Climate Impacts in the Czech Republic

Authors/Contributors

Nicole van Maanen, Research Analyst

Emily Theokritoff, Research Analyst

Inga Menke, Research Associate

Carl-Friedrich Schleussner, Head of Climate Science and Impacts

This scientific report is an independent product based on the most recently available science. The authors are uninfluenced as to form or content by the exigencies of litigation. All sources used in this report are stated in the annex.

Date: 18 January 2021

Table of Contents

1. Summary

This report provides scientific evidence on observed and projected impacts of climate change in the Czech Republic. Today at global warming of about 1.1°C above pre-industrial levels, the Czech Republic has increasingly experienced the impacts of climate change. In 2020, the Czech Republic hit a new record high of average annual air temperature: 2°C higher than that of 1960s.

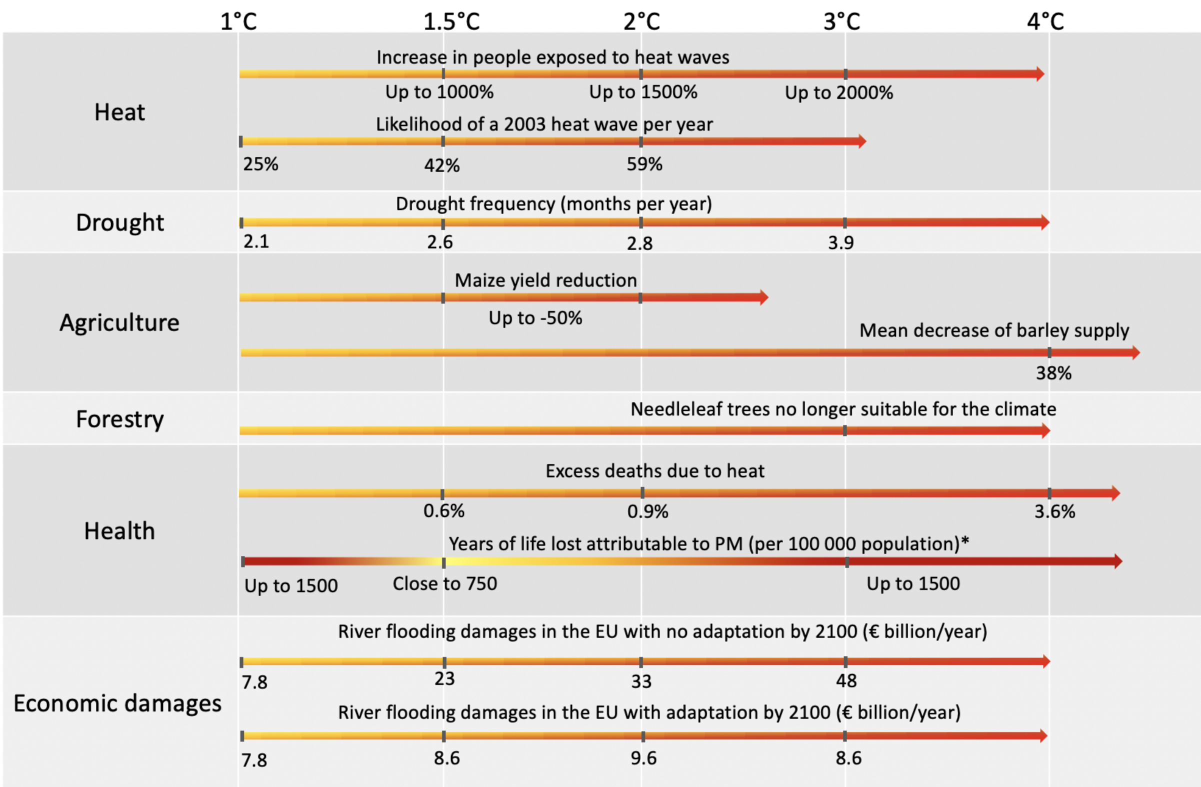
In recent years, the Czech Republic has seen an increase in heat waves, which will likely continue with increasing global warming. The frequency and duration of droughts are also expected to increase and so are the damages. In previous years, droughts alone costed the Czech Republic damages estimated at 500 million EUR. The combination of droughts and heat waves also result in extreme wildfires in the Czech Republic and they are projected to worsen over time with climate change.

Heavy precipitation is also projected to occur more frequently in the Czech Republic, with up to a 35% increase in winter precipitation projected for the period 2071-2100. The resulting more severe and frequent floods can pose a great threat to the country, particularly because they are expected in vulnerable areas around the Morava River (part of the Danube River Basin), where around 2.8 million people live. Moreover, the Czech Republic has a historically high death rate from flooding compared to other European countries.

Climate change also affects food security in the Czech Republic. Farming systems have already documented declines in crop productivity owing to rising temperatures and changes in precipitation. The arable land and land dedicated to permanent crops have already fallen drastically in the past years. The production of wheat, for example, the most important crop in the Czech Republic, is projected to decline by up to 100 000 tonnes by 2030 compared to 2000 and that of maize is expected to decrease by half at 1.5°C of global warming. Forests are no exception. Climate change affects the timing, intensity, rate and frequency of disturbances and its impact on forest ecosystems. The incidence of pests and diseases, such as the infestation of bark beetles that put 50% of Czech forests at risk, which are at least partly linked to climate change, will likely intensify.

There are also health-related climate change impacts. Between 1990-2016, up to 1000 fatalities in the Czech Republic were due to extremely high temperature. This will likely increase drastically and at 4°C global warming, extreme heat is projected to claim 3.6% of total deaths. And the repercussions will be more severe in urban areas with denser populations. The occurrence of vector-borne diseases, such as the West Nile virus infections, and respiratory diseases will become more common and widespread. In 2018, up to 1500 premature deaths were attributed to air pollution (specifically, particulate matter) in the Czech Republic. The exposure to air pollutants can, moreover, lead to more severe and lethal forms of COVID-19 and can delay or complicate the recovery of patients. Finally, mental health is also at risk. Especially for young people, climate- or eco-anxiety poses a major threat at a crucial point in their physical and psychological development. Eco-anxiety can cause stress, anxiety, depression and may even lead to substance use and other disorders.

Table 1: *Projected impacts of climate change in the Czech Republic at different levels of warming. The data refers to the end of the century. All data and sources can be found in this report.*



**assuming that under a 3 to 4°C scenario, pollution and Particulate Matter (PM) levels would remain similar to current ones, whereas a 1.5°C scenario would bring this number down by at least half by mid-century.*

2. Demographic analysis

The Czech Republic has a population of about 10.6 million people, 20% of which are under the age of 19. An average 16-year-old Czech national is expected to live until the age of 87. These demographic estimates can be coupled with the projections of global mean temperature increase. Following the best estimate of the future temperature trajectory based on the Climate Action Tracker, the increase in global mean temperature of 1.5°C will be exceeded around the year 2035, 2°C around 2055, and more than 3°C in 2100. Today's Czech 16-year-old has a 99% probability of being alive in 2035, 96% in 2055 and 6% in 2100. This means that nearly all of the Czech Republic's children will likely live in a 2°C warmer world and experience the ensuing impacts.

Table 2: Likelihood of different age groups of Czech Republic to live until 2035, 2055 and 2100. Source: World Data Lab (2019). The World Population Project. Available at: http://www.population.io

				Survival probability in year		
Country	Age	Sex	Life expectancy	2035	2055	2100
Czech Republic	16	F	89	99%	97%	8%
		M	85	99%	95%	4%
		Average	87	99%	96%	6%
	30	F	87	98%	90%	0%
		M	83	97%	83%	0%
		Average	85	98%	87%	0%
	60	F	86	3%	0%	0%
		M	82	2%	0%	0%
		Average	84	3%	0%	0%

3. Technical note: Representative Concentration Pathways – temperature warming

Representative Concentration Pathways

A scenario provides a plausible description of how the future may develop, based on several assumptions about key forces that drive climate change and the relationships between them (IPCC, 2014). Representative Concentration Pathways (RCPs) are a suite of scenarios developed based on possible future emissions trajectories and concentrations of greenhouse gases, aerosols and land use (Moss et al., 2008).

The International Panel on Climate Change (IPCC) and the climate modelling community use four different RCPs named after their radiative forcing potential at the end of the century (RCP 2.6, 4.5, 6.0, 8.5) (Moss et al., 2010). Each RCP is associated with an approximation of the range of global average temperature increase by 2100 in comparison to pre-industrial times. The Table 3 below shows the median (best estimate) projected temperature increase, as assessed in the IPCC Fifth' Assessment Report (AR5). It further provides the "likely" (i.e. 66% probability) range of temperature increase associated with each RCP in parenthesis. In other words, with a 66% likelihood, warming will fall within that range. This leaves a non-negligible 17% chance of even higher levels of warming.

Name	Expected temperature increase over the 2081-2100 period (median and [66% range])
RCP2.6	1.6°C [0.9-2.3°C]
RCP4.5	2.4°C [1.7-3.2°C]
RCP6.0	2.8°C [2.0-3.7°C]
RCP8.5	4.3°C [3.2-5.6°C]

Table 3: Warming under different Representative Concentration Pathways scenarios. The median likely range (66%) are given. Temperature increases are given for 2081-2100, assuming 0.61°C warming has occurred prior to 1986–2005. Source: (Stocker et al., 2013)

Due to the uncertainties in feedback processes in the earth system, the response of the climate system to anthropogenic CO_2 emissions is subject to considerable uncertainty. The IPCC's Fifth Assessment Report estimates the transient climate response to cumulate CO_2 emissions to be between 0.2-0.7°C per 1000 Gt CO_2. This climate response uncertainty (based on the CMIP5 model ensemble) is reflected in the uncertainty ranges provided in Table 3.

Current policy projections

Based on countries' climate pledges under the Paris Agreement (National Determined Contributions, NDCs) and national policies, the Climate Action Tracker provides best estimates of the resulting emissions pathways throughout the 21st century and their respective warming trajectories. These are shown in Figure 1 below. Again, the ranges provided are the likely (66% probability) ranges for temperature increase under different scenarios, for example, the current climate change mitigation policies which have been adopted by countries globally. As in the case of the RCPs, the ranges reflect the uncertainties that exist in relation to the feedback processes in the earth system. A warming of 3.9°C by the end of the century is thereby within the *likely (66%)* range under current policy projections. Furthermore, there is a non-negligible 17% probability of warming exceeding 3.9°C by the end of the century under current policy projections. This partly overlaps with the warming range of 3.2-5.6°C assessed under the RCP8.5 scenario and the respective impacts assessed under this scenario.

Current policies would lead to a median warming of about 2.9°C by 2100.

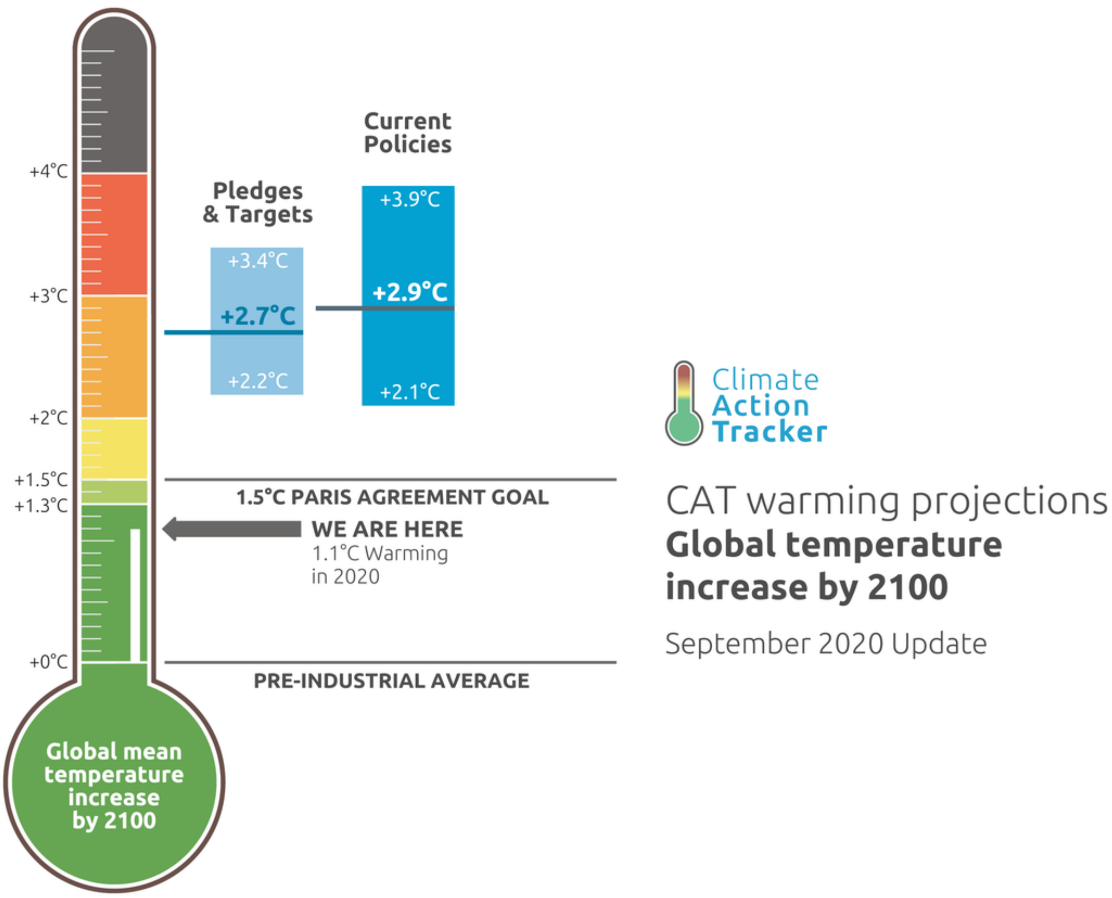


Figure 1: Climate Action Tracker emission and expected warming. Warming is shown for three different assumptions about future warming differentiating between targets of countries and actual policies in place to meet those targets: Countries fulfilling their current pledges and targets under the UNFCCC (Pledges &Targets), No further policies beyond those implemented today. The uncertainty ranges comprise the 66% likelihood range based on the best estimate range of the transient climate response to emissions (TCRE) based on the IPCC AR5. Source: (Climate Analytics; New Climate Institute, 2020)

Climate change impacts analysis

Substantial efforts are required to provide climate and climate impact simulations, which is why not all scenarios are relied upon in equal measure in the scientific studies which seek to generate different types of climate impact simulations. Many studies in climate research use a subset of the RCPs (deploying either RCP8.5, RCP4.5 or RCP2.6 or a combination of them) and hence do not provide estimates of impacts under all warming levels. The analysis that follows is based on the available studies on the anticipated impacts of climate change in the Czech Republic. Hereafter, we refer to the expected median temperature increase by 2100 associated with a particular RCP rather than the RCP itself. For high emission scenarios, either RCP8.5 or RCP6.0 is used, while RCP2.6 is used consistently for low emission scenarios.

4. Temperature

The Earth has undoubtedly experienced warming particularly over the last decades (see Figure 2). The IPCC states: "human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C. Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate (high confidence)" (Hoegh-Guldberg et al., 2018, p. 4).

