

**Interreg**



Co-funded by  
the European Union

**IPA** ADRION



---

**THEMATIC2GREEN**

# ANALYSIS OF OBSERVED AND EXPECTED CLIMATE CHANGES IN THE TERRITORY OF THE CITY MUNICIPALITY OF MEDIJANA

IPA-ADRION00228: THEMATIC2GREEN



**PARTNER CONSULTING**  
Working together

Jun 2025

The project is co-funded by the European Union through the Interreg IPA ADRION programme

Project title: IPA-ADRION00228 THEMATIC2GREEN

Activity: Activity 2: Territorial analysis of the impacts of climate change on economic systems  
Sub-activity 2.1: Analysis of observed climate changes in the Nišava region and in the territory of the city of Niš and the City Municipality of Medijana for the recent past period 2001–2020, with particular focus on the second decade of this climate period, 2011–2020, when greater impacts of climate change were observed.  
Sub-activity 2.2: Analysis of expected climate changes in the Nišava region and in the territory of the city of Niš and the City Municipality of Medijana for the climate periods 2011–2040, 2041–2070, and 2071–2100, according to the RCP4.5 and RCP8.5 scenarios of future greenhouse gas (GHG) concentrations.

Document title: Analysis of Observed and Expected Climate Changes in the Territory of the City Municipality of Medijana

Contracting Authority: City Municipality of Medijana

Contract number: 181/2025-62-1 from 06.05.2025.

Contractor: Radoje Laušević pr. Agencija Partner Consulting, Kneza Danila 7, Beograd – Palilula

Document prepared by: Prof. Dr. Slobodan Milutinović, climate change expert

Submission date: 10.06.2025.

Status: Draft

Version: 1

This has been produced with the financial assistance of the European Union. The content of the document is the sole responsibility of City municipality of Medijana and can under no circumstances be regarded as reflecting the position of the European Union and/or IPA ADRION programme authorities

## Table of content

<b>EXECUTIVE SUMMARY</b> .....	<b>3</b>
<b>INTRODUCTION</b> .....	<b>5</b>
<b>ANALYSIS OF CLIMATE CHANGE VARIABLES IN THE CITY MUNICIPALITY OF MEDIJANA</b> .....	<b>5</b>
OBSERVED CLIMATE CHANGES .....	5
<i>Observed changes in essential climate variables</i> .....	5
<i>Observed changes in climate indices</i> .....	8
FUTURE CLIMATE CHANGES.....	11
<i>Expected changes in essential climate variables</i> .....	11
<i>Expected changes in climate indices</i> .....	12
<b>DISCUSSION</b> .....	<b>15</b>
<b>CONCLUSIONS AND RECOMMENDATIONS</b> .....	<b>16</b>
REFERENCES.....	17

## Figures

FIGURE 1. OBSERVED VALUES OF AVERAGE DAILY TEMPERATURE ( $T_{AS}$ , °C) FOR THE CITY MUNICIPALITY OF MEDIJANA FOR THE PERIOD 1950–2020. ....	6
FIGURE 2. OBSERVED CHANGES FOR THE CITY MUNICIPALITY OF MEDIJANA: DEVIATION OF THE AVERAGE DAILY TEMPERATURE ( $T_{AS}$ , °C) IN THE PERIOD 1990–2020 COMPARED TO THE REFERENCE PERIOD 1961–1990. ....	7
FIGURE 3. OBSERVED CHANGES FOR THE MUNICIPALITY OF MEDIJANA: DEVIATION OF THE AVERAGE MAXIMUM TEMPERATURE ( $T_{AS\ MAX}$ , °C) IN THE PERIOD 1990–2020 COMPARED TO THE REFERENCE PERIOD 1961–1990. ....	7
FIGURE 4. OBSERVED CHANGES FOR THE MUNICIPALITY OF MEDIJANA: DEVIATION OF THE AVERAGE MINIMUM TEMPERATURE ( $T_{AS\ MIN}$ , °C) IN THE PERIOD 1990–2020 COMPARED TO THE REFERENCE PERIOD 1961–1990. ....	8
FIGURE 5. OBSERVED AVERAGE PRECIPITATION AMOUNTS FOR THE TERRITORY OF THE MEDIJANA CITY MUNICIPALITY (PR, MM) IN THE PERIOD 1950–2020. ....	8
FIGURE 6. DEVIATIONS (ANOMALIES) OF AVERAGE ANNUAL AIR TEMPERATURES, AVERAGED FOR THE TERRITORY OF THE MEDIJANA CITY MUNICIPALITY, FOR THE PERIOD 1961-2020 COMPARED TO THE MEAN VALUE OF THE REFERENCE PERIOD 1961-2000 .....	9
FIGURE 7. OBSERVED VALUES OF CLIMATE INDICES IN THE TERRITORY OF THE MEDIJANA CITY MUNICIPALITY: NUMBER OF HEATWAVES PER YEAR IN THE PERIOD 1950–2020.....	10
FIGURE 8. PROJECTED CHANGES IN AVERAGE DAILY TEMPERATURE, AVERAGE MAXIMUM TEMPERATURE, AND AVERAGE MINIMUM TEMPERATURE IN THE CITY MUNICIPALITY OF MEDIJANA FOR THE PERIOD 2011–2100 UNDER RCP4.5 AND RCP8.5 SCENARIOS.....	12
FIGURE 9. EXPECTED CHANGES IN CLIMATE INDICES IN THE NIŠAVA DISTRICT. (1) .....	13
FIGURE 10. EXPECTED CHANGES IN CLIMATE INDICES IN THE NIŠAVA DISTRICT. (2) .....	14
FIGURE 11. EXPECTED NUMBER OF DROUGHT YEARS PER DECADE IN THE NIŠAVA DISTRICT DURING THE PERIOD 2011–2100. ....	15

## Executive summary

This report provides a comprehensive analysis of observed and projected climate changes in the City Municipality of Medijana, as part of the IPA-ADRION00228 THEMATIC2GREEN project. The analysis focuses on changes in key climate variables and indices between 2001 and 2020 and projects trends through 2100 under two greenhouse gas concentration scenarios: RCP4.5 (moderate mitigation) and RCP8.5 (no mitigation).

### Key Observations

**Temperature Increase:** The average ground-level temperature in Medijana increased by 1.40°C in the period 2001–2020, and by 1.80°C in the 2011–2020 decade compared to the baseline period 1961–1990. Maximum temperatures rose faster than minimum ones, particularly in summer.

**Heatwaves and Extreme Events:** The frequency and duration of heatwaves have increased significantly, with a fourfold rise in extremely hot days (above 35°C) compared to the reference period. Warm periods are longer and more intense, while cold events (frost and ice days) have become rarer.

**Urban Heat Island Effect:** Medijana, as a dense urban core, shows stronger warming trends than surrounding districts, reinforcing the presence of an urban heat island.

**Precipitation Patterns:** While total annual precipitation has not deviated significantly (+8–10%), its seasonal and intensity distribution has changed. Precipitation is increasingly concentrated in fewer, more intense events, heightening the risk of flash floods. Simultaneously, the number of consecutive dry days has decreased, though prolonged dry periods are becoming more common.

### Projections for Future Climate

**Temperature Projections:** Under RCP4.5, average temperatures in Medijana are expected to rise by up to 2.05°C by the end of the century. Under RCP8.5, this increase could reach 4.12°C, with maximum temperatures rising by more than 5°C.

**Heat Extremes:** Summer days, tropical days, and tropical nights will all increase markedly. Days above 35°C may rise from 1–2 annually to over 27 under RCP8.5. The frequency of heatwaves may reach seven per year by 2100, with durations exceeding 70 days.

