OXFORD

BioScience, 2025, **75**, 1016–1027

https://doi.org/10.1093/biosci/biaf149

Advance access publication date: 29 October 2025

Special Report

The 2025 state of the climate report: a planet on the brink

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We are hurtling toward climate chaos. The planet's vital signs are flashing red. The consequences of human-driven alterations of the climate are no longer future threats but are here now. This unfolding emergency stems from failed foresight, political inaction, unsustainable economic systems, and misinformation. Almost every corner of the biosphere is reeling from intensifying heat, storms, floods, droughts, or fires. The window to prevent the worst outcomes is rapidly closing. In early 2025, the World Meteorological Organization reported that 2024 was the hottest year on record (WMO 2025a). This was likely hotter than the peak of the last interglacial, roughly 125,000 years ago (Gulev et al. 2021, Kaufman and McKay 2022). Rising levels of greenhouse gases remain the driving force behind this escalation. These recent developments emphasize the extreme insufficiency of global efforts to reduce greenhouse gas emissions and mark the beginning of a grim new chapter for life on Earth.

In this report, we seek to speak candidly to fellow scientists, policymakers, and humanity at large. Given our roles in research and higher education, we share an ethical responsibility to sound the alarm about escalating global risks and to take collective action in confronting them with clarity and resolve. We show evidence of accelerated warming and document changes in Earth's vital signs. These indicators build on the framework introduced by Ripple and colleagues (2020), who issued a declaration of a climate emergency that has garnered support from approximately 15,800 scientist signatories worldwide. We also examine recent extreme weather disasters and discuss physical and social risks. The final sections of the report include suggested climate mitigation strategies and the broader societal transformations needed to secure a livable future. A summary of key findings is given in box 1.

Vital signs

The last few years have seen surface temperature, ocean temperature, and sea ice extent records broken by extraordinary margins (supplemental figure S1). This is consistent with warming accelerating because of a large cloud feedback and decreasing emissions of aerosols that mask warming (Hansen et al. 2025, Tselioudis et al. 2025). The rapid pace of warming may also be partly because of a weakening land carbon sink. In 2023, land uptake of carbon dioxide dropped sharply from historical averages, likely driven by El Niño and intense forest fires (Friedlingstein et al. 2024). As a result, atmospheric carbon dioxide concentrations rose unusually quickly, despite only modest increases in fossil fuel emissions. Of the 34 planetary vital signs we continue to track (figures 1 and 2), 22 are at record levels (supplemental table S1), and many show alarming trends that we highlight below. Sources and additional details about each variable are provided in supplemental file S1. For vital signs measured with subannual frequency, ranks, and other statistics are based on year-to-date averages (table S1).

The human enterprise

Global human population size is at a record high in 2025 (figure 1a). Similarly, ruminant livestock and per capita meat consumption are at all-time highs, as of 2023 (figure 1c, 1d). Ruminant livestock methane emissions account for roughly half of all agricultural greenhouse gas emissions (FAO 2023). Human and ruminant population sizes are increasing by approximately 1.3 million and 0.5 million individuals per week, respectively (figure 1a, 1c). Global gross domestic product reached an all-time high in 2025, on the basis of preliminary data, with the world

Received: August 10, 2025. **Revised:** August 16, 2025. **Accepted:** August 19, 2025

Box 1. Key Highlights. (See main text for data sources.)

- The year 2024 set a new mean global surface temperature record, signaling an escalation of climate upheaval.
- Currently, 22 of 34 planetary vital signs are at record levels.
- Warming may be accelerating, likely driven by reduced aerosol cooling, strong cloud feedbacks, and a darkening planet.
- The human enterprise is driving ecological overshoot. Population, livestock, meat consumption, and gross domestic product are all at record highs, with an additional approximately 1.3 million humans and 0.5 million ruminants added weekly.
- In 2024, fossil fuel energy consumption hit a record high, with coal, oil, and gas all at peak levels. Combined solar and wind consumption also set a new record but was 31 times lower than fossil fuel energy consumption.
- So far, in 2025, atmospheric carbon dioxide is at a record level, likely worsened by a sudden drop in land carbon uptake partly due to El Niño and intense forest fires.
- Global fire-related tree cover loss reached an all-time high, with fires in tropical primary forest up 370% over 2023, fueling rising emissions and biodiversity loss.
- Ocean heat content reached a record high, contributing to the largest coral bleaching event ever recorded, affecting 84% of reef area.
- So far, in 2025, Greenland and Antarctic ice mass are at record lows. The Greenland and West Antarctic ice sheets may be passing tipping points, potentially committing the planet to meters of sea-level rise.
- Deadly and costly disasters surged, with Texas flooding killing at least 135 people, the California wildfires alone exceeding US$250 billion in damages, and climate-linked disasters since 2000 globally reaching more than US$18 trillion.
- Climate change is endangering thousands of wild animal species; more than 3500 species are now at risk and there is new evidence of climate-related animal population collapses.
- The Atlantic meridional overturning circulation is weakening, threatening major climate disruptions.
- Climate change is already affecting water quality and availability, undermining agricultural productivity, sustainable water management, and increasing the risk of water-related conflict.
- A dangerous hothouse Earth trajectory may now be more likely due to accelerated warming, self-reinforcing feedbacks, and tipping points.
- Climate change mitigation strategies are available, cost effective, and urgently needed. From forest protection and renewables to plant-rich diets, we can still limit warming if we act boldly and quickly.
- Social tipping points can drive rapid change. Even small, sustained nonviolent movements can shift public norms and policy, highlighting a vital path forward amid political gridlock and ecological crisis.
- There is a need for systems change that links individual technical approaches with broader societal transformation, governance, policies, and social movements.

economy expanding by approximately 3.5% over the previous year (figure 1e). Although this growth is often celebrated as a sign of progress, continued economic expansion remains largely coupled with increased resource consumption, ecological degradation, and increased greenhouse gas emissions (Wiedmann et al. 2020). Two-thirds of warming since 1990 has been attributable to the wealthiest 10% because of high-consumption lifestyles, high per capita fossil fuel use, and investments (Schöngart et al. 2025). Taken together, these trends suggest humanity is in a state of ecological overshoot—a state in which resources are consumed faster than they can be replenished (Rees 2023). However, the overconsumption of critical resources and the consequences in terms of suffering are also unequally distributed across the globe. Seven of the eight globally quantified safe and just planetary boundaries have been transgressed, highlighting both overshoot and deepening justice concerns (Rockström et al. 2023). Reducing ecological overshoot would help mitigate socioenvironmental pressures, but would require both cutting emissions and rethinking the consumer society while transitioning to a sustainable economy within safe and just Earth system boundaries (Gupta et al. 2024, Ripple et al. 2024).

