Climate change risk assessment 2021

The world is dangerously off track to meet the Paris Agreement goals.

The risks are compounding.

Without immediate action the impacts will be devastating in the coming decades.

Summary of research findings

Environment and Society Programme

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Introduction and context

This short report summarizes climate risks and their consequences for people, food and water security, as well as national and international security, migration, economies and trade, focusing on impacts that are likely to be locked in for the period 2040–50 unless emissions drastically decline before 2030.

The summary report is intended for heads of government and ministers. It is supported by a full-length Chatham House research paper to inform briefing officials, which gives fuller detail on all the content. Note that all references are provided in the research paper.

Current emissions and temperature pathways

Central estimate 2.7°C, plausibly higher

Global efforts to reduce CO_2 emissions are dangerously off track. Current nationally determined contributions (NDCs) indicate a 1 per cent reduction in emissions by 2030, compared with 2010. If policy ambition, low-carbon technology deployment and investment follow current trends, 2.7°C of warming by the end of the century is the central estimate, relative to pre-industrial levels, but there is a 10 per cent chance of warming of 3.5°C. These projections assume that countries will meet their NDCs; if they fail to do so, the probability of extreme temperature increases is non-negligible. A global temperature increase greater than 5°C should not be ruled out.

Consequences for reaching the Paris Agreement goals

Less than 1% chance

If emissions follow the trajectory set by current NDCs, there is a less than 5 per cent chance of keeping temperatures **well below 2°C,** relative to pre-industrial levels, and a less than 1 per cent chance of **reaching the 1.5°C Paris Agreement target.**

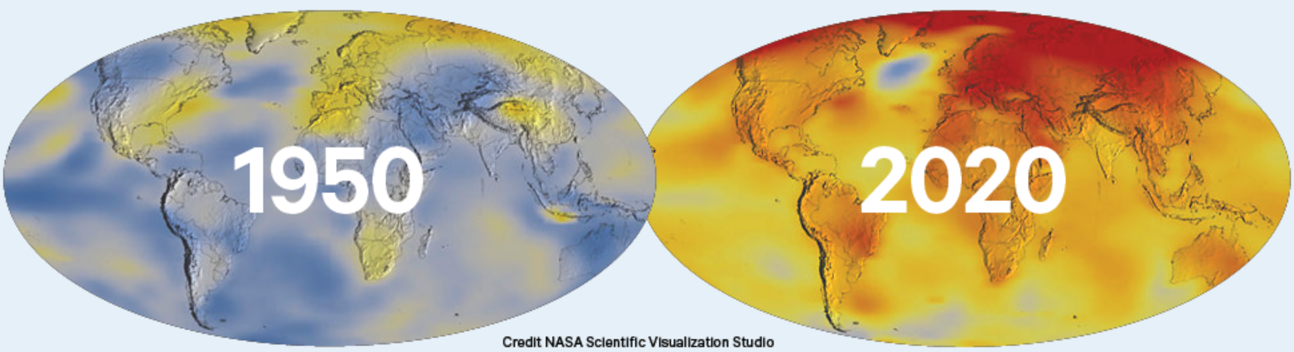
Net zero pledges

Many countries are currently focusing on net zero pledges, with an implicit assumption that these targets will avert climate change. However, net zero pledges lack policy detail and delivery mechanisms, and the gap between targets and the global carbon budget is widening every year. Unless NDCs are dramatically increased, and policy and delivery mechanisms are commensurately revised, many of the impacts described in this summary report will be locked in by 2040, and become so severe they go beyond the limits of what nations can adapt to.

An opportunity and necessity for greater mitigation action

The governments of highly emitting countries have an opportunity to accelerate emissions reductions through ambitious revisions of their NDCs, significantly enhancing policy delivery mechanisms and incentivizing rapid large-scale investment in low-carbon technologies. This will lead to cheaper energy and avert the worst climate impacts. For more information on accelerating the energy transition, see [redacted].

Variation of average global surface temperatures



Credit NASA Scientific Visualization Studio

How to read this summary report

Approach to climate risk

This report summarizes the climate risks and impacts associated with the current global emissions trajectory and existing NDCs. Our descriptions of these risks focus on the next 20–30 years, to highlight the urgent need for emissions reduction actions to avert them. Longer-term impacts regarding flooding and sea level rise are also provided.

Protests erupt after the wildfires in Greece, 2021.

Climate impact themes

- Heat, productivity and health
- Food security
- Water security
- Flooding
- Tipping points and cascading risks

The report sets out five areas of climate change impacts and adverse consequences that will become severe over the next 20–30 years.

Analysing these impact themes, and based on the central impact indicator estimate, we highlight:

- **The climate impacts of concern.**
- **What is already happening.**
- **How much worse impacts are likely to get by 2040–50, if emission trends continue.**
- **Impacts and consequences at a regional level and global scale.**

For fuller details on how to interpret the climate risks and impacts described in this summary report, see the supporting Chatham House research paper for briefing officials, which includes greater geographic granularity as well as methodological descriptions.

Read the full research paper at [redacted]

Heat, productivity and health

Impact of concern

Too hot to work or even survive outdoors, leading to productivity losses and health crises.

What is happening already?

>50%
COVID-19 lost working hours

In 2019, a potential **300 billion working hours were lost** due to temperature increases globally, 52 per cent more than in 2000. COVID-19 resulted in around 580 billion lost working hours in 2020; hence temperature increases are already resulting in the equivalent of over 50 per cent of COVID-19-induced lost working hours.

