almonds will have the least problems. In these species in the near future (2021-2040) the number of days of the overlap of the warm period and the end of the harvest greater than 50 will be in 31.8% of the territory of Serbia (Figure 24). In the mid-future (2041-2060), in 25.4% of the territory, and at the end of the century (2081-2100) in 33.2% of the territory of the Republic of Serbia. With these two species, towards the future, there will be no worsening of growing conditions, which are related to this environmental factor.

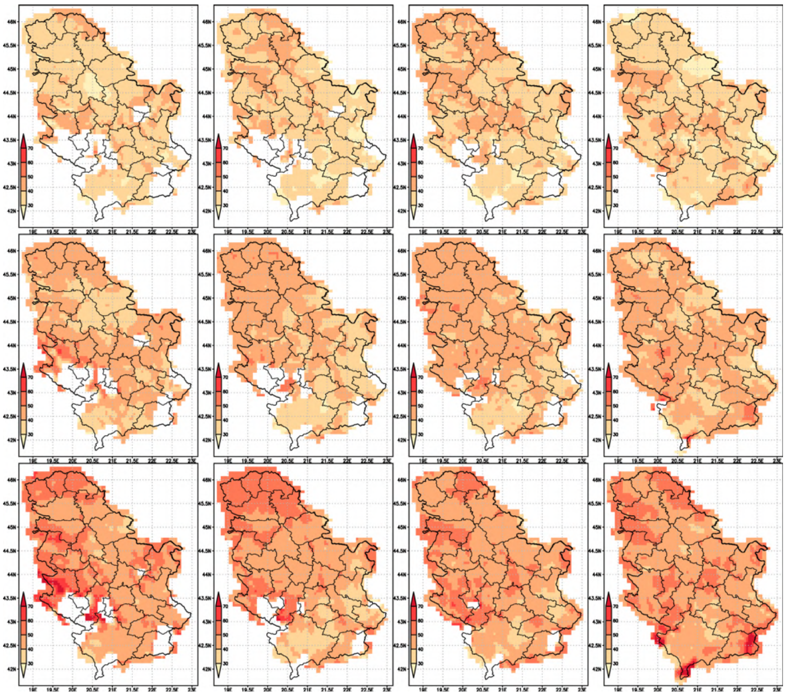


Figure 24. Number of days of the overlap of the warm period and the end of the harvest in the period for species that start vegetation earlier and whose fruits ripen earlier

Table 10. Percentages of the territory of the Republic of Serbia depending on the number of days of the overlap of the warm period and the end of the fruit harvest, according to the 75th percentile model

Types of fruit trees	Period	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)	1986-2005	9	0.0	0.0	0.0	5.2	47.6	32.0	4.2	1.2	0.0	0.0	0.0
	2021-2040	5.8	0.0	0.0	0.5	15.7	46.3	31.0	0.7	0.0	0.1	0.0	0.0
	2041-2060	2.7	0.0	0.0	0.6	9.0	62.2	24.8	0.6	0.1	0.0	0.0	0.0
	2081-2100	0.0	0.0	0.0	0.1	6.0	60.6	30.8	1.3	0.6	0.2	0.3	0.0
TB- 10°C, DV – 150 (peach, cherry)	1986-2005	11.2	0.0	0.0	0.0	0.9	14.9	58.1	12.2	2.3	0.5	0.0	0.0
	2021-2040	7.6	0.0	0.0	0.1	1.0	23.6	41.0	26.5	0.2	0.0	0.0	0.0
	2041-2060	2.7	0.0	0.0	0.0	0.6	14.0	72.2	10.2	0.3	0.0	0.0	0.0
	2081-2100	0.0	0.0	0.0	0.0	0.1	6.2	64.2	27.2	1.2	0.6	0.5	0.0
TB- 11°C, DV – 150 (plum, sour cherry)	1986-2005	13.1	0.0	0.0	0.0	0.2	1.8	37.3	42.3	4.8	0.5	0.1	0.0
	2021-2040	9.4	0.0	0.0	0.1	0.1	3.3	32.6	42.6	12.0	0.0	0.0	0.0
	2041-2060	3.1	0.0	0.0	0.0	0.0	1.1	25.1	67.8	2.7	0.2	0.0	0.0
	2081-2100	0.3	0.0	0.0	0.0	0.0	0.0	9.5	77.9	10.4	1.5	0.5	0.0
TB- 12°C, DV – 180 (apple, pear)	1986-2005	46.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	11.7	32.6	9.0
	2021-2040	35.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.6	10.3	17.8	34.3
	2041-2060	16.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	5.9	42.8	33.8
	2081-2100	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3	20.7	72.0

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

For species that start vegetation at average daily temperatures of 10°C (peach, walnut, hazel, strawberry, currant), in the near future (2021-2040) the number of days of the overlap of the warm period and the end of harvest greater than 50 will be in 67.5% of the territory of Serbia

(Figure 21c). In the mid-future (2041-2060), in 82.7% of the territory, and at the end of the century (2081-2100) in 93.7% of the territory of the Republic of Serbia.

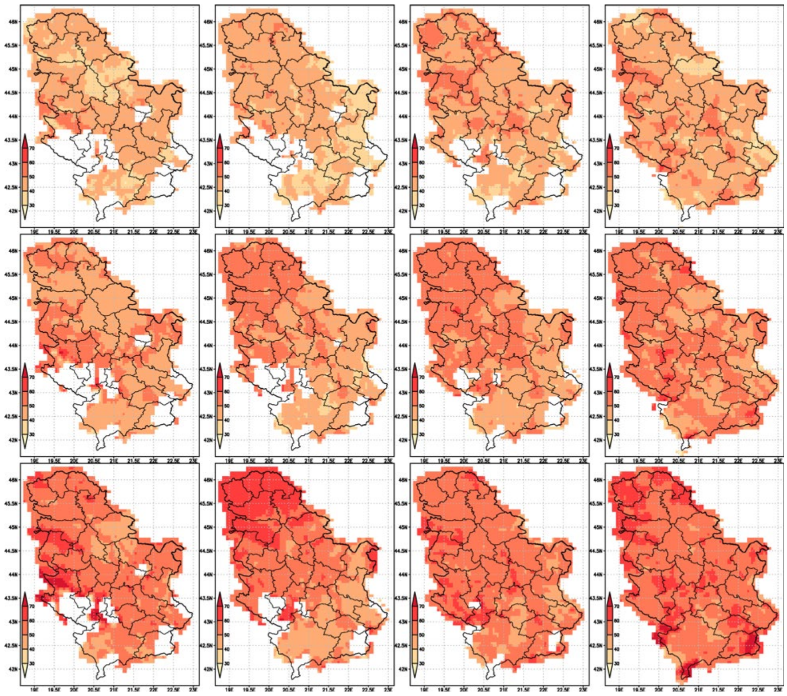


Figure 25. Number of days of the overlap of the warm period and the end of the harvest in the period for species that start vegetation at average daily temperatures of 10°C (peach, walnut, hazel, strawberry, currant)

For species that start vegetation at average daily temperatures of 11°C (plum, cherry) in the near future (2021-2040) the number of days of the overlap of the warm period and the end of the harvest greater than 60 will be in 54.6% of the territory of Serbia (Figure 21d)

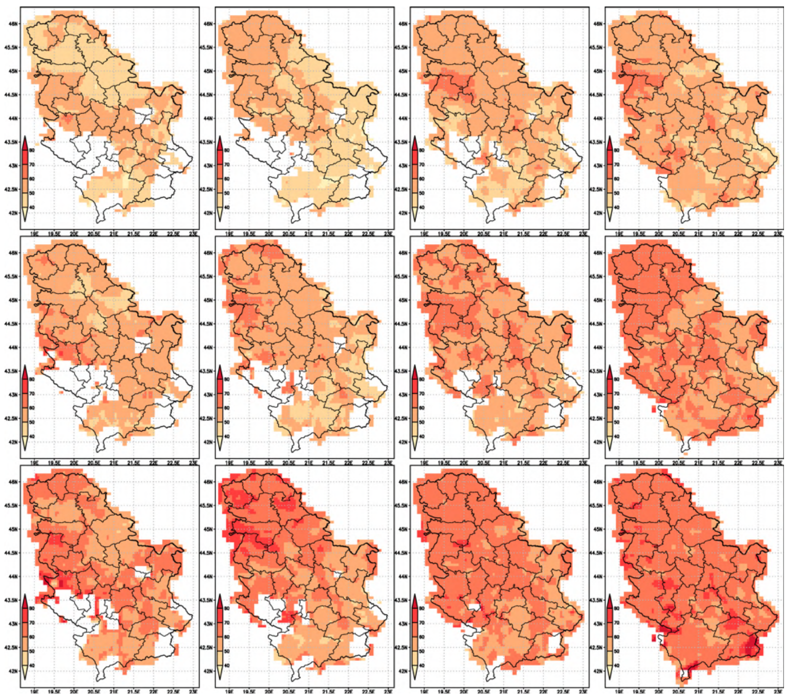


Figure 26. Number of days of the overlap of the warm period and the end of the harvest in the period for species that start vegetation at average daily temperatures of 11°C (plum, cherry)

In the mid-future (2041-2060), in 70.7% of the territory, and at the end of the century (2081-2100) in 90.3% of the territory of the Republic of Serbia (Table 11).

Table 11. Assessment of high temperatures risk by region

Crop: apple, pear, quince black currant, blueberry, blackberry Risk: Probability of the occurrence of the period of heat						
Admin. district	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present	Tendency
North Banat	Moderate	Large	Large	Moderate	Moderate	+
Central Banat	Moderate	Large	Large	Moderate	Moderate	+
South Banat	Moderate	Large	Very large	Large	High	+
North Bačka	Moderate	Large	Large	Moderate	Moderate	+
West Bačka	Moderate	Large	Large	Moderate	Moderate	+
South Bačka	Small	Large	Large	Moderate	Moderate	+
Srem	Small	Large	Large	Moderate	Moderate	+
City of Belgrade	Moderate	Large	Very large	Large	High	+
Danube River Basin	Moderate	Very large	Very large	Large	High	+
Braničevo	Moderate	Large	Very large	Large	High	+
Bor	Small	Large	Large	Moderate	Moderate	+
Zaječar	Small	Large	Large	Moderate	Moderate	+
Nišava	Moderate	Very large	Very large	Large	High	+
Pirot	Small	Large	Large	Moderate	Moderate	+
Toplica	Small	Large	Large	Moderate	Moderate	+
Jablanica	Small	Very large	Very large	Large	High	+
Pčinja	Small	Large	Large	Moderate	Moderate	+
Šumadija	Small	Large	Large	Moderate	Moderate	+
Pomoravlje	Moderate	Very large	Very large	Large	High	+
Raška	Small	Small	Small	Small	Low	0
Rasina	Small	Large	Large	Moderate	Moderate	+
Mačva	Small	Large	Large	Moderate	Moderate	+
Kolubara	Small	Large	Large	Moderate	Moderate	+
Moravica	Small	Moderate	Moderate	Small	Low	+
Zlatibor	Small	Small	Small	Small	Low	0
National level	**Small**	**Large**	**Large**	**Moderate**	**Moderate**	**+**

Crop: peach, plum, sour cherry, cherry, apricot, almond, raspberry, strawberry Risk: Probability of the occurrence of the period of heat						
Admin. district	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present	Tendency
North Banat	Low	Moderate	Moderate	Moderate	Low	+
Central Banat	Low	Moderate	Moderate	Moderate	Low	+
South Banat	Low	Moderate	High	High	Low	+
North Bačka	Low	Moderate	Moderate	Moderate	Low	+
West Bačka	Low	Moderate	Moderate	Moderate	Low	+
South Bačka	Low	Moderate	Moderate	Moderate	Low	+
Srem	Low	Moderate	Moderate	Moderate	Low	+
City of Belgrade	Low	Moderate	High	High	Low	+
Danube River Basin	Low	Moderate	High	High	Low	+
Braničevo	Low	Moderate	High	High	Low	
Bor	Low	Moderate	Moderate	Moderate	Low	+
Zaječar	Low	Moderate	Moderate	Moderate	Low	+
Nišava	Low	Moderate	High	High	Low	+
Pirot	Low	Moderate	Moderate	Moderate	Low	+
Toplica	Low	Moderate	Moderate	Moderate	Low	+
Jablanica	Low	Moderate	High	High	Low	+
Pčinja	Low	Moderate	Moderate	Moderate	Low	+
Šumadija	Low	Moderate	Moderate	Moderate	Low	+
Pomoravlje	Low	Moderate	High	High	Low	+
Raška	Low	Low	Low	Low	Low	0
Rasina	Low	Moderate	Moderate	Moderate	Low	+
Kolubara	Low	Moderate	Moderate	Moderate	Low	+
Moravica	Low	Low	Low	Low	Low	0
Zlatibor	Low	Low	Low	Low	Low	0
National level	Low	Moderate	Moderate	Moderate	Low	+
National level	**Small**	**Large**	**Large**	**Moderate**	**Moderate**	+

Risk of hail and natural disasters

Hail can cause significant negative consequences for the fruit. Based on the analysis of the frequency of hail in Serbia during the 1949-2012 period at 28 synoptic stations, hail larger than 2 mm in diameter most often occurs during June, May and April[6]. It most often occurs in the mountainous area in Southwestern Serbia. After 2000, a trend of increasing the frequency of hail at stations in Vojvodina was observed.

Data on hail in the territory of Serbia without Vojvodina for the 1981-2015 period were observed at about 1200 anti-hail stations, and in the territory of entire Serbia for the 2002-2015 period at about

6 Ćurić, M., Janc, D. (2016). Hail climatology in Serbia. International Journal of Climatology 36: 3270–3279.

1650 anti-hail stations[7]. The conclusion is that in about 80% of cases the size of hail is smaller than that of hazelnuts, and that in only 1% of events grains of hail are larger than the size of a walnut (Figure 27). Unlike Ćurić and Janac, these authors found that the months with the most frequent incidence of hail in the territory of Serbia are May, June and July. In Southwestern Serbia, an average of 1.2 days with hail per year was recorded (maximum 2.7 days), while in Vojvodina the average value was 0.7 days. Radler et al. (2019), based on the results of 14 regional climate models over Europe, calculated the average annual incidence of hail with a diameter of more than 2 cm and more than 5 cm for the reference 1971-2000 period and the end of the 21st century (2071-2100), under IPCC scenarios RCP 4 .5 and RCP 8.5[8]. The results showed that the average annual probability of the incidence of hail with a diameter of more than 2 cm in most parts of Serbia ranged from 0.4 to 0.8 days, and up to 1.2 days in the mountainous areas in the west, southwest and east of the country. The mean incidence of hail greater than 5 cm in diameter was between 0.07 and 0.14 days per year during the reference period. By the end of the 21st century, according to the RCP8.5 scenario, the climate models used in Serbia predict an increase in the frequency of hail incidence, from 40 to 80% in Vojvodina and from 20 to 40% in the rest of Serbia for hail larger than 2 cm in diameter, and from 40 to 80% throughout the territory for hail larger than 5 cm in diameter.

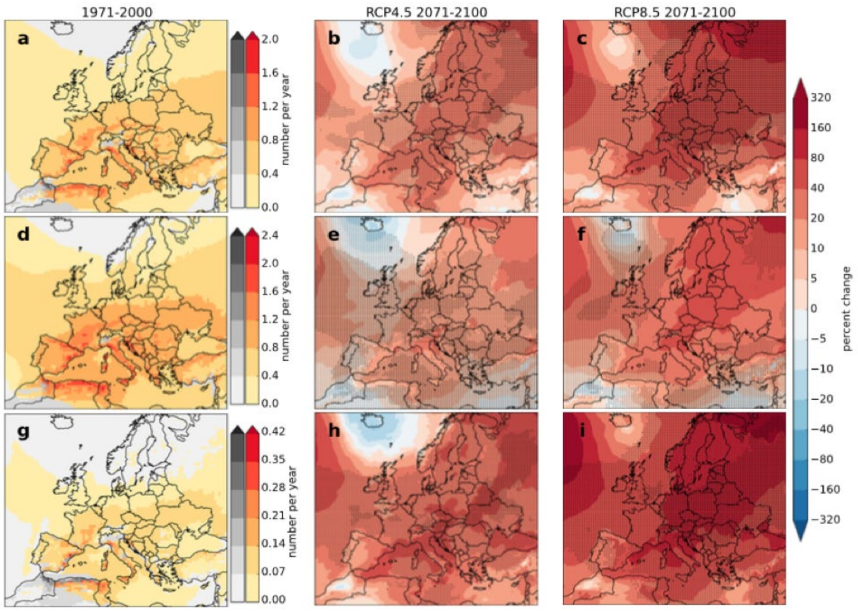


Figure 27. average annual number of days with hail greater than 2 cm in diameter (upper row), average annual number of days with gusts stronger than 25 m / s (middle row), average annual number of days with hail greater than 5 cm in diameter bottom row). Reference period 1971-2000 (left column), relative change for the period 2071-2100 according to the RCP4.5 scenario (middle column) and relative change for the period 2071-2100 according to the RCP8.5 scenario. (right column)

In the same paper, the incidences of wind gusts stronger than 25 m/s were analyzed. In the largest part of the territory of Serbia during the reference period, the average frequency of incidence of this event was from 0.8 to 1.2 days, while the mountainous areas in the west, south and east of the country had a slightly higher frequency, up to 1.6 days. By the end of the 21st century, according to the RCP8.5 scenario, the selected climate models predict an increase in the frequency of these events from 20 to 40% throughout Serbia. Statistically, significant changes are predicted only in the Košava area of Eastern Serbia (Table 12)

7 Nađ, J., Vujović, D., Vučković, V. (2021). Hail characteristics in Serbia based on data obtained from the network of hail suppression system stations. International Journal of Climatology. 1-17.

8 Radler, A., Groenemeijer, P., Faust, E., Sausen, R., Púčik, T. (2019). Frequency of severe thunderstorms across Europe expected to increase in the 21st century due to rising instability. Climate and Atmospheric Science, 30.