Energy

Total fossil fuel energy consumption reached a record high, rising by 1.5% in 2024 from 2023 (figure 1h). This was a result of coal, oil, and natural gas consumption each rising to a record high in 2024 (figure 1h). Solar and wind energy consumption together also reached a record high in 2024, rising 16.4%; however, fossil fuel energy consumption was roughly 31 times greater than solar and wind energy consumption (figure 1h).

As a result of surging fossil fuel consumption, energy-related emissions rose 1.3% in 2024, reaching an all-time high of 40.8 gigatons (Gt) of carbon dioxide equivalent (CO_2eq; figure 1j). In 2024, the greatest fossil fuel greenhouse gas emitters were China (30.7% of total), the United States (12.5%), India (8.0%), the European Union (6.1%), and Russia (5.5%); together, they accounted for 62.8% of global emissions (supplemental table S3). Much of the rise in fossil fuel electricity generation may be due to hotter temperatures (Graham et al. 2025).

Forests and wildfires

Global tree cover loss was 29.6 megahectares (Mha) in 2024, the second highest area on record and a 4.7% increase relative to 2023 (figure 1f). This was partly due to fire-related global tree cover loss reaching a record high largely because of climate change and El Niño (figure 2p). The losses within tropical primary forest were particularly large in 2024, with fire-related losses reaching a record high of 3.2 Mha, compared with just 0.69 Mha in 2023—a 370% increase (supplemental figure S4). In addition to major impacts on biodiversity and ecosystem services, the loss of primary

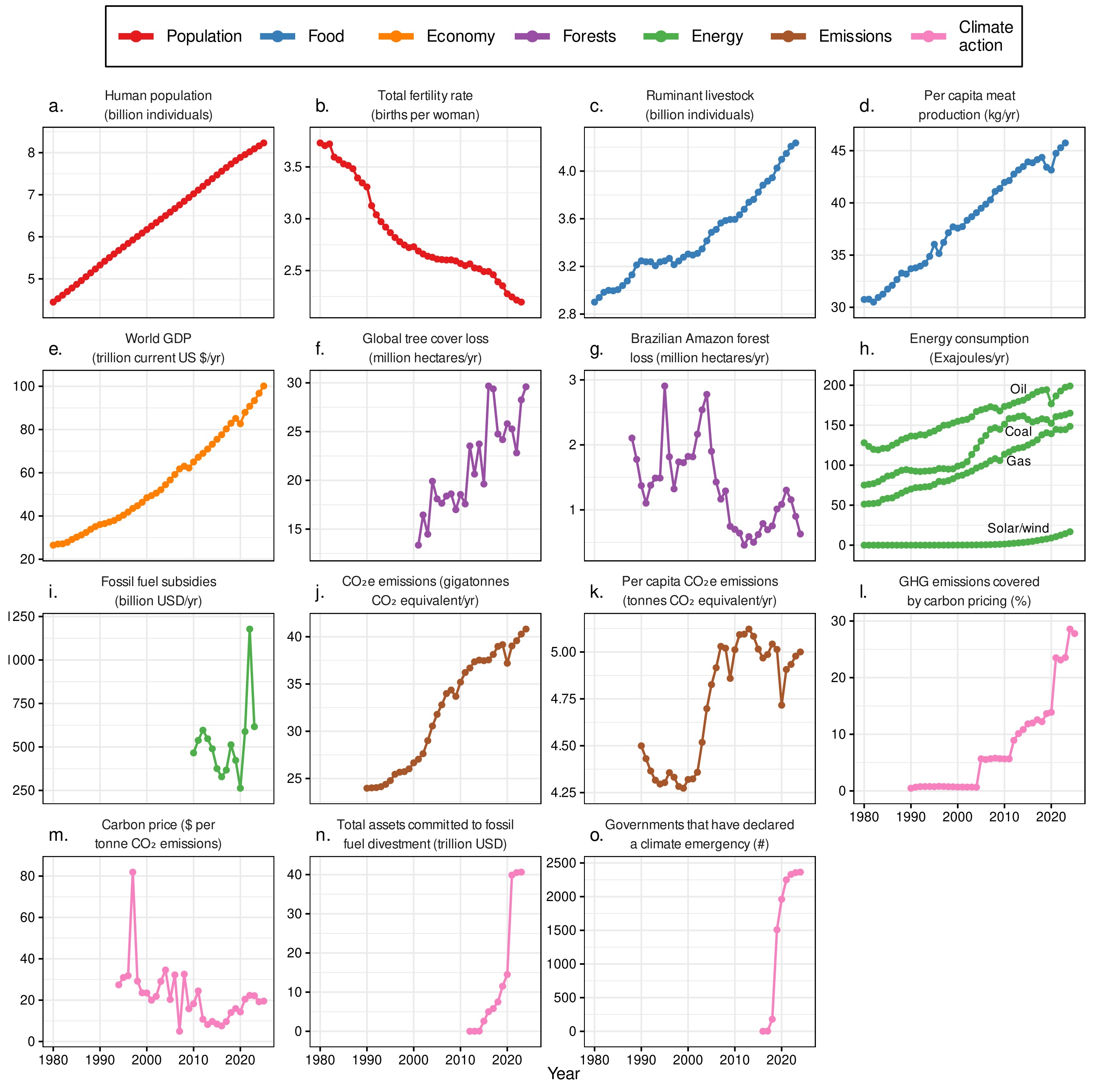

Figure 1. Time series of climate-related human activities. In panel (f), tree cover loss does not account for forest gain and includes loss due to any cause. For panel (h), statistics are based on total energy supply (Energy Institute 2025); hydroelectricity and nuclear energy are shown in supplemental figure S2. Sources and additional details about each variable are provided in supplemental file S1.

forest in 2024 alone resulted in roughly 3.1 Gt of CO_2eq greenhouse gas emissions, which is approximately 8% of total 2024 anthropogenic emissions (WRI 2025). Massive wildfires have also been occurring in 2025. By August, the European Union's wildfire season was already the most extensive on record in terms of area burned, exceeding 1 million hectares (Niranjan 2025). Canada's wildfire season is currently the second largest on record by area burned (Bowden 2025), and climate change is likely a major contributing factor (Seydi et al. 2025). This exemplifies a dangerous climate feedback loop as fires release vast carbon emissions that accelerate global warming, which in turn fuels more fire activity. Wildfires also have more direct impacts, including significant smoke-related morbidity and mortality (Alari et al. 2025).

