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Characterization of climate change in Lithuania in 1961–2020 using climate extreme indices

Juras Šukys*, Justinas Kilpys

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Abstract. Climate change manifests not only through shifts in mean conditions but also through increasing extremes. We analyzed changes in 12 extreme temperature and precipitation indices in Lithuania for the 1961–2020 period. We assessed trends and compared change in exceedance probabilities between 1961–1990 and 1991–2020. Results shows that the probability of hot days exceeding the 95th percentile more than doubled at both Vilnius and Klaipėda stations, while the probability of experiencing 10 very cold nights per year decreased from 65% to 25%. Over the past 60 years, the growing season length increased by 10 days, with the largest extension in Nida (27 days). Tropical nights began to emerge; however, a statistically significant increasing trend was determined only in Nida (0.5 nights per decade). Extreme precipitation also intensified: days with more than 20 mm of rainfall increased from 1 to 7 per year by the end of the study period. At the same time, the number of consecutive dry days also increased, indicating the increasing weather extremes in Lithuania as the global climate changes.

Keywords: *climate change; climate extreme indices; temperature; precipitation. climate variability; Lithuania; Baltic region*

✉ *Juras Šukys* (jurasukys@gmail.com),*
Justinas Kilpys (justinas.kilpys@chgf.vu.lt), *https://orcid.org/0000-0002-9998-0824,*
Vilnius University, Faculty of Chemistry and Geosciences, Institute of Geosciences, M.K. Čiurlionis 21/27, LT-03101 Vilnius, Lithuania
**Corresponding author*

INTRODUCTION

As the mean temperature of the planet increases, extreme climate events are becoming more frequent and more intense in many regions (Easterling *et al*. 2000; Newman, Noy 2023; Walsh *et al*. 2020). Over the last 50 to 100 years, different parts of the world have experienced increasing trends in climate and weather extremes (Heim 2015). Heat waves are among the fastest-increasing extreme events (AghaKouchak *et al*. 2020), with intense heat having a direct negative impact on human health, vegetation, and animal conditions, especially on vulnerable populations and fragile ecosystems (Khraishah *et al*. 2022; Teskey *et al*. 2015). Regions with already hot summers face a particularly high risk, and continued warming could render some areas uninhabitable (Steel *et al*. 2022).

Together with temperature rise, extreme precipitation events are also increasing in many parts of the world (O'Gorman, Schneider 2009; Sun *et al*. 2022). Global warming causes the acceleration of the hydrological cycle, which leads to a change in the frequency of extreme precipitation and drought events (Ehtasham *et al*. 2024; Pokhrel *et al*. 2021). Shifts in precipitation distribution negatively affect agriculture, intensify food scarcity, and degrade water quality (Amparo-Salcedo *et al*. 2025; Sinha *et al*. 2017). According to Monachese *et al*. (2025), increasing precipitation also poses challenges for water drain age and wastewater systems, particularly in urban areas where infrastructure may be overwhelmed.

Studies show that in the eastern Baltic Sea region, including Lithuania, mean annual minimum and maximum temperatures have increased by 0.3 °C/decade (Jaagus *et al*. 2014; Kažys *et al*. 2011). The total annual precipitation is also rising by 7–18 mm/decade, with the smallest increase observed in Lithuania (Jaagus *et al*. 2018). Extreme precipitation exhibits clear spatial patterns influenced by topography, with the highest daily values occurring along the Lithuanian Baltic Sea coast (Klimavičius *et al*. 2025). According to Ramanauskas *et al*. (2024), temperatures in the Baltic region in the 21st century will increase at a greater rate than the global average, primarily due to a high magnitude of warming in winter. Warm winters also mean an increase in liquid precipitation, and it will be the main contributor to the projected annual increase in total precipitation (Ramanauskas *et al*. 2024; Rimkus *et al*. 2018).

Most previous studies in the region have focused on changes in the mean annual and monthly temperature and precipitation. However, average values do not accurately capture the evolving frequency and intensity of extreme events (Di Luca *et al.* 2020). In this study, we used 12 climate indices to assess changes in temperature and precipitation extremes in Lithuania from 1961 to 2020. Our goal was to identify the trends in these indices and use them to describe the country's climate change patterns.

DATA AND METHODS

The study area focuses on Lithuania, located in the eastern part of the Baltic Sea region and characterized by a mostly flat landscape with low hills. According to the Köppen–Geiger classification, Lithuania's climate is predominantly warm-summer humid continental (Dfb), with cold winters and warm summers, except for a narrow zone along the Baltic Sea coast that belongs to the temperate maritime climate type (Cfb) (Rimkus *et al.* 2018). The types of extreme temperature and precipitation events observed are similar across the country, although their intensity and frequency may vary by region.

For the analysis of extreme climate event we used climate indices developed and recommended by the Expert Team for Climate Change Detection Monitoring and Indices (ETCCDMI) (Klein Tank *et al.* 2009). These indices capture the key aspects of a changing climate – including shifts in the intensity, frequency, and duration of extreme temperature and precipitation events – and include absolute, percentile-based, threshold, and duration indices (Alexander *et al*. 2006). To derive these indices for Lithuania, we used daily observations from 18 meteorological stations for the period from 1961 to 2020. The exception was Dūkštas stations, where in-situ observations begun on 11 08 1971. The main variables used for index calculation were daily precipitation amount, maximum daily temperature, minimum daily temperature, and mean daily temperature.

The calculation of climate extreme indices for each meteorological station was performed using the CLIMPACT package in R programming language (Climpact 2024). The input consisted of daily meteorological variables, geographical coordinates of the meteorological station, and the period of available observations. Although CLIMPACT can compute 78 extreme climate indices, we derived 12 indices for each station in this study. These indices were selected for their relevance in characterizing climate change in Lithuania and their direct implications for society. A detailed description of the indices is provided in Table 1. All indices represent annual values of the respective phenomena.

