BRIEFING PAPER

GLOBAL CLIMATE RISK INDEX 2020

Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2018 and 1999 to 2018

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GERMANWATCH

Brief Summary

The Global Climate Risk Index 2020 analyses to what extent countries and regions have been affected by impacts of weather-related loss events (storms, floods, heatwaves etc.). The most recent data available—for 2018 and from 1999 to 2018 —were taken into account.

The countries and territories affected most in 2018 were Japan, the Philippines as well as Germany. For the period from 1999 to 2018 Puerto Rico, Myanmar and Haiti rank highest.

This year's 15th edition of the Climate Risk Index clearly shows: Signs of escalating climate change can no longer be ignored – on any continent or in any region. Impacts from extreme weather events hit the poorest countries hardest as these are particularly vulnerable to the damaging effects of a hazard and have a lower coping capacity and may need more time to rebuild and recover. The Climate Risk Index may serve as a red flag for already existing vulnerabilities that may further increase as extreme events will become more frequent or more severe due to climate change. The heatwaves in Europe, North America and Japan also confirm: High-income countries are feeling climate impacts more clearly than ever before. Effective climate change mitigation is therefore in the self-interest of all countries worldwide.

At this year's Climate Summit in Madrid, the second review of the Warsaw International Mechanism for Loss and Damage will investigate whether the body fulfills its mandate to avert, minimise and address loss and damage and whether it is equipped to do so in the future. In that process, COP25 needs to debate the lack of climate finance to address loss and damage. Furthermore, the implementation of measures for adapting to climate change must be strengthened.

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Content

How to Interpret the Global Climate Risk Index

The Germanwatch Global Climate Risk Index is an analysis based on one of the most reliable data sets available on the impacts of extreme weather events and associated socio-economic data. The Germanwatch Climate Risk Index 2020 is the 15th edition of this annual analysis. Its aim is to contextualise ongoing climate policy debates – especially the international climate negotiations – looking at real-world impacts over the last year and the last 20 years.

However, the index must not be mistaken for a comprehensive climate vulnerability[1] scoring. It represents one important piece in the overall puzzle of climate-related impacts and the associated vulnerabilities. The index focuses on extreme weather events but does not take into account important slow-onset processes such as rising sea-levels, glacier melting or more acidic and warmer seas. It is based on past data and should not be used as a basis for a linear projection of future climate impacts. More specifically, not too far-reaching conclusions should be drawn for the purpose of political discussions regarding which country or region is the most vulnerable to climate change. Also, it is important to note that the occurrence of a single extreme event cannot be easily attributed to anthropogenic climate change. Nevertheless, climate change is an increasingly important factor for changing the likelihood of the occurrence and the intensity of these events. There is a growing body of research that is looking into the attribution of the risk[2] of extreme events to the influences of climate change.[3]

The Climate Risk Index (CRI) indicates a level of exposure and vulnerability to extreme events, which countries should understand as warnings in order to be prepared for more frequent and/or more severe events in the future. Not being mentioned in the CRI does not mean there are no impacts occurring in these countries. Due to the limitations of the available data[4], particularly long-term comparative data, including socio-economic data, some very small countries, such as certain small island states, are not included in this analysis. Moreover, the data only reflects the direct impacts (direct losses and fatalities) of extreme weather events, whereas, indirect impacts (e.g. as a result of droughts and food scarcity) are not captured. The results of this index must be viewed against the background of data availability and quality as well as the underlying methodology for their collection. Data quality and coverage may vary from country to country as well as within countries. This has led to an underrepresentation of, for example, African countries when it comes to heatwaves. Finally, the index does not include the total number of affected people (in addition to the fatalities), since the comparability of such data is very limited.

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[1] According to IPCC (2014b) we define vulnerability as "the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt".

[2] According to IPCC (2012) we define disaster risk as "the likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.

[3] See, for instance: American Meteorological Society 2018, Herring et al. (2018), Trenberth et al. (2018), Zhang et al. (2016); Hansen et al. (2016); Haustein et al. (2016) & Committee on Extreme Weather Events and Climate Change Attribution et al. (2016); Stott et al. (2015)

[4] See also the Methodological Remarks in Chapter 5.

Key Messages

- Japan, the Philippines and Germany are at the top of the list of the most affected countries in 2018.
- Between 1999 and 2018, Puerto Rico, Myanmar and Haiti were the countries most affected by extreme weather events.
- Altogether, about 495 000 people died as a direct result of more than 12 000 extreme weather events globally and losses between 1999 and 2018 amounted to around US$ 3.54 trillion (in purchasing power parities).
- Heatwaves were one major cause of damage in 2018. Of the ten most affected countries in 2018, Germany, Japan and India were suffering from extended periods of heat. Recent science has found a clear link between climate change and the frequency and severity of extreme heat. In Europe, for example, extreme heat spells are now up to 100 times more likely to occur than a century ago. Furthermore, due to a lack of data, the impacts of heatwaves, for example on the African continent, may be underrepresented.
- In many cases (e.g. Puerto Rico), single exceptional disasters have such a strong impact that the countries and territories concerned also have a high ranking in the long-term index. Over the last few years, another category of countries has been gaining relevance: Countries like Haiti, the Philippines and Pakistan that are recurrently affected by catastrophes continuously rank among the most affected countries both in the long-term index and in the index for the respective year.
- Of the ten most affected countries and territories in the period 1999 to 2018, seven were developing countries in the low income or lower-middle income country group, two were classified as upper-middle income countries (Thailand and Dominica) and one was an advanced economy generating high income (Puerto Rico).
- This year's climate summit in Madrid needs to address the lack of additional climate finance to help the poorest people and countries to address Loss and Damage. They are hit hardest by climate change impacts because they are more vulnerable to the damaging effects of a hazard but have lower coping capacity. The climate summit needs to result in: a) a decision on how the need for support for vulnerable countries concerning future loss and damage is to be determined on an ongoing basis and b) the necessary steps to generate and make available financial resources to meet these needs. c) strengthening the implementation of measures for adapting to climate change.

1 Key Results of the Global Climate Risk Index 2020

People all over the world are facing the reality of climate change – in many parts of the world this is manifesting in an increased volatility of extreme weather events. Between 1999 and 2018, about 495 000 people died worldwide and losses of US$ 3.54 trillion (in PPP) were incurred as a direct result of more than 12 000 extreme weather events. Slow-onset processes will add an additional burden in the future. The UNEP Adaptation Gap Report 2016 warns of increasing impacts and resulting increases in global adaptation costs by 2030 or 2050 that will likely be much higher than currently expected: “[...] two-to-three times higher than current global estimates by 2030, and potentially four-to-five times higher by 2050”.[5] Costs resulting from residual risks or unavoidable loss and damage are not covered in these numbers. Current estimates of climate finance needs for residual loss and damage range between US$ 290 billion to US$ 580 billion in 2030 (Markandya/González-Eguino 2018).[6] Similarly, the Intergovernmental Panel on Climate Change (IPCC) estimates in its recent Special Report on “Global Warming of 1.5°C” that the "mean net present value of the costs of damages from warming in 2100 for 1.5°C and 2°C (including costs associated with climate change-induced market and non-market impacts, impacts due to sea level rise, and impacts associated with large scale discontinuities) are US$ 54 trillion and US$ 69 trillion, respectively, relative to 1961–1990".[7] This gives the indication that the gap between the necessary financing to deal with climate induced risks and impacts is even bigger than earlier projected. On the other hand, the report highlights the importance of enhanced mitigation action towards limiting a global temperature increase to well below 2°C or even to 1.5°C, which could avoid substantive costs and hardships.[8]

The **Global Climate Risk Index (CRI)** developed by Germanwatch analyses quantified impacts of extreme weather events[9] – both in terms of fatalities as well as economic losses that occurred – based on data from the Munich Re NatCatSERVICE, which is considered worldwide as one of the most reliable and complete databases on this matter. The CRI examines both absolute and relative impacts to create an average ranking of countries in four indicating categories, with a stronger emphasis on the relative indicators (see chapter “Methodological Remarks” for further details on the calculation). The countries ranking highest (figuring in the “Bottom 10”[10]) are the ones most impacted and should consider the CRI as a warning sign that they are at risk of either frequent events or rare, but extraordinary catastrophes.

The CRI does not provide an all-encompassing analysis of the risks of anthropogenic climate change, but should be seen as just one analysis explaining countries' exposure and vulnerability to climate-related risks based on the most reliable quantified data available – alongside other analyses.[11] It is based on the current and past climate variability and – to the extent that climate change has already left its footprint on climate variability over the last 20 years – also on climate change.

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[5] UNEP 2016, p. xii

[6] Their figures depend on the climate scenario, the discount rate, the assumed parameters of the climate model and the socioeconomic model. The analysis is based on the case where equilibrium temperatures increase by 2.5–3.4 °C, implying some mitigation, but less than is required under the Paris accord. They note that uncertainties regarding these sources are very large and meaningful projections of residual damages in the medium to long-term are not possible

[7] IPCC 2018a, p 153

[8] Ibid. 2018a

[9] Meteorological events such as tropical storms, winter storms, severe weather, hail, tornados, local storms; hydrological events such as storm surges, river floods, flash floods, mass movement (landslide); climatological events such as freezing, wildfires, droughts.

[10] The term "Bottom 10" refers to the 10 most affected countries in the respective time period.

[11] See e.g. analyses of Columbia University; Maplecroft's Climate Change Vulnerability Index

Countries Most Affected in 2018

Japan, the Philippines and **Germany** were the most affected countries in 2018 followed by **Madagascar, India** and **Sri Lanka**. Table 1 shows the ten most affected countries (Bottom 10) in 2018, with their average weighted ranking (CRI score) and the specific results relating to the four indicators analysed.

Table 1: The 10 most affected countries in 2018

Ranking 2018 (2017)	**Country**	**CRI score**	Death toll	Deaths per 100 000 inhabitants	Absolute losses (in million US$ PPP)	Losses per unit GDP in %	Human Development Index 2018 Ranking[12]
1 (36)	Japan	5.50	1 282	1.01	35 839.34	0.64	19
2 (20)	Philippines	11.17	455	0.43	4 547.27	0.48	113
3 (40)	Germany	13.83	1 246	1.50	5 038.62	0.12	5
4 (7)	Madagascar	15.83	72	0.27	568.10	1.32	161
5 (14)	India	18.17	2 081	0.16	37 807.82	0.36	130
6 (2)	Sri Lanka	19.00	38	0.18	3 626.72	1.24	76
7 (45)	Kenya	19.67	113	0.24	708.39	0.40	142
8 (87)	Rwanda	21.17	88	0.73	93.21	0.34	158
9 (42)	Canada	21.83	103	0.28	2 282.17	0.12	12
10 (96)	Fiji	22.50	8	0.90	118.61	1.14	92

PPP = Purchasing Power Parities. GDP = Gross Domestic Product.