In contrast to the global trend, deforestation in Brazil's Amazon rainforest dropped by roughly 30%, reaching its lowest level in 9 years, with 0.63 million hectares cleared by 31 July 2024 compared with 0.90 million hectares by 31 July 2023 (figure 1g). These estimates are based on the Brazilian Amazon Rainforest Monitoring Program by Satellite methodology, which involves quantifying deforestation for areas exceeding 6.25 hectares in the Brazilian Legal Amazon using specialist photointerpretation of satellite imagery (de Almeida et al. 2021). The decline is attributed to strengthened environmental enforcement under President Luiz Inácio Lula da Silva's administration, which has prioritized conservation efforts (Vilani et al. 2023). However, despite the reduction in deforestation in the Brazilian Amazon, the region experienced a significant

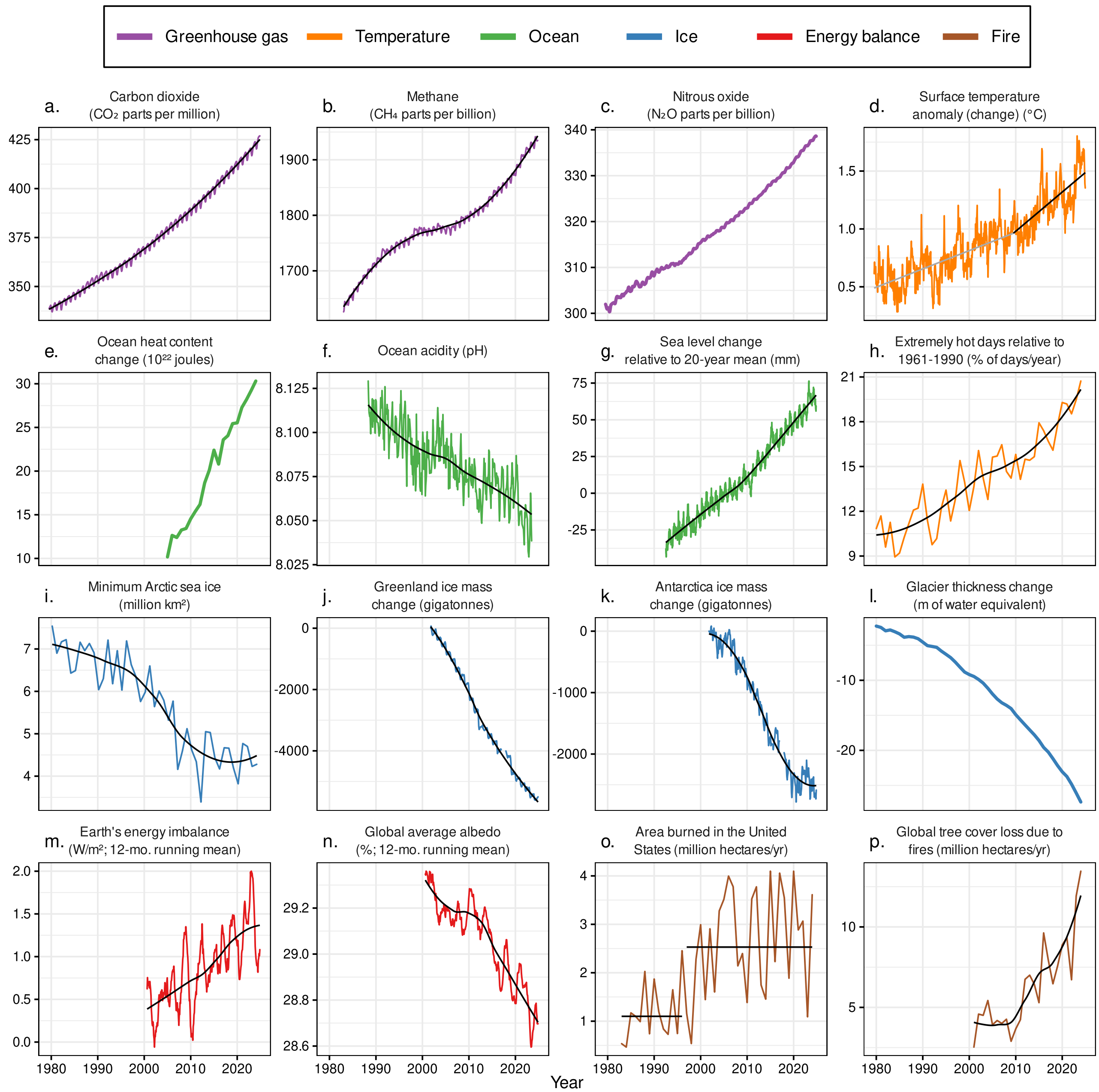

Figure 2. Time series of climate-related responses. For surface temperature anomaly (d), estimates based on a segmented linear regression model are shown in gray (prior to 2010) and black (beginning in 2010). For area burned (o), the black horizontal lines show changepoint model estimates, which indicate abrupt shifts (supplemental figure S3). For other variables with relatively high variability, local regression trendlines are shown in black. The variables were measured at various frequencies (e.g., annual, monthly, weekly). The labels on the x-axis correspond to midpoints of years. Sources and additional details about each variable are provided in supplemental file S1.

surge in fires because of severe drought conditions (Butler 2024). These fires, which are not always classified as deforestation, have raised concerns about ongoing ecosystem degradation and the challenges of accurately monitoring forest health. The Amazon continues to face threats from climate change and human activities, which underscores the need for sustained conservation efforts to increase its resilience (Schaeffer et al. 2025). By 2050, as much as 47% of the Amazon rainforest could face compounding disturbances, potentially leading to irreversible ecosystem transitions (Flores et al. 2024).

Global greenhouse gases and temperature

On the basis of year-to-date averages, atmospheric concentrations of carbon dioxide, methane, and nitrous oxide were all at record high levels again in 2025 (figure 2a–2c). In addition, in May 2025, the average carbon dioxide concentration at the Mauna Loa Observatory, in Hawaii, exceeded 430 parts per million—a level likely not seen in millions of years (Judd et al. 2024). So far, in 2025, global average surface temperature is at the second highest level on record (figure 2d, table S1), and the incidence of extreme heat based on the proportion of days where the maximum temperature exceeds the 90th percentile for the baseline period 1961–1990 reached a record high in 2024 (figure 2h). The past 10 years, 2015–2024, are the 10 warmest years on record (WMO 2025b).