Globally, heat-related mortality has increased by nearly 54 per cent in the over-65s in the past two decades, reaching 296,000 deaths in 2018.

Europe: 104,000 deaths **China: 62,000 deaths** **India: 31,000 deaths**

Deaths 54% up


Australian bushfire, 2021. Copyright © Paul Kane/Getty Images

The Australian bushfires in 2019–20 exhibited a heatwave intensity that is now **10 times more likely** than at the beginning of the last century. Property and economic damage resulting from the disaster is estimated to have totalled some US $70 billion.

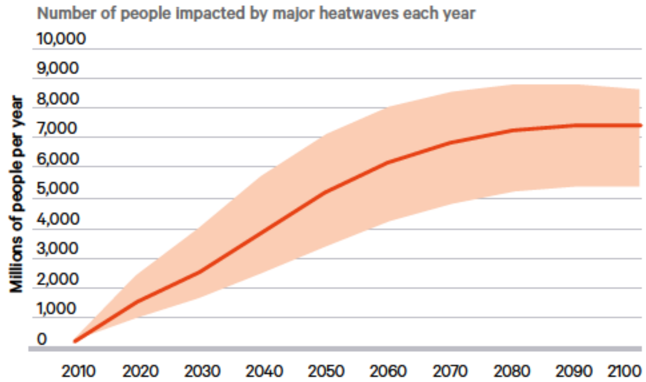
The 2020 heatwave in Siberia caused wide-scale wildfires, loss of permafrost, and an invasion of pests. Climate change has already made this heatwave at least **600 times more likely.**

Heat, productivity and health

How much worse will it get?

3.9 billion exposed to major heatwaves by 2040

If emissions do not come down drastically before 2030, then by 2040 3.9 billion people are likely to experience major heatwaves each year. Major heatwaves represent the most extreme historic temperatures, lasting four or more days. Hence they are comparable to the most severe historic heatwaves.

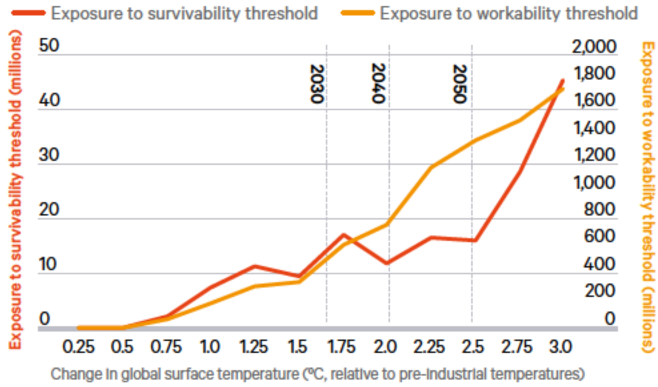


Shaded area represents the lower and upper estimates of the given impact.
Solid line represents the central estimate.

400 million unable to work and 10 million deaths per year

Globally, each year in the 2030s:

- More than 400 million people a year are likely to be exposed to temperatures exceeding the workability threshold (unable to work outdoors).
- More than 10 million people a year are likely to be exposed to heat stress exceeding the survivability threshold (likely to die outside).

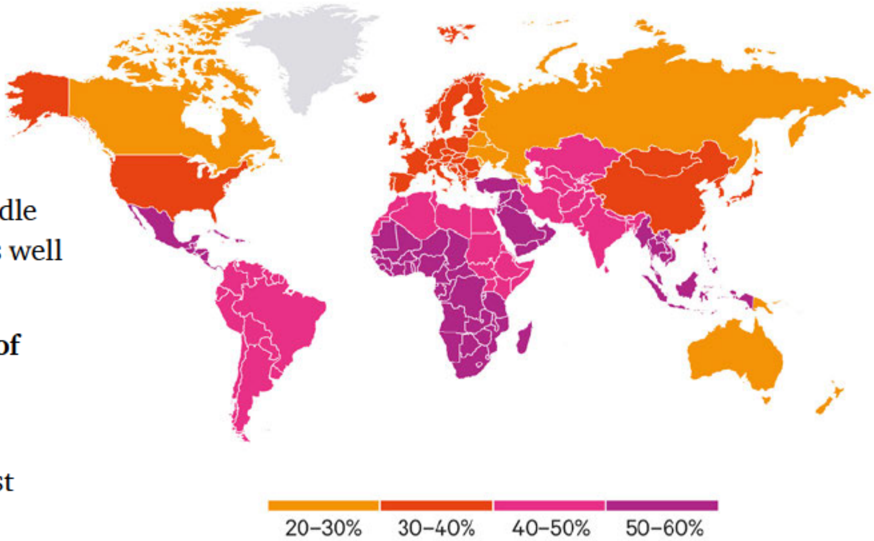


Regional impacts, 2040: proportion of population experiencing major heatwaves each year
(Major heatwaves are comparable to the most extreme historic heatwaves)

No region will be spared. **By 2040,** major heatwaves will be experienced each year by **50 per cent or more** of the populations in West, Central, East and Southern Africa, the Middle East, South and Southeast Asia, as well as Central America and Brazil.

By 2050, **more than 70 per cent of people in every region** will experience heatwaves each year.

Urban areas will suffer the greatest challenges of workability and survivability.



