Lost & Damaged
A study of the economic impact of climate change on vulnerable countries

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christian aid

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Cover: A farmer in Sudan. Sudan tops the list of countries expected to suffer economic harm due to climate change. Photo by Albert Gonzalez Farran – UNAMID

Executive Summary

Developing countries are bearing the brunt of climate change even though they have contributed least to the problem - making loss and damage a matter of justice. Extreme weather events and slow onset events are already resulting in loss and damage, both economic and non-economic. These are certain to increase as the climate changes further; but the extent of the increase will be determined by decisions taken now on mitigation. Put simply: the more developed nations do now to cut their own emissions and support the developing world to do the same, the lower the bill they will eventually face for loss and damage.

International climate negotiations, such as those taking place at COP26 in Glasgow, focus heavily on emissions cuts and climate finance, to fund adaptation and the energy transition out of fossil fuels. But because climate change is already causing economic damage, Lower Income Countries (LICs) and Small Island Developing States (SIDS) are increasingly calling for loss and damage to be genuinely recognised as the third pillar under the Paris Agreement alongside mitigation and adaptation. The permanent losses and damages which cannot be adapted to, and that arise from existing and already-inevitable impacts on the climate system, need to be paid for. These can include loss of home, land, livelihoods and even life.

Although the human cost is clear, it can be difficult to assign precise costs to loss and damage, given there have been few studies quantifying its impact on the countries most affected. Individual examples can be cited, such as islands lost completely to sea level rise or farms lost to desertification, and increasingly, the voices of people suffering from loss and damage are being heard.

Here we showcase estimates which paint the likely extent of economic damage to the world's poorest and most vulnerable nations in two possible futures. In one, governments take swift action to constrain emissions, putting the world on track to delivering the Paris Agreement goal of limiting global warming to 1.5°C by the end of the century. In the other, they do not, instead sticking with existing policies – which are projected to lead to global warming of about 3°C in 2100[1]. This study estimates the economic damage caused by climate change by modelling the negative impact on GDP for countries that make up two key negotiating blocs at the UNFCCC, the Least Developed Countries (LDCs) and Alliance of Small Island States (AOSIS), and those that are members of the Climate Vulnerable Forum (CVF).[2]

The findings make for stark reading. Under current climate policies, on average, these countries can expect to see climate change reducing their GDP by 19.6% by 2050 and by 63.9% by 2100. If governments limit global heating to 1.5ºC then the damage is reduced but remains significant. In a 1.5ºC world these nations will see GDP hit by 13.1% by 2050 and 33.1% by 2100.

African countries will face the brunt of this economic harm with Sudan topping the list with an -83.9% GDP impact by 2100 under current polices. Even with a Paris Agreement-aligned 1.5ºC future it will see a climate-induced GDP hit of 51.6%. Given that GDP per capita in Sudan was under $600 per person[3] in 2020 – meaning many of the population living in extreme income poverty of under $2 a day – then even with moderate economic growth, Sudan will still be a relatively poor country in 2050. Even that prospect is heavily dependent on how much climate-induced loss and damage there will be.

Eight of the top 10 most affected countries are in Africa with two in South America. All ten face GDP damage of over 70% by 2100 under our current climate policy trajectory and a 40% hit even if the world keeps to 1.5ºC. The loss and damage could be considerably higher because this modelling approach does not take into account the impact of extreme weather events. However, higher investment in adaptation could lower the eventual cost. The paltry amounts that western governments are committing to adaptation support for the poorest is one of the outstanding issues under discussion at COP26.

Underlying the injustice of climate change is the fact that these vulnerable countries have done the least to cause the climate change they are suffering from and will suffer into the future. The mean average per capita carbon emissions of the top 10 most impacted countries is 0.45 tonnes. The average American (per capita 16.1 tonnes) is responsible for more carbon dioxide than 36 people from these ten countries.

We can do projections for who is most likely to be harmed by climate change, and this report highlights the wider economic impacts of loss and damage at the national level. Many of these are low-income countries which struggle to provide decent basic public services. For example, all eight of the African countries in the top 10 list of most affected countries spend under $80 per person on healthcare per year, so further economic losses will make it even harder to attain decent public services which enable the fulfilment of human rights. And in poorer countries, more households will find it difficult to make up the shortfall in public spending.

