TMP

Intensifying Climate Impacts, Cascading Risks

How droughts, heatwaves and floods are already disrupting climate action – and what it means for Philanthropy

Contents

Executive Summary

Climate risk is now the single most powerful force shaping whether global climate action succeeds or fails. Extreme heat, drought and flooding are occurring with higher frequency, intensity and compound effects than planning systems, institutions and financing models are prepared for. These shocks are no longer episodic crises: they are the new operating conditions.

For philanthropy, this represents a structural shift. Climate impacts are not only humanitarian or environmental concerns – they directly determine the political, fiscal and economic space available for both climate mitigation and climate adaptation. Without deliberate philanthropic intervention, escalating physical risks will increasingly crowd out mitigation and adaptation efforts, destabilize fragile regions and lock vulnerable countries into cycles of crisis response rather than long-term transformation.

This report provides a near-term, systems-level assessment of three defining climate trends – intensifying drought, escalating heat extremes and rising flood risk – and examines how their interactions are reshaping food systems, energy transitions, infrastructure reliability, supply chains and geopolitical stability. It also proposes a new framing for philanthropic action that treats climate shocks not as external risks to be managed at the margins, but as core structural forces that are explicitly – and urgently – incorporated into funding strategies.

Climate risk is eroding the foundations of climate action

Across regions, climate shocks are undermining exactly the systems that climate action depends on. Drought is reducing hydropower reliability and constraining nuclear and thermal power generation, forcing countries to fall back on fossil fuels during crisis years. Extreme heat is lowering labor productivity, increasing health burdens and destabilizing electricity grids just as cooling demand surges. Floods are damaging infrastructure, disrupting trade and food supply, and increasing fiscal pressure as recovery costs rise and insurance markets retreat.

These dynamics directly affect philanthropy's theory of change. Climate shocks reduce governments' ability to invest in clean energy, adaptation and social protection. Repeated shocks fuel inflation, debt distress and political backlash – conditions under which climate ambition is often delayed, diluted or reversed.

The model–reality gap creates philanthropic blind spots

Most climate funding strategies still rely (explicitly or implicitly) on planning assumptions derived from climate models that lag behind observed reality. These models prioritize long-term averages and historical baselines, while philanthropic decisions increasingly need to account for near-term extremes, compound events and cascading systemic risk.

The result is a growing mismatch between where funding is deployed and where risk is emerging fastest. Without course correction, philanthropy risks:

- Overinvesting in adaptation approaches calibrated to outdated climate conditions.
- Underinvesting in emerging hotspots and compound-risk regions.
- Underestimating how quickly climate shocks can derail mitigation and development gains.

Climate shocks are both a threat and a leverage point

While escalating climate risk threatens stability, it also creates moments of accelerated change. Energy insecurity, food-system disruption and infrastructure failures can catalyze political and financial openness to new solutions – so long as capital and policy support are ready to move quickly.

Philanthropy is uniquely positioned to act at this frontier. Unlike public finance or private capital, it can move ahead of political consensus, absorb higher risk and support system-level interventions that protect long-term climate ambition during periods of acute stress.

Strategic implications for philanthropy

TMP's analysis points to four priority shifts in philanthropic strategy:

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1. **Fund adaptation for a world already under strain**
   Adaptation must succeed under worsening conditions, not in idealized scenarios. Philanthropy should prioritize real-time climate intelligence, anticipatory action, decentralized early-warning systems, heat resilience, water security and climate-smart food systems – especially where public institutions are overstretched.

2. **Protect mitigation pathways from climate disruption**
   Climate impacts increasingly undermine clean energy reliability, supply chains for critical minerals, and political support for decarbonization amidst claims that clean energy is "unreliable" or "too costly". Philanthropy can help by integrating resilience into clean energy planning, supporting demand-side efficiency, diversifying supply chains, and backing advocacy that safeguards climate ambition during economic and political shocks.

3. **Stabilize the energy transition's geopolitical and material foundations**
   Transition-critical supply chains are exposed to both climate risk and geopolitical fragmentation. Philanthropic support for responsible minerals governance, regional manufacturing capacity and community-centered just transition policies can reduce the risk that climate shocks derail decarbonization.

4. **Use crisis as a catalyst for green development**
   For many vulnerable countries, climate extremes threaten to lock economies into cycles of fiscal distress and stalled development. With catalytic finance and policy support, philanthropy can instead help accelerate investment in resilient infrastructure, climate-smart agriculture, green industrial policy and adaptation-linked job creation.

A decisive window for action

Climate change is accelerating. The next few years will determine whether escalating climate shocks fracture global stability or accelerate a transition toward resilient, low-carbon development. Climate risk will shape which mitigation pathways remain viable, where adaptation succeeds or fails, and which countries can build inclusive green economies.

For philanthropy, this demands a strategic realignment: funding that is faster, more flexible, more anticipatory and explicitly designed to operate in a world where climate shocks are not exceptions but constants. Aligning philanthropic capital with this reality is a prerequisite for sustaining meaningful climate action.

Introduction

Climate risk is no longer a distant concern: it is a clear and present force influencing the economic, political and operational context in which climate action must occur. Already at record levels, extreme events are accelerating more rapidly than is widely recognized, cascading across systems and outpacing existing planning tools. Managing climate change now demands a far more realistic understanding of these conditions.

Over the past two years, overlapping heatwaves, droughts and floods have disrupted trade, food systems and public infrastructure simultaneously. For example, drought in the Panama Canal has affected global supply chains,[1] while at the same time floods in East Africa[2] and Brazil[3] drove food price spikes and humanitarian crises. These shocks do not act in isolation: they propagate through global supply chains, energy markets and political systems, narrowing the space for effective climate action just as ambition needs to accelerate.

For the last decade, scientists have observed that climate change itself is accelerating.[4] Yet widely used climate models have struggled to keep pace with this reality.[5] Many models still prioritize high-confidence long-term averages, even as decision-makers are increasingly forced to operate in a near-term environment characterized by deep uncertainty and the rising frequency of high-impact, low-probability events. As a result, risks are systematically underestimated, warning windows are shortened, and adaptation strategies are often calibrated to conditions that no longer exist.

The implications of this modeling gap are far-reaching. Shorter and less reliable lead times reduce the effectiveness of early-warning systems and disaster-response planning. Sectoral decision-making – such as agricultural scheduling and reservoir operations – is increasingly based on assumptions that no longer hold. As a result, insurance risk is mispriced and budgets underestimate adaptation and emergency-response expenditures. Together, these factors strain budgets and pull capital away from mitigation efforts.

These dynamics increasingly threaten the feasibility and pace of climate action itself, both in terms of adaptation and decarbonization. Heat-driven power demand, drought-induced hydropower shortfalls, climate-linked supply-chain disruptions for critical minerals, and food price volatility all erode political and fiscal space for climate action. At the same time, climate shocks make global supply chains – particularly for critical minerals – more fragile, threatening the world's ability to decarbonize.

For countries in climate-vulnerable regions, these pressures risk locking economies into cycles of fiscal distress, food insecurity and stalled development. Yet they also create inflection points. If supported by more anticipatory decision-making and catalytic investment, the same stresses driving instability today could accelerate investment in resilient infrastructure, climate-smart food systems, clean energy and new green industries.