The change rates of the climate extreme indices were estimated using Sen's slope, and the statistical significance of these trends was evaluated using the Mann-Kendall test. A trend was considered statistically significant when the Mann-Kendall test statistic reached a significance level of $p < 0.05$. In addition, we assessed changes in the probability of extreme events for three indices: very hot days (TX90p), cold nights (TN10p), and the annual probability of heavy precipitation events (R95p). Changes in event probabilities were evaluated by comparing two periods, 1961–1990 and 1991–2020. Probabilities were derived using cumulative distribution functions for two

Table 1 Climate extreme indices used in this study

Index	Description	Units
TX90p	Annual percentage of days when maximum temperature (TX) > 90th percentile	%
TN10p	Annual percentage of days when minimum temperature (TN) < 10th percentile	%
CDDcold25	Cooling degree days when daily mean temperature is higher than 25˚C	°C
GSL	Growing season length. A period with at least 6 days with daily mean temperature > 5 °C	Days
TMge5	Number of days per year when daily mean temperature ≥ 5°C	Days
TR	Number of tropical nights per year when daily minimum temperature > 20 °C	Nights
HDDheat10	Heating degree days when daily mean temperature < 10 ˚C	°C
R20mm	Annual count of days when daily precipitation amount ≥ 20 mm	Days
CDD	The largest number of consecutive days where daily precipitation amount < 1 mm	Days
R99p	Total annual precipitation from very heavy rain days (> 99th percentile)	mm
R95p	Total annual precipitation from heavy rain days (> 95th percentile)	mm
Rx5day	Annual max 5-day precipitation	mm

stations – Vilnius and Klaipėda – which represent distinct climate regimes. Klaipėda characterizes the maritime climate (Cfb), whereas Vilnius represents the transitional continental climate (Dfb).

RESULTS

Trends and extreme values of climate indices

Our analysis showed that most of the climate indices related to the high temperatures (TX90p, TMge5, CDDcold25) and precipitation extremes (CDD, R95p, Rx5day) are increasing at the majority of meteorological stations in Lithuania (Table 2). At the same time, there is a decrease in TN10p and the number of heating degree days (HDDheat10) in all stations, indicating a significant decrease in extreme cold events. Although heavy precipitation events show an overall increasing tendency, statistically significant trends are observed at only 20–22 % of stations (Table 2). The fastest change rates of temperature indices were observed on the Baltic Sea coast (Nida, Klaipėda) whereas the largest changes in precipitation indices are found in southern Lithuania (Lazdijai).

During the study period, 9 out of 12 record-high climate indices values were observed in Nida (Table 3). Located on the Curonian Spit, the Nida station exhibits a distinct local climate compared with the continental part of Lithuania. Also, it is important to note that in all stations 2/3 of the maximum index values occurred within the last 15 years. This is an indication of a climate shift towards more frequent and more intense climate extremes.

Changes in temperature extremes

As the mean annual temperature in Lithuania increases, we observe a corresponding extension of the growing season (GSL) and a decrease in the heating degree days (HDDheat10). On average, the GSL is getting longer by the rate of 1.75 days per decade; however, this increasing trend is statistically significant only in Nida and Telšiai (Fig. 1). The largest lengthening of GSL was observed in western

Table 2 Trends of the analyzed climate extreme indices in Lithuania in 1961–2020. The trend column shows the number of stations with different tendencies, and the number in brackets shows the number of stations where trends are statistically significant ($\alpha < 0.05$). The change rate column shows mean, minimum, and maximum observed trend slope; statistically significant change rates are marked in bold

Index (unit)	Trend in number of stations		Change rate per decade		
	Increasing	Decreasing	Mean	Min	Max
TX90p (%)	18 (18)	0 (0)	1.74	**1.45** (Šilutė)	**2.19** (Dūkštas)
TN10p (%)	0 (0)	18 (17)	–1.22	–0.62 (Dūkštas)	**–1.88** (Nida)
CDDcold25 (°C)	18 (18)	0 (0)	0.00	–	**0.04** (Ukmergė)
GSL (days)	16 (2)	2 (0)	1.75	–0.45 (Vilnius)	**4.44** (Nida)
TMge5 (days)	18 (18)	0 (0)	4.39	**3.70** (Panevėžys)	**6.1** (Nida)
TR (nights)	18 (14)	0 (0)	0.03	–	**0.53** (Nida)
HDDheat10 (°C)	0 (0)	18 (18)	–97.8	**–83.9** (Klaipėda)	**–110.7** (Dotnuva)
R20mm (days)	18 (5)	0 (0)	0.11	–	**0.50** (Lazdijai)
CDD (days)	18 (2)	0 (0)	0.44	–	**1.0** (Panevėžys)
R99p (mm)	17 (3)	1 (0)	1.18	–	**6.30** (Lazdijai)
R95p (mm)	18 (4)	0 (0)	7.09	0.98 (Panevėžys)	**21.8** (Lazdijai)
Rx5day (mm)	15 (3)	3 (0)	1.22	–0.68 (Dūkštas)	**3.19** (Lazdijai)

Table 3 Highest and lowest values of climate extreme indices for the period 1961–2020

Index	Maximum			Minimum		
	Value	Year	Station	Value	Year	Station
TX90p	35	2020	Nida	1	1965	Nida
TN10p	29	1987	Nida	1	2020	Nida
CDDcold25	15,8	1994	Nida	0	–	18 stations
GSL	314	2005	Klaipėda	152	1979	Laukuva
TMge5	274	2020	Nida	173	1976	Dūkštas
TR	17	2010	Nida	0	–	18 stations
HDDheat10	2836	1985	Dūkštas	933.3	2020	Nida
R20mm	13	2007	Nida, Šilutė	0	–	16 stations
CDD	61	1992	Nida	11	–	3 stations
R99p	255.3	2005	Varėna	0	–	18 stations
R95p	450,6	2017	Nida	0	–	3 stations
Rx5day	201.8	2005	Nida	27.1	1995	Dotnuva

and south-western Lithuania, which is influenced by a milder maritime climate and already has a higher number of days with mean temperature close to 5 °C. Similar pattern was identified when analyzing TMge5. The largest amount of such days was observed in Kybartai, Nida, Šilutė, and Klaipėda, while the smallest was in Varėna, Utena, Laukuva, Raseiniai, Telšiai, Dūkštas, Biržai, Vilnius, and Panevėžys (Fig. 2a). Although the rate of change in TMge5 varies from 3.7 to 6.1 days/decade in different parts of the country, trends are statistically significant at all stations (Fig. 2b).

When comparing the periods 1961–1990 and 1991–2020, we determined a shift of extreme temperature probabilities towards the higher values. The probability of experiencing 10 very hot days (TX90p) per year increased from 30% to 70% in Vilnius and from about 23% to 69% in Klaipėda (Fig. 3). Conversely, the probability of having 10 cold nights (TN10p) decreased from around 67 % to 25% in Vilnius and from 65% to 28% in Klaipėda (Fig. 4). These results indicate a shift in the temperature distribution toward warmer conditions and a reduction in cold extremes in Lithuania.