Food security

Impact of concern

Agricultural drought and heat extremes reduce crop yields.

What is happening already?

In recent years, regional drought and heatwaves have caused 20–50 per cent crop harvest losses.

Up to 50% crop harvest loss

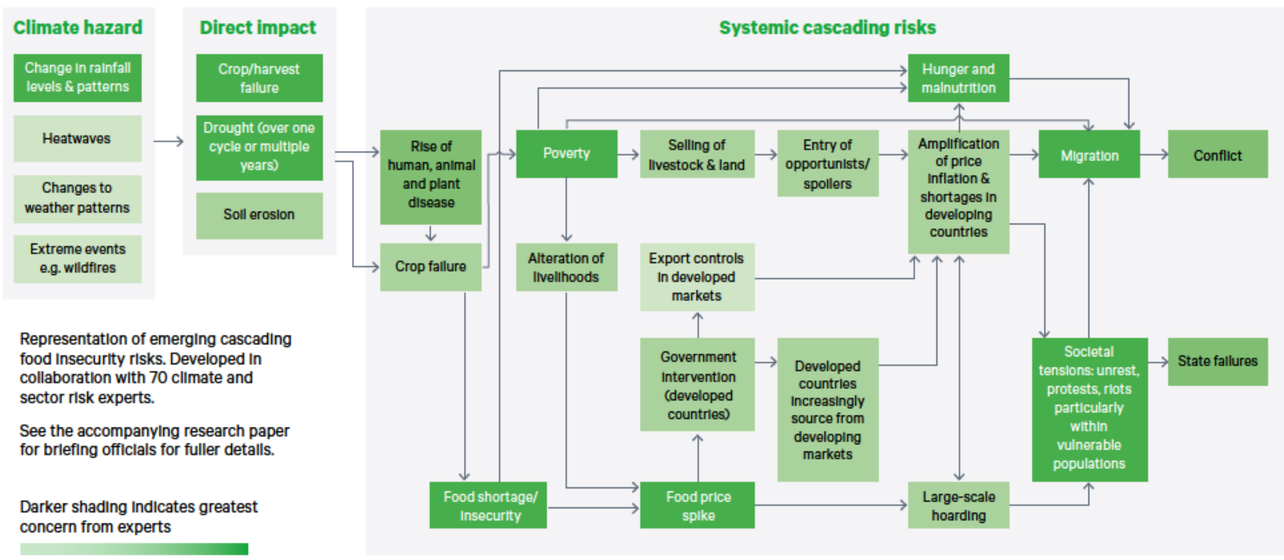
Australia: Severe drought caused a 50 per cent collapse of wheat harvests two years in a row (2006–07).

Europe: The 2018 heatwave led to multiple crop failures and yield losses of up to 50 per cent in Central and Northern Europe.

China: In Liaoning Province, drought years led to 20–25 per cent reductions in maize harvests.

The **global food crisis** of 2007–08, caused by depleted grain stores, Australian drought and regional crop failures, led to a doubling of global food prices, export bans, food insecurity for importers, social unrest, and mass protests in countries including Cameroon, Egypt, Indonesia, Mexico, Morocco, Nepal, Peru, Senegal and Yemen.

Emerging cascading food insecurity risks



Representation of emerging cascading food insecurity risks. Developed in collaboration with 70 climate and sector risk experts.

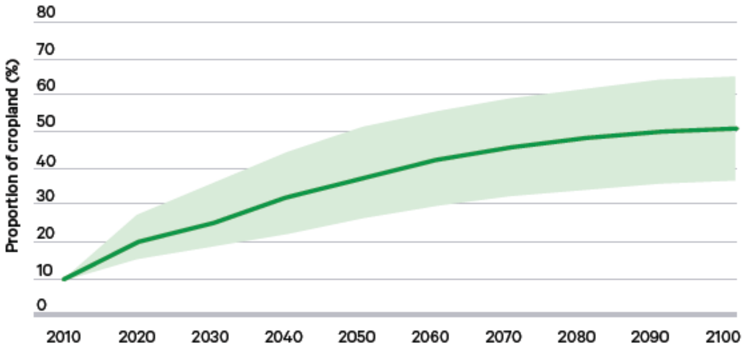
See the accompanying research paper for briefing officials for fuller details.

Darker shading indicates greatest concern from experts

How much worse will it get?

50% more food needed

To meet global demand, agriculture will need to produce almost 50 per cent more food by 2050. But yields could decline by 30 per cent in the absence of dramatic emissions reductions.



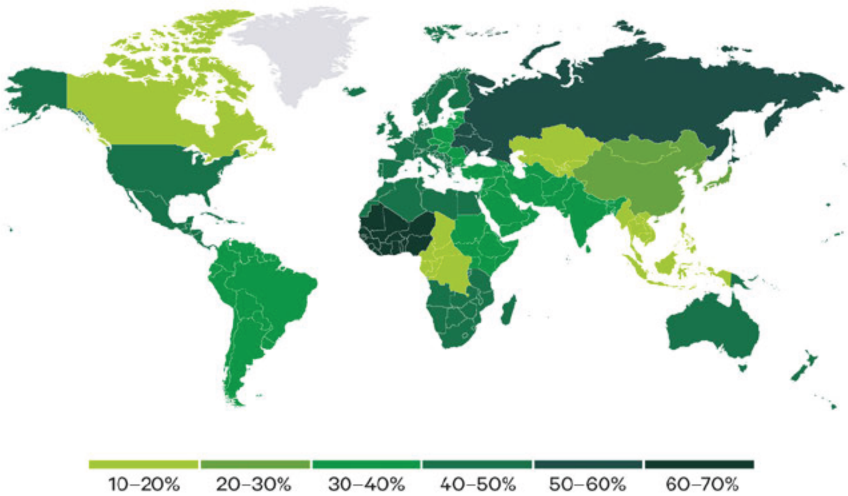
Shaded area represents the lower and upper estimates of the given impact.
Solid line represents the central estimate.