We already know that rising temperatures are already having a painful impact on developing countries. A 2019 study by Diffenbaugh and Burke[4] using the same methodology as the research in this paper, showed that GDP per capita is 13.6% lower across Africa than it would have been without warming from 1991-2010.

These staggering economic losses underscore an urgent need for a mechanism to address loss and damage, even if countries manage to stay below the 1.5C temperature limit of the Paris Agreement. Leaders from rich countries can no longer drag their feet on this issue at COP26 and beyond but must instead follow through on their commitments made in 2013 and again in 2015 to deliver real, tangible support. It is equally clear that the demands of the poorest nations for compensation from prosperous high-emitters will only increase if those governments fail meaningfully to accelerate their own decarbonisation and assist developing nations to do the same.

A short history of loss and damage

The remains of an animal in a dried up river bed, in drought-hit northern Kenya.
Russell Watkins/DFID

Loss and damage was first raised as an issue by the highly vulnerable countries of the Alliance of Small Island States (AOSIS), who, as early as 1991 highlighted the need for "an International Climate Fund to finance measures to counter the adverse consequences of climate change and a separate International Insurance Pool to provide financial insurance against the consequences of sea level rise"[5] The proposal further noted that such a proposal could be a model for "developing countries most vulnerable to desertification and drought".

It took over two decades for the international community to respond to the fears of highly vulnerable nations, with the establishment of the Warsaw International Mechanism for loss and damage (WIM) only in 2013[6]. The mechanism aims to promote implementation of approaches including comprehensive risk management, strengthening dialogue and coordination among stakeholders and enhancing support and action, including finance, technology and capacity building.

A major step forward was made in the 2015 Paris Agreement[7], where loss and damage was made a full article (Article 8), giving it a stronger standing in the negotiations. However, the issue remains politically charged around the fears of rich countries being held liable for the losses and damages suffered. This has meant that loss and damage was kept separate from discussions of finance until 2019 in Madrid, where small progress was made in that the COP asked the GCF Board to "continue providing financial resources for activities relevant to averting, minimizing and addressing loss and damage".

What is needed to really address loss and damage is greater analysis of need, and new and additional sources of climate finance being made available to respond to that need. With climate damages forecast to increase even if the Paris Agreement is delivered, the case for delivering on loss and damage strengthens with every year.

Report findings

The graph below shows the impact of climate change on per capita GDP for vulnerable countries under both a 1.5C scenario at 2050 and 2100 (yellow) and under the current policy trajectory at 2050 and 2100 (red).

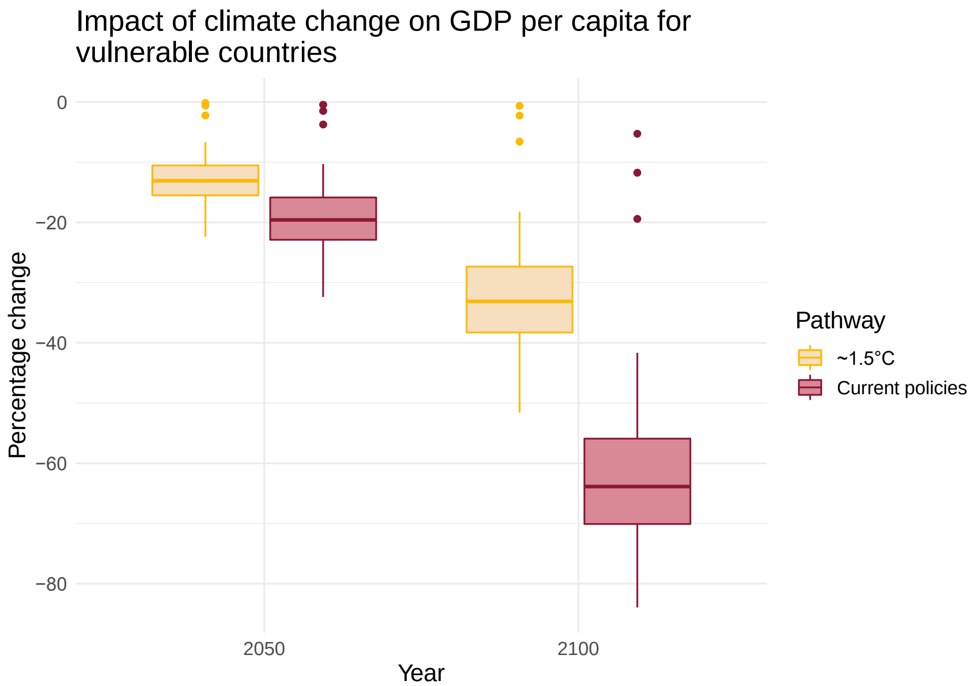
The horizontal lines in the four boxes show the median estimates.