As the probability of hot days in Lithuania increases, the demand for cooling also rises. Our results show that the highest number of cooling degree days (CDDcold25) occurs in Vilnius, Klaipėda, Nida, and Ukmergė, while the lowest values are found in Raseiniai and Laukuva (Fig. 5a). The strongest increase rate of CDDcold25 was observed in Ukmergė, reaching 0.04°C/decade, but even smaller changes in the rest of the country are statistically significant (Fig. 5b).

While the cooling degree days are increasing, winters in Lithuania are becoming warmer, and the need for heating is decreasing. Our analysis shows that HDDheat10 decreased on average by 98°C/decade, with the highest decline observed in Biržai and Dotnuva (Fig. 6b). Throughout the study period, the largest average annual number of heating degree days was determined in the eastern part of the country, exceeding 2000°C per year. The smallest annual HDDheat10 values were recorded on the Baltic Sea coast, often bellow 1700°C (Fig. 6a). On average, HDDheat10 differs by about 27% between western and eastern Lithuania.

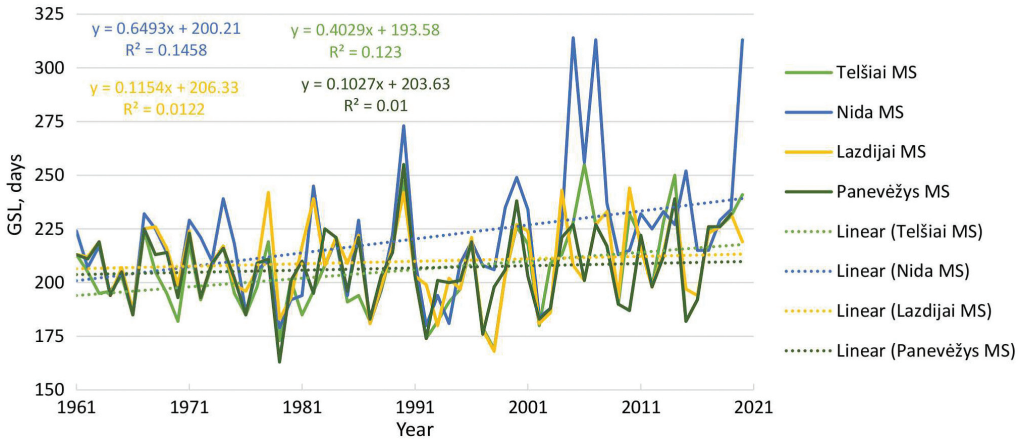

Fig 1 The change of the growing season length (GSL) over time in Telšiai, Nida, Lazdijai, and Panevėžys in the period of 1961–2020

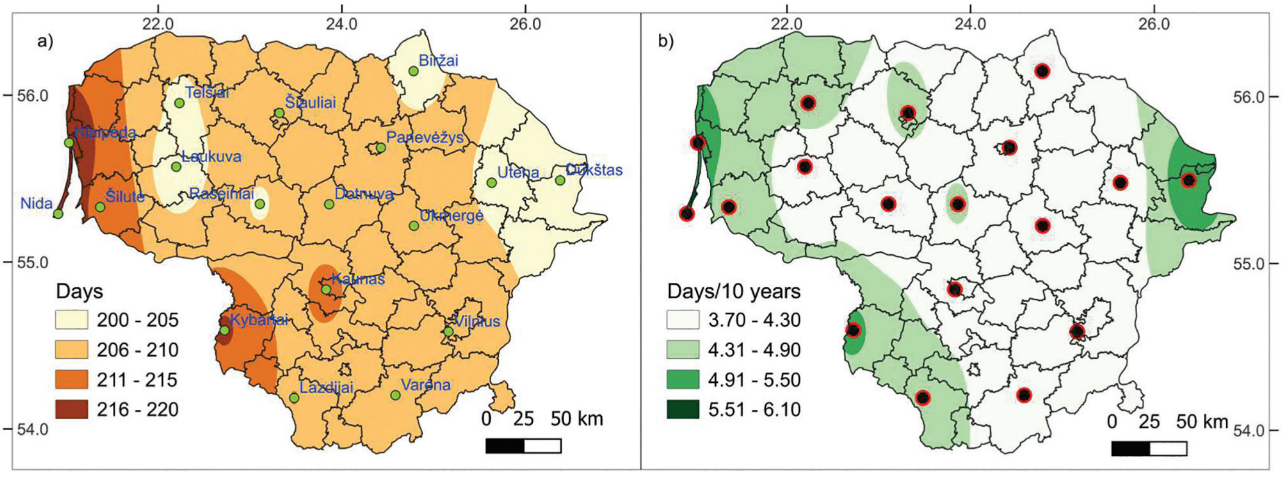

Fig. 2 The TMge5 spatial variation in Lithuania in 1961–2020: a) average number of cases per year, b) change rate (days/decade). Black dots with red circles mark the meteorological stations with a statistically significant trend

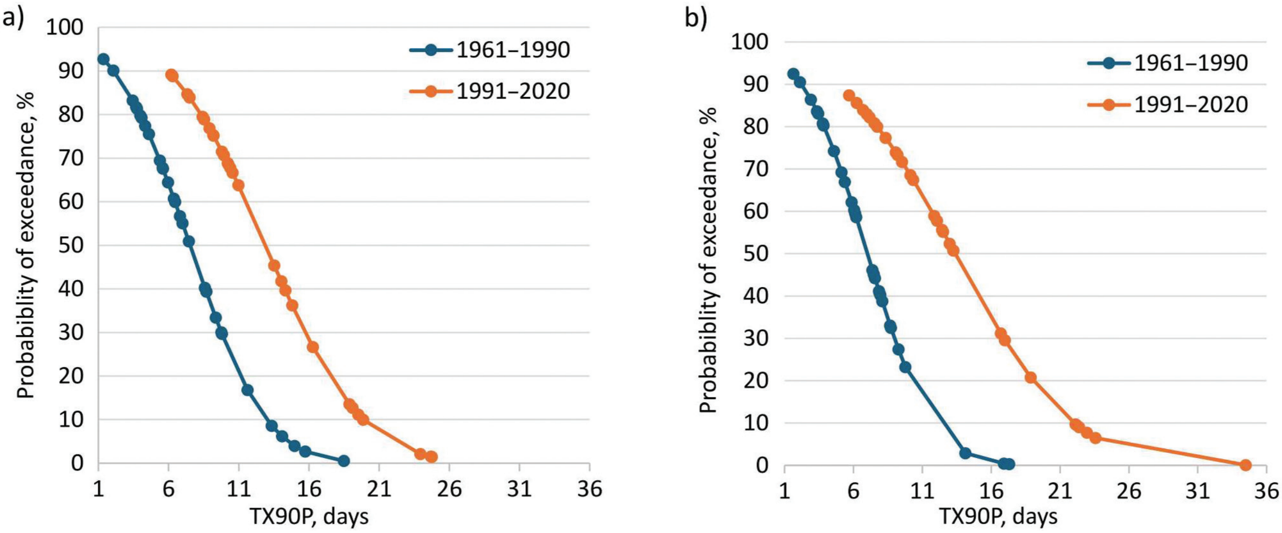

Fig. 3 Changes in the probability of exceedance of the annual number of hot days (TX90p) in: a) Vilnius, b) Klaipėda