This report responds to this shifting reality, delivering a more nuanced and systemic view of three defining climate trends: intensifying drought, escalating heat and temperature extremes, and increasing flood risk. In doing so, it starts to fill a critical gap in the current knowledge landscape: the need for an integrated, near-term, systems-level assessment of the interconnected risks already shaping food systems, energy transitions, infrastructure, geopolitics and economic stability.

Climate risk is now the most powerful force shaping the feasibility, pace and equity of global climate action. It will determine which mitigation pathways are viable, where adaptation succeeds or fails, and which countries can build green, resilient economies. Philanthropy must therefore align its strategies to a world in which climate shocks are not exceptions but operating conditions. Funding decisions must be faster, more flexible, more anticipatory and more directly aimed at reducing vulnerability while safeguarding the political and economic space for ambitious climate action.

1 https://www.morethanshipping.com/the-panama-canal-and-the-drought-crisis-what-to-know/
2 https://disasterphilanthropy.org/disasters/2024-east-africa-flooding-cyclone/
3 https://www.internal-displacement.org/spotlights/brazil-floods-in-rio-grande-do-sul-trigger-record-displacement/
4 https://wmo.int/news/media-centre/rate-and-impact-of-climate-change-surges-dramatically-2011-2020
5 Please see the Annex for a more detailed explanation of the gap in climate modeling.

Intensifying drought risk

Since the beginning of the 21st century, the **frequency and intensity of drought events have increased in all continents.** TMP's analysis of the drought risk indicator SPEI48 shows that for the entire period 1986 to 2018, less than 4% of basins worldwide were subject to drought conditions. Since 2019, drought risk has risen to unprecedented levels each year, culminating in no less than 18.9% of basins suffering from drought conditions in 2024 – meaning almost 1 in 5 basins globally was in a state of long-term drought that year.

Case study

Brazil and intensifying drought

We also analyzed trends in SPEI48[6] levels in Brazil, one of the world's major agricultural producers and a critical exporter of maize and soy (both central to global animal feed production and global food security). The results show substantial increases in prolonged drought risk, with some basins experiencing rises exceeding 100% relative to the 1985–2014 baseline period to which agricultural systems are currently adapted.[7] This escalation has unfolded over the past decade and is likely to persist in the immediate and short term, affecting key production regions and posing particular risks to Brazil's soy sector.

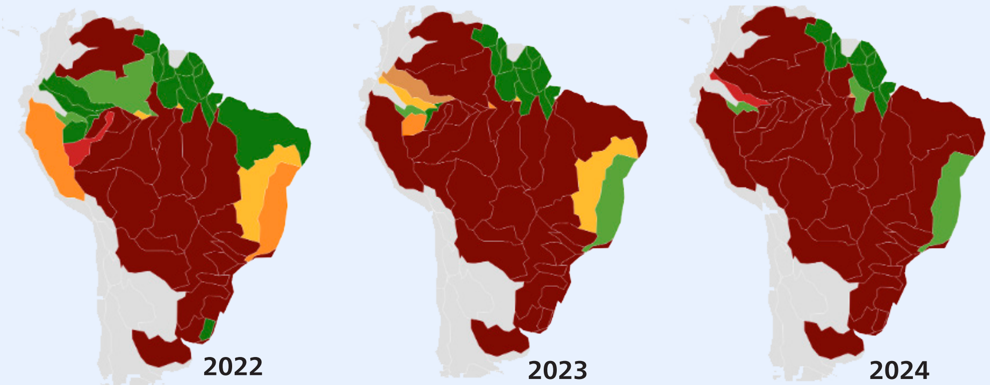
In 2023-2024, the Amazon River Basin experienced its most extreme drought to date.[8] By September 2024, water levels in many of the rivers in the Amazon basin reached their lowest on record.[9] This record drought **choked off river transportation**, reducing the volume of grain transport by about 40% and cargo to be rerouted to the south and southeast.[10]

In 2024, Hidrovias do Brasil suffered significant losses – estimated at US$ 114 million – due to drought conditions in the north and south corridors.[11] At the same time, the drought contributed to massive wildfires across the region.[12]

The erratic and unpredictable nature of the climate is likely to continue in the immediate (1-2 years) and short (2-5 years) term.

Rapidly increasing drought risk in Brazil's river basins

TMP's analysis of the increase in SPEI48 drought risk in Brazil's river basins, comparing 2022-2024 to a 1985-2014 baseline (Source: TMP/ERA5)



6 The 48-month Standardized Precipitation Index (SPI-48) is a meteorological drought indicator to monitor precipitation anomalies over 48-month accumulation periods and is a proxy indicator for long-term impacts, for example, reduced reservoir and groundwater recharge.

7 We spatially aggregate the risk data based on the WMOBB basins boundaries, as freshwater basins are a more relevant spatial boundary for agriculture, compared with administrative boundaries.

8 https://hal.inrae.fr/hal-05120509v1

9 https://www.bbc.com/news/articles/cd6qvpe0dxqo

10 https://agro.estadao.com.br/summit-agro/entenda-o-que-e-a-estiagem-e-quais-sao-seus-efeitos

11 https://agfeed.com.br/negocios/hidrovias-do-brasil-fecha-o-ano-no-vermelho-com-pressao-de-cambio-e-clima/

12 https://proinde.com.br/news/maritime-authority-guidance-to-ships-amid-amazons-hardest-drought/

Direct implications

Energy and infrastructure	Critical minerals	Agriculture	Trade
Persistent water deficits impact hydropower generation, nuclear power generation and municipal water supplies.	Droughts disrupt minerals supply chains, which require water for essential procedures including processing and extraction.	Droughts affect agricultural productivity including livestock and exacerbating food insecurity.	Shipping disruptions at drought-sensitive chokepoints (Panama, Rhine) lead to bottlenecks, delays and price shocks in logistics and trade.
In the summer of 2022, the French energy producer EDF had to reduce output at its nuclear power stations on the Rhône and Garonne rivers when reduced water levels and high river temperatures inhibited cooling.[13] As a result, in 2022 France's reactor fleet produced 282 TWh, well below the 10-year average of 395 TWh.[14] Although a part of this reduction was due to repairs, it still led to record net loss of €17.9 billion in 2022 for EDF.[15]	Dust control, the transportation and storage of slurry, and general site usage also depend heavily on water. Copper and lithium are particularly vulnerable to water stress given their high water requirements – especially since over 50% of today's lithium production is concentrated in areas with high water stress levels, while some 80% of copper output in Chile is produced in mines located in high water stress and arid areas.[17] This is expected to be 100% by 2040.[18]	In 2022, the EU's grain harvest decreased by 9%, and up to 32% in certain countries.[22] Drought stress negatively impacts plant productivity and quality, particularly during the plant's crucial growth phases.[23]	From 2022 to 2024, the Panama Canal suffered from severe drought conditions, which forced the canal to reduce transits and impose vessel weight restrictions to conserve water. The canal is critical to the U.S. economy and trade, handling about $270 billion in cargo every year.[25] Operations were reduced by a third during the drought, with ships having to queue for weeks or pay fees reaching US$4 million to jump the line.[26]
Hydropower is becoming unreliable due to repeated and increasingly severe droughts[16] with significant implications for countries including China, the US, Norway, Switzerland and Zambia as well as heavy industries including minerals production.	In 2024-2025, Zambia suffered a long-term drought. This impacted electricity generation capacity, forcing Zesco Ltd., the state-owned power utility, to request mining companies to cut power consumption by 40%.[19] This impacted production, with some actors being forced to temporarily reduce activity by up to 80%.[20] Copper production is a hard-currency earner, and the reduced production pushed Zambia's currency to record lows, straining its debt repayment capabilities.[21]	A recent study showed that drought reduced milk production and livestock holdings by 25.8% and 8.4%, respectively.[24]	The Yangtze river, one of the world's most important inland waterways, was affected by a prolonged drought in 2022, shrinking to half its normal size. The Mississippi river, the second most important inland waterway, transporting 600 million tonnes of goods every year, also experienced drought-induced bottlenecks in 2019 and again 2022.[27]