Energy balance

An important predictor of future warming is Earth's energy imbalance—the difference between the amount of solar energy absorbed and the amount radiated back into space (figure 2m). It is rising much more quickly than predicted by most climate models, possibly because of a darker planet corresponding to a large decrease in Earth's albedo (reflectivity; Goessling et al. 2025, Mauritsen et al. 2025), which is near an all-time low (figure 2n). Most of the recent decrease in albedo is, in turn, caused by an exceptionally strong cloud feedback (Hansen et al. 2025). Cloud characteristics are changing because of both rising temperatures and declining emissions of aerosols such as sulfur dioxide, which affect cloud brightness and formation (Hausfather 2025). Together, these factors may have contributed greatly to the recent acceleration in warming (figure 2d).

Oceans and ice

In 2025, on the basis of year-to-date averages, Greenland's and Antarctica's ice mass levels were at record lows (figure 2j, 2k). Recent research shows that the Greenland and West Antarctic ice sheets may have already passed critical tipping points because of current global warming levels (Stokes et al. 2025). Greenland is rapidly losing ice from surface melt and runoff, whereas West Antarctica faces a growing risk of irreversible collapse from ocean-driven melting beneath its ice shelves. With ice loss rates having quadrupled since the 1990s, these changes are likely to commit the planet to several meters of sea-level rise, even without additional emissions (Stokes et al. 2025). The current warming appears sufficient to trigger this long-term increase in the loss of ice. The rate of sea-level rise has doubled in the last three decades (figure 2g; also see Hamlington et al. 2024).

Another notable development is that ocean heat content reached a record high (figure 2e). This likely contributed to the ongoing coral bleaching event, affecting roughly 84% of the world's coral reef area between 1 January 2023 and 31 May 2025, making it the most extensive bleaching incident in recorded history (NOAA Coral Reef Watch 2025). Furthermore, ocean pH reached a record low, indicating the highest acidity on record (figure 2f) and new evidence suggests the global planetary boundary for ocean acidification may have been crossed in 2020 (Findlay et al. 2025). Ocean acidification poses a serious threat to marine calcifiers, including some corals and phytoplankton—the base of ocean food webs (Findlay et al. 2025).

Climate impacts and extreme weather

Each additional tenth of a degree of global warming leads to a disproportionately greater rise in disasters related to extreme weather and many additional people facing intolerable heat stress (Lenton et al. 2023). The past year has seen a surge in devastating climate-related disasters around the world (table 1). From deadly floods and wildfires to record-breaking storms and heatwaves, the evidence is overwhelming: Extreme weather is becoming more frequent, intense, and costly. The tendency for the stationary meanders in the summer jet stream that favor persistent weather patterns that can produce extremes such as major floods and heat domes has almost tripled since the 1950s—an additional impact on extreme weather that is not currently well captured in climate models (Li et al. 2025). In addition, the combined global intensity of droughts and floods has increased rapidly in more recent years (figure S5). These prolonged and intensifying water extremes, likely driven primarily by rising global temperatures, underscore growing hydroclimatic whiplash—extreme swings between wet and dry conditions (Li and Rodell 2023, Rodell and Li 2023).

More specifically, major disasters have recently struck multiple regions around the world (tables 1, S2). For example, Typhoon Yagi swept across Southeast Asia in 2024, causing widespread destruction with an estimated economic impact of more than US$14.7 billion and loss of life with more than 800 deaths. In the United States, Hurricane Helene killed 251 people and caused roughly US$79 billion in damages in 2024; the Los Angeles wildfires killed at least 30 people, caused at least US$250 billion in damages and disrupted millions of lives; and a catastrophic flash flood in Texas killed at least 135 people. Europe, East Africa, and Japan also experienced severe events, many with unprecedented intensity, including a devastating heat wave in Europe where researchers estimated that climate change directly contributed to the deaths of roughly 1500 people.

Although all climate and weather extremes have multiple physical drivers, these disasters are part of a broader pattern of escalating risk driven by a warming planet. Warmer temperatures (figure 2d, 2h) fuel more powerful storms, amplify droughts and rainfall extremes, and increase the likelihood of massive wildfires (figure 2o, 2p). Between 2000 and 2024, global spending related to climate disasters totaled approximately a massive US$18.5 trillion (Bloomberg Intelligence 2025). Vulnerable communities, especially in low-income countries, are often hit hardest, with lasting impacts on food security, water availability and quality, built infrastructure, and public health. The mounting toll of climate-related disasters is a stark reminder of the urgent need for both climate mitigation and adaptation efforts. As warming continues, the risks and costs will grow.

The risks

The accelerating climate crisis presents a range of deeply interconnected risks that threaten to destabilize the Earth system and society. In this section, we highlight four particularly urgent threats as examples: risks to Earth's wild animals, the potential collapse of the Atlantic meridional overturning circulation, risks to water resources, and the risk of crossing climate tipping points that could push the planet onto a self-sustaining hothouse Earth trajectory. As part of a broader polycrisis, each of these risks is amplified by feedback loops and systemic vulnerabilities that could lock in long-term consequences for human and planetary health.

Risks to biodiversity

Many of Earth's wild animal species are endangered, with habitat loss and overexploitation being dominant threats (Maxwell et al. 2016). Over the past 50 years, the average size of studied wildlife populations has decreased by 73% (WWF 2024). Climate change has now emerged as another serious threat to biodiversity, widely affecting species distributions, population dynamics, phenology, and ecosystem function (IPBES 2019). Currently, more than 3500 assessed wild animal species are threatened by climate change and numerous examples of climate-related species population collapse have been documented (Ripple et al. 2025). Climate change is expected to have greater, albeit highly uncertain, impacts on biodiversity in the future (Nunez et al. 2019). Climate change-related effects on biodiversity, especially changes in species distributions, can have implications for human

Table 1. Recent climate-related disasters since September 2024.

