NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro; doi.org/10.59665/rar4307

ROMANIAN AGRICULTURAL RESEARCH, NO. 43, 2026
First Online: December, 2025. DII 2067-5720 RAR 2025-15

Climate Change and Production of Agricultural Crops

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ABSTRACT

The paper presents the World Bank's risk assessment (security) for agriculture crops for Serbia. Based on these scenarios and forecasts, investment risk factors for the Serbian region in agriculture are formed. The results for the period from 2020 to 2039 are shown for the following indicators: risk categorization, population in accordance with temperature rise, display of complex risk on the map. Agriculture is an important segment of the economy. As the climate decreases, changes must also be monitored and appropriate solutions must be found. The paper presents the change in the yield of agricultural crops for the period 1986 to 2099. Based on the presented forecast, high temperatures are expected from 2051, when risk 4 (highest value) is assessed. These will cause a decrease in the yield of agricultural products. This leads us to the conclusion that it is necessary to plan additional measures that will remedy the forecasted high temperature values. The biggest reduction by the end of the century is predicted for corn in the region of Valjevo and Leskovac (-5.6 and -5.7), and for wheat in the region of Valjevo (-17.2). For the near future (2016-2035), a decrease is predicted for wheat in Valjevo (-1.3), but an increase is predicted for other regions. The biggest increase is predicted (8.3) in Negotin. For the near future (2016-2035), decreases are predicted for corn (0.1-0.3), while an increase is predicted in the Valjevo region (0.1). We can conclude that it is necessary to find solutions in the coming years that will solve the problems of agricultural crops, ie. adaptations that will be able to reduce yield reduction or increase yields. All the above-mentioned climate index projections indicate that it is necessary to monitor changes, assess risks and permanently adjust adaptation measures such as agro technical and other measures, in order to ensure stable and successful agricultural production.

Keywords: agricultures, climate change, World Bank, risk, security.

INTRODUCTION

Agriculture is a very important activity in Serbia, because its share in the gross national income together with forestry and fishing in the period 2015-2017, between 6-6.8% (Bureau of Statistic R. Serbia, 2018). Primary agriculture is mainly based on small family farms (a total of 631,552 households with 1,442,628 workers), which represents about 20% of the population, of which only 12% is engaged in additional activities such as food processing or rural tourism. The average size of the farmer's property is only 5.4 hectares, which consists of an average of 6 separate plots. The average size of the plots is about 1 hectare (Republic Institute of Statistic Census of Agriculture, 2012). Such an unfavorable property structure increases the vulnerability of agriculture and can slow down its development.

Total land area used in 2018 is 3,438,130 hectares. In the total value of agricultural production, plant production (61.7%) is more dominant than livestock production (38.3%). In the period 2015-2017 the most represented are arable land and gardens (75.9%), followed by meadows and pastures (18%), orchards (5.4%), vineyards (0.6%) and other (0.1%). Compared to the 2012 census of agriculture, there was an increase in the area under arable land, gardens and orchards at the expense of meadows and pastures. Agricultural production is carried out in all

Received 13 September 2025; accepted 16 December 2025.

parts of the country and on all terrains. In the plain areas, arable and vegetable production dominates, while in the hilly areas, in addition to arable and vegetable crops, fruit growing is somewhat more prevalent.

Plant production - Of the agricultural crops, the most represented are corn, wheat, sunflower and soybeans, and of the vegetables, potatoes, peppers and beans. Of the fruit plantations, the dominant production is plums, apples, raspberries and cherries, which occupy about 75% of the area under fruit, while other fruit plantations occupy the remaining 25% of the area. Fruit growing recorded an increase, both in terms of area and volume of production, especially in the production of apples, pears, raspberries and apricots, which is a consequence of the introduction of measures to adapt to climate change such as irrigation and/or rain nets.

