Climate Impacts in Italy

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About Climate Analytics

Climate Analytics is a non-profit climate science and policy institute based in Berlin, Germany with offices in New York, USA, Lomé, Togo and Perth, Australia, which brings together interdisciplinary expertise in the scientific and policy aspects of climate change. Our mission is to synthesise and advance scientific knowledge in the area of climate change and on this basis provide support and capacity building to stakeholders. By linking scientific and policy analysis, we provide state-of-the-art solutions to global and national climate change policy challenges.

Climate Analytics was founded in 2008 in Potsdam, Germany by Dr. (h.c) Bill Hare, Dr. Malte Meinshausen and Dr. Michiel Schaeffer to bring vanguard climate science and policy analysis to bear on one of the most pressing global problems of our time: human induced climate change. We are motivated by the desire to empower those most vulnerable – small island states and least developed countries – to use the best science and analysis available in their efforts to secure a global agreement to limit global warming to levels that don't threaten their very survival.

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ITALY

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1. Summary

This report provides scientific evidence on observed and future impacts of climate change in Italy. Italy is experiencing increasing climate change that manifests itself in a range of impacts for humans and ecosystems already today at about 1°C warming above pre-industrial levels.

Mean temperatures and extreme high temperatures have increased in the past decades and are projected to continue to do so. Southern European countries, including Italy, are already among the most critically affected by global warming in Europe and will experience disproportionally higher warming in the next decades. Under current emission trajectories leading to about 3°C warming by the end of the century, a today's Italian 15-year-old would live more than 2 thirds of his life above 1.5°C and almost half his life above 2°C above pre-industrial levels.

Italy is projected to experience some of the most intense heat waves across Europe, with a high increase in frequency for extreme droughts and increasing desertification particularly in the South (especially Sicily), leading to a higher risk of wildfires. Under a high warming scenario, annual precipitations will decrease by up to -30% at the end of the century compared to the baseline period of 1971-2000. Under a warming of 3.0°C by the end of the century, around 50% of the Mediterranean region will be under drought conditions and these droughts will last on average 10 years. Under scenarios exceeding >4°C (RCP8.5) global mean temperature rise by 2100, the local sea levels around the Italian coastline will rise by around 60 cm or more in 2081-2100, relative to 1986-2005. Limiting warming to around 1.6°C (RCP2.6) will reduce local sea level rise to about 20-40cms. In addition, Northern Italy is projected to experience some of the most severe floods in Europe. Italy is currently a hotspot for landslides in Europe. Debris flow and shallow landslides are projected to increase particularly in the center and in the south. Even though fires in Italy have decreased in recent years, increasing number of droughts, heat waves and dry spells increase the length and severity of the fire season. Under a high emission scenario (RCP8.5) the projected change in the fire weather index shows an increase in risk by more than 40% for some regions in Italy.

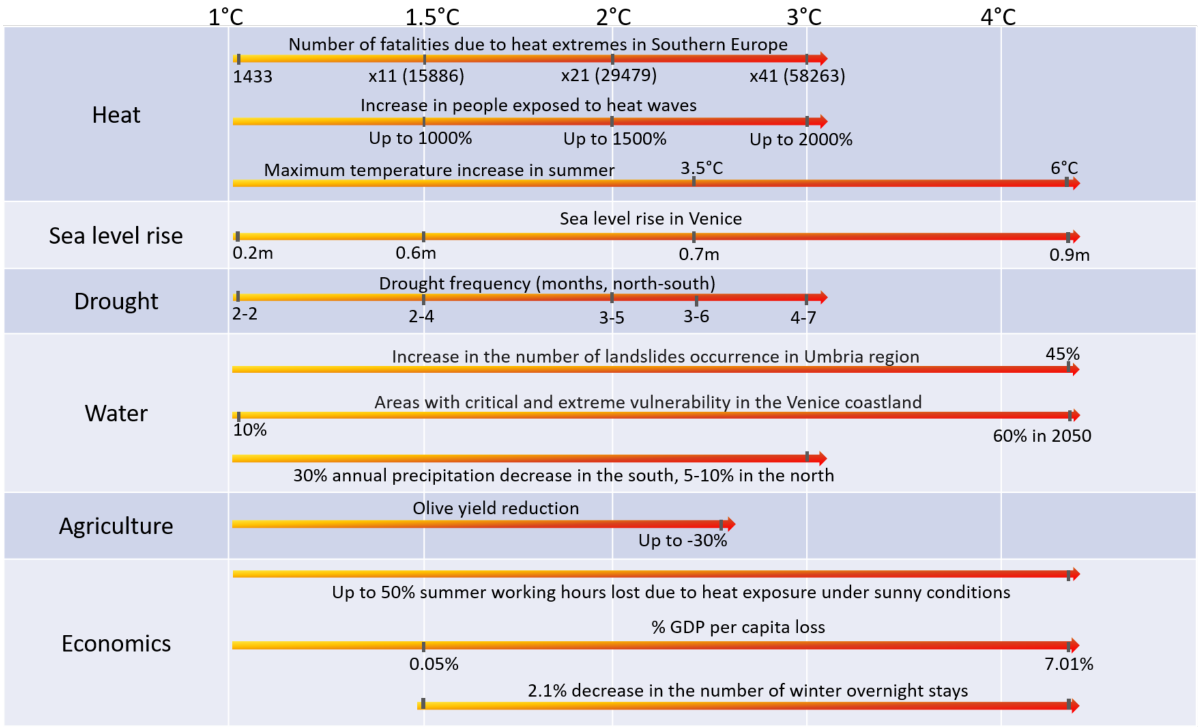


Table 1: Projected impacts of climate change in Italy. The data refers to the end of the century (for example, sea level rise in Venice will reach 0.9m for a warming of 4.3°C in 2100), except for the areas with critical and extreme vulnerability in the Venice coastland (for a warming of 4.3°C in 2100, 60% of the Venice coastland will be areas with critical and extreme vulnerability in 2050). All the data and sources can be found in this report.

These impacts will have sectoral consequences. Welfare losses in Southern Europe under 3°C warming have been estimated to be about 4 times larger than under a 1.5°C scenario.

In Italy, a decline of 5% or greater in agricultural yield has already been observed, and a further reduction in crop productivity together with a decrease in food and water availability are projected. The production of olive oil and wine are sensitive to increasing temperatures, with olive yield being projected to decrease in some parts of central Italy by up to -15% for warming exceeding 2°C, and the wine industry facing potential losses to product quantity and quality. The threats climate change poses to World Heritage Sites (e.g. Venice and its lagoons) and the reduction of the length of the ski season in the Alps will have a negative impact on the tourism industry. Climate change also affects human health and leads to fatal illnesses: Increasing temperatures lead to heat stress and cause increasing mortality from respiratory diseases. Already under a 1.5°C scenario, annual fatalities by extreme heat could be ten times higher in Southern Europe. If warming was to reach 3°C, numbers would more than triple compared to 1.5°C. Furthermore, vector-borne diseases such as West-Nile virus are projected to expand in Northern Italy.

2. Demographic and intergenerational aspect

Italy has a population of about 60 million, out of which 18% are children under the age of 19 (Wittgenstein Centre for Demography and Global Human Capital, 2018). An average 15-year-old Italian is expected to live until the age of 92 (World Data Lab, 2019). For comparison with the timelines of climate change, the demographic estimates on life expectancy can be coupled with the projections of global mean temperature increases. Following the best estimate of the future temperature trajectory based on the Climate Action Tracker (2019), increase in the global mean temperature is expected to exceed 1.5°C around the year 2035 (model median, range from 2030 to 2052), 2°C around 2055, and more than 3°C in 2100. Today's Italian15-year-old has a 99% probability of being alive in 2035, 98% in 2055 and 20% in 2100. These children therefore have a high probability of experiencing a 2°C world and its respective climate change impacts, if emissions were not curbed substantially, a today 15-year-old would live more than 2 thirds of their lives above 1.5°C and almost half their lives above 2°C.

3. Technical note: Representative Concentration Pathways – temperature warming

Representative Concentration Pathways

A scenario is a plausible description of how the future may develop, based on assumptions about key forces which drive climate change and the relationships between them (IPCC, 2014). Representative Concentration Pathways (RCPs) are a suite of scenarios 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 (RCP 2.6, 4.5, 6.0, 8.5) (Moss et al., 2010). Each RCP is associated with an approximation of the range of increases in the global average temperature by 2100 in comparison to pre-industrial times. The table below shows the mean (best estimate) projected temperature increase, as assessed in the IPCC Fifth' Assessment Report (AR5) Working Group 1 report. It further provides the 5-95% range of temperature increase associated with each RCP across the climate model ensemble used in the IPCC in parenthesis.

Name	**Expected temperature increase over the 2081-2100 period (mean and 5-95% model 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 2: Warming under different Representative Concentration Pathways scenarios. The mean and 5-95% range 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 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 Fifth' Assessment Report estimates that 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 2.

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 respective warming trajectories. Those are shown in Figure 1 below. Again, the ranges provided are the likely (66% probability) ranges for the temperature increase under these 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 which exist in relation to the feedback processes in the earth system. A warming of 3.9°C by the end of the century thereby is within the likely (66% probability) range under current policy projections. This means that there is a non-negligible 17% probability of warming to exceed this range under current policy projections, which would mean a global mean temperature increase of 4°C or more by the end of the century. There is thus a significant overlap 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 with the upper end of the likely (66% probability) warming range being in excess of 3.9°C. Climate impacts occurring under a RCP8.5 scenario thus cannot be excluded as a distinct possibility based on current mitigation policies globally.

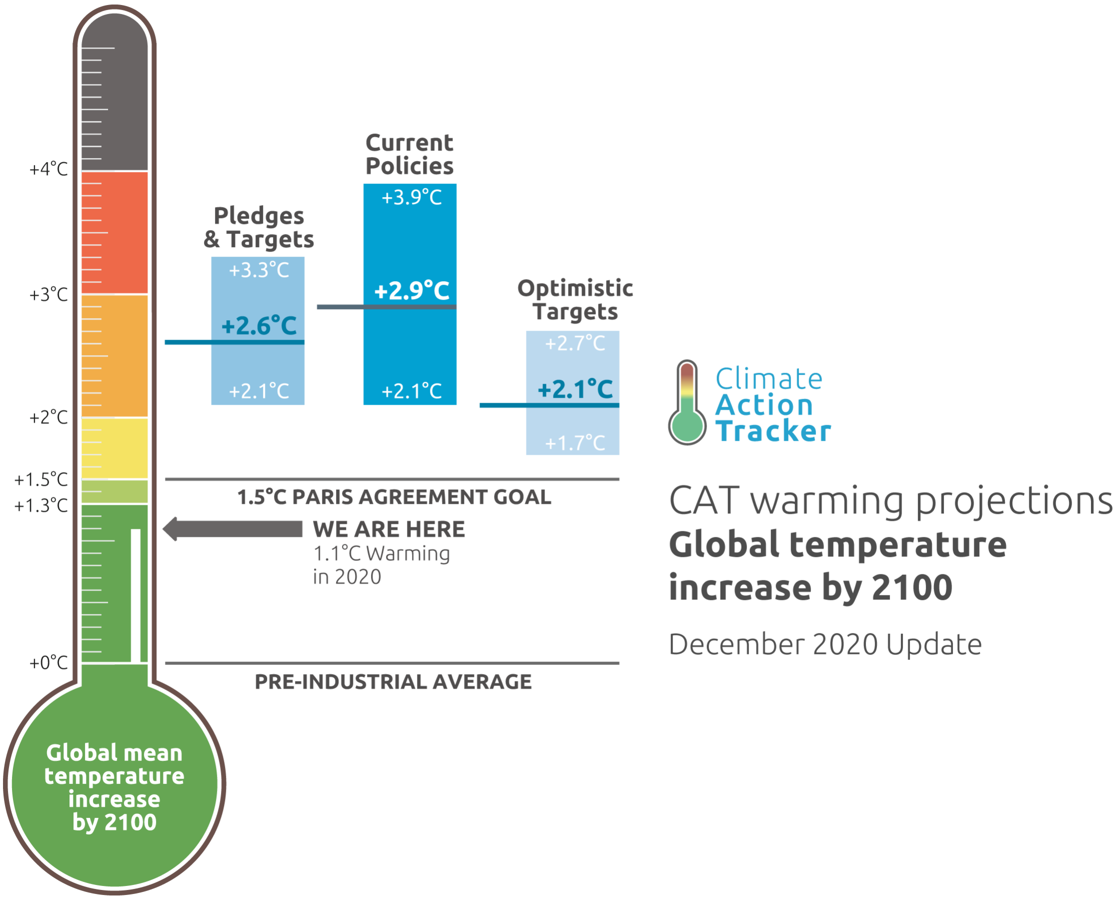


Figure 1: Climate Action Tracker emission and expected warming. Warming is shown for three different assumptions about future warming differentiating between targets of countries and actual policies in place to meet those targets: Countries fulfilling their current pledges and targets under the UNFCCC (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 effort is 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 several scenarios) and hence do not provide estimates of impacts under all warming levels. The analysis which follows draws on the available studies which analyse the impacts anticipated to result from climate change in Italy. In addition, we will 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 and 6.0 are used, while 2.6 is consistently used for a low emission scenario.

4. Temperature increase

The warming of the Earth is considered unequivocal at the global level. At the regional scale, many areas show an even increased warming (Hoegh-Guldberg et al., 2018). A very prominent example is the Arctic, “but also Mediterranean countries, and Italy in particular, are critically affected by a stronger warming” (Amendola et al., 2019, p. 2). The climatic conditions in Italy are very variable due to its location across the center of the Mediterranean. The presence of its mountain chains make the orography highly complex, leading to remarkably varied features in the Italian climate (Fratianni and Acquaotta, 2017, p.29).

Globally “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).

“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).

The projections shown in Figure 2 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 in the range of 1°C to 4.5°C for a global warming scenario of 2.5°C by 2100 (RCP4.5) and in the range of 2.5°C to 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). Moreover, the strongest warming is projected over southern Europe, and thus Italy, over summer (Füssel et al., 2017, p. 76). For example, as Figure 2 shows, summer temperatures in Italy would increase by up to 6°C under a global warming scenario of > 4°C by the end of the century (RCP8.5). For a global warming scenario of 2.5°C by 2100 (RCP4.5), summer temperatures in Italy would increase by up to 3.5°C compared to 1971-2000.

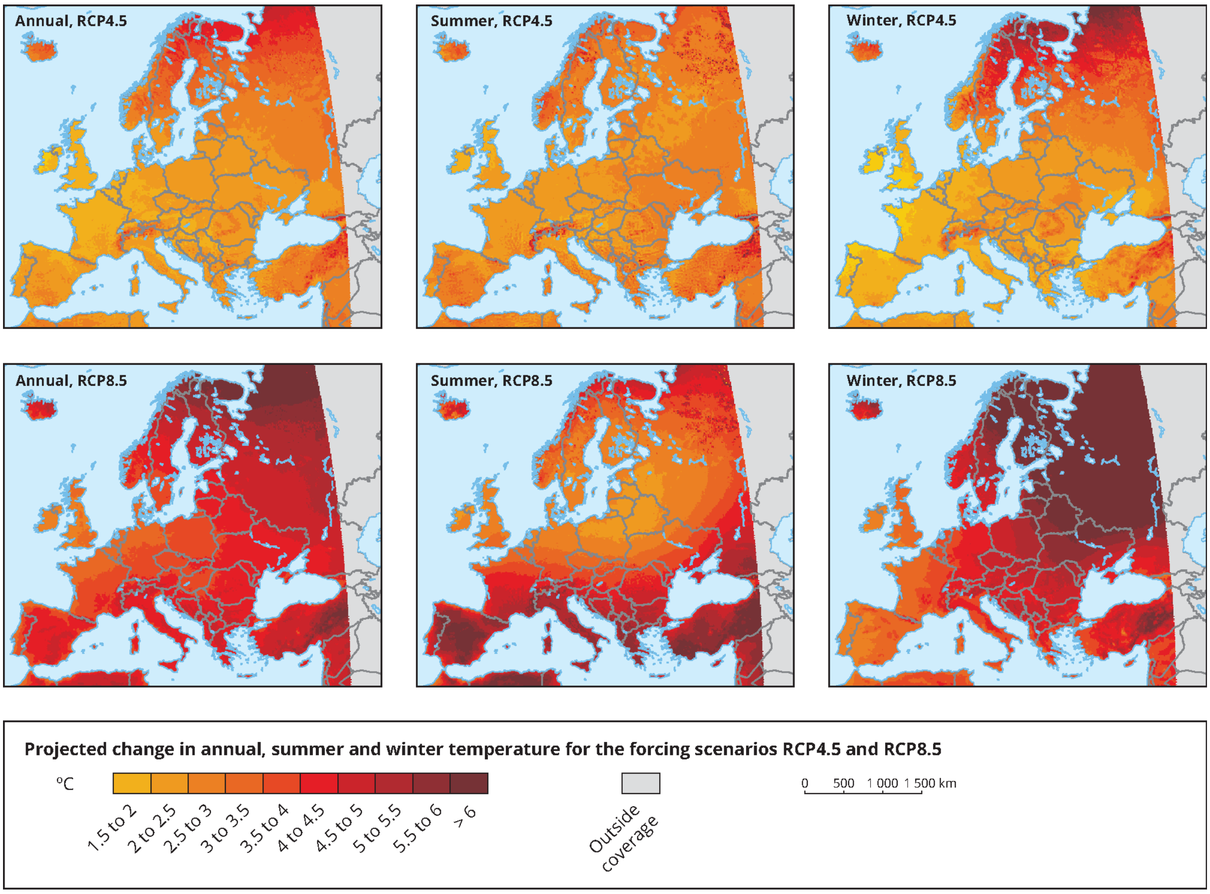


Figure 2 : Projected changes in annual (left), summer (middle) and winter (right) near-surface air temperature (°C) in the period 2071-2100, compared with the baseline period 1971-2000 for the forcing scenarios RCP4.5 (top – global warming scenario of 2.5°C by 2100) and RCP8.5 (bottom - > 4°C by 2100). 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

The IPCC Special Report on 1.5°C found, that southern Europe, and thus Italy, will be expecting “decreases in mean precipitation in summer” and that “precipitation changes reaching 20% have been projected for the 2°C scenario and are overall more pronounced than with 1.5°C of global warming” (Hoegh-Guldberg et al., 2018, p. 194).

These projected decreases in annual rainfall and increases in the rainfall intensity will potentially lead to recurring erosion events: “In the Mediterranean region, the observed and expected decrease in annual rainfall due to climate change is accompanied by an increase of rainfall intensity, and hence erosivity” (IPCC, 2019, p. 362).

As can be seen on Figure 3 “annual precipitation has increased in most parts of northern Europe and decreased in parts of southern Europe. These changes are projected to exacerbate in the future with continued climate change, and the projected decrease is greatest in southern Europe in the summer” (European Environment Agency, 2019b, p. 173). On the figure we can see that summer precipitation might decrease by up to -40% compared to the baseline period of 1971-

2000, whereas annual precipitation will also decrease by up to -30% in the southern parts of Italy.

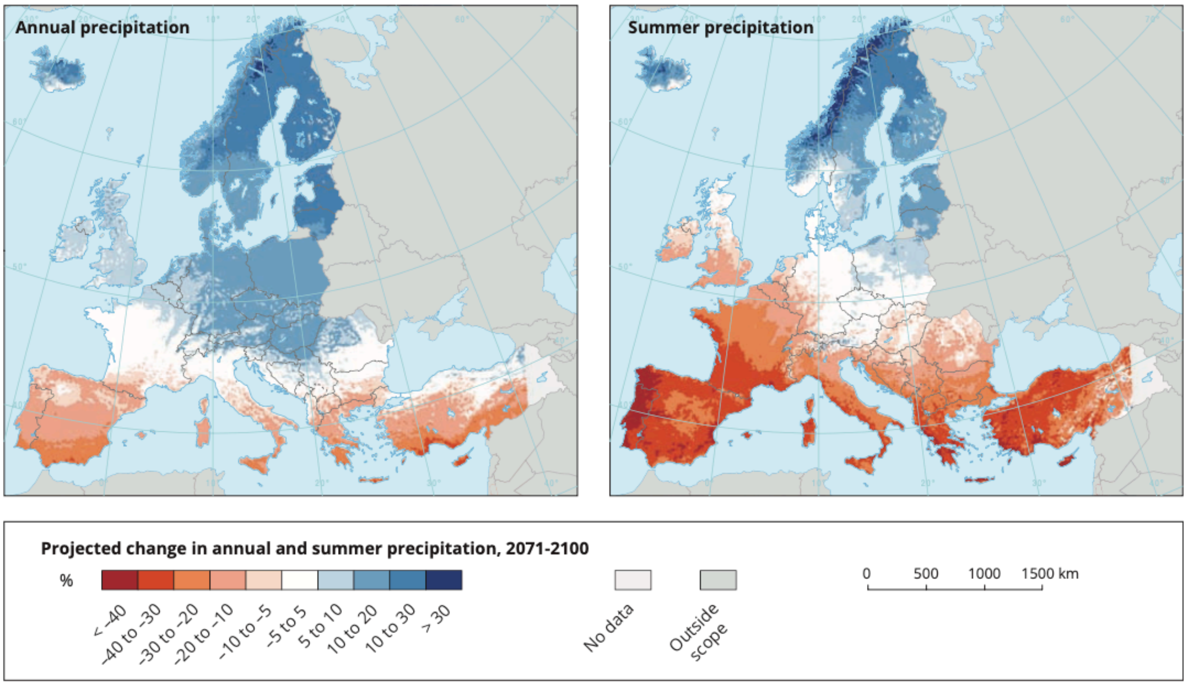


Figure 3 : Projected changes in annual (left) and summer (right) precipitation (%) in the period 2071-2100 compared with the baseline period 1971-2000 for a >4°C scenario (RCP8.5) based on the average of a multi-model ensemble of regional climate models (European Environment Agency, 2019b, p. 173, map 7.2).

In the figure below further illustrates the differences in changes in precipitation indices between 1.5°C and 2°C of global warming. A) displays total annual average of precipitation for Europe – For Italy we can see that especially in the South of Italy (Sicily-area), precipitation will reduce by up to -4%. B) displays the percentage change in summer precipitation over Europe. For Italy, we see an extreme decline in precipitation in the South with more than -8% precipitation difference between 1.5°C and 2°C of global warming. Moreover, summer precipitation will also reduce in the Northern parts of Italy by up to -6% for 2°C compared to 1.5°C of global warming. In d) we see the total winter precipitation, which displays an increase in winter precipitation in the North of Italy.