The median GDP loss on a 1.5C trajectory by 2050 is 13.1%.

The median GDP loss under current policies by 2050 is 19.6%

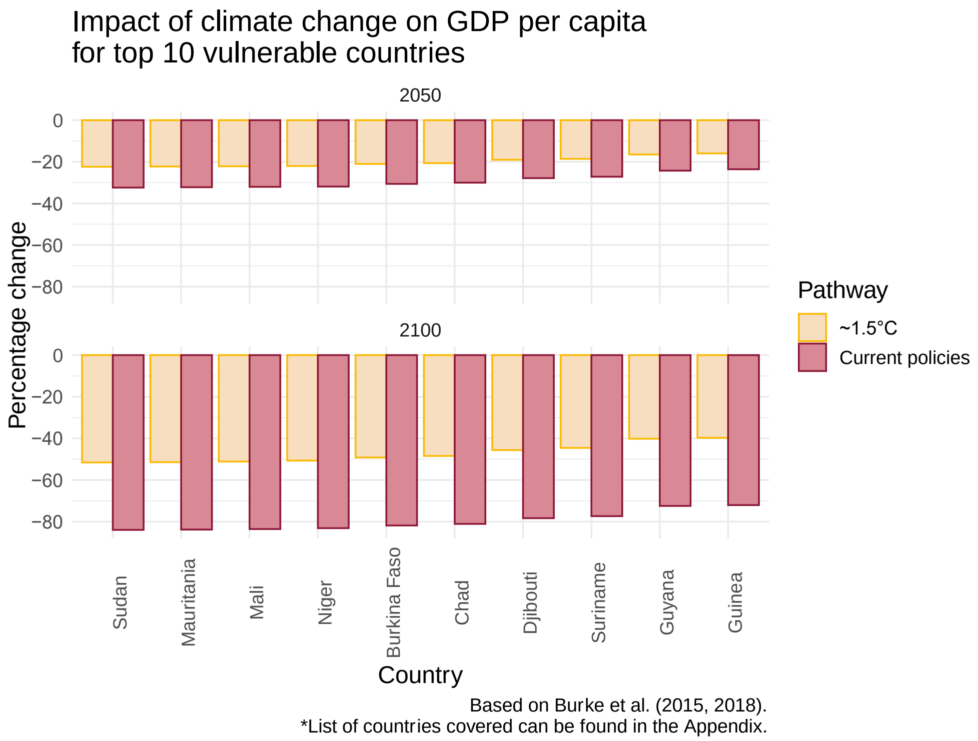
The median GDP loss on a 1.5C trajectory by 2100 is 33.1%

The median GDP loss under current policies by 2100 is 63.9%



Based on Burke et al. (2015, 2018).
*List of countries covered can be found in the Appendix.

The below graph shows the 10 worst affected countries by GDP loss. The exact findings for these 10 countries can be found in the table below and in the full data tables for all countries in Appendix 1.