13 https://www.theguardian.com/business/2022/aug/03/edf-to-reduce-nuclear-power-output-as-french-river-temperatures-rise
14 https://world-nuclear.org/information-library/country-profiles/countries-a-f/france
15 https://world-nuclear.org/information-library/country-profiles/countries-a-f/france
16 https://www.nytimes.com/2025/11/17/business/energy-environment/brazil-hydropower-clean-energy-cop30.html
17 https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/reliable-supply-of-minerals
18 https://mining2030.org/wp-content/uploads/2024/10/Mining2030-Report-v9.pdf
19 https://www.averifinance.com/zambia-requests-mines-to-cut-power-use-by-40-percent
20 https://www.chemanalyst.com/NewsAndDeals/NewsDetails/zambia-copper-smelting-plant-downscales-output-amid-electricity-shortages-25841
21 https://www.reuters.com/markets/currencies/zambias-currency-stuck-record-low-drought-persists-2025-01-08/
22 https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20231108-2
23 https://www.arcjournals.org/pdfs/ijrsas/v10-i2/1.pdf
24 https://academic.oup.com/erae/article/52/2/240/8129594
25 https://www.cnbc.com/2025/09/13/panama-canal-drought-el-nino-climate-change-shipping-trade.html
26 https://www.waterpowermagazine.com/analysis/panama-canal-plans-new-dam-to-tackle-drought-and-secure-water-supply/?cf-view
27 https://www.lowyinstitute.org/the-interpreter/shipping-great-shrinking-waterways)

Escalating heat and temperature extremes

Extreme heat continues to set new records around the world. Europe and the Mediterranean have recorded exceptional summer temperatures, with Spain's summer 2025 the hottest on record. Copernicus/ ECMWF confirms 2024 as the hottest year globally, with persistent land and marine heat anomalies into 2025.[28]

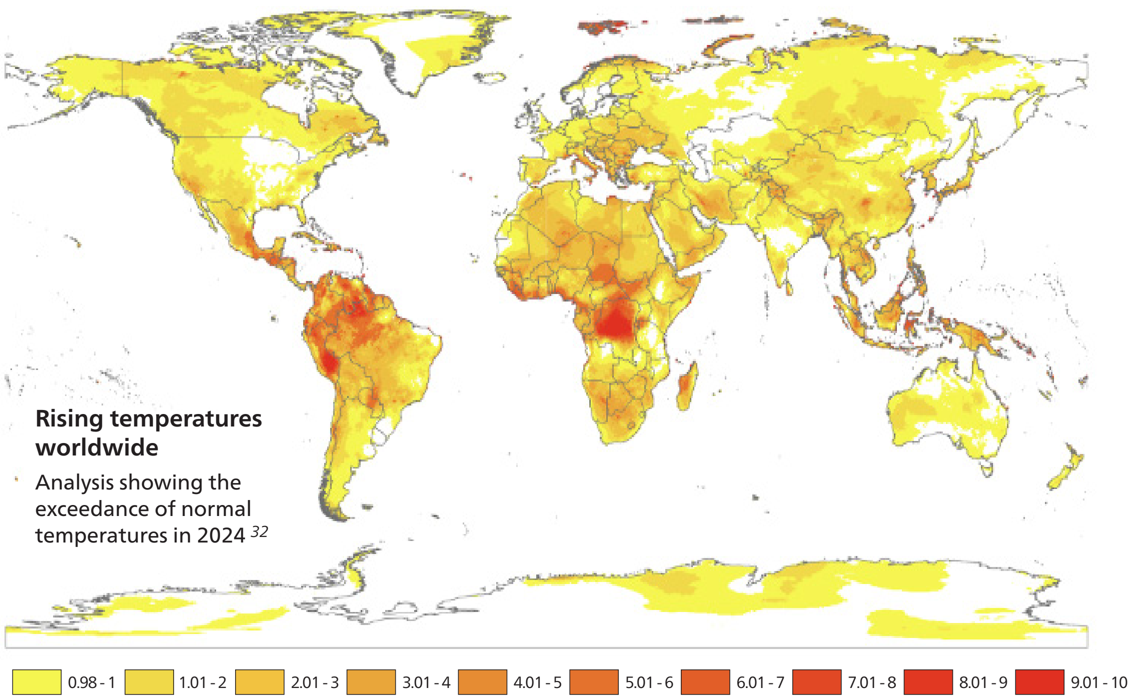
Heat is already depressing agricultural yields and intensifying health risks. Documented episodes include heat-linked crop stress in Asian rice belts[29] and sugar regions, as well as dangerous "wet-bulb" conditions in South Asia and the Middle East – pushing temperatures beyond what the human body can withstand and bringing parts of major cities to the brink of becoming unlivable.[30]

Case study

Global heat stress analysis

We analyzed the global risk of heat stress and found that many parts of the world are increasingly exposed to extreme heat in ways that climate models did not anticipate. This could disrupt key agricultural and mining productions, as well as fuel local conflict. Unsafe outside working conditions are becoming increasingly common, in some places exceeding 145 full days per year.[31]

Overall, we observe a decisive shift: extreme heat is no longer a seasonal event but a structural feature of the emerging climate regime. The erratic and intensifying nature of temperature extremes is expected to continue over the immediate (1-2 years) and short term (2-5 years). Extreme heat often occurs alongside drought in a mutually reinforcing cycle, increasing the likelihood of crop failures, grid stress, labor disruption and cascading economic impacts.



Rising temperatures worldwide

Analysis showing the exceedance of normal temperatures in 2024[32]

28 https://wmo.int/news/media-centre/wmo-confirms-2024-warmest-year-record-about-155degc-above-pre-industrial-level

29 https://www.iseas.edu.sg/articles-commentaries/iseas-perspective/2025-48-the-critical-impact-of-extreme-heat-on-rice-production-in-southeast-asia-by-elyssa-ludher

30 https://www.reuters.com/business/environment/how-is-climate-change-driving-dangerous-wet-bulb-temperatures-2023-08-09/

31 https://www.carbonbrief.org/more-than-half-a-trillion-hours-of-work-lost-in-2023-due-to-heat-exposure/

32 Source: Data – ERA5, analysis – TMP.

Direct implications

Energy and infrastructure

Rising global temperatures reduce operational capacity while increasing the demand for energy.