Event category	Event	Date	Description
Wildfires	California wildfires	January 2025	Wildfires burned more than 57,000 acres, caused at least US$250 billion in economic damages and losses, killed at least 30 people, damaged thousands of structures, and forced nearly 200,000 people to evacuate across the Los Angeles region.
	Japan and South Korea wildfires	March 2025	Wildfires burned 370 hectares in Japan and more than 48,000 hectares in South Korea, injuring 2 people, killing 32 people in South Korea, damaging homes, and prompting mass evacuations and emergency response.
	Canada Wildfires	May 2025	One of Canada's most intense early season wildfire outbreaks burned over 1.58 million hectares and forced 17,000 evacuations.
Heavy precipitation	Typhoon Yagi*	September 2024	Typhoon Yagi brought deadly flooding, landslides, and extreme winds to Vietnam and surrounding countries, resulting in an estimated 844 deaths, 2279 injuries, and over US$14.7 billion in damages.
	Storm Boris	September 2024	Storm Boris caused severe flooding, 27 deaths, and widespread power outages across Central and Eastern Europe, with rainfall up to four times the monthly average and economic damages likely exceeding US$2.2 billion.
	Japan Floods	September 2024	Record-breaking rainfall in Ishikawa triggered deadly floods and landslides, killing six, leaving ten missing, flooding thousands of homes, and isolating over 100 communities.
	Hurricane Helene*	September 2024	Hurricane Helene caused catastrophic flooding and wind damage across six southeastern US states, leading to 251 deaths and US$78.7 billion in damages.
	Storm Kirk*	October 2024	Storm Kirk brought widespread flooding and wind damage across western and northern France, with gusts up to 211 kilometers per hour and rainfall near 90 millimeters in a few hours; it resulted in one death and roughly US$110 million in economic losses in Western Europe.
	Hurricane Milton*	October 2024	With peak rainfall near 19 inches and winds reaching 160 kilometers per hour at landfall, Hurricane Milton caused roughly US$34.3 billion in damages and killed 45 people, primarily in Florida, United States.
	Italy Multiple Floods	October 2024	Severe floods across multiple Italian regions caused infrastructure damage, over 3000 evacuations, and at least one fatality amid extreme rainfall and flash floods.
	South-East Spain Floods	October 2024	Catastrophic flooding, extreme rainfall, hail, and tornadoes in southeastern Spain caused over 200 deaths and billions in damages.
	Colombia Floods	November 2024	Severe flooding along Colombia's Pacific coast affected 188,000 people in Chocó, triggered a nationwide emergency, and caused a major humanitarian crisis.
	Storm Darragh	December 2024	Storm Darragh brought hurricane-force winds, widespread power outages, major transport disruptions, and two fatalities across Ireland and the United Kingdom.
	Cyclone Chido*	December 2024	Cyclone Chido caused catastrophic damage in and near Southeast Africa, injuring 6534 people and resulting in at least 172 deaths and more than US$681 million in damages.
	Storm Éowyn*	January 2025	Storm Éowyn caused widespread power outages, severe property damage, and two fatalities across Ireland and the UK due to extreme winds and heavy rainfall.
	Queensland Flood	February 2025	Severe flooding in Queensland inundated homes and businesses, cut power to thousands, forced mass evacuations, and led to at least one fatality.
	Cyclone Zelia*	February 2025	Cyclone Zelia brought destructive 320 kilometer per hour winds, over 400 millimeters per day of rain, and flash flooding in Western Australia, causing US$733 million in damages.
	Cyclone Alfred*	March 2025	Cyclone Alfred caused power outages, school closures, evacuations, and flooding across eastern Australia, severely disrupting daily life and resulting in US$820 million in economic losses.
	Argentina Floods	March 2025	Over 400 millimeters of rain in 8 hours caused catastrophic flooding in Bahía Blanca, killing 17, and resulting in US$400 million in infrastructure damage, and overwhelming homes, hospitals, and drainage systems.
	Cyclades Storm	March 2025	Severe storms caused widespread flooding, infrastructure damage, and vehicle rescues across multiple Greek islands, with Paros, Mykonos, and Chania among the hardest hit.
	DR Congo Floods	May 2025	Severe flooding in South Kivu caused the Kasaba River to overflow, isolating communities and resulting in around 100 confirmed fatalities amid difficult rescue conditions.
	New South Wales Floods	May 2025	Severe flooding submerged roads and homes, broke rainfall records, isolated communities, killed five people, and forced evacuations across parts of New South Wales, especially around Lismore and Taree.
	Texas Floods	July 2025	A catastrophic overnight flash flood in Central Texas, in the United States, killed at least 135 people, and became one of the deadliest single-night disasters in state history.
High temperatures	India and Pakistan Heatwave	April 2025	The heatwave brought extreme temperatures up to 49°C, widespread power outages, crop failures, and severe health impacts across India and Pakistan, especially among vulnerable populations.

Table 1. Continued

Event category	Event	Date	Description
	Western European Heatwave	June 2025	An intense early season heatwave brought record-breaking temperatures to parts of western and southern Europe. It was part of a broader European heatwave where climate change resulted in an estimated 1500 additional deaths in 12 European cities between 23 June and 2 July.
	Eastern US Heatwave	June 2025	A record-breaking heatwave across the eastern United States caused infrastructure failures, widespread power outages, and hundreds of cases of heat-related illness.

* *Note:* We list numerous recent disasters that may be at least partly related to climate change. Disaster descriptions are primarily based on the ones provided in the Climameter hazards database (ClimaMeter 2025). Links to Climameter attribution analyses are given in the "Event" column of supplemental table S2. Where applicable, we have updated the disaster impacts (the "Description" column) using news and other sources as was indicated with hyperlinks in table S2. Information on the Climameter methodology is given in Faranda and colleagues (2024). This list of disasters is not intended to be exhaustive. Events labelled with an asterisk also involve strong winds. Some of these climate disasters may be at least partly related to changes in jet streams (Stendel et al. 2021, Rousi et al. 2022).

well-being, potentially affecting agriculture and food security, recreation and tourism, and the distribution of animal-borne pathogens (Pecl et al. 2017). Coral reefs are ecosystems of particular concern, because they are extremely biodiverse, provide ecosystem services to hundreds of millions of people, and are heavily affected by both global ocean warming and other threats, including fishing pressure and pollution (Hoegh-Guldberg et al. 2018).