**Drought Trends:** Based on SPEI6a indices, the number of drought years is expected to grow, particularly in the final decades of the century. Under RCP8.5, each year in the 2091–2100 period may experience drought conditions.

**Precipitation Outlook:** While overall annual precipitation may decline only slightly, a seasonal reduction in summer and winter rainfall is expected, further increasing drought risk and affecting water availability and agriculture.

### Implications

The findings indicate a trajectory of increasing climate variability and risk, with direct implications for public health, infrastructure, energy demand, water management, agriculture, and biodiversity. In urban environments like Medijana, these effects are likely to be more intense and damaging due to existing vulnerabilities.

### Recommendations

To address these emerging risks, the report recommends:

- Development of a local Climate Adaptation Action Plan aligned with Serbia's national adaptation strategy;
- Implementation of nature-based solutions and urban greening to mitigate heat;

- Climate-resilient infrastructure planning (e.g., drainage systems, building standards);
- Early warning systems for extreme weather events;
- Public awareness and institutional capacity building;
- Continuous monitoring and integration of climate data into spatial and sectoral planning.

## Introduction

In recent years, the City of Niš has experienced notable changes in its local climate, reflecting broader regional trends associated with climate change. Average temperatures have been steadily rising, while precipitation patterns have become more irregular. Summers are increasingly warmer, with August emerging as the hottest month, averaging around 22.3 °C. Winters, though still cold, show a slight warming trend, with January temperatures averaging approximately 0.6 °C. These developments suggest a gradual transition toward a warmer and more variable climate in the region.

## Analysis of climate change variables in the City Municipality of Medijana

The observed climate changes were analysed for the period of recent past 2001-2020, particularly for the second decade of this climate period 2011-2020 when the greater influences of climate changes were observed. Data for the analysis of observed climate changes and their effects were obtained from the E-OBS database<sup>1</sup> for the period 1961-2020, which includes interpolated daily data for temperatures and precipitation at a resolution of 0.11°. The period 1961-1990 is the reference climate period for analysing changes in the recent past and future until the end of the 21st century. This period is considered representative of climate conditions before significant changes occurred. The data used for the analysis of observed and future climate changes are available through the web portal Digital Climate Atlas of Serbia<sup>2</sup>. The observed climate changes were analysed for the period of recent past 2001-2020, with a special emphasis on the period between 2011 and 2020, when the greater influences of climate changes were observed. This was aimed at illustrating the significant acceleration of temperature rise and various other climate-related risks.

The observed climate changes were analysed for the of the City Municipality of Medijana. Considering that the City Municipality of Medijana predominantly encompasses densely populated urban core of the city of Niš, the aim of this analysis was to highlight the specificities of altered climate conditions in an urban environment in comparison to the entire territory of the city of Niš.

## Observed climate changes

### Observed changes in essential climate variables

The average daily ground-level temperature in the Nišava Administrative District increased by an average of 1.42°C in the period from 2001 to 2020, and by 1.82°C in the period from 2011 to 2020, compared to the reference period from 1961 to 1990. This aligns with the increase in average daily temperature observed across the territory of the Republic of Serbia. The increase in average annual temperature in Medijana compared to the reference period was slightly lower than the average increase in annual temperature at the national level (1.40°C compared to 1.42°C in the period 2001–2020, and 1.80°C compared to 1.82°C in the period 2011–2020). The greatest increase in average temperature occurred in the summer (June–July–August).

---

<sup>1</sup> Cornes, R., G. van der Schrier, E.J.M. van den Besselaar, P.D. Jones (2018). An Ensemble Version of the E-OBS Temperature and Precipitation Datasets. *JGR Atmospheres*, 123 (17), pp. 9391-9409

<sup>2</sup> Ministry of Environmental Protection (2022). *Digital Atlas of Climate and Climate Change of the Republic of Serbia*. Project "Improvement of medium- and long-term planning of adaptation measures to changed climate conditions in the Republic of Serbia". Available online at <https://atlas-klime.eko.gov.rs>