Japan (1) was hit by three exceptionally strong extreme weather events in 2018. From 6th to 8th of July, heavy rainfalls with more than 200 mm/day were measured, which is about twice as much rainfall as is usually experienced on the wettest day in Japan. The torrential rainfalls resulted in flash floods and mudslides, killing more than 200 people and leading to over 5 000 houses being damaged and the evacuation of 2.3 million people.[13] Overall, the rainfalls caused damage of over US$ 7 billion. From mid-July to the end of August 2018, two-tiered high-pressure systems caused a severe heatwave that led to 138 fatalities and more than 70 000 people requiring hospitalization due to heat strokes and heat exhaustion.[14] In the city of Kumagaya, temperatures of 41.1°C were reported – a national heat record in Japan.[15] In September 2018, Typhoon Jebi made landfall on Japan, becoming the most intense tropical cyclone in the country for over 25 years.[16] Jebi broke several historical records for sustained winds in Japan, causing economic damage of over US$ 12 billion.[17]

Typhoon Mangkhut ploughed through the northern part of the **Philippines** (2) in September 2018 as a category 5 typhoon – the most powerful typhoon recorded worldwide in 2018[18]. It reached top

[12] UNEP 2018
[13] World Weather Attribution 2018
[14] The Japan Times 2018
[15] The Strait Times 2018
[16] The Guardian 2018d
[17] The New York Times 2019b
[18] CNN 2018a

speeds of up to 270 kilometres per hour[19] when it made landfall, affecting more than 250 000 people across the country. About 59 people were killed, most by landslides set off by the heavy rainfalls.[20]

Germany (3) experienced the second hottest year since records began due to a severe heatwave.[21] The period between April and July 2018 was the hottest ever recorded in Germany, with temperatures 2.9°C above average.[22] Overall, the heatwave led to the death of 1 234 people. After heavy rainfalls in January, only 61% of the usual amount of rain fell during summer, resulting in 70% of the soil being affected by drought in October 2018.[23] Around 8 000 farmers were prompted to call for federal emergency relief worth around EUR 1 billion (US$ 1.18 billion) in order to compensate for their losses[24], after a massive decline in harvest caused a total of EUR 3 billion (US$ 3.54 billion) in damage.[25]

In January 2018, **Madagascar** (4) was hit by Cyclone Ava, which made landfall on the eastern part of the island, where towns were flooded and buildings collapsed.[26] Ava reached top speeds of 190 kilometres per hour and killed 51 people.[27] It was followed by Cyclone Eliakim in March 2018 impacting more than 15 000 people, which included 17 deaths and nearly 6 300 being temporarily displaced.[28] Cyclone Ava and Eliakim together were responsible for 70 000 people being forced to seek refuge.[29]

The yearly monsoon season, lasting from June to September, severely affected **India** (5) in 2018. The state of Kerala was especially impacted – 324 people died because of drowning or being buried in the landslides set off by the flooding,[30] the worst in one hundred years. Over 220 000 people had to leave their homes, 20 000 houses and 80 dams were destroyed.[31] The damage amounted to EUR 2.4 billion (US$ 2.8 billion).[32] Furthermore, India's east coast was hit by the cyclones Titli and Gaja in October and November 2018. With wind speeds of up to 150 kilometres per hour, cyclone Titli killed at least eight people and left around 450 000 without electricity.[33]

Sri Lanka (6) started the year 2018 with severe monsoon rains from 20th to 26th May affecting 20 districts, especially the south and west coast.[34]The provinces of Galle and Kalutara were the most affected. In Galle, 166mm of rain fell in 24 hours – usually the district has an average precipitation of 290mm in the full month of May.[35]. At least 24 people died, more than 170 000 people were affected[36] and nearly 6 000 people were displaced.[37]

[19] CNN 2018b
[20] BBC 2018c
[21] Süddeutsche Zeitung 2018
[22] Scinexx 2018
[23] Frankfurter Allgemeine Zeitung 2018a
[24] Deutsche Welle 2019b
[25] Bayerische Landesbank 2019
[26] Al Jazeera 2018
[27] Le Monde 2018
[28] OCHA 2018
[29] Deutsche Welle 2019a
[30] Zeit 2018
[31] The Guardian 2018b
[32] Frankfurter Allgemeine Zeitung 2018b
[33] BBC 2018c
[34] Ministry of Irrigation and Water Resources and Disaster Management 2018
[35] FloodList 2018d
[36] Disaster Management Centre of Sri Lanka 2018
[37] FloodList 2018e

Seasonal rains affected **Kenya** (7) and **Rwanda** (8) and other countries in East Africa.[38] Between March and July 2018, Kenya[39] experienced almost twice the normal rainfall of the wet season.[40] Kenya's most important rivers in the central highlands overflowed affecting 40 out of 47 counties[41] and causing the death of 183 people, injury of 97 and the displacement of 321 630 people[42], as well as the loss of livelihoods and livestock.[43] The heavy rains of March 2018 caused flooding along the Sebeya River in **Rwanda** (8). Approximately 25 000 people from 5 000 households were affected, and their homes were either destroyed or damaged by mud and overflow.[44] The floods aggravated cholera cases and resulted in an epidemic of the mosquito-borne chikungunya virus.[45]

Canada (9) started the year with extremely cold temperatures of -45.2°C and -48.2°C in the east, the lowest in 100 years.[46] In May 2018, over 4 000 people were displaced because of flooding, which affected the southern region of British Colombia. Record highs in temperatures in April melted heavy snowpacks, which caused rivers to overflow.[47] The same region suffered the worst wildfire season on record resulting in the evacuation of 16 000 people.[48] 2 117 wildfires burned 1 354 284 hectares,[49] and caused smoke-filled skies in west Canada, making the air quality among the worst in the world.[50] In July 2018, a severe heatwave reached Canada, killing 93 people in Quebec due to heat-related complications.[51]

Fiji (10) suffered the effects of three cyclones between February and April 2018. Cyclone Gita, with peak sustained winds of 126 kilometres per hour[52], reached the South of Fiji causing US$ 1.23 million of damage and the evacuation of 288 people.[53] Two weeks later, the Cyclone Josie and the severe flooding it caused, took the lives of eight people and almost 2 300 people were displaced[54]. Keni was last cyclone of the season was, making landfall in April. It affected Kadavu as a category 3 tropical cyclone[55] and 8 935 people had to leave their homes. Overall, cyclones Keni and Josie affected around 150 000 people.[56]

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[38] World Weather Attribution 2018a
[39] Rainfall totals in Nairobi at the five stations exceeded the normal amounts by two to three times in March and one to two times in April (Kilavi et al. 2018)
[40] Kilavi et.al. 2018
[41] The Guardian 2018c
[42] Kenya Red Cross 2018
[43] UNICEF 2018
[44] IFRC 2018.
[45] The Guardian 2018c
[46] The Weather Network 2018
[47] FloodList 2018c
[48] Daily Hive 2018
[49] British Columbia Official Website 2018
[50] BBC 2018a
[51] Summer 2018 was the hottest on record in the Atlantic coast and in the south, the third-warmest summer on record (Government of Canada 2018)
[52] Fiji Meteorological Services 2018
[53] Fijian Broadcasting Corporation. 2018
[54] FloodList 2018a
[55] FloodList 2018b
[56] Government of Fiji 2018

Countries Most Affected in the Period 1999–2018

Puerto Rico, Myanmar and **Haiti** have been identified as the most affected countries[57] in this twenty-year period. They are followed by the **Philippines, Pakistan** and **Vietnam**. Table 2 shows the ten most affected countries in the last two decades with their average weighted ranking (CRI score) and the specific results relating to the four indicators analysed.

Table 2: The Long-Term Climate Risk Index (CRI): The 10 countries most affected from 1999 to 2018 (annual averages)

CRI 1999-2018 (1998-2017)	**Country**	**CRI score**	Death toll	Deaths per 100 000 inhabitants	Total losses in million US$ PPP	Losses per unit GDP in %	Number of events (total 1999–2018)
1 (1)	Puerto Rico	6.67	149.90	4.09	4 567.06	3.76	25
2 (3)	Myanmar	10.33	7 052.40	14.29	1 630.06	0.83	55
3 (4)	Haiti	13.83	274.15	2.81	388.93	2.38	78
4 (5)	Philippines	17.67	869.80	0.96	3 118.68	0.57	317
5 (8)	Pakistan	28.83	499.45	0.30	3 792.52	0.53	152
6 (9)	Vietnam	29.83	285.80	0.33	2 018.77	0.47	226
7 (7)	Bangladesh	30.00	577.45	0.39	1 686.33	0.41	191
8 (13)	Thailand	31.00	140.00	0.21	7 764.06	0.87	147
9 (11)	Nepal	31.50	228.00	0.87	225.86	0.40	180
10 (10)	Dominica	32.33	3.35	4.72	133.02	20.80	8

Compared to the CRI 2019, which considered the period from 1998 to 2017[58], there have been a few changes in the CRI ranking: while Puerto Rico remains at the top of the list, Myanmar and Haiti each move up one place to become one of the three most affected countries over the past two decades. These rankings are attributed to the aftermath of the exceptionally devastating events such as Hurricane Maria in Puerto Rico in 2017 and hurricanes Jeanne (2004) and Sandy (2012) in Haiti. Likewise, Myanmar was struck hard by Cyclone Nargis in 2008, which was responsible for an estimated loss of 140 000 lives as well as the property of approximately 2.4 million people.[59] Honduras, which consistently featured among the three most affected countries in previous CRI rankings, falls out of the Bottom 10 due to the observation period of this year's CRI edition starting in 1999 (Hurricane Mitch, which was in 1998, was the major extreme weather event which had significantly affected Honduras' CRI score).[60]

[57] Note: Puerto Rico is not an independent national state but an unincorporated territory of the United States. Nevertheless, based on its geographical location and socio-economic indicators Puerto Rico has different conditions and exposure to extreme weather events than the rest of the USA. The Global Climate Risk Index aims to provide a comprehensive and detailed overview of which countries and regions are particularly affected by extreme weather events. Therefore, Puerto Rico was considered separately in our analysis.
[58] See Eckstein et al. 2018
[59] See OCHA 2012
[60] Nicaragua falls out of the Bottom 10 for the same reason.

Particularly in relative terms, poorer developing countries are hit much harder. These results emphasise the particular vulnerability of poor countries to climatic risks, despite the fact that the absolute monetary losses are much higher in richer countries. Loss of life, personal hardship and existential threats are also much more widespread in low-income countries.

Exceptional Catastrophes or Continuous Threats?

The Global Climate Risk Index 2020 for the period 1999–2018 is based on average values over a twenty-year period. However, the list of countries featured in the long-term Bottom 10 can be divided into two groups: those that have a high ranking due to exceptional catastrophes and those that are continuously affected by extreme events.

Countries falling into the former category include Myanmar, where Cyclone Nargis in 2008 caused more than 95% of the damage and fatalities in the past two decades, and Puerto Rico, where more than 98% of the damage in both categories was caused by Hurricane Maria in 2017. With new superlatives like Cyclone Idai in March 2019 being the deadliest and costliest cyclone on record in the Indian Ocean, and one of the worst tropical cyclones to ever affect Africa and the Southern Hemisphere, it seems to be just a matter of time until the next exceptional catastrophe occurs.[61] The severe 2017 hurricane season made 2017 the costliest year ever in terms of global weather disasters.[62]

Over the last few years, another category of countries has been gaining relevance: Countries like Haiti, the Philippines and Pakistan that are recurrently affected by catastrophes continuously rank among the most affected countries both in the long-term index and in the index for the respective year. Furthermore, some countries were still in the process of recovering from the previous year's impacts. One example is the Philippines, which is regularly exposed to tropical cyclones such as Bopha 2012, Hayan 2013 and Mangkhut 2018, due to its geographical location.