Droughts 3 x worse by 2040

By 2040, the proportion of global cropland affected by severe drought – equivalent to that experienced in Central Europe in 2018 (50 per cent yield reductions) – will likely rise to 32 per cent each year, more than three times the historic average.

Wheat and rice together make up 37 per cent of global average calorific intake. By 2050, more than 35 per cent of the global cropland used to grow both these crops will likely be exposed to damaging hot spells each year, causing reductions to yields. South Asia is likely to be the most impacted, with more than 60 per cent of winter wheat, spring wheat and rice exposed to damaging hot spells.

Regional impacts, 2050: proportion of cropland exposed to severe drought each year
(Severe drought is equivalent to that experienced in Central Europe in 2018)



Farmers in the worst-affected areas (including the critical breadbasket regions of **southern Russia** and the **US**) are likely to experience severe agricultural drought impacting 40 per cent or more of their cropland area every year during the 2050s.

During the 2040s there is a 50% chance of synchronous crop failure

A synchronous >10 per cent yield loss in the top four maize producing countries would have devastating impacts on availability and prices. Currently, there is a near zero chance of this happening. Over the decade of the 2040s, the risk of this increases to just under 50 per cent.

Water security

Impact of concern

Changes in rainfall patterns and water scarcity causing premature mortality, reductions in sanitation and hygiene, and greater malnutrition.

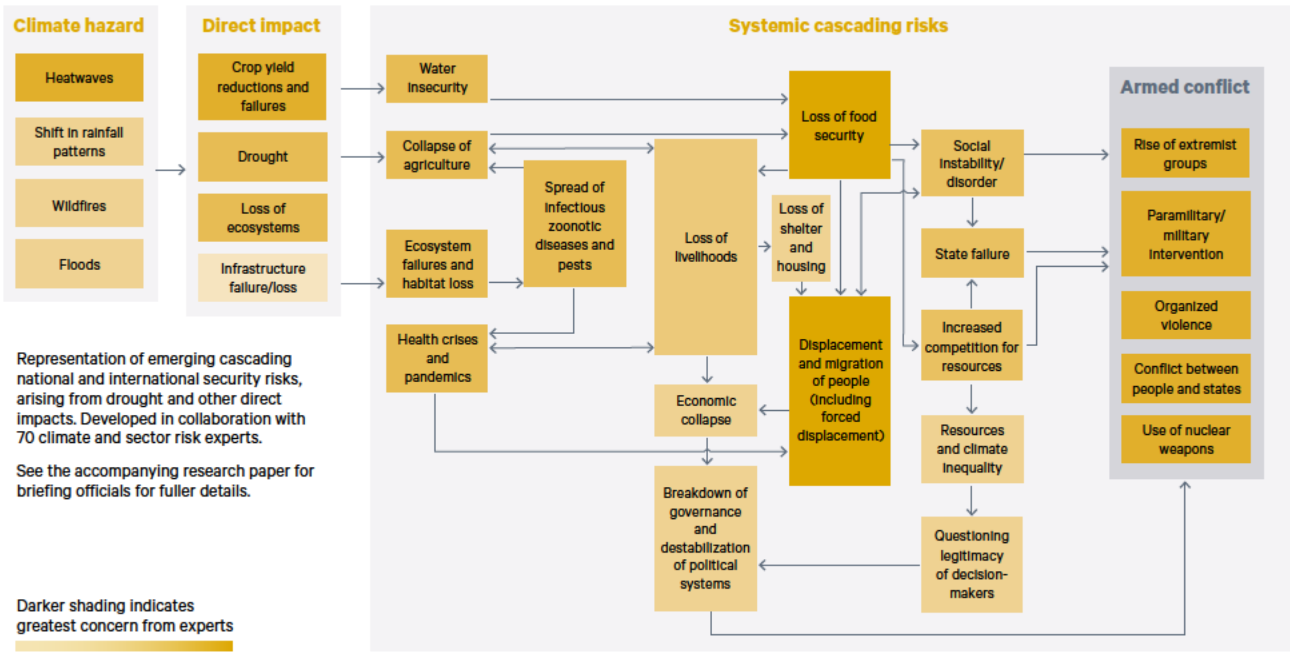
What is happening already?

13.4m in the Sahel needing relief aid

In the Sahel in 2020, some 13.4 million people in Mali, Niger and Burkina Faso were reported as being in need of humanitarian assistance because of drought. Over twice the global land area was affected by drought in 2019, compared with the historic baseline.

Water scarcity during the **US drought of 2012 was forecast to reduce GDP growth by 0.5–1 percentage point,** with natural disasters declared in 71 per cent of counties. In 2020, drought in the **China's Yunnan Province affected 1.5 million people.** Around 100 rivers were cut off, 180 reservoirs dried up, and 140 irrigation wells had insufficient water supply.