Risks to the Atlantic meridional overturning circulation

The Atlantic meridional overturning circulation, a major system of ocean currents that regulates global climate, is showing signs of significant weakening and emerging evidence points to greater and earlier tipping risks than previously recognized (Rahmstorf 2024). If the Atlantic meridional overturning circulation collapses, it could trigger abrupt and irreversible climate disruptions, including drastic shifts in regional weather patterns, intensified droughts and floods, and reduced agricultural productivity in key regions (Schaeffer et al. 2025). For example, Atlantic meridional overturning circulation collapse could lead to more intense cold extremes in Northwestern Europe (van Westen and Baatsen 2025). Because the Atlantic meridional overturning circulation is deeply interconnected with other climate tipping elements such as the large ice sheets on Greenland and West Antarctica, as well as the Amazon rainforest or the Subpolar Gyre, its collapse could also initiate cascading tipping events, amplifying the impacts to a catastrophic level (Wunderling et al. 2024). These impacts may already be occurring; for instance, between 2005 and 2022, up to half of the flooding events along the northeastern US coast may have been driven by Atlantic meridional overturning circulation weakening (Zhang et al. 2025).

Risks to freshwater

It has long been understood that the availability and quality of freshwater resources are highly vulnerable to climatic changes because of the tight coupling between the hydrologic cycle and the climate system. The projected impacts on water include increases in evaporation from land and ocean surfaces as global temperatures rise, changes in the frequency and intensity of extreme floods and droughts, loss of ice and snow cover, and shifts in water availability and use for both natural and human systems. These projected impacts are now being observed and accelerating in scope (Parmesan et al. 2022). High- and low-latitude wet regions are getting wetter and midlatitude dry areas are drying, but drying areas have increased, whereas the extent of wetting areas has decreased—a consequence of rising temperatures, accelerating drought, increasing extreme precipitation, and the loss of glaciers and snow (Chandanpurkar et al. 2025). There is clear evidence for the role of climate change in forcing changes in extreme events (see supplemental figure S5) and the level and timing of river flows (Gudmundsson et al. 2021). These changes in freshwater storage and flows are worsening unsustainable groundwater use, threatening irrigation supplies and agricultural productivity, reducing urban water availability and water quality, damaging the health of aquatic ecosystems, and increasing violent conflicts over water resources (Gleick and Shimabuku 2023).

Hothouse trajectory risks

For more than 11,000 years, Earth's climate has remained stable during the Holocene epoch, following the end of the last Ice Age (figure 3). Scholars have argued that this period of relative climatic calm enabled the development of agriculture, permanent settlements, and the rise of human civilizations. Global temperatures and hydrologic conditions fluctuated only slightly, creating environmental conditions that allowed both ecosystems and societies to thrive. That stability is now giving way to a period of rapid and dangerous change. Since the Industrial Revolution, human activities—primarily the burning of fossil fuels and land-use changes—have dramatically increased concentrations of heat-trapping greenhouse gases in the atmosphere. As a result, over the last 50 years, global temperatures have likely increased at a greater rate than at any other time in the last 2000 years (IPCC 2021). Under current policies, Earth is on track to reach as much as 3.1°C above preindustrial levels by 2100 (UNEP 2024).

Such warming greatly increases the likelihood of crossing climate tipping points, thresholds in Earth's system that, once breached, can trigger self-reinforcing feedback loops. These include the collapse of polar ice sheets, thawing of carbon-rich permafrost, and widespread forest dieback (Armstrong McKay et al. 2022). Crossing one tipping point could set off a cascade of other tipping point crossings with the majority of interactions being destabilizing (Wunderling et al. 2024). In the worst case, this could push the climate system onto a hothouse Earth trajectory, a pathway of continued warming even if emissions are eventually reduced (Steffen et al. 2018). This trajectory would lead to a fundamentally different planet with devastating impacts on natural systems and humanity.

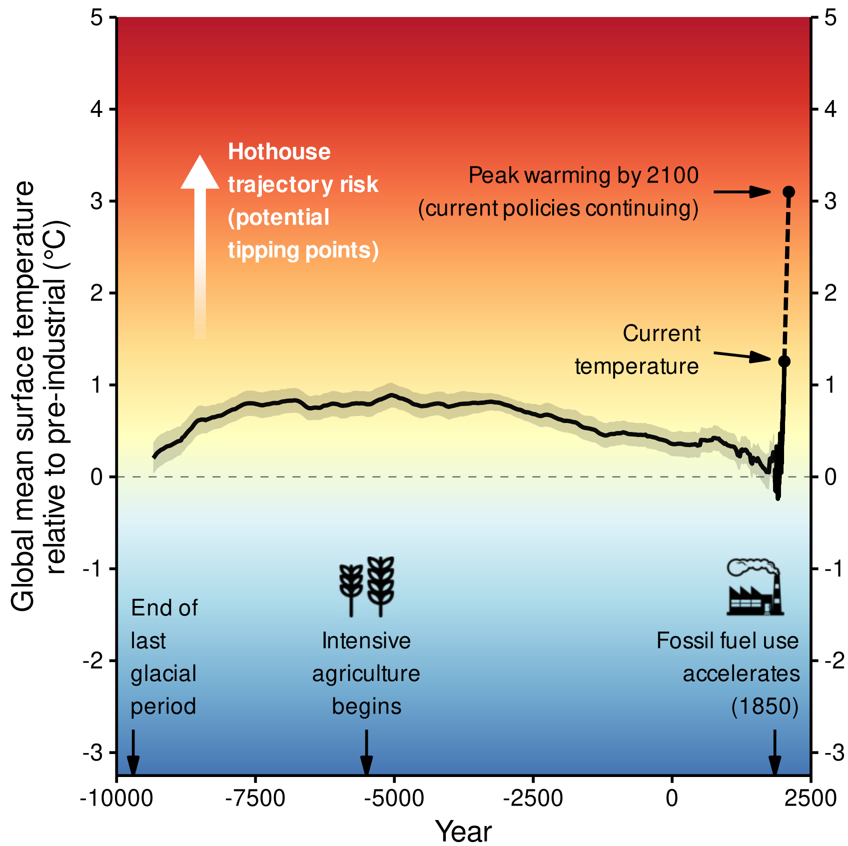

Figure 3. Approximate global average temperature from –9340 BCE to 2020 CE. Bands around time series indicate the standard deviation. The projection of roughly 3.1°C peak warming by 2100 is from UNEP (2024). See the supplemental methods and data sources section for additional information.

Climate change mitigation strategies

The cost of mitigating climate change is likely far lower than the global economic damages that climate-related impacts could cause. Climate mitigation can also offer many significant cobenefits that may be difficult to quantify economically. Transformative changes are essential, including governance at national and international levels, transforming our production systems, reducing overconsumption, especially among the wealthiest, while adopting ecological and postgrowth economic models that promote social equity and respecting safe and just planetary boundaries (Gupta et al. 2024, Ripple et al. 2024). In this section, we describe some proven strategies that can complement and support such broader efforts to address both ecological overshoot and climate change.