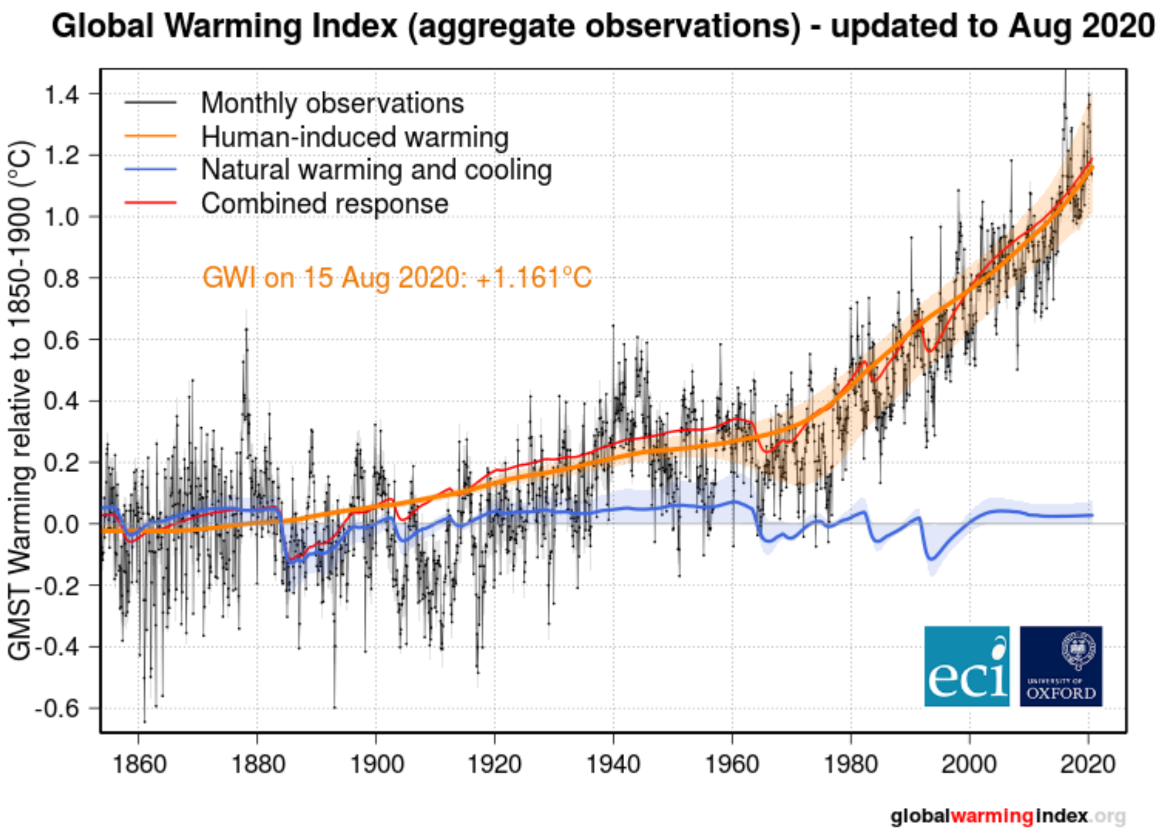


Figure 2: Global Warming Index, retrieved from: https://globalwarmingindex.org

The European Environment Agency reports that "the European land area has warmed by 1.6-1.7°C" compared to the pre-industrial average (1850-1899), with significant regional and seasonal differences (European Environment Agency, 2019b, p. 170). Moreover, 18 out of the 19 warmest summers on record have occurred since the year 2000 (European Environment Agency, 2019b, p. 170).

Figure 3 shows that, the average annual temperature of the Czech Republic has increased by 2°C over the last 60 years.

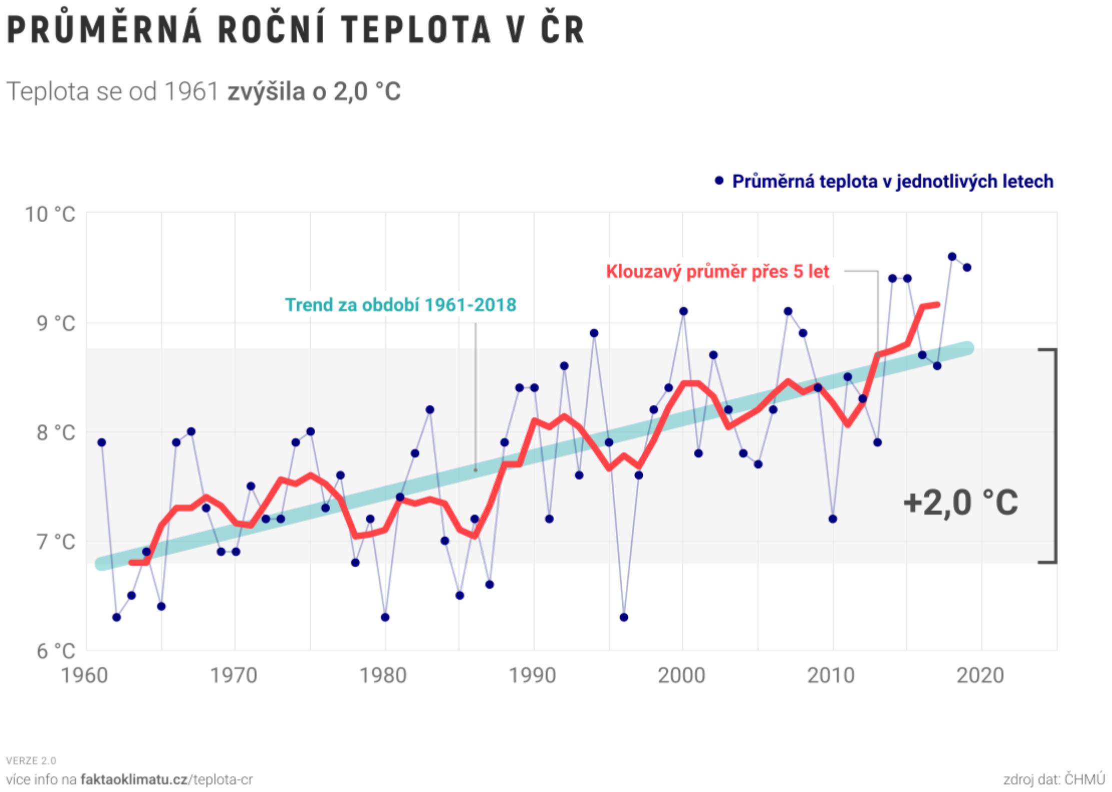


Figure 3: Average annual temperature in the Czech Republic since 1961, retrieved from [*https://faktaoklimatu.cz/infografiky/teplota-cr*](https://faktaoklimatu.cz/infografiky/teplota-cr)

An increase in the numbers of tropical days and a decrease in the number of ice days have also been observed in Prague since 1960 (Figure 4).

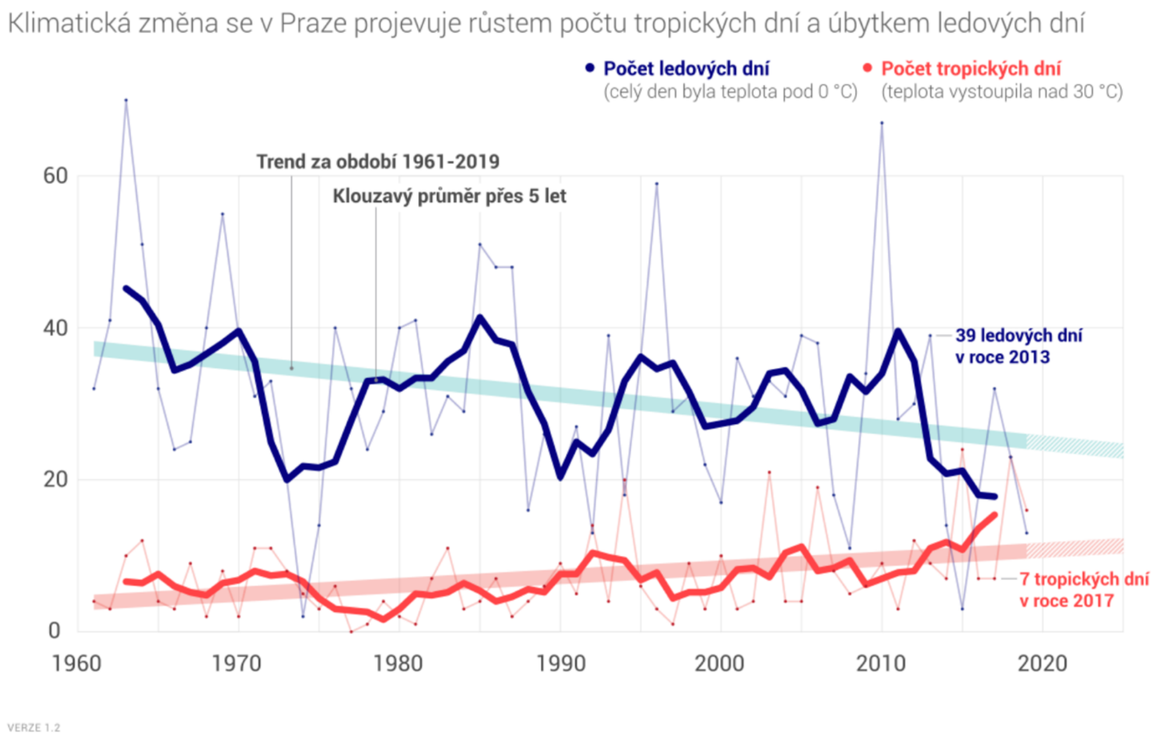


Figure 4: Tropical and ice days in Prague in the years 1961-2019, retrieved from: [*https://faktaoklimatu.cz/infografiky/tropicke-dny-praha*](https://faktaoklimatu.cz/infografiky/tropicke-dny-praha)

The projections of the European Environment Agency shown in Figure 5 below suggest "that European land areas will warm faster on average than global land areas" (Füssel et al., 2017, p. 76). The results show that land areas in Europe are projected to warm by between 1°C and 4.5°C for a global warming scenario of 2.5°C by 2100 (RCP4.5) and by between 2.5°C and 5.5°C for a global warming scenario of > 4°C by the end of the century (RCP8.5) (Füssel et al., 2017, p. 76). Under the warming scenario of 2.5°C by 2100 (RCP4.5) and that of > 4°C (RCP8.5), the Czech Republic's summer temperatures would increase by up to 2.5°C and 3.5°C, respectively, compared to the levels of 1971-2000. Its winter temperatures show an increase of up to 3°C and 5°C compared to 1971-2000 for a global warming scenario of 2.5°C by 2100 (RCP4.5) and > 4°C (RCP8.5), respectively.

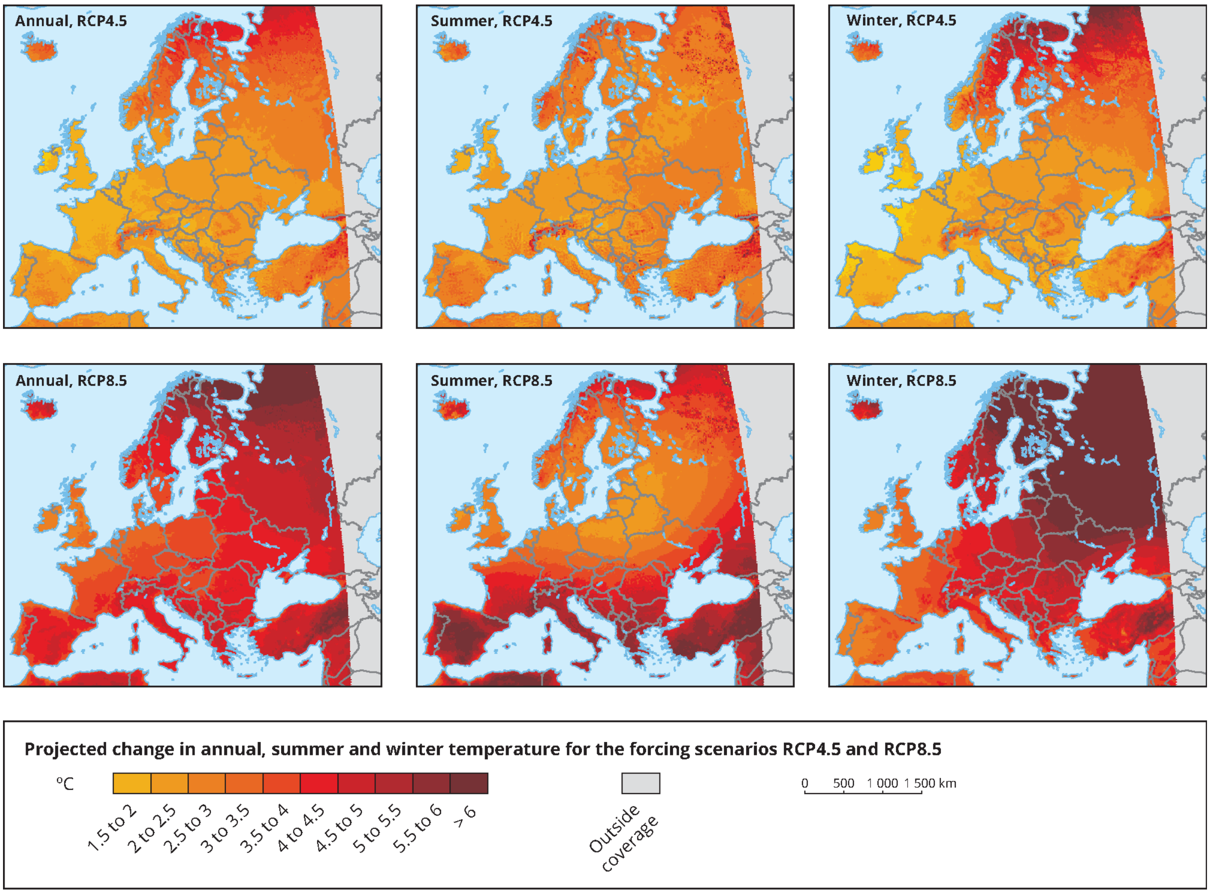


Figure 5 : Projected changes in annual (left), summer (middle) and winter (right) near-surface air temperature (°C) in the period 2071-2100, compared with the baseline period 1971-2000 for the forcing scenarios RCP4.5 (top – global warming scenario of 2.5°C by 2100) and RCP8.5 (bottom - > 4°C by 2100). Model simulations are based on the multi-model ensemble average of RCM simulations from the EURO-CORDEX initiative. (Füssel et al., 2017, p. 76, map 3.4).

5. Precipitation

As shown in Figure 6, the Czech Republic has experienced a slight decrease in annual (up to -20mm/decade) and summer (up to -10mm/decade) between 1960 and 2015.