Livestock production - is present on all terrains, and dominates in mountainous areas. Poultry production is dominant, with over 16.6 million, followed by pigs with over 3 million, followed by sheep and cattle breeding. It should be noted that the volume of livestock production decreased in terms of the number of poultry, goats, horses and pigs, while it remained at almost the same level in terms of the number of cattle, horses and sheep compared to the number according to the census of agriculture from 2012. Expressed by conditional head, there was to a decrease of around 9%. Only an increase in the number of hives (by about 22%) was recorded.

Production of organic food - increased from 218 to 6154 farms in the period from 2011 to 2017. The total arable area under organic production is 7,540 ha, and another 5,919 ha are in the process of transitioning to organic production. According to the latest data (Serbia Organica, 2019), total organic production is carried out on 19,200 hectares. The number of livestock in organic cattle production decreased from 283 to 87, while the number of sheep (4665), goats (248) and poultry (4415) remained stable (UN 2019).

Climate change refers to long-term changes in temperatures and weather patterns. Such changes can be natural, due to changes in the activity of the sun or large volcanic eruptions. But since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels like coal, oil and gas. Burning fossil fuels generates greenhouse gas emissions that act like a greenhouse wrapped around the Earth, trapping the sun's heat and raising the temperature. The main greenhouse gases that cause climate change are carbon dioxide and methane. They come from using gasoline to drive a car or coal to heat a building, for example. Land clearing and deforestation can also release carbon dioxide. Agriculture, oil and gas production are the main sources of methane emissions. Energy, industry, transport, buildings, agriculture and land use are among the main sectors that cause greenhouse gases (Bojic et al., 2016; Djelic et al., 2019; Kostic et al., 2020).

Climate scientists have shown that humans are responsible for almost all of the global warming of the last 200 years. Human activities such as those mentioned above are causing greenhouse gases to warm the world faster than at any time in at least the last two thousand years (Ketin et al., 2019; Sacirovic et al., 2019; Stanic et al., 2019; Matkovic Stojsin et al., 2023; Nikolic Roljevic et al., 2023).

The Earth's average surface temperature is now about 1.1°C warmer than it was in the late 1800s (before the Industrial Revolution) and warmer than at any time in the last 100,000 years. The last decade (2011-2020) was the warmest on record, and each of the last four decades was warmer than any previous decade since 1850.

Many people think that climate change generally means warmer temperatures. But rising temperatures are only the beginning of the story. Because the Earth is a system, where everything is connected, changes in one area can affect changes in all others.

EXPERIMENT

The paper shows the application of the analytical method of creating scenarios (the art of looking at problems in the long term) (Ratclifte, 2000). Results for two scenarios SSPS-4.5 and scenario SSPS-8.5 for the period 2020-2039 are presented.

The largest increase in global greenhouse gas emissions was between 1970 and 2004 and was a result of the energy supply sector (an increase of 145%). The growth of direct emissions in this period from traffic was 120%, from industry 65% and from tillage, land use changes and forestry 4-40%. Between 1970 and 1990, direct emissions from agriculture increased by 27%, from construction by 26%, and later remained at approximately the same level as in 1990. However, the construction sector has a high level of electricity use, which is why total direct and indirect emissions in this sector are significantly higher (75%) than direct emissions.

METHODS

Classical mathematical models of climate change base their predictions on the study of the relationship between greenhouse gases and the amount of heat that remains trapped on the Earth's surface. These mathematical calculations determined a possible increase in the average temperature from 1.4°C to 5.8°C in the period from 1990 to 2100. In a small number of cases, "living" models are applied that take into account the carbon cycle in nature and nature's ability to remove CO_2 from the atmosphere and return O_2 to it.