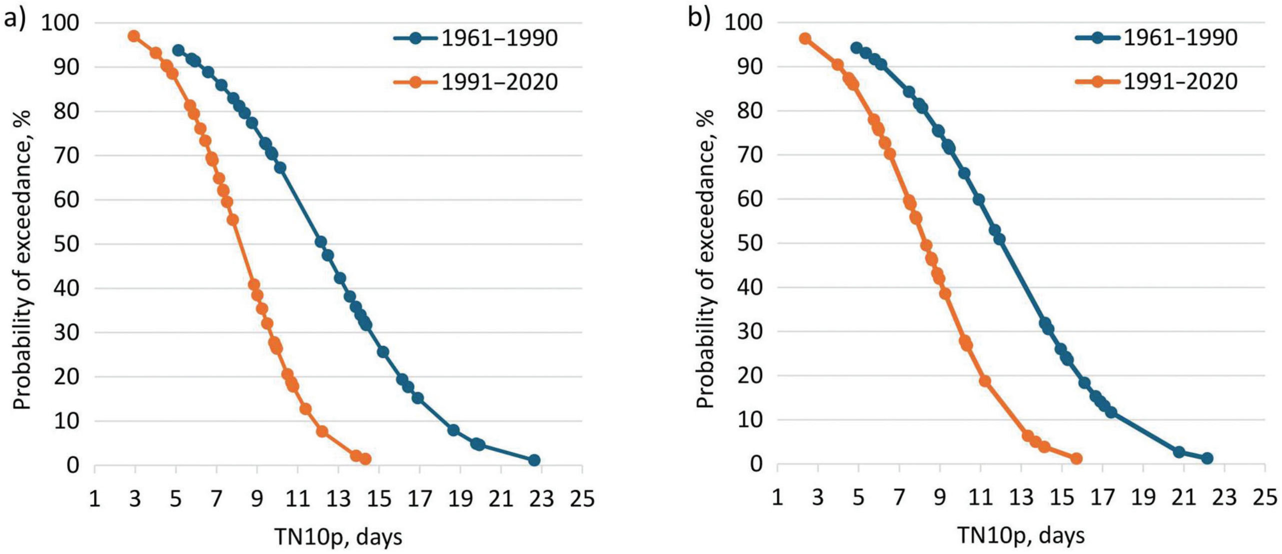

Fig. 4 Changes in the probability of exceedance of the annual number of cold nights (TN10p) in: a) Vilnius, b) Klaipėda

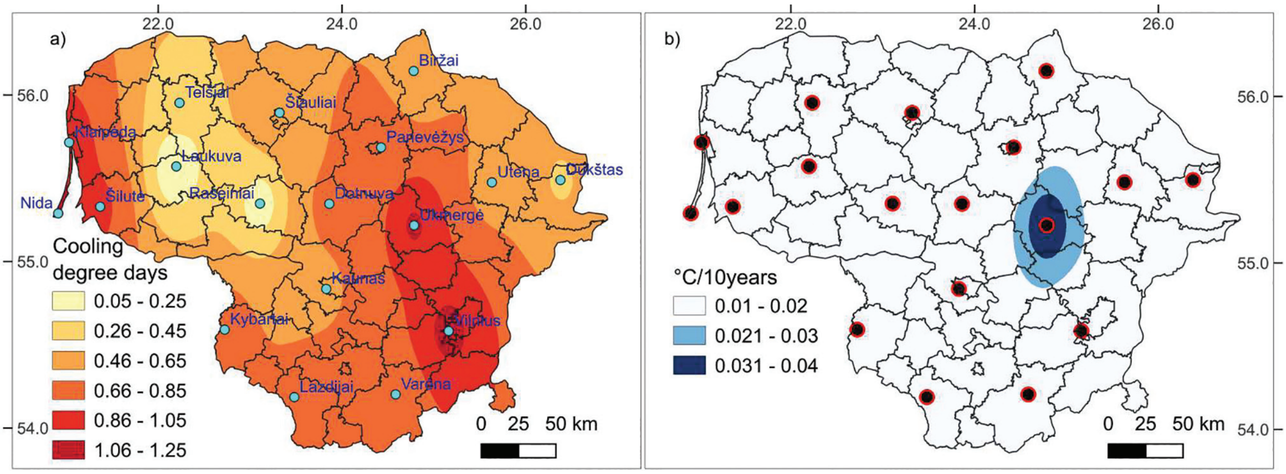

Fig. 5 The number of cooling degree days (CDDcold25) in Lithuania in 1961–2020: a) average number of cases per year, b) change rate (˚C/decade). Black dots with red circles mark the meteorological stations with a statistically significant trend

Another temperature-related climate extreme which increased in frequency during the 1961–2020 period was tropical nights (TR). The number of TR started to rise in the 1990s, and the most pronounced trend was determined in Nida, where frequency increased by 0.5 events per decade (Fig. 7). Tropical nights are most frequently recorded in the coastal region, where the warming influence of the Baltic Sea and the Curonian Lagoon helps nighttime temperatures remain above 20 °C even when temperatures in the rest of the country drop below this threshold (Dailidienė *et al.* 2023). Although the annual number of tropical nights at inland meteorological stations is generally low – rarely exceeding four events per year – their frequency has been increasing across all of Lithuania.

Changes in precipitation extremes

Our results show that the heavy and prolonged precipitation in Lithuania is becoming more frequent. We observed an increase in annual R20mm events and the total amount of precipitation that falls in 5 days (Rx5day). However, the trends are statistically significant in 6 out of 18 station data series. The spatial distribution of R20mm and Rx5day is very similar, with the largest values observed in the south-western and western part of Lithuania (Fig. 8–9).