Electricity generation capacity of power plants is maximized at 27°C. Extreme heat can decrease the capacity of power plants by up to 10%.[33]

Infrastructure is also exposed: roads, railways and bridges can buckle, warp and expand,[34] increasing the risk of logistical disruptions.

Critical minerals

Critical minerals supply chains are exposed to extreme heat conditions, which can negatively affect the safety of mining operations.

Extreme heat conditions can negatively affect the health and safety of mining workers (e.g., via heat stroke and in extreme cases, fatality).[35][36] Increases in heat are connected to increases in conflict,[37] which has implications for mines' social license to operate. Conflict between local communities and mines, or in the broader operating environment, can disrupt operations.

Mining infrastructure is also vulnerable and presents an increased risk as there are often no alternative logistics routes close to mines.

Agriculture

High heat can cause yield losses and quality downgrades for heat-sensitive crops.

In rice, a key crop for global food security, a 1°C increase in average daytime temperature during flowering results in an average yield loss of 6%.[38] In wheat, even short episodes of drought or high temperature around flowering carry a risk of high yield losses. Depending on genotype, every 1°C rise in average maximum temperature above the optimum (25–30°C) can reduce yields by up to 20%.[39]

Extreme heat also correlates with increased irrigation needs. This exacerbates water stress – especially in areas where water availability is already constrained.[40]

Social and economic impacts

High heat impacts the health and safety of exposed populations.

Heat-exposed sectors (construction, agriculture, logistics) experience declines in labor productivity, with growing "heat stoppage" days. Labor losses are already evident in many sectors that require outdoor workers: a record 512bn work hours were lost around the world in 2023 because of the risk of heat exposure.[41] Under a 2°C scenario, heat-related labor loss is projected to increase by 50%.[42]

Heat stress contributes to higher mortality and morbidity, especially for vulnerable groups: outdoor workers,[43] the elderly,[44] expecting mothers,[45] infants[46] and those without access to cooling.

33 https://iopscience.iop.org/article/10.1088/1748-9326/abd4a8
34 https://www.dw.com/en/transport-infrastructure-adaptation-to-a-hotter-world-solutions-for-hot-summer-days/a-72563060
35 https://www.watoday.com.au/national/western-australia/rio-tinto-worker-dies-after-walking-for-hours-in-extreme-heat-looking-for-drill-sites-20211026-p5936z.html
36 https://pmc.ncbi.nlm.nih.gov/articles/PMC10941724/
37 https://www.nature.com/articles/s41586-019-1300-6 ; https://pmc.ncbi.nlm.nih.gov/articles/PMC10303254/ ; https://www.pnas.org/doi/10.1073/pnas.0907998106
38 https://www.sciencedirect.com/science/article/abs/pii/S0048969723038792
39 https://pmc.ncbi.nlm.nih.gov/articles/PMC12855381/
40 https://www.tse-fr.eu/sites/default/files/TSE/documents/sem2025/environment/bruno.pdf
41 https://www.carbonbrief.org/more-than-half-a-trillion-hours-of-work-lost-in-2023-due-to-heat-exposure/
42 https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(23)01859-7/fulltext
43 https://hsph.harvard.edu/environmental-health/news/heat-stress-impacts-workers-and-the-bottom-line/
44 https://www.nature.com/articles/s41467-024-47197-5
45 https://www.sciencedirect.com/science/article/pii/S1871519225000654
46 https://www.lshtm.ac.uk/newsevents/news/2024/first-evidence-suggests-heat-stress-may-still-affect-babies-once-born

Increasing flood risk

Over the past five decades, the global frequency of floods has sharply increased, with annual flood events rising nearly fivefold since the 1970s.[45] The impacts, however, are highly uneven and region-specific. South and East Asia continue to account for the majority of global flood disasters, with Bangladesh, India, China and the Philippines recording some of the world's highest mortality and economic loss rates.

But the pattern is spreading. In 2024 alone, major floods inundated parts of the United States (California, Vermont), Europe, China (Guangdong, Hunan), Brazil (Rio Grande do Sul) and East Africa (Kenya, Somalia), often triggered by short-duration extreme rainfall that exceeded local drainage and river-system capacity.[46, 47, 48, 49, 50]

Observation data confirms the rising intensity of short-duration extreme rainfall, with increasing coincidence of heavy rain, snowmelt and cyclonic events causing compounding floods.[53] El Niño–La Niña oscillations have intensified rainfall variability, producing concurrent floods and droughts within the same hydrological basins.[54] This is especially dangerous, as heavy downpours during dry seasons or after a period of drought are more likely to lead to damaging flooding,[55] especially combined with an increasing number of unseasonal wet/dry episodes, including in traditionally dry places.[56]

Yet, climate models are still catching up. We analyzed flood risk in Indonesia, the largest producer of nickel – a metal that is crucial for decarbonization.

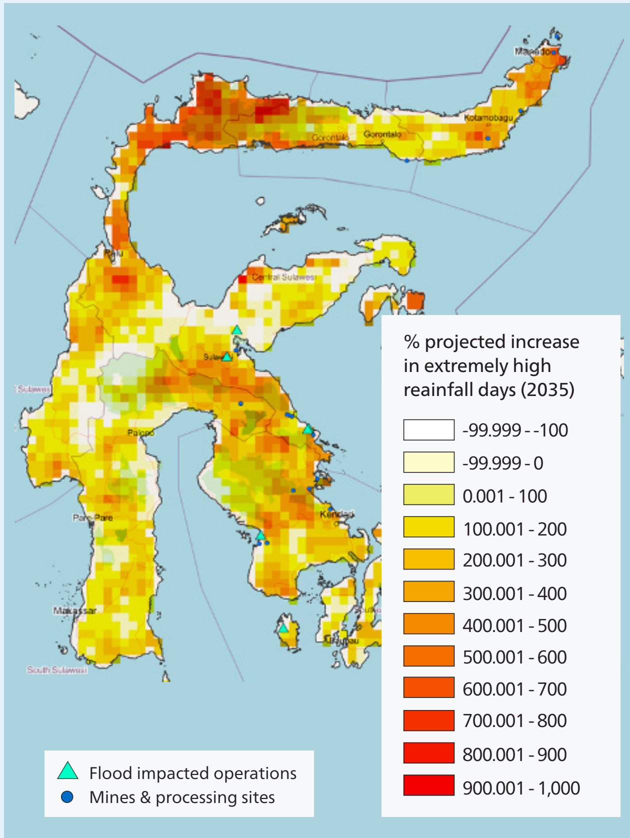
47 https://www.pnas.org/doi/10.1073/pnas.2206188120
48 https://edition.cnn.com/2024/10/25/weather/record-numbers-of-an-extreme-warning-show-the-reality-of-climate-change
49 https://www.lemonde.fr/en/environment/article/2025/04/15/europe-massively-affected-by-effects-of-climate-change-in-2024-study-finds_6740228_114.html
50 https://www.theguardian.com/world/article/2024/aug/02/china-flooding-record-weather
51 https://agupubs.onlinelibrary.wiley.com/doi/
52 https://disasterphilanthropy.org/disasters/2024-east-africa-flooding-cyclone/full/10.1029/2024GL112442
53 https://pmc.ncbi.nlm.nih.gov/articles/PMC8366905/
54 https://www.nature.com/articles/s41467-025-64619-0
55 https://floodriskamerica.com/blog/why-floods-follow-periods-of-drought/
56 https://www.researchgate.net/publication/395794191_Global_Increases_in_Dry-Wet_Abrupt_Alternation_Events_Under_Climate_Change

Case study

Flooding in Sulawesi, Indonesia

TMP analyzed ERA5 observational data and compared recent conditions with projected changes in flood risk for Sulawesi, Indonesia. The results show that flood frequency is rising far faster than climate models anticipated: in 2024 alone, Sulawesi experienced 273 flood events. In other words, the region is already encountering levels of flood risk well beyond what should be occurring at the current stage of global warming – leaving local mines, smelters and surrounding communities unprepared.