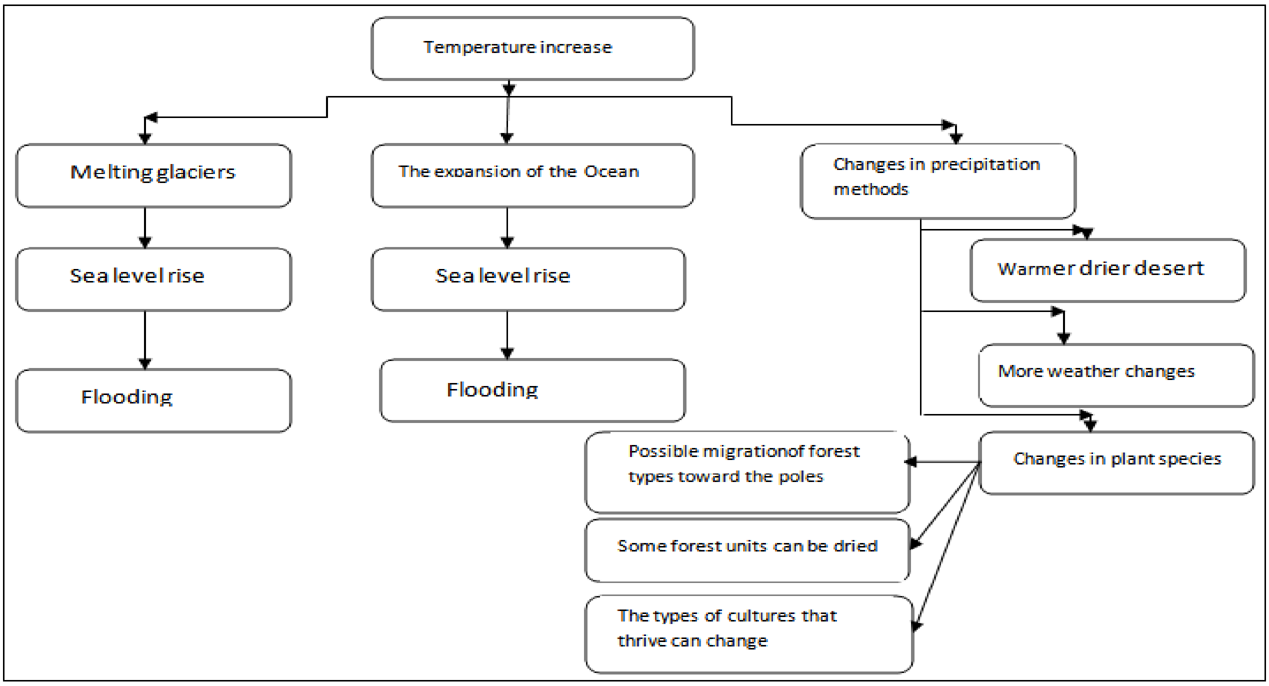


Figure 1. Effects of global warming (Schaltegger et al., 2003)

Live models show that it is possible to expect an increase in the average temperature on Earth of about 9°C by the end of this century. These models take into account the physiological processes of plants and show that once started, the process of global warming increasingly encourages soil respiration, reducing the net primary production that takes place through photosynthesis. This points to the fact that the biosphere is not only beginning to lose its ability to absorb CO_2, but is beginning to "pump" it back into the atmosphere. In that case, there could be an exponential decrease in the amount of carbon from the soil and biomass, an increasing accumulation of greenhouse gases in the atmosphere and faster global warming. The fact that greenhouse gas emissions mostly come from the energy supply sector essentially links the availability and types of energy on the market with the resulting climate changes (Figure 1).

Climate data, current and projected, can be downloaded from the World Bank website. Current climate data from 1901 to 2021 is obtained, as well as projected, i.e. predicted data until 2099.

This section presents a complex risk categorization (0-4) of heat + population based on temperature or heat + population based on temperature and humidity, allowing users to understand where and when risks may occur. The complex risk presentation can be explored spatially via the map (which shows the maximum heat risk categorization during the year). Investigations of specific seasonality of risk based on monthly categorizations are shown through a pie chart. Note how the seasonality of the highest heat risks may extend later, especially for higher emission pathways. The individual elements that contribute to compound risk (i.e., thermal conditions and population) are presented separately in the following sections.