Country	Year	Scenario	% GDP change	Per capita C02 emissions, tonnes, 2018
Sudan	2050	~1.5°C	-22.4	0.4
Sudan	2050	Current policies	-32.4	
Sudan	2100	~1.5°C	-51.6	
Sudan	2100	Current policies	-83.9	
Mauritania	2050	~1.5°C	-22.2	0.7
Mauritania	2050	Current policies	-32.2	
Mauritania	2100	~1.5°C	-51.5	
Mauritania	2100	Current policies	-83.8	
Mali	2050	~1.5°C	-22.1	0.1
Mali	2050	Current policies	-32.0	
Mali	2100	~1.5°C	-51.1	
Mali	2100	Current policies	-83.6	
Niger	2050	~1.5°C	-22.0	0.1
Niger	2050	Current policies	-31.9	

Niger	2100	~1.5°C	-50.7	
Niger	2100	Current policies	-83.1	
Burkina Faso	2050	~1.5°C	-21.0	0.2
Burkina Faso	2050	Current policies	-30.6	
Burkina Faso	2100	~1.5°C	-49.2	
Burkina Faso	2100	Current policies	-81.8	
Chad	2050	~1.5°C	-20.6	0.1
Chad	2050	Current policies	-30.0	
Chad	2100	~1.5°C	-48.4	
Chad	2100	Current policies	-81.1	
Djibouti	2050	~1.5°C	-19.0	1.1
Djibouti	2050	Current policies	-27.8	
Djibouti	2100	~1.5°C	-45.6	
Djibouti	2100	Current policies	-78.3	
Suriname	2050	~1.5°C	-18.6	4.0
Suriname	2050	Current policies	-27.2	
Suriname	2100	~1.5°C	-44.6	
Suriname	2100	Current policies	-77.4	
Guyana	2050	~1.5°C	-16.4	2.5
Guyana	2050	Current policies	-24.2	
Guyana	2100	~1.5°C	-40.2	
Guyana	2100	Current policies	-72.4	
Guinea	2050	~1.5°C	-15.9	0.2
Guinea	2050	Current policies	-23.5	
Guinea	2100	~1.5°C	-39.7	
Guinea	2100	Current policies	-72.1	

Case studies

Sudan

This study shows that Sudan faces the worst economic impact from climate change with a 83.9% loss of GDP by 2100 under current policies.

In September 2021 we were reminded of the country's acute vulnerability to extreme weather. Heavy rains and flash flooding affected over 314,000 people in 14 out of 18 states across the country as of 29 September.[8] Over 15,500 homes were destroyed, and 46,500 homes damaged, leading to the temporary displacement of about 100,750 people. The United Nations has attributed the strength of the rain to climate change[9]. Most of the displaced people had to shelter with friends or relatives or in public buildings within the vicinity of their homes, with some living in open spaces on high ground.

Only last year, Sudan declared a three-month state of emergency as flooding that the UN has called the country's worst in a century left around 140 people dead and 900,000 affected.[10]

Honduras

In 2020, Honduras was devastated by Hurricanes Eta and Iota, which caused losses estimated at more than $10 billion, with scientists linking the intensity of the hurricanes to climate change.[11] The impacts of the Covid-19 pandemic have further complicated disaster management. Resources are still desperately needed for essential reconstruction work, illustrating the need for funding to address loss and damage, and to reach local-level actors. In the municipality of Lepaera – a small district in the Department of Lempira which is home to just 37,000 people – Mayor Edgar Antonio Murillo Cruz estimates that the total cost of repairing roads and housing from the damage caused by Eta and Iota could exceed $503,000 – almost half of Lepaera's annual budget for 2021. He also observes that the production of coffee, a major cash crop, will take time to recover, causing significant losses to the local economy and to jobs.

Methodology

Estimates presented here are based on an econometric model that is based on the relationship between GDP growth and temperature, without accounting for the possible impacts of extreme events. Incorporating climate extremes such as droughts, floods or storms that could have an even more detrimental impact on economic performance. Recent advances in damage estimates that include extreme events are significantly larger than the ones who do not, implying that the optimal temperature pathways are the ones that limit global warming in line with the Paris Agreement (Piontek et al., 2021).

It is also worth keeping in mind that no adaptation measures which could potentially alleviate some of the damage are incorporated here. It is difficult to speculate about the extent of adaptation that will have taken place and the degree by mid and end of century. It is worth noting that the countries most affected are also the ones with very low capacities to adapt, as outlined the ND GAIN index of vulnerability and adaptative capacity so it is unreasonable to expect that they will be able to reduce these damages very substantially.[12]

Impacts of climate change on economic performance (here measured by country-level GDP per capita) were estimated using a two-step modeling procedure proposed by Burke et al. (2015, 2018). The first step estimates a historical relationship between GDP growth and climatic variables, and in the second step this relationship is extended to different temperature pathways over the 21st century to estimate how GDP growth might be affected by climate change.