Moreover, the trend is accelerating. Our data indicate that many parts of Sulawesi are likely to experience **more than a 100% increase in flood risk by 2035, with some areas exceeding a 400% increase.** This trajectory heightens the exposure of communities, infrastructure and mining operations to tailings dam failures, contamination hazards, damaged roads and landslides.



Flood risk in Sulawesi, Indonesia
% increase in extremely high rainfall days by 2035

Direct implications

Energy and infrastructure

Flooding can damage critical infrastructure and transport routes, and render homes and other private property uninsurable.

Flooding can significantly damage transport infrastructure or utilities like electricity, gas and water supply, significantly affecting individuals and communities.[58] Floodwater is often contaminated with pollutants such as agricultural pesticides, industrial chemicals, debris and sewage. During intense floods, water supply is typically contaminated, leaving inhabitants with no access to drinking water.[59] These pollutants can damage riverine or marine ecosystems, further impacting local livelihoods.

Climate-linked damages to housing and other private property have become so frequent and catastrophic that insurers are pulling out of high-risk markets. In the US, dozens of insurers have collapsed or been declared insolvent following searing wildfires and catastrophic hurricanes.[60] In 10 or 15 years, there may be entire regions where aspiring homeowners cannot get a mortgage because homes are uninsurable.

Critical minerals

Floods can cause major disruptions to critical minerals operations via damage to infrastructure (e.g., access roads, equipment), tailings failures[57] and associated downtime.

Flooding is the top driver of negative financial impact on global mining operations, accounting for 20% of this impact.[61] In September 2025, rainfall triggered a catastrophic mud rush at Indonesia's Grasberg mine, killing seven workers and suspending production at the facility, which supplies more than 3% of global copper output, until 2027.[62]

Flooding can also cause tailings dam failures and large-scale environmental damage. Tailings pond failures occur almost every year, but in recent years the frequency has been gradually increasing. Most tailings pond failures are directly related to heavy rainfall or earthquakes.[63]

Agriculture

Flooding can cause damages to agricultural production and/or reduced quality.

Floods damage crops and reduce yield and quality. In September 2025, Pakistan experienced significant flooding due to an intense monsoon season and dam releases from India, damaging about 50% of rice and 60% of cotton and maize crops.[64]

Heavy rainfall, even if short-lived, can also complicate harvests, particularly for mechanized crops. Early studies suggest that changes in land cover may contribute to or exacerbate this effect.[65]

Social and economic impacts

Floods can trigger mass displacement and shrink fiscal space for spending on government programs.

Floods are a major source of human displacement,[66] especially when resulting from storms. Twenty years of near-annual storms and flooding have plunged Haiti into poverty and conflict, resulting in the displacement of nearly 1.4 million people.[67] Migration from Senegal's western and central regions to the US increased after more than half a dozen major floods occurred in 2020.[68]

Fiscal space for adaptation narrows in lower-income countries when repeated climate events increase recovery and reconstruction costs. Following the 2022 floods in Brazil, total recovery and reconstruction costs from public funding exceeded $351 million.[69] Damages from storm-related floods are even more costly: Hurricane Harvey racked up $160 billion in damages. The retreat of insurers could further worsen the fiscal burden of paying for climate change, which is increasingly being transferred to already-strained public budgets.

57 https://www.sciencedirect.com/science/article/pii/S0013795222001429
58 https://aafloods.eu/transport-infrastructure-damaged-by-floods-has-a-detrimental-impact-on-recovery-the-irish-experience/
59 https://sevenseaswater.com/flooding-threatens-water-quality/
60 https://e360.yale.edu/features/climate-change-home-insurance
61 https://cdn.cdp.net/cdp-production/cms/reports/documents/000/004/613/original/CDP_Metals_and_mining_report_2019.pdf?1561049112
62 https://www.mining.com/web/graphic-grasberg-mine-accident-tightens-global-copper-supply-estimates/
63 https://www.mdpi.com/2075-4701/12/6/905
64 https://www.reuters.com/sustainability/climate-energy/pakistan-floods-batter-fields-factories-fiscal-plans-2025-09-23/
65 https://eos.org/articles/more-intense-rains-in-u-s-midwest-tied-to-farm-mechanization
66 https://www.pnas.org/doi/10.1073/pnas.2206188120
67 https://www.iom.int/news/displacement-haiti-reaches-record-high-14-million-people-flee-violence
68 https://www.theguardian.com/environment/2025/oct/22/climate-disasters-migration-new-york
69 EMDAT database - https://www.emdat.be/

Systemic and cascading risks

The direct impacts of intensifying drought, escalating heat extremes and rising flood risk only tell part of the story. The next decades depend on understanding how climate shocks cascade across systems to create interconnected geopolitical, social and other risks.

By their very nature, cascading risks resist neat classification. Through one lens, drought-induced agriculture losses look like a food security problem – before you consider their multiplier effect on conflict. By the same token, heat-induced blackouts can look primarily like energy risks – until they start knocking hospitals offline. For the sake of this document, we've grouped cascading risks into five categories: stability and security, health, economy and trade, energy and infrastructure, and compound-event amplification. We've also noted some of the areas where they overlap.

Compound-event amplification

- When floods coincide with heatwaves or storm surges, cascading failures can disrupt electricity grids, water treatment and logistics simultaneously, creating the 'perfect storm' for a humanitarian disaster.
- Heat extremes alter atmospheric circulation, intensifying precipitation volatility – producing alternating floods and droughts within the same year.
- In drought-to-flood sequences, burned or desiccated soils from heat-induced wildfires lose permeability, making subsequent storms more destructive and increasing flash-flood losses.
- These compound climate events (heat → fire → erosion → flood → pollution) degrade ecosystems, contaminate water supplies and undermine agricultural recovery, perpetuating economic fragility and heightening social tensions.

Drought Risk | Heat Risk | Flood Risk

Case study

Heat impacts on agricultural labor in Punjab, Pakistan

In 2022, extreme heat above 45°C swept Punjab, triggering heat-related illness, crop losses and livestock deaths. Soon after, unusually heavy monsoon rains caused devastating floods that destroyed infrastructure and farmland, displacing millions.