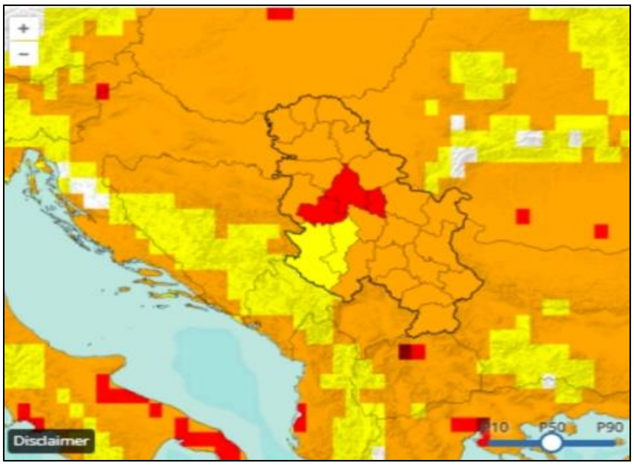
RESULTS AND DISCUSSION

The obtained results show that agriculture is particularly vulnerable to climate change because production is represented as a "factory under the sky". Plant production (farming, vegetable growing, fruit growing, viticulture), as well as animal husbandry and fishing, and through them also food production, is particularly threatened. Irregularity in the supply chain of raw materials for the food industry causes economic and social insecurity.

The climate in Serbia largely depends on the relief, altitude, larger bodies of water (lakes) and other conditions. Data from meteorological stations indicate significant climate changes in Serbia. The observed trends of climate change, based on eight-hour climate parameters in the period from 1961-2017 and 1998-2017, can manifest numerous negative impacts, although some positive impacts on agriculture can also be expected.

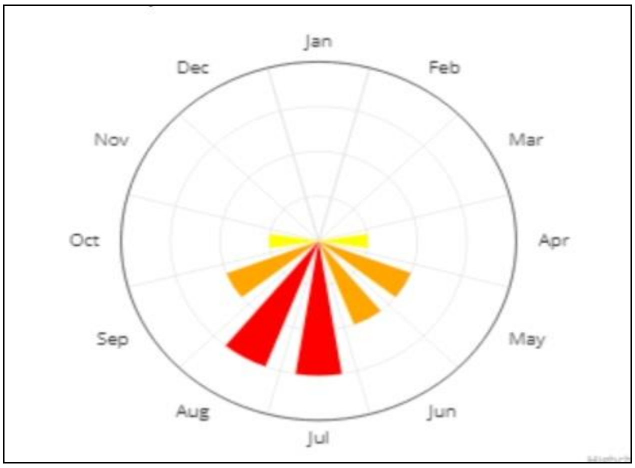
Based on the possible future emissions of greenhouse gases, a projection of climate indices until the end of the century was made. According to the two selected scenarios, which are assumed to be probable for our country, RCP4.5 and RCP8.5, there will be an increase in temperature of at least 0.6°C in the near future, up to a possible 4.3°C by the end of the century. Seasonal changes show that summer and autumn will have slightly larger changes than spring and winter. The projection of annual total precipitation does not show a clear trend. The changes are in the range of ▪ %, with positive values in the northern half of the territory and negative values in the southern half, which will more or less remain until the end of the century. In the analysis of changes in seasonal rainfall amounts, the reduction of rainfall during the summer season under both scenarios is highlighted, with a more pronounced anomaly in the further future up to -20%. The length of the dry period will not change significantly, in a few days, but there will be an increase in the number of tropical days and waves. Projections of changes in the increase of precipitation accumulation from over 20 mm, 30 mm and 40 mm indicate an increase of 20%, but also 30% in Vojvodina and 40% in certain parts of southeastern Serbia by the end of the century. An extension of the vegetation period of 10 days is expected in the near future, up to 50 days by the end of the century, and even 70 days at higher altitudes in the southwestern part of Serbia.

3.1. Graphic representation of the basic measured values from which the risk factor and risk categorization can be seen depending on the temperature.