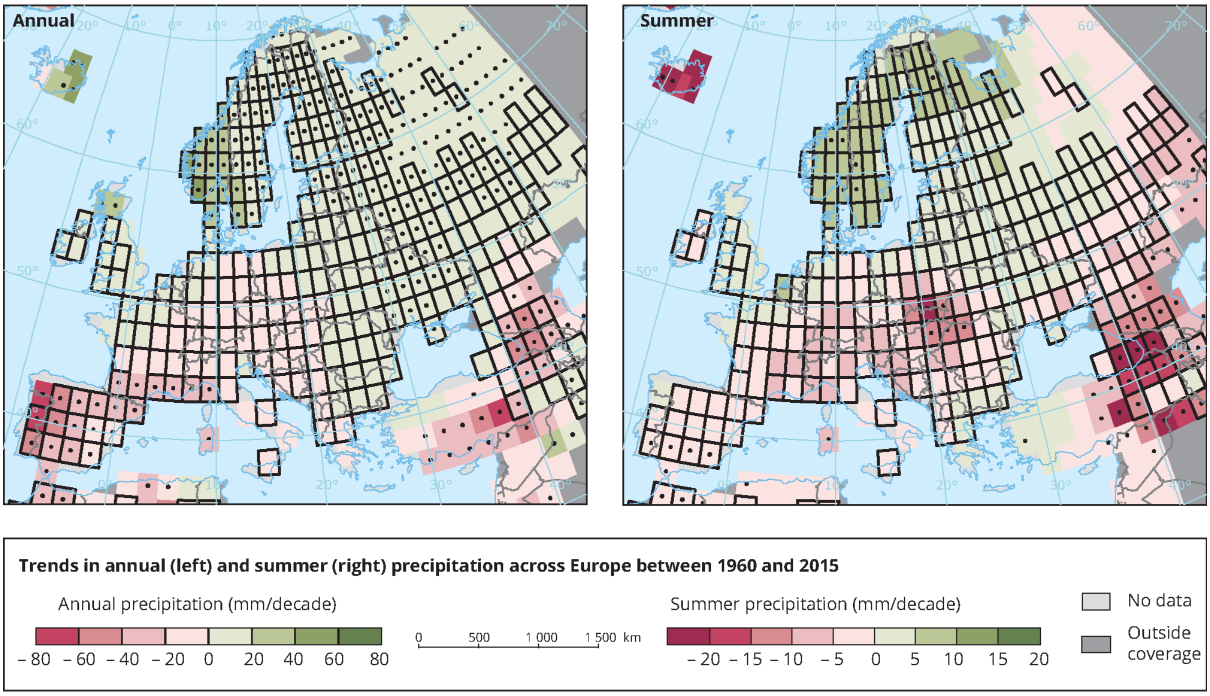


Figure 6: Trends in annual (left) and summer (right) precipitation across Europe between 1960 and 2015 (Füssel et al., 2017, p. 81)

"For Europe, recent studies (Vautard et al., 2014; Jacob et al., 2018; Kjellström et al., 2018) have shown that 2°C of global warming was associated with a robust increase in mean precipitation over central and northern Europe in winter but only over northern Europe in summer, and with decreases in mean precipitation in central/southern Europe in summer. Precipitation changes reaching 20% have been projected for the 2°C scenario (Vautard et al., 2014) and are overall more pronounced than with 1.5°C of global warming (Jacob et al., 2018; Kjellström et al., 2018)" (Hoegh-Guldberg et al., 2018, p.194).

Figure 7 highlights that in the Czech Republic, summer precipitation is projected to remain more or less unchanged (between -5% and 5%), whereas annual precipitation is projected to increase by up to 20% in the period 2071-2100 for a >4°C scenario by 2100 (RCP8.5) (European Environment Agency, 2019b, p. 173). Despite an overall increase in annual precipitation, which is seen mainly in the winter, however, this does not imply a reduced drought risk in particular during the summer period (for more information see sections 6.2 and 6.3). Also, the distribution of precipitation events will change with more intense extreme precipitation events in particular during winter months (compare Figure 11 below).

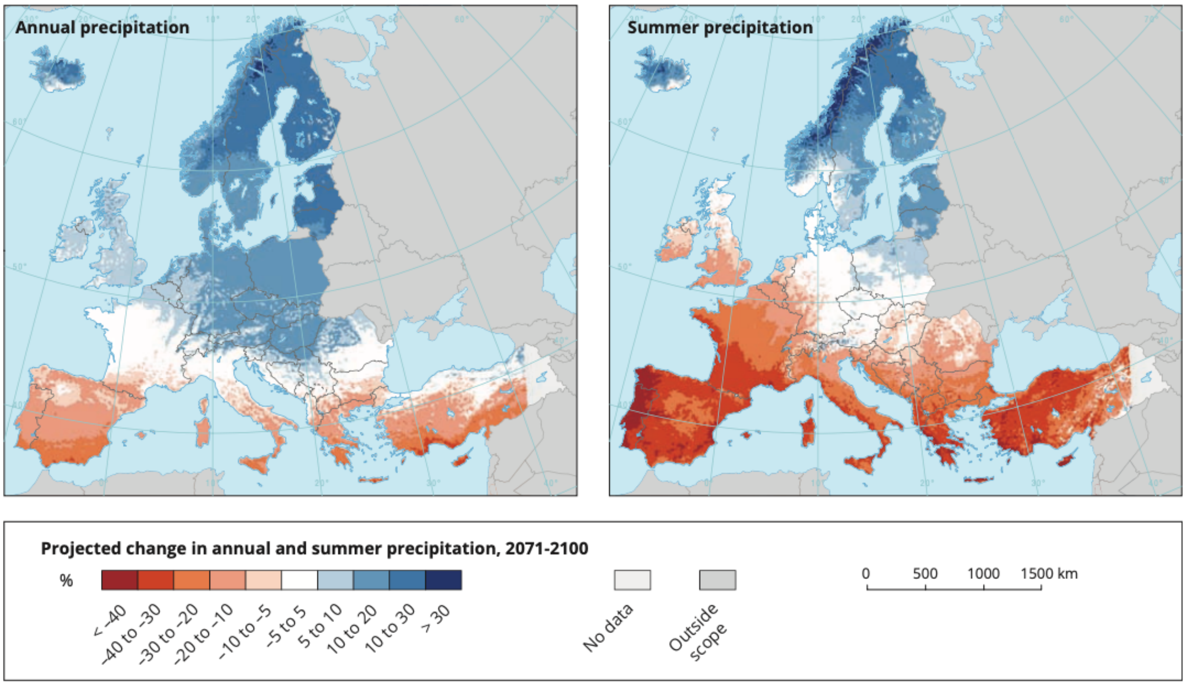


Figure 7 : Projected changes in annual (left) and summer (right) precipitation (%) in the period 2071-2100 compared with the baseline period 1971-2000 for a >4°C scenario (RCP8.5) based on the average of a multi-model ensemble of regional climate models (European Environment Agency, 2019b, p. 173, map 7.2).

6. Extreme events

6.1 Heatwaves

The European Environment Agency reports that "the number of warm days (those exceeding the 90th percentile threshold of a baseline period) have almost doubled since 1960 across the European land area". "Europe has experienced 11 intense and long heat waves between 1950 and 2015, most of which occurred after 2000 (in 2003, 2006, 2007, 2010, 2014 and 2015)" (Füssel et al., 2017, p. 77). Under >4°C scenario (RCP8.5), very extreme heat waves as strong as these or even stronger are projected to occur as often as every two years in the second half of the 21st century (ibid).

In the Carpathian region[1], heat waves have become longer, more intense and more frequent. Severe heat waves have been most frequent between 1961 and 2010, with four out of seven occurring between 2000 and 2010 (Spinoni et al., 2015). Moreover, the summer of 2015 was characterized by exceptionally high temperatures, with daily maximum temperatures over 3°C above the seasonal mean (1971-2000) (Ionita et al., 2017). It was the hottest and climatologically the driest summer between 1950–2015 for eastern Czech Republic (ibid).

[1] Encompasses eight countries: Croatia, Hungary, Slovakia, Czech Republic, Poland, Ukraine, Romania, and Serbia

Figure 8 below illustrates that currently up to 32,000 people are exposed to present 50-year heat waves on an annual basis in some parts of the Czech Republic (Naumann et al., 2020). In certain areas, the 3°C scenario could lead to about 20-fold increase of people exposed to heat waves, compared to the baseline (ibid). Limiting warming to 1.5°C would reduce the number of population exposed by about half.

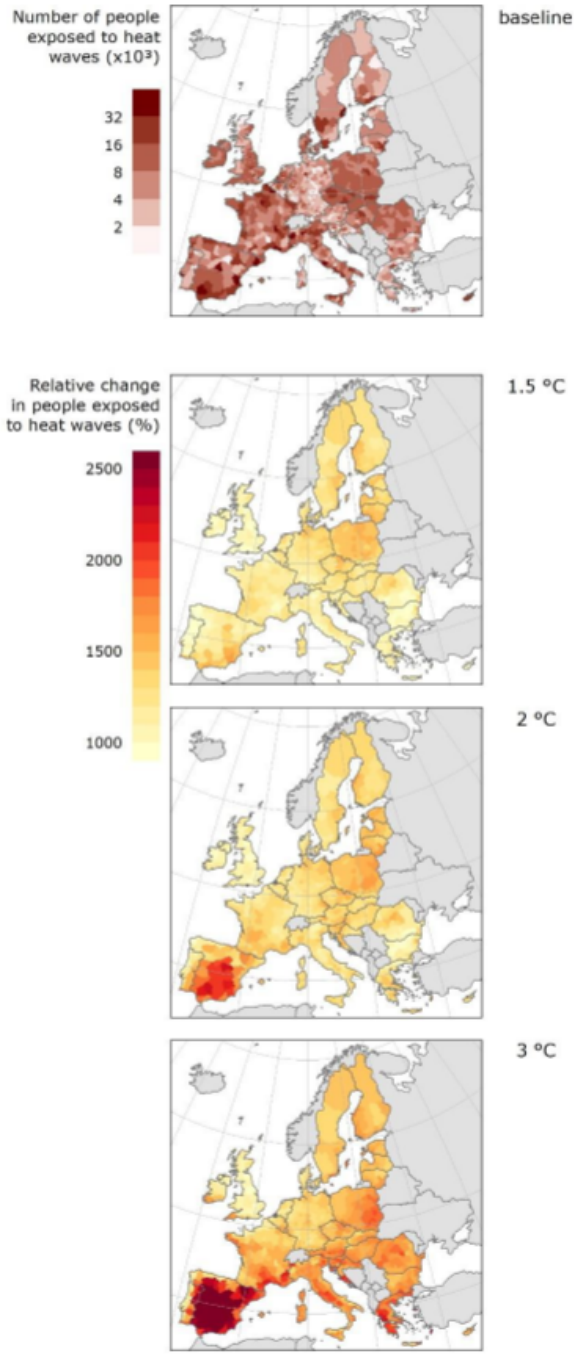


Figure 8: Number of people annually exposed to a present 50-year heatwave (top row, 1981-2010 baseline period) and projected relative changes in human exposure to these events for 1.5°C, 2.0°C and 3.0°C levels of global warming (Naumann et al., 2020)

The IPCC has found that : “For differences in regional temperature extremes at a mean global warming of 1.5°C versus 2°C, that is, a difference of 0.5°C in global warming, this implies differences of as much as 1°C–1.5°C in some locations, which are two to three times larger than the differences in global mean temperature. For hot extremes, the strongest warming is found in central and eastern North America, central and southern Europe, the Mediterranean, western and central Asia, and southern Africa (medium confidence)" (Hoegh-Guldberg et al., 2018, p. 190). "A global warming of 2°C versus 1.5°C would lead to more frequent and more intense hot extremes in all land regions, as well as longer warm spells, affecting many densely inhabited regions (very likely)" (Hoegh-Guldberg et al., 2018, p.191). "Limiting global warming to 1.5°C instead of 2°C could result in around 420 million fewer people being frequently exposed to extreme heatwaves, and about 65 million fewer people being exposed to exceptional heatwaves, assuming constant vulnerability (medium confidence)" (Hoegh-Guldberg et al., 2018, p. 191).

A study by King & Karoly (2017) show an increasing likelihood of similar heat wave events occurring with the current temperature increase of about 1°C, 1.5°C and 2°C, in comparison to a world without climate change (Figure 9). When looking at the 2003 heat wave in central Europe, this would be a once in 100 years event without climate change. At current warming levels, a similar event can be expected once every four years. For 1.5°C warming, the likelihood of heat wave occurrence increases to four out of ten summers and for 2°C warming to six out of ten.

			Likelihood of similar event per year			
EVENT	CONTEXT, IMPACT	VARIABLE	NATURAL	CURRENT	1.5°C	2°C
Europe 2016	Hottest year on record	T	0% (0%)	27% (17-37%)	52% (42-63%)	88% (83-92%)
Central England 2014	Hottest year on record	T	0% (0-1%)	19% (13-25%)	29% (21-37%)	48% (38-59%)
Central Europe JJA 2003	Hottest summer on record, thousands of heat-related deaths	T	1% (1-2%)	25% (17-33%)	42% (32-51%)	59% (50-70%)
		TXx	2% (0-6%)	21% (7-37%)	21% (9-34%)	31% (14-50%)

Figure 9: The change in the frequency of European climate extremes under different levels of global warming. The likelihoods in a given year of similar events to recent European extremes in a natural world, the current world, a 1.5°C world and a 2°C world. The best estimate is shown with the 90% confidence intervals in parentheses. (King & Karoly, 2017)

6.2 Droughts

The European Environment Agency states that "drought has been a recurrent feature of the European climate. From 2006–2010, on average 15 % of the EU territory and 17 % of the EU population have been affected by meteorological droughts each year. In the 1990s and 2000s the drought hotspots were the Mediterranean area and the Carpathian Region (Sepulcre-Canto et al., 2012; Spinoni et al., 2016). The frequency of meteorological droughts in Europe has increased since 1950 in parts of southern Europe and central Europe (Austria and Hungary)". "Trends in drought severity (based on a combination of the Standardised

Precipitation Index (SPI), the Standardised Precipitation Evapotranspiration Index (SPEI) and the Reconnaissance Drought Index (RDI)) also show significant increases in the Mediterranean region (…) and parts of central and south-eastern Europe" (Füssel et al., 2017, p. 145).

Central Europe experienced significant drought episodes in 2000, 2003, 2012 and 2015, which are estimated to have caused over 500 million Euro damages in the Czech Republic alone (Trnka et al., 2020). Droughts pose serious risks in terms of their impacts and damages, the events in 2000, 2003 and 2015 were among the top five droughts in terms of spatial extent, magnitude and duration, in June-August observed since 1961 (ibid).

The IPCC predicts that "more urban populations would be exposed to severe droughts at 1.5°C in central Europe, southern Europe, the Mediterranean, West Africa, East and West Asia, and Southeast Asia, and that number of affected people would increase further in these regions at 2°C" (Ove Hoegh-Guldberg et al., 2018, p. 215).

With global warming, the duration and frequency of droughts are expected to increase in the Czech Republic (Figure 10). Additional warming of 3.0 K[2] would put around 40% of Continental Europe (which includes the Czech Republic) under the risk of drought for an extended period of time (on average 122 months, or more than 10 years). The frequency of drought events would almost double, reaching around 3.9 drought months per year, compared to that of the reference period 1971-2000 (Samaniego et al., 2018, p. 425, table 1). In addition, an extreme drought event similar to the one that took place in 2003 would become twice as frequent (ibid). With 2.0 K warming, 36% of continental Europe would be under the risk of drought, of which the duration is 66 months and the frequency is 2.8 drought months per year. With 1.5 K additional warming, 35% of continental Europe would be under drought, drought would last 60 months and there would be 2.6 drought months per year.

[2] K stands for the unit Kelvin (same as °C), warming is given relative to the 1971-2000 reference period, around 0.5°C above pre-industrial levels.