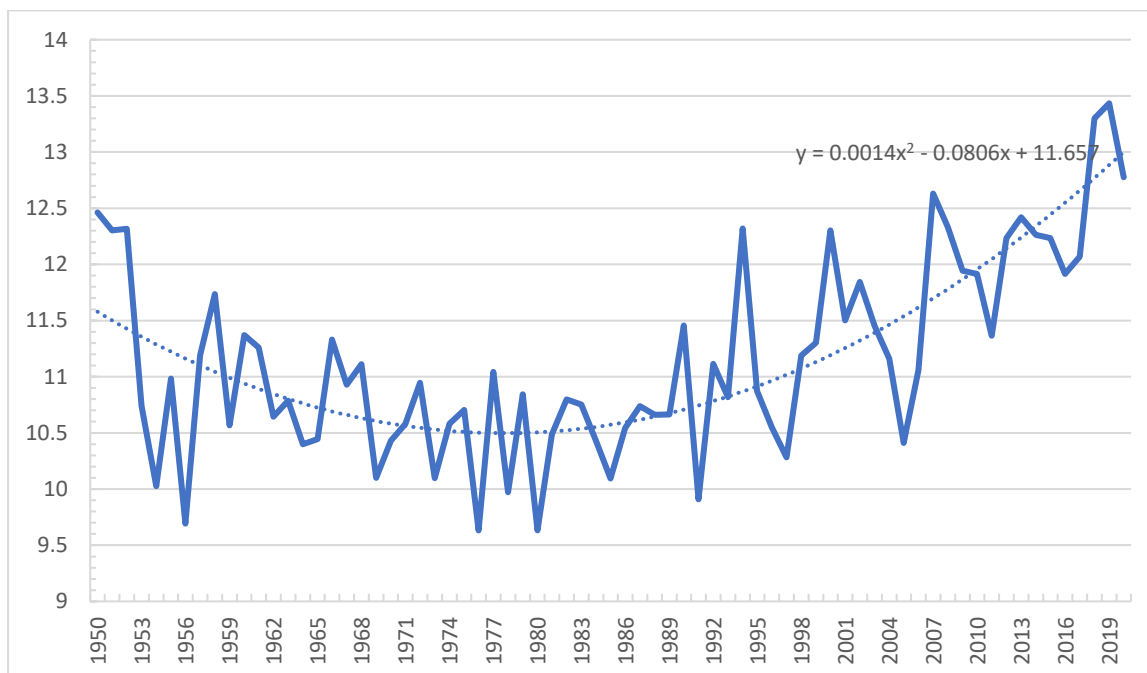


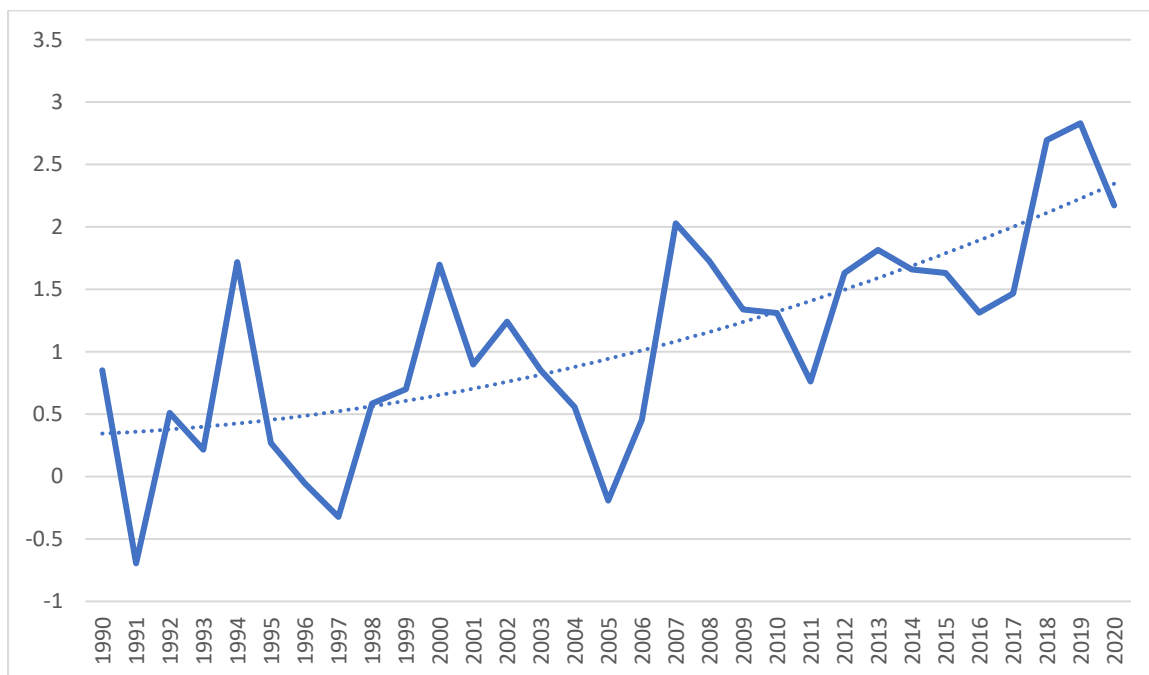
Figure 1. Observed values of average daily temperature ( $t_{as}$ , °C) for the City Municipality of Medijana for the period 1950–2020.

The maximum daily ground-level temperature in the Nišava District has increased more rapidly over the past two decades than the average minimum temperature. Between 2001 and 2020, it rose by 1.63°C, and between 2011 and 2020, it increased by 1.94°C compared to the reference period from 1961 to 1990.

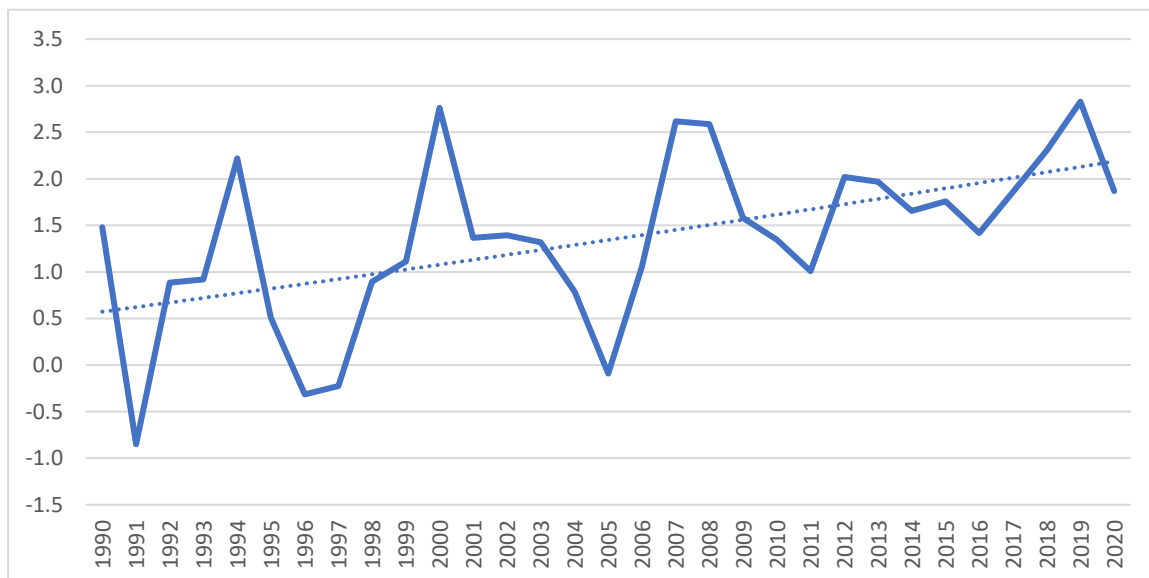
In the Medijana City Municipality, the increase in the average maximum daily ground-level temperature was higher than in the Nišava District during the period 2001–2020 (1.67°C compared to 1.63°C), but lower in the period 2011–2020 (1.85°C compared to 1.94°C), aligning with the increase observed at the national level across Serbia.

The average minimum daily ground-level temperature in the Nišava District increased by 1.29°C in the period from 2001 to 2020, and by 1.57°C in the period from 2011 to 2020, compared to the reference period from 1961 to 1990 (see Figure 3).

In the territory of the Medijana City Municipality, the average minimum ground level temperature rose slightly less than the average maximum temperature during the observed periods: from 2001 to 2020, this increase was 1.28°C, while from 2011 to 2020 it amounted to 1.58°C compared to the reference period from 1961 to 1990 (see Figure 4).



**Figure 2.** Observed changes for the City Municipality of Medijana: deviation of the average daily temperature ( $t_{as}$ , °C) in the period 1990–2020 compared to the reference period 1961–1990.



**Figure 3.** Observed changes for the Municipality of Medijana: deviation of the average maximum temperature ( $t_{as\ max}$ , °C) in the period 1990–2020 compared to the reference period 1961–1990.

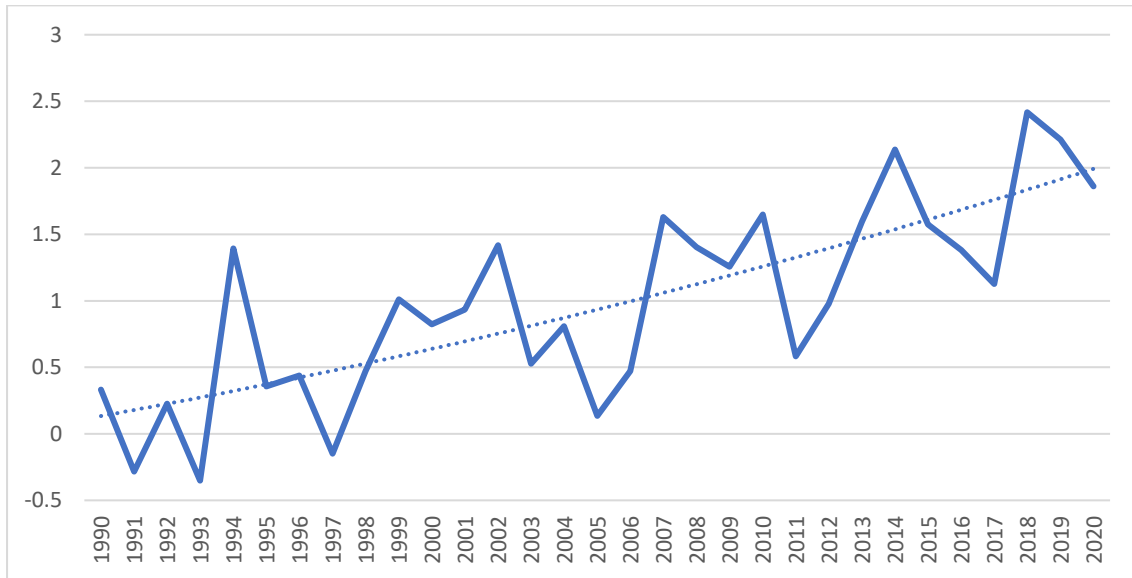


Figure 4. Observed changes for the Municipality of Medijana: deviation of the average minimum temperature ( $t_{as\ min}$ , °C) in the period 1990–2020 compared to the reference period 1961–1990.

The average annual precipitation in the territory of the Medijana City Municipality does not show significant deviations (see Figure 5). The average annual precipitation in the period 2001–2020 increased by 10% compared to the reference period 1961–1990, while in the period 2011–2020 it increased by 8.5% compared to the same reference period. The annual maximum of accumulated precipitation is shifting to an earlier part of the year—moving from the late spring (March–April–May) and early summer (June–July–August) seasons toward mid-spring.