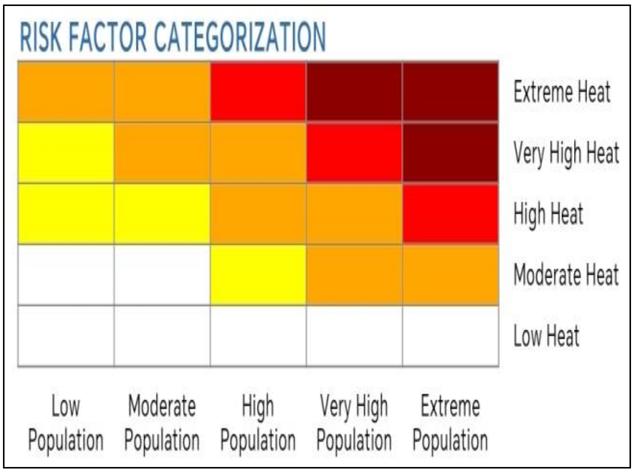
(Climate Change Knowledge Portal, 2024)

Graph 1. Categorization of Temperature-BASED Heat Population Risk Categorization for 2020-2039, Serbia



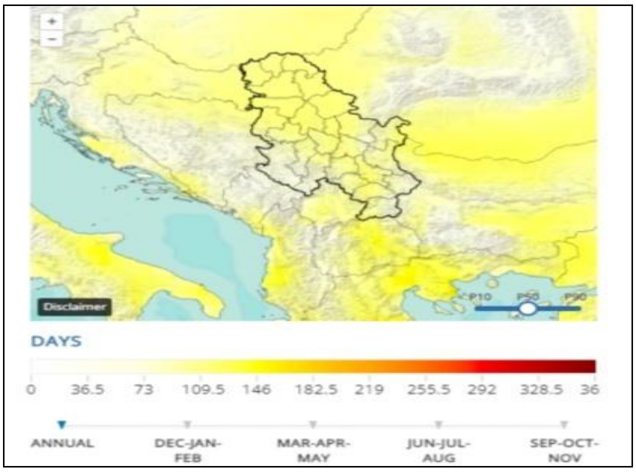
(Climate Change Knowledge Portal, 2024)

Graph 2. Temperature-BASED Heat Population Risk Categorization by month, for 2080-2099, Serbia



(Climate Change Knowledge Portal, 2024)

Graph 3. Risk factor categorization

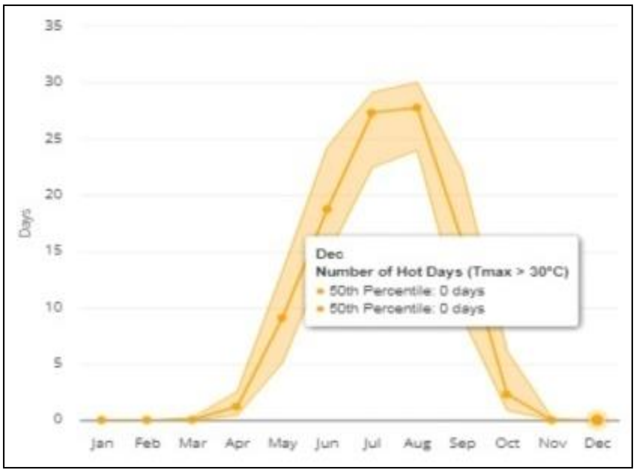


(Climate Change Knowledge Portal, 2024)