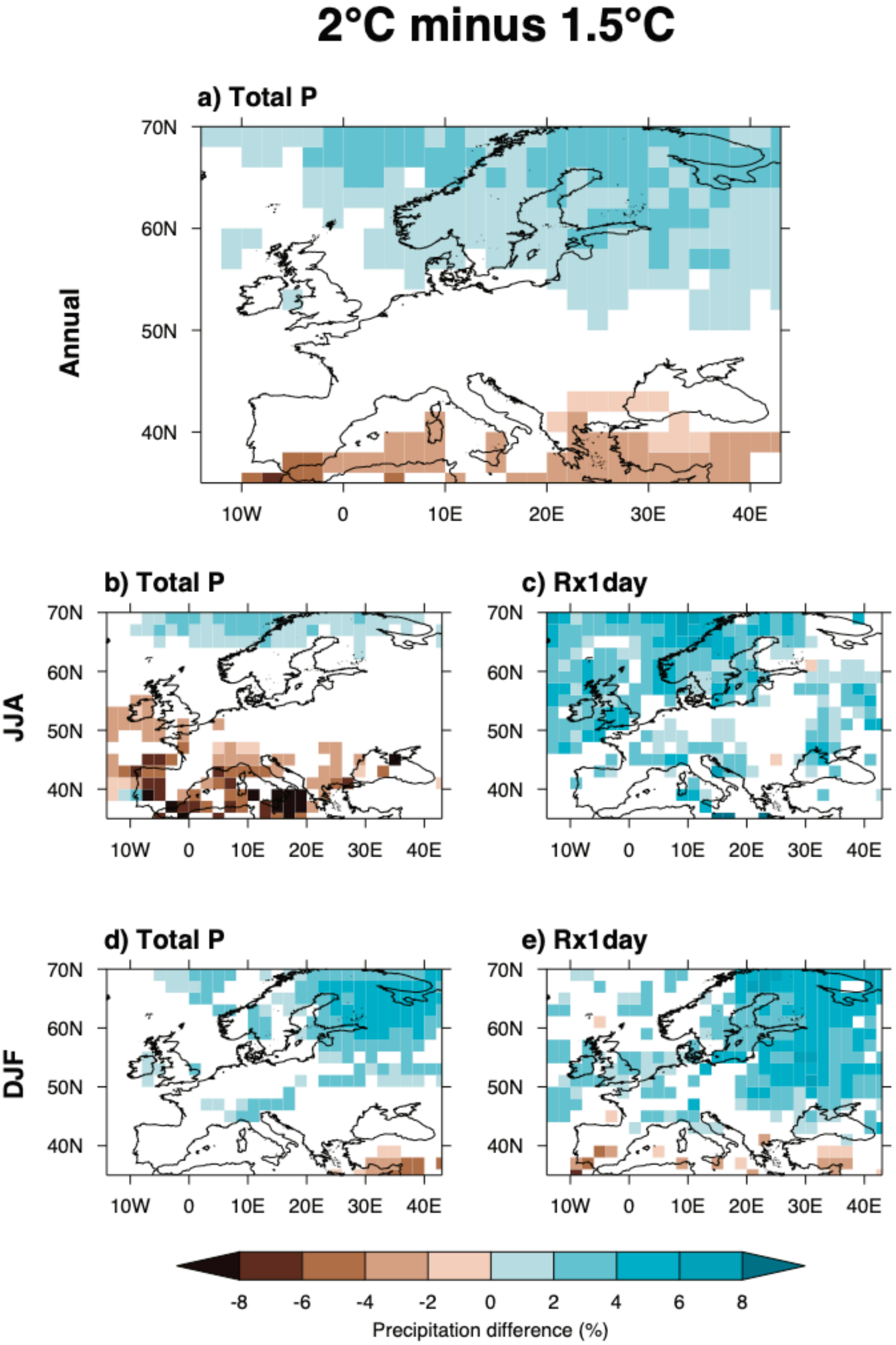


Figure 4: Changes in mean precipitation and precipitation extremes projected between 1.5°C and 2°C of global warming. Maps showing the difference in (a) annual average total precipitation, summer (b) total precipitation, and (c) highest 1 day precipitation and winter (d) total precipitation, and (e) highest 1 day precipitation, between 2°C and 1.5°C of global warming. All precipitation changes are given in percentage departures from the average at 1.5°C and are only shown where at least three-quarters of climate models agree on the sign of the change (King and Karoly, 2017, p.5, figure 2)

6. Sea level rise and coastal erosion

“Global sea level rise has accelerated since the 1960s. The average rate of sea level rise over the period 1993-2018, when satellite measurements have been available, has been around 3.3 mm/year” (EEA, 2019).

The IPCC states that: “there is medium confidence that global mean sea level rise will be about 0.1 m (within a 0.00–0.20 m range based on 17–84% confidence- interval projections) less by the end of the 21st century in a 1.5°C compared to a 2°C warmer world. Projections for 1.5°C and 2°C global warming cover the ranges 0.2–0.8 m and 0.3–1.00 m relative to 1986–2005, respectively (medium confidence)” (Hoegh-Guldberg et al., 2018, p. 207).

In its latest Special Report on Oceans and the Cryosphere it is mentioned that: “Sea level continues to rise at an increasing rate. Extreme sea level events that are historically rare (once per century in the recent past) are projected to occur frequently (at least once per year) at many locations by 2050 in all RCP scenarios, especially in tropical regions (high confidence). The increasing frequency of high-water levels can have severe impacts in many locations depending on exposure (high confidence). Sea level rise is projected to continue beyond 2100 in all RCP scenarios” (SROCC SPM, page20).

In addition: “In coming centuries under RCP8.5, sea level rise is projected to exceed rates of several centimetres per year resulting in multi-metre rise (medium confidence), while for RCP2.6 sea level rise is projected to be limited to around 1 m in 2300 (low confidence). Extreme sea levels and coastal hazards will be exacerbated by projected increases in tropical cyclone intensity and precipitation (high confidence). Projected changes in waves and tides vary locally in whether they amplify or ameliorate these hazards (medium confidence)” (SROCC SPM, page20).

A recent study by Mengel et al. 2018 analyses the relationship between near term emission reduction compatible with the Paris Agreement and sea level rise. As illustrated in Figure 5, the timing of mitigation actions matters for long-term sea level rise. Every 5 year delay in peaking global CO2 emissions will lead to a sea level rise commitment of 20 cm by 2300, about as much as observed sea level rise since the pre-industrial times. For higher emission scenarios, reaching 2°C, 3°C or even >4°C, much higher levels of sea level rise have to be expected (Clark et al., 2018). Future generations will therefore be affected by actions taken within the next decades (Mengel et al. 2018).

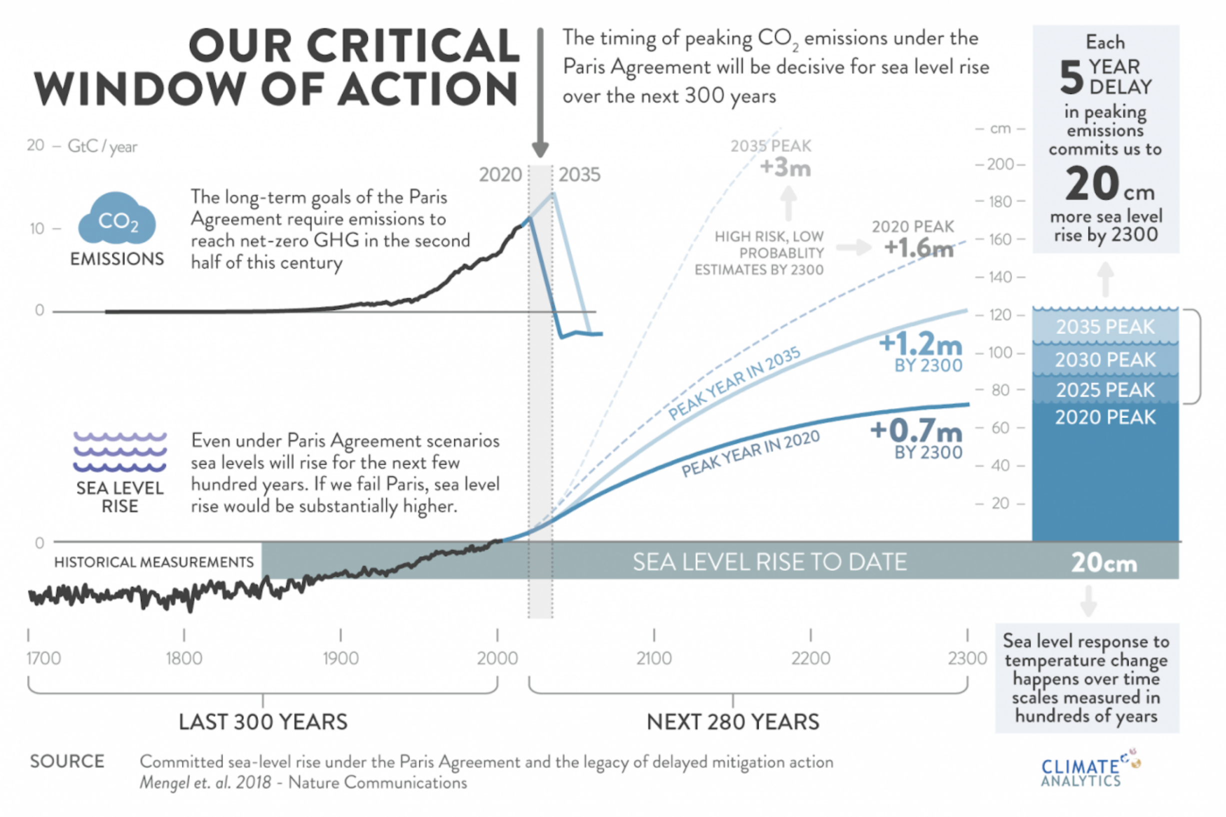


Figure 5: Critical window of action for sea level rise over the next 300 years.

"Projected sea level rise, possible changes in the frequency and intensity of storm surges, and the resulting coastal erosion are expected to cause significant ecological damage, economic loss and other societal problems along low-lying coastal areas across Europe unless additional adaptation measures are implemented" (Füssel et al., 2017, p. 122). The IPCC Special Report on Land also states that "erosion of coastal areas as a result of sea level rise will increase worldwide (very high confidence)" (Olsson et al., 2019, p. 370).

"The rise in sea level relative to land along most European coasts is projected to be similar to the global average", this includes the Italian coasts (Füssel et al., 2017, p. 124). "The cities at the highest risk of coastal floods in the late 21st century, driven by a combination of sea level rise and storm surges, are along the North Sea coast in Belgium, the Netherlands and Germany, as well as along the Mediterranean coast of northern Italy » (Füssel et al., 2017, p. 308).

Figure 6 shows that between 1993 and 2019, absolute sea level has been rising between 2 to 4 mm/year along the Italian coasts.

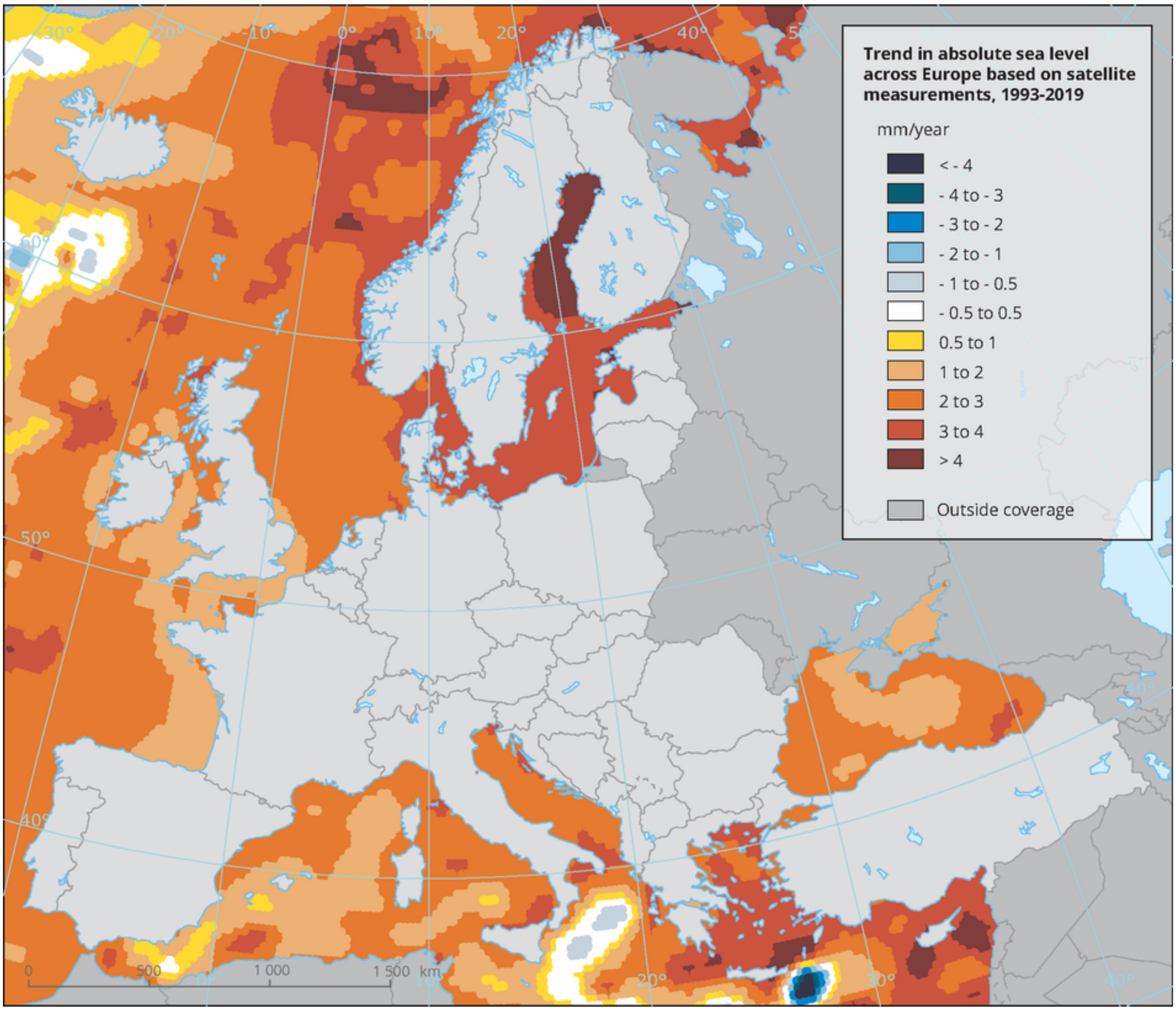


Figure 6: Trend in absolute sea level across Europe based on satellite measurements, 1993-2019 (EEA, 2019)

Figure 7 shows two scenarios of the projected change in relative sea level in Europe by 2081-2100 relative to 1986-2005. Under scenarios exceeding >4°C (RCP8.5) global mean temperature rise by 2100, the local sea levels around the Italian coastline will rise by around 60 cm or more in 2081-2100, relative to 1986-2005. Limiting warming to around 1.6°C (RCP2.6) will reduce local sea level rise to about 20-40cms.

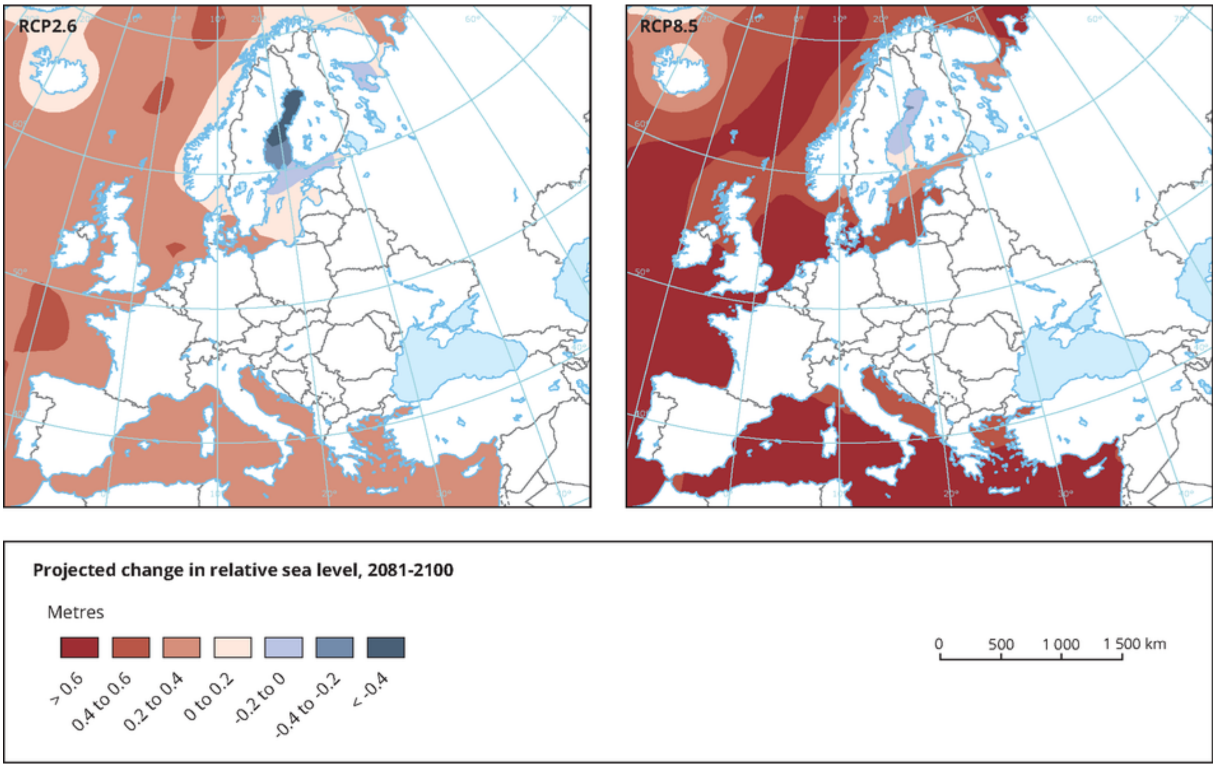


Figure 7: Projected change in relative sea level in Europe in the period 2081-2100 relative to 1986-2005, for scenarios of 1.6°C expected temperature rise by 2100 (RCP2.6) and scenarios of >4°C expected temperature rise by 2100 (RCP8.5) (EEA, 2019)

A Venice specific study found that “under the future scenario, i.e. by 2050, the areas with critical and extreme vulnerability are expected to cover 60 % of the Venice coastland” (with RCP8.5 which assumes a mean rate of 5mm/yr of global sea level rise by 2050) (Tosi et al., 2020, p.694).

In addition, for the Northern Adriatic coast, “maps produced for the worst scenario showed that beaches are the target at higher risk (with more than 90% of the surface in the higher relative risk class) due to the low elevation and high proximity to the coastline. Also cultural heritage (i.e., villas, historical buildings and roads) and wetlands are highly threatened by storm surge flooding. The relative risks will be lower (i.e., between 25% and 40% of their surface/length in the higher relative risk class) for most of the other receptors (i.e., local roads, railways, natural and semi-natural environments and agricultural areas), including population and buildings that are mostly classified in lower risk classes”. The worst scenario here assumes 42cm sea level rise for the future scenario 2070-2100, which is significantly below expected sea-level rise under a RCP8.5 scenario and more in line with local sea-level rise projected under a <2°C scenario (compare Fig. 8) (Rizzi et al., 2017, p.1).

Figure 8 shows the projections for the tide gauge station of Venice:

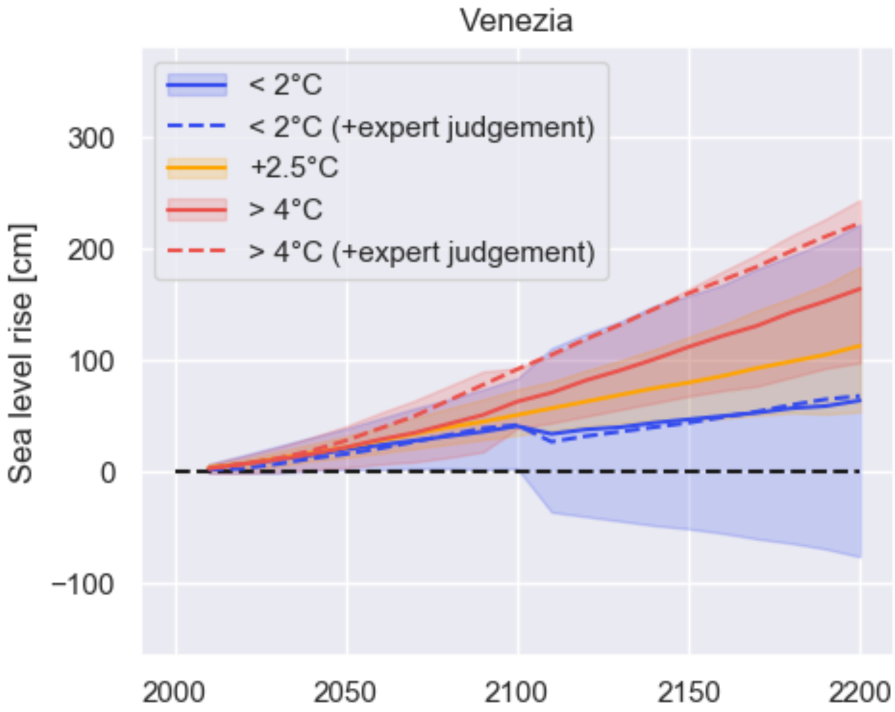


Figure 8 : Local sea-level projections for Venice under a scenario likely limiting 2100 warming to below +2°C (blue), a scenario leading to a global mean temperature increase of around 2.5°C (orange) and a scenario exceeding +4°C in 2100 (red). The solid lines represent multi-model medians, the shaded areas capture the 66% model range. Dashed lines show median sea-level projections for likely below +2°C and above +4°C scenarios including revised Antarctic ice-sheet contributions based on expert judgement presented in Bamber et al. (2019). (retrieved from http://localslr.climateanalytics.org/location/Venezia)

7. Extreme events

7.1 Extreme heat/Heatwaves

"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". "The number of unusually warm days (Tx90p: [Average number of days that the daily maximum temperature is above the 90th percentile of daily maximum temperatures of a five day window]) has increased by up to 10 days per decade since 1960 in most of southern Europe" "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)". 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. The impacts will be particularly strong in southern Europe" (Füssel et al., 2017, p. 77).