The appearance of some European countries among the Bottom 30 countries[63] can to a large extent be attributed to the extraordinary number of fatalities due to the 2003 heatwave, in which more than 70 000 people died across Europe. Although some of these countries are often hit by extreme events, the relative economic losses and the fatalities are usually relatively minor compared to the countries' populations and economic power.

2 The Role of Climate Change in Extreme Weather Events

In its "Fifth Assessment Report" published in 2014, the Intergovernmental Panel on Climate Change (IPCC) has already predicted that risks associated with extreme events will continue to increase as the global mean temperature rises.[64] Linking particular extreme weather events to human-induced and natural climate drivers remains a scientific challenge that attribution science tries to tackle. The field has recently taken huge leaps forward – even though gaps in knowledge and especially in data remain. In general, many studies conclude that "the observed frequency, intensity, and duration of some extreme weather events have been changing as the climate system has warmed".[65] Nevertheless, it is not trivial to investigate the impact of climate change on a single weather event as different

[61] New York Times 2019a, World Bank 2019
[62] MunichRe 2018, see also CRI2019 for an in-depth chapter on tropical cyclones
[63] The full rankings can be found in the Annexes.
[64] IPCC 2014a, p.12
[65] Committee on Extreme Weather Events and Climate Change Attribution et al. 2016, p. 2

regional circumstances need to be taken into account and data might be very limited.[66] Over the past few years, substantial research has been conducted on the attribution of extreme events to climate change, i.e. to what extend anthropogenic climate change has contributed to the events' likelihood and strength.[67] In the field known as Probabilistic Event Attribution (PEA), based on climate model experiments, studies compare the probability of an extreme weather situation, in today's world with human-caused greenhouse gas emissions, to a world without human induced climate change.[68] Due to methodological improvement, "fast track attribution" is now more feasible and can be undertaken within months of the event (as opposed to decades).[69] Additionally, more knowledge is generated on how underlying factors contributing to extreme weather are influenced by global warming. For example, higher temperatures intensify the water cycle, leading to more droughts as well as floods due to drier soil and increased humidity.[70] Of course, these approaches can only lead to statements about the change in probability of a certain event happening.

Considering this, the report "Explaining Extreme Events of 2017 From a Climate Perspective" offered new findings from 17 peer-reviewed analyses. The American Meteorological Society has published the report on an annual basis since 2012 in its bulletin, analysing selected extreme weather events. Out of the 146 research findings, 70% "identified a substantial link between an extreme event and climate change".[71] Again, "scientists have identified extreme weather events that they said could not have happened without warming of the climate through human-induced climate change."[72] Among others, one study concluded that the intense marine heatwaves in the Tasman Sea off Australia in 2017 and 2018 were "virtually impossible" without climate change.[73] Another study took a closer look at the persistent spring to summer heatwave in Northeast China in 2017 and concluded that the likelihood of such temperatures increased by about one third due to anthropogenic climate change.[74] For its part, the "Fourth Climate Assessment Report" (2018) considers, with a high level of confidence, a future increase in the frequency and intensity of extreme high temperature and precipitation events as the global temperature increases as being "virtually certain".[75]The data on the countries in the CRI 2020 show how destructive extreme precipitation can be – namely through the floods and landslides, which have hit many regions in South and South East Asia and Africa – regions which now feature in the Bottom 10. Extreme precipitation is expected to increase as global warming intensifies the global hydrological cycle. Thereby, single precipitation events are expected to increase in intensity at a higher rate than global mean changes in total precipitation as outlined by Donat et al. (2016). Furthermore, those increases are expected in wet as well as dry regions.[76] A study by Lehmann et al. (2015) strengthens the scientific link between record-breaking rainfall events since 1980 and rising temperatures. According to the scientists, the likelihood of a new extreme rainfall event being caused by climate change reached 26% in 2010.[77] A recent study by Blöschel et al. (2017) concludes that the timing of floods is shifting due to climate change. The research focuses on Europe and shows that floods occur earlier in the year, posing timing risks to people and animals. Flooding rivers affect more people worldwide than any other natural disaster and result in multibillion dollars of damage annually.[78] Nevertheless, the study is not fully able to single out human-

[66] Hansen et al. 2016
[67] Stott et al. 2015
[68] Carbon Brief 2014
[69] Haustein et al. 2016
[70] WMO 2017
[71] American Meteorological Society 2018, without page number
[72] Ibid.
[73] Perkins-Kirkpatrick et al 2018, p54
[74] Wang et al. 2018
[75] Wuebbles el al. 2017
[76] Donat et al. 2016
[77] Lehmann et al. 2015
[78] Blöschl et al. 2017

induced global warming as a cause – a problem researchers on extreme weather attribution are still facing.

Researchers explained that the sea surface temperature plays a key role in increasing storms, wind speeds and precipitation.[79] Another study on this subject showed that the rainfall during storms like Hurricane Harvey in 2017 is equivalent to the amount of evaporation over the ocean and thus the corresponding cooling effect of tropical cyclones on sea temperature. It is still difficult to distinguish between natural variability and human-induced extremes, but the rising sea level, which is largely caused by climate change, is responsible for the increased intensity of floods, storms and droughts. For example, a study shows that torrential rains like those in 2016 in Louisiana, USA, are now 40% more likely than in pre-industrial times. The rainfall was increased because the storm was able to absorb abnormal amounts of tropical moisture on its way to the US coast, releasing three times the precipitation of Hurricane Katrina in 2005.[80] Another example is a regional model used to analyse the occurrence of heatwaves in India, finding causalities regarding the 2016 heatwave and climate change. The model indicated that sea surface temperatures influence the likelihood of record-breaking heat.[81] Other studies have found similar results. A publication regarding the 2015 Southern African droughts also found causalities with regards to sea surface temperatures causing reduced rainfall, and increased local air temperatures.[82] Moreover, the above-mentioned study from 2018 concludes that Hurricane Harvey could not have produced such an enormous amount of rain without human-caused climate change.[83]

Furthermore, there is increasing evidence on the link between extreme El Niño events and global warming. Cai et al. (2018) found that the robust increase in the variability of sea surface temperatures is "largely influenced by greenhouse-warming-induced intensification of upper-ocean stratification in the equatorial Pacific, which enhances ocean-atmosphere coupling."[84] As a consequence, the frequency of strong El Niño events increases as well as extreme La Niña events. This finding is considered a milestone in climate research[85] and strengthens past research in the field.[86] In addition, the IPCC's Special Report "Global Warming of 1.5°C" was published in October 2018. It aims to determine the difference in consequences of 1.5°C climate change compared to 2°C. In order to do so, it investigates the effects of past global warming of the same extent. It identifies trends of increasing intensity and frequency of weather extremes during the past 0.5°C global increase. Furthermore, it shows that, at least in some regions, the likelihood of droughts and heavy precipitation is higher based on a 2°C increase, compared to one of 1.5°C.[87]

Extreme weather events are not the only risks aggravated by the influence of climate change. In their latest reports, the IPCC (2019)[88] focuses on the effect of climate change on, for example, the desertification and degradation of land. It suggests that climate change will accelerate several desertification processes and that, in the future, the risks of desertification will increase. This has various implications, such as the loss of biodiversity and an increase in the likelihood of wildfires. Williams et al. (2019) conclude that this is because of the increasing vapour pressure deficit due to the warming climate.[89]

[79] Trenberth et al. 2015; Zhang et al. 2016
[80] Climate Central 2016a
[81] Climate Central 2016b
[82] Funk et al. 2016
[83] Trenberth et al. 2018
[84] Cai et al. 2018, p. 201.
[85] Ham Y-G 2018
[86] Cai et al. 2014, Cai et al. 2012, Yeh et al. 2009
[87] IPCC 2018a
[88] IPCC 2019
[89] Williams et al 2019

Climate Change is a Real Game Changer for Heatwaves

Interview with Friederike Otto, leading scientist in the field of event attribution and Acting Director of the Environmental Change Institute at the University of Oxford

How well can extreme weather events generally be attributed to climate change?

This is highly dependent on the type of extreme weather event and the region in which it occurs. Large-scale events are generally easier to attribute, since the climate models available to us are more suitable for that. The least uncertainty arises from large-scale precipitation events. In addition, the confidence of the results depends on the data availability. In the case of droughts, robust conclusions are possible if good observational data is available. While there is data on the lack of precipitation, unfortunately, quite often there is a lack of relevant data beyond that, e.g. on soil moisture. This is especially true for countries of the global South. Regarding tropical storms, the resolution of most state-of-the-art models is not high enough. We can however robustly attribute precipitation associated with hurricanes in the Atlantic Ocean. In contrast, it is much more difficult in other regions.

How strong (and how well measurable) is the influence on heatwaves?

Climate change is a real game changer. The probability of heatwaves has already changed by orders of magnitude in Europe and will do so in almost every region of the world. Nevertheless, extreme weather events always have multiple causes, urbanization and land use, for example, play a role here.

How strong (and how well measurable) is the influence on heavy rain?

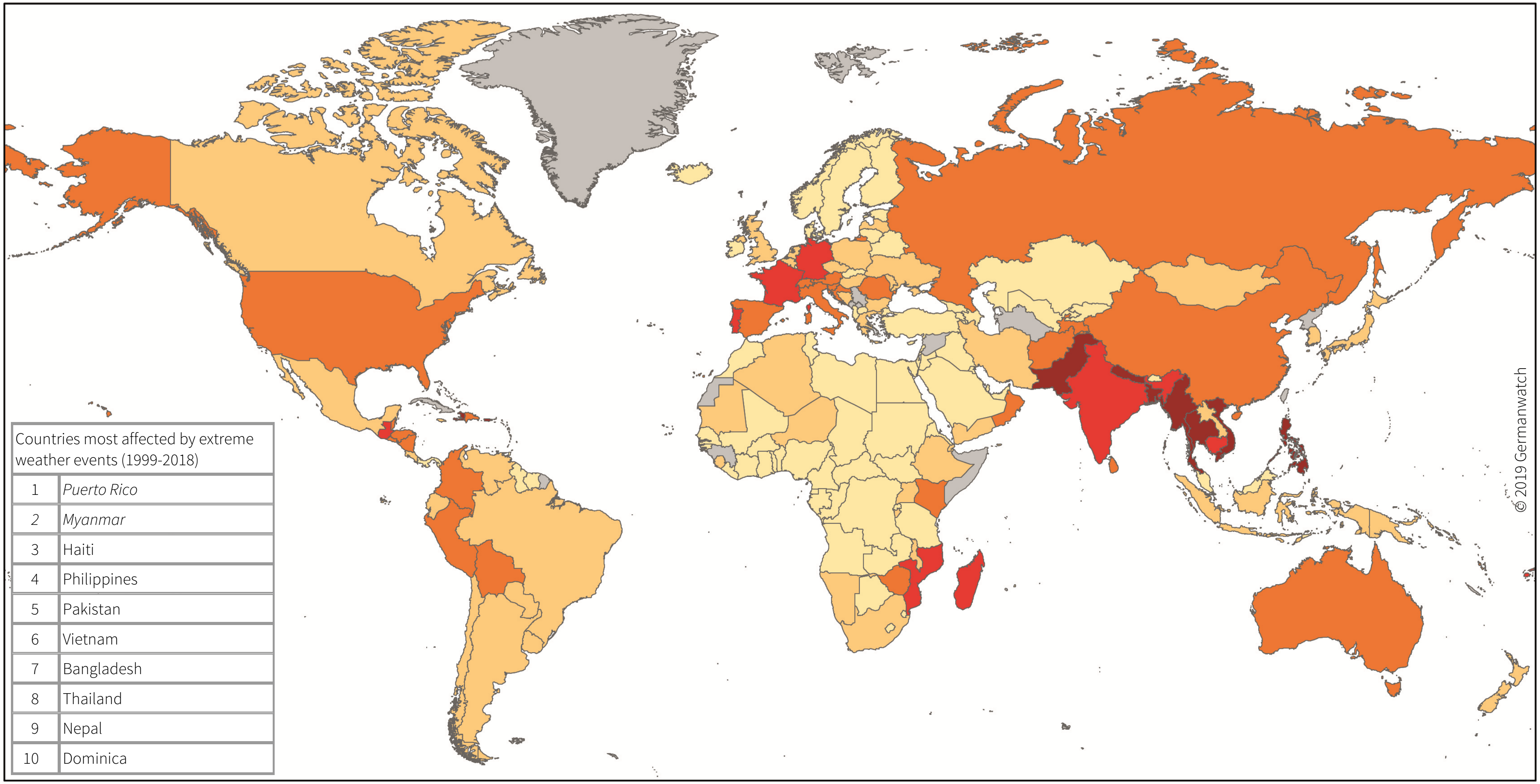
Climate change essentially affects weather in two ways: Firstly, through the thermodynamic effect, in other words the warming of the atmosphere. Warmer air can absorb more water vapour. Hence, we expect more extreme precipitation on a global average. The second effect is trickier. As we change the composition of the atmosphere, so does the atmospheric circulation and thus where weather systems are created and how they move. This effect varies by region and season, which is why we need attribution research. One example: While we can generally say that tropical cyclones will bring more intense and higher amounts of precipitation, we do not know whether and how their frequency will change.