Graph 4. Projected Number of Hot Days (Tmax>30°C) for 2080-2099 Annual

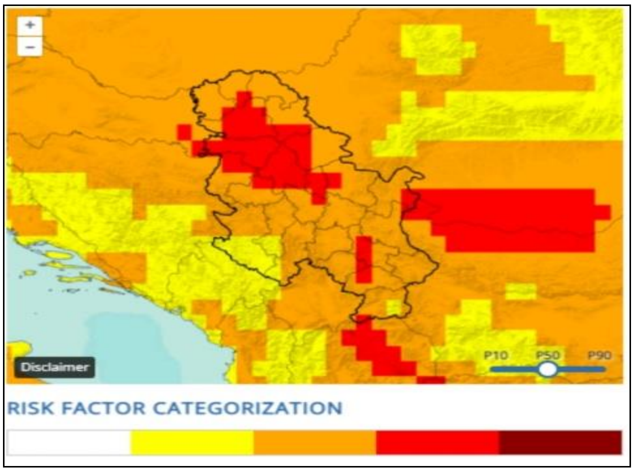
Graph 1, 2, 3, 4 shows the forecast for the change in temperature for the period from 2020 to 2039. The region that will be at high risk, ie. very warm or extremely warm for the months of July and August, is marked in black.

3.2. Understanding 'heat risk' comprehensively requires looking at the range of temperature and humidity conditions that may occur over a 24-hour period, season or year. We present multi-threshold metrics for daytime maximum temperatures, nighttime minimum temperatures, and a combined heat index (a measure of air temperature and humidity) as a basis for assessing changes and intensification of heat risk conditions for an area. It is crucial to understand where extreme heat conditions are more likely to occur and when higher heat conditions are expected in the seasonal cycle, as well as over time (Graph 1 - Graph 7).



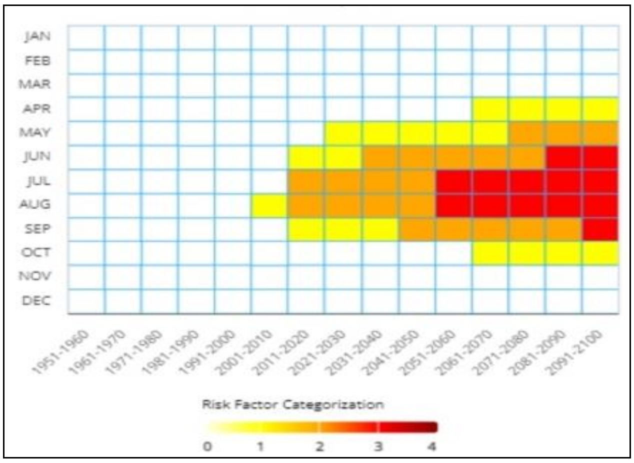
(Climate Change Knowledge Portal, 2024)

Graph. 5. Projected Seasonal Cycle of Daytime Temperatures; 2080-2099; SSPS-8,5, Serbia



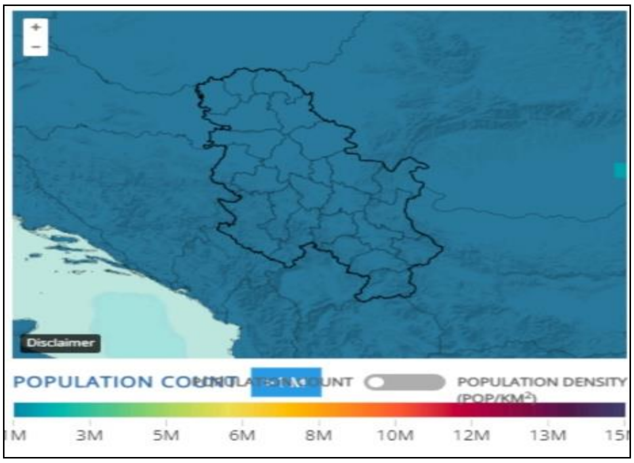
(Climate Change Knowledge Portal, 2024)

Graph 6. Heat Categorization: Hot Day Heat Risk Categorization for 2020-2039 (Annual); Serbia, SSPS-8,5



(Climate Change Knowledge Portal, 2024)

Graph. 7. Heatplot for Hot Day heat Risk Categorization for Serbia, SSPS-8,5



(Climate Change Knowledge Portal, 2024)

Graph. 8. Projected Population Count for 2020-2039; Serbia, SSPS-8,5

Graph 5 represents the number of days in a year when the temperature is higher than 30 degrees Celsius. We see that the forecast is that the number of such days is expected daily in July and August. While it is over 20 days, he is expecting in June and September. Graph 6 shows the regions (Vojvodina and the south of Serbia) which in the period from 2020 to 2039 will be categorized as a region under high risk. Regions are marked in black on the graphic.