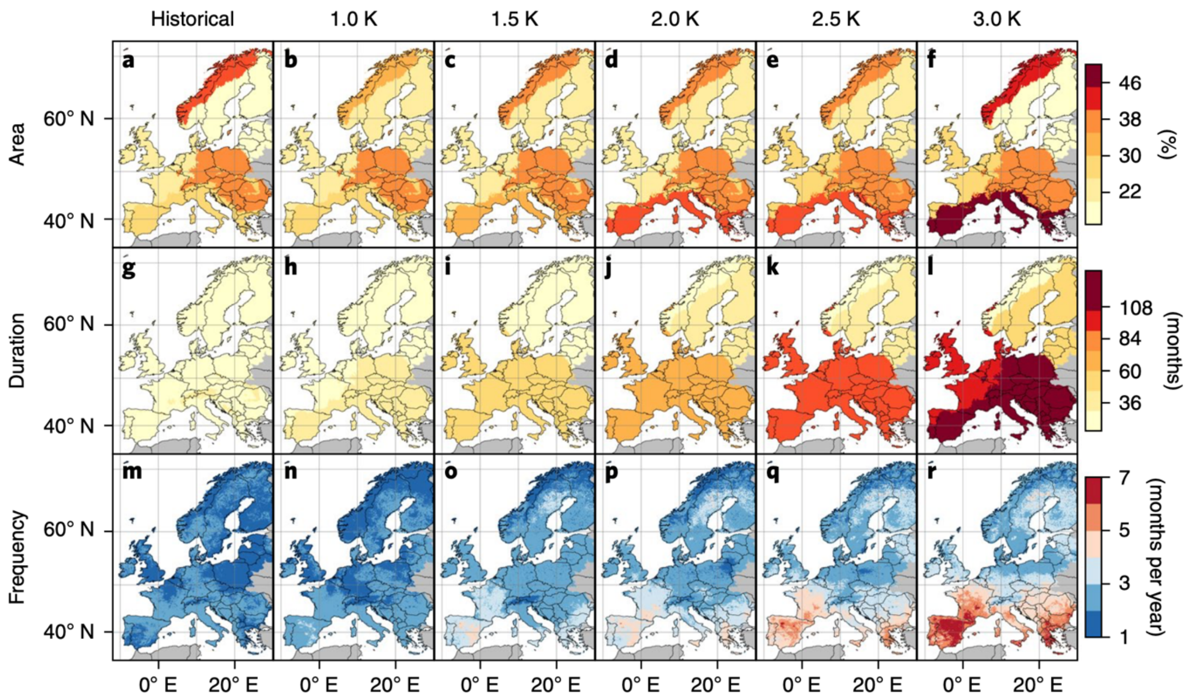


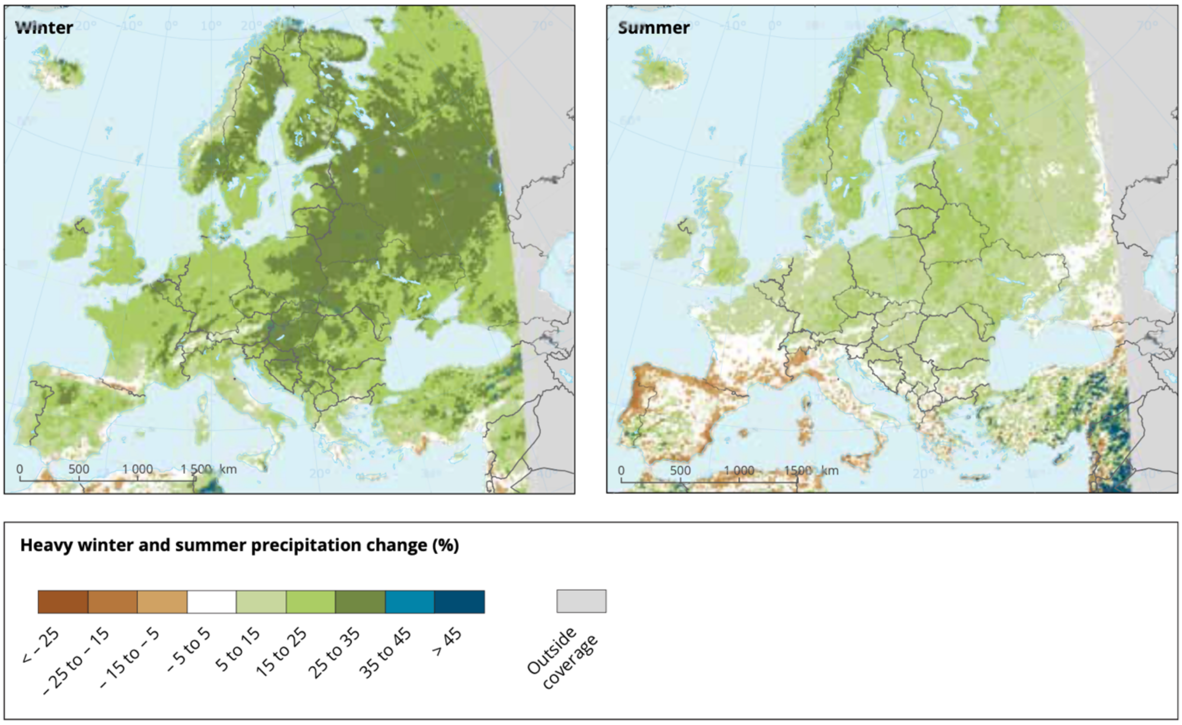
Figure 10: Spatial distribution of changes in drought area, duration and frequency (The area under drought is evaluated for the six IPCC AR5 regions and quantified as a percentage of the total area of each region for the different levels of warming. g–l, The drought duration for the same regions and warming levels. The area under drought and the drought duration are both calculated for the multimodel median of the largest drought events. m–r, The frequency of drought months is depicted at the individual grid cell level, which is calculated from the multimodel median estimates. All of the results are calculated assuming no adaptation to climate change) (Samaniego et al., 2018, p. 423, figure 2). *Changes in global mean temperature are given in [Kelvin] above the 1971-2000 period (about 0.5°C above pre-industrial levels).* `

6.3 Heavy precipitation

All indices of heavy precipitation show a consistent increase (about 20-30%) in winter precipitation in the western region of the Czech Republic for the period 1961-2005. (Kyselý, 2008).

The IPCC states that: "robust changes in heavy precipitation compared to pre-industrial conditions are found at both 1.5°C and 2°C global warming (…). This is also consistent with results for, for example, the European continent, although different indices for heavy precipitation changes have been analysed. Based on regional climate simulations, Vautard et al. (2014) found a robust increase in heavy precipitation everywhere in Europe and in all seasons, except southern Europe in summer at 2°C versus 1971–2000" (Ove Hoegh-Guldberg et al., 2018, p. 194).

Heavy precipitation events will likely become more frequent in most parts of Europe. The projected changes are most significant in Scandinavia and eastern Europe in winter, where heavy winter precipitation shows an increase of up to 35% for the period 2071-2100 under the >4°C scenario by 2100 (RCP8.5) (Figure 11) (Füssel et al., 2017). Figure 11 shows that under the same scenario(RCP8.5), heavy summer precipitation in the Czech Republic would also experience an increase of up to 25%.



Note: This map shows projected changes in heavy daily precipitation (%) in winter and summer for 2071–2100, compared with the baseline period 1971–2000, for the RCP8.5 scenario based on the ensemble mean of different RCMs nested in different GCMs.

Source: EURO-CORDEX (Jacob et al., 2014).

Figure 11: Projected changes in heavy precipitation in winter and summer for a warming scenario of >4°C by 2100 (RCP8.5) (Füssel et al., 2017, p.84)

6.4 Floods

"The number of very severe flood events in Europe increased over the period 1980–2010, but with large interannual variability. This increase has been attributed to better reporting, land-use changes and increased heavy precipitation in parts of Europe, but it is not currently possible to quantify the importance of these factors. Global warming is projected to intensify the hydrological cycle and increase the occurrence and frequency of flood events in large parts of Europe. Pluvial floods and flash floods, which are triggered by intense local precipitation events, are likely to become more frequent throughout Europe. In regions with projected reduced snow accumulation during winter, the risk of early spring flooding could decrease. However, quantitative projections of changes in flood frequency and magnitude remain highly uncertain" (Füssel et al., 2017, p. 140).

"Losses from flooding in Europe have increased substantially since the 1970s". "The trend for increasing losses from river floods is primarily attributable to socio-economic factors, such as increasing wealth located in flood zones, but increases in heavy precipitation in parts of Europe may also play a role". "Robust attribution is not yet possible because of insufficient data". "In terms of regional GDP, flood risks are highest in large parts of eastern Europe, Scandinavia, Austria and the United Kingdom and parts of France and Italy" (Füssel et al., 2017, p. 141).

"For the end of the 21st century, the greatest increase in one-in-a-century floods is projected for the British Isles, north-west and south-east France, northern Italy and some regions in south-east Spain, the Balkans and the Carpathians" (Füssel et al., 2017, p. 142).

The European Environmental Agency mentions an increasing vulnerability to flooding across urban areas of Europe. More specifically in the Czech Republic, Moravia shows a high vulnerability, due to its proximity to the Morava River in the Danube River Basin (European Environment Agency, 2020, p.90). This region would be particularly severely affected by floods, as it is densely populated with nearly 2.8 million inhabitants living along the Morava River (around 3.46% of the population in the Danube River Basin) (International Commission for the Protection of the Danube River, 2007). Factors that aggravate the vulnerability are "low income and low employment rates, physical features, such as the extent of soil sealing, public awareness of citizens' rights and political commitment to adaptation" (European Environment Agency, 2020, p.90). Figure 12 shows that the deaths per million inhabitants related to flooding in the Czech Republic have historically been very high compared to other European countries with 5-10 deaths (EEA, 2020).

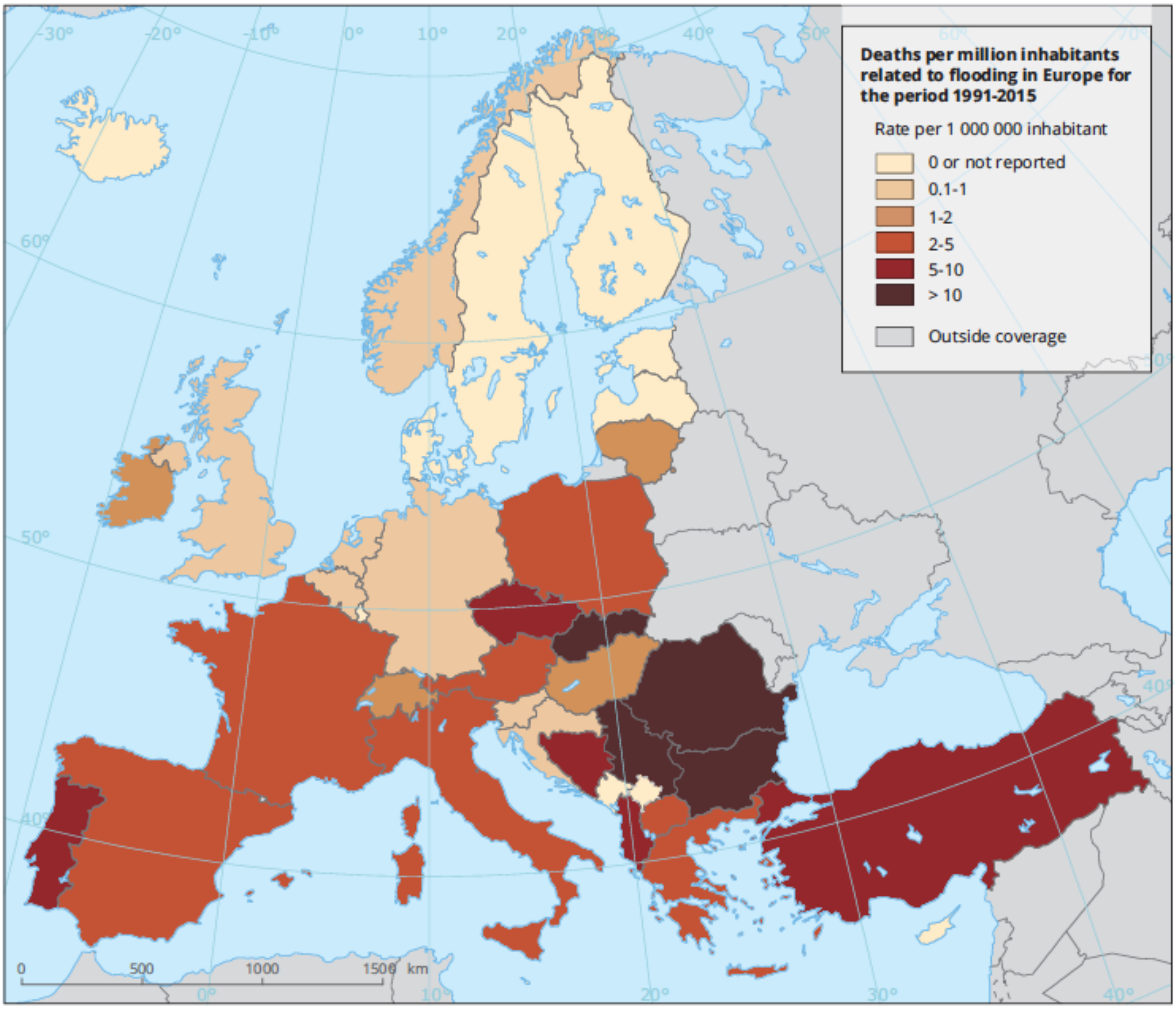


Figure 12: Number of European deaths related to flooding per million inhabitants (1991-2015) (European Environment Agency, 2020, p.85).

6.5 Wildfires

The frequency of vegetation fires[3] has increased by about 70% in the warmest and driest areas of the Czech Republic between 1991 and 2015, compared with the 1971-1990 period (Figure 13) (Mozny et al., 2020). Extreme occurrences of vegetation fires were found to be due to a combination of drought and heatwaves, thus climate change (ibid).

[3] "considered in this study as any uncontrolled vegetation fires" (Mozny et al., 2020)

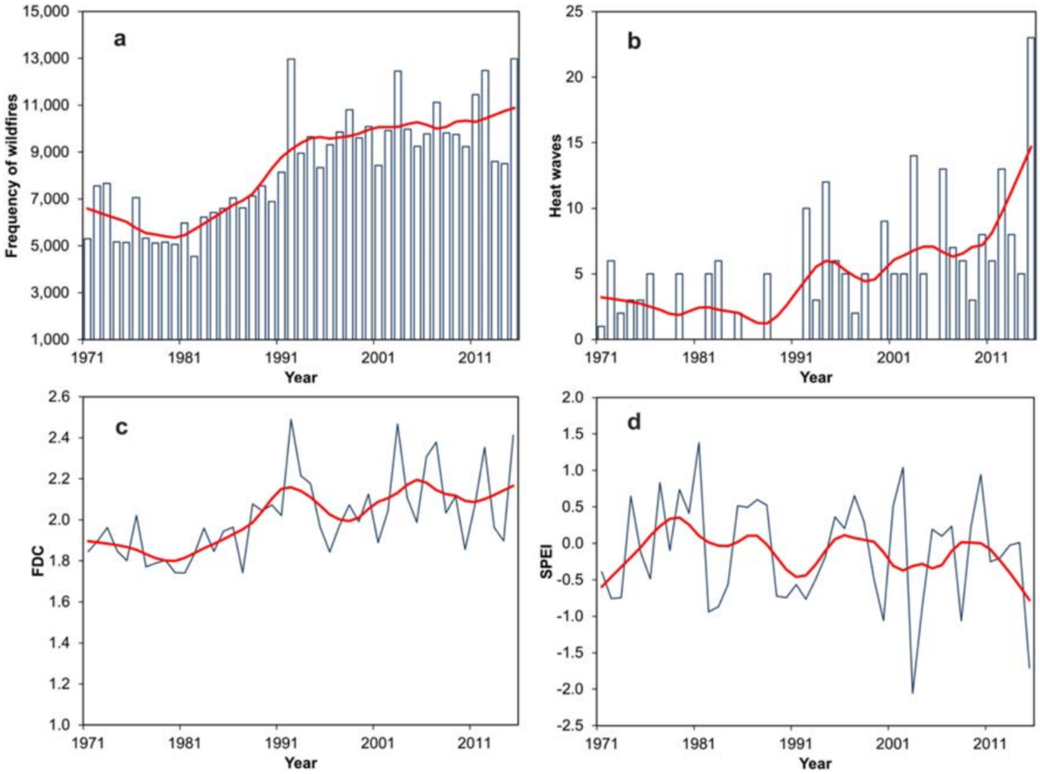


Figure 13: Fluctuations in the frequency of vegetation fires (a) and heat wave days (b), April-August FDC (c) and April-August SPEI (d) in the Czech Republic during the 1971-2015 period. Data are smoothed by a 10 year Gaussian filter (red line) (Mozny et al., 2020)

Regarding wildfires, the IPCC special report on land states that "current levels of global warming are associated with moderate risks from increased dryland water scarcity, soil erosion, vegetation loss, wildfire damage, permafrost thawing, coastal degradation and tropical crop yield decline (high confidence). Risks, including cascading risks, are projected to become increasingly severe with increasing temperatures. At around 1.5°C of global warming the risks from dryland water scarcity, wildfire damage, permafrost degradation and food supply instabilities are projected to be high (medium confidence). At around 2°C of global warming the risk from permafrost degradation and food supply instabilities are projected to be very high (medium confidence). Additionally, at around 3°C of global warming risk from vegetation loss, wildfire damage, and dryland water scarcity are also projected to be very high (medium confidence)" (IPCC, 2020, p. 17).