What are the greatest challenges for attribution science?

There are two bottlenecks. Firstly, there is a lack of observational data, which is essential to carry out valid research of meteorological events. In many regions of the world, meteorological stations are missing. Without observational data, climate models cannot be evaluated. Secondly, the field of research is very small. There are too few people working on attribution and it is very difficult to acquire sufficient funding.

What advantages does it have that extreme weather events can be better attributed to climate change?

We currently know relatively little about what the concrete effects of climate change mean in time frames and on local scales where humans live and make decisions. Attribution science is important to understand what climate change actually means. Many adaptation measures are based on trends in observational data. Yet, these trends have multiple causes. Limited resources for adaptation to climate change can only be used efficiently, if we know what the consequences of climate change are.



Italics: Countries where more than 90% of the losses or deaths occurred in one year or event

Climate Risk Index: Ranking 1999 - 2018 **1 - 10** **11 - 20** **21 - 50** **51 - 100** **>100** **No data**

3 Heatwaves Sweep the World

A string of deadly heatwaves took its toll on millions around the world in 2018. Temperatures far above the long-term average were witnessed foremost in the Northern Hemisphere, wreaking havoc on human health, agriculture, ecosystems and infrastructure.[90] As highlighted in Chapter 1, extreme heat caused a significant number of deaths in Japan and Germany as temperatures soared past 40°C.[91] In California, Sweden, Russia and Greece heatwaves triggered the most destructive wildfires experienced in recent years with a high number of fatalities and significant damage[92]. In the UK and across Northern Europe extreme heat aggravated prolonged dry spells, leading to dire droughts. In India, temperatures of up to 50°C were measured, the extreme water stress was omnipresent. Due to the drought in the southern Indian state of Tamil Nadu and empty water reservoirs, Chennai, a city with over a million inhabitants, could only be supplied with water by trucks and trains. The water supplies for the population had to be accompanied by the police.

A heatwave, also referred to as an extreme heat event, is commonly described as a period of abnormally hot weather[93], spanning **at least five consecutive days with a temperature of 5°C above average**.[94] It typically forms when a high-pressure system shifts into a region and stalls. The system can force warm air downward, creating a 'cap' that traps air in one place as it prevents the hot air near the surface from rising. The effects of heatwaves may be less obvious at first glance compared to other natural disasters such as storms or flooding, however, heatwaves cost just as many lives. According to our index, a total of 2 928 people reportedly died in 2018 from heat-related impacts, compared to 3 622 fatalities caused by floods, and 2 463 fatalities due to severe storms. Furthermore, with regard to overall losses, heat resulted in a total of US$ 60.42 billion (in PPP) in damage globally in 2018.

Heatwave Effects and Interactions with other Extreme Weather Events

Science suggests that periods of extreme heat will not only become **more commonplace** due to increasing global temperatures but will also interact with and **exacerbate already existing risks** such as droughts and extreme rainfall or floods.[95]

Warmer temperatures increase the evaporative demand, which, alongside concurrent shifts in precipitation, amplify drought conditions. The converse also holds true. Conditions of drought can boost or curb heatwave temperatures.[96] Like heatwaves, record droughts have made headlines in recent years, highlighting their devastating implications. Heatwave-fuelled droughts are being felt not only in industrialised countries like Germany, where record highs in 2018 caused widespread crop failure to the detriment of thousands of farmers[97], but, first and foremost, in developing countries, where those affected are poorly equipped to cope with severe climate conditions.

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[90] The New York Times 2018
[91] New Scientists 2018
[92] San Francisco Chronicle 2018
[93] IPCC 2012a
[94] Deutsche Welle 2018b
[95] This chapter focuses on how heatwaves can exacerbate droughts.
[96] Nature Climate Change 2018
[97] Deutsche Welle 2019b

In Sweden, a heatwave followed an exceptionally dry and warm period in the summer of 2018, which resulted in the worst outbreak of forest fires on record, engulfing roundabout 50 forests[98], equivalent to approximately 25 000 hectares, which destroyed almost 3 million cubic meters of wood[99].

How Climate Change Affects Heatwaves

The latest attribution research states that CO_2 emissions from human activities have doubled the likelihood of severe heat events in northern Europe (World Weather Attribution 2018). Studies further show that large-scale heat events, such as the Northern Hemisphere heatwave in 2018, could occur every year if global temperatures were to climb to 2°C above the pre-industrial levels, or it could occur in two out of every three years in a 1.5°C scenario (Vogel et al. 2018, see further information on attribution science in chapter 2). Another study warns that if current greenhouse emission pathways remain unaltered, three out of four people on the planet could, by the year 2100, be exposed to more than 20 days per year of the heat and humidity linked to fatal heatwaves (Nature Climate Change 2017).

Climate science indicates that heatwaves often have a common trigger: profound recent changes to jet streams — strong winds at altitudes of around 10 kilometres above the earth's surface which affects weather systems around the globe. Powered by differences in temperature between cooler polar regions and warmer air masses, circulating jet streams can be stalled due to changed conditions, leading to unusual weather patterns. While reinforcing cold snaps in one place, a jet stream can fan blasts of heat in another (Mann et al. 2018).

The IPCC's Fifth Assessment Report confirms that the warming of the planet is already having an effect on jet streams and, hence, on global weather patterns: "It is likely that circulation features have moved poleward since the 1970s, involving a widening of the tropical belt, a poleward shift of storm tracks and jet streams and a contraction of the northern polar vortex. Evidence is more robust for the NH [Northern Hemisphere] (IPCC 2013)."

Evidence is also mounting that the warming Arctic, which is warming twice as fast as the rest of the planet, constitutes a major factor for why the polar jet stream keeps getting stalled (Popular Mechanics 2019). Recent heatwaves sweeping the Northern Hemisphere are largely attributed to the accelerated warming of the Arctic causing an altering of the polar jet stream, illustrating the increasing risk of heatwaves due to global warming (New Scientist 2018).

Over and above the interconnections with other extreme events, heatwaves also have a number of sectoral impacts.

Heatwaves and Health

Heatwaves affect human health worldwide, leading to increased morbidity and mortality[100]. The combination of heat and high humidity is particularly exhausting for the human body as it slows down the evaporation of sweat, the body's cooling system.[101] The effect of high heat on health mostly manifests itself in cardiological and respiratory diseases.[102] The population groups especially affected are the elderly as well as those working outdoors or in non-cooled buildings.[103] A special

[98] The Local 2018
[99] Forestry.com 2018
[100] Anderson and Bell, 2011; Haines et al., 2006; Loughnan et al., 2010; Martiello and Giacchi, 2010; Zeng et al., 2016
[101] Hajat et al 2010; Kjellstrom et al 2016; Kravchenko et al 2013
[102] e.g. Bunker et al 2015
[103] e.g. Bai et al., 2014, Yin and Wang, 2017

burden also lies on the poor and vulnerable, due to unevenly distributed access to proper health care. Inhabitants of cities are particularly in danger of suffering from the "urban heat island" effect, which enhances the intensity of heatwaves in cities. A lack of consideration in urban planning of rising temperatures, resulting in dense infrastructure, can lead to a temperature increase of up to 12°C in cities compared to rural environments, particularly at night.[104]

In the summer of 2003, anthropogenic climate change increased the risk of heat-related mortality in Central Paris by 70%, and by 20% in London, which experienced lower extreme heat. Out of the estimated 315 and 735 summer deaths attributed to the heatwave event in Greater London and Central Paris, respectively, 64 (±3) deaths were attributable to anthropogenic climate change in London, and 506 (±51) in Paris.[105]

Agriculture and Food Security

Combined heatwaves and drought can lead to severe harvest failures with major implications for agricultural producers and the food security of communities all over the world. Adverse-effects are not only felt directly where climate extremes occur, but also indirectly in that regions suffer from the repercussions of reduced exports and higher food prices.[106] As highlighted in this year's CRI's Bottom 10, a European heatwave and drought in the summer of 2018 led to widespread harvest failures and a massive decline in agricultural productivity in many countries across the continent. Struggling to cope with the consequences, various national governments sought help from the European Commission.[107] In Germany alone, some 8 000 farmers were prompted to call for federal emergency relief worth around EUR 1 billion (US$ 1.18 billion) in order to be compensated for their losses,[108] after a massive decline in harvest resulted in total damages of EUR 3 billion (US$ 3.54 billion).[109] However, the countries most susceptible to heatwaves and prolonged drought – mainly in the global South – are often in a much more precarious situation as they cannot rely upon government support in the form of financial resources or technologies. Furthermore, many African countries are particularly drought-prone and are already subjected to desertification and other forms of land degradation, which negatively impacts agriculture and frequently spurs conflicts over subsistence crops, thus perpetuating food insecurity and the risk of hunger.[110]

Forestry

Heatwaves can have devastating effects on forests. Heat causes the soil to dry out as water increasingly evaporates and exacerbates the risk of forest fires.[111] If a heatwave only lasts for a very limited time span, the trees are generally able to cope well with the high temperatures (>40 °C), if they have sufficient water sources.[112] But frequently, heatwaves occur in combination with droughts. A devastating combination for forests as it has contributed to tree mortality worldwide.[113] The negative effects on trees are manifold. Trees cool their leaves evaporatively by transpiration, and the stem tissues convectively through heat transfer.[114] Therefore, a lack of water hinders the cooling of the leaves and stem tissues, potentially leading to damage. Other negative effects include a reduction in tree growth and negative impacts on physiological processes such as reduced photosynthesis.[115]