For further details, see Appendix 2.

Policy recommendations

At COP26 and beyond there are key measures which countries will need to take to ensure loss and damage is addressed.

- Provide new, additional and needs-based loss and damage finance and a system to deliver it to vulnerable developing countries. Scotland has announced it is committing a million pounds specifically to address loss and damage.
- A COP decision establishing how the Santiago Network on Loss and Damage is to be operationalised in a way that catalyses reliable action and support to countries and communities most at risk of loss and damage, including local, subnational and national initiatives and through a clear governance structure
- COP should decide on the commission of an annual loss and damage finance gap report to assess whether available financing is meeting needs, and this needs to feed into the UNFCCC stock take.
- A COP decision to establish a robust financing system for loss and damage within the UNFCCC based on an assessment of options for a system which delivers loss and damage finance to vulnerable developing countries and most vulnerable communities
- To create a permanent agenda item in the UN climate process subsidiary bodies on loss and damage so the evolving impacts can be tracked and addressed.

It is equally clear that the economic damage outlined above provide an unanswerable case for all major emitters, especially those in the Global North, to accelerate their own decarbonisation and deliver on their climate finance pledges. Failing to do so will significantly add to loss and damage experienced in the world's poorest and most vulnerable nations, and therefore to the support they will be entitled to demand from countries most responsible for the loss and damage.

Appendix 1

Country	Year	Scenario	% GDP change
Sudan	2050	~1.5°C	-22.4
Sudan	2050	Current policies	-32.4
Sudan	2100	~1.5°C	-51.6
Sudan	2100	Current policies	-83.9
Mauritania	2050	~1.5°C	-22.2
Mauritania	2050	Current policies	-32.2
Mauritania	2100	~1.5°C	-51.5
Mauritania	2100	Current policies	-83.8
Mali	2050	~1.5°C	-22.1
Mali	2050	Current policies	-32
Mali	2100	~1.5°C	-51.1
Mali	2100	Current policies	-83.6
Niger	2050	~1.5°C	-22
Niger	2050	Current policies	-31.9
Niger	2100	~1.5°C	-50.7
Niger	2100	Current policies	-83.1
Burkina Faso	2050	~1.5°C	-21
Burkina Faso	2050	Current policies	-30.6
Burkina Faso	2100	~1.5°C	-49.2
Burkina Faso	2100	Current policies	-81.8
Chad	2050	~1.5°C	-20.6
Chad	2050	Current policies	-30
Chad	2100	~1.5°C	-48.4
Chad	2100	Current policies	-81.1
Djibouti	2050	~1.5°C	-19
Djibouti	2050	Current policies	-27.8
Djibouti	2100	~1.5°C	-45.6
Djibouti	2100	Current policies	-78.3
Suriname	2050	~1.5°C	-18.6
Suriname	2050	Current policies	-27.2
Suriname	2100	~1.5°C	-44.6
Suriname	2100	Current policies	-77.4
Guyana	2050	~1.5°C	-16.4
Guyana	2050	Current policies	-24.2
Guyana	2100	~1.5°C	-40.2
Guyana	2100	Current policies	-72.4
Guinea	2050	~1.5°C	-15.9