Labor loss and income impact

Pakistan lost an estimated 26 billion labor hours (67%) to extreme heat in 2022 — a 115% increase from the 1990s – equal to US $16 billion, or 4.4% of GDP.[70] High temperatures reduce capacity for fieldwork, forcing workers to slow down or stop during peak hours, cutting harvested area, yields and wages. Informal and daily-wage laborers are hit hardest, unable to shift schedules or afford breaks. Severe heat also accelerates water evaporation, intensifying irrigation stress.[71]

Agriculture employs 42% of Pakistan's workforce and contributes 23% of GDP, while agro-based exports account for 80% of export earnings. Labor and yield losses weaken rural incomes, slow consumption and strain public finances. Falling tax revenue and rising relief costs limit investment in adaptation – reinforcing a cycle of vulnerability.

70 https://www.thefridaytimes.com/16-Nov-2023/high-heat-exposure-for-labour-cost-pakistan-dollar-16b-in-lost-income-in-2022
71 https://www.himalmag.com/politics/multan-punjab-farmers-heat-climate-crisis-health-livelihoods-agriculture

Economy and trade

Recurrent canal and river disruptions push firms to redesign global logistics networks, often adopting more carbon-intensive options. During the **severe low water** period of 2018,[72] German firms' exports along inland waterways fell by almost 20%, with emission-intensive road exports picking up the slack. Firms continued to avoid inland waterways shipping even after water levels returned to normal.[73] Restrictions of canal and river trade do not happen in a vacuum, but compound with other existing issues and restrictions – e.g., the Red Sea crisis.[74] However, more significant restructuring is to be expected in the next several years, particularly as new routes become available (e.g., the Arctic shipping route).

Commodity price spikes from disrupted food and energy supply chains worsen debt burdens in import-dependent economies and raise inflation volatility. Zambia's recent drought-induced maize shortages and fuel import costs drove sharp spikes in food and energy prices, pushing inflation into double digits. The resulting increase in borrowing costs deepened the country's debt stress, especially given the reduced export revenues due to disruptions to hydropower and thus mining production.

72 https://www.cleanenergywire.org/news/consequences-2018-drought-linger-germans-increasingly-see-climate-major-issue
73 https://www.cleanenergywire.org/news/short-term-climate-impacts-permanently-change-waterway-supply-chains-report
74 The Red Sea is a critical conduit for 30% of the world's container traffic, but saw a 50% decrease in shipping volume in 2024 due to attacks on commercial vessels. https://blogs.worldbank.org/en/developmenttalk/navigating-troubled-waters--the-red-sea-shipping-crisis-and-its-

Health

Overlapping heatwaves spread across continents, causing power demand and emergency admissions to surge simultaneously. Fragile grids buckle under the strain, resulting in blackouts that expose more people to extreme heat. In Iraq, recent summers have seen temperatures as high as 50°C, causing drought- and heat-induced migration towards cities, which further increases the demand for air conditioning. This puts additional strain on grids and leaves hospitals dealing with regular power outages despite having private generators.[75]

Floods accelerate outbreaks of waterborne diseases caused by contaminated water (e.g., cholera, leptospirosis) and vector-borne diseases spread by mosquitoes, which lay their eggs in standing water (e.g., dengue, malaria).[76] Displacement increases. Emergency and healthcare systems are overwhelmed.

Droughts and floods undermine food systems, driving malnutrition and food contamination. In East Africa, four consecutive failed wet seasons have caused crop failure and livestock death, leading to acute malnutrition for more than 2 million Kenyans.[77] The latest October-December wet period ranked among the driest ever recorded. At the same time, flooding can cause widespread agricultural damage, especially when water is contaminated with sewage or heavy metals. Floodwater is a carrier of biological, chemical and physical hazards affecting food safety and, in the case of recurring flood events, can cause long-term damage due to persistence of microbial pathogens in soils, water sources and processing environments.[78]

75 https://www.theguardian.com/global-development/gallery/2025/apr/15/faintings-blackouts-violence-iraqs-scorching-emergency-extreme-weathe
76 https://pmc.ncbi.nlm.nih.gov/articles/PMC11627491/
77 https://www.aljazeera.com/gallery/2026/2/10/severe-drought-leaves-over-two-million-kenyans-hungry-and-desperate
78 https://connectsci.au/ma/article/44/4/185/74215/Flooding-adversely-affects-fresh-produce-safety

Energy and infrastructure

Hydropower variability undermines clean energy reliability, forcing countries that lack sufficient clean energy from other sources to fall back to fossil fuels during drought years, raising emissions and energy insecurity.[79] During the 2022-2023 drought in China, emissions rose nearly 8% as it compensated for the loss of hydropower.[80] Nuclear energy production, which needs water for cooling, is also at risk of becoming unsustainable, not least in European contexts where major rivers including the Rhine, the Danube and the Rhône are experiencing declining water levels and rising temperatures.[81]

Flooding of ports, highways and power facilities interrupts supply chains and compounds energy shortages. Chronic inundation risks could render key coastal ports inoperable by 2050.[82] Effective responses to these challenges include relocating assets and investing in adaptation engineering. In all cases, these responses will increase costs without entirely protecting reliable operations, with significant implications for 'just-in-time' logistics models.

In drought-prone regions, water-intensive digital infrastructure such as semiconductors and data centers face production and cooling constraints, adding systemic vulnerabilities. The exposure of data centers to water stress is projected to be high in the 2020s, especially in Middle Eastern countries, Belgium, Greece, Spain, Chile, Peru and Mexico. Up to 43% of data centers globally are expected to face high water-stress that impacts operations.[83] At the same time, data centers exacerbate water scarcity, even in regions where water is abundant.[84]

79 https://www.pnas.org/doi/10.1073/pnas.230039512
80 https://www.france24.com/en/live-news/20231006-drought-caused-historic-global-hydropower-drop-in-early-2023
81 https://www.sciencedirect.com/science/article/pii/S0301421525001387
82 https://www.meinsurancereview.com/Magazine/ReadMagazineArticle?aid=47565
83 https://www.spglobal.com/sustainable1/en/insights/special-editorial/beneath-the-surface-water-stress-in-data-centers
84 Large data centers can consume up to 5 million gallons per day, equivalent to the water use of a town populated by 10,000 to 50,000 people. This is in addition to issues with water quality that have been observed in many communities living near data centers. In the US alone, over 1,240 data centers have been either built or approved for construction by the end of 2024, impacting the availability of fresh water across the country.

Stability and security

Geopolitical impacts

The complex nexus between water scarcity, worsened by drought, and conflict is well documented. In Algeria, water shortages contributed to riots,[85] and conflicts over water reached all-time highs in 2023 and again in 2024.[86]

Prolonged heat also pushes communities, farmers and industries into conflict over water allocation. In the Indus, Euphrates, and Nile basins, record temperatures coincide with shrinking reservoirs, reviving long-standing interstate and local tensions (e.g., India-Pakistan canal disputes, Ethiopia–Sudan–Egypt Nile negotiations).

Water availability is also used as a strategic lever in conflicts. Russia regularly targets dams and other water sources in Ukraine.

Social conflict

Chronic drought in transboundary basins (e.g., the Nile, Indus) intensifies migration toward urban centers, exacerbating sociopolitical stress.

Globally, water stress is linked to increased likelihood of social conflict.[87]

Wildfires caused by extreme heat exhibit a similar pattern. In southern Europe and north Africa, wildfires have destroyed agricultural land and forests that act as rural safety nets, displacing populations, intensifying urban unemployment and raising the risk of social unrest.