During the study period, the highest rate of change for R20mm was determined in Lazdijai, up to 0.5 days/decade (Fig. 8 b). On average, the largest number of such cases occurred in Laukuva, Telšiai,

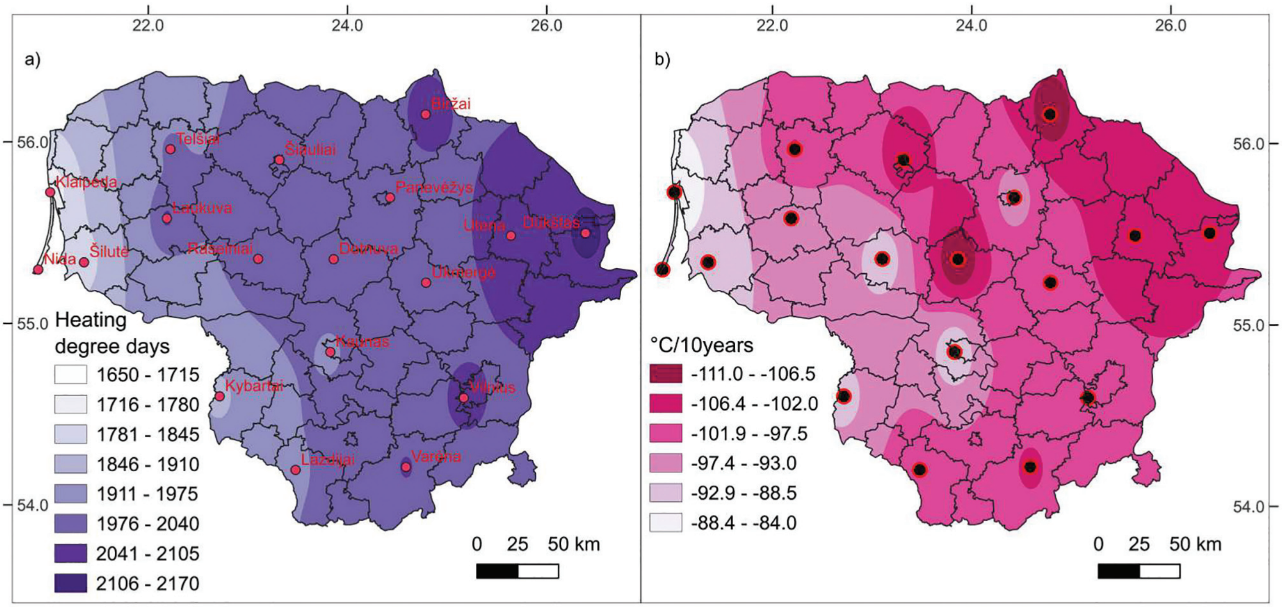

Fig. 6 The amount of heating degree days (HDDheat10) in Lithuania in 1961–2020: a) average number of cases per year, b) rate of change (˚C/decade). Black dots with red circles mark the meteorological stations with a statistically significant trend

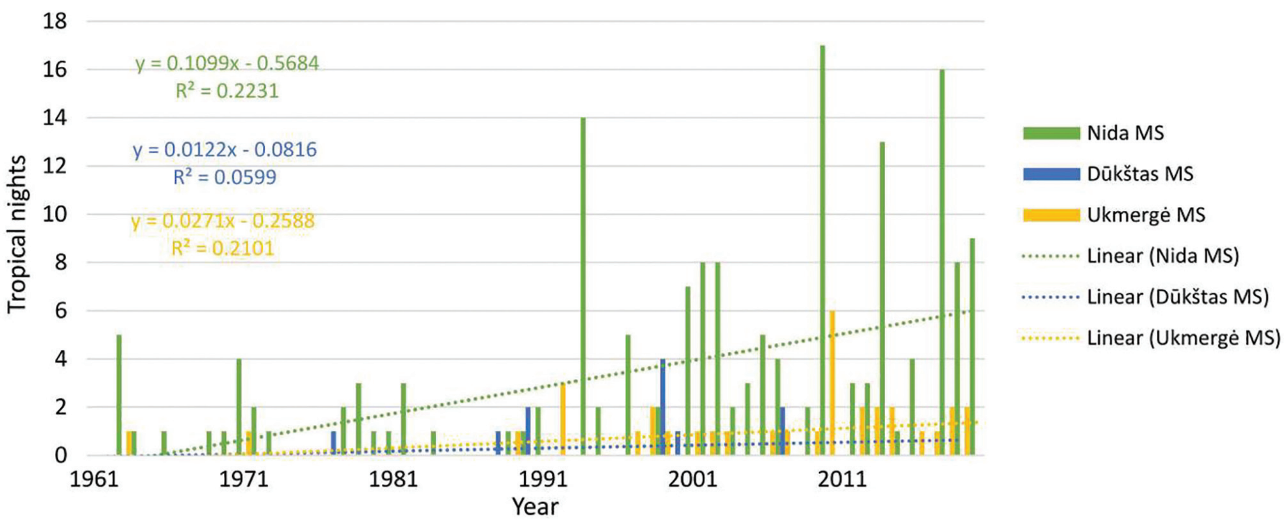

Fig. 7 The change in the number of tropical nights (TR) in Dūkštas, Ukmergė, and Nida for 1961–2020

Nida, Šilutė, and Klaipėda, while the lowest was in Biržai (Fig. 8a). Biržai is an interesting case because the annual number of R20mm cases was one of the lowest in Lithuania. However, the change rate is relatively rapid, 0.3 days/decade, and the trend is statistically significant.

Analysis showed that the highest Rx5day values were observed in Laukuva, Nida, Telšiai, and Šilutė. In contrast, the minimum values were determined in central Lithuania (Fig. 9a). The most significant increase of this type of precipitation was observed in Klaipėda and Lazdijai, up to 3.3 mm/decade (Fig. 9b). A statistically significant increasing trend of Rx5day was also detected in Biržai.

At the same time, as we see increasing precipitation totals of Rx5day, we also determine an increasing trend of consecutive dry days (CDD) in Lithuania. On average, in the period from 1961 to 2020, the largest number of CDD was observed in Dotnuva and Šiauliai (24 days), while the smallest number was noted in Vilnius (20 days) (Fig. 10a). The number of CDD is increasing fastest in Panevėžys, Raseiniai, and Šiauliai, up to 0.1 days/decade, but the trend is significant only in Raseiniai and Šiauliai (Fig. 9b).

Our analysis shows that total annual precipitation from very heavy rain days (R99p) has a tendency to increase, but the upward trend is statistically significant only in 3 stations: Biržai, Kaunas, and Lazdijai. The most significant change rate of R99p precipitation totals was observed in Lazdijai. It was higher than 6 mm/10 days (Fig. 11). The change rate of R99p index varies a lot in Lithuania, for example, in Biržai it is similar to Lazdijai, while in Varėna and Klaipėda it is about 2.5 times smaller and statistically insignificant (Fig. 11).