"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).

"The highest levels of warming for extreme hot days are expected to occur in central and eastern North America, central and southern Europe, the Mediterranean, western and central Asia, and southern Africa (medium confidence). These regions have a strong soil-moisture-temperature coupling in common as well as increased dryness and, consequently, a reduction in evaporative cooling" (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).

"Under a high-emissions scenario, very extreme heat waves (more severe than the 2003 heat wave affecting southern and central Europe or the 2010 heat wave affecting eastern Europe) are projected to occur as often as every 2 years in the second half of the 21st century (Map 7.1). The projected frequency of heat waves is greatest in southern and south-eastern Europe (Russo et al., 2014). The most severe economic and health risks from heat waves are projected for low altitude river basins in southern Europe and for the Mediterranean coasts, where many densely populated urban centres are located (Fischer and Schär, 2010). The effects of heat waves are exacerbated in large cities due to the urban heat island effect" (European Environment Agency, 2019b, p. 171).

7.2 Droughts

"Based on observations and modelling experiments, a drying trend is already detectable in the Mediterranean region, that is, at global warming of less than 1°C (medium confidence)" (Hoegh-Guldberg et al., 2018, p. 200).

"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 (in particular the Iberian Peninsula, France, Italy and Albania) and parts of central and south-eastern Europe" (Füssel et al., 2017, p. 145).

The Special Report on 1.5 from the IPCC also states that "there is medium confidence that enhanced greenhouse forcing has contributed to increased drying in the Mediterranean region (including southern Europe, northern Africa and the Near East) and that this tendency will continue to increase under higher levels of global warming” (Hoegh-Guldberg et al., 2018, p. 196).

Projections show “drier conditions for southern Europe for the mid-21st century, with increases in the length, magnitude and area of drought events”, with “the largest increases in frequency for extreme droughts in parts of the Iberian Peninsula, southern Italy and the eastern Mediterranean, especially at the end of the century with respect to the baseline period 1971–2000” (Füssel et al., 2017, p. 146).

Figure 9 below shows that “the exacerbation of drought conditions in the Mediterranean under global warming of 1.5 K [K stands for °C] and 2 K will be unprecedented since the last millennium. If a global warming of 3 K is reached, southern Spain and probably Italy and Greece will turn ‚into a desert’. This unprecedented change will also have severe impacts on Mediterranean vegetation and biodiversity, and thus on ecosystems and their services. The strong reductions in soil water availability during dry periods are mostly related to decreases in precipitation and increases in evapotranspiration” (Samaniego et al., 2018, p. 424).

With 3.0 K warming, around 50% of the Mediterranean region will be under drought, these droughts will last on average 125 months and there will be around 5.6 drought months per year (Samaniego et al., 2018, p. 425, table 1)

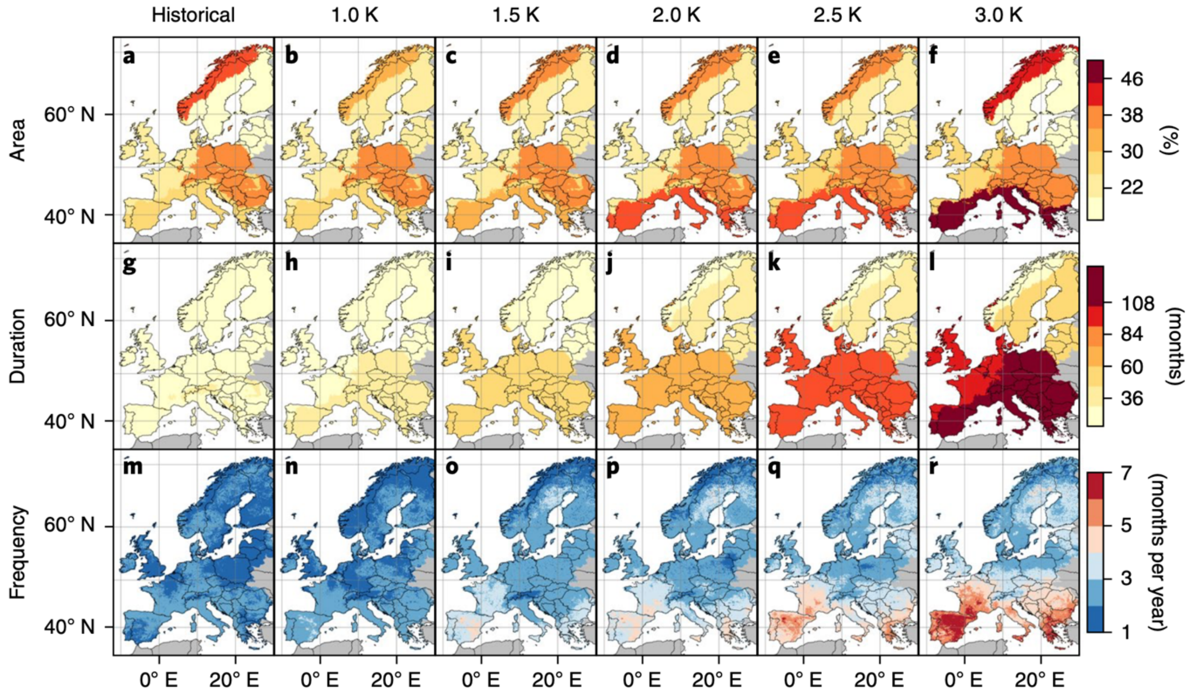


Figure 9: Spatial distribution of changes in drought area, duration and frequency (The area under drought is evaluated for the six IPCC AR5 regions and quantified as a percentage of the total area of each region for the different levels of warming. g–l, The drought duration for the same regions and warming 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)

“Limiting global warming to 1.5°C is expected to substantially reduce the probability of extreme changes in water availability in some regions compared to changes under 2°C of global warming (medium confidence). For shift from 1.5°C to 2°C of global mean surface temperature warming, the available studies and analyses suggest strong increases in the probability of dryness and reduced water availability in the Mediterranean region (including southern Europe, northern Africa and the Near East) and in southern Africa (medium confidence)” (Hoegh-Guldberg et al., 2018, p. 200).

“Overall, there is high confidence that strong increases in dryness and decreases in water availability in the Mediterranean and southern Europe would occur from 1.5°C to 2°C of global warming. (…) The risks (assuming current adaptation) related to water deficit in the Mediterranean are high for global warming of 2°C but could be substantially reduced if global warming were limited to 1.5°C” (Hoegh-Guldberg et al., 2018, p. 259).

7.3 Heavy precipitation

Past observations show that: “the intensity of heavy precipitation events in summer and winter have increased in northern and north-eastern Europe since the 1960s. Different indices show diverging trends for south-western and southern Europe” (Füssel et al., 2017, p. 82), meaning that cross southern Europe no uniform trend can be identified.

“Global warming is projected to lead to a higher intensity of precipitation and longer dry periods in Europe”, “in summer, an increase is also projected in most parts of Europe, but decreases are projected for some regions in southern and south-western Europe” (Füssel et al., 2017, pp. 82, 83).

However, daily extreme precipitation (Rx1day) might increase over parts of Italy in winter and summer despite a drying trend in summer (compare Figure 4) between 1.5°C and 2°C. The signal is most pronounced for Northern Italy.

On timescales of hours, the increases extreme precipitation might be even more pronounced, “the intensity of extreme precipitation, the frequency of sub-daily extreme precipitation is projected to increase. The frequency of 50-year and 100-year extreme precipitation events will be doubled under RCP4.5 and tripled under RCP8.5” (the extreme value analysis is based on annual maxima and the peak-over-threshold method) (Hosseinzadehtalaei et al., 2020, p.13).

7.4 Floods/landslides

“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).

Recent studies focused on regions of Italy: for Calabria, Gariano et al. found that on the entire region, the annual average regional rate of change in rainfall induced landslides occurrence is expected to be equal to +45.7% and to +21.2% for RCP4.5 and RCP8.5 scenario, respectively, compared to the period 1981-2010 (Gariano et al., 2017, p.421), alongside to an increase of +8% and +12% in winter (December-January-February). "This is in agreement with the expected increase in the intensity of heavy rain fall events in Europe in winter for the end of the 21st century" (Gariano et al., 2017, p.423). In Umbria region, Ciabatta et al. found an increase in the number of landslide occurrence, of about 30% and 45% for 2040-2069 and 2070-2099 (compared to 1990-2013), respectively, under RCP8.5 (Ciabatta et al., 2016, p.15). "During the warm-dry season (from April to September), due to the high increase in temperature, an evident strong decrease in soil moisture was predicted and, consequently, the number of landslide events unchanged with respect to the present period regardless of rainfall conditions. Conversely, during the cold-wet season (from October to March), as soil moisture conditions of future periods are similar to the present period, the number of landslide events was found to significantly increase (up to 107% for the 2070-2099 period) mainly due to positive variations in winter rainfall amount" (Ciabatta et al., 2016, p.19). Finally, for the Esino river basin, Sangelantoni et al. found an overall increase in projected landslide occurrence over the twenty-first century: under RCP8.5, the events above rainfall thresholds frequency shift from 0.025 to 0.05 (normalized to the total number of annual rainfall events) in the mountainous sector of the study area for the period 2070-2099 compared to 1971-2000) (Sangelantoni et al., 2018, p.1).

Figure 10 below shows that compared to other European countries, Italy, together with France, Germany and the UK, will be over proportionally hit with regards to expected annual damages from river floods, up to around 3000 M€/year if no adaptation measures are implemented in Italy by 2100 (assuming a 2°C warming scenario).

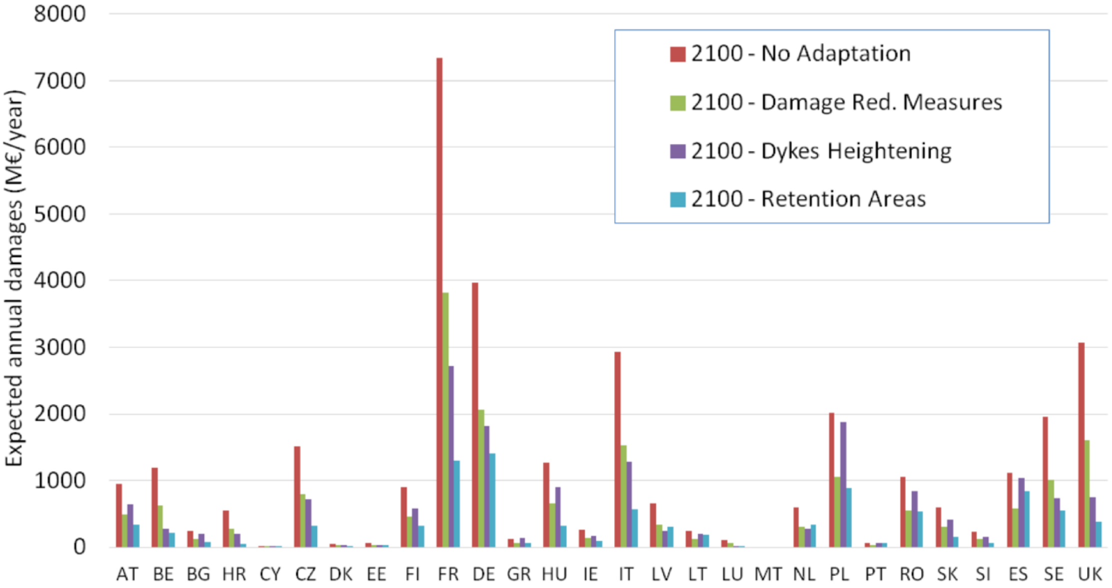


Figure 10: Comparison of expected annual damage in 2100 assuming no adaptation, and with the implementation of three different adaptation strategies. Results are calculated assuming a 2°C warming scenario (Feyen et al., 2020, p. 37, figure 18)

"Landslides are a form of land degradation, induced by extreme rainfall events. There is a strong theoretical reason for increasing landslide activity due to intensification of rainfall, but so far, the empirical evidence that climate change has contributed to landslides is lacking". "Human disturbance may be a more important future trigger than climate change" (Olsson et al., 2019, p. 370).

Figure 11 below highlights that Italy is currently a hotspot for landslides in Europe.

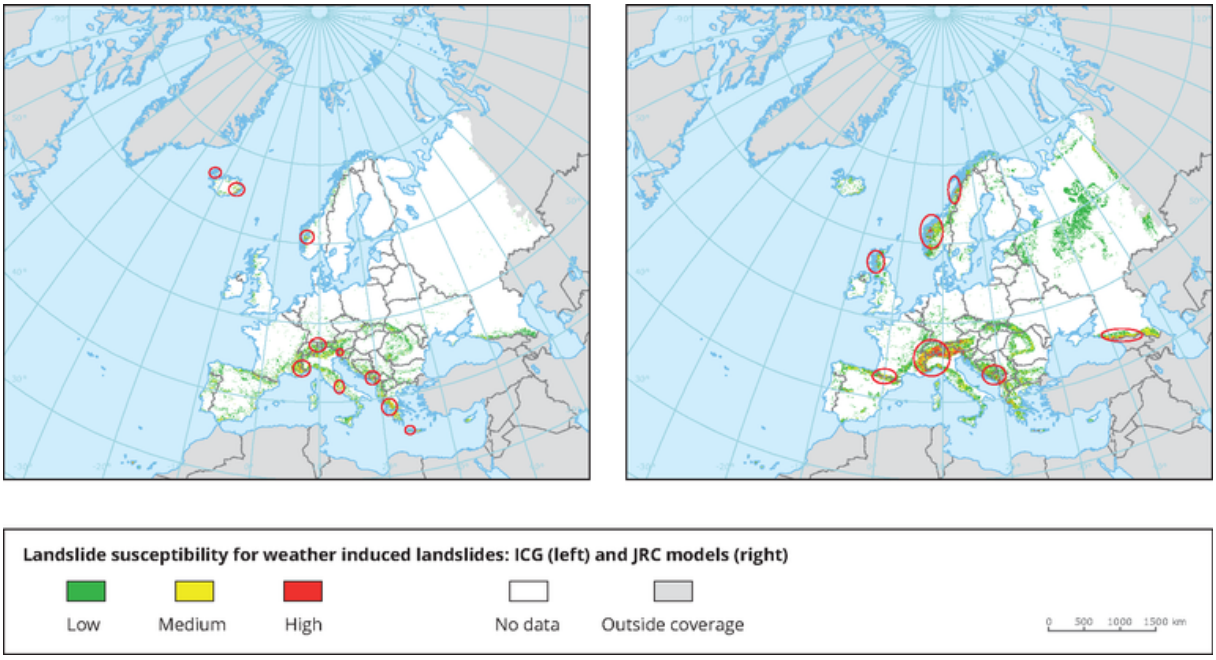
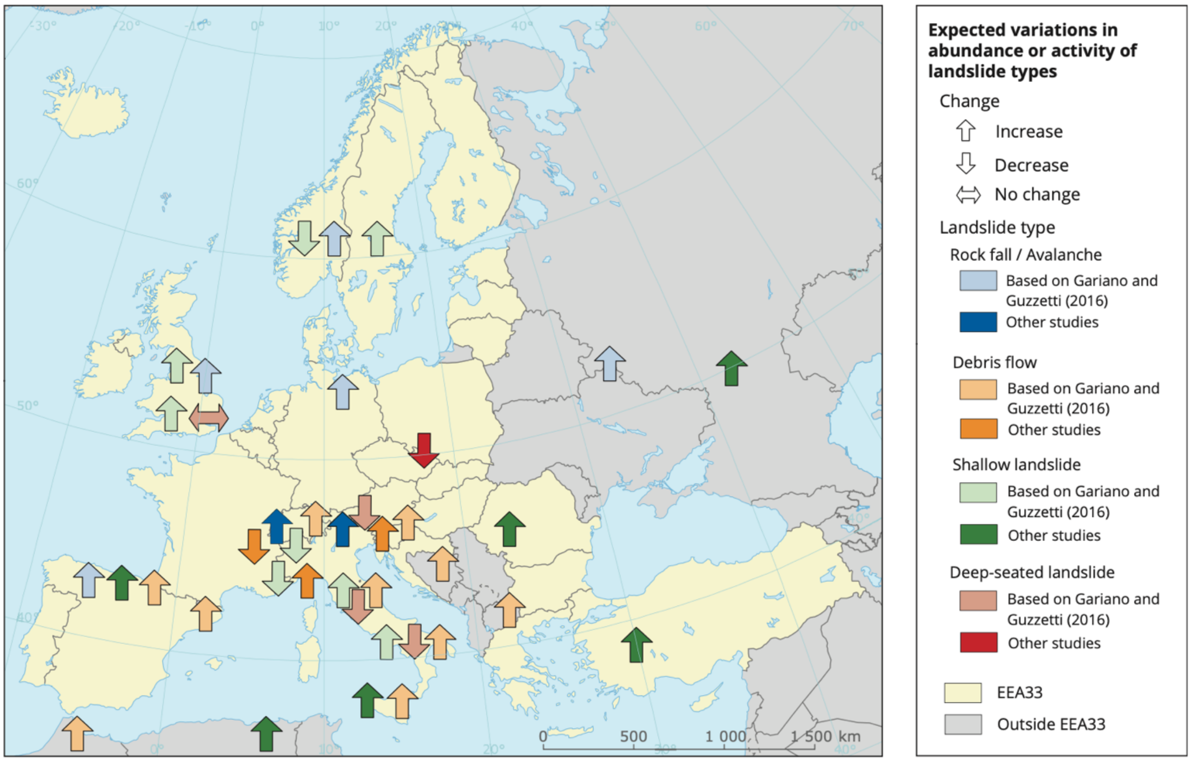


Figure 11: Map of landslide susceptibility for weather induced landslides. The classified hazard map of JRC (right) is definitely more conservative although it does incorporate hotspots of known hazard such as north-west Scotland, which the ICG model (left) does not. Red circles show possible hotspots. White colour represent region

without landslide hazard (retrieved from: https://www.eea.europa.eu/data-and-maps/figures/landslide-susceptibility-for-weather-induced-1)

Figure 12 below shows "shows variations in frequency or activity of four landslide types based on an ensemble of GCMs driven by different climate scenarios (see Gariano and Guzzetti, 2016 for an overview). The greatest evidence consists of a general decrease in abundance/activity of deep-seated landslides and of an increase in rock falls, debris flows and more generally in shallow landslides. It should not be overlooked that in the past decade there has been increasing wildfire-induced change on the natural surface, especially in Mediterranean areas, making the topsoil more prone to erosion; this has reduced the amount of rainfall required to initiate shallow landslides (such as debris flows and mudslides) and associated surface erosion processes (Moody et al., 2013; Santi et al., 2013)" (European Environment Agency, 2017, p. 67).



Note: Dark colours are projections from the literature based on different climate scenarios and light colours are projections from a study for the end of the 21st century, based on the RCP8.5 scenario (Gariano and Guzzetti, 2016).

Source: Adapted from Gariano and Guzzetti, 2016.

Figure 12: Map of expected variations in abundance or activity of four landslide types, driven by projected climate change (European Environment Agency, 2017, p. 67, map 3.14)

7.5 Forest fires

"The number of forest fires in the Mediterranean region increased from 1980 to 2000; it has decreased thereafter. The burnt area shows a decreasing trend over the period 1980–2013, but with strong interannual variability" (Füssel et al., 2017, p. 177).

Figure 13 shows the burnt areas and number of fires in Italy between 2001 and 2018.

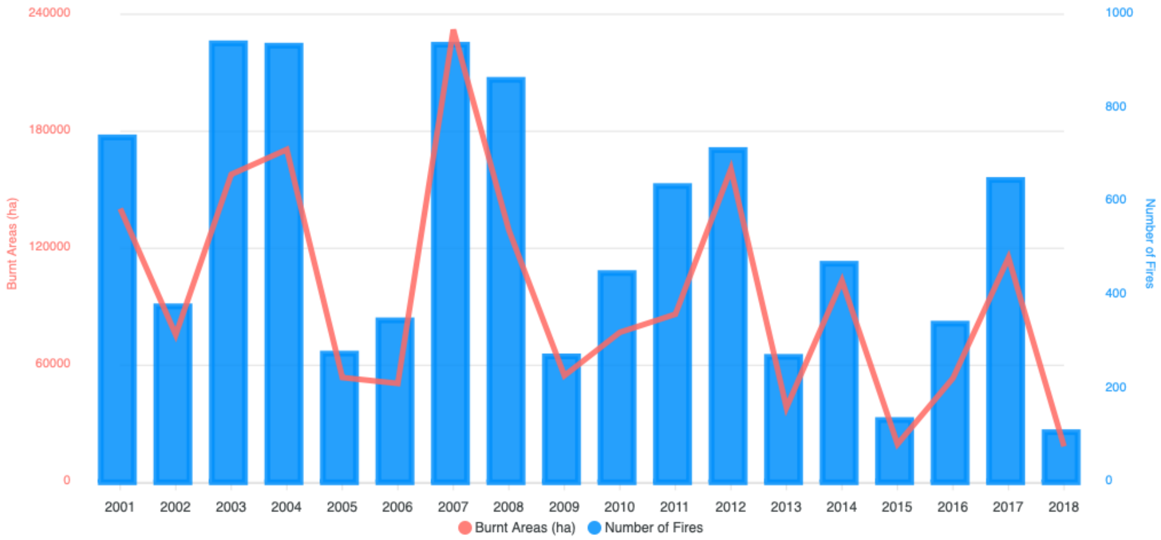


Figure 13 : Annual Country Statistics for Italy for burnt areas (ha, in red) and number of fires (in blue) between 2001 and 2018 (Retrieved from : https://gwis.jrc.ec.europa.eu/static/gwis.statistics.portal/countries-estimates/EU/IT)

"In a warmer climate, more severe fire weather and, as a consequence, an expansion of the fire-prone area and longer fire seasons are projected across Europe (see Figure 14). The impact of fire events is particularly strong in southern Europe" (Füssel et al., 2017, p. 177).

"Climate change projections suggest substantial warming and increases in the number of droughts, heat waves and dry spells across most of the Mediterranean area and more generally in southern Europe (see Sections 3.2.3 and 4.3.4). These projected changes would increase the length and severity of the fire season, the area at risk and the probability of large fires, possibly enhancing desertification (Moreno, 2014)" (Füssel et al., 2017, p.178).