6.6 Economics losses

For the period 1980-2017, the Czech Republic has lost 10,533 million Euro due to the impacts of extreme weather and climate related events (European Environment Agency, 2019b), the amount that translates into a loss of 1,018 Euro per capita (ibid).

The European Commission also reports that lack of adaptation would expose more people to river flooding and cause more serious damages under all scenarios (Figure 14) (Dottori et al., 2020).

	Today	2100 - no adaptation			2100 - adaptation		
		1.5˚C	2˚C	3˚C	1.5˚C	2˚C	3˚C
Damages (€ billion/year)	7.8	24	33	48	8.6	9.6	8.6
People exposed (1000/year)	172	252	338	482	92	100	90

Figure 14: EU + UK annual damages and population exposed to river flooding in the present and by 2100 for different levels of warming, with and without adaptation respectively. The "no adaptation" scenario refers to present-day flood protection measures. The "adaptation" scenario is based on the implementation of retention areas to store excess flood water to a level of protection that maximizes their economic benefit (Dottori et al., 2020)

7. Agriculture

7.1 Crop yields

"Climate change is already affecting food security" in Europe (high confidence) (IPCC, 2019, p.453). Both large-scale and smallholder farming systems in Europe have already documented declines in crop productivity due to rising temperatures and changes in precipitation (IPCC, 2019, p.453). Agricultural systems are highly vulnerable to climate change and climate variability, which in turn exacerbates future risk related to food security and socio-economic wellbeing. Reductions in future water availability and a higher exposure to heat extremes are, for example, projected to negatively impact local agricultural production (Schleussner et al., 2016). As mentioned in Chapter 6, heat waves are expected to increase in Europe and so are the "drought frequency and intensity" as a consequence (medium confidence) (IPCC, 2019, p.133). Eastern Europe will increasingly face the negative impacts of rising temperature on crops, as warming climate "is partially responsible for the stagnation in crop yields since the mid-1980s" (IPCC, 2019, p.453).

In the Czech Republic, specifically, yield stability of traditionally grown root vegetables in the warmest areas of the country is expected to decrease (IPCC, 2019, p.453). The EEA finds that in Eastern and Central Europe, changes in temperature and precipitation patterns have already negatively affected the potential yields of potato and cereals (wheat maize and barley) (European Environment Agency, 2019b, p.45). Average potato yields are projected to drastically decrease for all RCPs and time periods, in some cases even projecting negligible or zero average yield (Papadimitriou et al., 2019). Wheat, the most important crop in the Czech Republic, is also projected to further decline due to limited water availability. As shown in Figure 15 below, water-limited wheat production is projected to decline by up to 100 000 tons by 2030 compared to 2000 (European Environmental Agency, 2020).

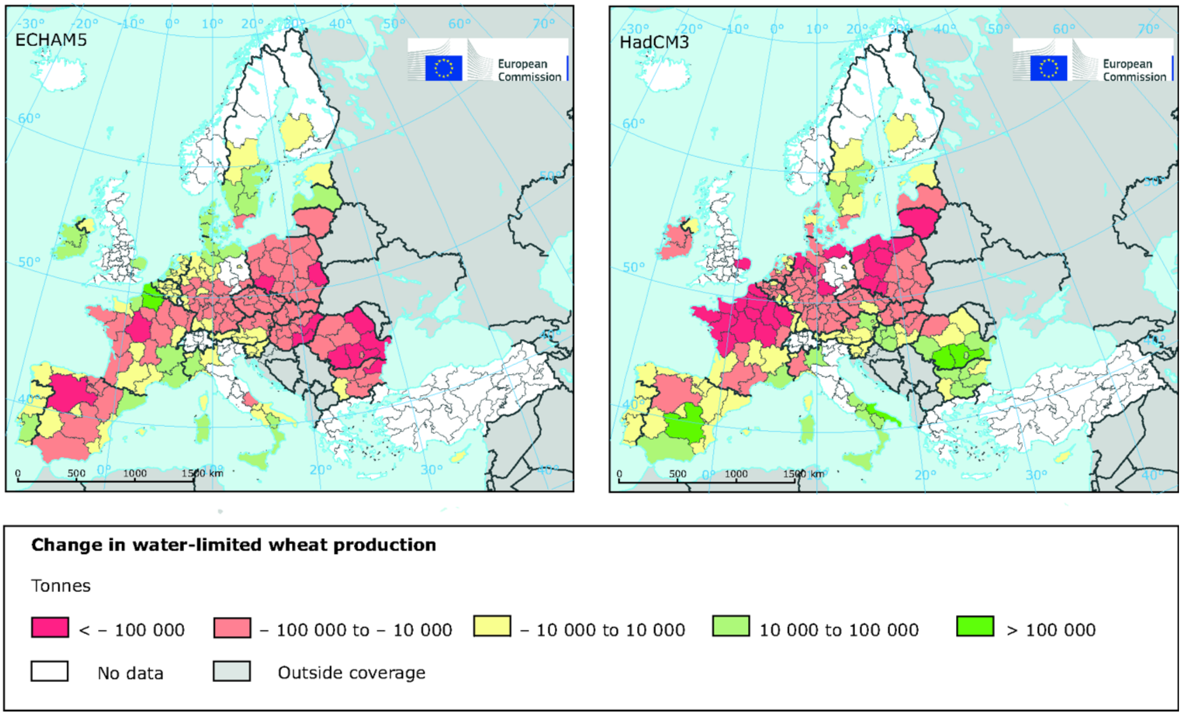


Figure 15: Simulated change in water-limited wheat production in Europe. The figure shows the simulated change in water-limited wheat production for 2030 compared with 2000 for 3°C of global warming by 2100 (A1B) using cold (left) and warm (right) climate change projections (European Environmental Agency, 2020).

Maize is projected to be most affected by climate change in Europe (Hristov et al., 2020, p.6). Under rainfed conditions, "a collapse of the European maize production around 2050 is projected, with yield decreases larger than 23% in all the EU countries" (Hristov et al., 2020, p.6). As shown in Figure 16 below, maize yield in the Czech Republic declines by up to 50% under both 1.5 and 2°C of global warming. Moreover, "tested adaptation strategies (e.g. changing sowing dates and sown variety to avoid heat stress and drought conditions) will not be sufficient to cope with the negative impacts of climate change" (Hristov et al., 2020, p.6).

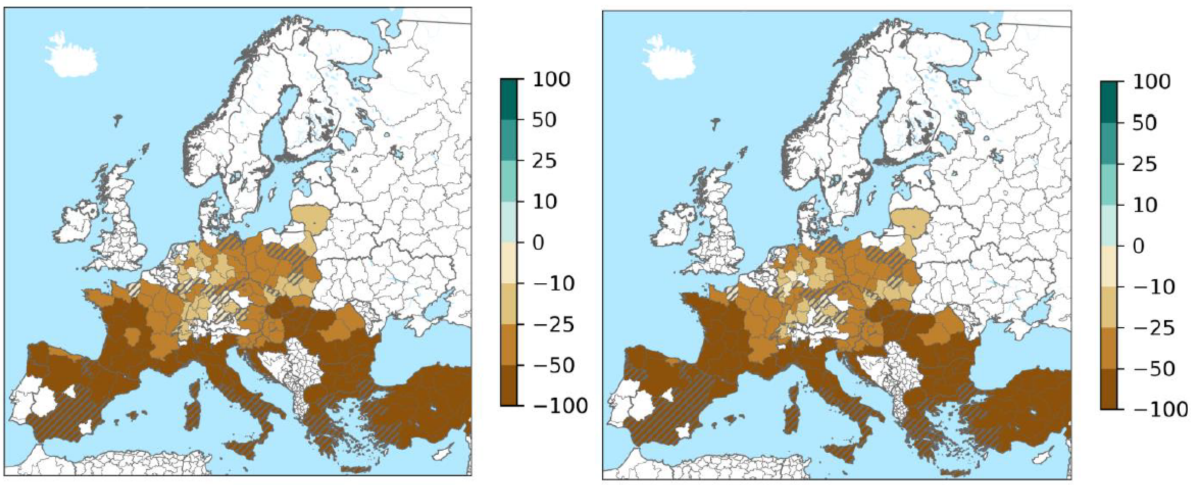


Figure 16: Ensemble mean changes of grain maize yield (% relative to the historical period) projected for 1.5°C (left panel) and 2°C (right panel) warming conditions, assuming that no additional irrigation will be implemented (i.e., rainfed). Hatching denotes areas with low model agreement (Hristov et al., 2020, p.7).

Extremely high temperatures reduce crop yields by minimizing plant photosynthetic and transpiration efficiencies and hindering root development (European Environment Agency, 2019b, p.48). As seen in Figure 17 below, the arable land and permanent crops in the Czech Republic have already seen one of the highest losses (over 5 ha/km^2) among European countries between 2000 and 2018. This loss has been recorded due to a number of environmental changes (e.g., loss of biodiversity) and climate impacts (e.g., droughts), undermining increasing vulnerability of the Czech Republic to the impacts of climate change (European Environmental Agency, 2019).

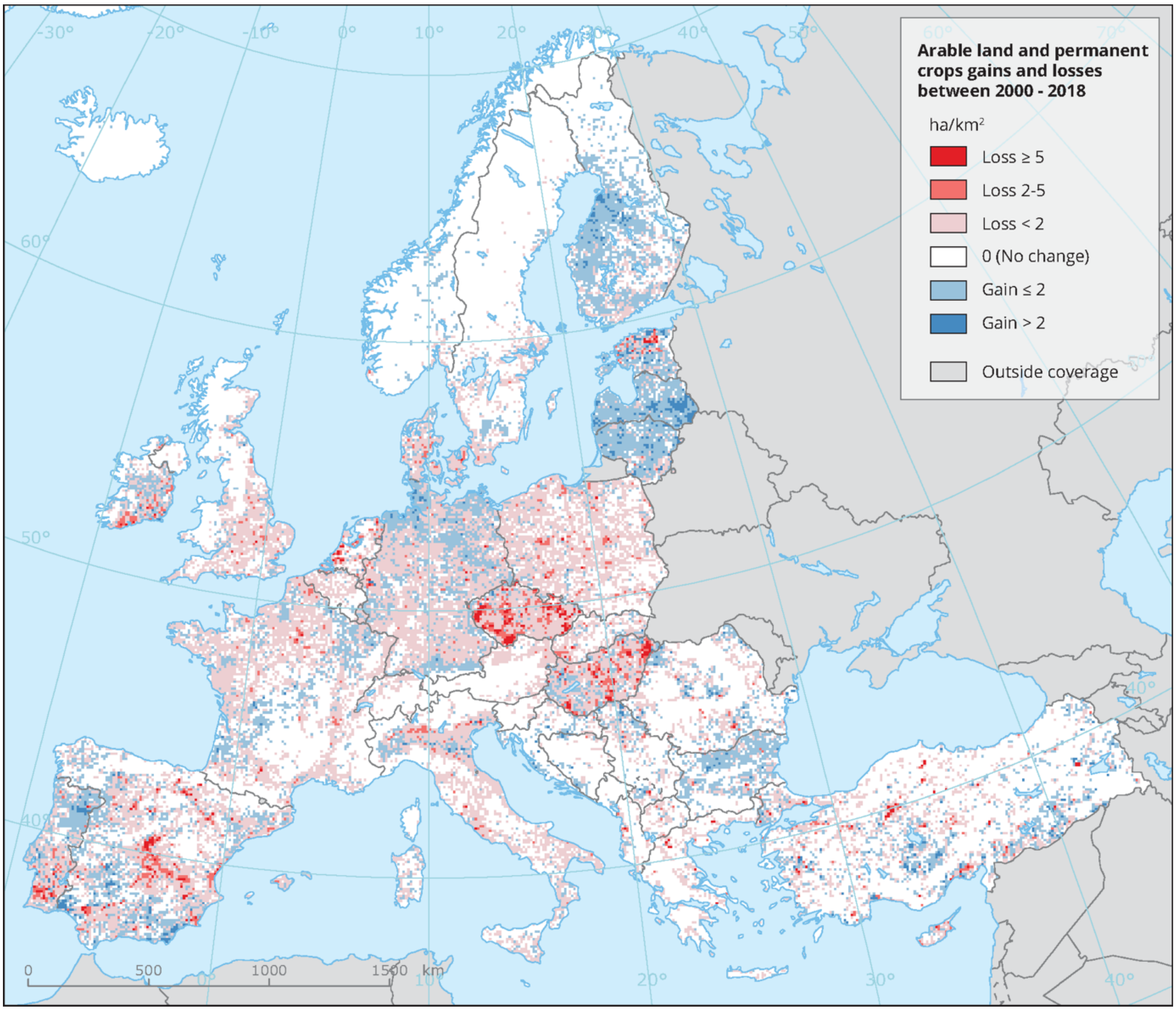


Figure 17: Arable land and permanent crops gains and losses between 2000 and 2018. This map shows the losses and gain of arable land and permanent crops. Changes are monitored at 1 ha level whereas the map is aggregated in a 10km^2 grid (European Environmental Agency, 2019)

Climate change will likely extend and accelerate the spread of pests and diseases, resulting in more severe and earlier pest infestation during crop seasons (European Environment Agency, 2019b, p.48). The number of pest generations is anticipated to burgeon in central Europe and the Czech Republic, causing damages to crops and reducing agricultural output (European Environment Agency, 2019b, p.48).

7.2 Livestock

The projected increase in extreme weather and climate events will also likely exacerbate crop yields and livestock productivity across all regions in Europe (European Environment Agency, 2019b, p.42). Particularly, drought is expected to play a major role in reducing livestock productivity by impacting the health of grassland and animals (European Environment Agency, 2019b, p.42). Generally, climate change affects livestock directly through effects on animal health and welfare and indirectly through impacts on feed, water resources and pathogens (European Environment Agency, 2019b, p.48). Moreover, it can increase the risk of infectious diseases for livestock (especially water- and vector borne diseases) (European Environment Agency, 2019b, p.48). Extreme events can also lead to scarcity of feed and water, e.g., through infrastructure breakdown, or to a reduced accessibility to grazing areas (European Environment Agency, 2019b, p.48). At above 25°C, dairy cattle experience increased heat stress that reduces their performance and makes them more prone to diseases (Gantner et al., 2011). As discussed in Chapter 6.1, an increased likelihood of more frequent heat waves over the coming decades and will thus threaten the profitability of livestock farming. Other projections suggest that arable agriculture in the Czech Republic might become more profitable than dairy and livestock farming (Papadimitriou et al., 2019).

7.3 Hop production

The Czech Republic, where hop growing has been a tradition for more than 1000 years, is among the world's leading hop producers (Mozny et al., 2009). The country specializes in the cultivation of Saaz hops, a kind of aromatic hops used in the brewing industry (Mozny et al., 2009). Climate change will diminish the yields "from increased temperatures during the growing season, shorter periods of crop development, reduced acids from unseasonal precipitation or adverse temperatures and sunshine during hop development (Mozny et al., 2009). Models suggest that "increasingly widespread and severe droughts and heat under climate change will cause considerable disruptions to global beer consumption and increase beer prices" (Xie et al., 2018a). Economic models also project that the mean supply of barley could decrease by up to 38% in the Czech Republic under a global warming scenario of 4.3°C until the end of the century, which could in turn have serious impacts on trade and the economy (Xie et al., 2018b).