We also analyzed precipitation totals from heavy rain days (R95p), which are less intense than 99th-percentile events, but both thresholds capture extreme precipitation R95p in all stations and have an

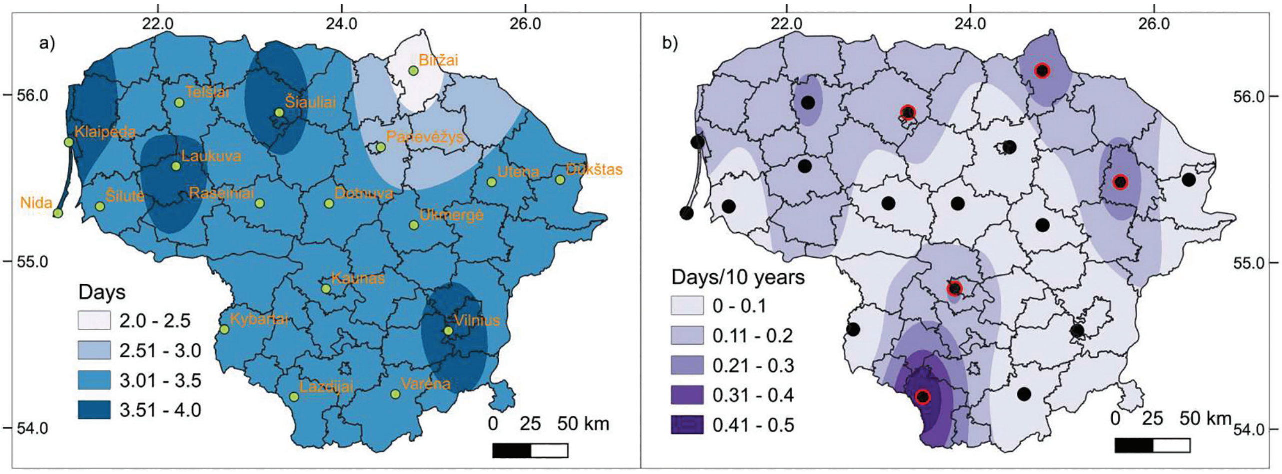

Fig. 8 The annual number of R20mm cases in Lithuania for the period 1961–2020: a) average number of cases per year, b) change rate (days/decade). Black dots with red circles mark the meteorological stations with a statistically significant trend

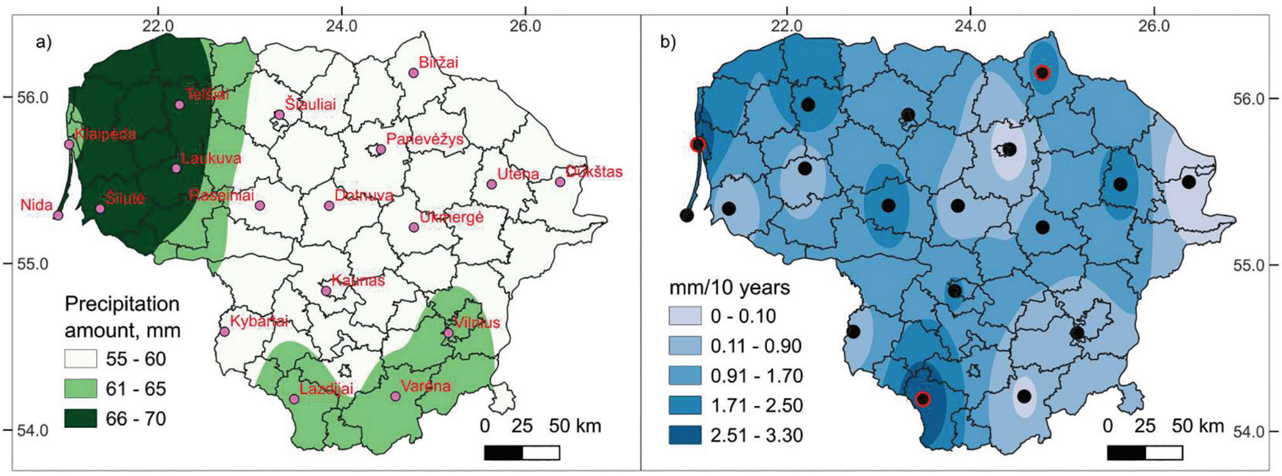

Fig. 9 The annual max 5-day precipitation amount (Rx5day) in Lithuania in the 1961–2020 period: a) average number of cases per year, b) change rate (mm/decade). Black dots with red circles mark the meteorological stations with a statistically significant trend

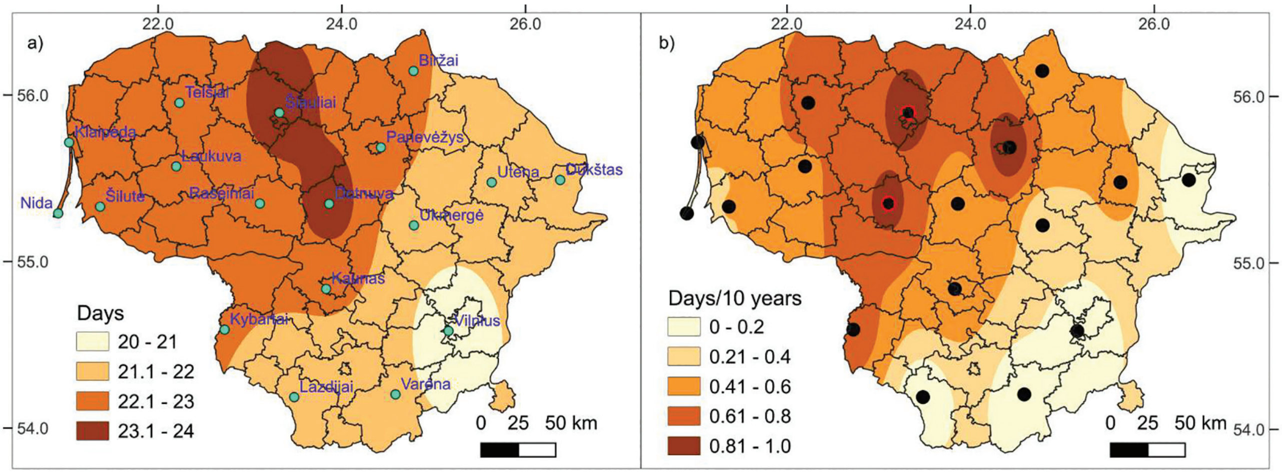

Fig. 10 The annual number of CDD in Lithuania in 1961–2020: a) average number of cases per year, b) rate of change (days/decade). Black dots with red circles mark the meteorological stations with a statistically significant trend