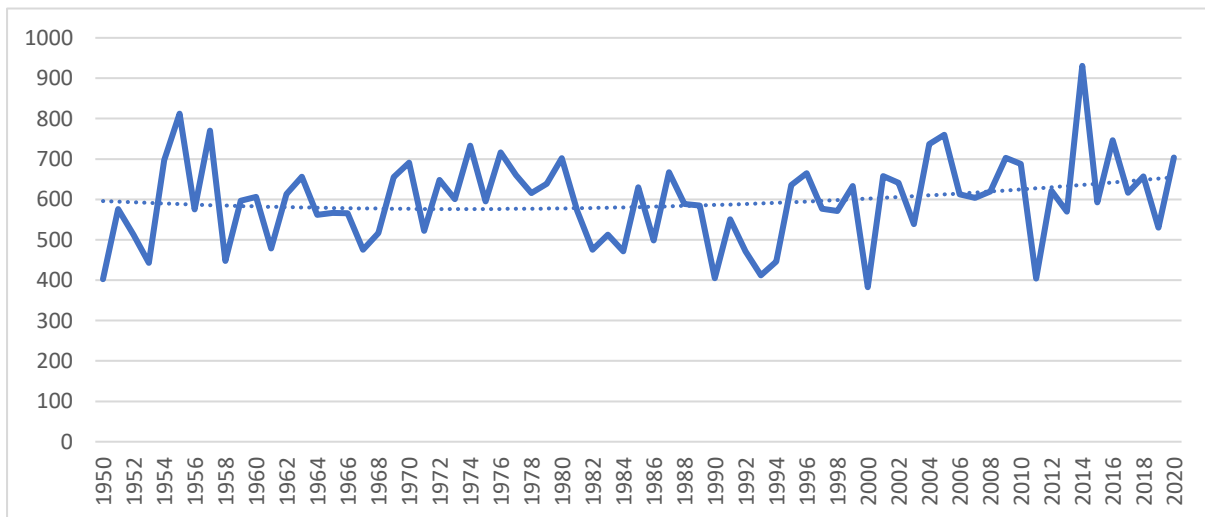


Figure 5. Observed average precipitation amounts for the territory of the Medijana City Municipality (pr, mm) in the period 1950–2020.

### Observed changes in climate indices

During the period from 2001 to 2020, an increased variability of thermal conditions was observed in the territory of the Medijana city municipality, specifically an increase in the range of differences in average annual temperatures compared to the average value for the reference period (Figure 6). Due to the rise in average annual temperature, these deviations were positive throughout the entire period (excluding 2005).

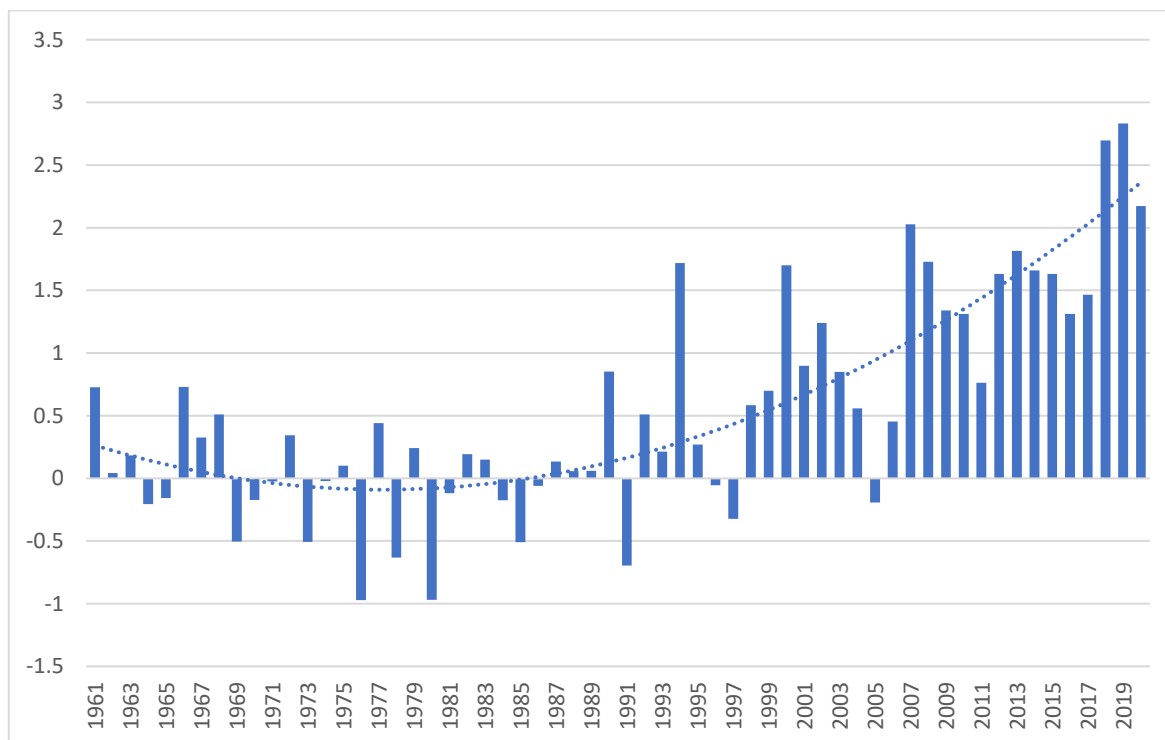


Figure 6. Deviations (anomalies) of average annual air temperatures, averaged for the territory of the Medijana city municipality, for the period 1961-2020 compared to the mean value of the reference period 1961-2000

The total average number of summer days (number of days in a year with a daily maximum temperature above 25°C) per year in the period between 2001 and 2020 in the territory of the Medijana city municipality increased by 22 compared to the reference period from 1961 to 1990. This increase was even more pronounced in the city municipalities of Niška Banja and Palilula. When looking at the last decade (from 2011 to 2020), the increase amounts to as much as 27 days on average per year.

The average number of tropical days (number of days with a daily maximum temperature above 30°C in one year) also increased, by 21 in the period between 2001 and 2020 compared to the reference period 1961–1990, which represents an 80% increase — or by 24 days in the period from 2011 to 2020 relative to the same reference period.

At the same time, the number of days with extremely high temperatures above 35°C more than quadrupled during this period (an increase of 420% compared to the reference period 1961–1990 in the last two decades, and as much as 454% when observing only the 2011–2020 decade). These values are significantly higher than the increases recorded at the level of the Nišava Administrative District, which — considering that the Medijana city municipality is predominantly urbanized — indicates the presence of an urban heat island. Similar changes have also been recorded for tropical nights (number of days in a year with a daily minimum temperature above 20°C).

At the same time, the average annual number of frost days in the territory of the Medijana city municipality (number of days in a year with a daily minimum temperature below 0°C) decreased by 16 during the period 2001–2011 compared to the reference period 1961–1990 (a reduction of 18%), while during the same period, the number of ice days (number of days in a year with a daily maximum temperature below 0°C) decreased by 7, or 25%.

One of the main characteristics of the altered climatic conditions throughout Serbia is the increased occurrence of heatwaves<sup>3</sup>. During the reference period 1961–1990, the territory of the Medijana city municipality experienced fewer than one heatwave per year (0.62), meaning they did not occur every year. In the period 2001–2020, an average of 2.65 heatwaves were recorded annually (2.95 in the period 2011–2020). Increased climate variability has led to the occurrence of more extreme years (in 6 years during the decade 2011–2020, there were three or more heatwaves per year, see Figure 7). The duration of heatwaves has also increased: from an average of 4.31 days in the period 1961–1990 to 21.77 average days per year in the period 2001–2020, and 25.20 average days in the period 2011–2020.