8. Forestry

Forests contribute to climate mitigation through "the large amounts of carbon they can remove from or release to the atmosphere, the absorption or reflection of solar radiation, cooling as a result of evapotranspiration, and the production of cloud-forming aerosols" (Bastrup-Birk et al., 2016, p. 39). Therefore, the loss of forests through land use change or conversion and forest degradation increases the CO_2 levels and further contributes to climate change (Bastrup-Birk et al., 2016, p. 39). Forests also help societies adapt to climate change by providing ecosystem services, e.g., water, climate and erosion regulation, that help reduce vulnerability, and cultural services, e.g., recreational or religious services (Research Center for International Forestry, 2012). Forests are specifically relevant for hydrological ecosystem services, as they can buffer the impacts of climate change by increasing infiltration, reducing surface run-off and controlling soil loss (Research Center for International Forestry, 2012).

Climate change will likely have a profound effect on Central European forests like the ones in the Czech Republic (Hlásny et al., 2014 p.1) by affecting the timing, intensity, rate and frequency of disturbances on forest ecosystems. For example, changes in temperature and water can influence the species range and forest composition (Bastrup-Birk et al., 2016, p. 39). As a result, some locations will become unsuitable for existing tree species due to droughts or diseases, which may lead to a decrease in forest areas. As seen in Figure 18 below, the habitat suitability of tree species in Europe would change considerably. Under the 3°C warming scenario by 2100, the Czech climate would no longer be suitable for needleleaf trees, the tree species that currently covers 65% of Czech forests (Fitzgerald and Lindner, 2013, p.20; Ministry of Agriculture of the Czech Republic, 2017). Furthermore, increasing temperatures and changing precipitation patterns impact "forest structure, growth patterns composition, productivity and functioning" (Bastrup-Birk et al., 2016, p. 39). Especially the Czech Republic, where soil degradation is already progressed, face a huge risk of desertification (Bastrup-Birk et al., 2016, p. 39).

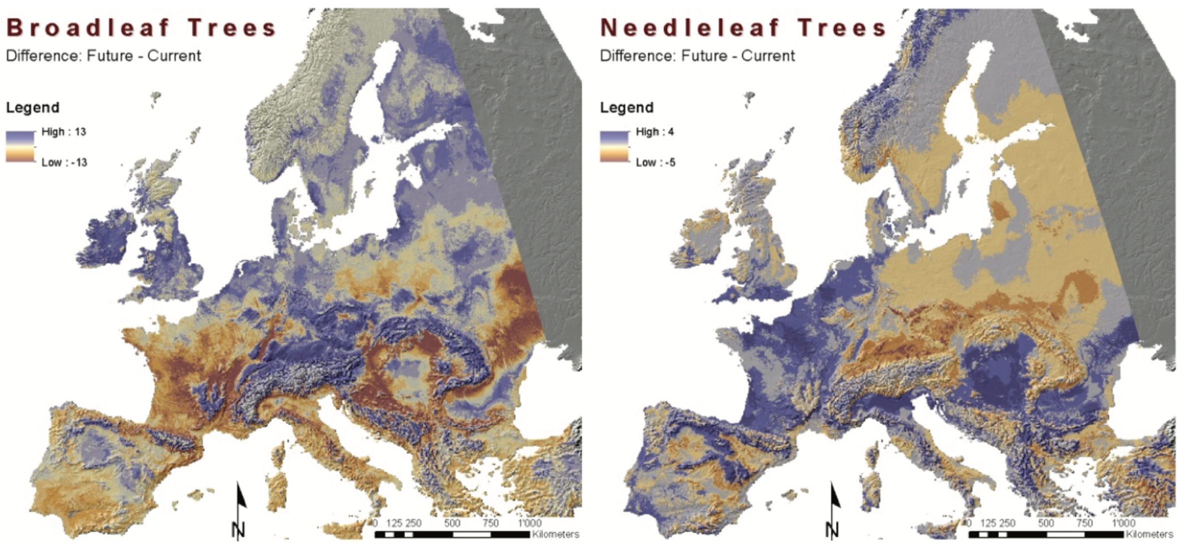


Figure 18: Projected changes in climatic suitability for broadleaf and needleleaf trees at 3°C of global warming in 2100 (A1B scenario) (Fitzgerald and Lindner, 2013, p.20)

Moreover, “climate change is likely to affect populations of forest insect pests as a result of longer warm seasons, variations in precipitation patterns, modifications in food availability and qualitative and quantitative changes in predator and parasite populations” (Bastrup-Birk et al., 2016, p. 37). European forests have already experienced an increase in the incidence of pests and diseases and a shift in the spatial and temporal ranges of insects today (Bastrup-Birk et al., 2016, p. 41). For example, tree defoliation by the gypsy moth has led to the decline in oak species throughout Central Europe (Bastrup-Birk et al., 2016, p. 41).

Particularly, the Czech Republic has been massively affected by bark-beetles (Ips typographus), a species that has destroyed European forests as hot and dry summers intensify as a result of climate change. Long- lasting droughts have helped bark beetles attack a number of trees in the Czech spruce forests, resulting in “half of all forests in the Czech Republic (…) currently at risk from the potential damage caused by the bark beetle” (Anthroposphere, 2019). In 2019, the country registered the bark beetle infestation in 20.7 million m^3 of harvested spruce woods, increased by more than 70% from 2018, as shown in Figure 19 (Fernandez-Carrillo et al., 2020). The massive spruce infestation has been caused by higher average temperatures and lower precipitation over the last five years compared with the long-term normal (Fernandez-Carrillo et al., 2020).

Warmer winters are expected to become more frequent in the Czech Republic (European Environment Agency, 2017; Fiala et al., 2010; Carbon Brief, 2018). This will further ease the spread of pests that were formerly controlled by frost. Reuters reports that in 2019, 1.7$ billions of damages has been done by “an escalating spread of bark beetle that are killing the central European country’s most common conifer trees” (Reuters, 2019). As bark beetles benefit from dry and hot summers that are prolonged and intensified with climate change, forests in the Czech Republic will face a greater risk of further degradation.

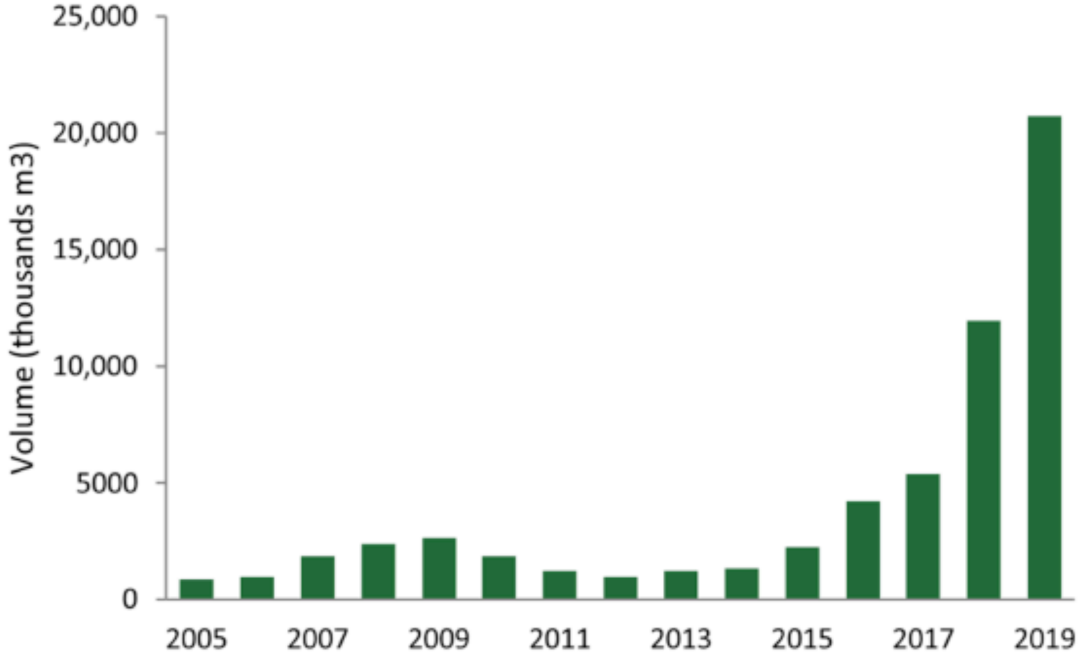


Figure 19: Recorded volume of bark beetle infested spruce wood harvested in the years 2005 to 2019 in the Czech Republic (Fernandez-Carrillo et al., 2020).

9. Health

"Climate change contributes to the burden of disease and premature deaths in Europe" (European Environment Agency, 2020, p.81). It poses a major health risk, "leading to injuries and increasing the risk of both communicable and non-communicable diseases" (European Environment Agency, 2020, p.81). There are direct risks to health due to conditions, such as extreme heat, wildfires and floods, but also indirect and long-term risks, such as changes in the distribution of infectious diseases and allergens (European Environment Agency, 2020, p.81). The population most vulnerable to these risks are not only "elderly, people with ill health, pregnant women, children and migrant and marginalized populations" but also "urban areas with dense populations" (European Environment Agency, 2020, p.81).

"In terms of the economic impacts of climate change, the total reported economic losses caused by weather- and climate-related extremes in the EEA member countries during the period 1980-2017 amounted to approximately EUR 453 billion, with over a third associated with flooding" (European Environment Agency, 2020, p.82).

9.1 Heat stress and urban heat island

Increasing temperature affects human well-being and mortality, causing heat fatigue, heat stroke, heat stress and can worsen existing health issues (European Environment Agency, 2020, p.82). “Heat waves are the deadliest type of extreme weather across Europe as a whole”, with 77 637 deaths attributed to heat waves during the period 1980-2017. In Eastern Europe, including the Czech Republic, cold events and storms are another source of excess deaths.

A total of 1000 and 100 fatalities were reported due to extreme high temperatures and low temperatures, respectively, between 1990-2016, as shown in Figure 20 (European Environment Agency, 2020, p.84). At 1.5°C of global warming, excess deaths arising from extreme heat are expected to account for 0.6% of total deaths in the Czech Republic (Carbon Brief, 2018). This number would increase to 0.9% at 2°C of global warming and to 3.6% at 4°C of global warming(ibid.)

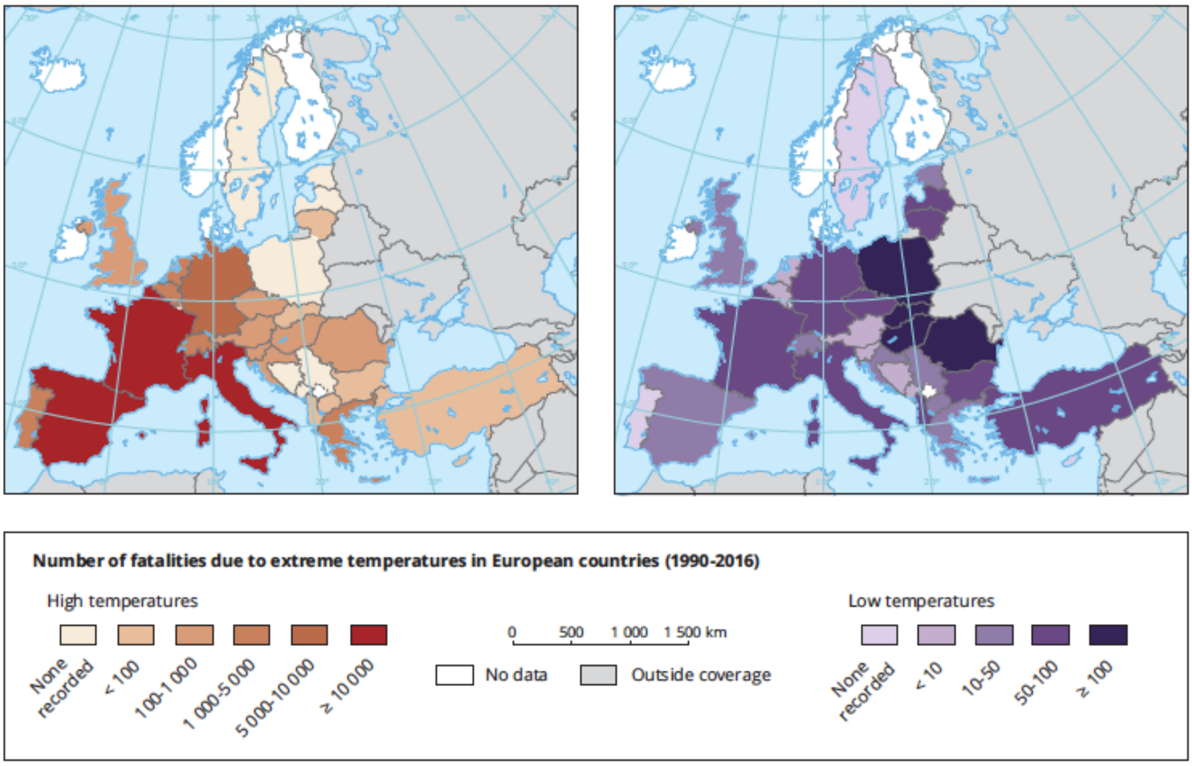


Figure 20: Number of fatalities due to extreme temperatures across Europe (1990-2016) (European Environment Agency, 2020, p.84).

As climate change greatly influences the microclimates of cities, urban areas with dense populations are particularly vulnerable (European Environment Agency, 2020, p.81). The urban heat island effect[4] further contributes to higher mortality rates seen in dense urban areas.

[4] An urban heat island is characterized by the difference in air temperature between the hotter city and its cooler surrounding countryside and reaches its maximum during night times under cloudless and calm weather conditions.

9.2 Fatalities

During 1980-2017, 90 325 additional deaths across Europe were caused by climate- and weather-related events. 13% of deaths, or 630 000 deaths per year, in Europe are attributed to environmental stressors, such as pollution (European Environment Agency, 2020, p.23). Environmental pollution leads to diseases, such as cancer, heart disease, stroke, respiratory disease and neurological disorders (European Environment Agency, 2020, p.23). Moreover, “90% of deaths attributable to the environment result from non-communicable diseases, including cancers, cardiovascular diseases, stroke, chronic obstructive pulmonary disease, mental, behavioral and neurological disorders, diabetes, kidney disease and asthma” (European Environment Agency, 2020, p.23). As shown in Figure 21 below, there is a strong discrepancy between different European countries where the Eastern parts of Europe see the highest fraction of national deaths attributable to the environment. In the Czech Republic, 14-16% of deaths are attributed to environmental stressors.