Emerging cascading water insecurity risks



Representation of emerging cascading national and international security risks, arising from drought and other direct impacts. Developed in collaboration with 70 climate and sector risk experts.

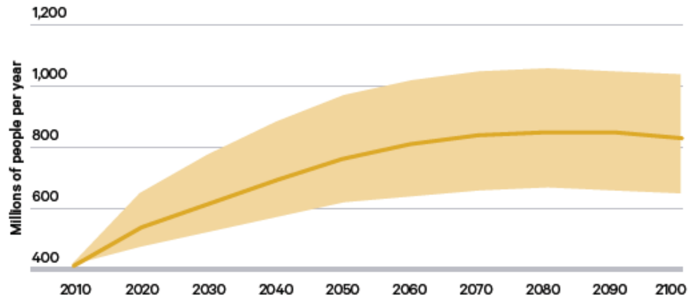
See the accompanying research paper for briefing officials for fuller details.

How much worse will it get?

By 2040 700 million exposed to drought

By 2040, almost 700 million people each year will likely be exposed to prolonged severe droughts of at least six months' duration. The severity and length of these future droughts are at least as bad as the first wave (1934) of the US Midwest 'dust bowl' drought of the 1930s.

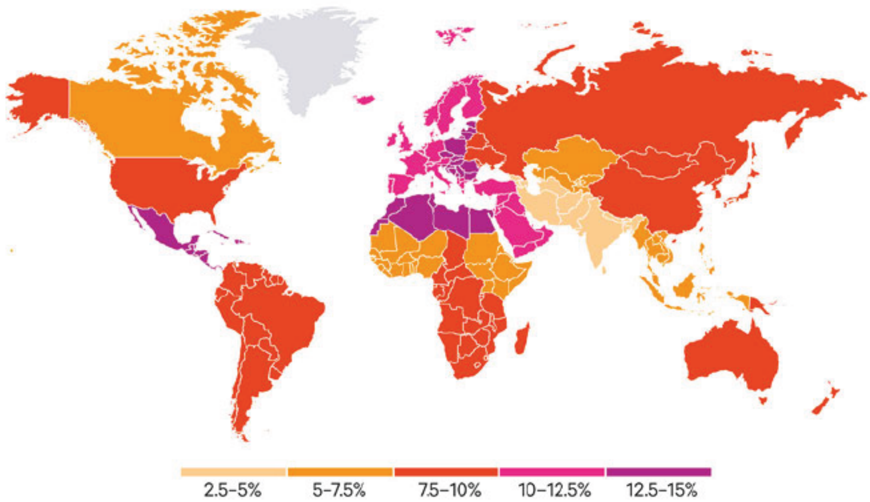
Global population experiencing drought of at least six months



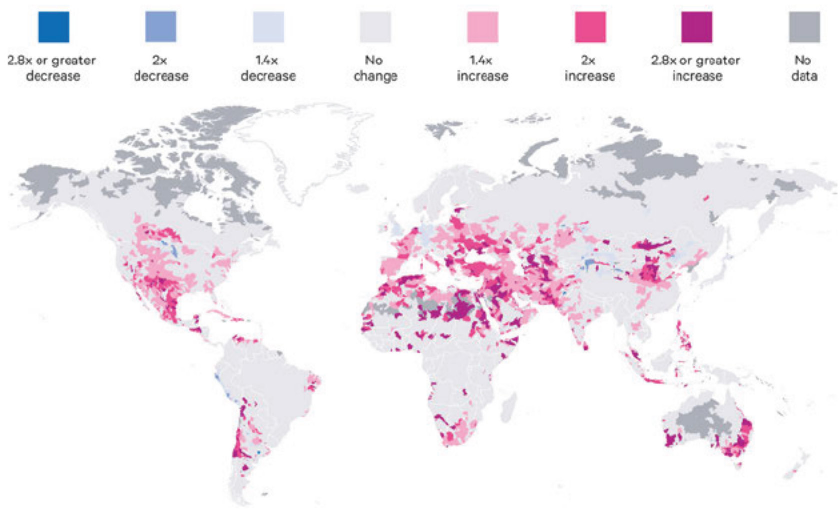
Shaded area represents the lower and upper estimates of the given impact. Solid line represents the central estimate.

Regional impacts, 2040: proportion of population experiencing prolonged severe drought each year

By 2040, North Africa, the Middle East, Western and Central Europe, and Central America will all see more than 10 per cent of their populations impacted by prolonged severe drought.



Regions of increasing water stress (demand relative to supply) in 2040, relative to 2019



Miller Cylindrical projection (10° E)   Water stress data: Aqueduct Water Risk Atlas   Country and boundary data: Natural Earth

North Africa and the Middle East are likely to have the greatest proportion of their populations experiencing extreme water stress (<500m^3 per head per year): 17 per cent and 14 per cent in 2050, respectively.

Flooding

Impact of concern

Coastal and river flooding, leading to population displacement

Increased rainfall → River flooding

Sea level rise → Coastal flooding

River flooding / Coastal flooding → Displaced populations

What is happening already?

23%
more floods in 2020

One billion people now occupy land less than 10 metres above current high tide lines, including 230 million below 1 metre.

In 2020 there were 23 per cent more floods than the annual average of 163 events in 2000–19, and 18 per cent more flood deaths than the annual average of 5,233 deaths.