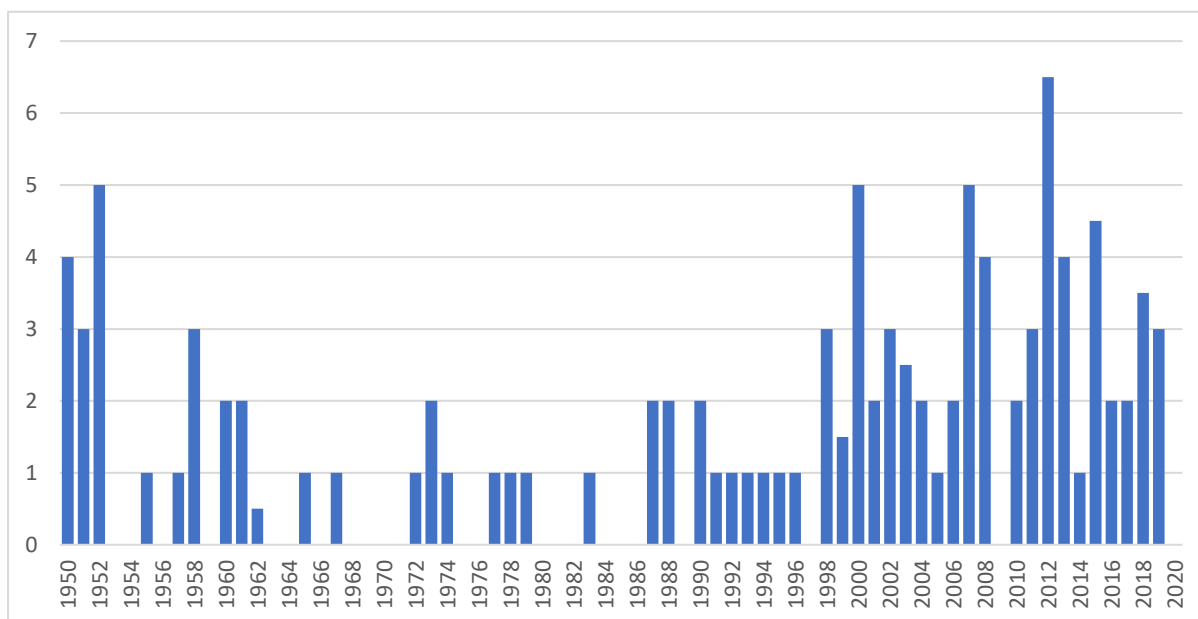


Figure 7. Observed values of climate indices in the territory of the Medijana city municipality: number of heatwaves per year in the period 1950–2020

The number of warm periods<sup>4</sup> has increased 2.5 times in the last two decades compared to the reference period, or by 165% in the last decade, while their duration increased from 14 days in the period 1961–1990 to 38 days in 2001–2020, and to 42 days in 2011–2020.

Increased climate variability contributes to the rapid rise in heatwaves, a significant increase in maximum temperatures, and uneven warming across the seasons. Specifically, the warmest time of the year is experiencing the most pronounced warming. This means that warm periods are heating up faster compared to cold periods, while extreme high-temperature events are becoming more intense.

As a result, there is a greater likelihood of drastic shifts between different weather conditions. This includes more frequent periods of intense weather variability, where temperatures rapidly shift from

<sup>3</sup> Heatwaves are defined as events lasting at least six consecutive days during which the maximum daily temperature exceeds a predetermined threshold value. In this case, the corresponding threshold is determined for each day of the year (a total of 365 values) as the 90<sup>th</sup> percentile of a dataset that includes maximum daily temperatures from the reference thirty-year period. This dataset consists of values for the specific calendar day in question, as well as for the days within a five-day window surrounding that day.

<sup>4</sup> The number of events lasting at least six consecutive days during which the maximum daily temperature exceeded a predetermined threshold value. In this case, the corresponding threshold is determined for each day of the year (a total of 365 values) as the 50<sup>th</sup> percentile of a dataset that includes maximum daily temperatures from the reference thirty-year period. This dataset consists of values for the specific calendar day in question, as well as for the days within a five-day window surrounding that day.

colder to warmer conditions and vice versa. These changes can occur annually, during specific seasons, or even within shorter intervals throughout the year.

Although the average annual precipitation total in the Medijana city municipality does not show significant deviations (up to +10%), there is a clear change in the seasonal distribution of precipitation and in the distribution by intensity. The maximum one-day accumulated precipitation (in mm) during the year increased by 2.8 mm in the period 2001–2020 compared to the reference period, while in the period 2011–2020 the increase was 5.1 mm (16%). The maximum five-day accumulated precipitation (in mm) during the year rose by 11% in the period 2001–2020, and by 19% in the period 2011–2020.

On the other hand, the number of dry days — defined as the longest uninterrupted period (number of consecutive days) during the year with less than 1 mm of precipitation — decreased by 12% in the period 2001–2020 (with a notable increase in the second decade of this period).

The number of days with very heavy precipitation (daily precipitation of 20–30 mm) increased to 1.42 in the period 2001–2020, and to 1.52 in the period 2011–2020, compared to 0 days in the reference period 1961–1990. Meanwhile, the number of days with extreme precipitation (daily precipitation over 30 mm) has remained unchanged.

## Future climate changes

### Expected changes in essential climate variables

According to the greenhouse gas mitigation scenario (RCP4.5), the expected increase in the average annual ground-level temperature in the territory of the City Municipality of Medijana will be 1.09°C in the period 2011–2041 compared to the reference period 1971–2000, or 0.90°C compared to the reference period 1986–2005. The increase in the period 2041–2070 compared to the reference period 1971–2000 would be 1.71°C, and in the period 2071–2100, it would be 2.05°C.

If greenhouse gas concentrations follow the RCP8.5 scenario, the increase in average annual temperature in the period 2011–2040 would be 1.18°C compared to the reference period 1971–2000 (1.06°C compared to the reference period 1986–2005); in the period 2041–2070, it would be 2.38°C compared to the reference period 1971–2000 (2.14°C compared to the reference period 1986–2005); and in the period 2071–2100, it would reach as much as 4.12°C compared to the reference period 1971–2000 (3.89°C compared to the reference period 1986–2005) (see Figure 8).

The expected increase in average maximum temperature will be slightly higher than that of the average daily temperature: during the period 2011–2041, the average maximum temperature will be 1.17°C higher compared to the reference period 1971–2000 (1.14°C compared to the period 1986–2005) under the greenhouse gas mitigation scenario. In the period 2071–2100, the average maximum temperature is expected to increase by more than 2°C. Under the non-mitigation scenario, this increase in the period 2011–2041 is expected to be 1.27°C. In the long term, for the period 2071–2100, the average maximum temperature is expected to increase by over 5°C compared to the reference period 1971–2000 if the RCP8.5 scenario occurs—i.e., if greenhouse gas emissions are not reduced in line with the Paris Agreement. The greatest increase in both average maximum and average daily temperatures will occur during the summer months (June–July–August) (Figure 8).