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[104] United States Environmental Protection Agency
[105] Mitchell et al. 2016
[106] Global Food Security Programme 2015
[107] Deutsche Welle 2018a
[108] Deutsche Welle 2019b
[109] Bayern LB 2019
[110] UNFCCC 2007
[111] Focus 2019
[112] Teskey et al 2015
[113] Allen et al. 2010
[114] Kolb & Robberecht 1996
[115] Teskey et al 2015

The impact of extreme heat and droughts does not often materialise directly. Damage usually occurs years after the event. Trees that have already been weakened by the direct impacts become more vulnerable in subsequent years to extreme events; insects and diseases then become the primary causes of death.[116]

In the European heatwave of 2003, that was accompanied by a drought, another factor came to light: due to a 30% decline in gross primary production (biomass) across Europe, the forests in the region became a net source of CO2 (0.5 PgC per year) – rather than a carbon-sink, as in previous years.[117]

Heatwaves – a Global Threat

The occurrence of heatwaves is a global problem, both for countries in the global South and in the global North. The Intergovernmental Panel on Climate Change (IPCC) concludes that it is likely that [due to climate change] the frequency of heatwaves has increased in large parts of Europe, Asia and Australia.[118] According to the IPCC's special report on 1.5 degrees "**the number of highly unusual hot days is projected to increase the most in the tropics**".[119]

The current figures on the effects of heatwaves on different parts of the world must, however, be viewed against the background of data availability and quality as well as the underlying methodology for their collection. For instance, the accurate attribution of a human loss to a particular extreme weather event faces certain methodological boundaries that data collectors have to work with (e.g. to determine whether the death of an elderly person during a heatwave is indeed the result of the extreme temperature or only due to the high age). Similarly, data quality and coverage may vary from country to country as well as within countries. Currently, many more studies have been conducted for developed countries, compared to developing countries.[120] There are efforts to change this[121], but the limited availability of data in developing countries is a barrier.[122] A recent study by Campbell et al. (2018)[123] found that **heatwave and health impact research is not evenly distributed across the globe**. They highlight that regions most at risk from heatwaves and health impact are under-represented in the research (Campbell et al. 2018). These circumstances may cause countries with large data gaps to appear less affected by heatwaves than they might be in reality. We also have to note that climate change disproportionately affects the poor. Many **low-income urban residents live in precariously located informal settlements**, characterised by poor-quality housing that is susceptible to extreme heat and they have less access to affordable healthcare. These factors make them both more exposed to heatwaves, and less able to deal with them when they occur.[124]

Looking at the results of the CRI 2020, four countries (Japan, Germany, India and Canada) of the Bottom 10 were especially affected by heatwaves. Below, a closer look is taken at the impacts of heatwaves as well as the related challenges in Europe and India.

European Heatwaves

In the summer of 2018, Europe suffered from heatwaves accompanied by a dry spell, which led to crop failure and numerous forest fires.[125] July 2018 was the warmest July ever recorded in Northern

[116] Allen et al. 2010, Gessler 2019
[117] Ciais et al. 2005
[118] IPCC 2014c
[119] IPCC 2018
[120] Otto et al. 2015
[121] Climate Central 2019
[122] Huggel et al. 2015
[123] Campbell et al. 2018
[124] C40 2019
[125] Imbery et al. 2018b

Europe. With temperatures of up to 26°C, the Baltic Sea was warmer than ever before.[126] In Germany 1 234 people died from the heat in 2018 and health risks were increased.[127] Power plants had to reduce production or be shut down entirely in Sweden, France, Finland[128] and Germany[129] as low water levels of nearby rivers reduced the availability of cooling water for the power plants. Due to low water levels, barges could only operate at limited capacity, leading to fuel shortages and disruption to production processes.[130]

Although Europe – especially France – has made progress in preventing heat fatalities by implementing better early warning systems,[131] disruptions have still been significant. Partly because **adaptation measures could not keep up with the rapid changes**. As an example: While it is clear that houses must be equipped with better insulation to deal with extreme heat[132] in Germany, less than 1% of residential buildings are being adapted annually.[133] Furthermore, there was a **lack of risk management**. German farmers were not adequately prepared.[134] In total, insurance experts estimate that only 0.2% of German farmland was covered by insurance against heat and drought.[135] As a result, leading politicians are currently considering subsidies for insurance products.[136] Being particularly dependent on the jet stream, **extreme heat during European summers is likely to occur more often and intensively in the future**. In 2019, in Germany the heat record was broken yet again several times, raising it by 2.3°C to 42.6°C in just one summer.[137]

Indian Heatwaves

As highlighted in Chapter 1, India suffered from one of the longest ever recorded heatwaves in 2018, with hundreds of deaths[138], when temperatures climbed to up to 48°C. Prolonged drought and resultant widespread crop failures, compounded by a water shortage, brought about violent riots and increased migration [139].

India is among those countries that were particularly affected by extreme heat in both 2018 and 2019. Since 2004, India has experienced 11 of its 15 warmest recorded years.[140] Since 1992, an estimated 25 000 Indians have died as a result of heatwaves.[141] Contributing factors include increasing temperatures, the "El Niño Modoki", an irregular El Niño in which the Central Pacific Ocean is warmer than the East Pacific, and the loss of tree cover, reducing shade as well as the moisture in the soil.[142] India is particularly vulnerable to extreme heat due to low per capita income, social inequality and a heavy reliance on agriculture.[143] The worst hit regions have also been among India's poorest. Additionally, a high number of people are working in areas such as agriculture and construction. A study by the International Labour Organization concludes that by 2030, India would lose 5.8% of its

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[126] Imbery et al. 2018b
[127] Bundesärztekammer et al. 2019
[128] Patel 2018
[129] Vogel et al. 2019
[130] Deutschlandfunk 2018; NT-V 2018
[131] Watts et al. 2019
[132] Salagnac 2007
[133] Handelsblatt 2019; Climate Transparency 2019
[134] Deutsche Welle 2019b
[135] GDV – Gesamtverband der Deutschen Versicherungswirtschaft 201
[136] Tagesspiegel 2019
[137] FAZ 2019
[138] Reuters 2018
[139] Future Earth 2019
[140] Earth observatory 2019
[141] The Guardian 2018a
[142] The Times of India 2019
[143] IPCC. 2014c

working hours due to heat stress, which is equivalent to 34 million full-time jobs out of a total of 80 million worldwide.[144]

In response to the growing number of deaths from heatwaves, the Indian government began implementing countermeasures. Heat plans include a combination of public awareness campaigns, training for medical staff, reducing school days, building heat shelters for the homeless equipped with drinking water, free water distribution and simple policy changes.[145]

Adapting to and Coping with Heatwaves

To limit the negative impacts of more frequent and more severe heatwaves in the future, more ambitious mitigation efforts are of utmost importance. Nevertheless, as outlined, today many regions of the world are already facing the dire consequences of these events. This calls for substantial efforts in two areas. Firstly, **adaptation measures must be implemented to prevent or limit the damage** heatwaves can cause. This has to be done with caution in order to prevent maladaptation – an intended adaptation measure that (unintendedly) increases vulnerability towards climate change and, hence, the risk of negative impacts, or that diminishes welfare.[146] Secondly, **coping strategies to deal with unavoidable consequences** and to ensure swift reactions during and after heatwaves must be introduced and strengthened .

Adaptation and coping measures vary greatly by sector, since heatwaves manifest differently. Regarding negative impacts on **health**, vulnerable people should be identified, approached and educated, since they sometimes may not acknowledge their own risk factors.[147] **Heat preparedness plans and early warning systems can reduce fatalities significantly**.[148] By introducing clear communication structures, responsibilities and instructions for heat events, adverse health effects can be minimised.[149] It is crucial to take into account different living conditions. Inhabitants of informal settlements are more susceptible to heat stress, creating yet another challenge for an already vulnerable population.[150] Furthermore, Infrastructure measures in urban areas should focus on reducing the urban heat island effect by increasing tree coverage and creating green belts that allow winds to circulate. Furthermore, green roofs and lighter coloured pavements and buildings can reflect some of the sun's radiation.[151] However**, the widespread installation of air conditioning systems has to be considered maladaptation**. Not only do high electricity consumption and most cooling agents contribute to climate change, but the high demand for electricity puts further stress on electricity grids[152] and the units' thermal discharge heats up cities even more.[153]

There are many promising **adaptation measures for agriculture and ensuring food security**, such as the usage of more adapted crops, crop diversification and rotation, modifications to crop calendars, agroforestry and the usage of cover crops that provide shade for cash crops, reduce soil erosion and manage nutrient levels.[154] Introducing irrigation farming to areas that used to rely purely on rainwater has to be well thought-out. It bears the risk of further increasing stress on water supplies and, hence, has to be considered a maladaptation in many cases. **As agriculture is also a**

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[144] ILO 2019
[145] The Guardian 2018a
[146] UNEP 2019
[147] Carter 2018
[148] Center for Climate and Energy Solutions 2019; Watts et al. 2019
[149] WHO Europe 2008
[150] NDRC 2013
[151] Chandra 2019
[152] Strohmayer 2019
[153] Louis 2018
[154] European Environment Agency 2019

major contributor to climate change, it is all the more important that farming practices which are low in greenhouse gas emissions be employed.

There are two strategies deal with forest heat stress. **Buffering measures aim at preventing and curbing disturbances**, for example preventing the spread of invasive species that benefit from heat stress, setting up firefighting reservoirs and building access roads for heavy machinery. This approach cannot prevent heat stress but can help with the associated consequences such as the aforementioned spread of vermin and fire. In many cases, it is only effective for a limited time span. Moreover, it often involves intense management and is therefore costly. In the long-run, **increased resilience can only be achieved by facilitating an ecosystem shift** by, for example, introducing genetic diversity and a large spectrum of forest types. Reducing non-climatic stressors, such as planting monocultures, aids both strategies.[155] Besides being carbon-sinks, **forests are themselves adaptation measures.** They regulate regional water supplies and temperature fluctuations and can therefore, among other things, alleviate the impacts of storms, flash floods and storm surges[156] and reduce heat stress in urban environments.[157]

In principle, **adaptation measures must be tailored to regional contexts**. Not only does climate change manifest itself differently in every region of the world, but cultural rules and practices or strategies to deal with extreme weather and seasonal variability also vary greatly. Traditional farmers, for example, have developed several coping mechanisms like crop diversification, or informal risk sharing arrangements and banking systems.[158] While in many cases these are or will not be sufficient going forwards, the existing mechanisms should be applied, strengthened or integrated wherever possible.[159]

Poor and vulnerable people are often more susceptible to climate change impacts. Moreover, adaptation measures themselves often entail distributional effects. This is why **adaptation measures should especially support the poor and vulnerable** and must avoid maintaining and enhancing social injustices and power imbalances.[160]