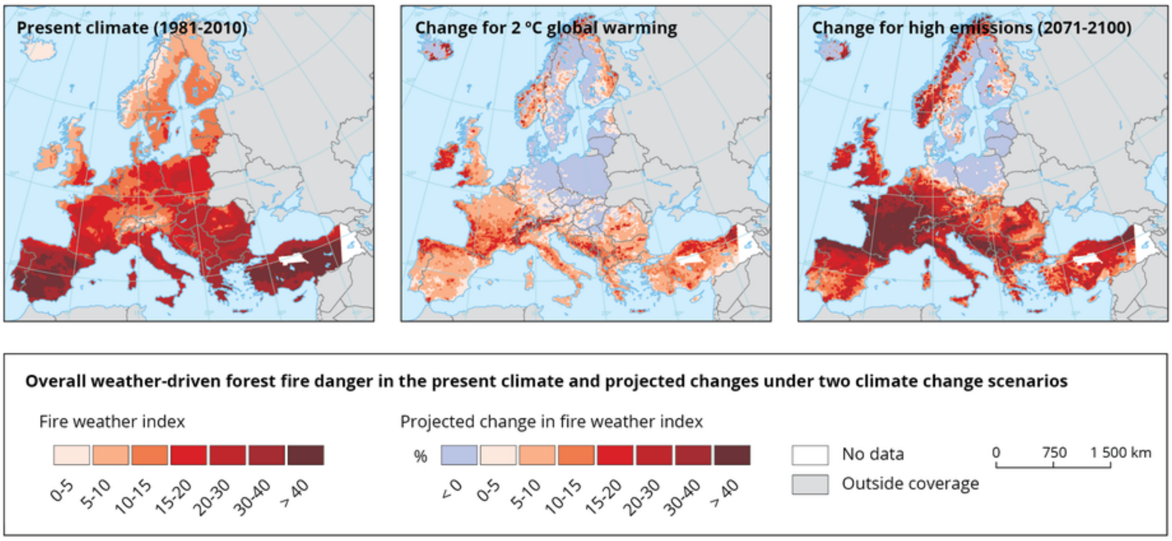


Figure 14 : Maps of forest fire danger in the present climate and projected changes under two climate change scenarios (retrieved at: https://www.eea.europa.eu/data-and-maps/indicators/forest-fire-danger-3/assessment)

"Urban sprawl with low-density housing has led to a growing intermingling of wild land and urban areas, which has increased the risk of forest fires in many residential areas over recent decades, in particular around cities in Portugal, Greece, southern France and Italy" (Füssel et al., 2017, p. 306).

Regarding wild fires, the IPCC special report on land states: "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).

8. Desertification

Due to the increasing temperatures, there is also "substantial evidence that human-induced global warming has led to an increased risk of drought in the Mediterranean region" (Hoegh-Guldberg et al., 2018, p. 177). It is undisputed, that above global warming of 1.5°C "an expansion of desert terrain and vegetation would occur in the Mediterranean biome (medium confidence), causing changes unparalleled in the last 10,000 years (medium confidence)" (Hoegh-Guldberg et al., 2018, p. 179). The European Environment Agency (EEA) indicated that 14 Mha, that is 8% of the territory of the European Union, and among others covering Italy "has a 'very high' and 'high' sensitivity to desertification" (IPCC, 2019, p. 264). The IPCC Special Report on Land also finds that Europe, and especially Italy, "is increasingly affected by desertification leading to significant consequences on land use" (IPCC, 2019, p. 264).

Figure 15 below shows a map of the sensitivity to desertification, indicating that especially the South of Italy (especially Sicily) is very sensitive to desertification.

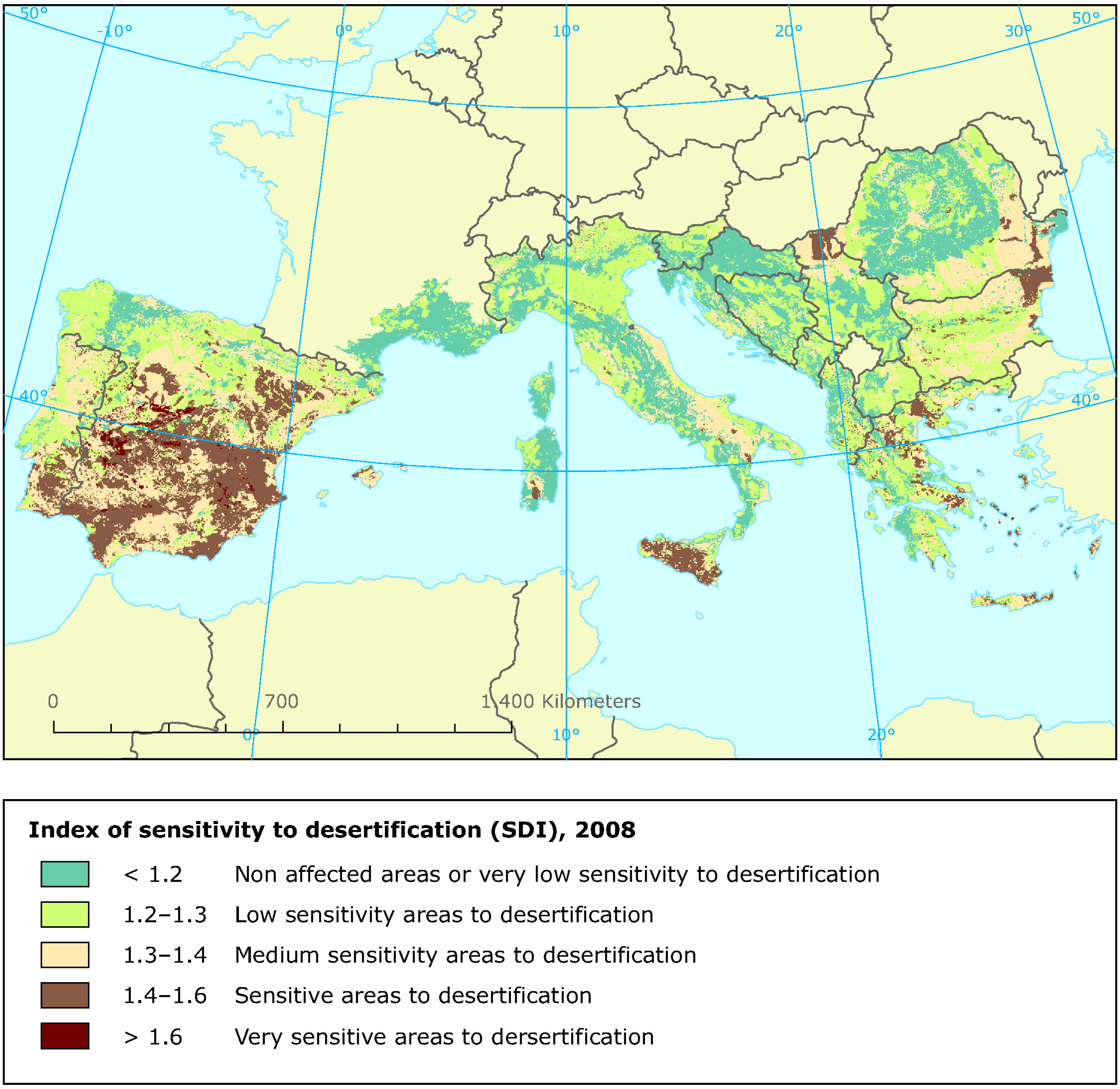


Figure 15: Sensitivity to desertification index map (retrieved from: https://www.eea.europa.eu/data-and-maps/figures/sensitivity-to-desertification-index-map)

It has been stated that in the Mediterranean “limiting warming to 1.5°C may have benefits for future drought risk” (Hoegh-Guldberg et al., 2018, p. 199). For example “hazards by droughts at 1.5°C could be reduced compared to the hazards at 2°C in (…) particular in the Mediterranean region” (Hoegh-Guldberg et al., 2018, p. 215).

The glossary of the IPCC defines hazard as: “the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. See also Disaster, Exposure, Risk, and Vulnerability” (IPCC, 2018).

9. Agriculture and food security

"Observed climate change is already affecting food security through increasing temperatures, changing precipitation patterns and greater frequency of extreme events (high confidence)" (IPCC, 2019, p. 56). Decreases in crops also affect the Mediterranean, as the region is "susceptible to disruptions from increased drought frequency, dust storms and fires (high confidence)" (IPCC, 2019, p. 67). In general "Mediterranean types of climate are projected to become drier, with the equatorward margins being potentially replaced by arid climate types" (IPCC, 2019, p. 277). This indicates that the Mediterranean climate (dry summers, wet winters), such as in Italy, could potentially be replaced by desert-type arid climates (equatorward climate).

This has already had negative effects on yields, as the IPCC found: "Warming compounded by drying has caused large negative effects on yields in parts of the Mediterranean" (IPCC, 2019, p. 56). The IPCC Special Report on Land states that warmer regions in Europe suffer more from warming and that "in Italy this effect has been amplified by a drying trend, leading to yield declines of 5% or greater" (IPCC, 2019, p. 453). Moreover, "livestock are projected to be adversely affected with rising temperatures depending on the extent of changes in feed quality, spread of diseases, and water resource availability (high confidence)" (Hoegh-Guldberg et al., 2018, p. 9).

These "reductions in projected food availability are larger at 2°C than at 1.5°C of global warming in (…) the Mediterranean (medium confidence)" (Hoegh-Guldberg et al., 2018, p. 9). "Generally, vulnerability to decreases in water and food availability is projected to be reduced at 1.5°C versus 2°C, especially in regions such as the (…) Mediterranean" (Hoegh-Guldberg et al., 2018, p. 238). This is due to the fact that "for plant species in the Mediterranean region, shifts in phenology, range contraction and health decline have been observed with precipitation decreases and temperature increases (medium confidence). Recent studies using independent complementary approaches have shown that there is a regional-scale threshold in the Mediterranean region between 1.5°C and 2°C of global warming" (Hoegh-Guldberg et al., 2018, p. 221). This would lead to Mediterranean plant species drastically declining when global warming exceeds 1.5-2°C of global warming.

"biome shifts unprecedented in the last 10,000 years can only be avoided if global warming is constrained to 1.5°C (medium confidence) – whilst 2°C of warming will result in a decrease of 12-15% of the Mediterranean biome area" (Hoegh-Guldberg et al., 2018, p. 221). This means that 12-15% of the area, which is currently a biome area with Mediterranean species, will be reduced to either new species (adjusted to the new climate) or no species.

9.1 Olive oil production

Olive trees are "one of the oldest permanent crops grown in the Mediterranean basin". "Perennial species, such as olive trees and grapevines (…) are subject to a great risk from temperature increase due to climate change" (European Environment Agency, 2019b, p. 45).

"For olive trees, rising temperatures in the future might impact the phenological responses, that is, an advancement of flowering of between 10 and 34 days in southern Italy by 2100, which may affect crop production" (European Environment Agency, 2019b, p. 45). As can be seen in Figure 16 below, olive yields are expected to decrease in some parts of central Italy down to -15% (Fraga et al., 2020, p. 6). This is due to the fact that "higher water demand and lower water availability will enhance the water stress for olive trees in the future" (Fraga et al., 2020, p. 9).

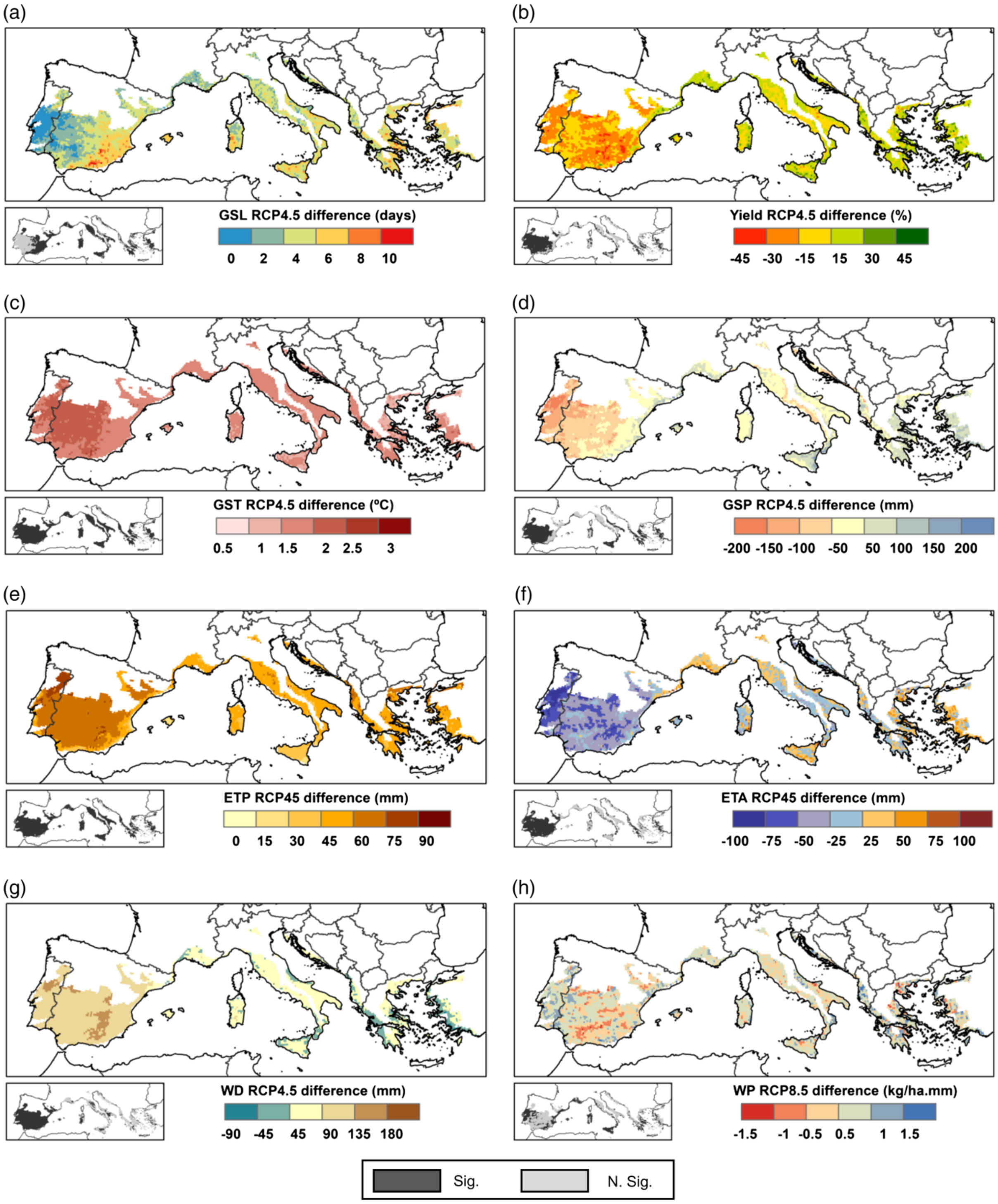
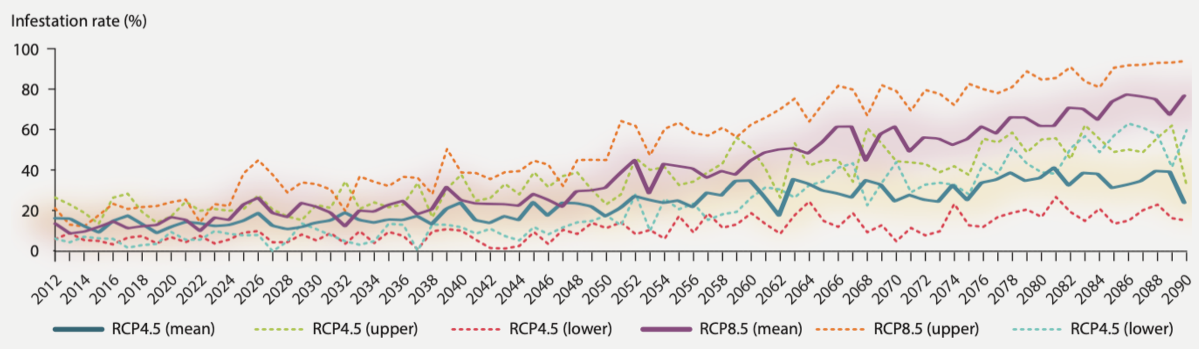


Figure 16 : Patterns for Olives for the differences between global warming of 2.5°C in 2100 and recent past (1989-2005) for the variables: (a) growing season length (days), (b) yield (kg ha^{-1}), (c) growing season mean temperature (°C), (d) growing season precipitation sum (mm), (e) potential evapotranspiration in the growing season (mm), (f) actual evapotranspiration in the growing season (mm), (g) water deficit (ETP minus ETA; mm)

in the growing season, (h) water productivity (kg ha^{-1} mm; yield divided by ETA) in the growing season (Fraga et al., 2020, p. 7, figure 3)

Olive trees have a strong socio-economic importance for countries like Italy – 80% of the worldwide olive trees are grown in southern Europe and "produce roughly 95% of the world olive oil supply" (Fraga et al., 2020, p. 1). In total, 24% of the worlds olive oil production is concentrated in Italy itself (Fraga et al., 2020, p. 1).

"A pest impact indicator was developed to link the growth cycle of the Batrocera aleae (Rossi) fruit fly population to changes in climate conditions in Tuscany (Italy). The study area represents 63.4% of the national area for the production of high-quality extra virgin olive oil. The study revealed that warmer temperatures (especially higher minimum temperatures during the winter season) and extreme weather events (drought) can alter population dynamics by modifying the insect's rate of development, reproduction and mortality. These conditions will lead to reduced olive yields and an increase in pest infestation" (European Environment Agency, 2019a, p. 66).



Notes: Spring Flight is the calculated day of first annual appearance of *B. oleae* (olive fruit fly) in spring. AgriCLASS has used this data to calculate the presence of B. oleae in relation to olive growing in Italy. Mean values and lower and upper limits based on several models are presented.

Figure 17 : Olive infestation by fruit fly in early summer in Italy (European Environment Agency, 2019a, p. 66, figure 4.2).

9.2 Wine production

Literature as well as empirical evidence has shown, that "the wine sector is extremely vulnerable" (Sacchelli et al., 2017, p. 891) to climate change risk. The variability in the climate that will strongly impact the grape yields is "mainly associated with an increase in average temperature and decrease in average precipitation. These aspects are also combined with a high likelihood for the intensification of extreme events such as drought, particularly in Europe" (Sacchelli et al., 2017, p. 891). The wine industry is at great risk from negative climate change effects that would lead to potential losses to product quantity and quality, also leading to consequences on revenues and production costs throughout the supply chain (Sacchelli et al., 2017, p. 891). For example "excess precipitation events can lead to crop damage and to soil erosion in agricultural fields" and in Italy "widespread heavy rains has caused delays in summer crop and tree and vine crop harvesting as well as winter grain planting" (European Environment Agency, 2019b, p. 55).

10. Health

10.1 Heat stress

The 2019 report of The Lancet Countdown on health and climate change states: "The most immediate and direct impact of a changing global climate on human health is seen in the steady increase in global average temperature, and the increased frequency, intensity, and duration of extremes of heat. The pathophysiological consequences of heat exposure in humans are well documented and understood, and include heat stress and heat stroke, acute kidney injury, exacerbation of congestive heart failure and increased risk of interpersonal and collective violence. In particular, during periods of extreme heat, young children have a greater risk of electrolyte imbalance, fever, respiratory disease, and kidney disease" (Watts et al., 2019, p. 1841).

The IPCC reports: "Increases in ambient temperature are linearly related to hospitalizations and deaths once specific thresholds are exceeded. […] Even if global warming is restricted to below 2°C, there could be a substantial increase in the occurrence of deadly heatwaves in cities if urban heat island effects are considered, with impacts being similar at 1.5°C and 2°C but substantially larger than under the present climate (Matthews et al., 2017)." (Hoegh-Guldberg et al., 2018, p.263).

It also claims that "The strongest warming of hot extremes is projected to occur in central and eastern North America, central and southern Europe, and the Mediterranean region" (Hoegh-Guldberg et al., 2018, p.177).

Figure 18 shows the current and projected exposure to heat and cold waves in Europe:

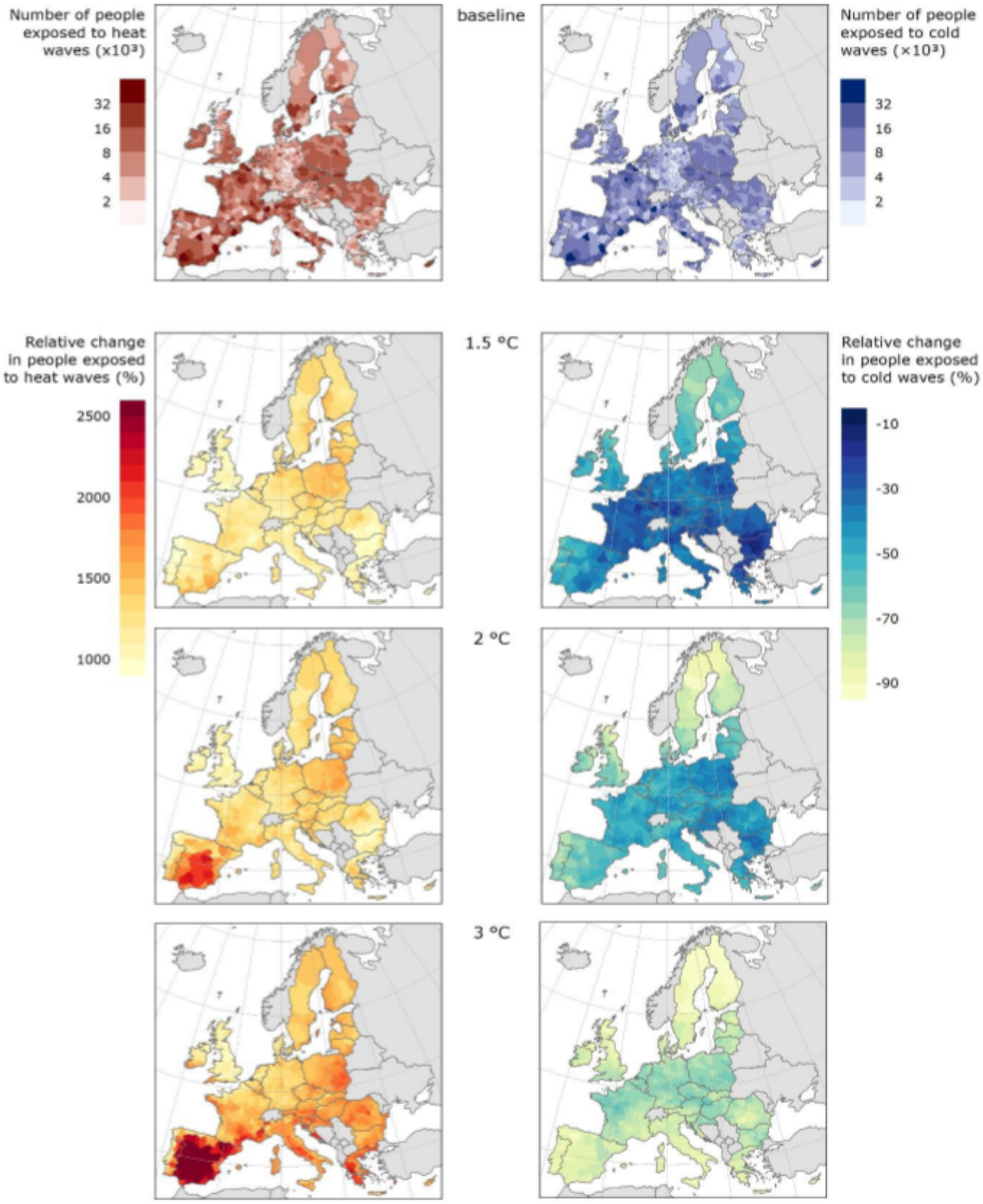


Figure 18: Number of people annually exposed to a present 50-year heatwave and cold wave (top row) and projected changes in human exposure to these events for 1.5°C, 2.0°C, and 3.0°C levels of global warming. (Naumann et al., 2020, p.11, figure 4)

The observed and projected (for RCP 8.5, a global warming scenario reaching >4°C warming by 2100) summer maximum heat exposure and observed and projected number of days with high heat risk are given in Figure 19 and Figure 20. Italy is already and will be one of the most severely European country affected by high temperatures in the summer, with more than 60 days per year of high heat risk projected under RCP 8.5 in Sicilia (Casanueva et al., 2020).