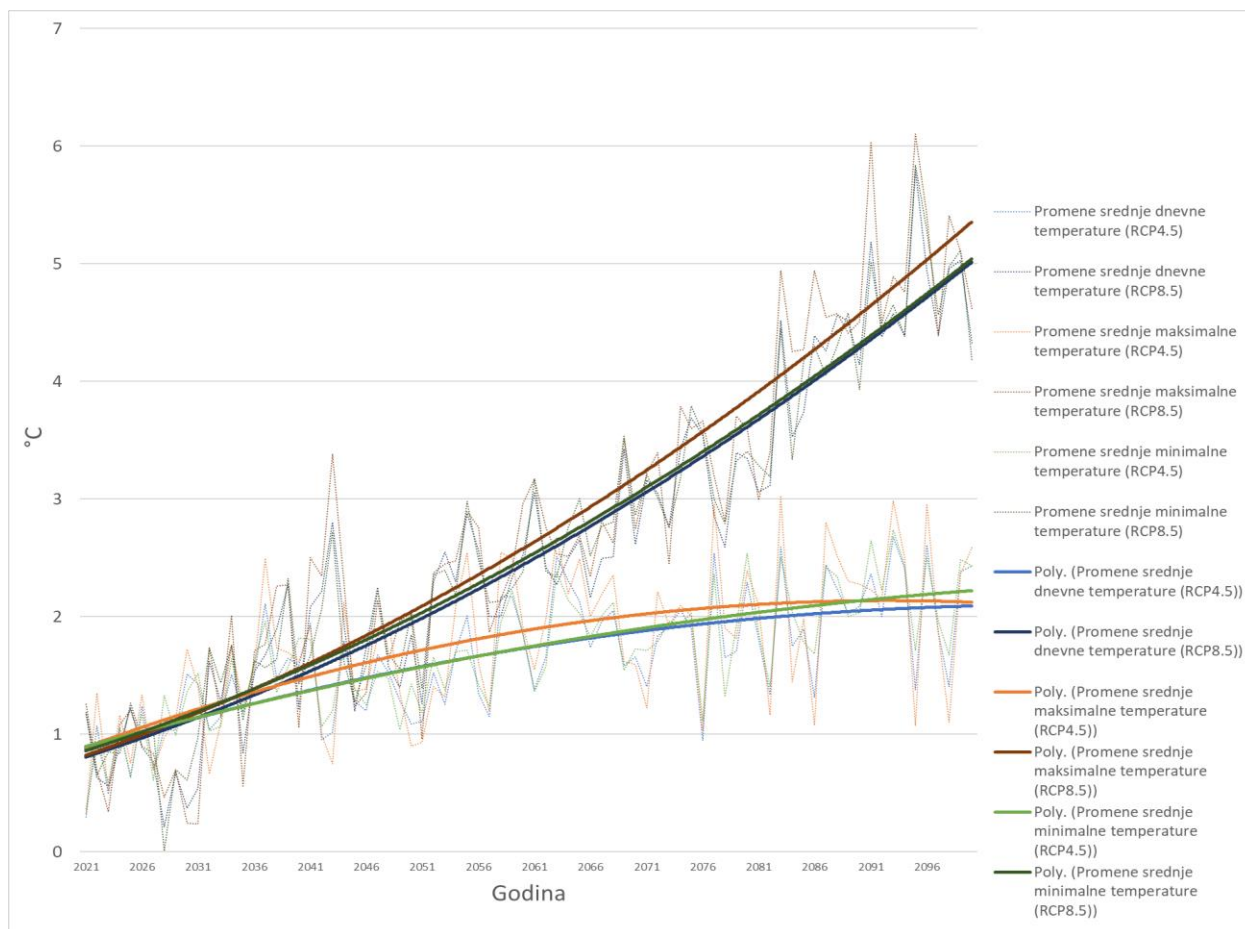


Figure 8. Projected changes in average daily temperature, average maximum temperature, and average minimum temperature in the City Municipality of Medijana for the period 2011–2100 under RCP4.5 and RCP8.5 scenarios.

Regarding precipitation, a mild decrease is expected in the future. A notable reduction in the average annual cumulative precipitation in Mediana city municipality is expected to occur only in the period from 2071 to 2100, based on the RCP8.5 scenario (2% to 3.5%, depending on the reference period). The reduction in precipitation will be more pronounced in the summer and winter, while it will be minimal in the spring and autumn.

### Expected changes in climate indices

The overall average number of summer days per year, defined as days with a daily maximum temperature exceeding 25°C, is set to notably rise in the future. In the near future, compared to the reference period of 1971-2000, there will be an increase of 16 days under the mitigation scenario and an increase of 15 days compared to the reference period of 1986-2005. Looking ahead to the period from 2071 to 2100, there will be an increase of 29 days compared to the reference period of 1971-2000 and an increase of 28 days compared to the reference period of 1986-2005, potentially reaching up to +55 days in the period from 2071 to 2100 under the scenario without mitigation. A similar trend is anticipated for tropical days, with a potential increase of +29 days by 2070 and +54 days by 2100 (Figure 9).

The number of days with extreme temperatures above 35°C, which averaged 1 to 2 per year during the period 1971-2000, will likely increase to 4 in the near future, or 10 to 11 in the period 2070-2100, and if there is no mitigation, to 5 in the near future, or even 27 in the period 2070-2100. The number

of tropical nights (annual count of days when daily minimum temperature is above 20°C) will also significantly increase, from an average number below 1 in the reference period 1971-2000, to almost 20 in the distant future without mitigation of climate change (Figure 9).