4 Addressing Climate Risks and Impacts: a Stocktake of 2019 Developments

The Climate Risk Index (CRI) 2020 clearly shows: Signs of escalating climate change can no longer be ignored – on any continent or in any region. In addressing the related climate risks and impacts, the year 2019 has been characterised less by political milestones but rather by initiatives for action and its further scientific underpinning. Above all, research on climate risks and concrete climate change impacts has made significant progress. **Two Special Reports of the Intergovernmental Panel on Climate Change** (IPCC), one on the Ocean and Cryosphere in a Changing Climate[161] and the second on impacts of climate change on land [162] clearly show that both **extreme weather**

[155] Pramova 2012
[156] Pramova 2012
[157] McDonald 2018
[158] Hutfils 2019
[159] Germanwatch 2019
[160] UNEP 2019
[161] IPCC 2019a
[162] IPCC 2019b

events and slow onset processes have tended to be underestimated in the past and have already caused devastating consequences worldwide today. Significant increases in the near future are predicted. The reports show, with a high level of confidence, that climate change, including increases in the frequency and intensity of extremes but also the shrinking cryosphere in the Arctic and high-mountain areas, has led to predominantly negative impacts on food security, water resources, water quality, livelihoods, health and well-being as well as on the culture of human societies, particularly for indigenous peoples. The reports note that some impacts of climate-related changes challenge current governance efforts to develop and implement adaptation responses from local to global scales, and in some cases, push them to their limits. People with the highest exposure and vulnerability are often those with the lowest capacity to respond. Drawing an even more severe picture, a recent study by Climate Central concludes that **rising sea levels are threatening to erase coastal mega-cities** such as Bangkok, Shanghai and Mumbai. Around 150 million people are now living on land that will be below the high-tide line by the mid-century, based on moderate emission cuts.[163]

On a political level, addressing the need to ramp up climate action was the goal of the **United Nations Climate Action Summit** (UNSG) in New York. On 23rd September, UN Secretary-General António Guterres brought together national governments, their subnational and local counterparts, civil society and private businesses to, amongst others, advance global efforts to address and manage the impacts and risks of climate change, particularly in those communities and nations, which are most vulnerable. One concrete outcome of the UNSG summit was a "Call for Action on Adaptation and Resilience". It aims for progress in dealing with climate impacts through better adaptation and strengthened resilience.

Fostering implementation is also the goal of the **Global Commission on Adaptation** (GCA), which seeks to accelerate adaptation action and support. In early September 2019, it presented its flagship report, which concluded that investment of US$ 1.8 trillion in just five areas of adaptation during the upcoming decade **could prevent US$ 7 trillion in losses and damages by 2050**. Spending US$ 800 million per year on early warning systems alone would avoid losses of US$ 3 billion to US$ 16 billion per year. However, **in 2017 only US$ 13.3 billion in public and private adaptation finance was provided and mobilised**.[164] Furthermore, that does not include any financing for loss and damage.[165]

Whether the UN summit or the GCA were and will contribute to increased resilience for vulnerable people, can only be determined in the upcoming years. However, the considerable lack of resilience financing points to the **need for more encompassing, systematic and longer-term support** in general. While presenting selected success stories as well as funding lighthouse projects adds a lot of value, it will not suffice if the international community does not provide the means to put those lessons learned to use across the world.

Resilience Agenda at Chilean COP25 in Madrid

Climate change-related losses and damages threaten livelihoods, food security, human security and sustainable economic development. However, climate change impacts hit the poorest countries hardest because they lack the economic and financial capacity to deal with the loss and damage. Those most affected are those least responsible for the cause of the climate crisis. So far, there is a lack of political and legal rules to determine how those responsible for climate change should pay for the consequences of their emissions. In the context of the UN climate negotiations, additional

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[163] Kulp et al. 2019
[164] OECD 2019
[165] Global Commission on Adaptation 2019

financial resources to help the poorest people and countries cope with loss and damage are lacking. During the forthcoming climate summit in Madrid one of the big issues therefore must be: How can developing countries be supported in dealing with increasing loss and damage? How can polluters, in particular, contribute to the costs?

The CRI 2020 clearly shows the devastating impacts of climate change induced extreme weather events. COP25 will put Loss and Damage prominently on the agenda as **the body dealing with averting, minimizing and addressing Loss & Damage** (the Warsaw International Mechanism for Loss and Damage – WIM) **will be reviewed** in Madrid for the second time. The review must identify successes but also gaps in the implementation in order to decide which crucial steps should be taken to make the WIM fit for purpose. The review should help to officially address the "elephant in the room", namely the **lack of climate finance to address loss and damage**. One of the WIM's tasks – *"Enhancing action and support, including finance, technology and capacity-building"* – has not been implemented sufficiently yet, even the space for debates itself is lacking while at the same time, needs and affectedness are rising. The review therefore needs to assess:

a) how the mechanism can effectively assist vulnerable countries in dealing with loss and damage;
b) whether the WIM is able to meet the needs of vulnerable countries in dealing with future loss and damage based on best available science, taking into account the latest IPCC reports; and
c) how financial resources can be generated and made available to meet these needs.

Regarding adaptation, COP25 uses a similar implementation approach as the UN Climate Action Summit. Accordingly, adaptation is one of the initiatives the COP Presidency launched under the topic "Time to Act". However, some important negotiation issues remain on the agenda, such as the National Adaptation Plans (NAPs). This is a particularly interesting item, since the first NAP cycle will end in 2020. Developing countries should have completed a NAP process by then and have a respective plan in place. At present, however, there are only 13 countries worldwide, which have submitted a NAP and the process has turned out to be highly complex and challenging, especially for the least developed countries. **More support, in terms of finance and capacity building through strong partnerships, is required** in that regard in order to prepare those countries for the effects of climate change that do not possess the capacity to do so on their own and in order to share successful approaches.

5 Methodological Remarks

The presented analyses are based on the worldwide data collection and analysis provided by Munich Re's NatCatSERVICE. "The information collated by MunichRe, the world's leading re-insurance company, can be used to document and perform risk and trend analyses on the extent and intensity of individual natural hazard events in various parts of the world."[166] Broken down by countries and territories, Munich Re collects the number of total losses caused by weather events, the number of deaths, the insured damages and the total economic damages. The last two indicators are stated in million US$ (original values, inflation adjusted).

In the present analysis, only weather-related events – storms, floods as well as temperature extremes and mass movements (heat and cold waves etc.) – are incorporated. Geological incidents like earthquakes, volcanic eruptions or tsunamis, for which data are also available, are not relevant

[166] MunichRe NatCatSERVICE

in this context as they do not depend on the weather and therefore are not possibly related to climate change. To enhance the manageability of the large amount of data, the different categories within the weather-related events were combined. For single case studies on particularly devastating events, it is stated whether they concern floods, storms or another type of event.

It is important to note that this event-related examination does not allow for an assessment of continuous changes of important climate parameters. For instance, a long-term decline in precipitation that was shown in some African countries as a consequence of climate change cannot be displayed by the CRI. Nevertheless, such parameters often substantially influence important development factors like agricultural outputs and the availability of drinking water.

Preparing an index requires the analysis of a vast amount of data. Thus, data availability and quality play an important role as well as the underlying methodology for their collection. For instance, the accurate attribution of a human loss to a particular extreme weather event faces certain methodological boundaries that data collectors have to work with (e.g. to determine whether the death of an elderly person during a heatwave is indeed the result of the extreme temperature or due to the high age alone). Similarly, data quality and coverage may vary from country to country as well as within countries. A recent study by Campbell et al. (2018) found that heatwave and health impact research is not evenly distributed across the globe. They highlight that "regions most at risk from heatwaves and health impact are under-represented in the research."[167] The data analysed for the CRI rely on scientific best practice and methodologies used are constantly evolving with the view of ensuring the highest degree of accuracy, completeness and granularity.

Although certainly an interesting area for analysis, the present data do not allow for comprehensive conclusions about the distribution of damages below the national level. The respective data quality would only be sufficient for a limited number of countries. The island of Réunion, for example, would qualify for a separate treatment but data are insufficient.

Analysed Indicators

For the examination of the CRI, the following indicators were analysed:

1. number of deaths,
2. number of deaths per 100 000 inhabitants,
3. sum of losses in US$ in purchasing power parity (PPP) as well as
4. losses per unit of gross domestic product (GDP).

For the indicators 2–4, economic and population data primarily provided by the International Monetary Fund were taken into account. It must be added, however, that especially for small (e.g. Pacific Small Island Developing States) or extremely politically unstable countries (e.g. Somalia), the required data are not always available in sufficient quality for the entire time period observed. Those countries needed to be omitted from the analyses.

The CRI 2020 is based on the loss figures of 181 countries from the year 2018 and the period 1999 to 2018. This ranking represents the most affected countries. In each of the four categories ranking is used as a normalisation technique. Each country's index score has been derived from a country's average ranking in all four indicating categories, according to the following weighting: death toll, 1/6; deaths per 100 000 inhabitants, 1/3; absolute losses in PPP, 1/6; losses per GDP unit, 1/3.

[167] Campbell et al. 2018

For example, in the Climate Risk Index for 1999-2018, Bangladesh ranks 9th in fatalities among all countries analysed in this study, 37th in Fatalities per 100 000 inhabitants, 17th in losses and 40th in losses per unit GDP (see Annexes, Table 4). Hence, its CRI Score is calculated as follows:

CRI Score = 9 x 1/6 + 37 x 1/3 + 17 x 1/6 + 40 x 1/3 = 30.00

Only six countries have a lower CRI Score for 1999-2018, hence Bangladesh ranks 7th in this index category (see Table 2).

The Relative Consequences Also Depend on Economic and Population Growth

Identifying relative values in this index represents an important complement to the otherwise often dominating absolute values because it allows for analysing country specific data on damages in relation to real conditions and capacities in those countries. It is obvious, for example, that for richer countries like the USA or Japan damages of one billion US$ cause much less economic consequences than for the world's poorest countries, where damages in many cases constitute a substantial share of the annual GDP. This is being backed up by the relative analysis.

It should be noted that values, and hence the rankings of countries regarding the respective indicators do not only change due to the absolute impacts of extreme weather events, but also due to economic and population growth or decline. If, for example, population increases, which is the case in most of the countries, the same absolute number of deaths leads to a relatively lower assessment in the following year. The same applies to economic growth. However, this does not affect the significance of the relative approach. Society's ability of coping with damages through precaution, mitigation and disaster preparedness, insurances or the improved availability of means for emergency aid, generally grows along with increasing economic strength. Nevertheless, an improved ability does not necessarily imply enhanced implementation of effective preparation and response measures. While absolute numbers tend to overestimate populous or economically capable countries, relative values give more prominence to smaller and poorer countries. In order to consider both effects, the analysis of the CRI is based on absolute (indicators 1 and 3) as well as on relative (indicators 2 and 4) scores. Being double weighted in the average ranking of all indicators generating the CRI Score, more emphasis and therefore higher importance is given to the relative losses.

The Indicator "Losses in Purchasing Power Parity" Allows for a More Comprehensive Estimation of How Different Societies are Actually Affected

The indicator "absolute losses in US$" is identified by purchasing power parity (PPP) because using this figure expresses more appropriately how people are actually affected by the loss of US$ 1 than by using nominal exchange rates. Purchasing power parity is a currency exchange rate, which permits a comparison of, for instance, national GDPs, by incorporating price differences between countries. This means that a farmer in India can buy more crops with US$ 1 than a farmer in the USA with the same amount of money. Thus, the real consequences of the same nominal damage are much higher in India. For most countries, US$ values according to exchange rates must therefore be multiplied by a factor bigger than one.