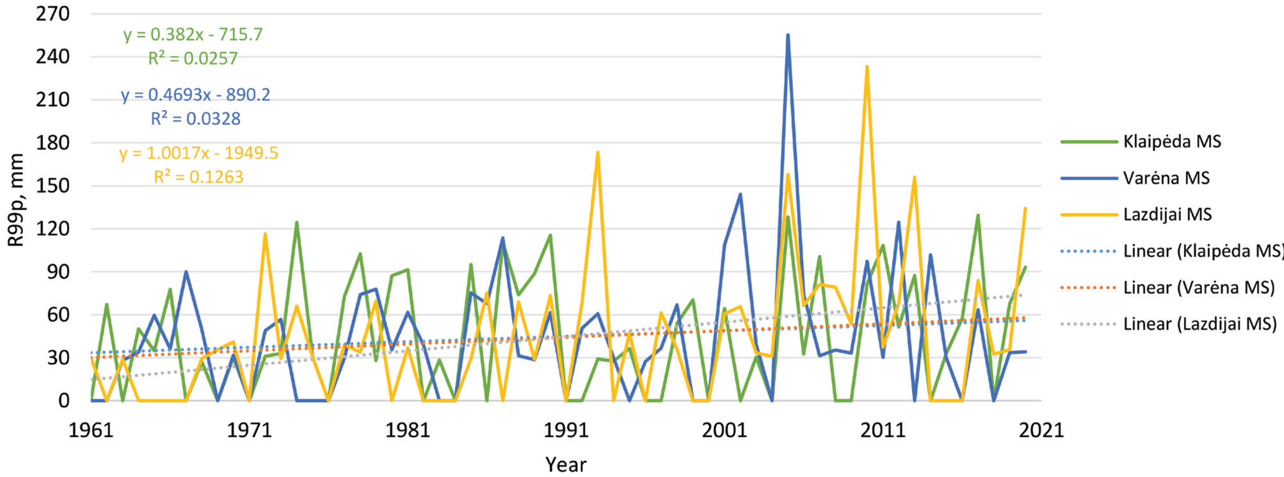

Fig. 11 The total annual precipitation from very heavy rain days (R99p) change overtime in Varėna, Lazdijai, and Klaipėda meteorological stations for the 1961–2020 period

increasing tendency, but it is statistically significant only in Biržai, Kaunas, Klaipėda, and Lazdijai. When comparing the 1961–1990 and 1991–2020 periods, we determined a shift in the probability of high precipitation accumulation from R95p events. In the 1961–1990 period, the probability of R95p exceeding 200 mm in Vilnius was only 12%, while in1991–2020 it rose to 31% (Fig. 12). However, the probability of R95p exceeding100 mm did not change and stayed at around 75%. Results in Vilnius indicate that in the recent decades there is an increase in the probability of a very high total amount or precipitation (> 250 mm) which falls during the intense rains (Fig. 12). The highest annual R95p values in Vilnius were determined in 2010 with the precipitation total of 395.6 mm. 11% of that annual amount fell on 28 August 2010, when Vilnius had heavy downpour with precipitation reaching 42.2 mm in one day.

Meanwhile, in the coastal area (in Klaipėda), the change in probabilities of index values is more uniform. The probability of all precipitation totals increased by 5–8% in 1991–2020. For example, the probability that R95p will reach 100 mm in Klaipėda in 1961–1990 was 69%, while the 1991–2020 probability grew to 77% (Fig. 12). In Klaipėda, the highest annual R95p values were observed in 2010, with a precipitation total of 350.6 mm. The heaviest precipitation event of that year occurred on 18 September 2017, with a total daily precipitation amount of 39.4 mm.

DISCUSSION

This paper aimed to analyze the climate change trends in Lithuania using climate extreme indices. Using long-term data from the 1961–2020 period, we were able to determine the statistical significance of observed trends and derive the change rate of different extreme climate events.

The findings of our study showed that climate phenomena associated with the warm season, such as hot days (TX90p), the number of days when the daily mean temperature is above 5°C (TMge5), and cooling degree days (CDDcold25), are on the rise in

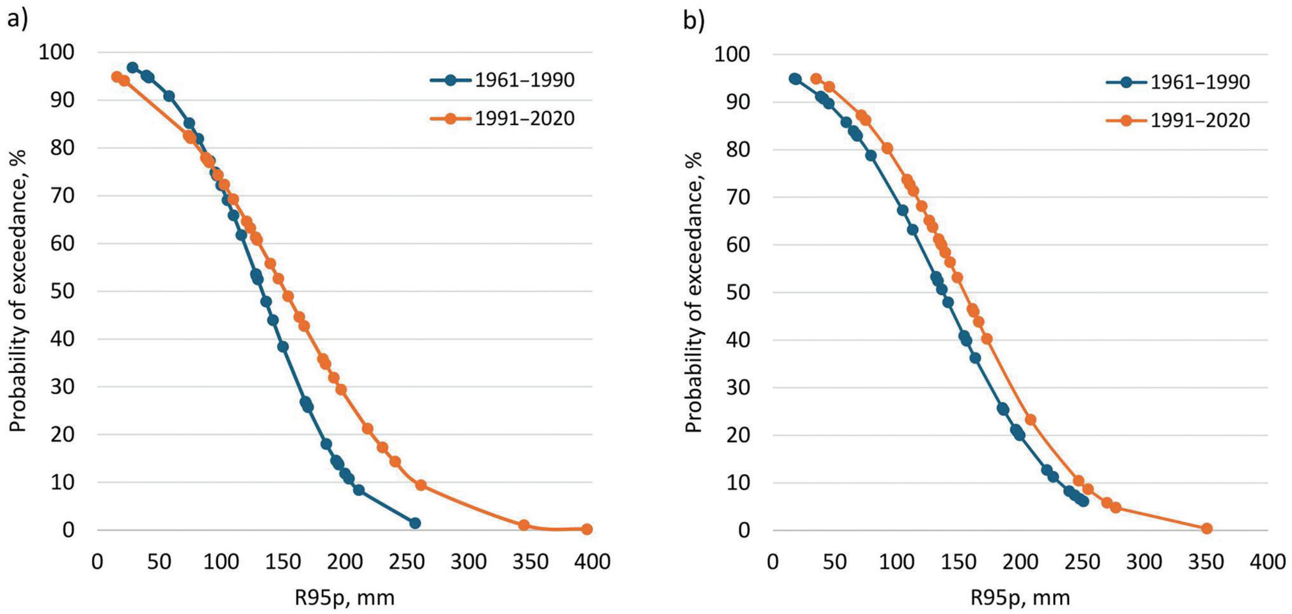

Fig. 12 The total annual precipitation from heavy rain days (R95p) cumulative probability distribution: a) in Vilnius, b) in Klaipėda