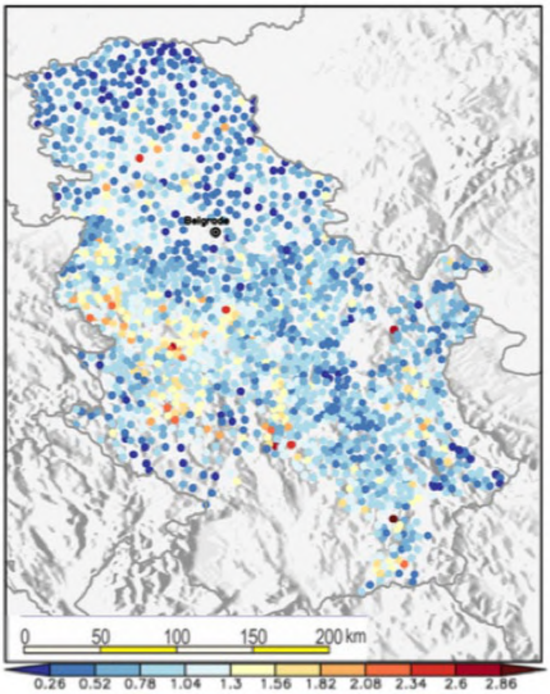


Figure 28. The average annual number of days with hail recorded at anti-hail stations in Serbia in the 1981-2015 period (Nađ et al., 2021)

Table 12. Hail and disaster risk assessment by region

Crops: All fruit species Risk: Probability of hail						
	Exposure				Risk	
Admin. district	present 1971-2000	end of the century 2071-2100	Mid-century 2041-2060	Vulnerability	Present	Tendency
North Banat	Small	Large	Moderate	Low	+	+
Central Banat	Small	Large	Moderate	Low	+	+
South Banat	Moderate	Very large	Large	Moderate	+	+
North Bačka	Small	Large	Moderate	Low	+	+
West Bačka	Small	Large	Moderate	Low	+	+
South Bačka	Moderate	Large	Moderate	Moderate	+	+
Srem	Moderate	Large	Moderate	Moderate	+	+
City of Belgrade	Moderate	Large	Large	Moderate	+	+
Danube River Basin	Moderate	Large	Large	Moderate	+	+
Braničevo	Moderate	Large	Large	Moderate	+	
Bor	Moderate	Large	Moderate	Moderate	+	+
Zaječar	Moderate	Large	Moderate	Moderate	+	+
Nišava	Moderate	Large	Large	Moderate	+	+
Pirot	Moderate	Large	Moderate	Moderate	+	+
Toplica	Moderate	Large	Moderate	Moderate	+	+
Jablanica	Moderate	Very large	Large	High	+	+
Pčinja	Large	Very large	Large	High	+	+
Šumadija	Moderate	Large	Moderate	Moderate	+	+

Pomoravlje	Moderate	Very large	Large	High	+	+
Raška	Large	Very large	Large	High	+	0
Rasina	Moderate	Large	Moderate	Moderate	+	+
Mačva	Moderate	Large	Moderate	Moderate	+	+
Kolubara	Moderate	Large	Moderate	Moderate	+	+
Moravica	Large	Very large	Large	High	+	0
Zlatibor	Large	Very large	Large	High	0	0
National level	**Moderate**	**Large**	**Moderate**	**Moderate**	**+**	**+**

4. Risk and vulnerability assessment in the future climate – viticulture

Climate change will have a major impact on the sustainability of the grapevine in the future. Various papers and studies on the significant impacts of climate change on viticulture are available[9, 10, 11, 12, 13]. The main results on the potential impacts of future climate change are described as changes in the phenological stages of grapevine development, changes in the grape and wine composition, effects on grape yield, expansion of vineyards to areas previously unsuitable for grape growing and significant geographical shifts in traditional wine-growing regions. Climatic conditions tightly control the microclimatic conditions in the vineyard, growth and development of the vine, the physiology of the grapevine, yield and composition of berries, thus playing a vital role in the terroir of a specific wine-growing region[14, 15, 16].

Length of the vegetation period, air temperature and amount of precipitation

Climatic factors exert their influence on the grapevine throughout the annual cycle, mostly during the vegetation period. Based on the analysis of projected values of temperatures for the vegetation period (Tveg) which are shown in Figure 29 it can be concluded that in the last 40 years of this century (periods 2041-2060 and 2080-2100) there will be significant changes in these

9 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

10 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.

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

12 Vukovic, A., Vujadinovic, M., Ruml, M., Vasic, Z., Przic, Z., Beslic, Z., Matijasevic, S., Vujović, D., Todic, S., Markovic, N., Sivcev, B., Zunic, D., Zivotic, L., Jaksic, D. (2018). Implementation of climate change science in viticulture sustainable development planning in Serbia. E3S Web of Conferences. 50. 01005. 10.1051/e3sconf/20185001005.

13 Ruml, M., Vuković A., Vujadinović M., Djurdjević, V., Ranković-Vasić, Z., Atanacković, Z., Sivcev, B., Marković, N., Matijašević, S., Petrović, N. (2012). On the use of regional climate models: Implications of climate change for viticulture in Serbia. Agric. For. Meteorol., 158-159, 53–62.

14 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.

15 Ruml, M., Korać, N., Vujadinovć, 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.

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

temperatures in relation to the reference period for climate change (1986-2005) and the first period of the future (2021-2024). Changes in the mean temperature of the growing season have been projected, which will be higher, for the 50th and 75th percentile in the entire wine-growing region of Vojvodina and certain parts of the wine-growing region of "Three Morava Rivers", as well as the Niš and Nišava regions.

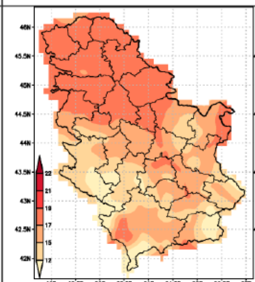
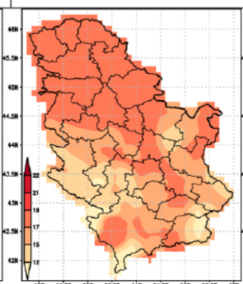
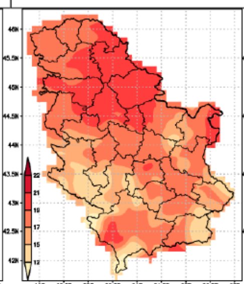
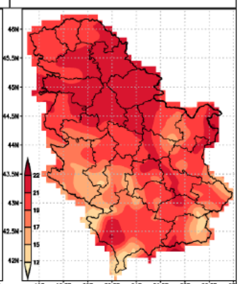
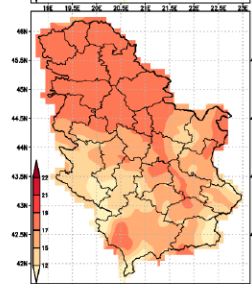
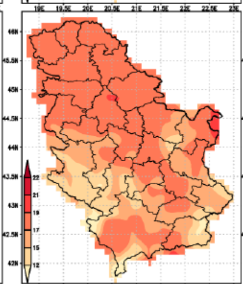
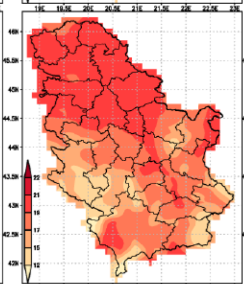
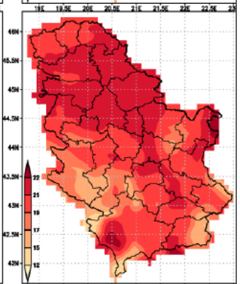
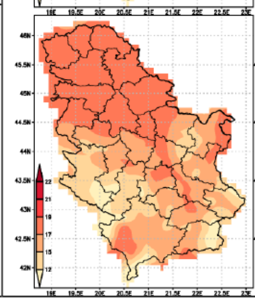
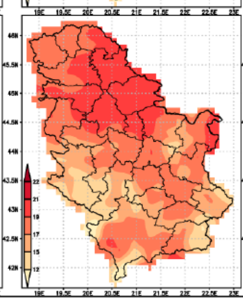
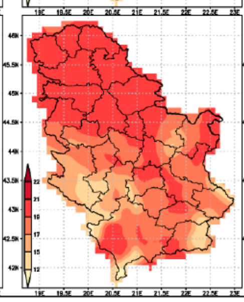
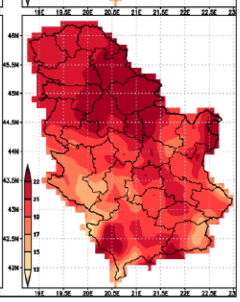
Period/ Probability of occurrence	1986-2005	2021-2040	2041-2060	2080-2100
25%				
50%				
75%				

Figure 29. Mean projected values of temperatures for the vegetation period (Tveg) – probabilitz of occurrence

Knowledge of phenological changes during the vegetation of the grapevine, on the one hand, and climatic factors on the other, are important factors in the selection of cultivars in the wine-growing region. Meteorological conditions have a greater influence on the phenological dynamics than the genetic characteristics of cultivars [17].

The start (GSS) and end (GSE) of the vegetation period (Figures 30 and 31) will also change in the future. Vegetation will start earlier in all three periods of the future.

17 Ruml, M., Korać, N., Ivanišević, D., Vujadinović, M., Vuković, A. (2013). Analysis of grapevine phenology in the region of Sremski Karlovci, Journal of Agricultural Sciences, 58 (1): 73-84.

Period/ Probability of occurrence	1986-2005	2021-2040	2041-2060	2080-2100
25%				
50%				
75%				

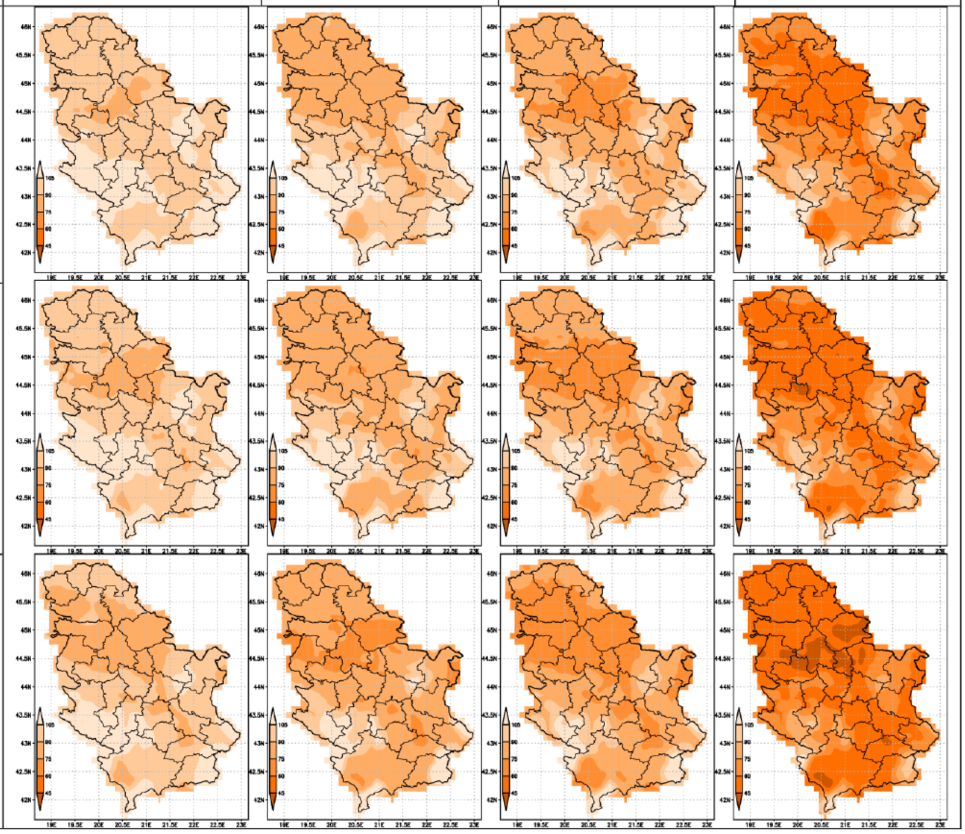


Figure 30. Start of the vegetation period (GSS) – probability of occurrence

The biological zero for grapevine (average daily temperature higher than 10°C since the beginning of the year) will occur earlier in all regions of the wine-growing region of Vojvodina, as well as in the regions of Central Serbia (Pocer-Valjevo, Belgrade, Negotinska Krajina, Three Morava Rivers, Niš, Nišava, etc.).

Period/ Probability of occurrence	1986-2005	2021-2040	2041-2060	2080-2100
25%				
50%				
75%				

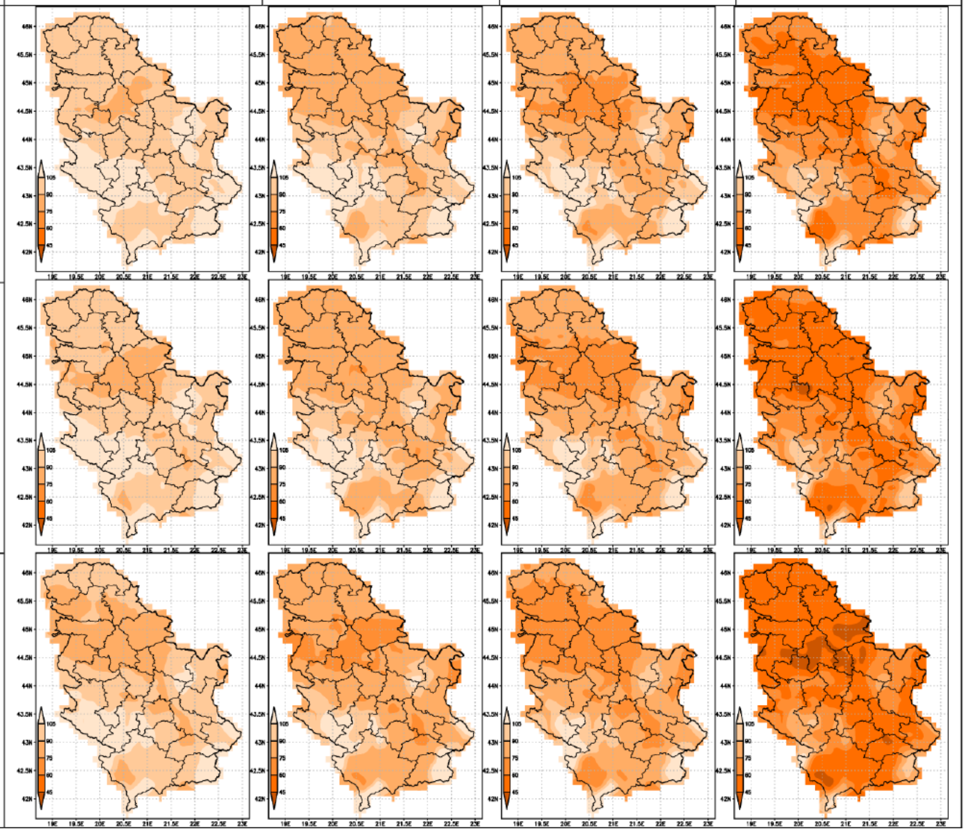


Figure 31. End of the vegetation period (GSE) – probability of occurrence

The end of the vegetation also shifts. Five consecutive days with an average daily temperature lower than 10°C in the second half of the year will occur later. Due to these changes, the projected length of the vegetation period (GSL) will also change since the vegetation will last longer. In the region of Belgrade, parts of the Pocer-Valjevo and South Banat regions in the third phase of the future (2018-2100), for the 75th percentile, it is projected that the vegetation will last over 280 days (Figure 32). Even in the current climate, the vegetation period begins earlier and ends later. The biggest change is the period of earlier blooming and ripening, precisely because of the increase in air temperatures [18].

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

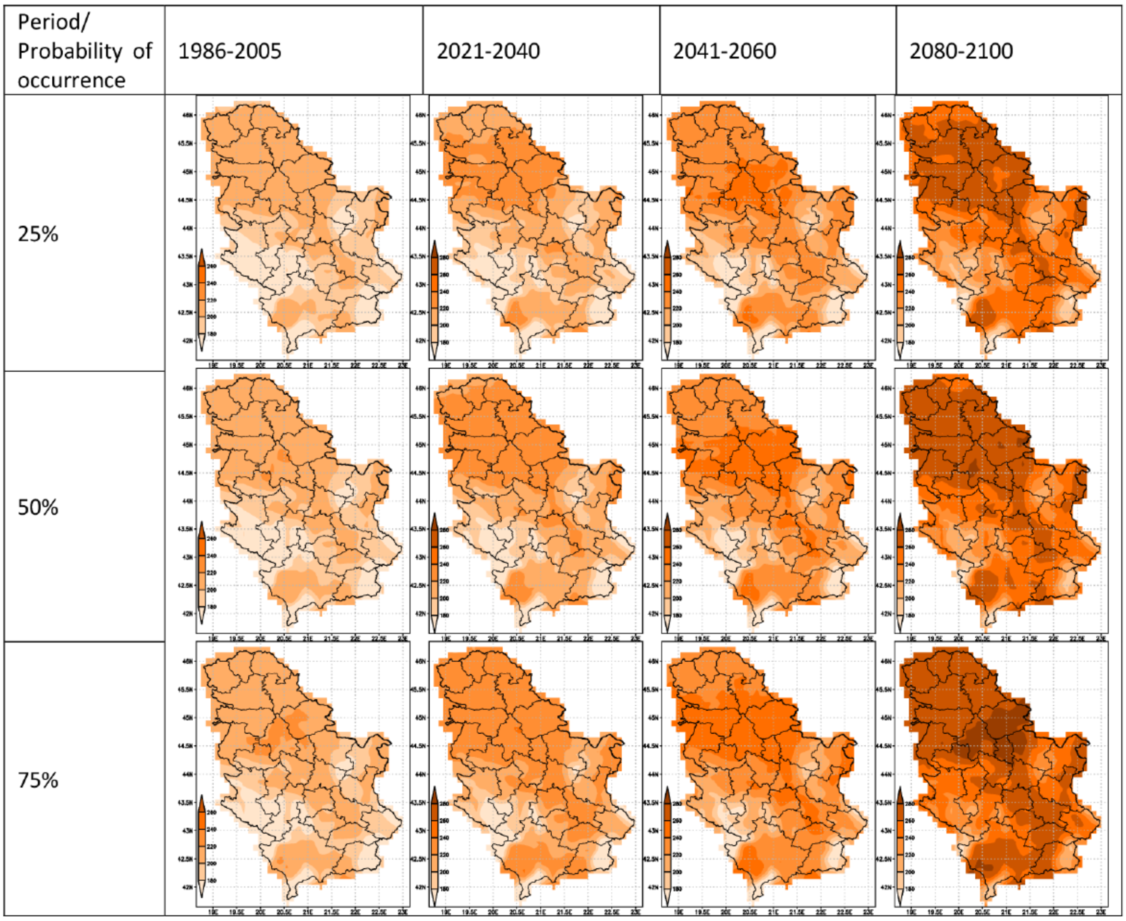


Figure 32. Duration of the vegetation period (GSL) – probability of occurrence

The increase in air temperature will be accompanied by a decrease in precipitation, especially during the vegetation period (Figure 33).