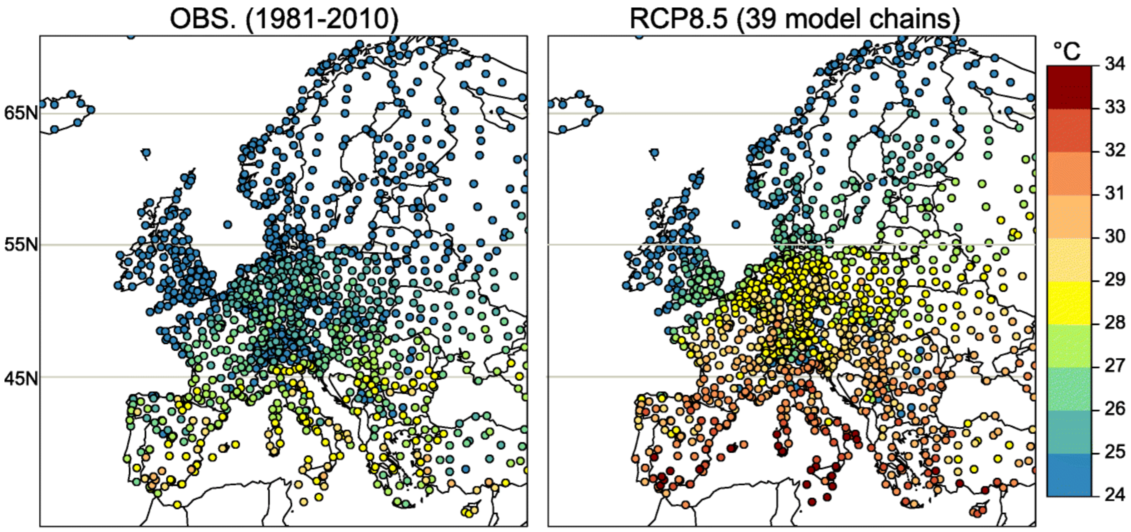


Figure 19: Observed and projected summer maximum heat exposure in the shade. Projections show the ensemble median (over 39 model chains) for the strongest emission scenario for 2070–2099. The highest values are plotted on top of lower ones to highlight the most affected locations. (Casanueva et al., 2020, p.7, figure 2)

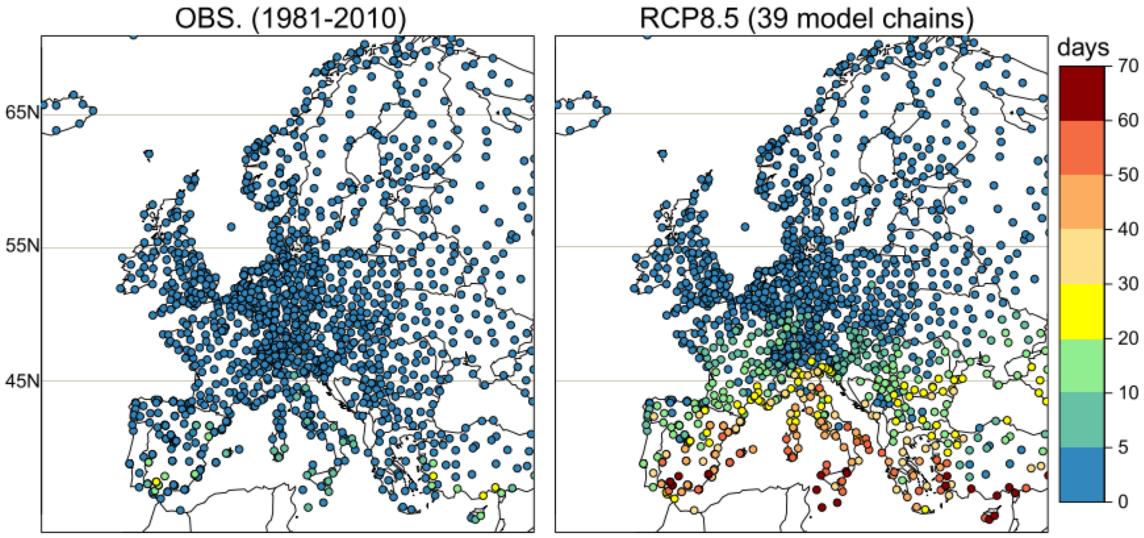


Figure 20: Observed and projected number of days with high heat risk in shaded conditions. Projections show the ensemble median (over 39 model chains) for the strongest emission scenario for 2070–2099. The highest values are plotted on top of lower ones to highlight the most affected locations. (Casanueva et al., 2020, p.7, figure 3)

Globally, the elderly are the most affected by heat stress, particularly in Europe and the Eastern Mediterranean, as highlighted by The Lancet report (2019): “Populations aged 65 years and older are particularly vulnerable to the health effects of climate change, and especially to extremes of heat. From 1990 to 2018, populations in every region have become more vulnerable to heat and heatwaves, with Europe and the Eastern Mediterranean remaining the most vulnerable. In 2018, these vulnerable populations experienced 220 million heatwave exposures globally, breaking the previous record of 209 million set in 2015” (Watts et al., 2019, p.1837). Figure 21 shows the evolution of people aged 65 years and older exposed to heatwaves.

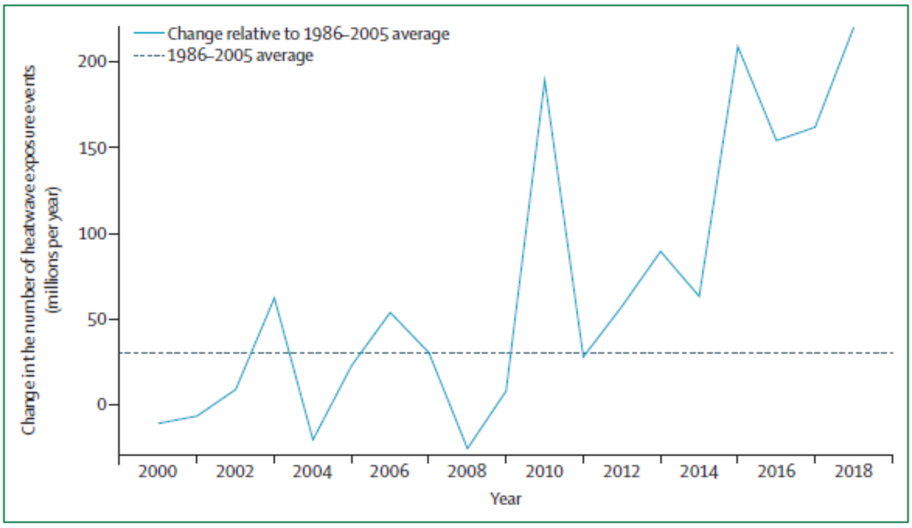


Figure 21 : Global change in the number of heatwaves exposure events in people aged 65 years and older, compared with the historical 1986-2005 average number of events (Watts et al., 2019, p.1842, figure 1).

In 2019, approximately 23% of the Italian population was aged 65 years or older (Onder et al., 2020, p. 1).

“The increase in frequency and intensity of heat waves together with population ageing will have a significant impact on health in the future.” (World Health Organization & United Nations, 2018, p.3). A today’s 15-year-old Italian, who will be 65 years old in 2070, will, therefore, have an increasing chance of suffering from heat stress.

Heat can also lead to a reduced labour productivity (for more details on this topic, please refer to section 10.2: Economic Impacts on the Agricultural sector):

“Reduced labour productivity is often the first symptom of the health effects of heat, and, if not addressed, could lead to more severe health effects, such as heat exhaustion and heat stroke” (Watts et al., 2019, p.1842)

10.2 Fatalities due to extreme events

Italy recorded 20,657 deaths due to extreme events between 1980 and 2017, and therefore is the second European country after France with the highest number of fatalities related to extreme events (European Environment Agency, 2019c).

Figure 22 shows the origin of fatalities related to extreme events in EU-28 between 1980 and 2017.

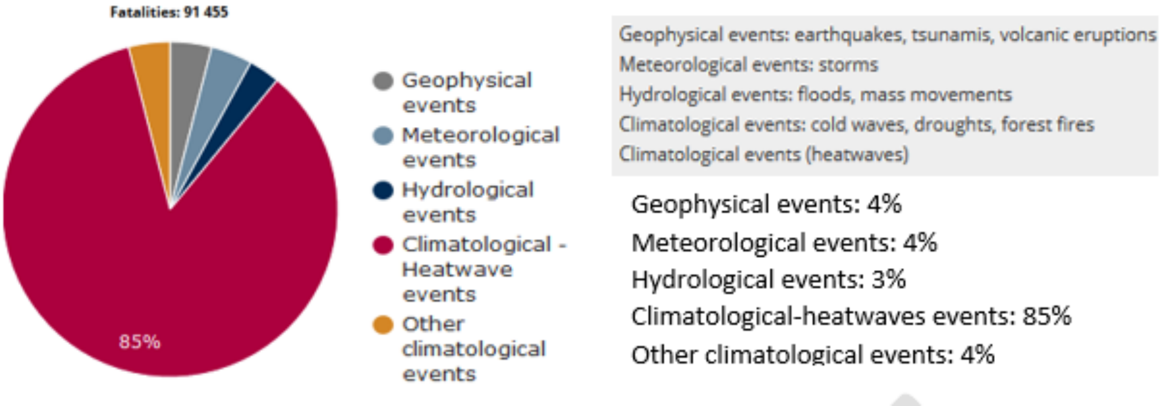
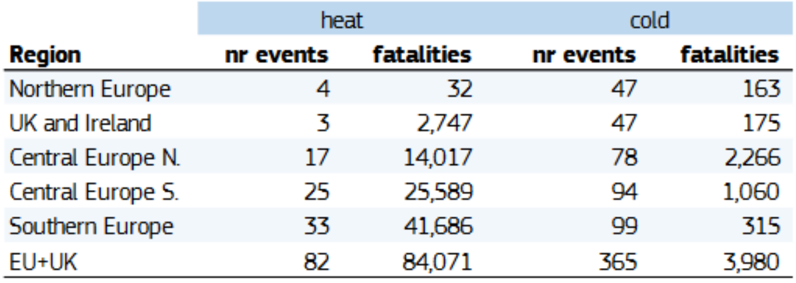


Figure 22 : Origin of fatalities related to extreme events in EU-28 between 1980 and 2017 (European Environment Agency, 2019c)

Heatwaves

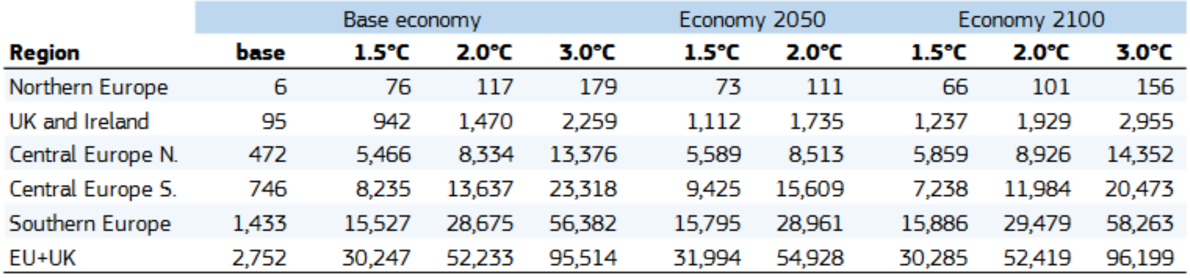
“Projections show that the number of citizens in the EU and UK exposed to heatwaves will grow from 10 million/year (average 1981-2010) to nearly 300 million/year, or more than half the EU population, in a scenario with 3°C global average warming by the end of this century. In case of no adaptation this could result in 96,000 fatalities/year from extreme heat, compared to 2,750 annual deaths at present. Curbing global warming to 1.5°C would limit mortality from extreme heat to around 30,000 fatalities/year” (Naumann et al., 2020, p. 4).

“Assuming present vulnerability and no additional adaptation, annual fatalities from extreme heat in 2100 could rise from 2,750 deaths now to 30,000 at 1.5°C global warming, 52,000 at 2°C and 96,000 at 3°C. The rise in human exposure to and fatalities from extreme heat is most pronounced in southern European countries and the highest number of fatalities will occur in France, Italy and Spain” (Naumann et al., 2020, p.5).



	heat		cold	
Region	**nr events**	**fatalities**	**nr events**	**fatalities**
Northern Europe	4	32	47	163
UK and Ireland	3	2,747	47	175
Central Europe N.	17	14,017	78	2,266
Central Europe S.	25	25,589	94	1,060
Southern Europe	33	41,686	99	315
EU+UK	82	84,071	365	3,980

Table 3 : Reported heat and cold wave impacts in Europe. Number of reported heat- and cold- waves events and related fatalities over the period 1980-2017. Italy belongs to Southern Europe. (Naumann et al., 2020, p.22, table A3)



	Base economy				Economy 2050		Economy 2100		
Region	**base**	**1.5°C**	**2.0°C**	**3.0°C**	**1.5°C**	**2.0°C**	**1.5°C**	**2.0°C**	**3.0°C**
Northern Europe	6	76	117	179	73	111	66	101	156
UK and Ireland	95	942	1,470	2,259	1,112	1,735	1,237	1,929	2,955
Central Europe N.	472	5,466	8,334	13,376	5,589	8,513	5,859	8,926	14,352
Central Europe S.	746	8,235	13,637	23,318	9,425	15,609	7,238	11,984	20,473
Southern Europe	1,433	15,527	28,675	56,382	15,795	28,961	15,886	29,479	58,263
EU+UK	2,752	30,247	52,233	95,514	31,994	54,928	30,285	52,419	96,199

Table 4 : Regional values of current and future fatalities due to heat extremes. The reference scenario spans the period 1981-2010, referred to as "base". The analysis first evaluates heat and cold wave mortality in a comparative static socio-economic setting, therefore only considering the influence of the climate change signal (left columns). The right columns (2050 and 2100) provide a dynamic socio-economic assessment considering the 2015 Ageing Report projections of population and look at how heat and cold extremes at the different warming levels would impact EU population projected for 2050 and 2100. Impacts are compared for the baseline with those over 30-year time slices centred on the year that global average temperature is 1.5, 2 and 3°C above preindustrial temperature. At mid-century human exposure and fatalities of 1.5 and 2°C warming on 2050's society are evaluated (as 3°C is unrealistic by mid-century) and at the end of the century the effect of the three warming levels on 2100's society are considered (Naumann et al., 2020, p.24, table A8)

Floods

Regarding floods, according to the European Environment Agency, "if no additional adaptation measures were taken, the number of people affected by coastal flooding in the EU at the end of the 21st century would range from 775 000 to 5.5 million people annually, depending on the emissions scenario" (Füssel et al., 2017, p.206).

"For a medium emissions scenario (SRES A1B [which is close to the current RCP6.0]) and in the absence of adaptation, river flooding is estimated to affect about 300 000 people per year in the EU by the 2050s and 390 000 people by the 2080s; the latter figure corresponds to more than a doubling with respect to the baseline period (1961–1990). The British Isles, western Europe and northern Italy show a robust increase in future flood hazards; these regions also show the greatest increase in the population affected by river floods" (Füssel et al., 2017, p.205).

"Flooding is also associated with mental health impacts. Coastal flooding in the EU could potentially cause five million additional cases of mild depression annually by the end of the 21st century under a high sea level rise scenario [RCP 8.5, global warming scenario reaching >4°C warming by 2100], in the absence of adaptation" (Füssel et al., 2017, p.206).

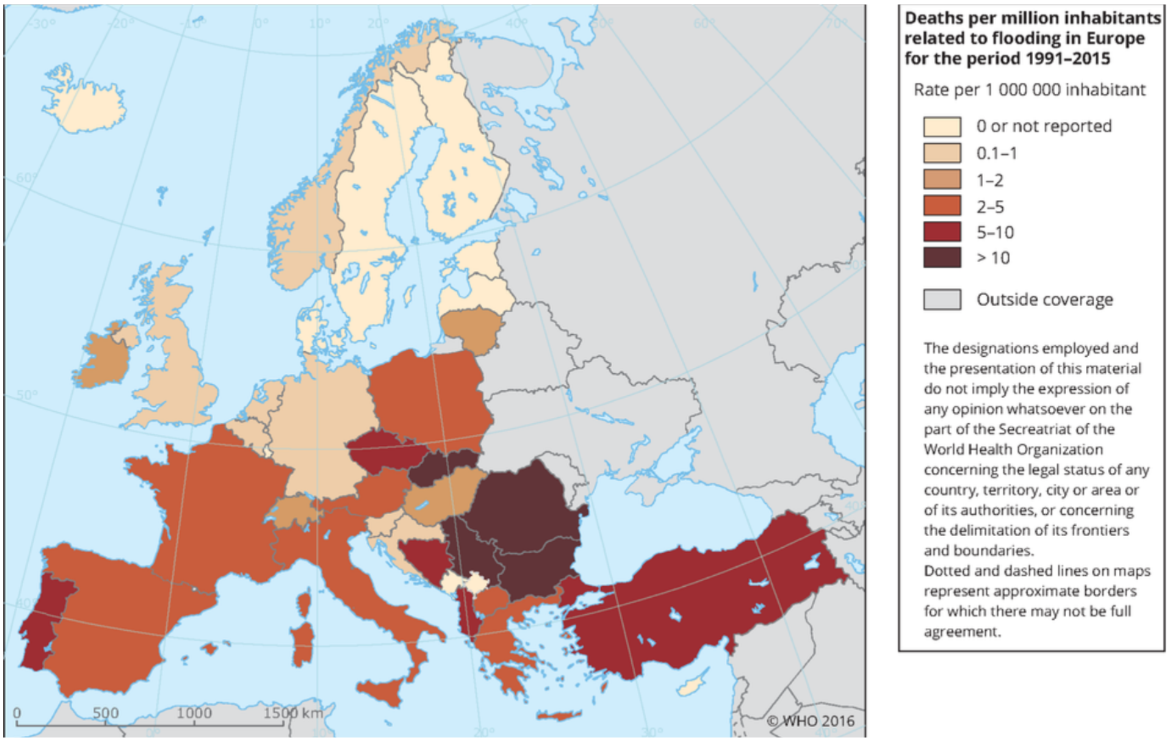


Figure 23 : Deaths related to flooding in Europe for the period 1991-2015 (Füssel et al., 2017, p.206, map 5.1)

10.3 Vector-borne diseases

“Climate change may influence the emergence of vector-borne diseases as the life-cycle dynamics of the vector species, pathogenic organisms and reservoir organisms are all sensitive to weather conditions. The rates of replication, development and transmission of the pathogens depend more strongly on temperature than on other host–pathogen interactions. In recent years, several outbreaks of different vector-borne diseases have been documented in the Mediterranean region. There is high certainty that the recent observed climatic trends will contribute to the future transmission potential of vector-, food- and water-borne diseases in the region” (Cramer et al., 2018, p. 5).