Lithuania. Climate indices associated with the cold season, such as heating degree days (HDDheat10) and number of cold nights (TN10p), are decreasing throughout the country. These observed trends align with the study done by Jaagus *et al*. (2014), which concluded that there was a statistically significant increase in minimum and maximum temperature in all Baltic States during 1951–2010. Jaagus *et al*. (2014) reported that maximum temperature was increasing by 0.3 °C/decade, and we determined that in Lithuania TX90p was increasing at a rate of 1.7 °C/decade on average. The trend determined in our study is much higher, but it is important to note the analyzed variables and different territories.

Another sign of global warming is a faster increase of nighttime temperature compared to daytime. We determined that the annual number of tropical nights (TR) was rising by 0.5 days/decade on the Baltic Sea coast, and it is of the same magnitude as reported by Dailidienė *et al*. (2023). Though the trend values are similar, we report a smaller total number of TR events. This difference arises because we used a more conservative approach based on the minimum air temperature measured by a minimum thermometer, which can occur at any moment during the night. In contrast, Dailidienė *et al.* (2023) used hourly data, which record temperatures only at fixed times (e.g., 05 or 06 UTC) and may miss the true minimum. They also restricted their analysis to nighttime hours (21–06 UTC), whereas our dataset did not include this limitation.

In other parts of Lithuania, the number of TR is much smaller compared to the Baltic Sea coast. Tropical nights are more frequent in the coastal region because of the warming effect of the sea and the Curonian Lagoon. In general, all our analyzed temperature indexes had their record maximum values (or minimum for HDDheat10) in Nida or Klaipėda. Both stations are on the coast and are very close to the water (< 400 m), which determines particular microclimatological conditions favourable for maintaining high mean temperatures.

Four temperature indices (TX90p, CDDcold25, TMge5, HDDheat10) had a statistically significant trend in all analyzed stations, indicating that these changes are unequivocal. Due to climate change, all regions of Lithuania show a tendency toward more extreme heat, a longer vegetation season, increasing cooling degree days, and a reduced need for heating. These tendencies are consistent with observed temperature trends across the Baltic Sea region and align with future climate projections (Meier *et al.* 2022).

Precipitation indices analysis showed that during the last decades, heavy precipitation events are more frequent (R20mm) and more precipitation falls during these events (R99p, R95p, Rx5day) compared to the 1961–1990 period. Christensen *et al*. (2015) claimed that a warmer atmosphere can retain more moisture as a response to growing global temperatures. Climate models also forecast the intensification of the hydrological cycle. Across Europe, this would mean more precipitation in Northern Europe and a lower amount of precipitation in Southern Europe.

While our analysis focused more on extreme heavy rain events which mostly happen in summer, other studies show that in the Baltic States the largest increase in total precipitation is in winter (Jaagus *et al*. 2018). Dyrrdal *et al*. (2021) and Mačiulytė *et* *al*. (2023) who analyzed heavy daily and long-term precipitation in the Baltic Sea region concluded that maximum daily precipitation increased and rainy periods were recorded earlier during the last 50–70 years. Our results show the same story, and we determined that annual precipitation from heavy rains (R95p) is increasing at a rate of 7 mm/decade in Lithuania.

Counterintuitive to the observed increasing trends in precipitation, we also determined an increase in the consecutive dry days (CDD). According to Rimkus *et al*. (2014), the setup for a dry period over the Baltic region involves a greater increase in the meridional and a decrease in the zonal circulation. Processes associated with blocking also favour drier periods over the Baltic region. Rimkus *et al*. (2014) also claimed that anomalies when drier periods alternate with more humid ones are quite common in the warm season of the year. Though our study did not directly analyse the alternation between wet and dry periods, we observed increasing trends in both CDD and extreme precipitation. This suggests that prolonged dry spells and intense rainfall events are becoming more pronounced. Such a pattern is consistent with the findings of Rimkus *et al.* (2014).

Compared to the traditional analysis of mean temperature and precipitation trends, the application of climate extreme indices helps better define changes in extreme weather phenomena. Mean variables can hide important variations of minimum and maximum values. The list of indices used in this study is limited, but it can be easily expanded and adapted to the different needs of researchers, sector specialists, and decision makers.

CONCLUSIONS

We calculated and analyzed 12 different climate extreme indices for the 1961–2020 period in Lithuania. Results show that phenomena associated with the warm season are increasing, such as the number of hot days (TX90p), tropical nights (TN), and days with a mean temperature greater than or equal to 5°C (TMge5). The highest change rates of temperature indices were determined on the Baltic Sea coast (Nida and Klaipėda).

We determined that TX90p, TMge5, and cooling degree days (CDDcold25) increased in all analyzed meteorological stations, and all trends were statistically significant. This shows a uniform shift towards a warmer climatic regime, with a greater demand for cooling and an increasing growing season length. Cold-season indices, such as heating degree days (HDDheat10) and the annual number of cold nights (TN10p) are decreasing by approximately 98 °C/decade and 1.2 days/decade, respectively. These changes are significant in most stations and indicate that the cold season in Lithuania is warming and the need for heating is decreasing.

Analysis of precipitation indices shows that in most of the country heavy precipitation events (R20 mm, R99p, R95p, Rx5day) are increasing. However, these trends are statistically significant only in 18–35% of stations. We also determined that a number of consecutive dry days (CDD) was increasing in all stations by the mean rate of 0.44 days/decade, but this change was significant only in Šiauliai and Raseiniai. Results indicate that precipitation patterns in Lithuania are becoming more erratic, with a heightened risk of heavy precipitation and more frequent dry periods.

Using climate extreme indices to assess climate change has several limitations. Station-based indices represent point measurements, which may not accurately reflect conditions in surrounding areas, particularly for highly localized events. Trend detection is also challenging because extreme events show strong interannual variability, and for rare events even a single extreme year can change the statistics. Moreover, though the indices describe how extremes are changing, they do not explain the underlying drivers. Future research could address some of these limitations by using longer time series and analysing key drivers, such as atmospheric circulation patterns.

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