There are a number of approaches, ranging from forest protection and renewable energy to plant-rich diets, that could together dramatically reduce net emissions (figure 4). As examples, below, we briefly review three high-impact groups of actions involving strategies around energy, nature, and the global food system (Hawken 2017). It is important to note that a full systems change, connecting policies, technologies and governance across sectors may be required for scalable and just societal transformations. Such change could also link individual technical strategies with broader cultural shifts and social movements.

Although there are environmental impacts, renewable energy sources have substantial climate mitigation potential (Clarke et al. 2022). They also offer other important cobenefits, such as reductions in other air pollutants and water consumption. By 2050, solar and wind energy could supply nearly 70% of global electricity (IEA 2021). Although solar and wind energy consumption have been rising rapidly, they still lag far behind fossil-fuel consumption (figure 1h), despite being increasingly economical, even with the ongoing fossil-fuel subsidies that are estimated in the range of US$7 trillion in 2022 when unpriced externalities are accounted for (Black 2023). Some of us have argued there is a need for grassroots social movements that advocate for a just fossil-fuel phaseout and limits on the fossil-fuel industry's financial and political influence (Wolf et al. 2025). A fossil-fuel phaseout would also help to reduce emissions of methane—a potent greenhouse gas.

Protecting and restoring ecosystems on land and in the ocean is one of the most powerful strategies for addressing climate change while also supporting biodiversity and human well-being (UNEP/IUCN 2021). Forests, grasslands, savannas, wetlands, peatlands, mangroves, sea grasses, and phytoplankton all help capture and store large amounts of carbon while regulating nutrient cycles and buffering against environmental extremes. The conservation of intact ecosystems with high carbon stocks, especially primary forests, provides particularly large benefits, while allowing forests to continue growing through proforestation further increases long-term carbon storage (Moomaw et al. 2020). Carefully implemented large-scale restoration efforts, including reforestation, afforestation, and the rehabilitation of degraded habitats, can add substantial capacity to absorb carbon. Although land availability may limit the scale of some actions, nature-based solutions could potentially achieve emission reductions and

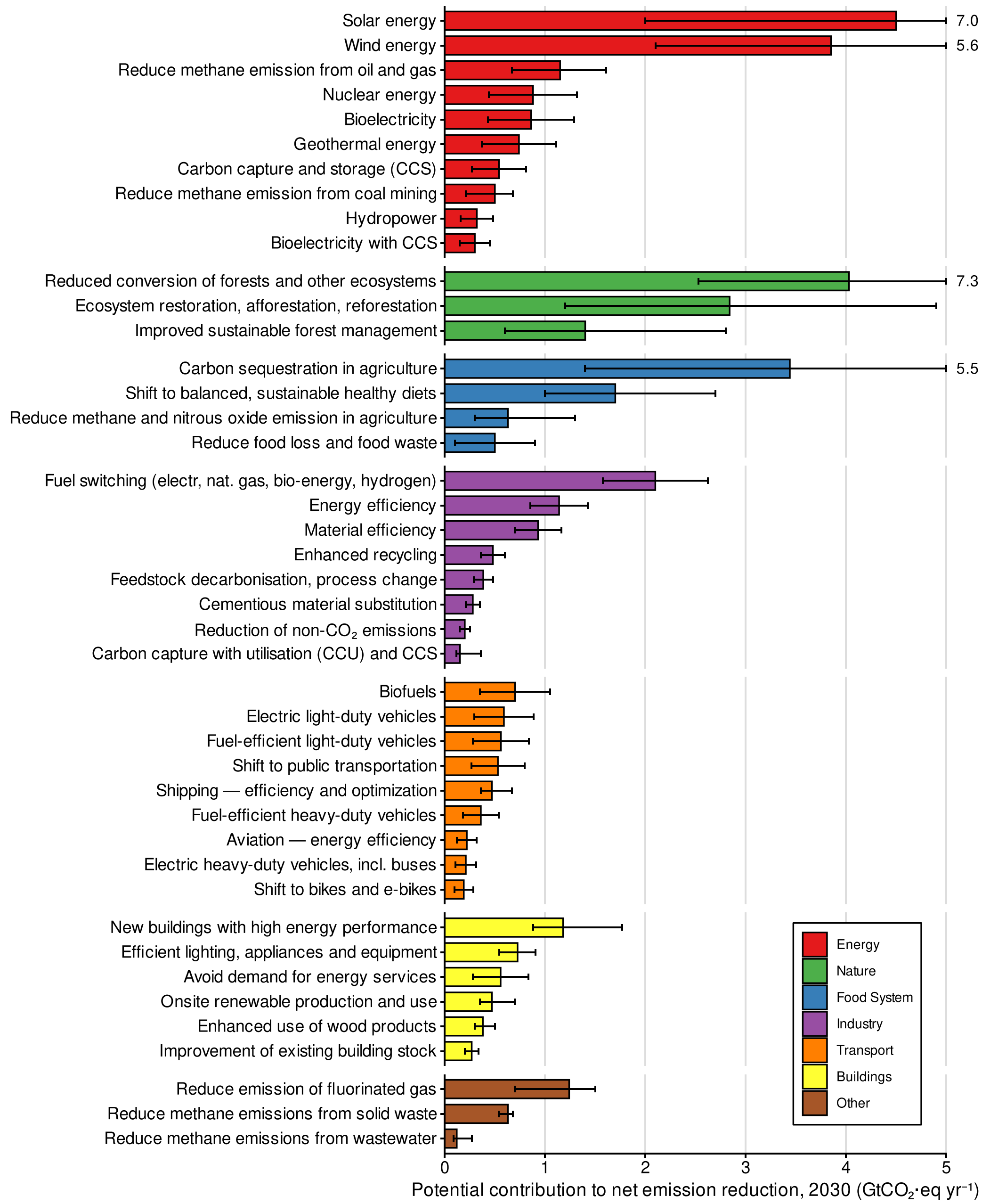

Figure 4. Climate mitigation options based on IPCC (2022). Uncertainty ranges are shown in black and clipped to a maximum of 5 $GtCO_2$eq/year for plotting. The sector grouping comes from IPCC (2022) except we split the IPCC's "Agriculture, Forestry and Other Land Use" sector into "Nature" and "Food System" sectors. Mitigation costs are not taken into account in this figure. Mitigation potentials are uncertain, varying with technology, context, and time. Some options are controversial, and inclusion does not imply endorsement. See table S4 for more details.

removals on the order of 10 Gt CO_2/year by 2050, equivalent to roughly 25% of current emissions (UNEP/IUCN 2021).