Graph 7 represents the categorization of risk for Serbia, from which we can conclude that July and August become extremely high temperatures in the period 2051-2060. This trend continues with 2100 until the forecast is shown. The risk category for the specified period is 4, marked in black.

3.3. In order to assess the future risks of drought, a water deficit analysis for corn and wheat was done. The deficit for corn and wheat was determined by the AquaCrop model (Steduto et al., 2009). 5 localities were chosen (Rimski šančevi, Valjevo, Kragujevac, Negotin and Leskovac), so that the risks of drought in the entire country are shown in a representative way. The input climate data are the results of an ensemble of nine regional climate models from the EURO-CORDEX database. The median of the ensemble of results obtained for each member of the ensemble was taken as the most probable value. The reference (base) period is 1986-2005, future periods are: 2016-2035 (near future), 2046-2065 (mid-century) and 2080-2099 (end of the century).

The analyzes were performed according to the RCP8.5 scenario (constant SO_2 increase scenario), which is assumed to include the most likely range of possible future outcomes.

Table 1. Wheat yields (t/ha) calculated by the AquaCrop model for 9 climate models and the RCP 8.5 scenario

Location	Rimski šančevi				Valjevo				Kragujevac				Negotin				Leskovac			
Period of time	min	max	med	change	min	max	med	change	min	max	med	change	min	max	med	change	min	max	med	change
1986-2005	5.5	6.2	5.7	-	5.2	5.9	5.5	-	4.9	6.4	5.4	-	4.7	5.8	5.3	-	4.8	6.1	5.3	-
2016-2035	4.7	6.7	5.8	2.9	4.6	6.8	5.5	-1.3	4.7	6.5	5.8	6.8	5.1	6.2	5.7	8.3	5.0	6.1	5.4	3.0
2046-2065	4.3	6.0	5.6	-1.8	4.5	6.4	5.0	-9.3	4.8	7.0	5.0	-7.3	5.1	6.7	5.6	7.1	3.4	6.2	5.1	-3.0
2080-2099	3.5	6.1	5.5	-3.8	3	5.2	4.6	-17.2	2.9	7.3	5.4	0.1	3.8	6.5	5.4	1.9	4.5	6.1	5.4	1.9

Table 2. Maize yields (t/ha) calculated by the AquaCrop model for 9 climate models and the RCP 8.5 scenario

Location	Rimski šančevi				Valjevo				Kragujevac				Negotin				Leskovac			
Period of time	min	max	med	change	min	max	med	change	min	max	med	change	min	max	med	change	min	max	med	change
1986-2005	11.2	11.7	11.5	-	11.7	12.1	11.9	-	11.6	12.1	11.8	-	9.9	10.7	10.6	-	11.4	12.2	11.7	-
2016-2035	11	11.8	11.5	-0.3	11.4	12.3	11.9	0.1	11.5	12.3	11.8	-0.3	10.1	10.9	10.6	-0.1	11.4	12.4	11.7	-0.3
2046-2065	10.7	11.8	11.6	-3.9	11.6	12	11.8	-0.6	11.1	12	11.7	-1.0	10	10.9	10.7	1.6	11	11.9	11.7	-0.7
2080-2099	10.2	11.6	11.1	-3.5	10.5	11.6	11.2	-5.7	10.6	11.6	11.2	-5.5	9.7	11	10.3	-2.3	10.6	11.3	11.1	-5.6

Based on the presented tables, we can clearly see the forecast for the reduction of agricultural crops (wheat and corn) in the coming years. The biggest reduction by the end of the century is predicted for corn in the region of Valjevo and Leskovac (-5.6 and -5.7), and for wheat in the region of Valjevo (-17.2).