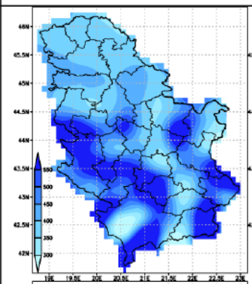
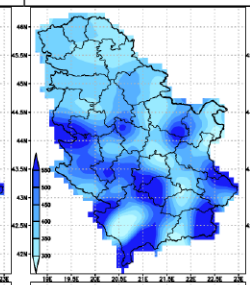
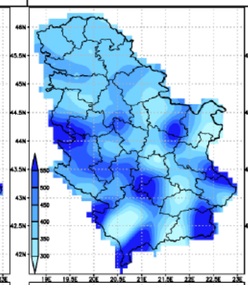
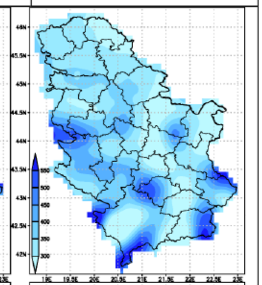
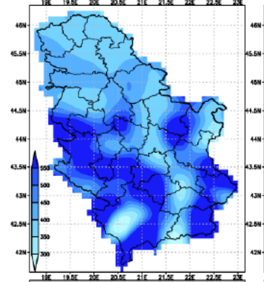
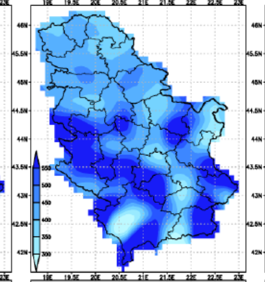
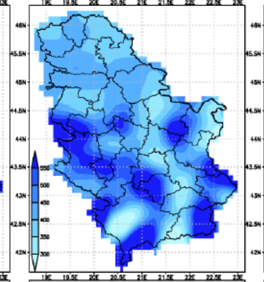
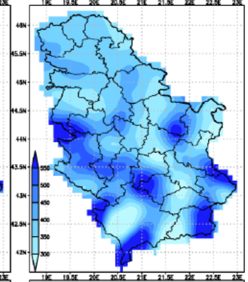
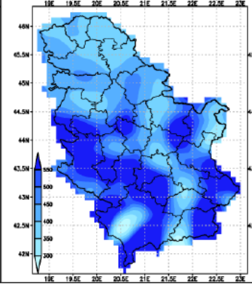
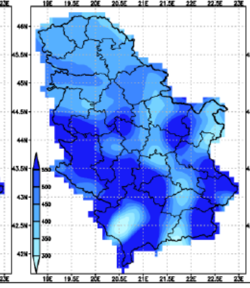
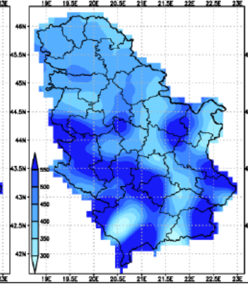
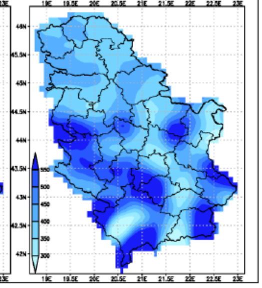
Period/ Probability of occurrence	1986-2005	2021-2040	2041-2060	2080-2100
25%				
50%				
75%				

Figure 33. The amount of precipitation during the vegetation period (RRVEG) – probability of occurrence

During the phenophase of grapevine blooming (late May-early June), the amount of precipitation has a very large impact on the flow and dynamics of blooming, pollination, fertilization, berry germination and yield. In the vineyards of Serbia, the amount of precipitation in this period does not exceed 30 mm (Figure 34).

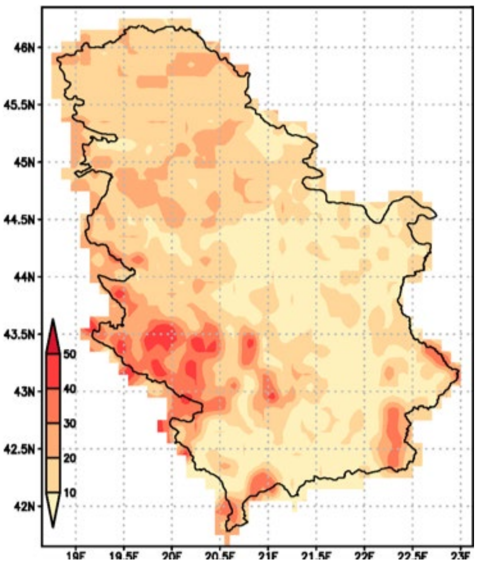


Figure 34. The amount of precipitation during the blooming period (cvetRR) – projection for the period 2000-2019

Projections for the future also predict a decrease in precipitation in this period, in some vineyards of Vojvodina and Central Serbia and below 10 mm (Figure 34).

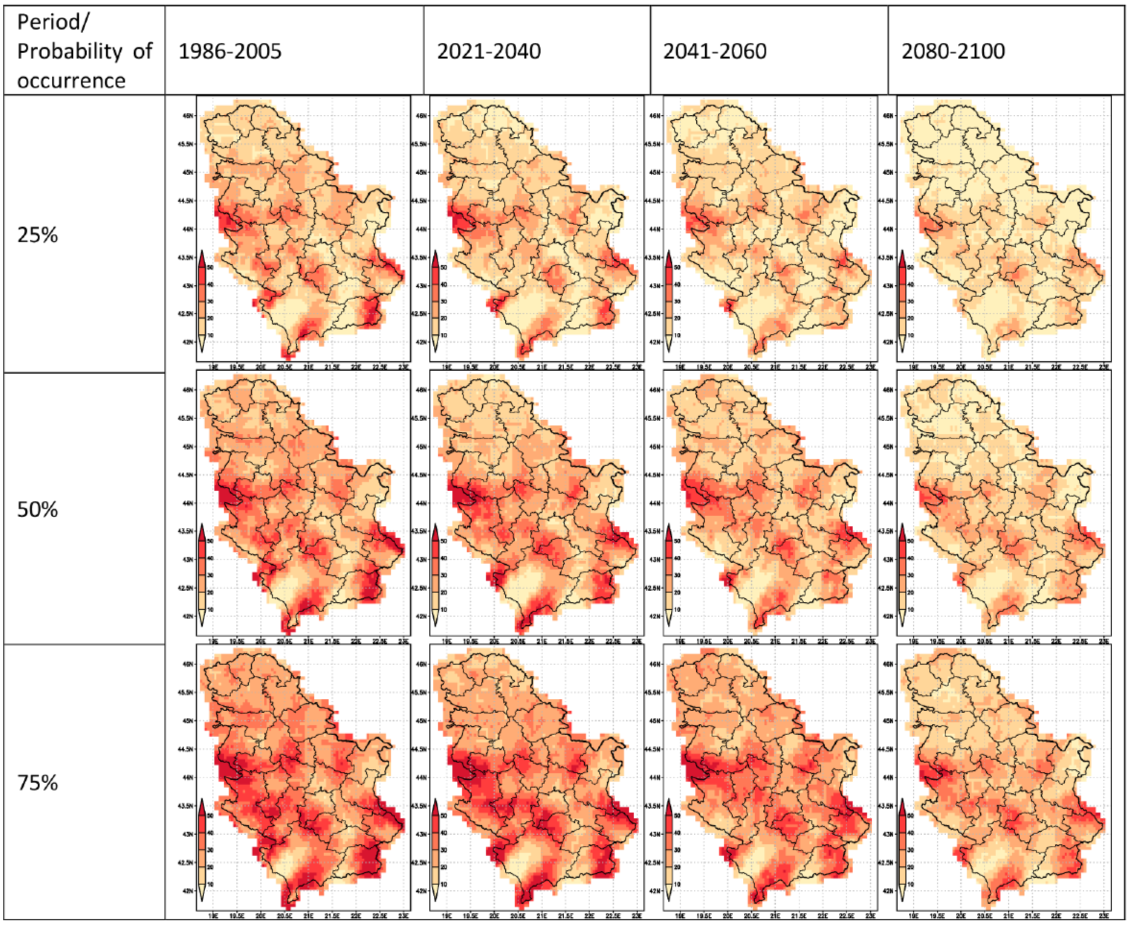


Figure 34. The amount of precipitation during the blooming period – probability of occurrence

The most important viticultural indices

Climate projections for the 2041-2060 and 2081-2100 periods show changes in all viticultural indices in the entire territory of wine-growing Serbia. It is predicted that in the next twenty years the Winkler Index will move to the WIN III zone (1668-1944°C) for most wine regions of Vojvodina and zone IV (1945-2222°C) for Belgrade and parts of Banat. In the second period (2041-2060) entire Vojvodina, except for small parts of the Subotica region and parts around Fruška Gora, will be WIN IV (1945-2222°C), and in the last projected period of the future (2081-2100) the region of Vojvodina, eastern and southern parts of Serbia, the region of Three Morava Rivers, Pocer-Valjevo and Belgrade region will be in the highest WIN V zone with over 2222°C (Figure 35).

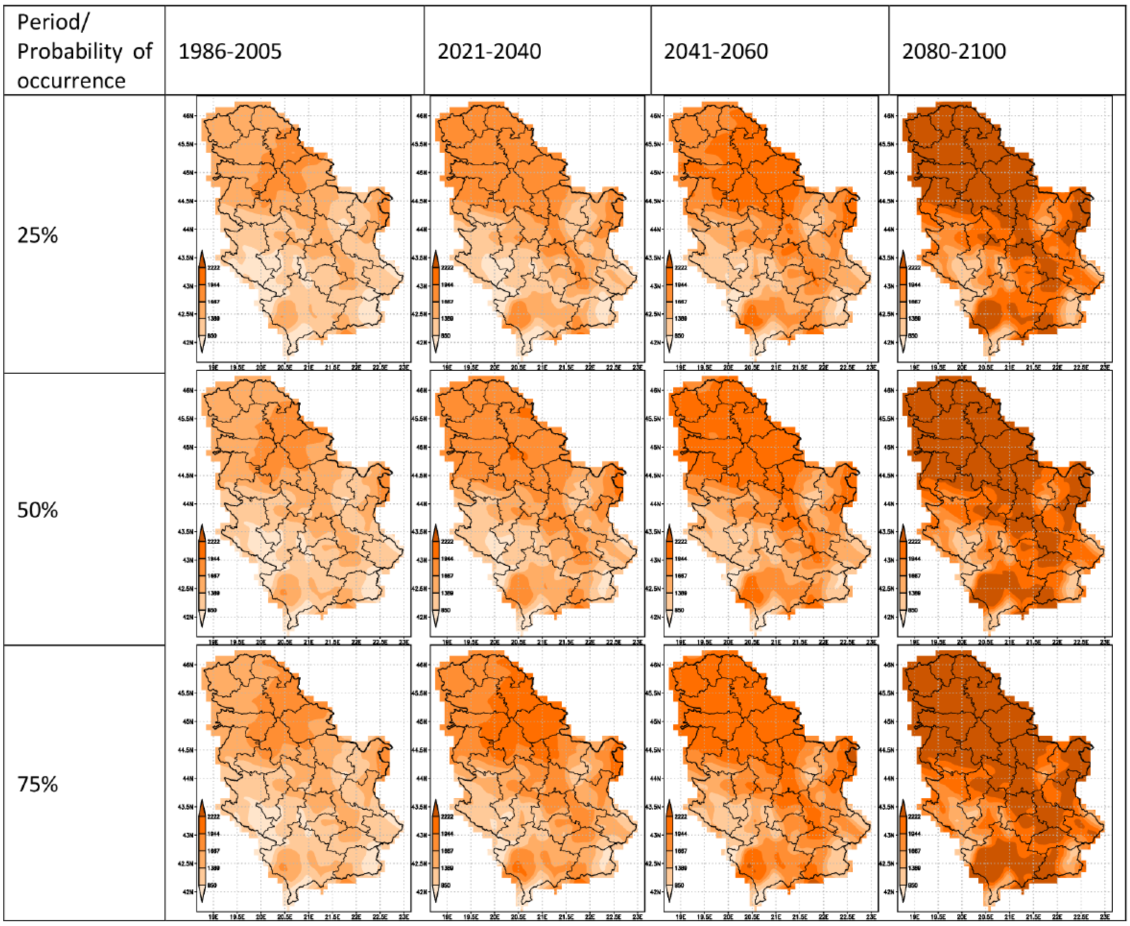


Figure 35. Projection of Winkler Index (WIN)

The Huglin Index (HI) also predicts a move towards a warmer climate that almost all wine-growing regions will have. Thus, in the 2081-2100 period, all regions of Vojvodina, except Subotica, will be in the HI+3 zone (> 2700°C). Also, Pocer-Valjevo and the region of Three Morava Rivers will be in this highest class, as well as parts of Niš, Nišava, the region of Negotinska Krajina, etc. (Figure 36). The mean minimum temperature in September (CI) in the reference period for climate change (1986-2005) belongs to the category of very cold nights (CI<12°C) in the entire territory of Serbia, except for separate parts of Belgrade, Banat and the far east where CI is 12-14°C (cold nights).

Period/ Probability of occurrence	1986-2005	2021-2040	2041-2060	2080-2100
25%				
50%				
75%				

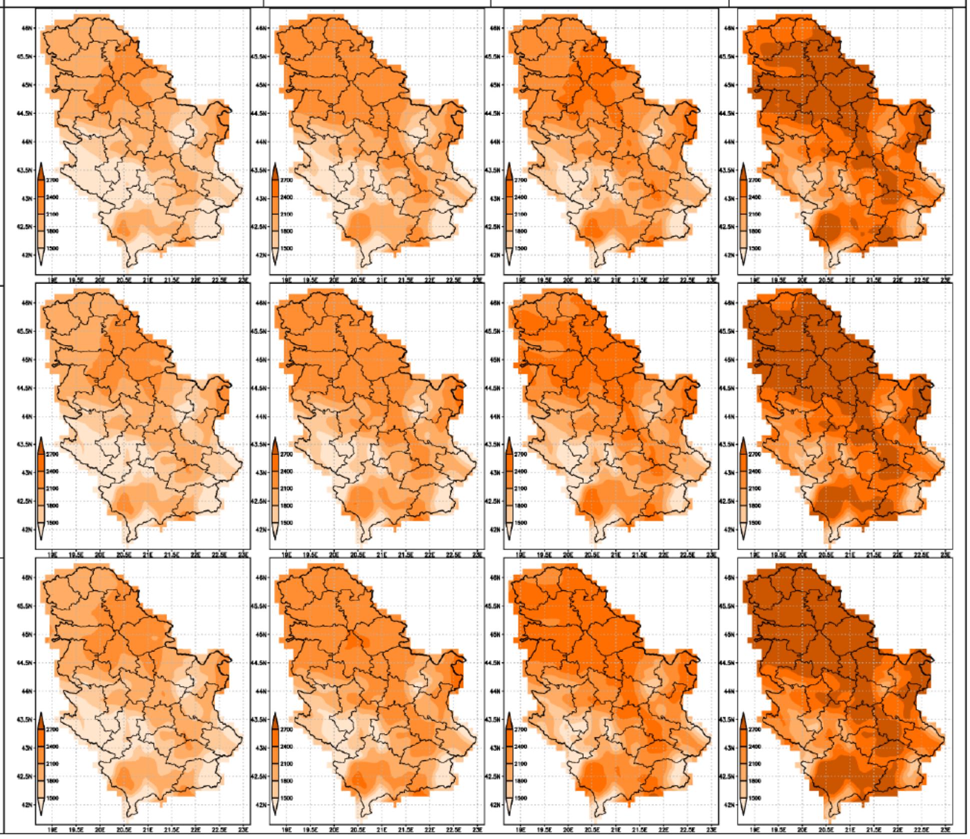


Figure 36. Projection of the Huglin Index (HI)

In the near and distant future, significant changes will occur in this index as well, so that in the 2081-2100 period (50th percentile) in entire Vojvodina, parts of Three Morava Rivers, Knjaževac, Niš, Leskovac, Toplica and Vranje nights will be moderate (CI 14-18°C, and in the same period (75^{th} percentile), the region of Belgrade would have warm nights (CI>18°C) (Figure 36).

Period/ Probability of occurence	1986-2005	2021-2040	2041-2060	2080-2100
25%				
50%				
75%				

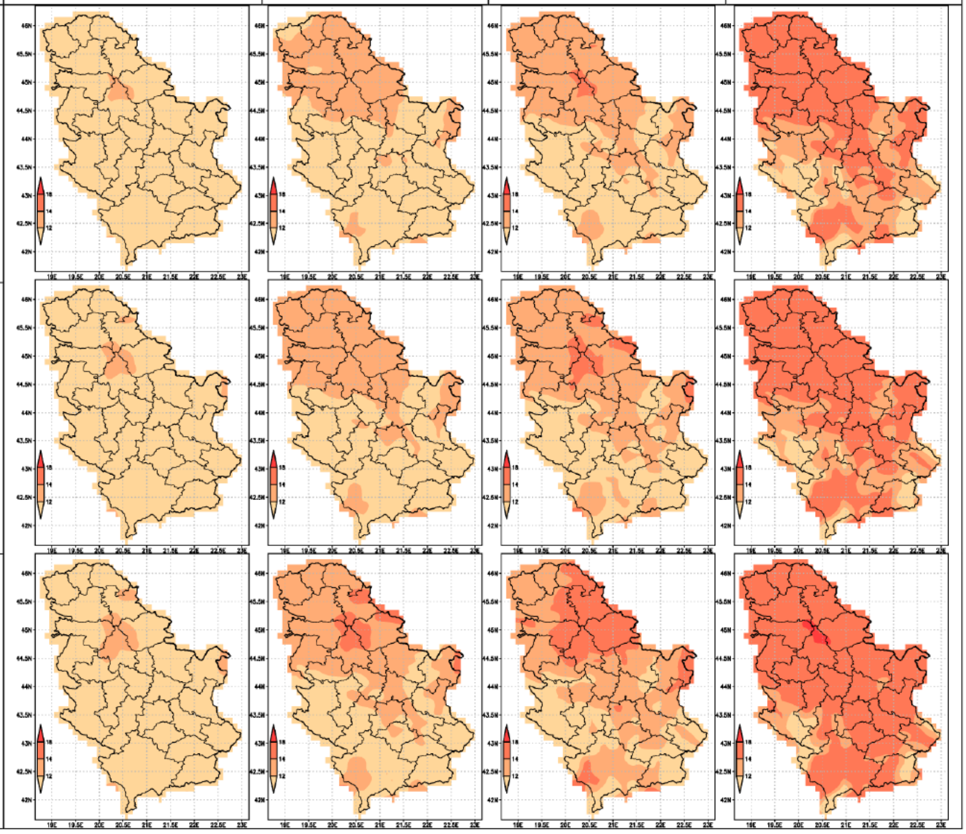


Figure 37. Projection of the Cool night index (CI)

The changes projected for the end of the 21st century (2081-2100) are very characteristic also in terms of the drought index (DI) shown in Figure 38. The transition of the wine-growing regions of Vojvodina, Pocer-Valjevo, Belgrade, Niš, Nišava, Vranje regions, vineyards in eastern Serbia is envisaged, as well as the vineyards of the Three Morava Rivers region from the subhumid climate category (DI-1) to the dry category (DI+1).

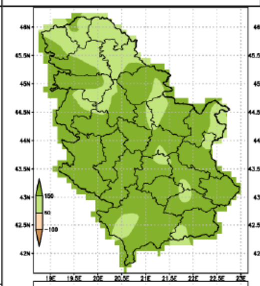
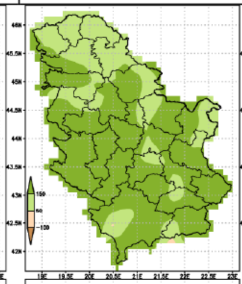
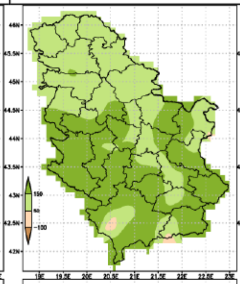
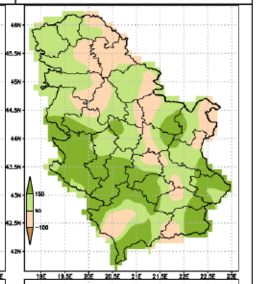
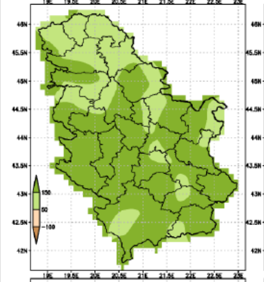
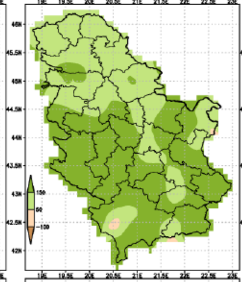
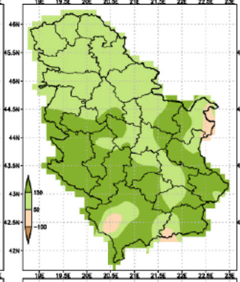
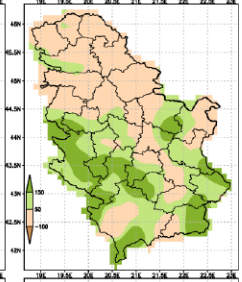
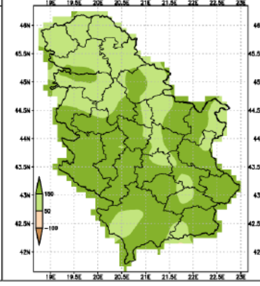
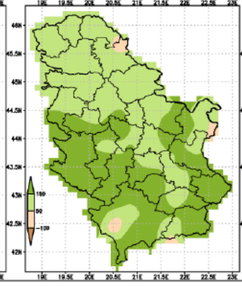
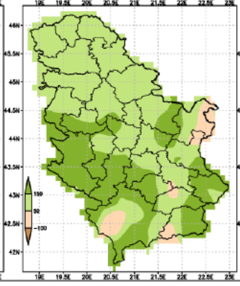
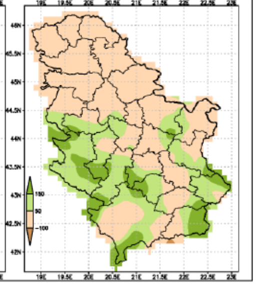
Period/ Probability of occurrence	1986-2005	2021-2040	2041-2060	2080-2100
25%				
50%				
75%				

Figure 38. Projection of Dryness index (DI)

Risk of high summer air temperatures

As already confirmed in various papers and projects, high air temperatures during the ripening/ maturing period adversely affect the yield and quality of grapes[19, 20]. Projections for the future show that the probability of occurrence of two consecutive days with a temperature higher than 35^{o}C (NTX35 index) will grow significantly, especially in the last twenty years of this century (Figure 39).