Food security

Heat-driven crop failures reduce exports and drive domestic price spikes, especially in import-dependent states (e.g., Middle East, North Africa), heightening the probability of "bread-price" protests like those seen during past heat-induced harvest shocks.

Floods in major breadbaskets (e.g., China, Brazil) disrupt global grain and commodity markets, amplifying volatility and undermining food security in these same import-dependent regions. Food price volatility is at an all-time high and has continued to rise in the past five years.[88]

Soils saturated by flooding cause crop losses that drive long-term land-use shifts, threatening to lock in lower productivity or the abandonment of fertile deltas. At the same time, pressure increases on already over-populated areas.

Drought affects the food production sector due to its high dependence on water resources. Between 2008 and 2018, droughts caused over 82% of damages to the food production sector across low- and middle-income countries.[89] Currently, the EU loses about €28.3bn in lost crops and livestock per year, with more than half of the losses being caused by drought.[90]

85 https://apnews.com/article/algeria-drought-rain-tebboune-tiaret-riots-09ce23f4ba235aaf1e3afecc7bfe3574
86 https://www.latimes.com/environment/story/2025-11-26/la-enviro-violence-over-water
87 https://www.sciencedirect.com/science/article/abs/pii/S0095069622000171
88 https://www.foodsecurityportal.org/tools/excessive-food-price-variability-early-warning-system
89 https://openknowledge.fao.org/handle/20.500.14283/cb3673en
90 https://www.fi-compass.eu/library/market-analysis/insurance-and-risk-management-tools-agriculture-eu

Case study

Cascading impacts and feedback loops resulting from drought in Germany

The Rhine's disruption hit Germany amid a post-pandemic slowdown, high energy prices from the Ukraine war, and declining export competitiveness with China – turning a climate event into a systemic macroeconomic impact that reduced industrial output and deepened recessionary pressures.

Economic contagion: When Rhine shipping halts, German factories – especially in chemicals (BASF), steel and auto manufacturing – face delivery delays and surging input costs. These industries anchor EU value chains; disruption propagates through to Italy, France and Central Europe. Higher freight and energy costs contribute to inflation across the Eurozone.

Fiscal and financial risk: Repeated climate-linked disruptions increase public expenditure on relief and infrastructure retrofits while simultaneously reducing industrial tax revenues. Such shocks, if recurrent, could deepen the country's structural fiscal imbalance, currently projected to be at -1.8% in 2026 before rising to 1.1% in 2031.[91] Insurance markets have a tendency to withdraw coverage from high-risk sectors, potentially shifting financial liabilities onto public budgets – and amplifying sovereign risk exposure.

Strategic and geopolitical implications: Germany's export competitiveness already faces structural pressure from China's dominance in green tech (EVs, batteries, solar). If climate disruptions undermined industrial performance and drove higher input prices, Europe's reindustrialization agenda and green transition funding could come under stress.

Political impacts: Industrial slowdown and rising living costs from climate-driven inflation fuel public frustration, which populist and climate-skeptic parties exploit. In Germany, the AfD's regional gains in 2024[92] coincided with periods of high energy and transport costs.

Feedback loop: As fiscal and political constraints grow, investment in climate adaptation and infrastructure resilience risks being deferred, increasing the likelihood of future shocks – a classic adaptation trap where short-term austerity undermines long-term stability. Similarly, decarbonization plans and investments in energy transition might receive pushback in times of economic downturn, pushing the world towards a warmer, riskier future.

91 https://www.bruegel.org/policy-brief/what-germanys-medium-term-fiscal-plan-means-europe
92 https://www.theguardian.com/world/2024/sep/22/far-right-afd-eyes-further-electoral-gains-in-key-german-state-of-brandenburg

Case study

Systemic and cascading flood risk in Sulawesi, Indonesia

Global nickel demand is projected to nearly double from 2024 to 2035, driven by the energy transition. Indonesia, the largest holder of nickel reserves as well as a leading producer, occupies the driver's seat of global nickel production, especially since its nickel export ban was implemented in 2020. At the same time, the country has recorded a significant increase of extreme weather events. As climate change intensifies, the combination of physical risks like flooding and growing environmental, social and governance (ESG) pressures is turning what were once compliance issues into a complex and cascading risk for Indonesia's critical minerals supply chain.

Extreme weather induced tailings landslide. In 2025, heavy rainfall triggered a tailings landslide at Indonesia Morowali Industrial Park (IMIP), killing three workers. Operations were halted and gradually restarted at 70% to 80% of capacity one month after the incident.

Threatened Social License to Operate. The IMIP incident was extreme, but it wasn't rare. Treating extreme weather events as isolated, short-term occurrences overlooks the cascading nature of climate change and ESG-related risks which, over time, can influence companies' social license to operate.

In Sulawesi, the heart of Indonesia's nickel industry, flood incidents surged from 67 in 2016 to 273 in 2024. In the same timeframe, mining-related protests and conflicts climbed from 6 cases to 35, reflecting rising community concern over environmental and social impacts.

Conclusion

The trends outlined in this analysis – climate models lagging behind reality, intensifying precipitation shocks and escalating global heat – are already reshaping the economic, political and operational landscape in which climate action must occur. Adaptation will have to succeed under duress. For philanthropy, the implications are clear: the next five years will determine whether climate shocks derail global stability or catalyze a decisive pivot toward resilient, low-carbon development.

First, these trends demand a fundamental upgrade in global adaptation and resilience capacity. Traditional planning tools, outdated climate baselines and slow-moving institutions are no match for the speed and scale of emerging extremes. Philanthropy must push for – and directly fund – systems that deliver real-time climate intelligence, anticipatory action and rapid response, especially in regions where public institutions remain overstretched. Investments in heat resilience, urban cooling strategies, decentralized early-warning systems, resilient water and food systems, and smallholder inclusion will determine whether billions of people face recurrent humanitarian crises or disruptive but fundamentally manageable challenges. The window to prevent chronic adaptation failure and ongoing maladaptation is closing.

Second, these climate shocks threaten to stall mitigation progress unless philanthropy intervenes strategically. Drought-driven hydropower shortfalls, heat-induced grid instability, disrupted minerals and technology supply chains, and climate-linked food price volatility all risk eroding political space for decarbonization. Although the operating environment is becoming increasingly complex, climate impacts are not always an active constraint. They can present an opportunity for philanthropy to shape mitigation outcomes if investments are made accordingly. This means accelerating demand-side efficiency, integrating resilience into clean-energy planning, supporting community-centered just transition policies, and backing advocacy that protects climate ambition during periods of economic and political stress.

Third, the energy transition is becoming more geopolitically fragile and materially constrained. Supply chains for solar, batteries, and transition minerals are now exposed to climate-linked chokepoints at the same time as geopolitical fragmentation. Philanthropic action should work to strengthen regional manufacturing capacity, diversify supply chains, support responsible minerals governance, and build political coalitions for resilient clean-energy deployment.

Finally, climate extremes are redefining the pathways for green economic development. For many countries, escalating heat, water scarcity, crop losses and supply-chain disruptions could lock economies into cycles of fiscal distress, food insecurity and stalled industrialization. But backed by catalytic finance and strategic policy support, these same pressures can accelerate investment in green industries, resilient infrastructure, climate-smart agriculture, local value addition for transition minerals, and new adaptation-related job markets. Philanthropy has a critical role in tapping into the opportunities for systemic transformation that arise from climate change.