Flood devastation in Germany, 2021. Copyright © Ina Fassbender/AFP/Getty Images

How much worse will it get?

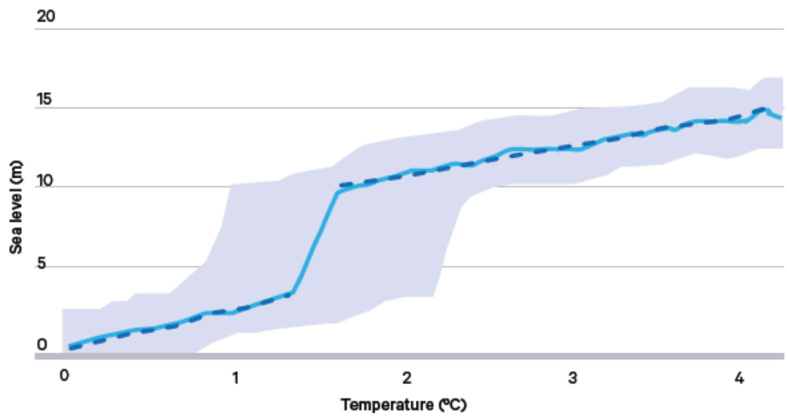
200 million people at risk of frequent, devastating '100-year' floods

Coastal flooding is likely to occur over a longer time frame. The long-term central estimate of **committed sea level rise is around 12 metres,** if temperatures are held at 2°C. This could occur over 500 years or 10,000 years: the time frames are extremely uncertain.

By 2100, nearly 200 million people worldwide will be living below the 100-year flood level. However, if the rate of Antarctic ice melt continues at the rate of recent years, this is likely to be an underestimate.

A 1 metre rise in relative sea level increases the probability of current 100-year flood events by around 40 times for Shanghai, around 200 times for New York, and around 1,000 times for Kolkata.

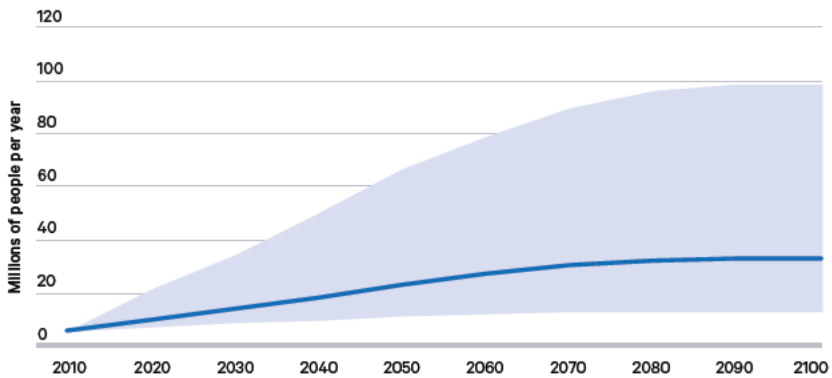
Committed sea level rise as a function of long-term global temperature increase



60 million people per year will be impacted by river flooding

River flooding will likely impact nearly 60 million people a year globally by 2100. The impacts are concentrated in South Asia, where 33 million a year are likely to be affected.

River flooding greater than the reference 50-year flood (assumes no additional flood defences)



Shaded area represents the lower and upper estimates of the given impact.
Solid line represents the central estimate.

Instability and tipping points

Abrupt changes – or tipping points – are difficult to characterize and predict. There are growing concerns that climate models may under-represent the influence of tipping points.

One such example is the melting of the permafrost in the Arctic leading to the release of methane. The latest IPCC climate models show a cluster of such abrupt shifts between 1.5 °C and 2 °C. If tipping points are reached at lower temperatures, the impacts presented in the previous sections are likely to be an underestimate, occurring with a higher probability, sooner in time. Moreover, the severity and frequency of the impacts will be far more extreme, which in turn will hugely reduce the capacity of societies the world over to adapt, compounding the impacts.

Global temperatures can rise significantly beyond those characterized in the previous sections. Current atmospheric CO_2 concentration is around 420 parts per million. Around 50 million years ago, atmospheric CO_2 exceeded 1,000 parts per million, while global mean surface temperatures were 9° to 14°C.

Examples of tipping points include:

- **Greenland and West Antarctic ice sheet disintegration:** Melting of ice reduces reflection of sunlight back out into space, resulting in accelerated warming and increased sea level rise.
- **Permafrost loss:** Abrupt increase in emissions of CO_2 and methane through the thawing of frozen carbon-rich soils. Methane is a more potent greenhouse gas than CO_2, resulting in accelerated warming.
- **AMOC breakdown:** Caused by an increased influx of freshwater into the North Atlantic, reducing the ability of oceans to disperse heat around the globe.
- **Boreal forest shift:** Dieback of boreal forests, potentially turning some regions to carbon sources as pests and wildfires create large-scale disturbances.
- **Amazon rainforest dieback:** A shift towards savannah, resulting in large release of CO_2.

Glacial ice sheet, Greenland, 2013.

Ice sheets are crucial for the stability of the climate system as a whole, and are already at risk of transgressing their temperature thresholds within the Paris Agreement range of 1.5°–2°C. A domino-like effect has recently been identified between various tipping points, with the potential to lead to abrupt non-linear responses. Tipping point cascades (two or more tipping points being initiated for a given temperature level) have been identified in more than 60 per cent of simulations, with the initial trigger likely to be polar ice sheet melting, and the Atlantic Meridional Overturning Circulation (AMOC) acting as a mediator transmitting cascades.