19 Project of the Ministry of Education, Science and Technological Development of the R. of Serbia: "Research on climate change and its impact on the environment – monitoring, adaptation and mitigation" (No. 43007) (2011-2019).

20 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.

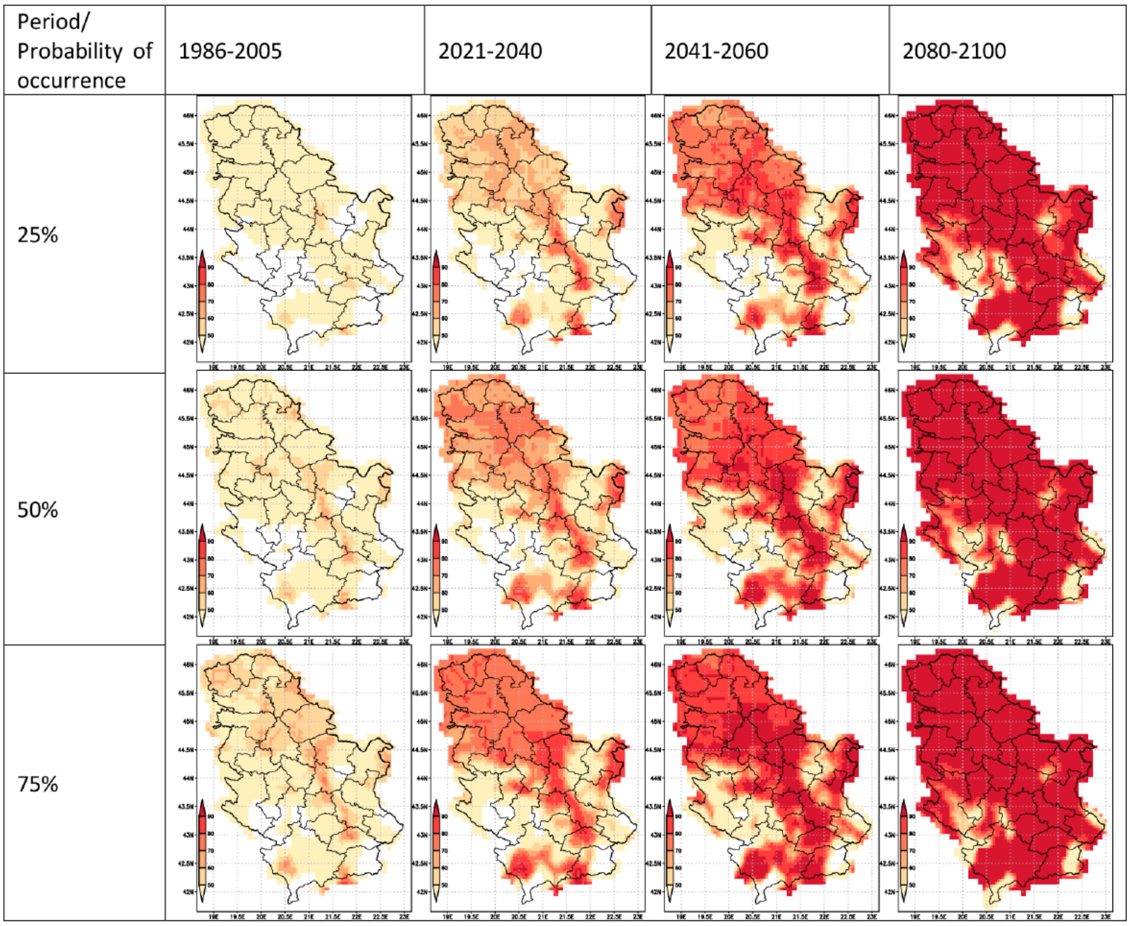


Figure 39. Probability of occurrence of the very warm days (Tx>35oC) (NTX35 index)

Table 13 shows the exposure, vulnerability and risk of high temperatures (Tx> 35°C), which can significantly reduce the accumulation of anthocyanins in the skin of the berry. This risk is of particular importance for red wine cultivars, the quality of grapes and the quality of the wine produced.

Admin. district	Crop: grapevine Risk: Probability of high temperatures incidence (Tx> 35oC)					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present	Tendency
North Banat	Moderate	Large	Large	Moderate	Moderate	+
Central Banat	Moderate	Large	Large	Moderate	Moderate	+
South Banat	Moderate	Large	Very large	Large	High	+
North Bačka	Moderate	Large	Large	Moderate	Moderate	+
West Bačka	Moderate	Large	Large	Moderate	Moderate	+
South Bačka	Small	Large	Large	Moderate	Moderate	+
Srem	Small	Large	Large	Moderate	Moderate	+
City of Belgrade	Moderate	Large	Very large	Large	High	+
Danube River Basin	Moderate	Very large	Very large	Large	High	+
Braničevo	Moderate	Large	Very high	Large	High	
Bor	Moderate	Large	Large	Moderate	Moderate	+
Zaječar	Moderate	Very high	Very high	Moderate	Moderate	+
Nišava	Moderate	Very high	Very high	Large	High	+
Pirot	Small	Large	Large	Moderate	Moderate	+
Toplica	Moderate	Very high	Very high	Large	Moderate	+
Jablanica	Small	Very high	Very high	Large	High	+
Pčinja	Small	Large	Large	Moderate	Moderate	+
Šumadija	Small	Large	Large	Moderate	Moderate	+
Pomoravlje	Moderate	Very high	Very large	Large	High	+
Raška	Small	Small	Small	Small	Low	0
Rasina	Small	Large	High	Moderate	Moderate	+
Mačva	Small	Large	High	Moderate	Moderate	+
Kolubara	Small	Large	High	Moderate	Moderate	+
Moravica	Small	Moderate	Moderate	Small	Low	+
Zlatibor	Small	Small	Small	Small	Low	0
National level	**Small, Moderate**	**Large**	**Large**	**Moderate**	**Moderate**	+

Table 13. Risk of high temperatures in grapevines

Risk of late spring frost

Figure 40 shows the probability of low temperatures (T<-2°C) at the beginning of the vegetation (period of bud starting) which increases towards the end of the 21st century.

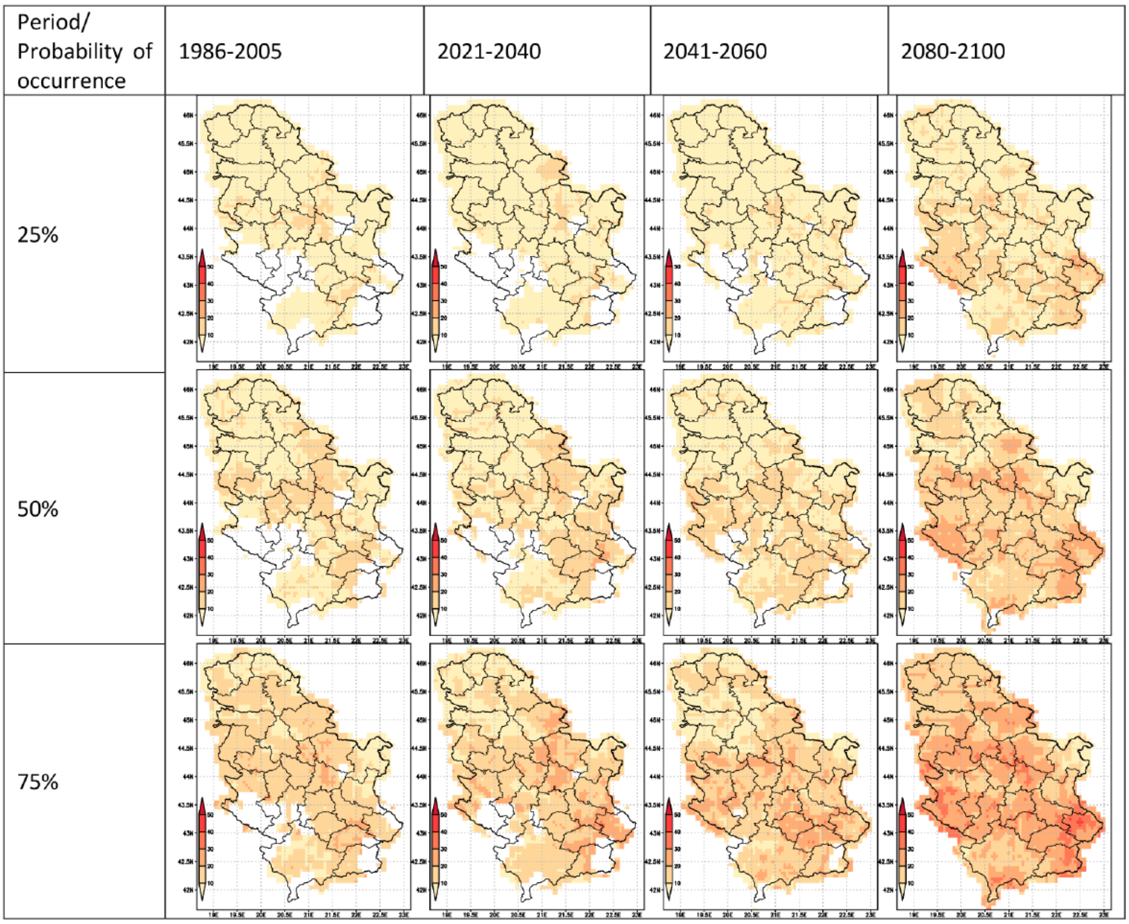


Figure 40. Probability of occurrence of low temperatures (T<-2°C) at the beginning of the vegetation period (period of bud starting)

Very young shoots and leaves freeze at about -2°C. During this spring (early April), low temperatures in some vineyards caused significant damage to newly activated buds. The differences between individual cultivars in this regard can be very large, even up to 15 days. Cultivars starting this phase earlier are more exposed to the threat of late spring frosts[21]. The risk assessment of late spring frost is shown in Table 14.

21 Cindrić, P., Korać, N., Ivanišević, D. (2019). Ampelography and selection of grapevines. University of Novi Sad, Faculty of Agriculture, Novi Sad.

Table 14. Risk assessment of late spring frost by regions

Admin. district	Crop: grapevine Risk: Late spring frost					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present	Tendency
North Banat	Moderate	Moderate	Moderate	Moderate	Low	0
Central Banat	Large	Large	Large	Moderate	Moderate	0
South Banat	Large	Large	Large	Large	High	0
North Bačka	Moderate	Moderate	Large	Moderate	Moderate	+
West Bačka	Moderate	Moderate	Large	Moderate	Moderate	+
South Bačka	Large	Moderate	Moderate	Large	High	-
Srem	Large	Moderate	Moderate	Moderate	Moderate	-
City of Belgrade	Moderate	Moderate	Moderate	Moderate	Moderate	0
Danube River Basin	Large	Large	Large	Large	High	0
Braničevo	Large	Large	Large	Very Large	High	
Bor	Moderate	Large	Large	Large	High	+
Zaječar	Large	Large	Large	Large	High	0
Nišava	Moderate	Large	Large	Very Large	High	0
Pirot	Large	Large	Large	Very Large	High	0
Toplica	Large	Large	Very Large	Large	High	+
Jablanica	Large	Large	Large	Very Large	High	0
Pčinja	Moderate	Large	Very Large	Moderate	Moderate	+
Šumadija	Large	Large	Very Large	Large	High	+
Pomoravlje	Large	Large	Large	Large	High	0
Raška	Moderate	Large	Large	Moderate	Moderate	+
Rasina	Large	Large	Very Large	Moderate	Moderate	+
Mačva	Large	Large	Large	Large	High	0
Kolubara	Large	Large	Large	Large	High	0
Moravica	Large	Large	Large	Moderate	High	0
Zlatibor	Large	Large	Large	Large	High	0
National level	**Moderate**	**Large, mod-erate**	**Large**	**Large**	**High**	

Risk of low winter temperatures

Low winter temperatures, which in some years, especially in the vineyards of Vojvodina, can cause freezing of certain parts of the vine could not be part of the projections of the model used, because it detected *Tn < -15°C* only in mountainous areas not part of wine-growing regions (Figure 41). The most resistant are the cultivars belonging to the Western European ecological-geographical group (*convarietas occidentalis, subconvarietas galica*), and the most sensitive are table varieties originating from the east (*oriental convarietas, antasiatica subconvarietas*). But the cultivars that belong to the same ecological-geographical group are not all of the same resilience, because it also depends on the microclimatic conditions, protection, nutrition of vines, etc[22]. Stone varieties are less resistant than wine varieties. Based on the endurance limit, cultivars can be divided into three groups: 1) cultivars that freeze from -15 to -18^{o}C (stone varieties: Cardinal, Afus ali, Crveni drenak, etc.); 2) cultivars that freeze from -20 to -24^{o}C (wine and table varieties: Frankovka, Muscat Hamburg, Merlot, etc.); 3) cultivars that freeze at temperatures below -24^{o}C (Burgundy black, Italian Riesling, Traminac, etc).

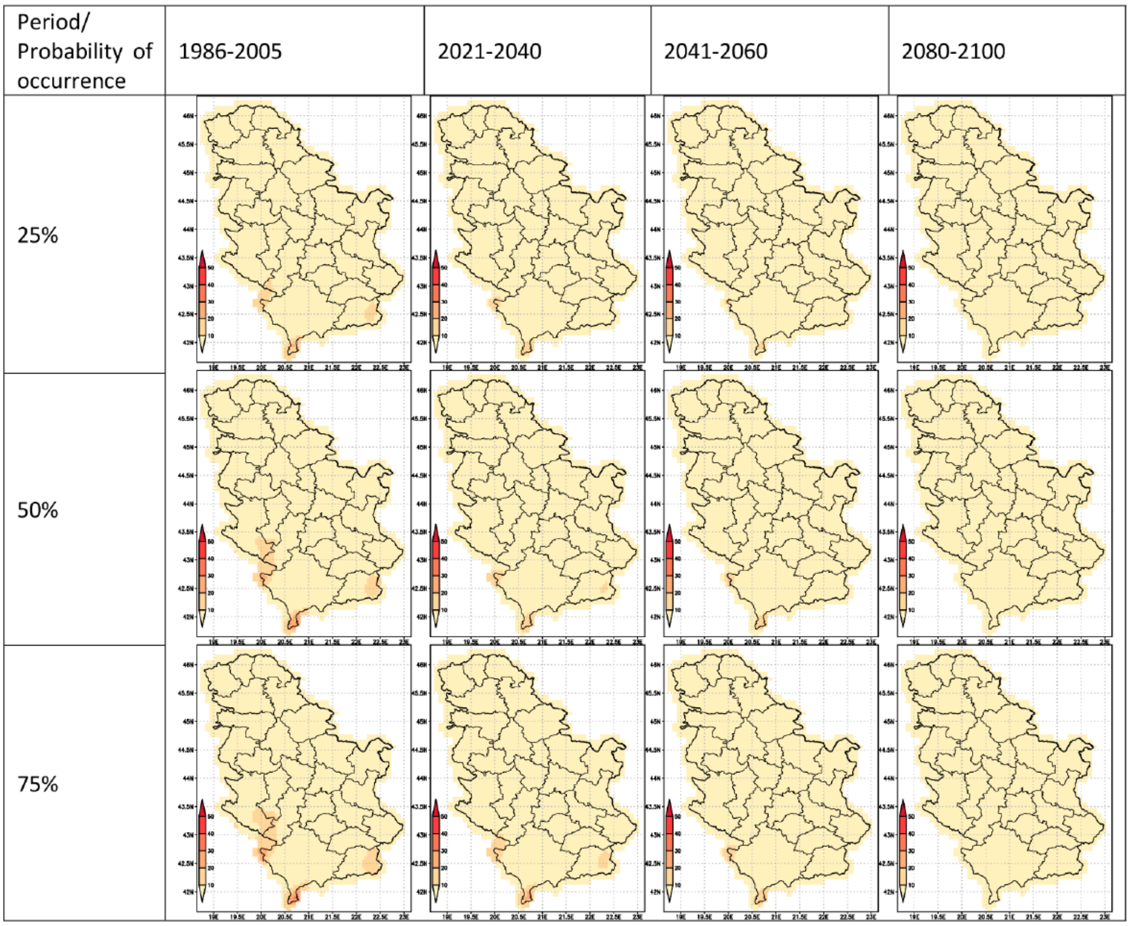


Figure 41. Probability of occurrence of the low winter temperatures (Tn < -15^{o}C)

Vineyards located at lower altitudes (below 200 m) have a high risk of low winter temperatures. Parts of Vojvodina (Sremski Karlovci, Temerin, Banoštor, Čoka, Vršac, Bela Crkva, etc.) are especially exposed to great risk[23]. In our agro-ecological conditions, the grapevine is especially sensitive to low temperatures in February, if a period of cold weather occurs after warmer and sunnier weather.

22 Cindrić, P., Korać, N., Ivanišević, D. (2019).Ampelography and selection of grapevines. University of Novi Sad, Faculty of Agriculture, Novi Sad.yt

23 Korać, N. (2012). Štete na vinovoj lozi u Vojvodini nastale smrzavanjem i mogućnost regenreracije čokota. |Advising for fruit and wine growers. Faculty of Agriculture, Novi Sad. Lecture, March 2012

Risk of hail and natural disasters

A very great threat for the grapevine is damage from hail, which occurs due to the appearance of strong storm clouds, whose frequency and intensity increase. In the viticulture in the Republic of Serbia, there is no practice of using anti-hail nets, which is why the grapevine is extremely vulnerable to these incidences and hail is the greatest threat in viticulture. Damages from hail are manifested on the grapevine in one production year, but they can also significantly reduce the yield in the following year.

Based on the results of 14 regional climate models over Europe, under IPCC scenarios RCP4.5 and RCP8.5, the mean incidence of hail larger than 2 cm in diameter for Serbia was between 0.07 and 0.14 days per year during the reference period (1970- 2000). For the end of the 21st century (2071-2100), an increase in the frequency of hail is predicted in Serbia, from 40 to 80% in Vojvodina and from 20 to 40% in the rest of Serbia for hail larger than 2 cm in diameter[24].