“Increased warming in North America and Europe could result in geographic expansions of regions (latitudinally and altitudinally) climatically suitable for West Nile virus transmission, particularly along the current edges of its transmission areas, and extension of the transmission season” (Hoegh-Guldberg et al., 2018, p.241). “

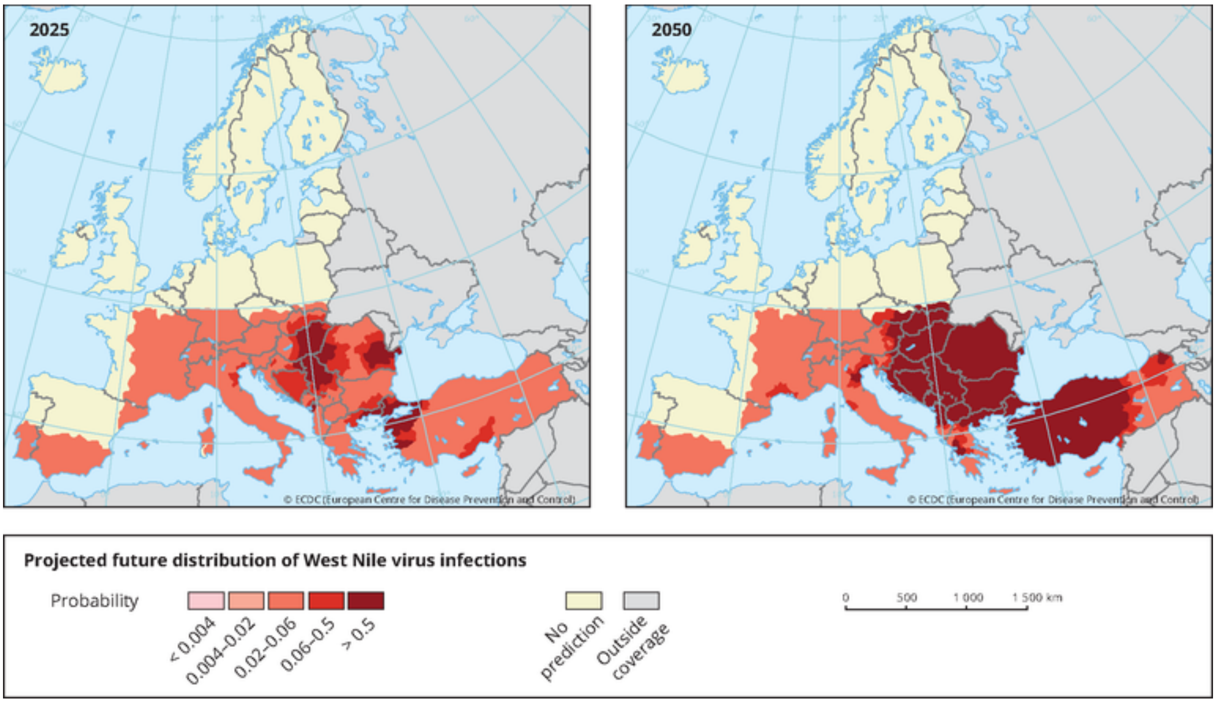


Figure 24: Projected future distribution of West Nile Virus infections (European Environment Agency, 2016)

“For 2025 and 2050, the areas with elevated probability for West Nile infections (linked to climate change), will probably expand and eventually include most Mediterranean countries. During recent years, dengue fever cases were reported in several Mediterranean countries, such as Croatia, France, Greece, Italy, Malta, Portugal and Spain. During the hot summer of 2017, outbreaks of chikungunya were reported in France and Italy. Today, there is an apparent threat of outbreaks, transmitted by Aedes mosquitoes, in the European Mediterranean countries” (Cramer et al., 2018, p. 5).

According to a World Health Organization & United Nations report on Italy’s climate and health country profile (2018), “there is a concrete risk of the re-emergence of previously endemic agents (such as tick-borne encephalities, Lyme disease, Mediterranean spotted fever and West Nile fever)” because of climate change. In Italy, “an increasing number of outbreaks of West Nile disease, with occurrences of human cases, have been reported since 2008, mainly in the North Eastern regions of the country” (World Health Organization & United Nations, 2018, p. 1).

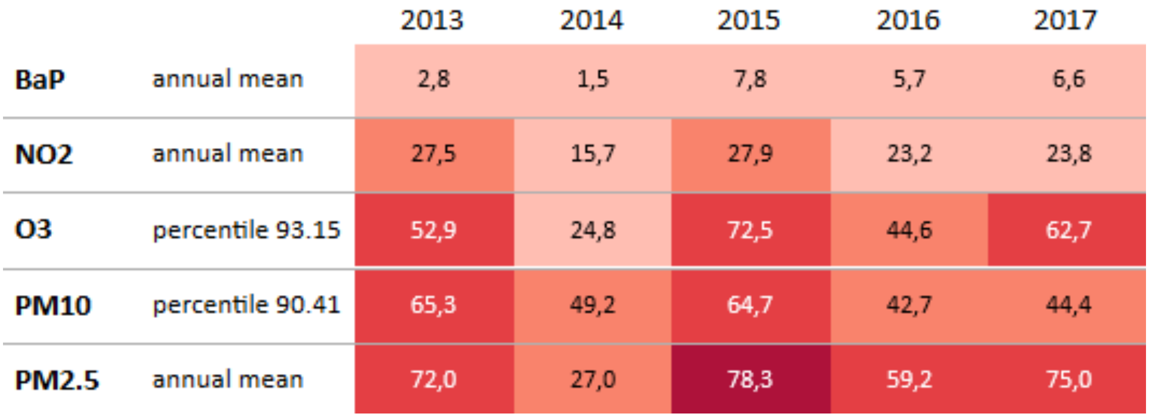
Moreover, the World Health Organization & United Nations state in the same report: “Mosquito-borne diseases are spreading worldwide, including in temperate regions, due to the impact of climate change, the increase in human travel and commercialization, and other factors such as urbanization and land-use changes. Several emerging mosquito-borne outbreaks reported recently in the Mediterranean basin were caused by viruses mainly belonging to the family Togaviridae (Chikungunya virus) and to the Flavivirus genus as West Nile virus and Usutu virus transmitted by Culex species or Dengue virus and Zika virus, transmitted by Aedes species. In 2007, a Chikungunya outbreak occurred in the Emilia-Romagna region of Italy. Another outbreak caused by this tropical virus occurred in the summer of 2017” (World Health Organization & United Nations, 2018, p. 5).

10.4 Air quality and respiratory diseases

According to a World Health Organization & United Nations report on Italy's climate and health country profile (2018), "many of the drivers of climate change, such as inefficient and polluting forms of energy and transport systems, also contribute to air pollution. […] The impact that atmospheric pollutants have on human health results in an estimate of a total of 555,000 premature deaths in 2013, with 91,050 premature deaths only in Italy, the highest number among the European countries." (World Health Organization & United Nations, 2018, p. 9)

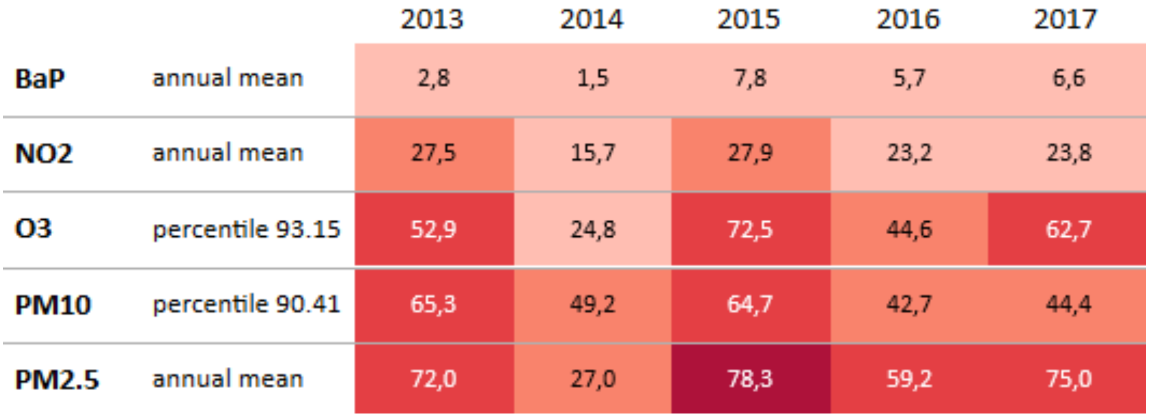
Premature deaths are deaths that occur before a person reaches an expected age. This expected age is typically the age of standard life expectancy for a country and gender.

"In 2017, air pollution was the fifth highest mortality risk factor globally and was associated with about 4.9 million deaths and 147 million years of healthy life lost" (Health Effects Institute, 2019). "Air pollution collectively reduced life expectancy by 1 year and 8 months on average worldwide, a global impact rivalling that of smoking. This means a child born today will die 20 months sooner, on average, than would be expected in the absence of air pollution" (ibid).



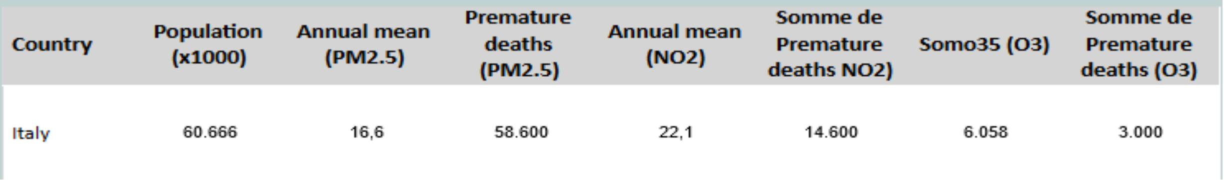
		2013	2014	2015	2016	2017
BaP	annual mean	2,8	1,5	7,8	5,7	6,6
NO2	annual mean	27,5	15,7	27,9	23,2	23,8
O3	percentile 93.15	52,9	24,8	72,5	44,6	62,7
PM10	percentile 90.41	65,3	49,2	64,7	42,7	44,4
PM2.5	annual mean	72,0	27,0	78,3	59,2	75,0

Table 5 shows the Italian urban population exposed to concentrations above EU standards:



		2013	2014	2015	2016	2017
BaP	annual mean	2,8	1,5	7,8	5,7	6,6
NO2	annual mean	27,5	15,7	27,9	23,2	23,8
O3	percentile 93.15	52,9	24,8	72,5	44,6	62,7
PM10	percentile 90.41	65,3	49,2	64,7	42,7	44,4
PM2.5	annual mean	72,0	27,0	78,3	59,2	75,0

Table 5 : Percentage of urban population exposed to concentration above EU standards for selected air pollutants in Italy, between 2012 and 2017. (European Environment Agency, 2019d)



Country	Population (x1000)	Annual mean (PM2.5)	Premature deaths (PM2.5)	Annual mean (NO2)	Somme de Premature deaths NO2)	Somo35 (O3)	Somme de Premature deaths (O3)
Italy	60.666	16,6	58.600	22,1	14.600	6.058	3.000

Table 6 : Premature deaths attributable to PM2.5, NO2 and O3 in Italy in 2016. (European Environment Agency, 2019d)

The IPCC states: "Because ozone formation is temperature dependent, projections focusing only on temperature increase generally conclude that ozone-related mortality will increase with additional warming, with the risks higher at 2°C than at 1.5°C (*high confidence*)" (Hoegh-Guldberg et al., 2018, p.241).

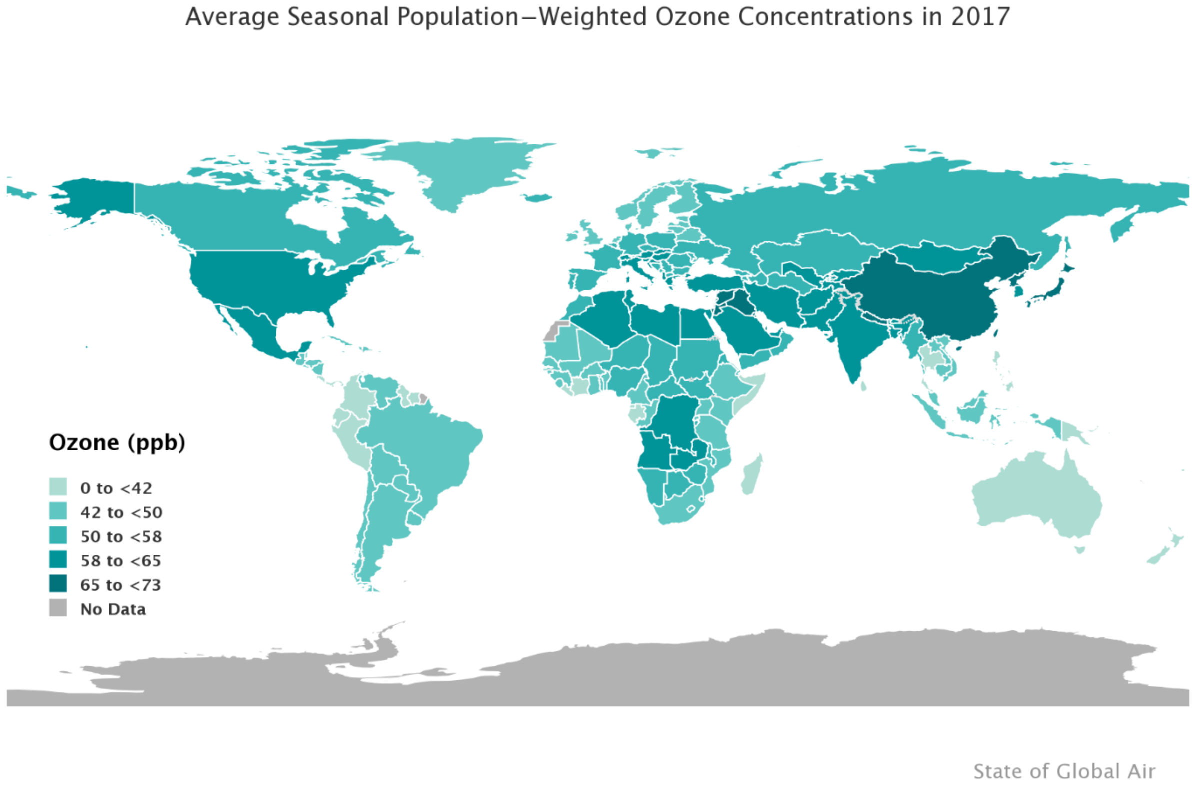


Figure 25: Population-weighted seasonal average (8-hour max) ozone concentrations in countries around the world in 2017. (Health Effects Institute, 2019, p.9, figure 5)

"Ozone pollution accounted for nearly half a million early deaths worldwide in 2017. That number represents a 20% increase since 1990, with most of the growth seen in the past decade." (Health Effects Institute, 2019, p.13). "Global patterns of ozone-attributable deaths generally mirror the global patterns of population-weighted seasonal ozone concentrations around the world" (ibid).

According to a study by Conticini et al., air pollution “may partly explain a higher prevalence and lethality of a novel, very contagious, viral agent such as SARS-CoV-2, among a population living in areas with a higher level of air pollution” (Conticini et al., 2020, p.2).

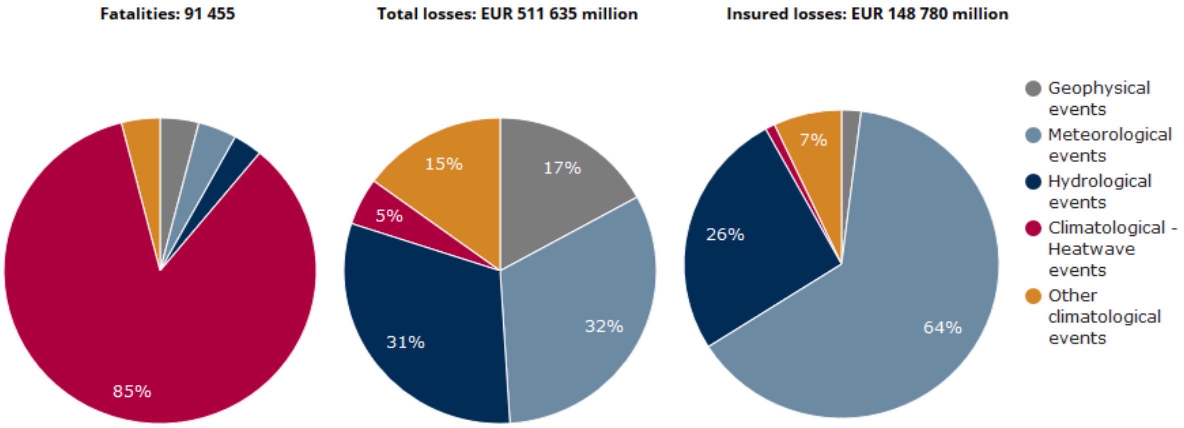
“Since the virus began to spread in Italy, Lombardy and Emilia Romagna recorded a substantial high level of lethality if compared with other countries but also than other Italian regions.”[…] According to the AQI [Air Quality Index of the European Environment Agency] the area covering Lombardia and Emilia Romagna results to be the most polluted area in Italy (and one of the most polluted in Europe)” (Conticini et al., 2020, p. 1).

In a recent study conducted in the US, Wu et al. found that a “long-term exposure to air pollution increases vulnerability to the most severe COVID-19 outcomes”. They found “statistically significant evidence that an increase of 1 μg/m3 in long-term PM2.5 exposure is associated with an 8% increase in the COVID-19 mortality rate” (Wu et al., 2020, p.14).

11. Economic impacts

11.1 Extreme events

According to the European Environment Agency (EEA), in the EU Member States (EU-28), disasters caused by weather and climate-related extremes accounted for some 83 % of the monetary losses over the period 1980-2017. Weather and climate-related losses amounted to EUR 426 billion (at 2017 values). The highest overall economic losses in absolute terms (in order of rank) were registered in Germany, Italy, and France (European Environment Agency, 2019c), with Italy accounting for about 12 % of the EU-wide losses and more than 20% of the fatalities (this number includes climatological events as well geophysical events such as earthquakes).



Notes:

Geophysical events: earthquakes, tsunamis, volcanic eruptions
Meteorological events: storms
Hydrological events: floods, mass movements
Climatological events: cold waves, droughts, forest fires
Climatological events (heatwaves)

Figure 26 : Natural hazards in EU-28 (1980-2017). (European Environment Agency, 2019c)

Country	Losses (million Euro)	Loss per capita (Euro)	Loss per sq.km (Euro)	Insured losses (million Euro)	Insured losses (%)	Fatalities
Italy	64,673	1,120	214,099	2,918	5	20,657

Table 7 : Impacts of extreme weather and climate related events in Italy (1980-2017). (European Environment Agency, 2019c)

The PESETA IV report (Szewczyk et al., 2020) assesses the welfare loss of selected climate impacts in % of GDP for the EU-27 and UK for three levels of global warming:

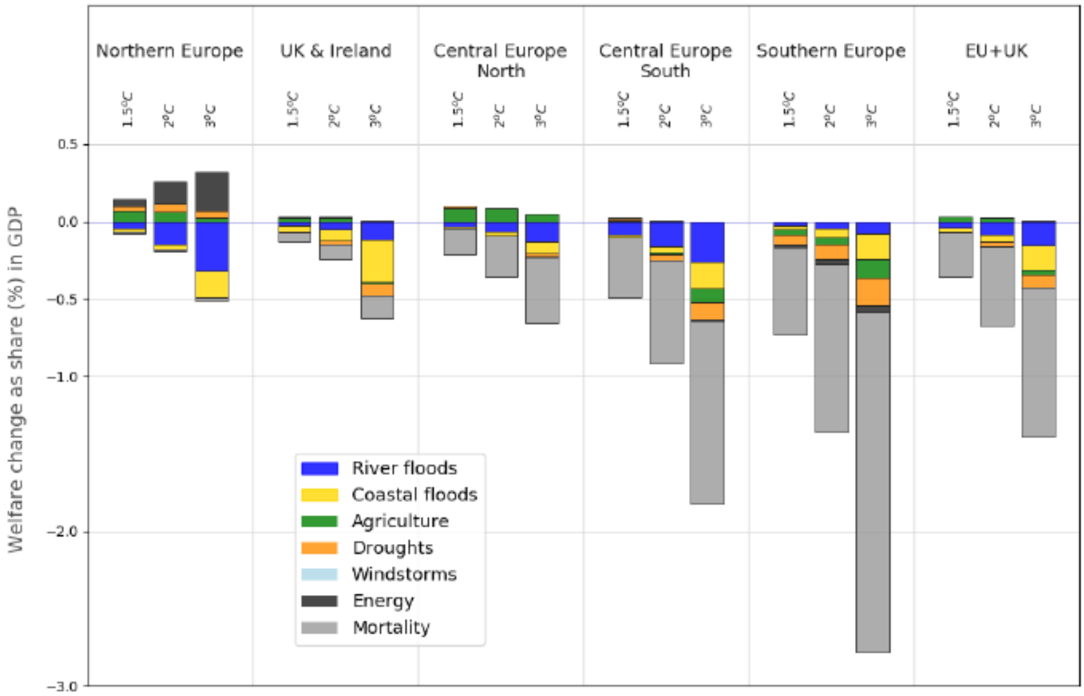


Figure 27 : Welfare change from selected climate impacts (% of GDP) for the EU-27 and UK, and for the constituent EU macro regions, for three levels of global warming. The results represent change with respect to current economy (Szewczyk et al., 2020, p. 32, figure 20).

The following table summarises the data for Southern Europe:

Sector	**Welfare change, bn €** **(additional to base)**			**Welfare change as share in GDP (%)**		
	1.5°C	**2°C**	**3°C**	**1.5°C**	**2°C**	**3°C**
Inland floods	-0.9	-1.5	-2.5	-0.03	-0.05	-0.08
Coastal floods	-0.9	-1.8	-5.2	-0.03	-0.06	-0.16
Agriculture	-1.0	-1.4	-3.7	-0.03	-0.04	-0.12
Droughts	-1.8	-3.0	-5.6	-0.06	-0.09	-0.18

Energy	-0.7	-1.0	-1.4	-0.02	-0.03	-0.04
Mortality	-17.6	-34.1	-68.9	-0.56	-1.09	-2.20
Sum of the sectors	-23.0	-42.7	-87.3	-0.73	-1.36	-2.78

Table 8 : Welfare change from selected climate impacts (bn € and % of GDP) in Southern Europe, for three levels of global warming. The results represent change with respect to current economy. Data source: Szewczyk et al., 2020; table 7.