Currently, approximately 30% of food is lost or wasted globally (see supplemental methods and data sources section). Reducing food loss and waste could greatly reduce greenhouse gas emissions since it accounts for roughly 8–10% of global emissions (Mbow et al. 2019). Addressing food loss and waste would also bolster food and water security, especially in developing countries (Shafiee-Jood and Cai 2016). In addition, policies supporting more plant-rich diets could help mitigate climate change, while offering many benefits related to human health, food security, and biodiversity (Sabaté and Soret 2014, Arrieta and Aguiar 2023). The technical mitigation potential associated with dietary changes may be on the order of 0.7–8.0 $GtCO_2$eq per year by 2050 (Mbow et al. 2019). Improved agricultural practices could also be employed to increase carbon sequestration and decrease methane and nitrous oxide emissions (IPCC 2022). Finally, better adoption of clean fuels for cooking could reduce emissions and also decrease household air pollution-related mortality (Hystad et al. 2019). Currently, only about half of people in lower middle and low income countries have access to clean fuels and technologies (Frostad et al. 2022). Roughly 2% of global emissions are related to the lack of clean cooking fuels (IEA et al. 2022).

The three mitigation strategy groups described above should be viewed only as examples. See figure 4 and table S4 for a more comprehensive overview of global climate change mitigation strategies developed by IPCC (2022), including their estimated annual greenhouse gas reduction potentials.

Social tipping points

Social tipping points can trigger accelerated climate action through cascading effects in societies, institutions, and economic systems once a critical threshold is crossed (Eker et al. 2024). An example is the adoption of new proenvironmental norms and values (Otto et al. 2020). Research shows that sustained, nonviolent movements and protests involving just a small proportion of a population (e.g., approximately 3.5 percent) can help trigger transformative change (Chenoweth 2021). These movements succeed not simply because of their size but because they disrupt the status quo and shift public opinion. However, many people underestimate how widely shared their climate concerns are. Despite majorities in nearly every country supporting strong climate action, most individuals believe they are in the minority (Andre et al. 2024). This pluralistic ignorance fosters disengagement and isolation. Correcting these misperceptions can unlock public potential, helping individuals recognize their alignment with the broader population and empowering collective action.

A key societal challenge is translating widespread concern into organized and sustained civic engagement. Climate activism can shape public discourse and influence media coverage (Thomas-Walters et al. 2025), but deeper transformation requires building coalitions with justice movements, expanding organizing capacity, and engaging in well-planned nonviolent resistance (Chenoweth 2020). Social science offers valuable guidance for such efforts (Fisher 2024), which may include grassroot strategies leveraging social networks to spread norms and using visible, peaceful protest to shift expectations. As awareness grows and people see their values reflected in others, the conditions for social tipping points are strengthened. These cultural and political shifts can ripple across institutions and economies, accelerating the adoption of large-scale climate solutions. Reaching this positive tipping point will require more than facts and policy; it will take connection, courage, and collective resolve (Lenton 2025).

Conclusions

The accelerating climate crisis is now a major driver of global instability. Extreme weather is causing widespread impacts and direct loss of life, while also driving resource scarcity, displacement, and civil unrest. These challenges are further compounded by weakening international cooperation and reductions in foreign aid. These converging pressures are straining national governments, multilateral institutions, and communities around the world. A strategy that embeds climate resilience into national defense and foreign policy frameworks is urgently needed. Without it, cascading risks may overwhelm systems of peace, governance, and public and ecosystem health.

Avoiding every fraction of a degree of warming is critically important. We are entering a period where only bold, coordinated action can prevent catastrophic outcomes. Social tipping points, moments when shifts in policy and public norms rapidly accelerate, offer a critical pathway to progress. But, unlocking these tipping points will require courageous leadership, public engagement, and widespread institutional change. Climate policy must be consistent with what is scientifically and ethically required, regardless of political concerns. Delay only increases the human and environmental toll.

To ensure a livable and just future, we must confront the deeper challenge of aligning human civilization with the limits of the Earth's natural systems. Transformative change is needed to address ecological overshoot and the worsening climate emergency. This includes reducing overconsumption, particularly among the affluent, stabilizing the human population through the empowerment of girls and women, shifting toward plant-based food systems, providing safe water and sanitation to all, and adopting economic models that prioritize well-being, equity, and sustainability over perpetual growth (Ripple et al. 2020, Gupta et al. 2024). These systemic shifts are necessary to safeguard the biosphere and promote long-term well-being.

Climate change is a threat to ecosystem and human health, but it is also fundamentally a social justice issue. We are disproportionately harming the vulnerable and marginalized—those least responsible for the crisis. As we confront rising seas, burning forests, and destabilized communities, we must remain guided by a commitment to justice, dignity, and the common good. The future is still being written. Through choices in policy, investment, education, and care for one another and the Earth, we can still create a turning point. It begins by embracing our shared humanity and recognizing the profound interconnectedness of all life on the planet.

Acknowledgments

We thank William H. Calvin, Katherine Graubard, Stephanie Morét, William Rees, Karen Wolfgang, Jennifer Krauel, Mark Olsoe, Thomas H. DeLuca, and Steve Lundeberg for providing helpful suggestions. We thank Skye Morét for graphics consultation and graphics design ideas. Partial funding was received from the CO_2 Foundation and Roger Worthington. The World Scientists' Warning of a Climate Emergency paper (Ripple et al. 2020) now has approximately 15,800 signatories from 167 countries, and the project continues to collect signatures from scientists. To sign or learn more, visit the Alliance of World Scientists website at https://scientistswarning.forestry.oregonstate.edu. To read about science-based advocacy and view *A Scientist's Warning*, a documentary film on scientists speaking out, visit https://www.youtube.com/watch?v=byXGCPo-80w.

Supplemental material

Supplemental figures, tables, and methods appear in supplemental file S1 of this article. A list of the scientist signatories for Ripple and colleagues (2020) as of August 2025 appears in supplemental file S2 of this article. Note that these signatures are not for the current article.

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Received: August 10, 2025. **Revised:** August 16, 2025. **Accepted:** August 19, 2025