For the same reference period (1971-2000), the percentage of storms with the hail diameter ≥5 cm (RCP8.5 scenario) classifies Serbia as an almost safe part of Europe from the threat of hail with a very low risk in the far north and west of the country. The scenario up to 2100 predicts an increase in storms in all regions and in all climatic conditions for both Europe and the territory of Serbia. Entire Vojvodina, the western parts of central Serbia, as well as the vineyards in the east of the country, will be significantly affected by thunderstorms and hail[25].

The average frequency of wind gusts stronger than 25 m/s, which can cause damage to the grapevine, in most of the territory of Serbia during the reference period was from 0.8 to 1.2 days. By the end of the 21st century, according to the RCP8.5 scenario, the selected climate models predict an increase in the frequency of these events from 20 to 40% throughout Serbia. Statistically significant changes are predicted only in the Košava area of Vojvodina and Eastern Serbia (Table 15).

24 Radler, A., Groenemeijer, P., Faust, E., Sausen, R., Púčik, T. (2019). Frequency of severe thunderstorms across Europe expected to increase in the 21st century due to rising instability. Climate and Atmospheric Science, 30.

25 Radler, A., Groenemeijer, P., Faust, E., Sausen, R., Púčik, T. (2019). Frequency of severe thunderstorms across Europe expected to increase in the 21st century due to rising instability. Climate and Atmospheric Science, 30.

Table 15 Hail and disaster risk assessment by regions

Crop: grapevine Risk: hail larger than 2 cm in diameter and natural disasters					
	Exposure			Risk	
Admin. district	present 1971-2000[1]	the end of the century 2071-2100[2]	Vulnerability	Present	Tendency
North Banat	Small	Large	Moderate	Low	+
Central Banat	Small	Large	Moderate	Low	+
South Banat	Moderate	Very large	Large	Moderate	+
North Bačka	Small	Large	Moderate	Low	+
West Bačka	Small	Large	Moderate	Low	+
South Bačka	Moderate	Large	Moderate	Moderate	+
Srem	Moderate	Large	Moderate	Moderate	+
City of Belgrade	Moderate	Large	Large	Moderate	+
Danube River Basin	Moderate	Large	Large	Moderate	+
Braničevo	Moderate	Large	Large	Moderate	
Bor	Moderate	Large	Moderate	Moderate	+
Zaječar	Moderate	Large	Moderate	Moderate	+
Nišava	Moderate	Large	Large	Moderate	+
Pirot	Moderate	Large	Moderate	Moderate	+
Toplica	Moderate	Large	Moderate	Moderate	+
Jablanica	Moderate	Very large	Large	High	+
Pčinja	Large	Very large	Large	High	+
Šumadija	Moderate	Large	Moderate	Moderate	+
Pomoravlje	Moderate	Very large	Large	High	+
Raška	Large	Very large	Large	High	+
Rasina	Moderate	Large	Moderate	Moderate	+
Mačva	Moderate	Large	Moderate	Moderate	+
Kolubara	Large	Very large	Moderate	Moderate	+
Moravica	Large	Very large	Large	High	+
Zlatibor	Large	Very large	Large	High	0
National level	**Moderate**	**Large**	**Moderate**	**Moderate**	+

1 reference period;

2 RCP8.5 scenario[26]

26 Radler, A., Groenemeijer, P., Faust, E., Sausen, R., Púčik, T. (2019). Frequency of severe thunderstorms across Europe expected to increase in the 21st century due to rising instability. Climate and Atmospheric Science, 30.

5. Risk and vulnerability assessment in the future climate – crop growing

Impacts and affectedness observed/identified

Crop growing predominates in the agricultural production of Serbia, with about 60% of the total arable land. Yields of the most important field crops in recent decades are characterized by large fluctuations due to several factors: demand in domestic and world markets, domestic agricultural policy, level of applied agricultural techniques, but some of the changes also come from climatic conditions. The main consequences of climate change are shorter duration of the growing season, fewer days needed from sowing to f blooming and number of days from sowing to ripening, caused mainly by increasing air temperature during the year and increasing sum of temperatures, as well as a sharp increase in summer and tropical days. In the conditions of climate change, numerous changes are observed and expected in terms of the incidence of diseases and pests.

One of the first reviews of previous climate change in Serbia, as well as climate projections for the 21st century, are provided in *the First National Communication of the Republic of Serbia*[27]. The largest increase in temperature was recorded in the autumn period, which is somewhat more positive from the point of view of crop production, than in the case of an increase in temperatures in the summer period. Namely, in the autumn period, increased air temperatures can affect the accelerated mripening of spring crops, and if increased air temperatures are accompanied by a lack of precipitation, it negatively reflects on the beginning and quality of basic tillage, thus delaying and reducing the quality of sowing and sprouting of winter crops. By monitoring the amount of precipitation in the 1946-2016 period a positive trend was established in most of Serbia, except in the eastern and southeastern part of Serbia where there is an evident decrease in precipitation, while in western Serbia there was an increase in precipitation up to 15 mm per year, with an uneven distribution by region and year. The distribution has a greater impact on the reduction of yields in a crop growing than the insufficient amount of precipitation. The lack of precipitation is mostly reflected in the critical period of vegetation for certain crops[28].

27 MoEP (2017). Second Report of the Republic of Serbia under the United Nations Framework Convention on Climate Change. Ministry of Environmental Protection.

28 Dolijanović, Ž., Kovačević, D., Oljača, S., Simić, M. (2020). Adaptation of agrotechnical measures in crop growing 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.

Expected impacts and affectedness

It is very likely that Serbia will face an increased number of natural disasters in the near future, primarily floods, droughts and fires. Such natural disasters would affect crop production and the population, especially in remote, underdeveloped rural areas. The population of these areas mainly relies on agriculture, and their capacity to implement adaptation measures is at an extremely low level due to the depopulation and insufficient economic development of certain areas.

Based on several previous models, for the territory of Vojvodina it is projected that the increase in temperature and summer drought will generally significantly threaten the yields of spring crops in relation to winter crops. In winter crops, the positive effects (extension of the vegetation season) are expected to outweigh the indirect negative effects[29].

Wind erosion, to which a significant part of Vojvodina is exposed[30], will be significantly intensified due to prolonged periods of drought and high air temperatures. In the future, as an indirect consequence of climate change, various, new causes of plant diseases, weeds and pests may appear, which can significantly threaten crops.

Maize

In recent years, the area under this crop has been constantly declining, and by the end of this century it is estimated that yields will be lower than 22-52% compared to the current ones[31].

The risk of reduced yields is small if the optimal date of sowing corn is observed (from April 5 to May 1), except in the largest part of South Banat, part of Belgrade and smaller parts of Srem and the Central Banat region. In these areas, the optimal sowing would be in early April. In the future (2021-2040), the risk will increase to the entire territory of Vojvodina, entire Danube region, part of the Mačva, Pomoravlje and Bor Districts. For the second period (2041-2060), the situation in other regions is similar, and there is a high risk in the entire South Banat region, as well as parts of the Belgrade, Srem and Central Banat regions. In the last analysed period (2081-2100), the current optimal sowing period can be presented as high risk in all districts, except for larger parts of Pčinja, Pirot and Zlatibor, and smaller parts of the Braničevo, Zaječar and Raška regions (Table 16). The issue of changing the optimal sowing dates for maize in regions with large production is already a burning issue.

29 Lalic, B., Mihailovic, TD, Podrascanin, Z. (2011). The future state of the climate in Vojvodina and the expected impact on crop production. Ratar Povrt 48: 403-418.

30 Savić, R., Letić, Lj., Božinović, M. (2002). Aeolian erosion on arable land. Annals of scientific papers of the Faculty of Agriculture vol. 26, no. 1: 60-66. Novi Sad.

31 Ђурђеевић, B. (2015). Adapting to new climatic conditions – drought or two harvests. Media workshop "Focus on climate change: understanding the challenges – awareness of solutions", November 25, 2015, Belgrade.

Table 16. Risks and vulnerabilities in maize production

Admin. district	Crop: Maize Risk: Optimal sowing period of corn					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Moderate	Large	Moderate	Moderate	Low	+
Central Banat	Large	Large	Large	Large	High	0
North Bačka	Moderate	Large	Moderate	Moderate	Low	+
South Banat	Large	Large	Large	Large	High	0
West Bačka	Moderate	Large	Moderate	Moderate	Low	+
South Bačka	Moderate	Large	Moderate	Moderate	Low	+
Srem	Large	Large	Moderate	Moderate	Moderate	+
City of Belgrade	Large	Large	Large	Large	High	0
Danube River Basin	Moderate	Large	Large	Large	Moderate	+
Braničevo	Moderate	Large	Large	Large	Moderate	
Bor	Moderate	Moderate	Small	Moderate	Low	+
Zaječar	Moderate	Moderate	Small	Moderate	Low	+
Nišava	Moderate	Moderate	Moderate	Moderate	Low	+
Pirot	Small	Small	Small	Very Small	Low	+
Toplica	Moderate	Small	Small	Small	Low	+
Jablanica	Small	Small	Small	Very Small	Low	+
Pčinja	Small	Small	Small	Very Small	Low	+
Šumadija	Small	Small	Small	Very Small	Low	+
Pomoravlje	Moderate	Large	Moderate	Moderate	Low	+
Raška	Small	Small	Small	Very Small	Low	+
Rasina	Moderate	Large	Moderate	Moderate	Low	+
Mačva	Moderate	Large	Moderate	Moderate	Low	+
Kolubara	Moderate	Large	Moderate	Moderate	Low	+
Moravica	Small	Small	Small	Very Small	Low	+
Zlatibor	Small	Small	Small	Very Small	Low	+
National level	**Moderate**	**High**	**Moderate**	**Moderate**	**Low**	+

The threat of low temperatures in the early stages of maize (late spring frosts) is practically non-existent, except in the distant future (2081-2100) in a small part of the Raška, South Banat, Braničevo and Srem regions. (Table 17).

Table 17. Risks and vulnerabilities in maize production

Administrative district	Crop: Maize Risk: low temperatures in the early stages of maize					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Small	Small	Small	Small	Low	0
Central Banat	Small	Small	Small	Small	Low	0
North Bačka	Small	Small	Small	Small	Low	0
South Banat	Small	Small	Small	Small	Low	0
West Bačka	Small	Small	Small	Small	Low	0
South Bačka	Small	Small	Small	Small	Low	0
Srem	Small	Small	Small	Small	Low	0
City of Belgrade	Small	Small	Small	Small	Low	0
Danube River Basin	Small	Small	Small	Small	Low	0
Braničevo	Small	Small	Small	Small	Low	
Bor	Small	Small	Small	Small	Low	0
Zaječar	Small	Small	Small	Small	Low	0
Nišava	Small	Small	Small	Small	Low	0
Pirot	Small	Small	Small	Small	Low	0
Toplica	Small	Small	Small	Small	Low	0
Jablanica	Small	Small	Small	Small	Low	0
Pčinja	Small	Small	Small	Small	Low	0
Šumadija	Small	Small	Small	Small	Low	0
Pomoravlje	Small	Small	Small	Small	Low	0
Raška	Small	Small	Small	Small	Low	0
Rasina	Small	Small	Small	Small	Low	0
Mačva	Small	Small	Small	Small	Low	0
Kolubara	Small	Small	Small	Small	Low	0
Moravica	Small	Small	Small	Small	Low	0
Zlatibor	Small	Small	Small	Small	Low	0
National level	**Small**	**Small**	**Small**	**Small**	**Low**	0

The most important parameter that determines the yield and stability of maize cultivation are high air temperatures followed by a lack of precipitation in the critical period for maize (from the V12 phase concluding with the R3 phase). Currently, the Pčinja, Pirot, Raška, Moravica, Kolubara, South Banat and Srem regions are favorable on this basis. In the near future, the most endangered will be Bor, Zaječar, Nišava, Jablanica and part of the Pčinja region. In the future (2041-2060), the risk will increase in Mačva and part of the Braničevo District, and a very high risk is predicted in Bor, Zaječar, Nišava, Jablanica and part of the Pčinja and Pirot Districts. In the distant future (2081-2100), similar to the previous period, with less risk in the Braničevo, Pomoravlje and Nišava districts (Table 18).

Table 18. Risks and vulnerabilities in maize production

Administrative district	Crop: Maize Risk: high air temperatures and lack of precipitation in the critical period					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Small	Small	Small	Small	Low	0
Central Banat	Small	Small	Small	Small	Low	0
North Bačka	Small	Small	Small	Small	Low	0
South Banat	Small	Small	Small	Small	Low	0
West Bačka	Small	Small	Small	Small	Low	0
South Bačka	Small	Small	Small	Small	Low	0
Srem	Small	Small	Small	Small	Low	0
City of Belgrade	Small	Small	Small	Small	Low	0
Danube River Basin	Small	Small	Small	Small	Low	0
Braničevo	Small	Small	Small	Small	Low	
Bor	Small	Small	Small	Small	Low	0
Zaječar	Small	Small	Small	Small	Low	0
Nišava	Small	Small	Small	Small	Low	0
Pirot	Small	Small	Small	Small	Low	0
Toplica	Small	Small	Small	Small	Low	0
Jablanica	Small	Small	Small	Small	Low	0
Pčinja	Small	Small	Small	Small	Low	0
Šumadija	Small	Small	Small	Small	Low	0
Pomoravlje	Small	Small	Small	Small	Low	0
Raška	Small	Small	Small	Small	Low	0
Rasina	Small	Small	Small	Small	Low	0
Mačva	Small	Small	Small	Small	Low	0
Kolubara	Small	Small	Small	Small	Low	0
Moravica	Small	Small	Small	Small	Low	0
Zlatibor	Small	Small	Small	Small	Low	0
National level	**Small**	**Small**	**Small**	**Small**	**Low**	0

The biological sum of temperatures during the vegetation period of maize leads to the conclusion that in the future there will be many more problems when it comes to temperatures in relation to precipitation. The trend of biological sums of temperatures in the main regions of maize production indicates a Large, and towards the very end of the century a very Large risk (Table 19).

Table 19. Risks and vulnerabilities in maize production

Administrative district	Crop: Maize Risk: The biological sum of temperatures during the vegetation period					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Large	Very Large	Very Large	Large	High	0
Central Banat	Very Large	Very Large	Very Large	Large	High	0
North Bačka	Large	Very Large	Very Large	Large	High	0
South Banat	Very Large	Very Large	Very Large	Large	High	0
West Bačka	Large	Very Large	Very Large	Large	High	0
South Bačka	Very Large	Very Large	Very Large	Large	High	0
Srem	Very Large	Very Large	Very Large	Large	High	0
City of Belgrade	Very Large	Very Large	Very Large	Large	High	0
Danube River Basin	Very Large	Very Large	Very Large	Large	High	0
Braničevo	Large	Very Large	Very Large	Large	High	
Bor	Large	Very Large	Very Large	Large	High	0
Zaječar	Moderate	Large	Large	Large	Moderate	+
Nišava	Large	Very Large	Very Large	Large	High	0
Pirot	Low	Moderate	Large	Moderate	Low	+
Toplica	Moderate	Large	Large	Moderate	Moderate	+
Jablanica	Moderate	Large	Large	Moderate	Moderate	+
Pčinja	Low	Moderate	Moderate	Moderate	Low	+
Šumadija	Moderate	Large	Large	Large	Moderate	+
Pomoravlje	Large	Very Large	Large	Large	High	0
Raška	Low	Moderate	Moderate	Moderate	Low	0
Rasina	Large	Large	Large	Large	High	0
Mačva	Large	Large	Large	Large	High	0
Kolubara	Moderate	Large	Large	Large	Moderate	+
Moravica	Moderate	Moderate	Moderate	Moderate	Moderate	+
Zlatibor	Low	Moderate	Moderate	Moderate	Low	+
National level	**Large**	**Large**	**Large**	**Large**	**High**	

Winter crops

The average optimal sowing date of winter crops in the future will be preserved, due to lower risks to the success of cultivation than at present. Slightly higher risk exists at higher altitudes, but with an increase in mean annual air temperature in the future, this risk will be significantly lower (Table 20). Numerous studies to date have shown that the reduction in winter wheat yields caused by climate change (primarily increased air temperatures) will reach a maximum of 10% by the end of the century[32].

32 Ђурђеевић, В. (2015). Adapting to new climatic conditions – drought or two harvests. Media workshop "Focus on climate change: understanding the challenges – awareness of solutions", November 25, 2015, Belgrade.

Table 20. Risks and vulnerabilities in winter wheat production

Administrative district	Crop: Winter wheat Risk: Optimal sowing date of winter crops					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Small	Small	Small	Small	Low	0
Central Banat	Small	Small	Small	Small	Low	0
North Bačka	Small	Small	Small	Small	Low	0
South Banat	Small	Small	Small	Small	Low	0
West Bačka	Small	Small	Small	Small	Low	0
South Bačka	Small	Small	Small	Small	Low	0
Srem	Small	Small	Small	Small	Low	0
City of Belgrade	Small	Small	Small	Small	Low	0
Danube River Basin	Small	Small	Small	Small	Low	0
Braničevo	Moderate	Moderate	Small	Moderate	Moderate	
Bor	Small	Small	Small	Small	Low	0
Zaječar	Moderate	Moderate	Small	Moderate	Moderate	
Nišava	Small	Small	Small	Small	Low	0
Pirot	Moderate	Moderate	Small	Moderate	Moderate	
Toplica	Small	Small	Small	Small	Low	0
Jablanica	Moderate	Moderate	Small	Moderate	Moderate	-
Pčinja	Moderate	Moderate	Small	Moderate	Low	0
Šumadija	Small	Small	Small	Small	Low	0
Pomoravlje	Small	Small	Small	Small	Low	0
Raška	Large	Large	Moderate	Moderate	Moderate	
Rasina	Small	Small	Small	Small	Low	0
Mačva	Small	Small	Small	Small	Low	0
Kolubara	Small	Small	Small	Small	Low	0
Moravica	Large	Large	Moderate	Moderate	Moderate	-
Zlatibor	Large	Large	Moderate	Moderate	Moderate	-
National level	**Small**	**Small**	**Small**	**Small**	**Low**	0

The risk of the lack of precipitation from germination to the end of blooming is very low, and in the future a small risk is forecast for the 2021-2040 and 2061-2080 periods, only in most of South Banat and smaller parts of the Braničevo and Danube region (Table 21).

Table 21. Risks and vulnerabilities in winter wheat production

Administrative district	Crop: Winter wheat Risk: the lack of precipitation from germination to the end of blooming					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Small	Small	Small	Small	Low	0
Central Banat	Small	Small	Small	Small	Low	0
North Bačka	Small	Small	Small	Small	Low	0
South Banat	Small	Moderate	Moderate	Moderate	Moderate	-
West Bačka	Small	Small	Small	Small	Low	0
South Bačka	Small	Small	Small	Small	Low	0
Srem	Small	Small	Small	Small	Low	0
City of Belgrade	Small	Small	Small	Small	Low	0
Danube River Basin	Moderate	Moderate	Moderate	Moderate	Low	0
Braničevo	Small	Moderate	Moderate	Moderate	Moderate	
Bor	Moderate	Small	Small	Small	Low	0
Zaječar	Small	Moderate	Moderate	Moderate	Moderate	-
Nišava	Moderate	Small	Small	Small	Low	0
Pirot	Small	Small	Small	Small	Low	+
Toplica	Moderate	Small	Small	Small	Low	0
Jablanica	Moderate	Small	Small	Small	Low	+
Pčinja	Small	Small	Small	Small	Low	0
Šumadija	Small	Small	Small	Small	Low	0
Pomoravlje	Small	Small	Small	Small	Low	0
Raška	Small	Large	Large	Large	Low	+
Rasina	Small	Small	Small	Small	Low	0
Mačva	Small	Small	Small	Small	Low	0
Kolubara	Small	Small	Small	Small	Low	0
Moravica	Small	Small	Small	Small	Low	0
Zlatibor	Small	Small	Small	Small	Low	0
National level	**Small**	**Small**	**Small**	**Small**	**Low**	0

The risk of frostbite in winter may be the reason for a significant reduction in grain yield of winter crops, but that there is very little risk in the first half of this century, at higher altitudes where winter rye or winter oats are grown (Table 22).