For the near future (2016-2035), a decrease is predicted for wheat in Valjevo (-1.3), but an increase is predicted for other regions. The biggest increase is predicted (8.3) in Negotin. For the near future (2016-2035), decreases are predicted for corn (0.1-0.3), while an increase is predicted in the Valjevo region (0.1). From Tables 1 and Table 2, we can conclude that it is necessary to find solutions in the coming years that will solve the problems of agricultural crops, ie. adaptations that will be able to reduce yield reduction or increase yields.

Table 7. Water deficit (irrigation norms) for corn in the current and future climate conditions for the region Rimski šančevi and Leskovac

Location	Rimski šančevi				Leskovac			
Period of time	min	max	med	change	min	max	med	change
1986-2005	187	268	212	-	214	333	272	-
2016-2035	204	267	240	13.0	220	334	302	11.2
2046-2065	180	266	201	-5.2	244	335	284	4.5
2080-2099	175	256	204	-4.0	246	335	276	1.7

The deficit for corn and wheat was determined by the AquaCrop model.

Water deficits for wheat will remain in the range of current values, because the sum of precipitation by the end of the century of over 400 mm in all observed areas shows that there will be enough water to achieve high yields. However, there will be large variations in yield from year to year due to the autumn drought, which will delay crop emergence. Although the occurrence of autumn precipitation will ensure the sowing and sprouting of crops in the optimal terms for sowing, there will be a frequent problem of autumn drought. In addition to drought, overwetting during the growing season will be a problem for crop growth, so attention must also be paid to drainage measures in the future. Larger deficits will be avoided due to milder winters, a shorter period of dormancy, flowering in a period when temperatures are more favorable and faster ripening of wheat. Irrigation norms for achieving high and stable corn yields will not change significantly either in the north or in the south of the country, but only if sowing is done in the optimal terms (Table 3).

3.4. This section explores the socio-economic background against which heat risks should subsequently be assessed. The following are presented: population (density: persons/km^2 and number) and poverty classification. Understanding where the population is and what their relative poverty level can help decision makers identify key areas of need (Graph 8).

Population and poverty data from the past to the present largely reflect the results of censuses and surveys (roughly up to 2010 in the presentations here). Future projections are made in collaboration with the formulation of the narrative of social development within the framework of the Common Socioeconomic Pathways (SSP). The goal of SSP is to describe a series of possible social futures where different technological, political and life trajectories are described. Within each of these stories, a trajectory of demographic change is generated, which then, based on technology assumptions, leads to likely emissions patterns that reflect that trajectory. From these emission lines, a set of the most representative likely radiation levels at the end of the 21st century is then selected to provide input to climate models. The SSPs reflect the most advanced iteration of socioeconomic narratives offered to date. They take into account social factors such as demography, human development, economic growth, inequality, governance, technological change and political orientations. While most factors are given as narratives outlining broad patterns of change globally and for major world regions, a subset (population, GDP, urbanization and educational attainment) are given as country-specific quantitative projections. These variables were chosen based on their common use as inputs to emission or impact models and their interrelationships. The data presented below describe the population growth, poverty scale, age and gender classifications for each SSP.

CONCLUSIONS

Assessments that include forecasts and climate changes are needed and will be considered more and more in the future, due to the impact on the population, risk increase and other important factors for human life. Agriculture is considered here from the point of view of the amount of production of agricultural products, the capacity of water resources and the investments that will be realized in the coming period.

Based on the presented forecast, high temperatures are expected from 2051, when risk 4 (highest value) is assessed. These will cause a decrease in the yield of agricultural products. This leads us to the conclusion that it is necessary to plan additional measures that will remedy the forecasted high temperature values.

Natural disasters in farming and vegetable growing result in plant stress, difficult agro-ecological conditions for production and the impossibility of applying adequate agricultural practices and technologies. When certain climatic factors vary so that they do not reach or exceed the optimal needs of plants, plant stress occurs and there is a decrease in yield and product quality.

All the above-mentioned climate index projections indicate that it is necessary to monitor changes, assess risks and permanently adjust adaptation measures such as agro technical and other measures, in order to ensure stable and successful agricultural production.

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