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Annexes

CRI = Climate Risk Index; GDP = gross domestic product; PPP = purchasing power parity

Table 3: Climate Risk Index for 2018

CRI Rank	Country	CRI score	Fatalities in 2018 (Rank)	Fatalities per 100 000 inhab-itants (Rank)	Losses in mil-lion US$ (PPP) (Rank)	Losses per unit GDP in % (Rank)
125	**Albania**	108.00	102	87	124	124
109	**Algeria**	93.83	47	76	110	127
80	**Angola**	76.00	52	72	82	89
135	**Antigua and Barbuda**	125.00	115	115	135	135
40	**Argentina**	48.33	61	101	5	11
135	**Armenia**	125.00	115	115	135	135
43	**Australia**	49.50	62	86	11	26
49	**Austria**	56.00	88	89	20	25
135	**Azerbaijan**	125.00	115	115	135	135
135	**Bahrain**	125.00	115	115	135	135
98	**Bangladesh**	85.50	18	79	97	120
135	**Barbados**	125.00	115	115	135	135
130	**Belarus**	111.83	115	115	102	112
90	**Belgium**	81.83	102	112	39	63
135	**Belize**	125.00	115	115	135	135
101	**Benin**	88.00	77	77	109	94
135	**Bhutan**	125.00	115	115	135	135
59	**Bolivia**	63.50	71	66	62	58
129	**Bosnia and Herzegovina**	109.67	115	115	113	100
135	**Botswana**	125.00	115	115	135	135
91	**Brazil**	82.83	38	105	43	103
135	**Brunei Darussalam**	125.00	115	115	135	135
116	**Bulgaria**	101.00	115	115	85	88
135	**Burkina Faso**	125.00	115	115	135	135
25	**Burundi**	36.33	50	32	72	16
38	**Cambodia**	47.67	29	17	79	72
122	**Cameroon**	105.83	64	91	129	130
9	**Canada**	21.83	13	19	12	34
135	**Cape Verde**	125.00	115	115	135	135
73	**Central African Republic**	71.17	77	51	116	66
135	**Chad**	125.00	115	115	135	135
87	**Chile**	81.17	115	115	36	53
33	**China**	45.17	5	94	4	37
75	**Chinese Taipei**	72.33	53	65	55	98
53	**Colombia**	61.00	20	39	70	99
135	**Comoros**	125.00	115	115	135	135
96	**Costa Rica**	84.67	93	82	87	82
106	**Côte d'Ivoire**	89.50	46	55	125	128
126	**Croatia**	108.33	115	115	101	102
76	**Cyprus**	73.50	81	13	120	107
35	**Czech Republic**	46.83	71	63	28	28
68	**Democratic Republic of Congo**	69.83	24	69	91	83
135	**Democratic Republic of Ti-**	125.00	115	115	135	135
55	**Denmark**	61.33	93	88	33	33
31	**Djibouti**	44.67	93	27	81	20
135	**Dominica**	125.00	115	115	135	135
99	**Dominican Republic**	86.50	81	84	84	93
112	**Ecuador**	97.00	62	73	122	126
131	**Egypt**	113.67	115	115	93	122
30	**El Salvador**	44.33	71	49	49	24

CRI Rank	Country	CRI score	Fatalities in 2018 (Rank)	Fatalities per 100 000 inhabitants (Rank)	Losses in million US$ (PPP) (Rank)	Losses per unit GDP in % (Rank)
135	**Eritrea**	125.00	115	115	135	135
108	**Estonia**	90.50	115	115	76	61
111	**Eswatini**	96.67	102	54	128	121
57	**Ethiopia**	62.83	26	70	63	74
10	**Fiji**	22.50	64	6	47	6
135	**Finland**	125.00	115	115	135	135
34	**France**	46.17	32	62	13	54
135	**Gabon**	125.00	115	115	135	135
113	**Georgia**	97.83	115	115	92	75
3	**Germany**	13.83	3	1	6	36
65	**Ghana**	68.33	22	24	108	116
11	**Greece**	23.67	14	4	38	41
70	**Grenada**	70.50	102	5	127	92
83	**Guatemala**	77.33	102	113	46	45
135	**Guinea**	125.00	115	115	135	135
37	**Guinea-Bissau**	47.50	55	7	112	52
135	**Guyana**	125.00	115	115	135	135
104	**Haiti**	88.67	81	85	111	85
45	**Honduras**	51.67	48	25	78	67
123	**Hungary**	107.17	81	81	134	133
135	**Iceland**	125.00	115	115	135	135
5	**India**	18.17	1	34	2	19
64	**Indonesia**	68.17	11	74	42	104
66	**Iraq**	68.50	41	58	64	95
81	**Ireland**	76.50	93	80	54	76
24	**Islamic Republic of Afghanistan**	36.00	15	21	61	49
60	**Islamic Republic of Iran**	64.83	48	100	21	60
106	**Israel**	89.50	60	41	131	132
21	**Italy**	33.67	28	56	8	27
128	**Jamaica**	109.50	115	115	118	97
1	**Japan**	5.50	2	2	3	12
50	**Jordan**	56.33	38	16	94	87
115	**Kazakhstan**	98.50	115	115	66	90
7	**Kenya**	19.67	12	23	26	17
135	**Kiribati**	125.00	115	115	135	135
81	**Korea, Republic of**	76.50	34	57	75	118
135	**Kosovo**	125.00	115	115	135	135
57	**Kuwait**	62.83	102	102	25	23
134	**Kyrgyz Republic**	117.50	102	106	133	129
22	**Lao People's Democratic Republic**	35.50	26	8	69	51
44	**Latvia**	50.00	102	75	32	8
62	**Lebanon**	67.17	50	18	105	106
56	**Lesotho**	61.50	58	11	121	84
135	**Liberia**	125.00	115	115	135	135
135	**Libya**	125.00	115	115	135	135
19	**Lithuania**	29.33	77	28	23	10
95	**Luxembourg**	84.33	115	115	65	48
4	**Madagascar**	15.83	17	20	30	4
93	**Malawi**	83.67	77	96	95	69
97	**Malaysia**	84.83	45	61	96	123
118	**Maldives**	103.33	115	115	119	78
135	**Mali**	125.00	115	115	135	135
135	**Malta**	125.00	115	115	135	135
135	**Marshall Islands**	125.00	115	115	135	135

CRI Rank	Country	CRI score	Fatalities in 2018 (Rank)	Fatalities per 100 000 inhabitants (Rank)	Losses in million US$ (PPP) (Rank)	Losses per unit GDP in % (Rank)
116	**Mauritania**	101.00	115	115	107	77
84	**Mauritius**	78.83	115	115	68	30
26	**Mexico**	37.67	10	44	14	57
135	**Micronesia**	125.00	115	115	135	135
135	**Moldova**	125.00	115	115	135	135
17	**Mongolia**	26.67	64	22	34	9
114	**Montenegro**	98.17	115	115	104	70
135	**Morocco**	125.00	115	115	135	135
54	**Mozambique**	61.17	56	78	71	42
48	**Myanmar**	53.83	20	43	59	79
85	**Namibia**	79.17	88	40	115	96
20	**Nepal**	29.67	8	10	56	47
62	**Netherlands**	67.17	81	99	24	50
46	**New Zealand**	53.17	88	68	37	29
52	**Nicaragua**	60.17	64	42	83	65
27	**Niger**	39.67	31	26	77	39
18	**Nigeria**	28.83	7	31	16	44
135	**North Macedonia**	125.00	115	115	135	135
94	**Norway**	84.00	102	104	48	73
13	**Oman**	24.33	71	30	9	3
100	**Pakistan**	87.83	19	90	90	119
92	**Panama**	83.33	75	37	117	117
135	**Papua New Guinea**	125.00	115	115	135	135
127	**Paraguay**	109.33	102	107	114	113
110	**Peru**	94.00	64	97	86	110
2	**Philippines**	11.17	4	14	7	14
41	**Poland**	49.00	42	60	22	55
72	**Portugal**	70.67	88	92	40	56
124	**Puerto Rico**	107.67	115	115	99	101
135	**Qatar**	125.00	115	115	135	135
135	**Republic of Congo**	125.00	115	115	135	135
28	**Republic of Yemen**	41.33	35	38	57	40
89	**Romania**	81.67	58	67	80	109
79	**Russia**	75.50	44	103	31	86
8	**Rwanda**	21.17	16	9	51	21
70	**Samoa**	70.50	115	115	74	2
103	**Saudi Arabia**	88.50	37	48	130	134
120	**Senegal**	104.50	115	115	100	91
61	**Serbia**	65.50	93	93	44	35
135	**Seychelles**	125.00	115	115	135	135
135	**Sierra Leone**	125.00	115	115	135	135
135	**Singapore**	125.00	115	115	135	135
102	**Slovak Republic**	88.33	64	36	132	131
51	**Slovenia**	57.83	93	52	58	46
29	**Solomon Islands**	43.17	88	12	103	22
47	**South Africa**	53.33	53	95	15	31
133	**South Sudan**	116.00	115	115	123	114
38	**Spain**	47.67	33	53	19	64
6	**Sri Lanka**	19.00	36	29	10	5
135	**St. Kitts and Nevis**	125.00	115	115	135	135
135	**St. Lucia**	125.00	115	115	135	135
135	**St. Vincent and the Grenadines**	125.00	115	115	135	135
42	**Sudan**	49.33	30	45	52	62
135	**Suriname**	125.00	115	115	135	135
105	**Sweden**	89.00	102	111	50	80
77	**Switzerland**	73.67	93	98	35	59

CRI Rank	Country	CRI score	Fatalities in 2018 (Rank)	Fatalities per 100 000 inhab-itants (Rank)	Losses in mil-lion US$ (PPP) (Rank)	Losses per unit GDP in % (Rank)
73	**Tajikistan**	71.17	75	64	88	68
68	**Tanzania**	69.83	42	71	73	81
67	**Thailand**	68.83	25	59	60	105
135	**The Bahamas**	125.00	115	115	135	135
135	**The Gambia**	125.00	115	115	135	135
135	**Togo**	125.00	115	115	135	135
15	**Tonga**	25.17	102	3	41	1
88	**Trinidad and Tobago**	81.33	115	115	67	38
35	**Tunisia**	46.83	56	47	45	43
85	**Turkey**	79.17	40	83	53	108
135	**Tuvalu**	125.00	115	115	135	135
14	**Uganda**	24.67	23	35	29	13
121	**Ukraine**	105.33	93	114	89	111
135	**United Arab Emirates**	125.00	115	115	135	135
78	**United Kingdom**	73.83	64	110	17	71
12	**United States**	23.83	6	50	1	18
23	**Uruguay**	35.67	81	46	27	7
135	**Uzbekistan**	125.00	115	115	135	135
31	**Vanuatu**	44.67	102	15	106	15
119	**Venezuela**	104.17	81	108	98	115
16	**Vietnam**	26.17	9	33	18	32
135	**Zambia**	125.00	115	115	135	135
132	**Zimbabwe**	114.50	93	109	126	125