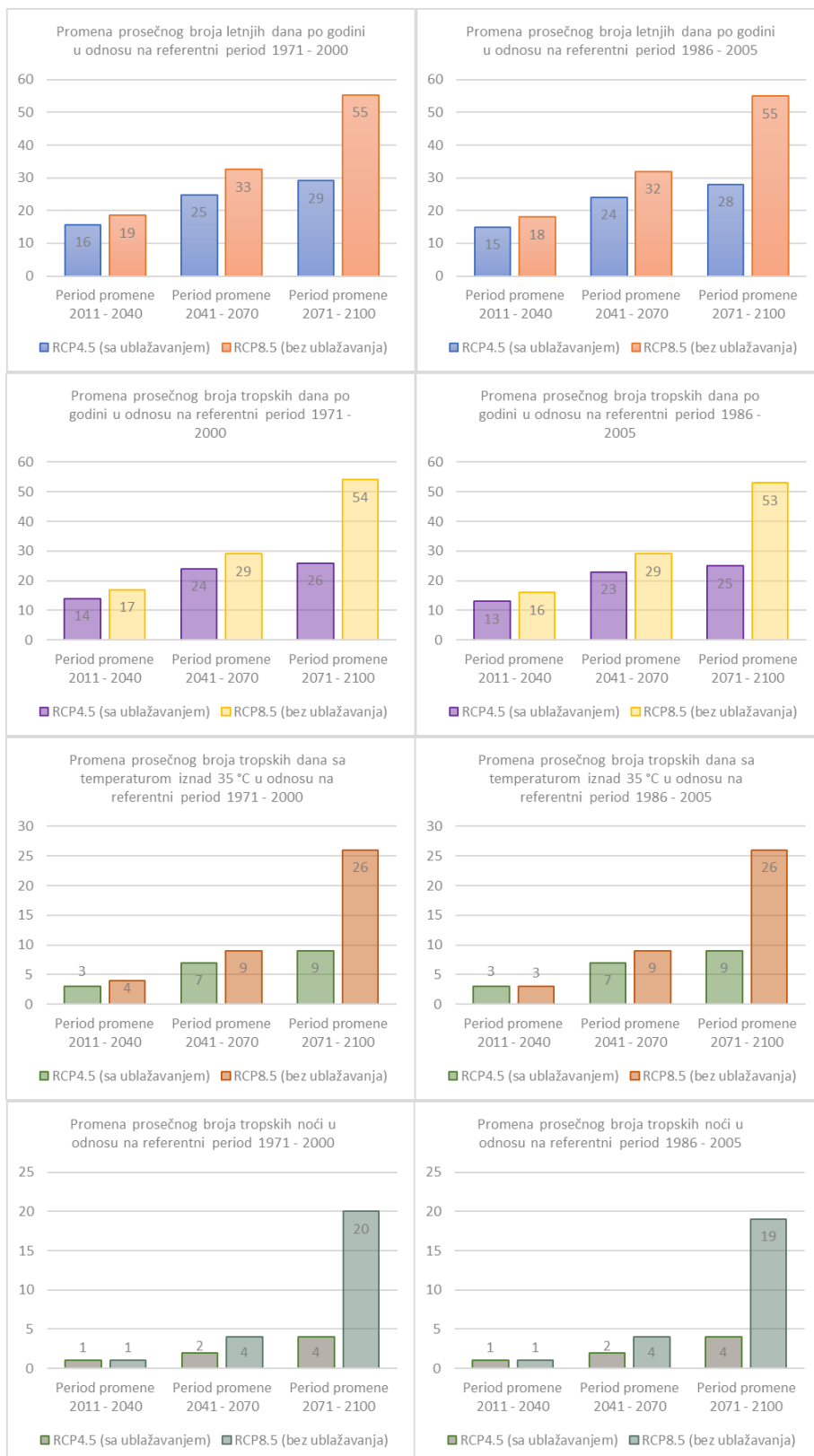


Figure 9. Expected changes in climate indices in the Nišava District. (1)

The heatwaves in Serbia did not occur every year on average before 1990, with their average number per year being less than one. In the last decade, the number of heatwaves per year in the Nišava District has increased to 2.45 per year on average, while in the period 2071-2100, 3 heatwaves per year can be expected under the mitigation scenario and up to 7 under the no mitigation scenario. The duration of heatwaves will also increase: in the period 2011-2040 by 13 (15 under the RCP8.5 scenario) days per year, in the period 2041-2071 by 21 days (32 under the RCP8.5 scenario), and in the period 2071-2100 by 29 days (up to 71 under the RCP8.5 scenario). It should be noted that in the decade 2011-2020, the average number of heatwaves per year in Serbia was more than 4 (more than statistically modeled), indicating a faster increase in the frequency of years with prolonged extremely warm periods (Figure 10).

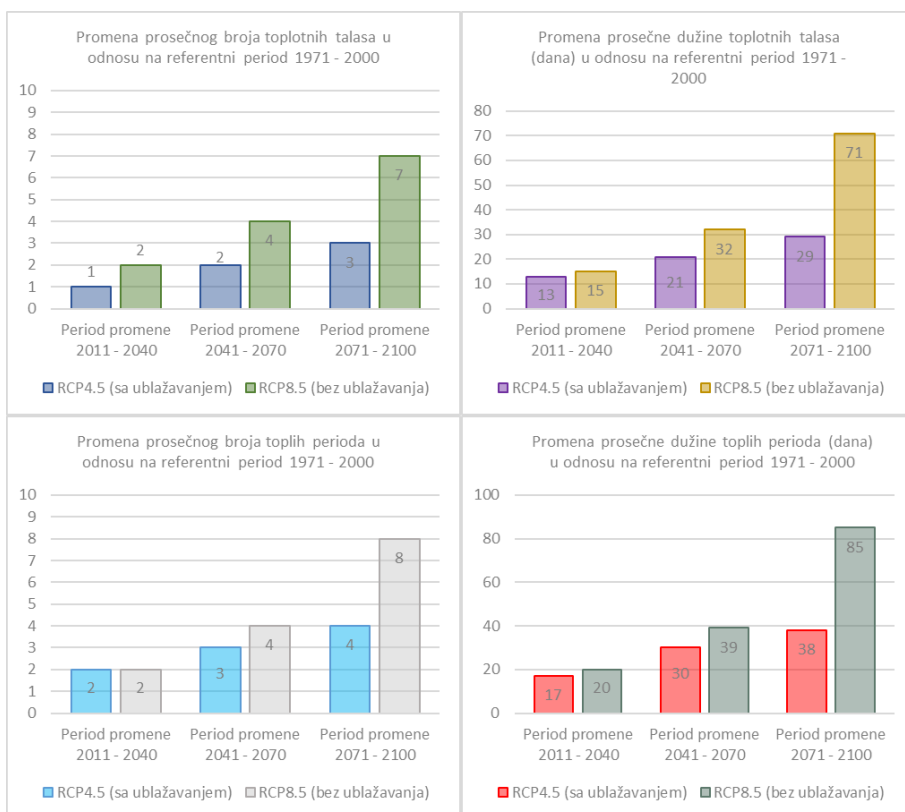


Figure 10. Expected changes in climate indices in the Nišava District. (2)

Before 1990, heatwaves in Serbia did not occur every year, with an average of less than one per year. However, in the last decade, the number of heatwaves per year in the Nišava District has increased to an average of 2.45 per year. Looking ahead, in the period 2071-2100, 3 heatwaves per year can be expected under the mitigation scenario and up to 7 under the no mitigation scenario. Additionally, the duration of heatwaves is projected to increase over time: by 13 days per year in the period 2011-2040 (15 under the RCP8.5 scenario), by 21 days in the period 2041-2071 (32 under the RCP8.5 scenario), and by 29 days in the period 2071-2100 (up to 71 under the RCP8.5 scenario). Notably, in the decade 2011-2020, the average number of heatwaves per year in Serbia exceeded 4, indicating a rapid increase in the frequency of years with prolonged extremely warm periods (Figure 10).

As Serbia currently lacks a defined methodology for monitoring and declaring drought, the analysis of the Standardized Precipitation-Evapotranspiration Index (SPEI6a) is utilized. This index covers a 6-month period ending in August, using values from the reference period of 1971-2000, similar to the analysis carried out in the Programme for Adaptation to Changed Climatic Conditions with Action Plan. The analysis indicates that changes in accumulated precipitation and, particularly, rising temperatures will lead to an increase in the number of drought years. There is a noticeable trend of decreasing

average values of the SPEI6a index across all observed periods, indicating an increase in the number of drought years in a ten-year span. This increase extends to as many as ten drought years within a ten-year period in the decade 2091-2100 for the scenario without mitigation, implying that each year will, on average, experience drought conditions and that droughts will become stronger and more prolonged.

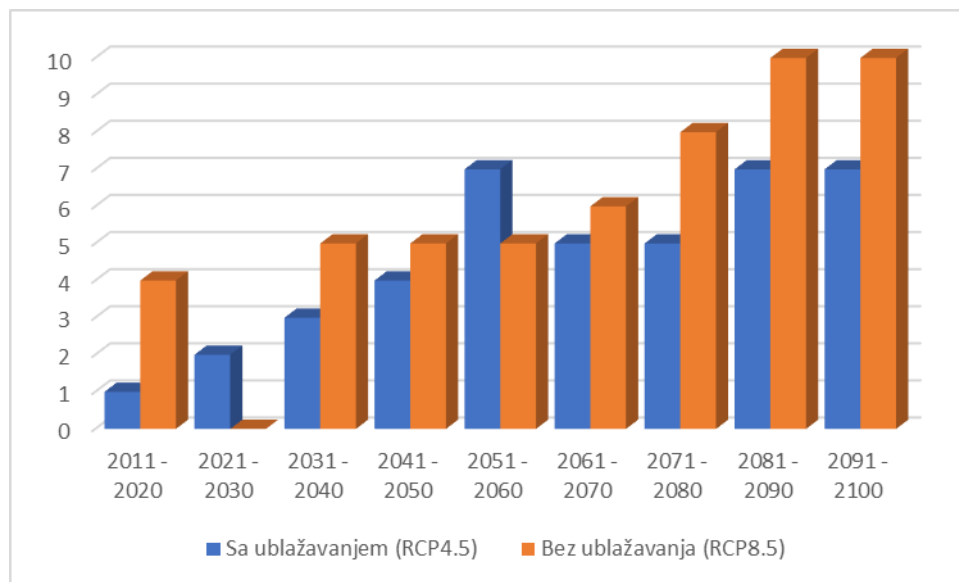


Figure 11. Expected number of drought years per decade in the Nišava District during the period 2011–2100.