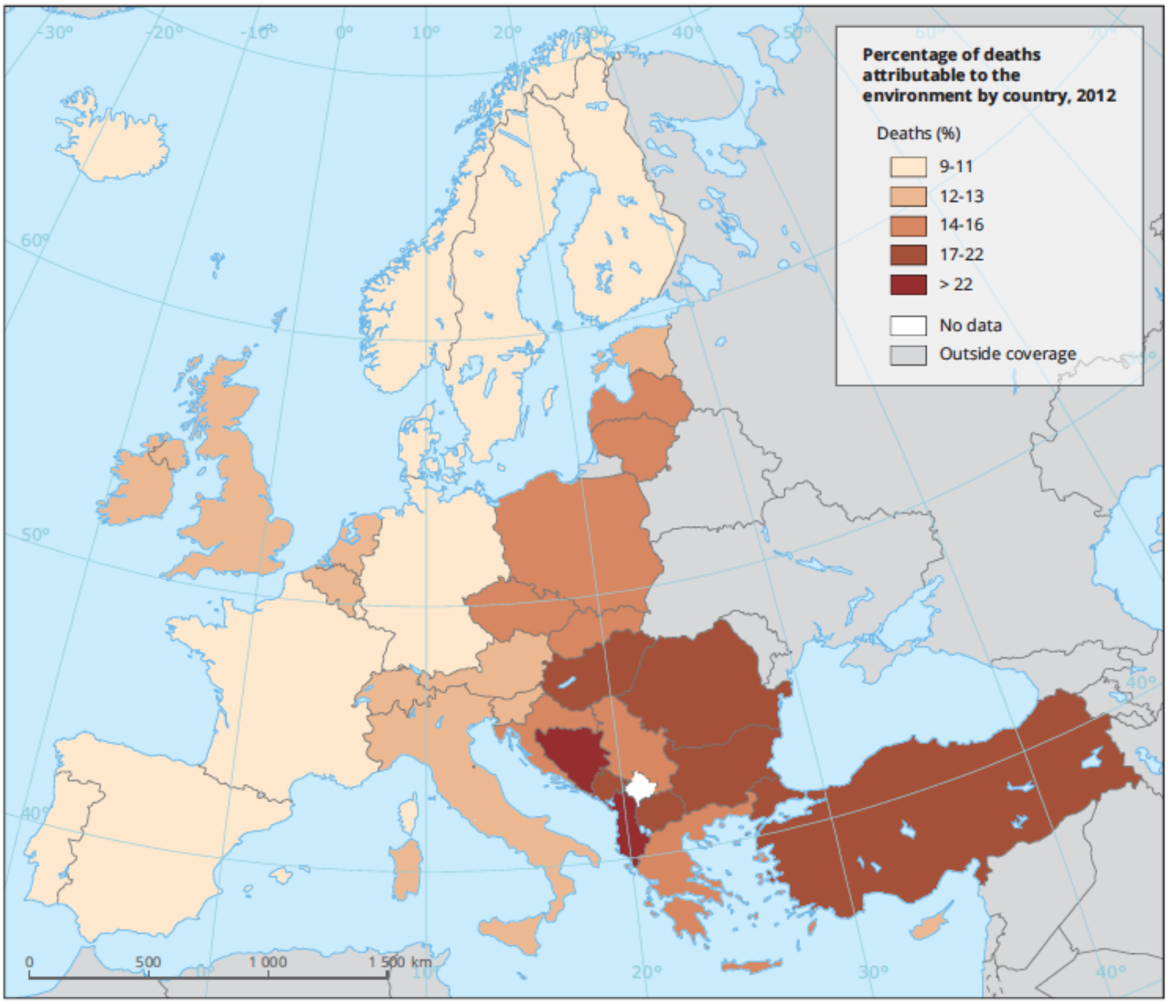


Figure 21: Percentage of deaths attributable to the environment by country in 2012 (European Environment Agency, 2020, p.26).

The Lancet report found that the number of annual heat-related mortality in the population older than 65 years averaged from 2014-2018 was between 1001-10000 in the Czech Republic (Watts et al., 2020).

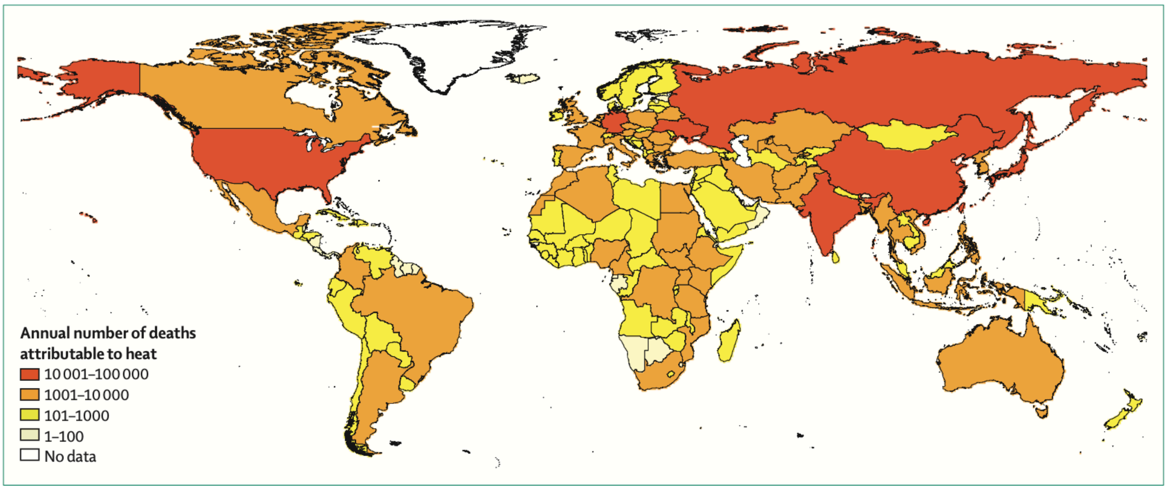


Figure 22: Annual heat-related mortality in the population older than 65 years averaged from 2014 to 2018. Source: Watts et al., 2020, p.8)

9.3 Vector-borne diseases

Vector-borne diseases are diseases often transmitted by insects or rodents. "Climate change is projected to induce substantial shifts in the geographical and seasonal distribution of vectors and their associated diseases in Europe and might enable the establishment of exotic diseases currently not present on the continent" (European Environment Agency, 2020, p.85).

Climate change was identified as the main driver of the expansion of the tick species called Ixodes Ricinus, the vector of Lyme borreliosis and tick-borne encephalitis (European Environment Agency, 2020, p.86). Moreover, the Asian tiger mosquito, which often transmits the dengue, chikungunya, and Zika viruses have substantially expanded throughout Europe with increasing global warming (European Environment Agency, 2020, p.86). Places that are projected to become warmer and wetter, such as the Czech Republic, would become more suitable to these species. Moreover, the West Nile virus, which is transmitted by mosquitos, is predicted to increase over eastern Europe (European Environment Agency, 2020, p.86). The projection of future distribution of the West Nile Virus infections (Figure 23) shows an above 0.5 probability of the Czech Republic experiencing the infections in 2050 (EEA, 2016).

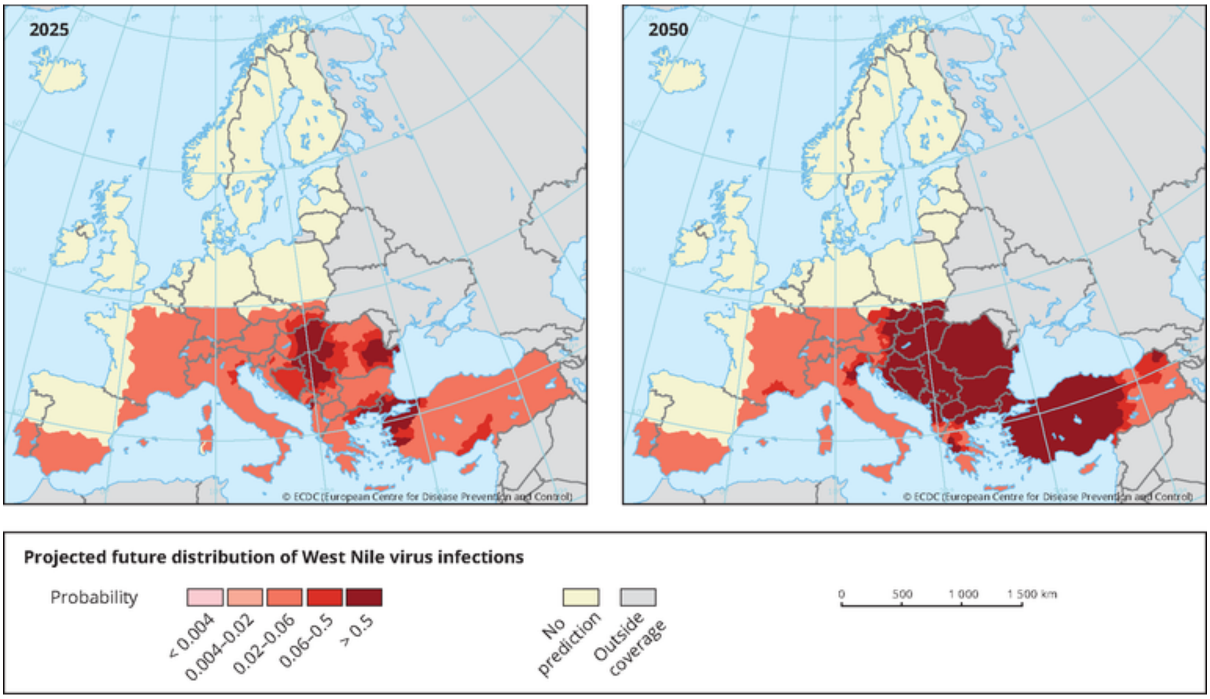


Figure 23: Projected future distribution of the West Nile Virus Infections (European Environment Agency, 2016).

9.4 Air quality and respiratory diseases

“Air pollution is the single largest environmental health risk in Europe and has significant impacts on the health of the European population, particularly in urban areas” (European Environment Agency, 2020, p.63). Air pollution causes respiratory and cardiovascular diseases which can lead to reduced lung function, respiratory infections and aggravated asthma (European Environment Agency, 2020, p.63).

The most serious pollutants harming human health in Europe, including the Czech Republic, are particulate matter (PM), nitrogen dioxide (NO_2) and ground-level ozone (European Environment Agency, 2020, p.63). In 2018, “there were about 379 000 premature deaths attributable to PM in the 28 member states of the EU. Furthermore, 19 400 deaths were attributable to ozone exposure and 54 000 to NO_2 exposure (European Environment Agency, 2020, p.65).

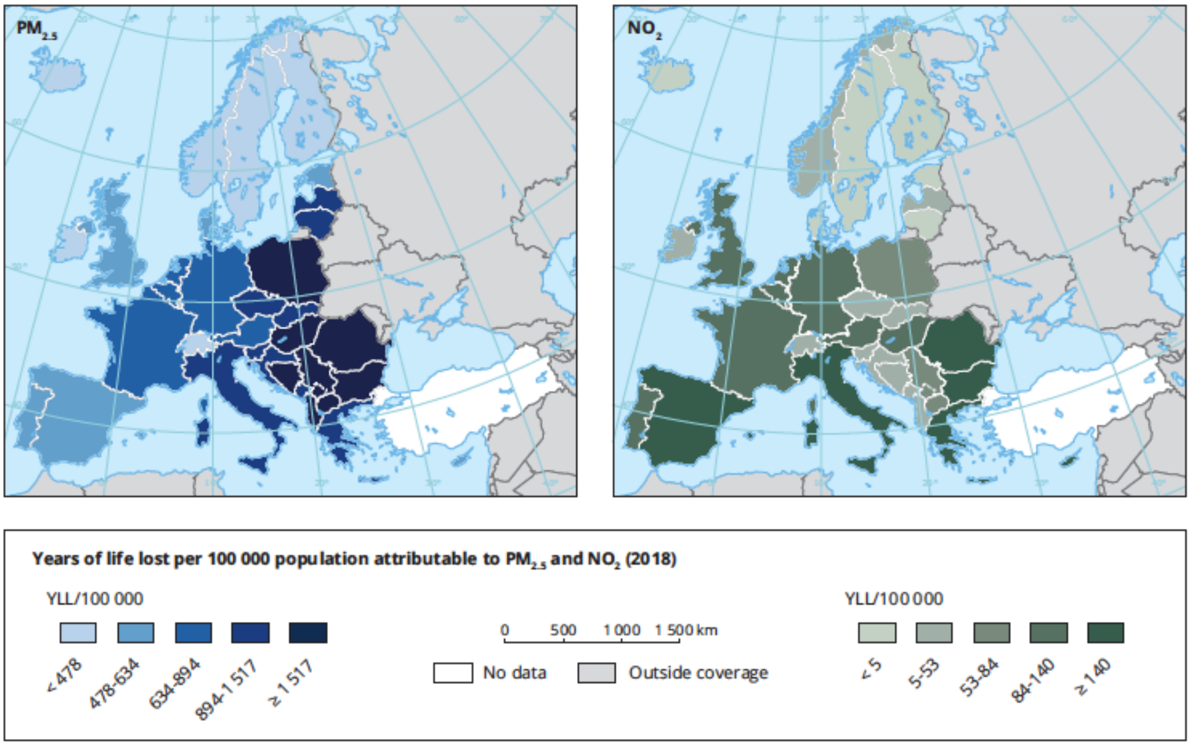


Figure 24: Years of life lost per 100 000 of the population attributable to PM (left) and NO_2 (right) in 2018 (European Environment Agency, 2020, p.67).

Figure 24 shows that in the Czech Republic between 894 – 1 517 years of life and 5-53 years of life per 100 000 population were lost due to PM and NO_2, respectively (European Environment Agency, 2020, p.67). More than 50% of the PM in Czech urban areas come from sources other than agriculture (Thunis et al., 2018). Therefore, through phasing out fossil fuels completely and complying with the 1.5°C goal, the country could reduce PM by 50% or more by 2050 (conservative estimate).

Tropospheric ozone (O_2) is a major air pollutant that affects the cardio-pulmonary system (Jahn and Hertig, 2020a). For example, a high concentration of ozone can cause lung inflammation, lung tissues damage, asthma, heart attacks, and other respiratory or cardiovascular diseases (Jahn and Hertig, 2020b). As seen in Figure 25, the ozone concentration is projected to increase throughout the 21st century, posing a great threat to human life. A combination of high ozone concentration with rising temperature in the same areas could create an “intensified threat to human life as a result of their associated and combined health affects” (Jahn and Hertig, 2020b).