Table 22. Risks and vulnerabilities in winter wheat production

Administrative district	Crop: Winter wheat Risk: Occurrence of frostbite					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Small	Small	Small	Small	Low	0
Central Banat	Small	Small	Small	Small	Low	0
North Bačka	Small	Small	Small	Small	Low	0
South Banat	Small	Small	Small	Small	Low	0
West Bačka	Small	Small	Small	Small	Low	0
South Bačka	Small	Small	Small	Small	Low	0
Srem	Small	Small	Small	Small	Low	0
City of Belgrade	Small	Small	Small	Small	Low	0
Danube River Basin	Small	Small	Small	Small	Low	0
Braničevo	Small	Small	Small	Small	Low	
Bor	Small	Small	Small	Small	Low	0
Zaječar	Small	Small	Small	Small	Low	0
Nišava	Small	Small	Small	Small	Low	0
Pirot	Small	Small	Small	Small	Low	0
Toplica	Small	Small	Small	Small	Low	0
Jablanica	Small	Small	Small	Small	Low	0
Pčinja	Moderate	Moderate	Small	Small	Low	0
Šumadija	Small	Small	Small	Small	Low	0
Pomoravlje	Small	Small	Small	Small	Low	0
Raška	Moderate	Moderate	Small	Small	Low	0
Rasina	Small	Small	Small	Small	Low	0
Mačva	Small	Small	Small	Small	Low	0
Kolubara	Small	Small	Small	Small	Low	0
Moravica	Small	Small	Small	Small	Low	0
Zlatibor	Small	Small	Small	Small	Low	0
National level	**Small**	**Small**	**Small**	**Small**	**Low**	0

The risk of the lack of precipitation in the critical period for winter crops (from earing to watering) is an indicator on which the yield depends most. In the future, the expected risks in the most important production area (Vojvodina) are lower than at present. Large risks are mainly present in the eastern and central parts of the Republic of Serbia, both in the present and in the future (Table 23).

Table 23. Risks and vulnerabilities in winter wheat production

Administrative district	Exposure: Present 2000-2019	Exposure: Near future 2021-2040	Exposure: Mid-century 2041-2060	Vulnerability	Risk: Present time	Risk: Tendency
Crop: Winter wheat Risk: Lack of precipitation in the critical period						
North Banat	Large	Large	Large	Moderate	Moderate	0
Central Banat	Large	Large	Large	Moderate	Moderate	0
North Bačka	Large	Large	Large	Moderate	Moderate	0
South Banat	Moderate	Moderate	Moderate	Moderate	Low	+
West Bačka	Large	Large	Large	Moderate	Moderate	0
South Bačka	Large	Large	Large	Moderate	Moderate	0
Srem	Moderate	Moderate	Moderate	Moderate	Low	+
City of Belgrade	Moderate	Moderate	Moderate	Moderate	Low	+
Danube River Basin	Moderate	Moderate	Moderate	Moderate	Low	+
Braničevo	Moderate	Moderate	Moderate	Moderate	Low	
Bor	Large	Large	Large	Moderate	Moderate	0
Zaječar	Small	Small	Small	Small	Low	+
Nišava	Moderate	Moderate	Moderate	Moderate	Low	+
Pirot	Small	Small	Small	Small	Low	+
Toplica	Small	Small	Small	Small	Low	+
Jablanica	Moderate	Moderate	Moderate	Moderate	Low	+
Pčinja	Small	Small	Small	Small	Low	+
Šumadija	Small	Small	Small	Small	Low	+
Pomoravlje	Small	Small	Small	Small	Low	+
Raška	Small	Small	Small	Small	Low	+
Rasina	Moderate	Moderate	Moderate	Moderate	Low	+
Mačva	Moderate	Moderate	Moderate	Moderate	Low	+
Kolubara	Moderate	Moderate	Moderate	Moderate	Low	+
Moravica	Small	Small	Small	Small	Low	+
Zlatibor	Small	Small	Small	Small	Low	+
National level	**Moderate**	**Moderate**	**Moderate**	**Moderate**	**Moderate**	+

Based on the forecast of the state of risks in the cultivation of winter crops depending on Large temperatures during the critical phases of generative development, there is currently a slight risk in the West Bačka and a small part of the Srem region (Table 24). The risk will increase in the future, especially in the distant future when it will reach a Large level, especially in the parts of Vojvodina, Mačva and Srem.

Table 24. Risks and vulnerabilities in winter wheat production

Administrative district	Crop: Winter wheat Risk: Large temperatures during the critical phases of generative development					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Small	Moderate	Moderate	Moderate	Low	+
Central Banat	Small	Moderate	Moderate	Moderate	Low	+
North Bačka	Small	Moderate	Moderate	Moderate	Low	+
South Banat	Small	Small	Moderate	Moderate	Low	+
West Bačka	Moderate	Large	Moderate	Moderate	Low	+
South Bačka	Small	Moderate	Moderate	Moderate	Low	+
Srem	Moderate	Moderate	Large	Moderate	Low	+
City of Belgrade	Small	Moderate	Moderate	Moderate	Low	+
Danube River Basin	Small	Moderate	Moderate	Moderate	Low	+
Braničevo	Small	Moderate	Large	Moderate	Low	
Bor	Small	Small	Moderate	Small	Low	+
Zaječar	Small	Small	Moderate	Small	Low	+
Nišava	Moderate	Small	Small	Small	Low	+
Pirot	Small	Small	Small	Small	Low	+
Toplica	Small	Small	Small	Small	Low	+
Jablanica	Moderate	Small	Large	Moderate	Low	+
Pčinja	Small	Small	Small	Small	Low	+
Šumadija	Small	Small	Small	Small	Low	+
Pomoravlje	Moderate	Small	Small	Small	Low	+
Raška	Small	Small	Small	Small	Low	+
Rasina	Small	Small	Small	Small	Low	+
Mačva	Small	Moderate	Large	Moderate	Low	+
Kolubara	Small	Large	Small	Small	Low	+
Moravica	Small	Small	Small	Small	Low	+
Zlatibor	Small	Small	Small	Small	Low	+
National level	**Small**	**Small**	**Moderate**	**Moderate**	**Low**	+

Soybeans

Soybean is an extremely important field crop, very sensitive to Large temperatures and the lack of precipitation, especially during the summer. Soybean is a crop of late spring sowing, which exposes it to Large air temperatures at the time of sowing, because there is a risk of moderate intensity in the South Banat, Central Banat, part of the North Banat, Belgrade, Srem and South Bačka region. In the following period, the risk will spread to the entire territory of Vojvodina, together with Belgrade, part of the Danube Rive Basin, Kolubara and Mačva regions. In the third period (2041-2060), a Large risk is expected in the South Banat, Central Banat, part of the North

Banat, Belgrade, Srem and South Bačka region, and a moderate risk can be expected in Bor, Zaječar, Pomoravlje, Rasina and part of the Nišava region. In the last 20 years of this century, a very Large risk can be expected in the territory of entire Vojvodina, Danube River Basin region and the Belgrade region. A Large or moderate risk is forecast for the rest of Serbia (Table 25). In Banat now, and in other parts of Vojvodina and Serbia as early as from the half of this, moving the sowing dates earlier would reduce the risk of Large temperatures in the critical phases of soybean crops (blooming and fertilization).

Table 25. Risks and vulnerabilities in soybean production

Crop: Soybean Risk: Optimal period of sowing						
Admnistrative district	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Large	Large	Large	Large	High	+
Central Banat	Moderate	Large	Very large	Large	Moderate	+
North Bačka	Moderate	Large	Large	Moderate	Moderate	+
South Banat	Large	Large	Very large	Large	High	+
West Bačka	Moderate	Large	Large	Moderate	Moderate	+
South Bačka	Large	Large	Large	Large	High	+
Srem	Moderate	Large	Large	Moderate	Moderate	+
City of Belgrade	Large	Large	Very large	Large	High	+
Danube River Basin	Moderate	Large	Moderate	Moderate	Moderate	+
Braničevo	Moderate	Large	Moderate	Moderate	Moderate	
Bor	Moderate	Moderate	Large	Moderate	Moderate	+
Zaječar	Moderate	Moderate	Large	Moderate	Moderate	+
Nišava	Small	Small	Moderate	Moderate	Small	+
Pirot	Small	Small	Small	Small	Small	+
Toplica	Small	Small	Small	Small	Small	+
Jablanica	Small	Small	Small	Small	Small	+
Pčinja	Small	Small	Small	Small	Small	+
Šumadija	Small	Small	Small	Small	Small	+
Pomoravlje	Moderate	Moderate	Moderate	Moderate	Moderate	+
Raška	Small	Small	Small	Small	Small	+
Rasina	Moderate	Moderate	Moderate	Moderate	Moderate	+
Mačva	Small	Small	Moderate	Moderate	Small	+
Kolubara	Moderate	Moderate	Moderate	Moderate	Moderate	+
Moravica	Moderate	Moderate	Small	Moderate	Moderate	+
Zlatibor	Small	Small	Small	Small	Small	+
National level	**Moderate**	**Moderate**	**Large**	**Moderate**	**Moderate**	+

The risk of low temperatures in the early stages of soybean crops (late spring frosts) is practically non-existent (Table 26). Since the incidence of late spring frosts is mainly related to the first two decades of April, the risk may increase in the future by switching to earlier sowing dates of this crop.

Table 26. Risks and vulnerabilities in soybean production

Crop: Soybean Risk: Low temperatures in the early stages						
Administrative district	**Exposure**			**Vulnerability**	**Risk**	
	Present 2000-2019	**Near future 2021-2040**	**Mid-century 2041-2060**		**Present time**	**Tendency**
North Banat	Small	Small	Small	Small	Low	+
Central Banat	Small	Small	Small	Small	Low	+
North Bačka	Small	Small	Small	Small	Low	+
South Banat	Small	Small	Small	Small	Low	+
West Bačka	Small	Small	Small	Small	Low	+
South Bačka	Small	Small	Small	Small	Low	+
Srem	Small	Small	Small	Small	Low	+
City of Belgrade	Small	Small	Small	Small	Low	+
Danube River Basin	Small	Small	Small	Small	Low	+
Braničevo	Small	Small	Small	Small	Low	
Bor	Small	Small	Small	Small	Low	0
Zaječar	Small	Small	Small	Small	Low	0
Nišava	Small	Small	Small	Small	Low	0
Pirot	Small	Small	Small	Small	Low	0
Toplica	Small	Small	Small	Small	Low	0
Jablanica	Small	Small	Small	Small	Low	0
Pčinja	Moderate	Small	Small	Small	Low	0
Šumadija	Small	Small	Small	Small	Low	0
Pomoravlje	Small	Small	Small	Small	Low	0
Raška	Small	Small	Small	Small	Low	0
Rasina	Small	Small	Small	Small	Low	0
Mačva	Small	Small	Small	Small	Low	0
Kolubara	Small	Small	Small	Small	Low	0
Moravica	Small	Small	Small	Small	Low	0
Zlatibor	Moderate	Small	Small	Small	Low	0
National level	**Small**	**Small**	**Small**	**Small**	**Low**	0

Large air temperatures followed by a lack of precipitation during the critical period (blooming and fertilization of soybean crops) have the greatest impact on the decline in yield and on the safety of soybean production. It is estimated that the yield will gradually decline by the end of the century and will amount to 20%[33]. Risks in the main production area (Vojvodina) are currently higher than in the near future, and very similar to the analyzed third period (Table 27). In the third and fourth analyzed period, a Large and very Large risk is expected in the territory of Vojvodina in parts of Braničevo, Pomoravlje, Pirot, Rasina, Pčinja and Šumadija, i.e. the entire Bor, Zaječar, Nišava and Jablanica regions.

Table 27. Risks and vulnerabilities in soybean production

Crop: Soybean Risk: Large air temperatures followed by a lack of precipitation during the critical period						
Admnistrative district	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Large	Moderate	Large	Large	High	0
Central Banat	Large	Moderate	Large	Large	High	0
North Bačka	Large	Moderate	Large	Large	High	0
South Banat	Large	Moderate	Moderate	Moderate	Moderate	0
West Bačka	Moderate	Moderate	Moderate	Moderate	Low	+
South Bačka	Large	Moderate	Large	Large	High	0
Srem	Large	Moderate	Large	Large	High	0
City of Belgrade	Moderate	Moderate	Moderate	Moderate	Low	+
Danube River Basin	Moderate	Moderate	Moderate	Moderate	Low	+
Braničevo	Moderate	Moderate	Very large	Large	Moderate	
Bor	Moderate	Large	Very large	Large	Moderate	+
Zaječar	Moderate	Moderate	Large	Moderate	Low	+
Nišava	Moderate	Moderate	Very large	Large	Moderate	+
Pirot	Small	Small	Moderate	Moderate	Low	+
Toplica	Small	Small	Moderate	Moderate	Low	+
Jablanica	Moderate	Moderate	Moderate	Moderate	Low	+
Pčinja	Small	Moderate	Very large	Moderate	Low	+
Šumadija	Moderate	Moderate	Moderate	Moderate	Low	+
Pomoravlje	Moderate	Moderate	Very large	Large	Moderate	+
Raška	Small	Small	Small	Small	Low	+
Rasina	Small	Moderate	Very large	Moderate	Low	+
Mačva	Large	Large	Large	Large	High	0
Kolubara	Moderate	Moderate	Moderate	Moderate	Low	+
Moravica	Small	Small	Large	Moderate	Low	+
Zlatibor	Small	Small	Small	Small	Low	+
National level	**Large**	**Moderate**	**Large**	**Moderate**	**Moderate**	+

This confirms the importance of earlier sowing dates in order to mitigate the risk of Large temperatures at the start of vegetation. It is important that the plant enters the critical phases of blooming and fertilization earlier, and in this manner avoid the negative effects of hot days and

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

the lack of precipitation during the summer. The tropical days of recent years are mostly more related to the end of July and August, and earlier the month of July was better known for this.

Sunflower

The optimal time for sowing sunflowers is at a soil temperature of 7-8°C and in the conditions of Vojvodina, it is mostly the last decade of March or the first decade of April. Exposure to low temperatures is currently, except for Vojvodina, increased in parts of Braničevo, Podunavlje, Kolubara, Mačva, Rasina Bor and Nišava regions (Table 28).

Table 28. Risks and vulnerabilities in sunflower production

Crop: Sunflower Risk: Optimal time for sowing						
Administrative district	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North banat	Moderate	Large	Large	Moderate	Low	+
Central banat	Moderate	Large	Large	Moderate	Low	+
North bačka	Moderate	Large	Large	Moderate	Low	+
South banat	Moderate	Large	Very large	Large	Moderate	0
West bačka	Moderate	Moderate	Large	Moderate	Low	+
South bačka	Moderate	Large	Large	Moderate	Low	+
Srem	Moderate	Moderate	Large	Moderate	Low	+
City of Belgrade	Moderate	Large	Very large	Large	Moderate	0
Danube river basin	Moderate	Large	Large	Moderate	Low	+
Braničevo	Moderate	Moderate	Moderate	Moderate	Low	
Bor	Moderate	Moderate	Large	Moderate	Low	+
Zaječar	Small	Moderate	Moderate	Moderate	Low	+
Nišava	Moderate	Moderate	Moderate	Moderate	Low	+
Pirot	Small	Small	Moderate	Moderate	Low	+
Toplica	Small	Moderate	Moderate	Moderate	Low	+
Jablanica	Small	Moderate	Moderate	Moderate	Low	+
Pčinja	Small	Small	Small	Moderate	Low	+
Šumadija	Small	Moderate	Moderate	Moderate	Low	+
Pomoravlje	Small	Moderate	Moderate	Moderate	Low	+
Raška	Small	Moderate	Moderate	Moderate	Low	+
Rasina	Moderate	Moderate	Large	Moderate	Low	+
Mačva	Moderate	Moderate	Large	Moderate	Low	+
Kolubara	Moderate	Moderate	Large	Moderate	Low	+
Moravica	Small	Small	Moderate	Moderate	Low	+
Zlatibor	Small	Small	Small	Moderate	Low	+
National level	**Small**	**Moderate**	**Moderate**	**Moderate**	**Low**	+

Other regions have low levels of exposure. In the second and third observed period, the level of exposure increased, especially in the South Banat and Belgrade regions. The distant future is accompanied by an increase in the level of exposure and risk, which can be viewed as moderate or Large throughout the Republic of Serbia.

The greatest needs in water for the sunflower are during the intensive growth and blooming (about 65%) of the total water intake. An insufficient amount of water in this period is common in the main production areas of sunflower, and the degree of exposure can be marked as moderate (South Banat, North Banat, North Bačka, South Bačka and West Bačka). A similar situation is expected in the near future (2021-2040), with a tendency to increase the level of exposure in the Bor, Nišava, Jablanica and Rasina regions (Table 29). For the third and fourth analysed period, an increase in the degree of exposure and risk can be expected in the North Bačka, North Banat, Bor, Nišava, Mačva, Srem and Pčinja regions.