Guinea	2050	Current policies	-23.5
Guinea	2100	~1.5°C	-39.7
Guinea	2100	Current policies	-72.1
Central African Republic	2050	~1.5°C	-16.1
Central African Republic	2050	Current policies	-23.8
Central African Republic	2100	~1.5°C	-39.5
Central African Republic	2100	Current policies	-72
Sierra Leone	2050	~1.5°C	-16.1
Sierra Leone	2050	Current policies	-23.8
Sierra Leone	2100	~1.5°C	-39.6
Sierra Leone	2100	Current policies	-71.7
Cambodia	2050	~1.5°C	-16
Cambodia	2050	Current policies	-23.6
Cambodia	2100	~1.5°C	-39.5
Cambodia	2100	Current policies	-71.5
Benin	2050	~1.5°C	-16
Benin	2050	Current policies	-23.6
Benin	2100	~1.5°C	-39.2
Benin	2100	Current policies	-71.3
Ghana	2050	~1.5°C	-15.8
Ghana	2050	Current policies	-23.3
Ghana	2100	~1.5°C	-39
Ghana	2100	Current policies	-71
Belize	2050	~1.5°C	-15.6
Belize	2050	Current policies	-23
Belize	2100	~1.5°C	-38.3
Belize	2100	Current policies	-70.3
Senegal	2050	~1.5°C	-15.5
Senegal	2050	Current policies	-22.9
Senegal	2100	~1.5°C	-38.3
Senegal	2100	Current policies	-70.1
Togo	2050	~1.5°C	-15.1
Togo	2050	Current policies	-22.3
Togo	2100	~1.5°C	-37.3
Togo	2100	Current policies	-68.8
Bangladesh	2050	~1.5°C	-14.7
Bangladesh	2050	Current policies	-21.8
Bangladesh	2100	~1.5°C	-36.7
Bangladesh	2100	Current policies	-68.3

Gambia	2050	~1.5°C	-14.7
Gambia	2050	Current policies	-21.8
Gambia	2100	~1.5°C	-36.7
Gambia	2100	Current policies	-68.2
Mozambique	2050	~1.5°C	-14.5
Mozambique	2050	Current policies	-21.5
Mozambique	2100	~1.5°C	-36.2
Mozambique	2100	Current policies	-67.9
Congo - Kinshasa	2050	~1.5°C	-14
Congo - Kinshasa	2050	Current policies	-20.9
Congo - Kinshasa	2100	~1.5°C	-35.6
Congo - Kinshasa	2100	Current policies	-67.3
Eritrea	2050	~1.5°C	-14.3
Eritrea	2050	Current policies	-21.2
Eritrea	2100	~1.5°C	-35.3
Eritrea	2100	Current policies	-67
Honduras	2050	~1.5°C	-14.1
Honduras	2050	Current policies	-20.9
Honduras	2100	~1.5°C	-35.2
Honduras	2100	Current policies	-66.5
Yemen	2050	~1.5°C	-13.6
Yemen	2050	Current policies	-20.2
Yemen	2100	~1.5°C	-34.3
Yemen	2100	Current policies	-65.7
Vietnam	2050	~1.5°C	-13.5
Vietnam	2050	Current policies	-20
Vietnam	2100	~1.5°C	-34.1
Vietnam	2100	Current policies	-65.1
São Tomé & Príncipe	2050	~1.5°C	-13.2
São Tomé & Príncipe	2050	Current policies	-19.7
São Tomé & Príncipe	2100	~1.5°C	-33.8
São Tomé & Príncipe	2100	Current policies	-64.3
Guinea-Bissau	2050	~1.5°C	-13.5
Guinea-Bissau	2050	Current policies	-20
Guinea-Bissau	2100	~1.5°C	-34.1
Guinea-Bissau	2100	Current policies	-64.7
Nepal	2050	~1.5°C	-13.1
Nepal	2050	Current policies	-19.6
Nepal	2100	~1.5°C	-33.2
Nepal	2100	Current policies	-64.7
Malawi	2050	~1.5°C	-13.1
Malawi	2050	Current policies	-19.6