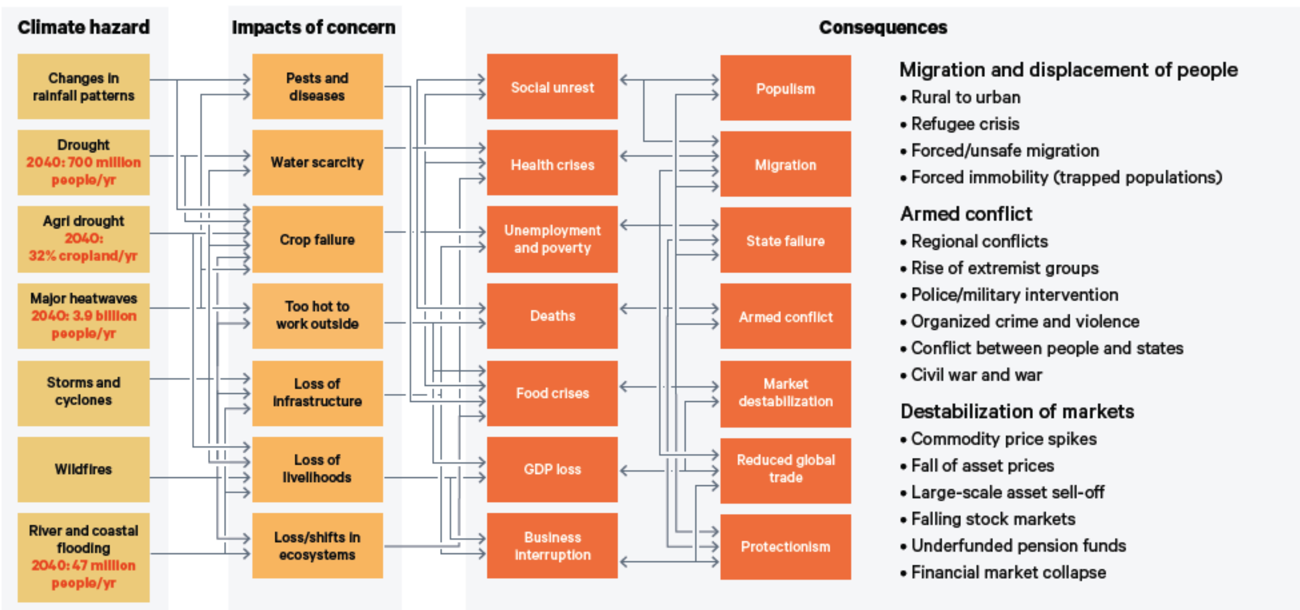
Cascading risks: economic, national and international security

Systemic risks arise from the consequence of direct impacts – materializing as a chain, or cascade, of impacts – compounding to produce even more severe impacts for people and societies. Due to their complex nature, it is not possible to quantify the probability and severity of systemic risks. Instead, 70 experts from a broad range of disciplines contributed to an exercise to identify the major systemic risk dynamics and impacts that climate scientists and sector risk experts are concerned will occur as direct impacts increase in prevalence. Their insights are captured in the six diagrams and associated descriptions included in the research paper for briefing officials. The figure on this page summarizes the detailed risk cascades.

Cascading climate impacts can be expected to cause higher mortality rates, drive political instability and greater national insecurity, and fuel regional and international conflict.