Table 29. Risks and vulnerabilities in sunflower production

Crop: Sunflower Risk: Lack of precipitation during the intensive growth and blooming						
Administrative district	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North banat	Moderate	Moderate	Large	Large	Moderate	0
Central banat	Moderate	Moderate	Moderate	Moderate	Low	+
North bačka	Moderate	Moderate	Moderate	Moderate	Low	+
South banat	Moderate	Moderate	Moderate	Moderate	Low	+
West bačka	Moderate	Moderate	Large	Large	Moderate	+
South bačka	Moderate	Moderate	Moderate	Moderate	Low	+
Srem	Small	Moderate	Moderate	Moderate	Low	+
City of Belgrade	Small	Moderate	Moderate	Moderate	Low	+
Danube river basin	Small	Moderate	Moderate	Moderate	Low	+
Braničevo	Moderate	Moderate	Moderate	Moderate	Low	
Bor	Moderate	Moderate	Large	Large	Moderate	0
Zaječar	Small	Moderate	Moderate	Moderate	Low	+
Nišava	Moderate	Moderate	Moderate	Moderate	Low	+
Pirot	Small	Small	Moderate	Small	Low	+
Toplica	Small	Small	Small	Small	Low	+
Jablanica	Small	Moderate	Large	Moderate	Low	+
Pčinja	Small	Small	Moderate	Small	Low	+
Šumadija	Small	Moderate	Moderate	Moderate	Low	+
Pomoravlje	Moderate	Moderate	Moderate	Moderate	Low	+
Raška	Small	Small	Moderate	Small	Low	+
Rasina	Moderate	Moderate	Moderate	Moderate	Low	+
Mačva	Small	Moderate	Large	Moderate	Low	+
Kolubara	Small	Moderate	Moderate	Moderate	Low	+

Moravica	Small	Small	Moderate	Small	Low	+
Zlatibor	Small	Small	Small	Small	Low	+
National level	**Small**	**Moderate**	**Moderate**	**Moderate**	**Low**	+

The greatest risk of declining yields of sunflower seeds and oils is due to the occurrence of high temperatures in combination with the lack of precipitation in the period from blooming to ripening. The current exposure to this risk is highest in the South Banat, Belgrade, Central Banat and North Banat regions. In the future, a gradual increase in the level of exposure and risk is expected in all regions of the Republic of Serbia (Table 29)

Table 30. Risks and vulnerabilities in sunflower production

Crop: Sunflower Risk: Large temperatures in combination with the lack of precipitation in the period from blooming to ripening						
Admnistrative district	**Exposure**			**Vulnerability**	**Risk**	
	Present 2000-2019	**Near future 2021-2040**	**Mid-century 2041-2060**		**Present time**	**Tendency**
North Banat	Moderate	Large	Large	Large	Moderate	+
Central Banat	Moderate	Large	Large	Large	Moderate	+
North Bačka	Moderate	Large	Large	Large	Moderate	+
South Banat	Moderate	Large	Large	Large	Moderate	+
West Bačka	Moderate	Large	Very Large	Large	Moderate	0
South Bačka	Moderate	Large	Large	Large	Moderate	+
Srem	Moderate	Large	Large	Large	Moderate	+
City of Belgrade	Moderate	Large	Large	Large	Moderate	+
Danube River Basin	Moderate	Large	Very Large	Large	Moderate	0
Braničevo	Moderate	Moderate	Very Large	Large	Moderate	
Bor	Moderate	Large	Large	Large	Moderate	+
Zaječar	Small	Moderate	Moderate	Moderate	Low	+
Nišava	Small	Large	Very Large	Large	Low	0
Pirot	Small	Small	Small	Small	Low	+
Toplica	Small	Large	Moderate	Moderate	Low	+
Jablanica	Moderate	Large	Very Large	Large	Moderate	0
Pčinja	Small	Small	Small	Small	Low	+
Šumadija	Small	Moderate	Large	Small	Low	+
Pomoravlje	Moderate	Large	Very Large	Large	Moderate	0
Raška	Small	Large	Small	Moderate	Low	+
Rasina	Small	Large	Large	Small	Low	+
Mačva	Small	Moderate	Large	Moderate	Low	+
Kolubara	Small	Moderate	Moderate	Moderate	Low	+
Moravica	Small	Small	Moderate	Small	Low	+
Zlatibor	Small	Small	Small	Small	Low	+
National level	**Small**	**Large**	**Large**	**Large**	**Moderate**	+

Sugar beet

Sowing sugar beet in the current optimal period does not have a larger degree of exposure, and the analysis of future scenarios expects an increased exposure and increased risk, especially in the part of Serbia where the production of this crop is most represented (Table 31).

Table 31. Risks and vulnerabilities in sugar beet production

Crop: Sugar beet Risk: Optimal sowing period						
Admnistrative district	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Moderate	Moderate	Large	Large	Moderate	+
North Banat	Moderate	Large	Very Large	Large	Moderate	+
Central Banat	Moderate	Moderate	Large	Large	Moderate	+
North Bačka	Moderate	Large	Very Large	Large	Moderate	+
South Banat	Moderate	Moderate	Large	Large	Moderate	+
West Bačka	Moderate	Large	Large	Large	Moderate	+
South Bačka	Moderate	Moderate	Large	Large	Moderate	+
Srem	Moderate	Large	Large	Large	Moderate	+
City of Belgrade	Moderate	Moderate	Large	Moderate	Moderate	+
Danube River Basin	Moderate	Moderate	Large	Moderate	Moderate	
Braničevo	Small	Moderate	Large	Moderate	Low	+
Bor	Small	Moderate	Moderate	Moderate	Low	+
Zaječar	Small	Moderate	Moderate	Moderate	Low	+
Nišava	Small	Small	Moderate	Small	Low	+
Pirot	Small	Moderate	Moderate	Moderate	Low	+
Toplica	Small	Moderate	Moderate	Moderate	Low	+
Jablanica	Small	Small	Small	Small	Low	+
Pčinja	Small	Small	Moderate	Small	Low	+
Šumadija	Small	Moderate	Moderate	Moderate	Low	+
Pomoravlje	Small	Small	Moderate	Small	Low	+
Raška	Small	Moderate	Large	Moderate	Low	+
Rasina	Small	Moderate	Large	Moderate	Low	+
Mačva	Small	Moderate	Large	Moderate	Low	+
Kolubara	Small	Small	Moderate	Small	Low	+
Moravica	Small	Small	Small	Small	Low	+
National level	**Small**	**Moderate**	**Large**	**Moderate**	**Low**	+

The risk of low temperatures in the early stages of sugar beet (late spring frosts) is slightly higher than in previous spring crops, because the crop is sown earlier in spring. Currently, the exposure is low-moderate and the risk of low intensity throughout the country, while in the future an increase in the degree of exposure and risk intensity can be expected, especially in the regions of Eastern and Central Serbia (Table 32).

Table 32. Risks and vulnerabilities in sugar beet production

Administrative district	Crop: Sugar beet Risk: Low temperatures in the early stages					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Moderate	Large	Large	Large	Moderate	+
Central Banat	Large	Large	Large	Large	Large	0
North Bačka	Moderate	Large	Large	Large	Moderate	+
South Banat	Very Large	Very Large	Very Large	Large	Large	0
West Bačka	Moderate	Large	Large	Large	Moderate	+
South Bačka	Large	Large	Very Large	Large	Large	0
Srem	Moderate	Moderate	Large	Moderate	Low	+
City of Belgrade	Large	Moderate	Large	Large	Large	0
Danube River Basin	Large	Large	Large	Large	Large	0
Braničevo	Large	Very Large	Very Large	Large	Large	
Bor	Moderate	Moderate	Large	Moderate	Low	+
Zaječar	Moderate	Large	Very Large	Large	Moderate	+
Nišava	Moderate	Moderate	Moderate	Moderate	Low	+
Pirot	Moderate	Moderate	Moderate	Moderate	Low	+
Toplica	Moderate	Large	Large	Large	Moderate	+
Jablanica	Moderate	Large	Large	Large	Moderate	+
Pčinja	Moderate	Moderate	Moderate	Moderate	Low	+
Šumadija	Moderate	Moderate	Moderate	Moderate	Low	+
Pomoravlje	Large	Moderate	Large	Large	Large	+
Raška	Moderate	Large	Moderate	Moderate	Low	+
Rasina	Moderate	Moderate	Moderate	Moderate	Low	+
Mačva	Moderate	Moderate	Moderate	Moderate	Low	+
Kolubara	Moderate	Moderate	Moderate	Moderate	Low	+
Moravica	Moderate	Moderate	Moderate	Moderate	Low	+
North Banat	Moderate	Moderate	Moderate	Moderate	Low	+
National level	**Moderate**	**Moderate**	**Large**	**Moderate**	**Moderate**	+

The greatest water demand is during the intensive growth of the aboveground mass and the secondary thickening of roots (from the end of June to the middle of August) and this is the critical period for water with the sugar beet. The availability of water in this period and the yield of sugar beet roots are in direct connection, because in addition to the root yield, the average digestion is dependent on water. Currently, the exposure is Large in most regions of the Republic of Serbia, and in the future the exposure will increase, especially in the regions of Eastern and Central Serbia, while in Vojvodina the exposure will even be reduced compared to the current one (Table 33).

Table 33. Risks and vulnerabilities in sugar beet production

Admnistrative district	Crop: Sugar beet Risk: Lack of precipitation during the critical period					
	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present time	Tendency
North Banat	Very large	Large	Large	Large	Large	0
Central Banat	Very large	Large	Large	Large	Large	0
North Bačka	Very large	Large	Large	Large	Large	0
South Banat	Very large	Large	Large	Large	Large	0
West Bačka	Very large	Large	Large	Large	Large	0
South Bačka	Very large	Large	Large	Large	Large	0
Srem	Very large	Large	Large	Large	Large	0
City of Belgrade	Very large	Large	Large	Large	Large	0
Danube River Basin	Very large	Very large	Very large	Large	Large	0
Braničevo	Large	Large	Very large	Large	Large	
Bor	Very large	Very large	Very large	Large	Large	0
Zaječar	Large	Large	Very large	Large	Large	0
Nišava	Large	Very large	Very large	Large	Large	0
Pirot	Small	Moderate	Moderate	Moderate	Low	+
Toplica	Moderate	Moderate	Moderate	Moderate	Low	+
Jablanica	Large	Very large	Very large	Large	Large	+
Pčinja	Small	Large	Large	Moderate	Low	+
Šumadija	Moderate	Moderate	Large	Moderate	Low	+
Pomoravlje	Very large	Very large	Very large	Large	Large	0
Raška	Moderate	Moderate	Moderate	Moderate	Low	+
Rasina	Large	Large	Very large	Large	Large	0
Mačva	Large	Very large	Very large	Large	Large	0
Kolubara	Large	Large	Moderate	Moderate	Moderate	+
Moravica	Small	Moderate	Moderate	Moderate	Low	+
North Banat	Small	Small	Moderate	Small	Low	+
National level	**Large**	**Large**	**Large**	**Large**	**Large**	0

From the analyzed crop growing species, spring crops are expected to be more affected in the future than winter ones. Among spring crops, maize will be most affected, especially under the influence of Large air temperatures and the lack of precipitation during the summer months. The dependence of the yield of this species will also be Large on the optimal sowing time. The situation is similar with other spring crops, such as soybeans and sugar beets, where the greatest exposures and risks are expected under the influence of Large temperatures and the lack of precipitation during the summer, in critical periods of these crops for heat and moisture.

6. Risk and vulnerability assessment in the future climate – meadows and pastures

The benefits of grasslands are manifold:

- cheap fodder is obtained
- food production becomes cheaper for people,
- water and land resources are preserved,
- they are excellent pre-crops,
- they are good for bee grazing.

The basic characteristics of this production in Serbia today are[34]

- late mowing of meadows and improper exploitation of pastures;
- insufficient attention paid to weed species on the pasture;
- application of fertilizers without soil testing;
- a small share of sown meadows and pastures.

The problem of reducing the number of cattle in most mountainous areas is obvious, which negatively affects the vegetation of grass formations. This is one of the few areas of agriculture in which the reduction of use does not help the conservation of natural resources but, in most cases, further degrades them. The survival of grasslands depends on the survival of livestock farming because in Serbia, the vast majority of them were created by human activity and grazing by animals. Semi-natural meadow ecosystems are the result of very long semi-intensive (sustainable) use and cannot be quickly and completely restored if they are plowed or destroyed otherwise. Their sustainable use, proper grazing, mowing, combined and other measures of utilization are necessary. The most important factors that affect the productivity of meadow communities are water and the availability of nutrients in the soil, and each of these factors in its own manner affects the biodiversity of the community[35]. Various studies have shown that large amounts of nutrients, such as phosphorus, nitrogen and potassium, negatively affect the biodiversity of different meadow communities[36], as well as that an antagonistic relationship or synergism of elements (e.g. nitrogen and phosphorus) is sometimes a much more important factor than the concentration of individual elements (e.g. phosphorus itself). The availability of nutrients is also affected by soil pH, temperature and soil salinity. Mainly with the shift of acidity towards the neutral reaction of the soil, there is an increase in the biodiversity of meadow communities.

It is known that under the influence of environmental factors, the altitude zones of grass vegetation occur[37]. The appearance and survival of vegetation in a certain area, in addition to other ecological conditions, largely depends on the climatic characteristics of the area, especially on the characteristics of the climate of a certain altitude zone.

34 Simić A. (2019). Fodder plants. Faculty of Agriculture, University of Belgrade.

35 Ruprecht, E., Enyedi, MZ, Eckstein, RL, Donath, TW (2010). Restorative removal of plant litter and vegetation 40 years after abandonment enhances re-emergence of steppe grassland vegetation. Biological conservation 143, 449-456.

36 Merunková, K., Chytrý, M. (2012). Environmental control of species richness and composition in upland grasslands of the southern Czech Republic. Plant Ecology 213, 591–602.

37 Simić, A. (2018). The state of fertility of meadows and pastures in Western Serbia. Monographic study, Faculty of Agriculture, University of Belgrade.

The climate on the grasslands in Serbia is formed by the impact of influences from distant parts of the Atlantic Ocean, Adriatic and Aegean Seas, Eastern European lowlands and the Dinarides, as well as under the influence of local conditions. This area is characterized by a temperate continental climate[38], with modifications of transition to pre-mountainous.

The climate of the mountainous part of Western Serbia is a somewhat temperate climate of our central mountains. The general climatic characteristics of this region are: increased amount of atmospheric sediments; large amounts of snowfall; harsh and long winters; short and fresh summers; sudden temperature differences during the day and night and constant winds.

The amount of precipitation as well as their distribution should have a favorable effect on the development of vegetation on pastures. However, their favorable effect is significantly reduced by winds. Winds on the leading massifs of Western Serbia (Zlatibor and Murtenica) blow throughout the year. During the summer, north and northeast winds intensify the evapouration of soil moisture from the shallow soil under the pastures. In winter, winds from the south and southwest prevail. As the pastures are mostly on plateaus and slopes, the winds blow snow off them and deposit it in the lower areas. Therefore, the pasture flora in winter is often exposed to the adverse effects of frost. Comparing the most important climatic indicators from the reference meteorological stations, the parameters that affect the development of grass biomass are observed, as well as those with a negative effect. Less precipitation in the plains and lower hilly areas is certainly a limitation in the large demands of grassland for moisture during the growing season. Also, large temperature variations and higher average summer temperatures have an adverse effect on biomass regeneration and production. On the other hand, lower temperatures in the spring delay the start of grass vegetation and shorten the period of grassland exploitation, and higher amounts of precipitation are limited efficiencies due to the small capacity of the soil to retain moisture in the mountainous region of Serbia. In general, the climatic conditions of Serbia and their effect on grasslands cannot be observed separately from orographic, pedological and biogenic ones, and they must be observed in a complex manner for each location separately. Favorable precipitation regimes during autumn and winter mean that most of the examined grass-pasture complexes have sufficient amounts of precipitation, but the accumulation of moisture depends on the capacity of the soil of the location. From May, climatic conditions move upwards to tropical extremes, which peak in July, retaining extreme values in August and thus limiting the normal growth and regeneration of major grassland species and their overall yield.

Impact on soil under meadows and pastures

In the areas of intensive cattle breeding and increased grazing, which is prominent in some parts of Serbia, especially in the west, the number of conditional heads is higher than recommended for the given area. The negative impact on the soil is reflected in excessive compaction, disturbance of the water, air and biological regime of the soil, but on the other hand, there are also good sides, which increase the fertility of the soil. Thus, leaving the excrement of cattle is favorable for the development of grasses and a measure of the natural fertilization of lawns, while grazing emphasizes the development of the white clover, which enriches the soil with nitrogen through nitrogen fixation.

38 Republic Hydrometeorological Institute of the Republic of Serbia http://www.hidmet.gov.rs/

Shallow and moderate-deep, skeletoid and skeletal soils dominate at higher altitudes, which are significantly degraded and largely eroded, generally shallow, of acidic reactions and low fertility, very poor in phosphorus, moderately provided with potassium and poorly provided with accessible nitrogen. Given these properties of the soil, they are not suitable for intensive cultivation and cultivation of field plants, both because of their unfavorable properties (physical, chemical and biological) and the small depth, potency and permanent effect of erosion. This is why these soils can only and must be used for the production of fodder on natural grasslands because in addition to this function, it is important for them to successfully protect the soil from erosion and preserve the environment in general.

Expected impacts and affectedness

Based on the study of natural grasslands in Serbia, it has been determined that they are distinguished by diversity due to climatic, orographic, soil and plant characteristics. A rough division could be done according to altitude, into meadows and pastures of lower and higher altitudes.

Grasslands at lower altitudes are located in the northern part of Serbia, they have more favorable conditions for development due to different climatic, soil and socio-economic conditions. The soil has better agrochemical properties, suitable for agrotechnical measures (mowing, fertilization, control of undesirable species), and the population is preserved in rural communities and of a slightly better age structure than in the hilly and mountainous part. On the other hand, the grasslands located in the central part of Serbia, at higher altitudes, are in a very unfavorable position. Natural conditions are more unfavorable for intensive production, the relief is steeper, and the soil has poor agrochemical properties. In terms of climate, snow retains longer in this area, winds easily dry out the shallow ground cover, although slightly higher amounts of precipitation and lower average temperatures have a favorable effect on the development of meadows and pastures. Grasslands at higher altitudes are often unmown or rarely used for grazing.

The reduction of the production potential of natural meadows and pastures is also caused by the long-term effect of erosion, to which unfavorable climatic conditions of areas under grasslands can be added, as well as improper management and use. Increasing the production potential of these grasslands can be achieved by fertilizing with different amounts and types of organic and mineral fertilizers. Previous practice and research have shown the positive effects of organic fertilizers, combined with moderate amounts of mineral fertilizers, for the application in meadows and pastures.

IBy observing meadows and pastures by districts, the possibility of a dry period in Serbia with less than 150 mm of precipitation during the summer (Figure 42) indicates that in the near future the Districts of Bor and partly Zaječar, then Pomoravlje, are particularly exposed, with partially or completely the Braničevo, Pomoravlje, Nišava, Jablanica and Pčinja disctrics. In addition, the lowland part of Kosovo, i.e. the area of Metohija is exposed to the lack of summer precipitation needed for grasslands. Forecasts for the future indicate that the grasslands will be exposed to strong drought practically throughout Serbia, except for the areas of the westernmost districts, such as the southern parts of Mačva, the western part of Kolubara and the largest part of Zlatibor. In other districts, only areas of Large mountains, as oases, will have enough precipitation during the summer for undisturbed growth and development of grasses.

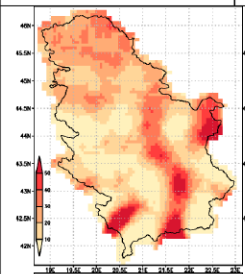
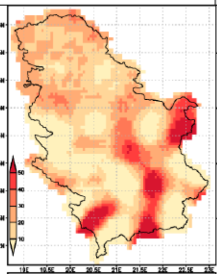
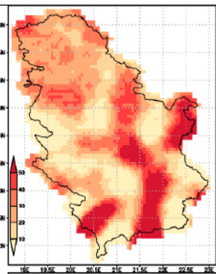
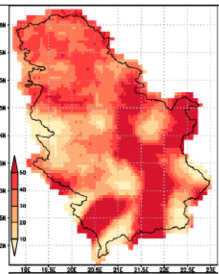
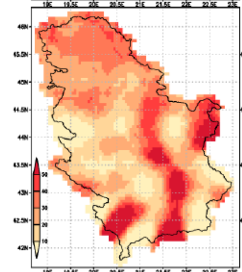
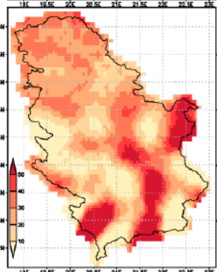
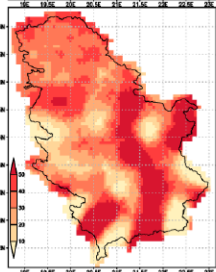
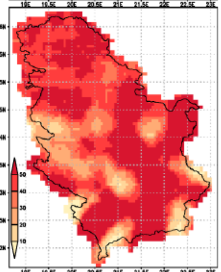
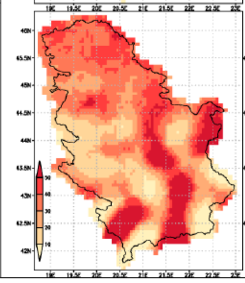
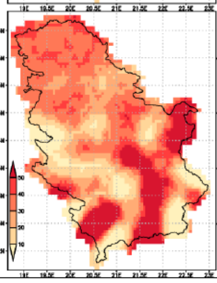
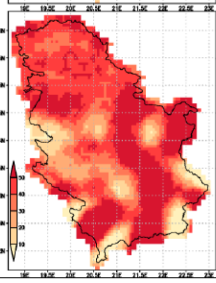
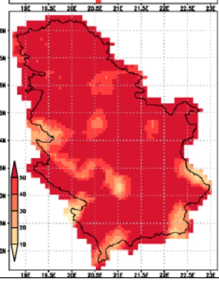
Period/ Probability of occurrence	1986-2005	2021-2040	2041-2060	2080-2100
25%				
50%				
75%				

Figure 42. Frequency of occurrence of small amounts of precipitation during the summer (criterion less than 150 mm of precipitation)

The chances of less than 150 liters of rain per square meter falling during the summer months (June-August) are moderate for the next 20 years, as in the recent past, but it is very likely that in the 2041-2060 period this shortage will manifest itself in most parts of Serbia (Table 34). The vulnerability of grasslands to extreme moisture deficits is moderate, as is the risk, but with a tendency to increase the risk.