Climate risk is now the most powerful force shaping the feasibility, pace and equity of global climate action. It will determine which mitigation pathways are viable, where adaptation succeeds or fails, and which countries can build green, resilient economies.

Philanthropy must therefore align its strategies to a world in which climate shocks are not exceptions but operating conditions. Funding decisions must be faster, more flexible, more anticipatory and more directly aimed at reducing vulnerability while safeguarding the political and economic space for ambitious climate action.

This report is the first in a series examining the direct and cascading risks of three defining climate trends: intensifying drought, escalating heat extremes and rising flood risk. Future reports will focus on critical minerals and geopolitics respectively.

To discuss the findings of this report and their implications for your funding strategy, as well as for philanthropy more broadly, please contact TMP by emailing ivana.pavkova@asktmp.com to arrange a conversation with our team.

TMP is a global group of experts tackling complex climate, social, environmental and security challenges. Founded in 2009, we're the only organization completely focused on the convergence of these problems over the next 10 years. Our unique datasets, ground-level research and advanced analytical methods have helped stakeholders in 60 countries prepare for climate impacts in the near term. Find out more at asktmp.com.

Annex: Gaps in climate modeling

Climate data comes in two main forms: observations (what has happened) and projections (what models estimate will happen). Projections rely on Global Climate Models (GCMs) — complex simulations of interactions between the ocean, atmosphere, and land. While GCMs provide credible estimates of long-term change at continental scales,[93] they are less effective for understanding near-term, local risk.

1. Resolution limitations.

a. Geographic: The results of GCMs are too coarse (resolutions of ~250-600 km)[94] to model risk effectively for local decision-making. Dynamic downscaling to a higher resolution introduces additional uncertainty. In comparison, the ERA5 observation data, used by TMP, is available at resolutions of 0.25 degrees (~27-28 km).

b. Temporal: GCMs are designed to capture long-term averages and broad spatial patterns, not short-term or fine-grained temporal variability. As a result, GCMs can underestimate the timing, duration, and intensity of short-lived but high-impact events, which creates a blind spot for planning.[95]

2. Outdated source data.

Most projections draw from the Coupled Model Intercomparison Project Phase 6 (CMIP6), which uses historical data only up to 2014. Since then, climate change has accelerated dramatically — the ten hottest years on record have all occurred in the past decade[96] — yet this recent behavior is not reflected in CMIP6 outputs.

3. Growing model–reality gap.

Comparisons between CMIP6 projections (2015–2025) and observed data show that many climate impacts have outpaced expectations. Recent years have brought unprecedented heat and marine temperature spikes in the North Atlantic and Pacific, along with persistent heatwaves and drought–flood cycles that most models failed to capture in scale or frequency. The result is widening climate uncertainty: models remain accurate about long-term warming trends but increasingly miss the timing and severity of the disruptions now shaping global risk.

Overall, current climate models are increasingly divorced from reality. This introduces an added layer of uncertainty into an already changing world.

93 https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter8-1.pdf
94 https://www.ipcc-data.org/guidelines/pages/gcm_guide.html
95 For instance, a GCM might predict "wetter conditions" over a region for a given decade, yet fail to capture that rainfall increasingly arrives in shorter, more intense bursts separated by longer dry spells — a change that has enormous implications for agriculture, water management, and disaster response.
96 https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

Mean Daily TX Increase at 1.5°C Warming

CMIP6 consensus increase in °C annual increase over 1995-2014 baseline of TX. Warming in °C above 1850-1900 (Source: IPCC WGI IA)

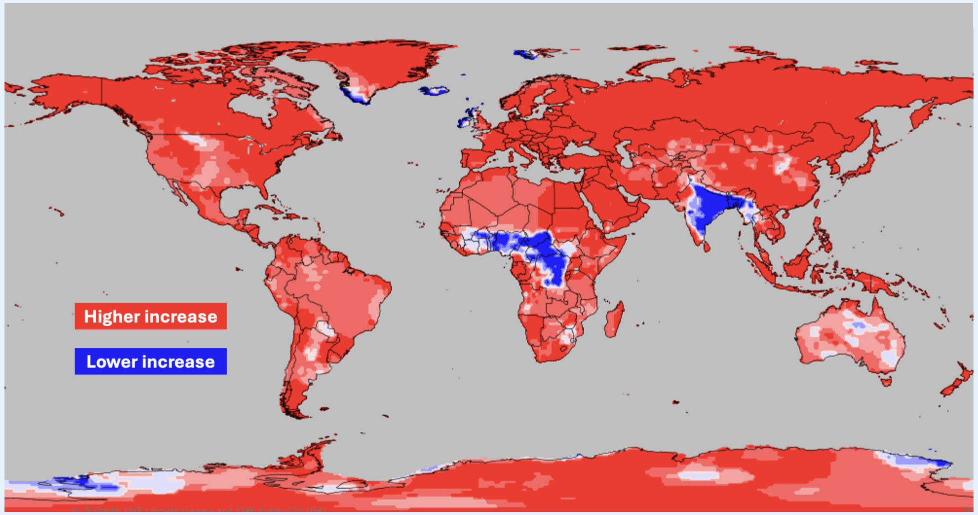


Figure A1. A map showing the CMIP6 projections of average daily maximum temperature at 1.5℃ compared to a 1995-2014 baseline.

TX change at 1.5°C

"2015-2024" scenario

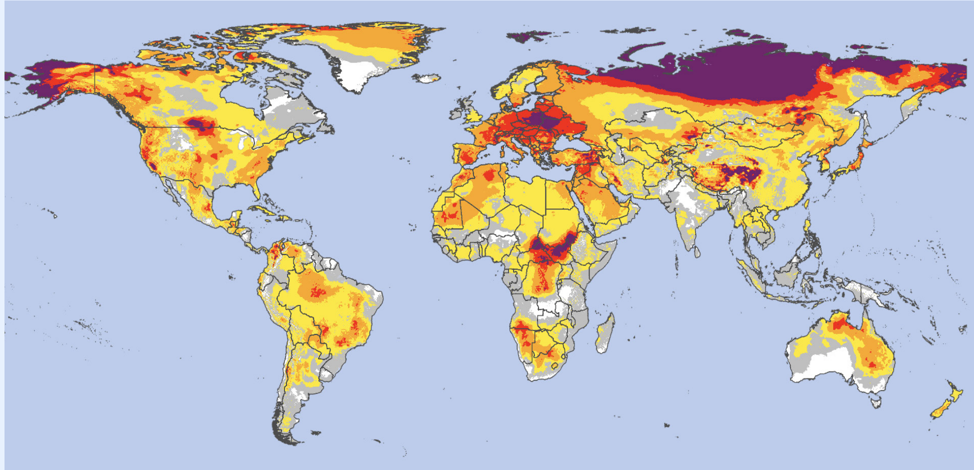


Figure A2. A map showing TMP's projections of average daily maximum temperature at 1.5℃ based on the 2015-2024 trend. Areas in white and grey are expected to behave similarly to what CMIP6 projections suggest. Areas in yellow, orange, red and purple are expected to overshoot the expectations.