Table 4: Climate Risk Index for 1999–2018

Exemplary calculation: Albania ranks 137th in fatalities among all countries analysed in this study, 130th in Fatalities per 100 000 inhabitants, 114th in losses and 87th in losses per unit GDP. Hence, its CRI Score is calculated as follows:

CRI Score = 137 x 1/6 + 130 x 1/3 + 114 x 1/6 + 87 x 1/3 = 114.17

CRI Rank	Country	CRI score	Fatalities 1999-2018 (Rank)	Fatalities per 100 000 inhabitants 1999-2018 (Rank)	Losses in mil-lion US$ (PPP) 1999-2018 (Rank)	Losses per unit GDP in % 1999-2018 (Rank)
129	**Albania**	114.17	137	130	114	87
99	**Algeria**	92.50	35	66	84	152
103	**Angola**	97.00	53	69	101	145
47	**Antigua and Barbuda**	58.00	160	39	98	6
84	**Argentina**	79.50	62	116	23	80
157	**Armenia**	145.17	172	172	133	111
33	**Australia**	50.17	44	63	11	60
44	**Austria**	55.67	63	48	33	71
146	**Azerbaijan**	133.67	127	155	99	133
179	**Bahrain**	171.83	168	168	175	176
7	**Bangladesh**	30.00	9	37	17	40
151	**Barbados**	141.67	171	159	157	102
152	**Belarus**	142.00	109	134	143	166
55	**Belgium**	63.83	26	13	63	134
32	**Belize**	48.50	131	25	96	7
149	**Benin**	141.00	113	140	153	150
103	**Bhutan**	97.00	134	59	154	88
28	**Bolivia**	45.33	50	35	58	47
66	**Bosnia and Herzegovina**	70.17	125	115	40	13

CRI Rank	Country	CRI score	Fatalities 1999-2018 (Rank)	Fatalities per 100 000 inhabitants 1999-2018 (Rank)	Losses in million US$ (PPP) 1999-2018 (Rank)	Losses per unit GDP in % 1999-2018 (Rank)
145	**Botswana**	132.33	151	150	125	109
88	**Brazil**	83.17	21	108	16	123
175	**Brunei Darussalam**	169.17	168	154	179	180
67	**Bulgaria**	70.83	85	89	48	57
106	**Burkina Faso**	99.33	92	125	110	72
71	**Burundi**	73.67	81	82	119	39
12	**Cambodia**	35.33	40	34	52	26
147	**Cameroon**	133.83	87	135	138	154
95	**Canada**	88.17	76	133	15	86
155	**Cape Verde**	143.50	162	126	169	139
159	**Central African Republic**	149.33	139	151	167	144
110	**Chad**	100.83	106	128	105	69
93	**Chile**	87.83	83	121	36	83
43	**China**	55.50	5	104	2	59
41	**Chinese Taipei**	54.83	33	45	28	89
44	**Colombia**	55.67	24	49	32	90
140	**Comoros**	122.67	144	73	174	136
95	**Costa Rica**	88.17	94	74	97	95
153	**Côte d'Ivoire**	142.67	91	143	151	164
31	**Croatia**	48.33	55	19	65	66
144	**Cyprus**	129.67	150	101	146	140
85	**Czech Republic**	79.67	90	107	34	70
141	**Democratic Republic of Congo**	125.83	46	118	149	162
177	**Democratic Republic of Timor-**	170.33	168	167	176	172
126	**Denmark**	112.83	147	162	44	81
64	**Djibouti**	69.50	113	31	140	51
10	**Dominica**	32.33	116	2	72	1
50	**Dominican Republic**	58.50	52	36	69	79
100	**Ecuador**	92.83	69	84	86	117
156	**Egypt**	143.67	77	158	121	174
25	**El Salvador**	42.50	65	41	54	27
122	**Eritrea**	109.17	164	170	107	22
158	**Estonia**	148.83	155	148	144	149
115	**Eswatini**	103.50	151	119	124	54
56	**Ethiopia**	64.67	29	91	53	62
13	**Fiji**	37.17	89	15	80	12
166	**Finland**	155.67	163	169	113	160
15	**France**	38.00	4	8	12	98
174	**Gabon**	167.33	155	153	181	181
102	**Georgia**	94.17	115	96	106	76
17	**Germany**	38.67	10	23	6	85
113	**Ghana**	102.50	56	81	115	141
82	**Greece**	78.83	71	70	50	106
21	**Grenada**	39.83	128	7	91	3
16	**Guatemala**	38.33	31	27	45	50
170	**Guinea**	161.33	132	161	172	171
124	**Guinea-Bissau**	111.33	140	103	158	82
120	**Guyana**	107.17	160	142	127	36
3	**Haiti**	13.83	15	4	42	9
42	**Honduras**	55.00	66	52	76	42
61	**Hungary**	69.00	59	47	59	101
177	**Iceland**	170.33	172	172	170	168
17	**India**	38.67	3	55	3	58
77	**Indonesia**	76.83	16	92	21	120
150	**Iraq**	141.33	96	157	108	165
136	**Ireland**	119.17	137	149	64	108

CRI Rank	Country	CRI score	Fatalities 1999-2018 (Rank)	Fatalities per 100 000 inhabitants 1999-2018 (Rank)	Losses in million US$ (PPP) 1999-2018 (Rank)	Losses per unit GDP in % 1999-2018 (Rank)
24	**Islamic Republic of Afghanistan**	41.83	13	14	82	64
83	**Islamic Republic of Iran**	79.00	42	113	22	92
139	**Israel**	120.50	111	124	90	137
26	**Italy**	43.67	6	9	18	110
57	**Jamaica**	64.83	112	80	71	23
62	**Japan**	69.33	23	93	7	100
133	**Jordan**	116.00	110	122	104	119
154	**Kazakhstan**	142.83	99	147	126	169
37	**Kenya**	53.67	39	71	43	49
134	**Kiribati**	116.17	172	172	159	11
87	**Korea, Republic of**	82.83	48	98	25	114
163	**Kuwait**	152.00	155	165	109	159
123	**Kyrgyz Republic**	109.33	78	53	160	156
76	**Lao People's Democratic Republic**	76.33	86	77	92	63
89	**Latvia**	83.83	107	64	100	84
138	**Lebanon**	120.00	118	110	118	132
118	**Lesotho**	106.50	148	138	129	43
165	**Liberia**	155.33	159	166	165	138
168	**Libya**	158.83	143	160	150	170
109	**Lithuania**	100.50	121	97	94	97
105	**Luxembourg**	97.17	95	12	148	158
11	**Madagascar**	32.83	32	38	51	19
80	**Malawi**	77.83	82	112	95	33
114	**Malaysia**	103.33	64	102	66	143
175	**Maldives**	169.17	172	172	173	163
135	**Mali**	116.67	98	136	122	104
164	**Malta**	152.83	164	145	161	151
172	**Marshall Islands**	165.00	172	172	180	147
81	**Mauritania**	78.50	104	75	111	53
116	**Mauritius**	104.67	145	106	117	77
54	**Mexico**	61.83	25	95	10	73
46	**Micronesia**	56.67	124	5	164	21
92	**Moldova**	86.17	134	129	75	25
53	**Mongolia**	61.67	93	51	83	46
107	**Morocco**	100.00	73	127	67	103
14	**Mozambique**	37.50	28	32	77	28
2	**Myanmar**	10.33	1	1	19	20
60	**Namibia**	66.67	80	28	116	74
9	**Nepal**	31.50	17	17	56	41
68	**Netherlands**	71.83	30	30	57	142
90	**New Zealand**	84.17	116	105	49	65
38	**Nicaragua**	53.83	67	40	88	44
73	**Niger**	74.00	67	85	103	52
117	**Nigeria**	104.83	27	114	68	153
107	**North Macedonia**	100.00	123	83	123	94
148	**Norway**	138.83	140	156	89	146
23	**Oman**	41.17	84	44	27	24
5	**Pakistan**	28.83	11	46	8	31
118	**Panama**	106.50	101	79	120	130
98	**Papua New Guinea**	91.33	72	54	136	116
70	**Paraguay**	73.50	108	111	47	32
47	**Peru**	58.00	34	60	38	78
4	**Philippines**	17.67	7	16	9	29
78	**Poland**	77.17	43	88	30	107

CRI Rank	Country	CRI score	Fatalities 1999-2018 (Rank)	Fatalities per 100 000 inhabitants 1999-2018 (Rank)	Losses in million US$ (PPP) 1999-2018 (Rank)	Losses per unit GDP in % 1999-2018 (Rank)
19	**Portugal**	38.83	20	11	41	75
1	**Puerto Rico**	6.67	19	3	5	5
181	**Qatar**	173.67	172	172	168	179
162	**Republic of Congo**	151.50	130	123	177	178
74	**Republic of Yemen**	74.67	49	68	81	91
35	**Romania**	53.17	51	67	24	55
30	**Russia**	47.67	2	6	14	129
111	**Rwanda**	102.00	75	72	145	124
71	**Samoa**	73.67	155	57	141	16
112	**Saudi Arabia**	102.17	60	94	55	155
142	**Senegal**	129.50	102	139	135	131
69	**Serbia & Montenegro & Kosovo**	73.33	97	117	35	37
169	**Seychelles**	159.50	172	172	171	135
91	**Sierra Leone**	85.67	57	29	155	122
180	**Singapore**	172.17	172	172	163	177
121	**Slovak Republic**	108.00	119	120	79	105
40	**Slovenia**	54.33	79	26	73	61
65	**Solomon Islands**	70.00	128	33	156	35
79	**South Africa**	77.33	47	100	31	93
125	**South Sudan**	112.50	87	109	128	121
29	**Spain**	47.33	8	10	26	115
22	**Sri Lanka**	40.17	36	43	29	45
127	**St. Kitts and Nevis**	113.50	172	172	137	14
51	**St. Lucia**	59.33	142	24	132	17
52	**St. Vincent and the Grenadines**	59.83	148	21	139	15
101	**Sudan**	93.00	45	87	87	126
173	**Suriname**	166.00	164	152	178	175
142	**Sweden**	129.50	136	163	61	127
34	**Switzerland**	52.33	41	22	37	96
49	**Tajikistan**	58.17	74	65	85	30
130	**Tanzania**	114.33	70	132	102	125
8	**Thailand**	31.00	22	62	4	18
20	**The Bahamas**	39.67	122	18	60	10
86	**The Gambia**	81.00	103	50	147	68
160	**Togo**	149.67	126	146	166	157
75	**Tonga**	75.67	164	76	130	4
161	**Trinidad and Tobago**	150.17	153	137	152	161
130	**Tunisia**	114.33	105	131	93	113
132	**Turkey**	115.17	61	144	46	148
128	**Tuvalu**	113.67	172	172	162	2
62	**Uganda**	69.33	54	90	70	56
94	**Ukraine**	88.00	38	86	62	128
167	**United Arab Emirates**	158.33	145	164	131	173
58	**United Kingdom**	65.00	18	58	20	118
27	**United States**	44.17	12	78	1	48
97	**Uruguay**	88.33	120	99	78	67
171	**Uzbekistan**	162.00	154	171	142	167
38	**Vanuatu**	53.83	133	20	134	8
59	**Venezuela**	66.00	37	61	39	99
6	**Vietnam**	29.83	14	42	13	34
137	**Zambia**	119.67	100	141	112	112
36	**Zimbabwe**	53.33	58	56	74	38

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