Table 34. Risks and vulnerabilities in the exploitation of meadows and pastures with higher moisture deficit

Crop: Pastures and meadows Risk: less than 150 liters of rain per square meter falling during the summer months (June-August)						
Admin. district	Exposure			Vulnerability	Risk	
	Present 2000-2019	Near future 2021-2040	Mid-century 2041-2060		Present	Tendency
North Banat	Large	Large	Large	Large	Large	0
Central Banat	Large	Large	Large	Large	Large	0
North Bačka	Large	Large	Large	Large	Large	0
South Banat	Large	Large	Large	Large	Large	0
West Bačka	Large	Large	Large	Large	Large	0
South Bačka	Large	Large	Large	Large	Large	0
Srem	Large	Large	Large	Large	Large	0
City of Belgrade	Moderate	Moderate	Large	Moderate	Moderate	+
Danube River Basin	Moderate	Moderate	Large	Moderate	Moderate	+
Braničevo	Moderate	Moderate	Large	Moderate	Moderate	
Bor	Large	Large	Very large	Large	Large	+
Zaječar	Large	Large	Very large	Large	Large	+
Nišava	Large	Large	Very large	Large	Large	+
Pirot	Moderate	Moderate	Large	Moderate	Moderate	+
Toplica	Moderate	Moderate	Large	Moderate	Moderate	+
Jablanica	Large	Large	Very large	Large	Large	+
Pčinja	Large	Large	Large	Large	Large	0
Šumadija	Moderate	Moderate	Large	Moderate	Moderate	+
Pomoravlje	Large	Large	Very large	Large	Large	+
Raška	Small	Small	Moderate	Small	Low	+
Rasina	Moderate	Moderate	Large	Moderate	Moderate	+
Mačva	Moderate	Moderate	Large	Moderate	Moderate	+
Kolubara	Small	Small	Moderate	Small	Low	+
Moravica	Small	Small	Moderate	Small	Low	+
Zlatibor	Small	Small	Moderate	Small	Low	+
National level	**Moderate**	**Moderate**	**Large**	**Moderate**	**Moderate**	+

Taking the criterion of a maximum of 200 mm of precipitation during the summer, it can be seen that the situation in entire Serbia is already critical and that in the future even the highest altitudes will be exposed to the lack of precipitation (Figure 43).

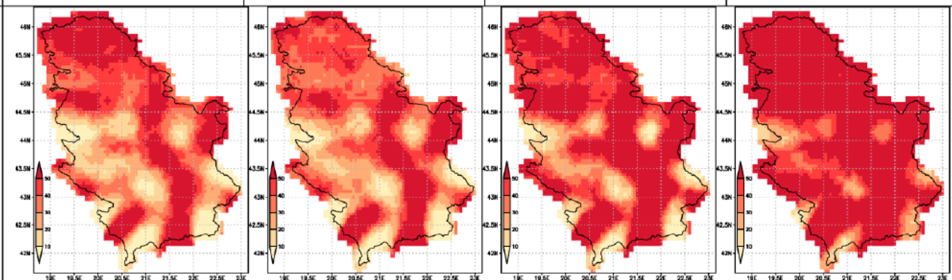
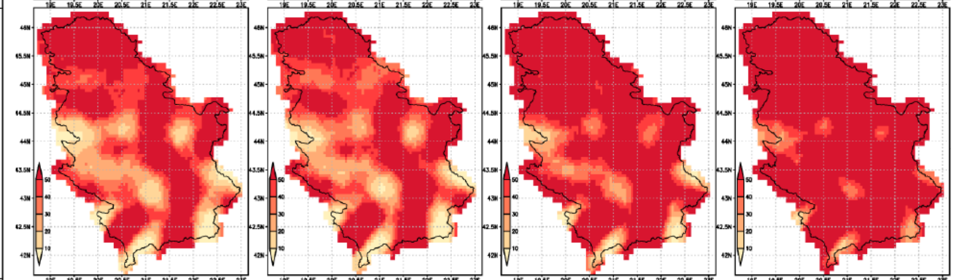
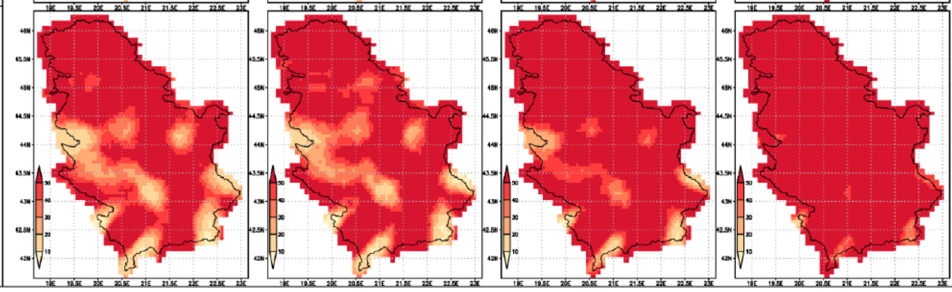
Period/ Probability of occurrence	1986-2005	2021-2040	2041-2060	2080-2100
25%				
50%				
75%				

Figure 43. Frequency of small amounts of precipitation

during the summer (criterion less than 200 mm)

Based on the analysis by regions, the risks and vulnerability of grasslands were Large in the past period to receive less than 200 mm of precipitation during the summer months (Table 35) and there is very high exposure of grasslands in the coming decades, with very Large vulnerability and Large risk in the present.

Period	Farm 1			Farm 2		
	2021-2040	**2041-2060**	**2081-2100**	**2021-2040**	**2041-2060**	**2081-2100**
May	0,249	0,895	2,606	0,081	0,496	2,744
June	0,858	1,35	3,599	0,594	1,162	3,188
July	0,214	1,055	3,444	0,009	1,215	3,671
August	0,024	1,313	3,556	0,134	1,348	3,583
September	1,072	1,3	4,563	0,792	1,352	4,352

Table 39. Estimated average monthly temperature changes in the given periods expressed in °C

7. Risk and vulnerability assessment in the future climate – livestock farming

The impact of climate change on the livestock farming sector in the future is necessary to observe through the direct impact of rising temperatures on the microclimate in animal husbandry facilities and through the secondary impact reflected in the impact on production and quality of animal feed.

The adverse impact of deteriorating microclimatic conditions in animal housing facilities will result in a drop in productivity, which will cause direct material damage. In addition to direct damage, the negative impact of unfavorable microclimatic conditions will endanger the health, welfare and reproduction of domestic and farmed animals, which will result in no less economic losses compared to direct losses. The direct negative impact on microclimatic conditions in animal husbandry facilities will be most pronounced during the warmer period of the year, from 1 May to 30 September.

The assessment of the impact of climate change on the livestock farming sector relies on knowledge of changes in climate parameters in the future, primarily changes in the air temperature, which has a crucial impact on the microclimate in animal housing facilities. Temperature changes were established for two farms that were involved in measuring microclimatic conditions. One farm (Farm 1) is located in Vojvodina, in the South Bačka region, Bečej Municipality, while the other farm (Farm 2) is located in the Mačva region, Loznica Municipality. These two farms were selected in order to assess the changes in the two most represented and most important areas of production for livestock farming, lowland and hilly, where most of the production takes place today. The first farm is located in the flat part of our country and at an altitude of 80 m. The second farm is located in the hilly part at an altitude of 214 m. An estimate of the average monthly temperature change for both farms in three future periods was made: 2021-2040, 2041-2060, 2081-2100 and for the more "pessimistic" of the 75th percentile (Table 40).

Period	Farm 1			Farm 2		
	2021-2040	2041-2060	2081-2100	2021-2040	2041-2060	2081-2100
May	0,249	0,895	2,606	0,081	0,496	2,744
June	0,858	1,35	3,599	0,594	1,162	3,188
July	0,214	1,055	3,444	0,009	1,215	3,671
August	0,024	1,313	3,556	0,134	1,348	3,583
September	1,072	1,3	4,563	0,792	1,352	4,352

Table 40. Estimated average monthly temperature changes in given periods expressed in ° C

When estimating the future humid temperature index, farms are grouped according to the altitude and the region where they are located, so for farms in the lower part of the country the average monthly temperature changes from Farm 1 were used, while for farms in the hilly part

and with higher altitude changes from Farm 2 were used. The TH-index was calculated according to the methodology provided in **Chapter 2**, in the first phase of this report.
The measured ambient temperature was the temperature measured on the same day and hour on a given farm (already determined by the actual measurement), increased or decreased by the average temperature change in a given month for Farm 1 or 2, depending on where the given farm is located. Chart 10 provides average THI values in the analyzed periods for all farms. An upward trend is observed with the average values of THI measured in the previous period, as well as an estimate for the examined periods in the future. Average values of THI in the warmer period of the year exceed the limit (THI = 72) when it is considered that the heads are under the influence of heat stress.

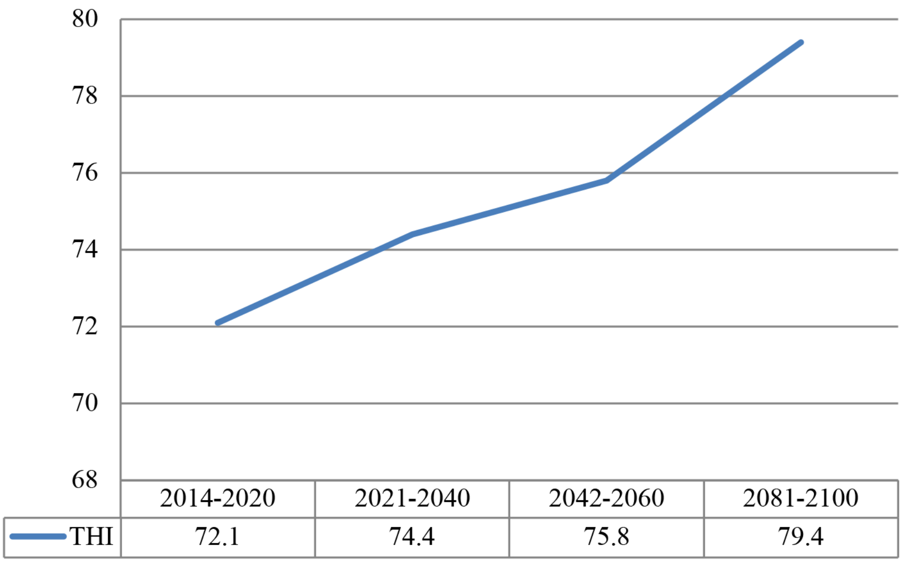


Chart 10. Average THI values in the analyzed periods for all farms

The estimated average growth in the next 20 years is 2.3 and 3.2%, respectively. As the climate changes, THI growth will be highest in the last two decades of the 21st century. In this period, the average values of THI in the warmer period of the year will increase by 7.3 or 10.1% in relation to the current situation. When it comes to the maximum values of THI, the frequency of their occurrence will increase and their values will increase to a greater extent than the average values. In each of the analyzed periods, in the assessment of THI values, its extremely Large values were determined, which can cause the death of animals. An even better indicator of exposure to heat stress is the ratio of the period when the heads are not, i.e. are under the influence of heat stress in the examined periods (Charts 11, 12, 13 and 14).

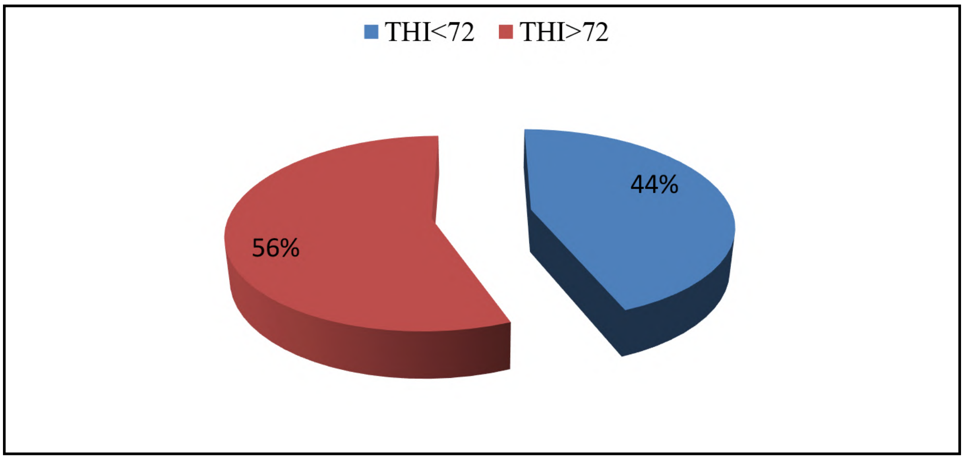


Chart 11. Ratio of the period when the heads are not, i.e. are under the influence of heat stress in the examined period 2014-2020

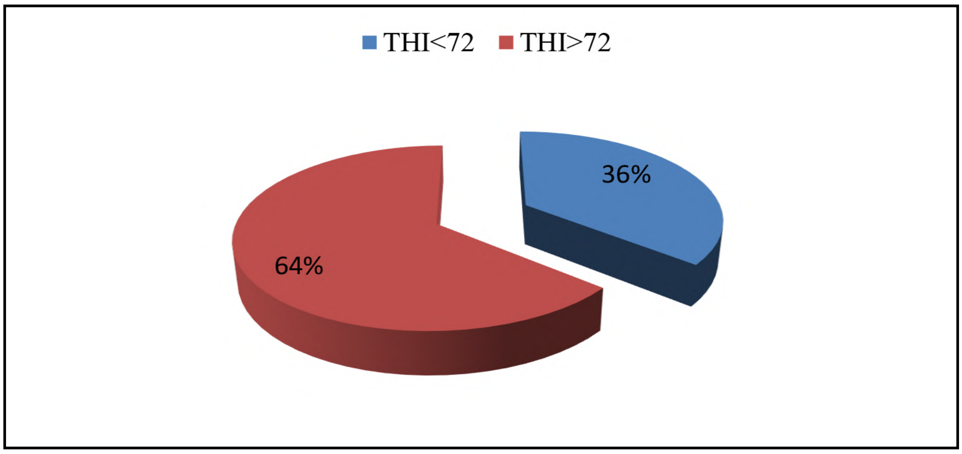


Chart 12. Ratio of the period when the heads are not, i.e. are under the influence of heat stress in the examined period 2021-2040

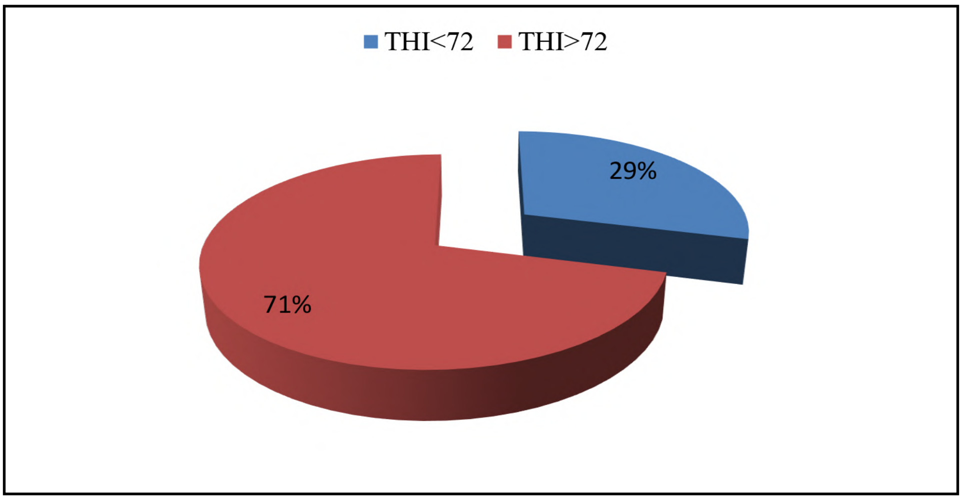


Chart 13. Ratio of the period when the heads are not, i.e. are under the influence of heat stress in the examined period 2041-2060

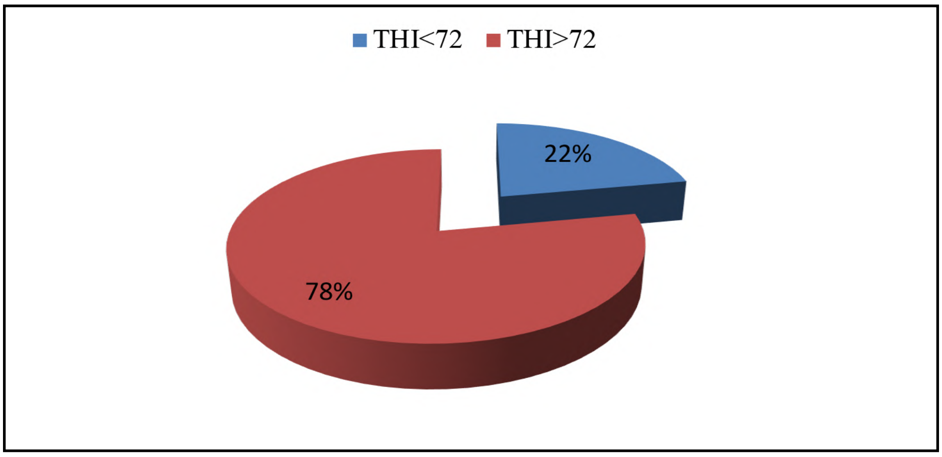


Chart 14. Ratio of the period when the heads are not, i.e. are under the influence of heat stress in the examined period 2081-2100

It can be seen from the chart that the number of periods when the heads are not exposed to heat stress will decrease two times during the last two decades of the 21st century compared to the current situation. Based on this, it is estimated that direct losses in the milk production sector will amount to over 25 million euros.

In the future, livestock farming production will be exposed to the great impact of climate change, i.e. its vulnerability will be Large and can lead to significant economic losses and may affect certain social categories, such as owners and breeders of animals. The probability of heat waves that cause economic losses in livestock farming production is very Large, i.e. almost every year strong heatwaves can be expected to cause significant economic damage. The risk of vulnerability will increase by the end of the 21st century.

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