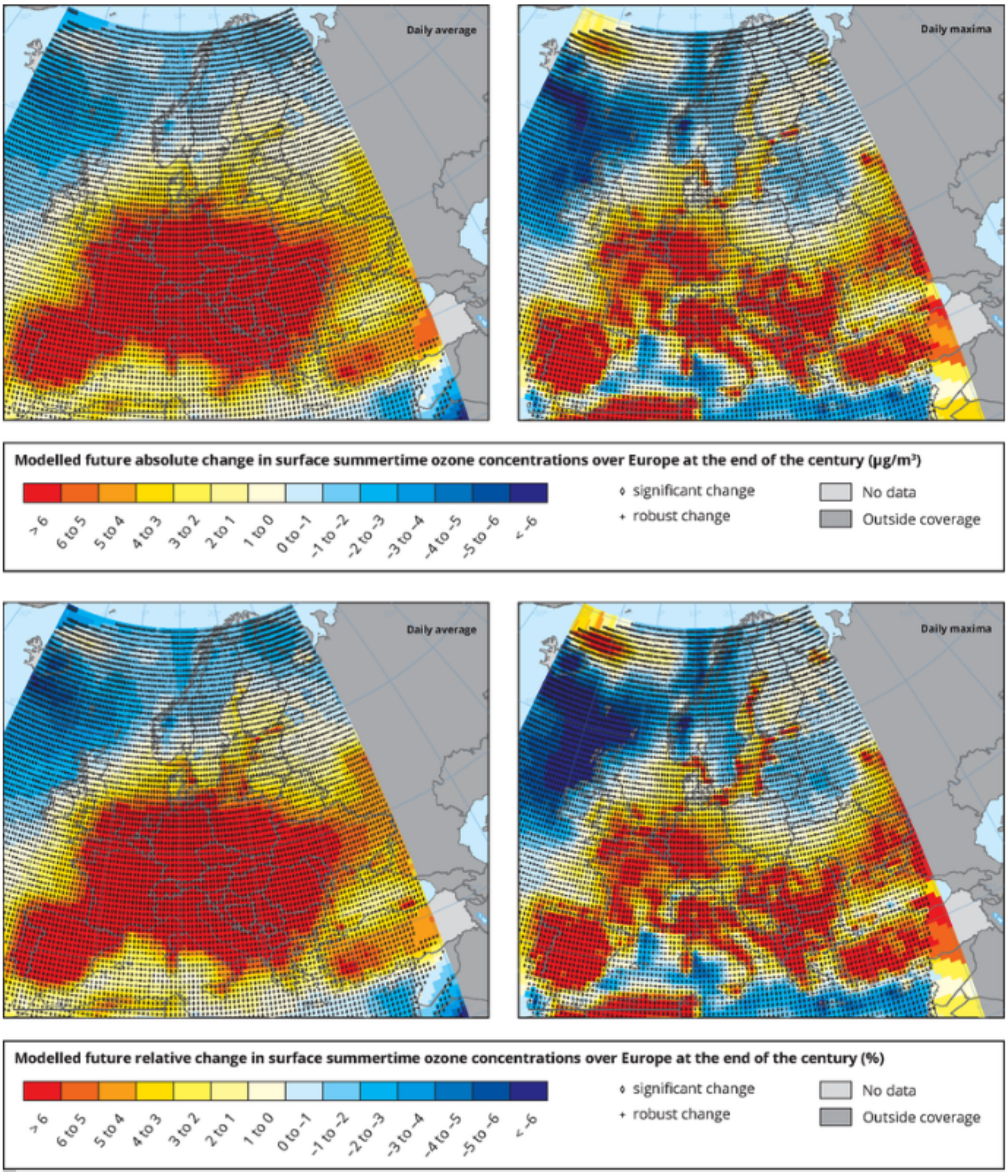


Figure 25: Modelled future change (absolute and relative) in surface summertime ozone concentrations (left: daily average, right: daily maxima) over Europe at the end of the century. Absolute and relative difference between future (2071-2100) and present (1960-2010) summertime average daily and maxima ozone levels in a 3-model ensemble. The modelled changes shown are only due to climate variability and climate change. A diamond sign is plotted where the change is significant, and a plus sign is added where the change is robust across two-third of modelled years. The period 2071-2100 is taken as representative of the end of the 21st century (2100) (European Environment Agency, 2015)

Air quality and resulting respiratory diseases will likely have considerable economic losses, such as "cutting lives short, increasing medical costs and reducing productivity through working days lost across the economy" (European Environment Agency, 2020, p.65).

As mentioned above, air pollution (e.g., PM) is associated with several adverse health outcomes, such as asthma, and is commonly found at high levels in cities or in the vicinity of different chemical industries. Recently "an association between air concentrations of these pollutants and human respiratory viruses interacting to adversely affect the respiratory system" has been reported (Domingo et al., 2020). Moreover, a number of studies suggest "that chronic exposure to certain air pollutants leads to more severe and lethal forms of COVID-19 and delays/complicates the recovery of patients of this disease" (Domingo et al., 2020).

9.5 Mental health

Climate change poses a major threat to mental health (Wu et al., 2020, p.435). Even in countries that are not yet directly affected by the devastation caused by climate change, "there are numerous personal and clinical accounts of subclinical depressive emotions, despair, and guilt associated with the climate crisis and other global environmental issues" (Ingle and Mikulewicz, 2020, p.1). Knowing that danger is coming but not having the appropriate skills or agency to mitigate it, is a key factor contributing to climate- or eco-anxiety, which can lead to "dramatic reactions, such as loss of appetite, sleeplessness, and panic attacks" (Ingle and Mikulewicz, 2020, p.1). People can develop feelings of powerlessness, arising from not being able to improve the situation, and be left with an unresolved sense of loss, helplessness, and frustration (Ingle and Mikulewicz, 2020, p.1). Particularly vulnerable groups, such as people with a low socio-economic status, can develop fear that climate change impacts could lead to life disruption, such as loss of life, resources, social support, or relocation (Cianconi et al., 2020). An increase in mental distress is more likely to be found in countries hardly hit by environmental disasters.

The current risk of floods in the Czech Republic, discussed in Chapter 6.4, is particularly relevant, as it affects the mental health of victims. The EEA states: "The stress that flood victims feel can affect their mental health for a long time after the event. Up to three quarters of people affected by a flood have experienced mental health effects" (European Environment Agency, 2020, p.85).

The Lancet report finds youths (aged 10-24) to be disproportionately affected by eco-anxiety and resulting psychological effects (Wu et al., 2020, p.435). 1.6 million school-aged protesters (March 2019 alone) showed the anxiety they have about their collective futures. Increased rates of depression, anxiety, post-traumatic stress and mental health disorders are likely as a result of natural disasters, such as floods (Wu et al., 2020, p.435). Young people are "at a crucial point in their physical and psychological development, when enhanced vulnerability to the effects of stress and everyday anxiety elevate their risk of developing depression, anxiety, and substance use disorders" (Wu et al., 2020, p.435).

References

Anthroposphere, 2019. https://www.anthroposphere.co.uk/post/on-bark-beetles-and-droughts-in-the-czech-republic.

Bastrup-Birk, A., Reker, J., Zal, N., 2016. European forest ecosystems: State and trends, EEA Report n° 5/2016.

Carbon Brief, 2018. https://interactive.carbonbrief.org/impacts-climate-change-one-point-five-degrees-two-degrees/.

Climate Analytics; New Climate Institute, 2020. The CAT thermometer [WWW Document]. URL https://climateactiontracker.org/global/cat-thermometer/ (accessed 11.17.20).

Domingo, J.L., Marquès, M., Rovira, J., 2020. Influence of airborne transmission of SARS-CoV-2 on COVID-19 pandemic. A review. Environ. Res. 188, 17–20. https://doi.org/10.1016/j.envres.2020.109861

Dottori, F., Mentaschi, L., Bianchi, A., Alfieri, L., Feyen, L., 2020. JRC Technical report. Adapting to rising river flood risk in the EU under climate change JRC PESETA IV project-Task 5. https://doi.org/10.2760/14505

European Environment Agency, 2020. Healthy environment, healthy lives: how the environment influences health and well-being in Europe.

European Environment Agency, 2019a. Climate change adaptation in the agriculture sector in Europe. EEA Rep. 112.

European Environment Agency, 2019b. Economic losses from climate-related extremes in Europe [WWW Document]. URL https://www.eea.europa.eu/data-and-maps/indicators/direct-losses-from-weather-disasters-3/assessment-2 (accessed 11.16.20).

European Environment Agency, 2019c. Climate change adaptation in the agriculture sector in Europe 112.

European Environment Agency, 2015. Air pollution due to ozone: health impacts and effects of climate change [WWW Document]. URL https://www.eea.europa.eu/data-and-maps/indicators/air-pollution-by-ozone-2/assessment

European Environmental Agency, 2020. https://www.eea.europa.eu/data-and-maps/figures/simulated-change-in-water-limited.

European Environmental Agency, 2019. https://www.eea.europa.eu/data-and-maps/figures/agriculture-land-loss-and-difference [WWW Document].

Fitzgerald, J., Lindner, M., n.d. Adapting to climate change in European forests 110.

Füssel, H.-M., Jol, A., Marx, A., Hildén, M., 2017. Climate change, impacts and vulnerability in Europe 2016 — European Environment Agency, European Environment Agency.

Hlásny, T., Mátyás, C., Seidl, R., Kulla, L., Merganičová, K., Trombik, J., Dobor, L., Barcza, Z., Konôpka, B., 2014. Climate change increases the drought risk in Central European forests: What are the options for adaptation? For. J. 60, 5–18. https://doi.org/10.2478/forj-2014-0001

Hoegh-Guldberg, O., D. Jacob, M., Taylor, M., Bindi, S., Brown, I., Camilloni, A., Diedhiou, R., Djalante, K.L., Ebi, F., Engelbrecht, J., Guiot, Y., Hijioka, S., Mehrotra, A., Payne, S.I., Seneviratne, A., Thomas, R.W., Zhou, G., 2018. Chapter 3: Impacts of 1.5°C of Global Warming on Natural and Human Systems, in: Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M., Waterfield, T. (Eds.), Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change. IPCC, Geneva, Switzerland, pp. 175–311.

Hristov, J., Toreti, A., Pérez, I., Dentener, F., Fellmann, T., Elleby, C., Ceglar, A., Fumagalli, D., Niemeyer, S., Cerrani, I., Panarello, L., Bratu, M., 2020. Analysis of climate change impacts on EU agriculture by 2050. https://doi.org/10.2760/121115

Ingle, H.E., Mikulewicz, M., 2020. Mental health and climate change: tackling invisible injustice. Lancet Planet. Heal. 4, e128–e130. https://doi.org/10.1016/S2542-5196(20)30081-4

International Commission for the Protection of the Danube River, 2007. Czech Republic [WWW Document]. URL https://www.icpdr.org/main/danube-basin/czech-republic (accessed 11.16.20).

Ionita, M., Tallaksen, L.M., Kingston, D.G., Stagge, J.H., Laaha, G., Van Lanen, H.A.J., Scholz, P., Chelcea, S.M., Haslinger, K., 2017. The European 2015 drought from a climatological perspective. Hydrol. Earth Syst. Sci. 21, 1397–1419. https://doi.org/10.5194/hess-21-1397-2017

IPCC, 2020. Summary for Policymakers, in: Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmot. pp. 1–15. https://doi.org/10.1002/9781118786352.wbieg0538

IPCC, 2019. Summary for Policymakers. IPCC Spec. Rep. Clim. Chang. Desertif. L. Degrad. Sustain. L. Manag. food Secur. Greenh. gas fluxes Terr. Ecosyst. https://doi.org/10.4337/9781784710644

IPCC, 2014. Data Distribution Centre [WWW Document]. IPCC. URL https://www.ipcc-data.org/guidelines/pages/glossary/glossary_s.html

Jahn, S., Hertig, E., 2020a. Modeling and projecting health-relevant combined ozone and temperature events in present and future Central European climate. Air Qual. Atmos. Heal. 3.

Jahn, S., Hertig, E., 2020b. Modeling and projecting health-relevant combined ozone and temperature events in present and future Central European climate. Air Qual. Atmos. Heal. 3.

King, A.D., Karoly, D.J., 2017. Climate extremes in Europe at 1.5 and 2 degrees of global warming. Environ. Res. Lett. 12, 114031. https://doi.org/10.1088/1748-9326/aa8e2c

Kyselý, J., 2008. Trends in heavy precipitation in the Czech Republic over 1961-2005. Int. J. Climatol. 2011–2029. https://doi.org/10.1002/joc.1784

Ministry of Agriculture of the Czech Republic, 2018. https://informar.eu/sites/default/files/pdf/Presentation%20CZ%20062018.pdf.

Moss, R., Babiker, M., Brinkman, S., Calvo, E., Carter, T., Edmonds, J., Elgizouli, I., Emori, S., Erda, L., Hibbard, K., Jones, R., Kainuma, M., Kelleher, J., Lamarque, J.F., Manning, M., Matthews, B., Meehl, J., Meyer, L., Mitchell, J., Nakicenovic, N., O'Neill, B., Pichs, R., Riahi, K., Rose, S., Runci, P., Stouffer, R., Vuuren, D. van, Weyant, J., Wilbanks, T., Ypersele, J.P. van, Zurek, M., 2008. Towards New Scenarios for Analysis of Emissions, Climate Change, Impacts and Response Strategies, IPCC Expert Meeting Report. Intergovernmental Panel on Climate Change, Geneva, Switzerland.

Moss, R., Edmonds, J., Hibbard, K., Manning, M., Rose, S., van Vuuren, D., Carter, T., Emori, S., Kainuma, M., Kram, T., Meehl, G. a, Mitchell, J.F.B., Nakicenovic, N., Riahi, K., Smith, S.J., Stouffer, R.J., Thomson, A.M., Weyant, J.P., Wilbanks, T.J., 2010. The next generation of scenarios for climate change research and assessment. Nature 463, 747–56. https://doi.org/10.1038/nature08823

Mozny, M., Tolasz, R., Nekovar, J., Sparks, T., Trnka, M., Zalud, Z., 2009. The impact of climate change on the yield and quality of Saaz hops in the Czech Republic. Agric. For. Meteorol. 149, 913–919. https://doi.org/10.1016/j.agrformet.2009.02.006

Mozny, M., Trnka, M., Brázdil, R., 2020. Climate change driven changes of vegetation fires in the Czech Republic.

Naumann, G., Russo, S., Formetta, G., Ibarreta, D., Forzieri, G., Girardello, M., Feyen, L., 2020. Global warming and human impacts of heat and cold extremes in the EU. Publ. Off. Eur. Union. https://doi.org/10.2760/47878

Ove Hoegh-Guldberg, Jacob, D., Taylor, M., et al, 2018. Chapter 3: Impacts of 1.5°C global warming on natural and human systems, in: Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M., Waterfield, T. (Eds.), Global Warming of 1.5 C :An IPCC Special Report on the Impacts of Global Warming of 1.5 C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change,. IPCC, Geneva, Switzerland. https://doi.org/10.1093/aje/kwp410

Reuters, 2019. https://www.reuters.com/article/czech-environment-barkbeetle-idUSL5N26S1SE.

Samaniego, L., Thober, S., Kumar, R., Wanders, N., Rakovec, O., Pan, M., Zink, M., Sheffield, J., Wood, E.F., Marx, A., 2018. Anthropogenic warming exacerbates European soil moisture droughts. Nat. Clim. Chang. 8, 421–426. https://doi.org/10.1038/s41558-018-0138-5

Spinoni, J., Lakatos, M., Szentimrey, T., Bihari, Z., Szalai, S., Vogt, J., Antofie, T., 2015. Heat and cold waves trends in the Carpathian Region from 1961 to 2010. Int. J. Climatol. 35, 4197–4209. https://doi.org/10.1002/joc.4279

Stocker, T.F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., (eds.), V.B. and P.M.M., 2013. Summary for Policymakers, in: Intergovernmental Panel on Climate Change (Ed.), Climate Change 2013 - The Physical Science Basis. Cambridge University Press, Cambridge, pp. 1–30. https://doi.org/10.1017/CBO9781107415324.004

Thunis, P., Degraeuwe, B., Pisoni, E., Trombetti, M., Peduzzi, E., Belis, C.A., Wilson, J., Clappier, A., Vignati, E., 2018. PM2.5 source allocation in European cities: A SHERPA modelling study. Atmos. Environ. 187, 93–106. https://doi.org/10.1016/j.atmosenv.2018.05.062

Trnka, M., Hlavinka, P., Možný, M., Semerádová, D., Štěpánek, P., Balek, J., Bartošová, L., Zahradníček, P., Bláhová, M., Skalák, P., Farda, A., Hayes, M., Svoboda, M., Wagner, W., Eitzinger, J., Fischer, M., Žalud, Z., 2020. Czech Drought Monitor System for monitoring and forecasting agricultural drought and drought impacts. Int. J. Climatol. 1–18. https://doi.org/10.1002/joc.6557

Wu, J., Snell, G., Samji, H., 2020. Climate anxiety in young people: a call to action. Lancet Planet. Heal. 4, e435–e436. https://doi.org/10.1016/S2542-5196(20)30223-0

Xie, W., Xiong, W., Pan, J., Ali, T., Cui, Q., Guan, D., Meng, J., Mueller, N.D., Lin, E., Davis, S.J., 2018a. Decreases in global beer supply due to extreme drought and heat. Nat. Plants 4, 964–973. https://doi.org/10.1038/s41477-018-0263-1

Xie, W., Xiong, W., Pan, J., Ali, T., Cui, Q., Guan, D., Meng, J., Mueller, N.D., Lin, E., Davis, S.J., 2018b. Decreases in global beer supply due to extreme drought and heat. Nat. Plants 4, 964–973. https://doi.org/10.1038/s41477-018-0263-1