Impact of wildfires

The 2019 report of The Lancet Countdown on health and climate change states: "the global economic burden per person affected by wildfires is more than twice that of earthquakes and 48 times higher than that of floods, although the global number of events and number of people affected by floods are much higher than for wildfires. Furthermore, climatic changes, including increasing temperature and earlier snowmelt, contribute to hotter, drier conditions, which increase the risk of wildfires." (Watts et al., 2019, p.1842)

11.2 Agricultural Sector

"Socio-economic impacts of climate change can have direct or indirect effects on the agriculture sector in Europe. Direct economic impacts are due to changes in crop productivity and yields, while indirect economic impacts affect the sector through changes in trade flows triggered by changes in crop production and yields. These can, in turn, spread across the whole economy of the sector with macro-economic effects on food prices, farm incomes and, ultimately, food security."(European Environment Agency, 2019d, p.56)

"Two thirds of the loss in land values in the EU could be concentrated in Italy, where the revenues of Italian farms are very sensitive to seasonal changes in climate parameters, especially under more severe climate scenarios (Bozzola et al., 2018). The projections show that Italy has the largest aggregate loss of farmland value, ranging from EUR 58 billion to EUR 120 billion by 2100 (34-60 % decrease) according to climate scenarios (Van Passel et al., 2017) compared to present climate (baseline period 1961-1990)." (European Environment Agency, 2019d, p.60)

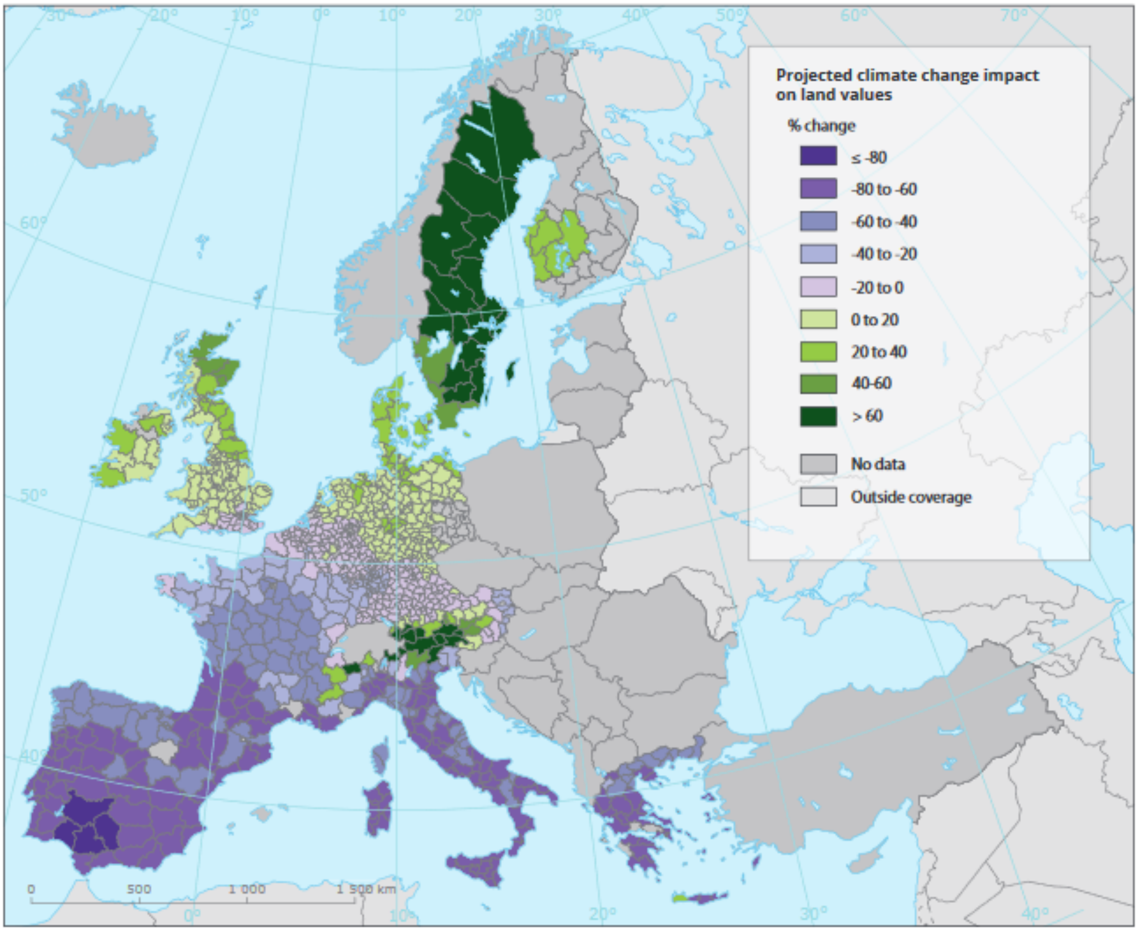


Figure 28 : Percentage change in farmland values projected for the period 2071-2100 compared to 1961-1990. (European Environment Agency, 2019d, p.60, map 4.9)

Labour productivity

“In 2018, 45 billion additional potential work hours were lost due to rising temperatures, compared with in the year 2000” (Watts et al., 2019, p. 1842). As Figure 29 shows, the majority of the work hours lost globally were in the agricultural sector.

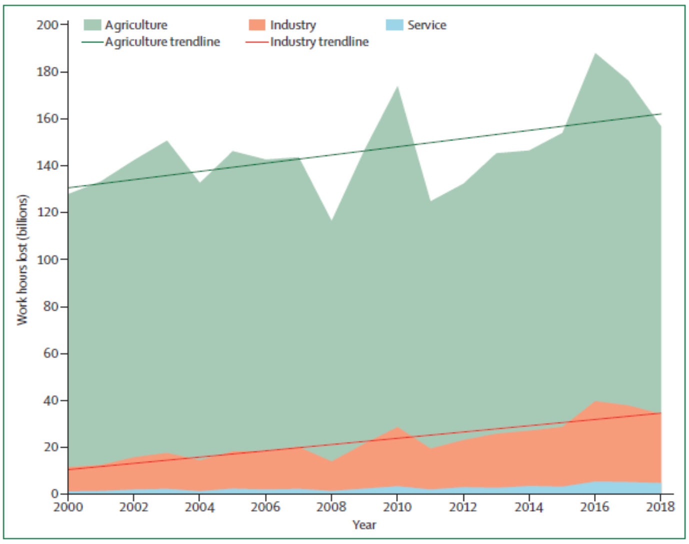


Figure 2: Potential global work hours lost per sector due to heat, 2000–18

Figure 30 also shows the potential full-time annual work lost in 2018 in the shade (top) or in the sun (bottom) based on the percentage of people working in agriculture (400 Watts), industry (300 Watts) and services (200 Watts). The number of watts is the average metabolic rate that characterizes the mean workload for a given occupation. On average, work in the agricultural sector requires more energy per minute than in the industry or services sectors (1 kcal/min=69.78 W). In Italy in the sun, most of the potential full-time workers lost as a consequence of exposure to extreme heat can be found in the south and Sicilia.

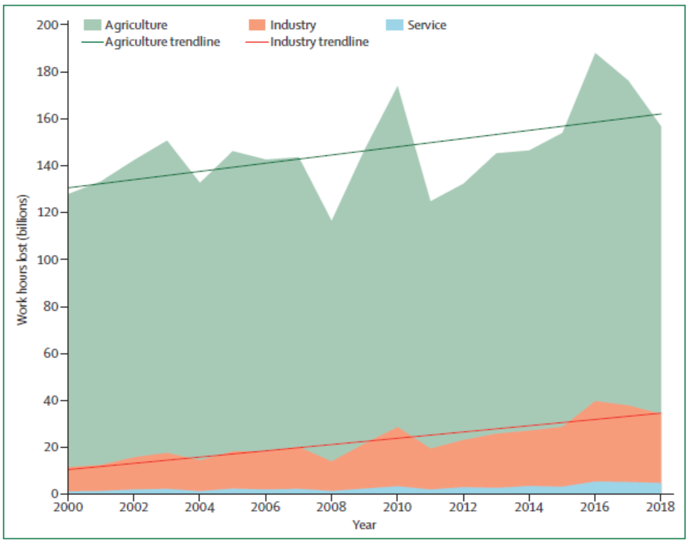


Figure 2: Potential global work hours lost per sector due to heat, 2000–18

Figure 29: Potential global work hours lost per sector due to heat, 2000-2018. (Watts et al., 2019, p.1842, figure2)

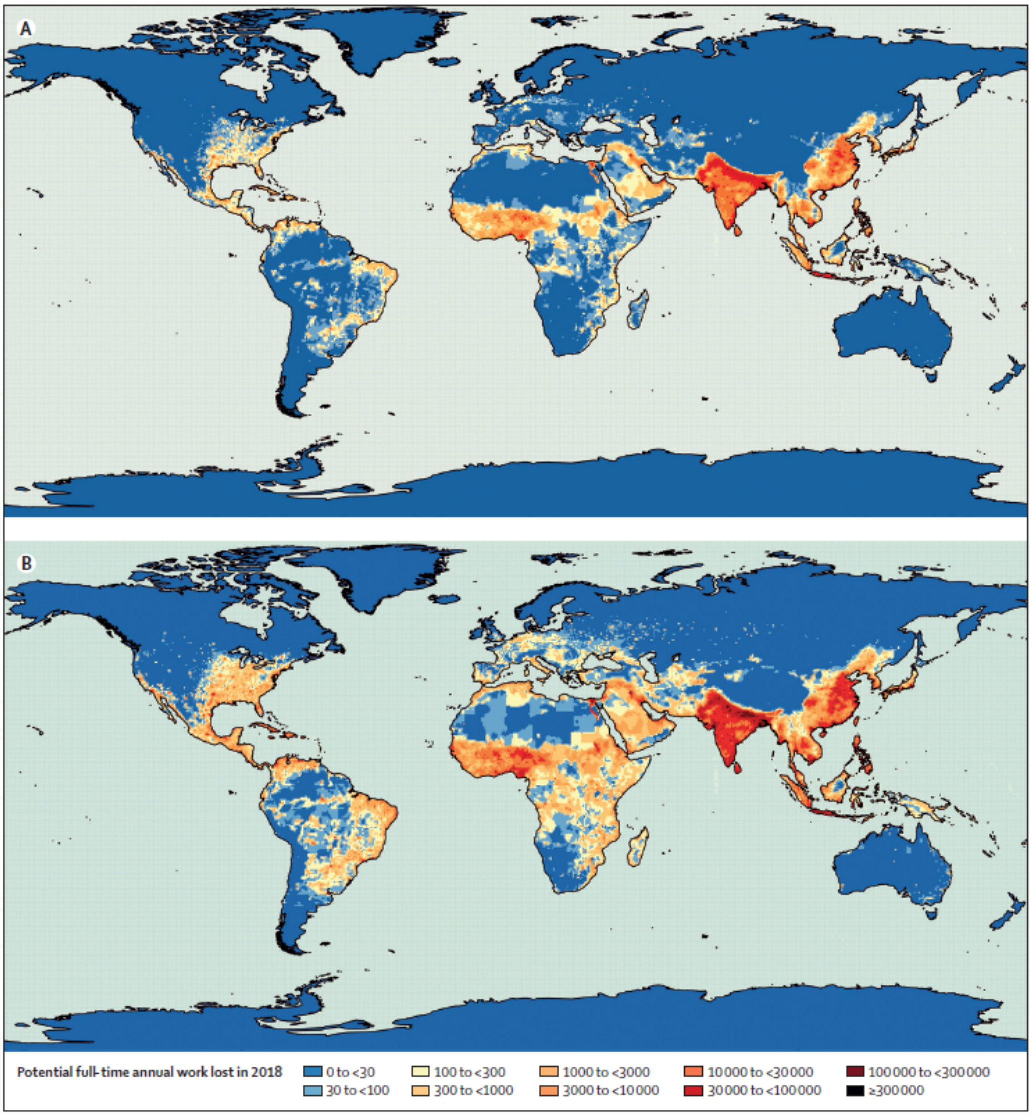


Figure 30 : Potential full-time annual work lost in 2018 in the shade (top) or in the sun (bottom) based on the percentage of people working in agriculture (400 Watts), industry (300 Watts) and services (200 Watts). The values are given for each 0.5x0.5 degree grid cell (about 50kmx50km) (Watts et al., 2019, p.1843, figure 3)

According to a recent study by Casanueva et al., for a scenario of 4.3°C expected temperature increase by 2100 (RCP8.5), Southern Europe, including Italy, will experience a widespread loss of working hours by at least 15% by the end of the century. Even if stronger global mitigation actions are implemented (<2°C scenario, RCP2.6), high heat risk is found for large parts of Southern Europe during the twenty-first century (Casanueva et al., 2020). Figure 31 shows the observed and projected percentage of summer working hours lost due to heat exposure under sunny conditions for scenario RCP8.5:

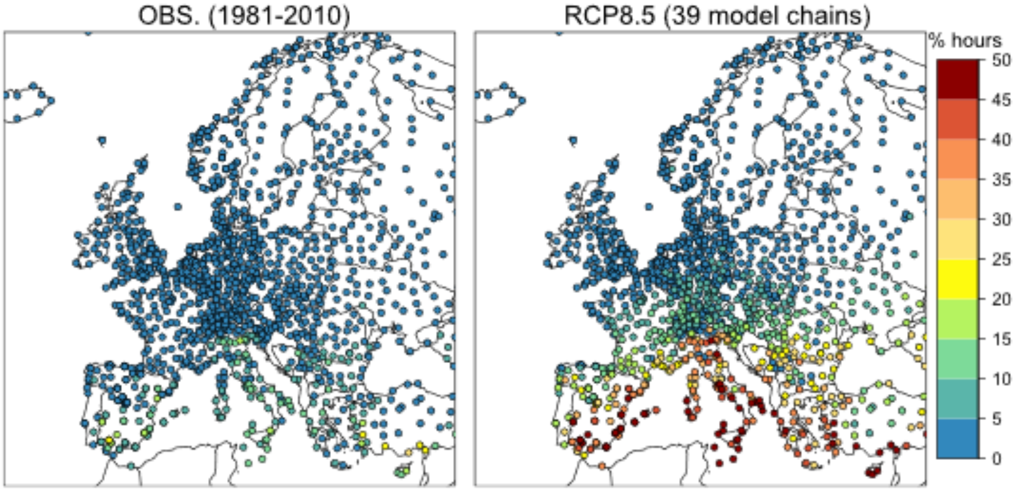


Figure 31: Productivity loss due to environmental heat exposure. Observed (left) and projected (right) percentage of summer working hours lost due to heat exposure under sunny conditions. Projections show a median of several models (over 39 model chains) for scenario RCP8.5 and the period 2070-2099. (Casanueva et al., 2020, p.7, figure 2)

"The estimated direct cost of agricultural productivity loss in the EU due to soil erosion (i.e. land suitability), which also has a climatic component, is around EUR 1.25 billion (between 2010 and 2020), corresponding to 0.43 % of the EU's total agriculture sector contribution. Erosion is expected to increase in the future due to more extreme rain events but also sectoral changes such as increased farm size, heavier machinery and increased compaction play a role." (European Environment Agency, 2019d, p.63). "The negative impact of soil erosion on crop productivity is mostly experienced by Mediterranean countries (Italy, Greece, Spain and Slovenia) and particularly affects rice and wheat, as these are the dominant crops in the region." (ibid)

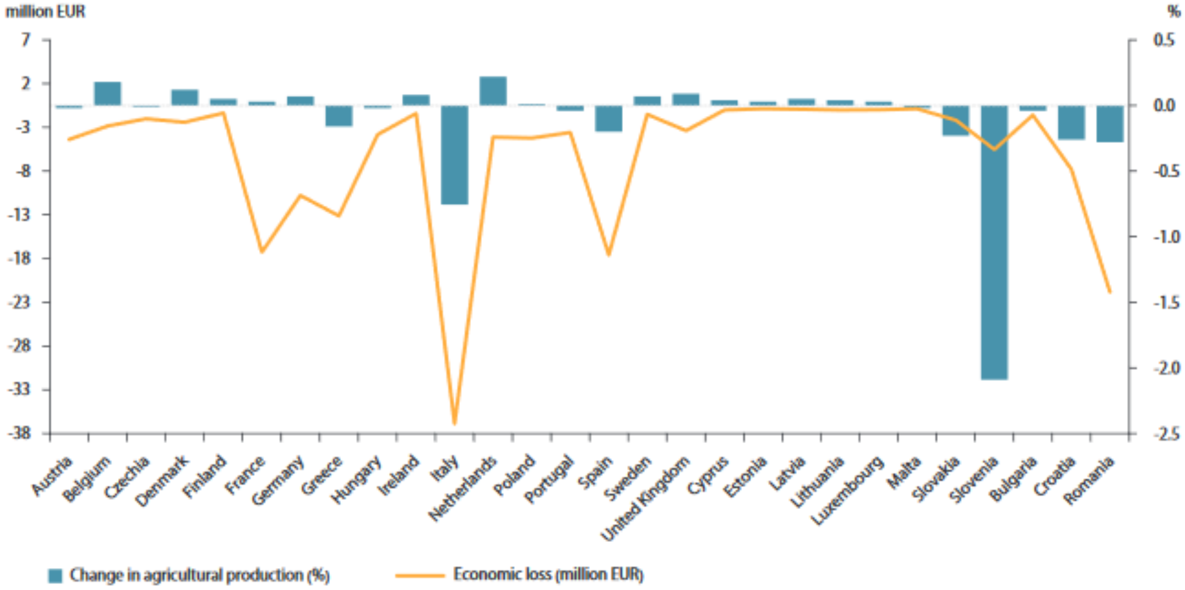


Figure 32 : Changes in agricultural production and economy losses in the EU due to soil erosion. The figure shows changes in agricultural production in percentages and GDP (million euros) in 2020 (compared with 2010)

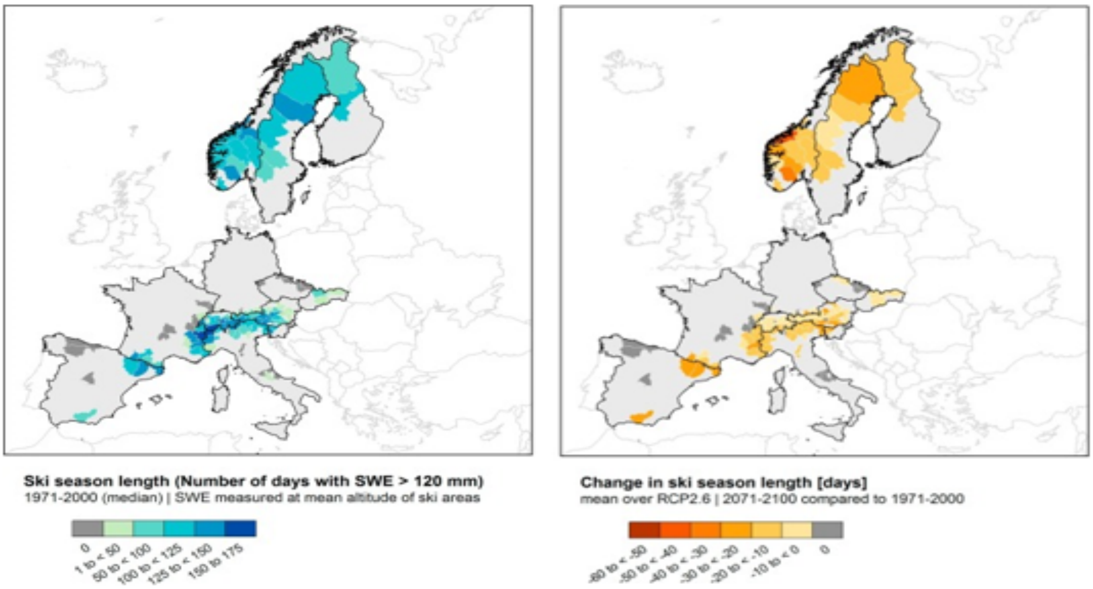
across European countries due to soil erosion, showing differences between direct and indirect effects. For instance, in terms of percentage physical losses, Italy is almost three times less affected than Slovenia. Nonetheless, this translates into greater loss in Italy than in Slovenia because a greater proportion of Italian land is subjected to severe erosion (33 %) and it is a bigger country than Slovenia. (European Environment Agency, 2019d, p.63, figure 4.1)

11.3 Tourism

According to the IPCC's Special Report: Global Warming of 1.5 ºC, a study by Ciscar et al. (2014) projected that "a 2°C warmer world would reduce European tourism by 5% (€15 billion per year), with losses of up to 11% (€6 billion per year) for southern Europe" (Hoegh-Guldberg et al., 2018, p.242).

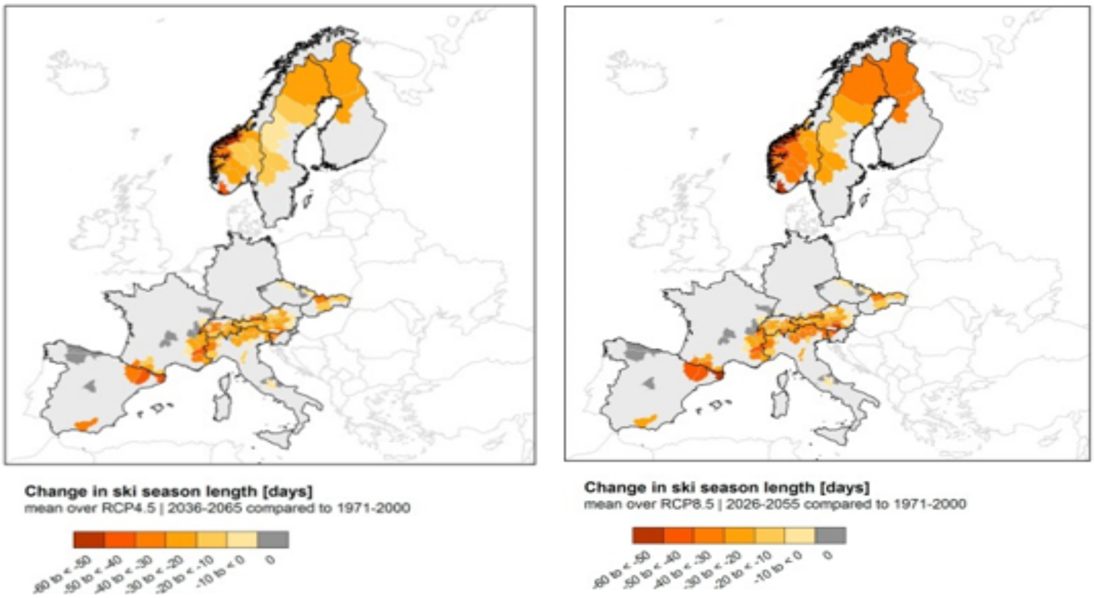
Climate change jeopardizes Italian tourism, both summer and winter tourism. While warming may be beneficial for countries further north, this is not the case for Mediterranean countries, as highlighted by the IPCC Special Report on 1.5°C: "Based on analyses of tourist comfort, summer and spring /autumn tourism in much of western Europe may be favoured by 1.5°C of warming, but with negative effects projected for Spain and Cyprus (decreases of 8% and 2%, respectively, in overnight stays) and most coastal regions of the Mediterranean. […] Similar geographic patterns of potential tourism gains (central and northern Europe) and reduced summer favourability (Mediterranean countries) are projected under 2°C" (Hoegh-Guldberg et al., 2018, p.242).