## Discussion

The comprehensive analysis of both observed and projected climate changes in the territory of the City Municipality of Medijana unequivocally demonstrates that the region is experiencing and will continue to experience significant climate shifts. These changes are consistent with global and regional trends but are further intensified by local urban characteristics, placing Medijana among the particularly vulnerable areas in Serbia.

Over the past two decades, the territory of Medijana has seen a substantial rise in average daily temperatures—up to 1.82°C above the 1961–1990 baseline in the most recent decade. The increase in maximum temperatures is particularly pronounced, accompanied by more frequent and intense heatwaves, longer warm periods, and a marked decline in frost and ice days. These developments are clear indicators of a shift toward a warmer and more volatile local climate.

Precipitation patterns have remained largely unchanged in terms of total annual quantities, but notable changes in timing and intensity were detected. There has been a shift in the seasonal distribution of precipitation toward earlier spring, as well as increases in maximum one-day and five-day rainfall totals, pointing to a greater risk of flash floods. At the same time, the number of dry spells and drought-prone periods is growing, suggesting more pronounced hydrological extremes.

Urban effects such as the “heat island” phenomenon in densely built-up Medijana have further intensified warming, particularly in comparison to surrounding municipalities. This indicates that built environment characteristics significantly modulate local climate dynamics, with implications for heat stress, energy consumption, and urban health outcomes.

Projections for future climate conditions in Medijana, based on RCP4.5 and RCP8.5 scenarios, paint a concerning picture. If greenhouse gas emissions are not curtailed (RCP8.5), average annual

temperatures could rise by over 4°C by the end of the century. Maximum daily temperatures could increase by more than 5°C, dramatically expanding the number of summer days, tropical days, and tropical nights. The number of extremely hot days (above 35°C) may increase more than tenfold, with potential serious health consequences, particularly for vulnerable populations.

Similarly, the number and duration of heatwaves are expected to grow significantly. While in the reference period heatwaves were rare and short-lived, projections suggest that under a no-mitigation scenario, the number could reach seven per year, with durations extending beyond two months annually by 2100.

The number of drought years is also projected to increase drastically, especially toward the end of the century. Under RCP8.5, drought conditions may become the norm, occurring in virtually every year in the final decades of the century. This raises urgent concerns for agriculture, water supply, ecosystem stability, and overall climate resilience.

The described changes are likely to exacerbate existing vulnerabilities in urban infrastructure, energy systems, water management, and public health. Some of the anticipated impacts include increased energy demand for cooling during longer and hotter summers; strain on water resources, with reduced availability and quality of drinking water; greater health risks, especially from heat stress, respiratory issues, and vector-borne diseases; increased frequency of urban flood events; damage to infrastructure from temperature extremes and precipitation-related stressors; loss of biodiversity, especially in peri-urban ecosystems; and economic disruptions due to climate-related damages and adaptation costs.

## Conclusions and recommendations

Climate change is no longer a distant possibility—it is a present and accelerating challenge with far-reaching consequences. The City Municipality of Medijana must urgently embrace a holistic and evidence-based approach to adaptation and mitigation. The findings of this analysis provide a strong foundation for future planning, enabling the local government, civil society, and the private sector to work together in creating a resilient and sustainable urban environment.

The analysis of climate change impacts in the City Municipality of Medijana reveals a clear and consistent warming trend, both historically and in future projections. Between 2001 and 2020, the region experienced a notable rise in average daily, maximum, and minimum temperatures, with the most significant increases occurring during the summer months. These changes are further intensified in the more recent decade (2011–2020), confirming a local manifestation of broader global climate trends.

Precipitation patterns have remained relatively stable in terms of annual totals but exhibit growing irregularity in seasonal distribution and intensity. Notably, the frequency and intensity of extreme weather events—such as heatwaves, droughts, and heavy precipitation—have increased significantly, pointing to greater climate variability and more frequent climate extremes.

Urban factors, such as the heat island effect in densely populated Medijana, contribute to higher local temperature increases compared to surrounding areas, highlighting the vulnerability of urban environments to climate change. The growing number of summer days, tropical nights, and extreme heat events underscores the need for targeted local adaptation strategies.

Looking ahead, the projections under both RCP4.5 (mitigation) and RCP8.5 (non-mitigation) scenarios indicate that warming will continue, with potentially severe consequences by the end of the 21st century if mitigation measures are not implemented. Under the high-emission scenario, average

annual temperatures could rise by over 4°C by 2100, with a drastic increase in extreme heat days and prolonged drought periods. These conditions are expected to have serious implications for public health, infrastructure, water availability, agriculture, and biodiversity.

The findings of this analysis underline the urgent need for local and regional climate adaptation planning. Strategic actions should prioritize enhancing urban resilience, managing water resources sustainably, upgrading infrastructure to withstand extreme events, and implementing early warning systems and health protections. Climate change is no longer a distant risk—it is a current reality with escalating impacts. Immediate and sustained mitigation and adaptation efforts are critical to safeguard the well-being of the residents of Medijana and ensure the region's sustainable development.

Given the high likelihood and severity of climate impacts, the City Municipality of Medijana must take proactive steps to adapt and build resilience. The following measures are recommended:

- Development of a Local Climate Adaptation Action Plan, aligned with Serbian 2023 – 2030 Climate Change Adaptation Programme (NAP), and international commitments (e.g., the Paris Agreement);
- Implementation of nature-based solutions (e.g., urban greening, restoration of natural water retention areas) to mitigate urban heat and flood risks;
- Upgrading of infrastructure to ensure resilience to heatwaves, heavy precipitation, and drought (e.g., permeable pavements, green roofs, energy-efficient buildings);
- Establishment of early warning systems and health response protocols for extreme weather events;
- Capacity building and awareness-raising among stakeholders, from policymakers to local communities;
- Integration of climate risks into land use and spatial planning, prioritizing areas most vulnerable to climate impacts;
- Monitoring and continuous assessment of local climate indicators to inform adaptive decision-making.

## References

Milutinović, S. (2023). Climate change adaptation planning at the local level in Serbia: Current status and lessons learned. *Facta Universitatis, Series: Working and Living Environmental Protection*, 20(2), 63 - 76.

The Government of the Republic of Serbia. (2023). Low Carbon Development Strategy of the Republic of Serbia for the period from 2023 to 2030 with Projections until 2050. Belgrade: Official Gazzete of RS, 46/2023.

The Government of the Republic of Serbia. (2023). Program for Adaptation to Changed Climatic Conditions for the period 2023 - 2030 with Action Plan. Belgrade. Available online at [https://www.srbija.gov.rs/extfile/sr/757263/program-prilagodjavanja-na-izmenjene-klimatske-uslove-za-period-od-2023-do-2030\\_0098-lat.zip](https://www.srbija.gov.rs/extfile/sr/757263/program-prilagodjavanja-na-izmenjene-klimatske-uslove-za-period-od-2023-do-2030_0098-lat.zip)

Cornes, R., G. van der Schrier, E.J.M. van den Besselaar, P.D. Jones (2018). An Ensemble Version of the E-OBS Temperature and Precipitation Datasets. *JGR Atmospheres*, 123 (17), 9391-9409

Ministry of Environmental Protection (2022). Digital Atlas of Climate and Climate Change of the Republic of Serbia. Project "Improvement of medium- and long-term planning of adaptation measures to changed climate conditions in the Republic of Serbia". Available online at <https://atlas-klime.eko.gov.rs>