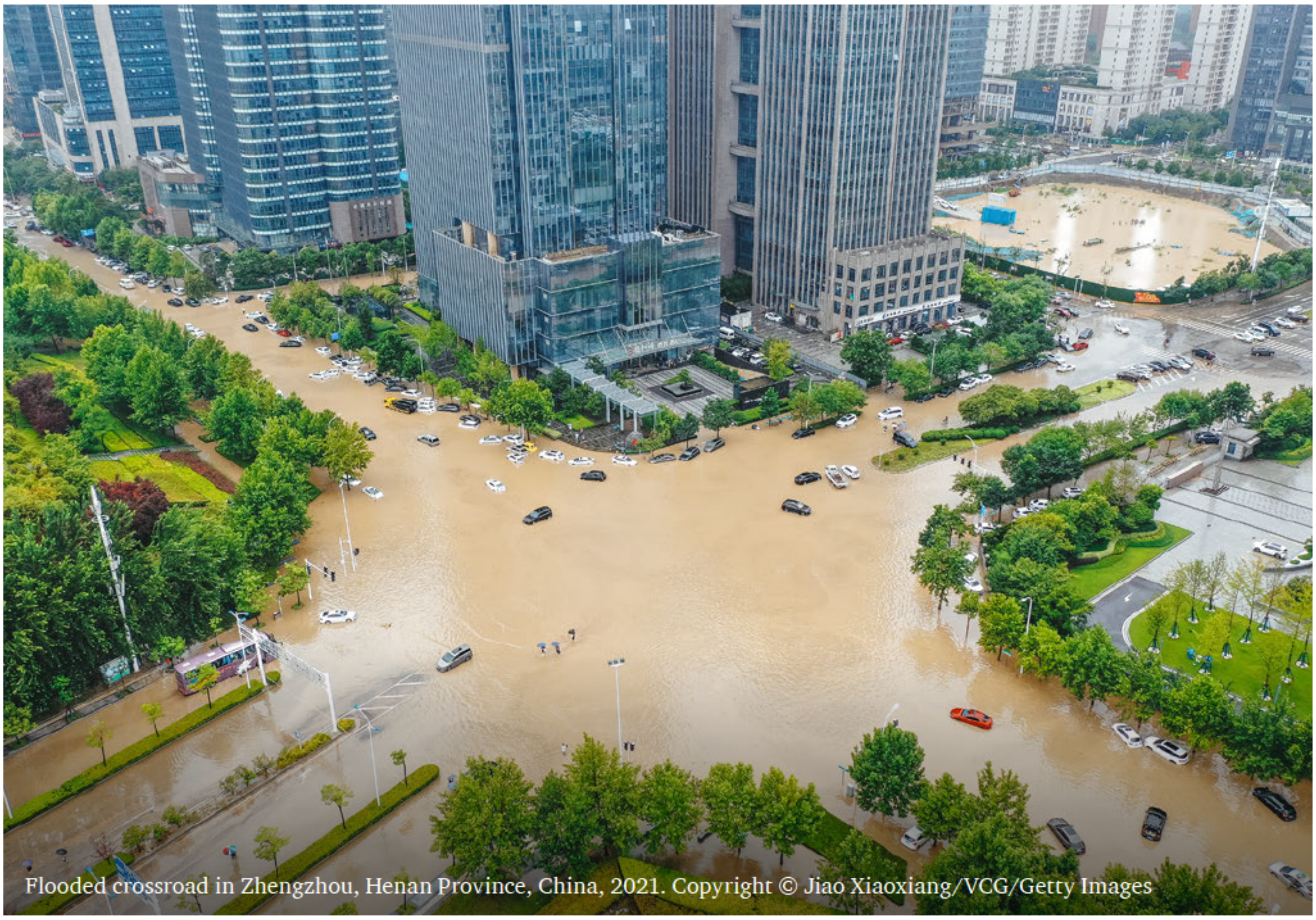
The cascading risks that most concern the contributing experts are the interconnections between shifting weather patterns, resulting in changes to ecosystems, and the rise of pests and diseases, which combined with heatwaves and drought will likely drive unprecedented levels of crop failure, food insecurity and migration. In turn, all will likely result in increased infectious diseases, and a negative feedback loop that compounds each of these impacts.

Extreme weather events often initiate compounding cascading impacts across borders and disrupt global supply chains. The American Meteorological Society has found a substantial link between climate change and extreme weather in 70 per cent of instances studied (146 research findings) between 2011 and 2018.



Recent examples of cascading impacts, due to extreme weather

- Globally, every year since 2008, an average of 21.8 million people have been internally displaced by weather-related disasters (extreme heat, drought, floods, storms or wildfires). In 2015, as the number of refugees and migrants entering Europe, having fled conflict in the Middle East and Africa, reached its highest point, at more than 1 million, an equivalent number of people – some 1.1 million – were displaced by extreme weather events in sub-Saharan Africa alone. In 2020, some 30 million people in 143 countries worldwide were displaced by weather-related disasters, 4.3 million of whom in sub-Saharan Africa.
- An abnormally cold spell in Texas in February 2021 brought rolling power outages, resulting in a lack of safe drinking water, and forcing a shutdown of semiconductor chip factories that contributed to a global shortage. Evidence points to the warming of the Arctic, and the resultant weakening of the polar vortex, pushing cold air far further south than normal, and bringing about the coldest period Texas has experienced in more than 30 years.
- The Yangtze river flooding of 2020, caused by the highest rainfall in 60 years, forced authorities to destroy a dam at risk of collapse, and disrupted cargo ships down the river and within Shanghai port itself. The floods caused hundreds of deaths and other casualties in affected areas, as well as heavy financial losses for China, and disrupted global supply chains, including exports of personal protective equipment intended for health workers battling COVID-19.



Flooded crossroad in Zhengzhou, Henan Province, China, 2021. Copyright © Jiao Xiaoxiang/VCG/Getty Images

About the authors

Dr Daniel Quiggin is a senior research fellow with the Environment and Society Programme at Chatham House. He has expertise in the modelling, analysis and forecasting of national and global energy systems, having modelled various UK and global energy scenarios.

As a senior policy adviser at the UK Department for Business, Energy & Industrial Strategy in 2018–20, Daniel led work on the post-Brexit policy implications for the energy sector's trade of goods and services, and helped shape effective strategies for the energy and climate package of the UK–EU FTA negotiations. He also previously worked as an analyst at Investec Asset Management within a commodities and resources investment team.

Daniel holds master's degrees in particle physics and climate science, and a PhD in energy system modelling.

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Kris has a PhD in cybernetics from the University of Reading, and a master's in systems engineering from KU Leuven.

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Lucy has a PhD in climate change engagement from the University of Exeter, and a master's in climate change from the University of East Anglia.

Antony Froggatt joined Chatham House in 2007, and is deputy director and a senior research fellow in the Environment and Society Programme.

He has worked as an independent consultant for 20 years with environmental groups, academics and public bodies in Europe and Asia. His most recent research projects are concerned with understanding the energy and climate policy implications of Brexit, and the technological and policy transformation of the power sector.

Since 1992 Antony has been the co-author of the World Nuclear Industry Status Report, a now annual independent review of the nuclear sector.

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