Increasing temperatures and snow scarce winter seasons challenge the winter tourism industry. Figure 33 shows the decreasing sea season length under three warming scenarios:



Ski season length (Number of days with SWE > 120 mm)
1971-2000 (median) | SWE measured at mean altitude of ski areas

Change in ski season length [days]
mean over RCP2.6 | 2071-2100 compared to 1971-2000



Change in ski season length [days]
mean over RCP4.5 | 2036-2065 compared to 1971-2000

Change in ski season length [days]
mean over RCP8.5 | 2026-2055 compared to 1971-2000

Figure 33 : Change in ski season length between 1971-2000 and 2071-2100 under RCP 2.6 (about 1.6°C warming by 2100), between 1971-2000 and 2036-2065 under RCP 4.5 (about 2.5°C warming by 2100) and between 1971-2000 and 2026-2055 under RCP 8.5 (>4°C warming by 2100). (Damm et al., 2017, p. 16, figures 2 and A1)

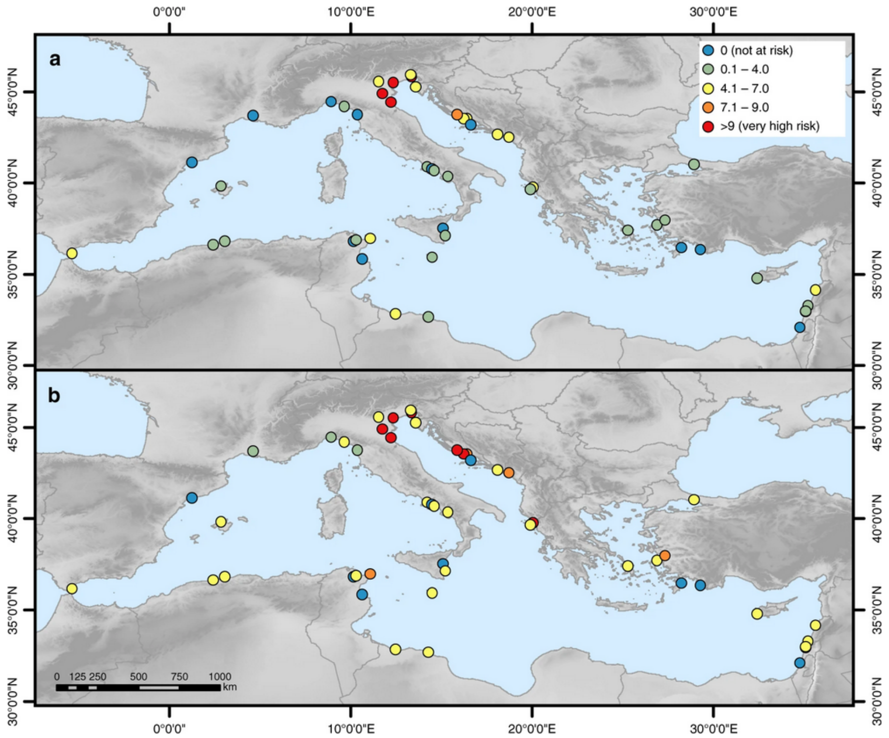
In Italy, considering potential changes in natural snow under a +1.5°C scenario, winter overnight stays are projected to decline by 1.7% (-600,000 overnights). Under a +2°C scenario, this number reaches 2.3% (-800,000 overnights). Considering the additional effects of climate change due to socioeconomic changes in Italy, under a 1.5°C scenario, the decrease in the number of overnights is projected to reach -750,000 overnights, and under a 2°C scenario, -1.5 million overnights (Jacob et al., 2018, p. 17).

World Heritage Sites

Furthermore, climate change threatens Italian World Heritage sites. Italy counts 55 properties inscribed on the World Heritage List, 50 of them being cultural properties and 5 natural properties.

"Climate change is likely to exacerbate existing stresses [on World Heritage properties] and bring direct impacts of its own. Sea-level rise, higher temperatures, habitat shifts and more frequent extreme weather events such as storms, floods and droughts, all have the potential to rapidly and permanently change or degrade the very attributes that make World Heritage sites such popular tourist destinations" (Markham et al., 2016, p. 5). "In adopting the Paris Agreement in December 2015, 195 countries acknowledged the importance of reducing greenhouse gases to a level that will keep global average temperature rise since pre-industrial times well below 2°C. Achieving this goal is vital for the future of World Heritage" (ibid).

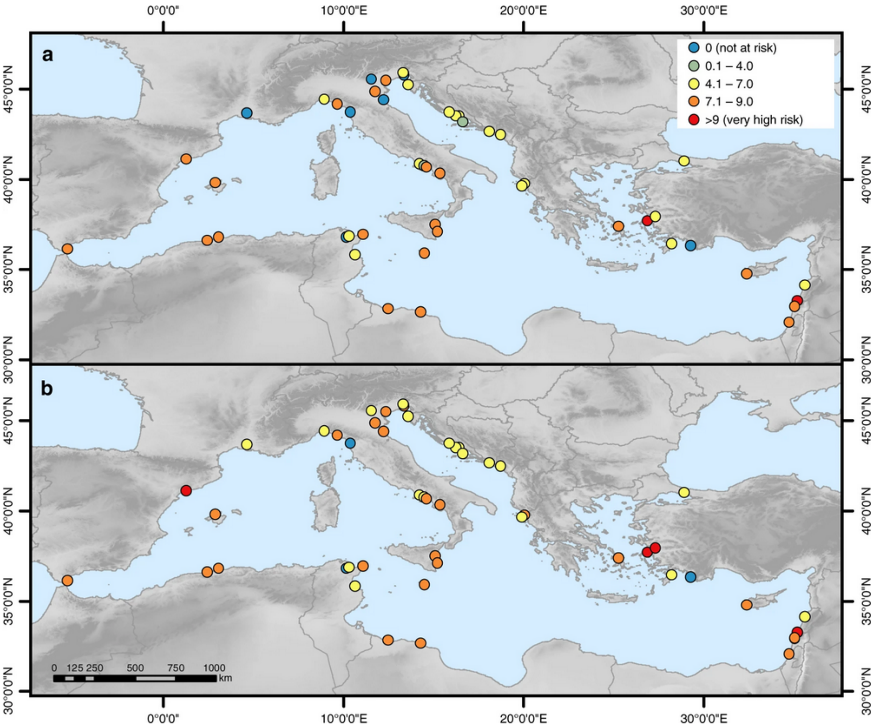
The following maps show how floods and erosion, also linked to sea level rise, affect Mediterranean World Heritage Sites (WHS):



Flood risk index at each World Heritage site under current and future conditions. **a** In 2000 and **b** in 2100 under the high-end sea-level rise scenario

Figure 34 : Flood risk index at each World Heritage site under current and future conditions. A. In 2000 and b. In 2100. (Reimann et al., 2018, p. 4, figure 3)

"Venice is one of the World Heritage sites most at threat from sea-level rise, with major implications for its burgeoning tourism industry. The city's extraordinary assemblage of Byzantine, gothic, renaissance and baroque architecture is under immediate threat from rising sea levels" (Markham et al., 2016a, p. 85).



Erosion risk index at each World Heritage site under current and future conditions. **a** In 2000 and **b** in 2100 under the high-end sea-level rise scenario

Figure 35 : Erosion risk index at each World Heritage site under current and future conditions. a. In 2000 and b. In 2100. (Reimann et al., 2018, p.5, figure 5)

The highest number of World Heritage sites (WHS) around the Mediterranean basin at risk because of floods can be found in Italy (13), including Venice and its Lagoon that ranks 10 (very high risk) on the risk index. The highest number of Mediterranean World Heritage sites at risk due to erosion can be found in Italy (14) (Reimann et al., 2018).

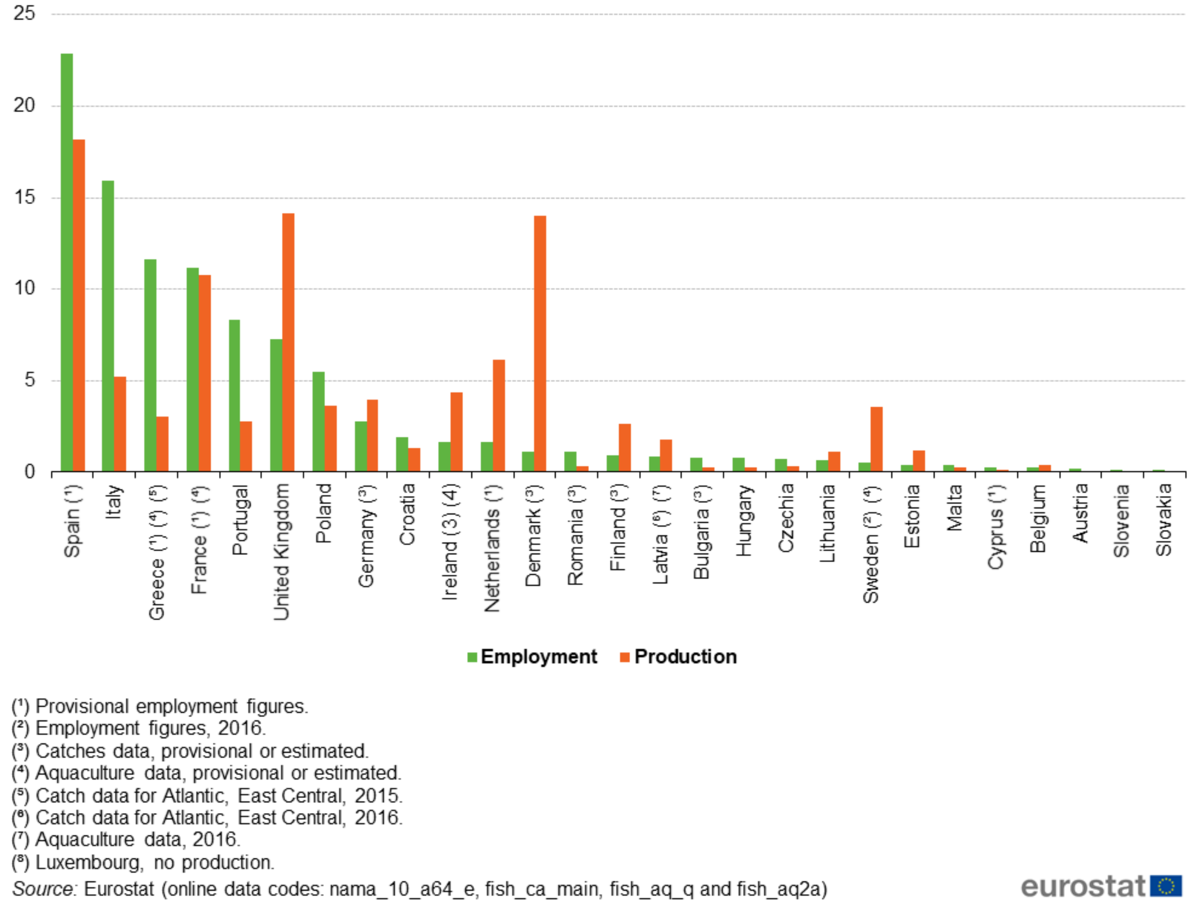
"As the risk of coastal hazards such as flooding and erosion increases with sea-level rise, a considerable number of coastal World Heritage Sites will gradually be exposed to these hazards in the future, threatening the Outstanding Universal Value (OUV) of affected sites and potentially leading to losses in economic revenue as WHS are popular tourist destinations […]. WHS may lose their OUV in the next centuries and may consequently be removed from the UNESCO World Heritage list." (Reimann et al., 2018, p.2)

11.4 Fisheries

The IPCC states in its Special Report on 1.5°C: "There are multiple lines of evidence that ocean warming and acidification corresponding to 1.5°C of global warming would impact a wide range of marine organisms and ecosystems, as well as sectors such as aquaculture and fisheries (high confidence)" (Hoegh-Guldberg et al., 2018, p.178).

There are 29 000 people in Italy working in the fishing industry. 40% of the total EU catch in the Mediterranean and Black Sea was by Italy (Eurostat, 2019).

Figure 36 shows the employment in the EU fisheries industry and fisheries production in 2017.



(1) Provisional employment figures.
(2) Employment figures, 2016.
(3) Catches data, provisional or estimated.
(4) Aquaculture data, provisional or estimated.
(5) Catch data for Atlantic, East Central, 2015.
(6) Catch data for Atlantic, East Central, 2016.
(7) Aquaculture data, 2016.
(8) Luxembourg, no production.

Source: Eurostat (online data codes: nama_10_a64_e, fish_ca_main, fish_aq_q and fish_aq2a)

Figure 36 : Employment in the EU fisheries industry and fisheries production, 2017. (% share of EU-28 totals). (Eurostat, 2019)

The IPCC 1.5 Special Report states: “Present-day risks for mid-latitude bivalve fisheries and aquaculture become undetectable up to 1.1°C of global warming, moderate at 1.3°C, and moderate to high up to 1.9°C. For instance, Cheung et al. (2016a), simulating the loss in fishery productivity at 1.5°C, 2°C and 3.5°C above the pre-industrial period, found that the potential global catch for marine fisheries will likely decrease by more than three million metric tonnes for each degree of warming.” (Hoegh-Guldberg et al., 2018, p.238).

“For existing international and national ocean and fisheries governance, there are concerns about the reduced effectiveness to achieve mandated ecological, economic, and social objectives because of observed climate impacts on fisheries resources (high confidence)” (Bindoff, N.L. et al., 2019).

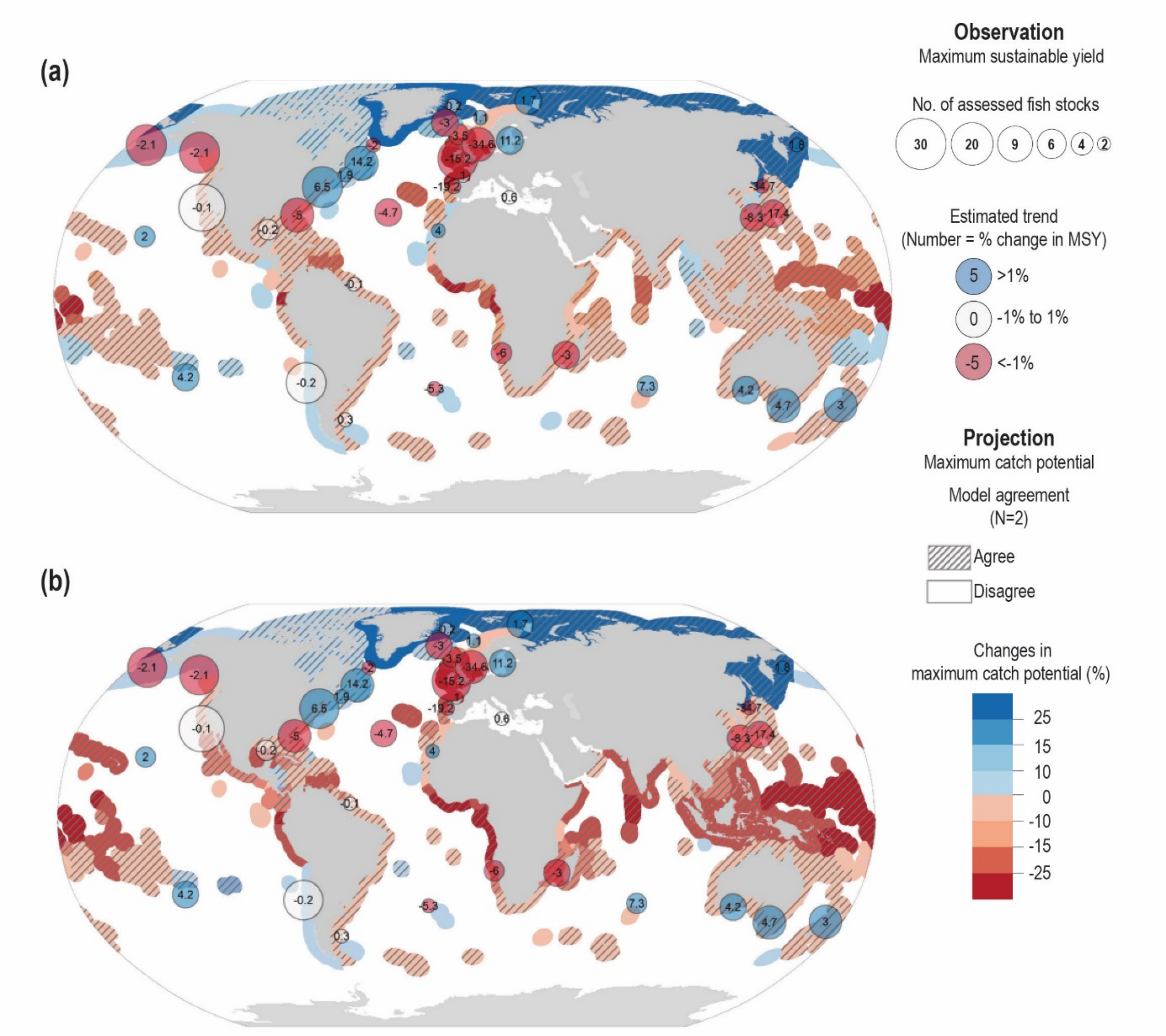


Figure 37 : Historical and projected maximum sustainable yield (MSY) and maximum fish catch potential by region. The size of the circle represents the number of assessed fish stocks while the number in the circle represents the estimated percent change in MSY since the 1930s (Bindoff, N.L. et al., 2019, p.504, figure 5.18)

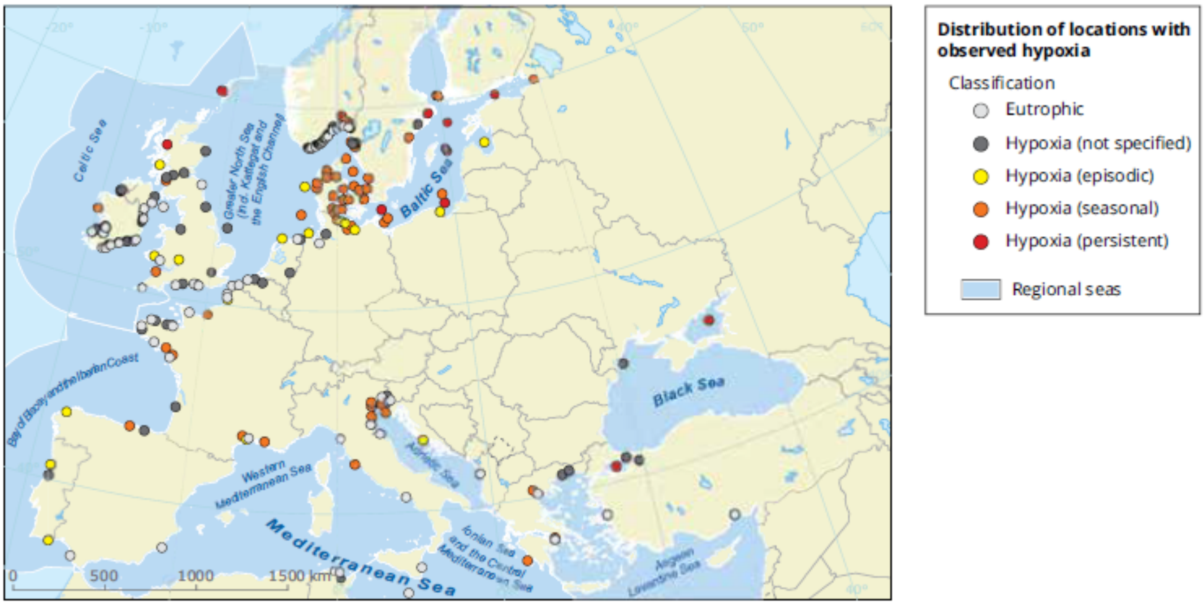
"Fisheries models project a decrease in maximum catch potential under RCP 2.6 [holding warming below 2°C, leading to a median warming of about 1.6°C by 2100] of 3.9–8.5% by 2041-2060 and 3.4–6.4% by 2081-2100 relative to 1986-2005 […]. Under RCP 8.5 [global warming scenario reaching >4°C warming by 2100], the projected decrease was larger: 8.6–14.2% and 20.5–24.1% by the mid- and end- of the 21st century. […] A single fisheries model with atmospheric warming projected a potential catch loss of 3.4 million tonnes and decreases of 6.4% of catch potential of the exploited species per degree Celsius atmospheric warming relative to 1951–1960 level" (Bindoff, N.L. et al., 2019, p.505).

"In the Mediterranean Sea, the change in fisheries catch potential is partly due to northward and eastward shifts in fish distribution that result in the invasion of warmer-water species into higher latitudes (e.g. Adriatic Sea) and local extinction in the southern Mediterranean region. Thus, in the near future, species that are commercially important in some areas may no longer be available. This may be already the case of the once abundant sardine (Sardina pilchardus), which has decreased drastically in the northern Mediterranean Sea in the last decade" (Moullec et al., 2016).

"By 2050, under a high emission scenario (Representative Concentration pathway 8.5), Cheung et al. (2016) predicted an up to 5% reduction in the potential catches at the Mediterranean scale. Furthermore, when considering changes in biogeochemistry such as ocean acidification and reduction in oxygen concentration, these authors also predicted a decrease in fish growth performance, which, along with a higher rate of distributional shift, may reduce estimated catch potential (Cheung et al. 2011). Changes in phytoplankton community structure may even reduce the projected catch potential by a further 10%" (Moullec et al., 2016).

"Accelerated nutrient flow into the sea (mostly from agricultural fertilisers) in combination with warming water temperatures can lead to large phytoplankton blooms and subsequent increases in primary production (a process called eutrophication). When these organisms sink to the sea floor, oxygen is utilised in their decomposition. If mixing within the water column cannot supply enough oxygen to the sea floor, this can lead to oxygen reduction (hypoxia) to levels that severely limit biological activity and ultimately to complete oxygen depletion (anoxia)" (Füssel et al., 2017, p. 119). "Oxygen depletion may also interact with other anthropogenic stressors in affecting marine ecosystems and fisheries, such as overfishing or the introduction of invasive species" (ibid).

The reduction in oxygen content can lead to changes in the distribution of species, including so called 'dead-zones'. "The number of 'dead zones' has roughly doubled every decade since the 1960s and has increased from about 20 in the 1950s to about 400 in the 2000s" (Füssel et al., 2017, p. 119).



Note: Circles depict scientifically reported accounts of eutrophication-associated 'dead zones'. The area covered by 'dead zones' is not presented, as such information is not generally available.

Figure 38: Distribution of oxygen-depleted 'dead zones' in European seas. (Füssel et al., 2017, p. 120, map 4.1)

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