Malawi	2100	~1.5°C	-33.1
Malawi	2100	Current policies	-64.2
Sri Lanka	2050	~1.5°C	-13.2
Sri Lanka	2050	Current policies	-19.7
Sri Lanka	2100	~1.5°C	-33.6
Sri Lanka	2100	Current policies	-64
Dominican Republic	2050	~1.5°C	-13.2
Dominican Republic	2050	Current policies	-19.6
Dominican Republic	2100	~1.5°C	-33.3
Dominican Republic	2100	Current policies	-63.9
Uganda	2050	~1.5°C	-12.7
Uganda	2050	Current policies	-19
Uganda	2100	~1.5°C	-32.3
Uganda	2100	Current policies	-63.1
Haiti	2050	~1.5°C	-12.7
Haiti	2050	Current policies	-19
Haiti	2100	~1.5°C	-32.5
Haiti	2100	Current policies	-62.7
Laos	2050	~1.5°C	-12.7
Laos	2050	Current policies	-19
Laos	2100	~1.5°C	-32.4
Laos	2100	Current policies	-62.7
Angola	2050	~1.5°C	-12.6
Angola	2050	Current policies	-18.8
Angola	2100	~1.5°C	-31.3
Angola	2100	Current policies	-61.8
Bahamas	2050	~1.5°C	-12.7
Bahamas	2050	Current policies	-18.8
Bahamas	2100	~1.5°C	-32
Bahamas	2100	Current policies	-61.8
Zambia	2050	~1.5°C	-12.2
Zambia	2050	Current policies	-18.3
Zambia	2100	~1.5°C	-31.3
Zambia	2100	Current policies	-61.8
Tanzania	2050	~1.5°C	-12.2
Tanzania	2050	Current policies	-18.3
Tanzania	2100	~1.5°C	-31.2
Tanzania	2100	Current policies	-61.5
St. Vincent & Grenadines	2050	~1.5°C	-12.6
St. Vincent & Grenadines	2050	Current policies	-18.7

St. Vincent & Grenadines	2100	~1.5°C	-31.8
St. Vincent & Grenadines	2100	Current policies	-61.4
Cuba	2050	~1.5°C	-12.3
Cuba	2050	Current policies	-18.4
Cuba	2100	~1.5°C	-31.3
Cuba	2100	Current policies	-61
Solomon Islands	2050	~1.5°C	-12.3
Solomon Islands	2050	Current policies	-18.4
Solomon Islands	2100	~1.5°C	-31.4
Solomon Islands	2100	Current policies	-60.8
Philippines	2050	~1.5°C	-12.2
Philippines	2050	Current policies	-18.2
Philippines	2100	~1.5°C	-31.1
Philippines	2100	Current policies	-60.5
Guatemala	2050	~1.5°C	-11.9
Guatemala	2050	Current policies	-17.7
Guatemala	2100	~1.5°C	-30.3
Guatemala	2100	Current policies	-60
Trinidad & Tobago	2050	~1.5°C	-12
Trinidad & Tobago	2050	Current policies	-17.8
Trinidad & Tobago	2100	~1.5°C	-30.5
Trinidad & Tobago	2100	Current policies	-59.6
Comoros	2050	~1.5°C	-11.2
Comoros	2050	Current policies	-16.8
Comoros	2100	~1.5°C	-28.9
Comoros	2100	Current policies	-57.5
Burundi	2050	~1.5°C	-10.5
Burundi	2050	Current policies	-15.8
Burundi	2100	~1.5°C	-27.3
Burundi	2100	Current policies	-55.9
Samoa	2050	~1.5°C	-10.9
Samoa	2050	Current policies	-16.3
Samoa	2100	~1.5°C	-28.1
Samoa	2100	Current policies	-55.9
Rwanda	2050	~1.5°C	-10.4
Rwanda	2050	Current policies	-15.7
Rwanda	2100	~1.5°C	-27.1
Rwanda	2100	Current policies	-55.6
Costa Rica	2050	~1.5°C	-10.5
Costa Rica	2050	Current policies	-15.8
Costa Rica	2100	~1.5°C	-27.3

Costa Rica	2100	Current policies	-55.4
Colombia	2050	~1.5°C	-10
Colombia	2050	Current policies	-15.1
Colombia	2100	~1.5°C	-26.1
Colombia	2100	Current policies	-53.8
Tunisia	2050	~1.5°C	-9.5
Tunisia	2050	Current policies	-14.4
Tunisia	2100	~1.5°C	-25.2
Tunisia	2100	Current policies	-53
Vanuatu	2050	~1.5°C	-10
Vanuatu	2050	Current policies	-15
Vanuatu	2100	~1.5°C	-26
Vanuatu	2100	Current policies	-52.8
Ethiopia	2050	~1.5°C	-9.4
Ethiopia	2050	Current policies	-14.4
Ethiopia	2100	~1.5°C	-24.9
Ethiopia	2100	Current policies	-52.4
Mauritius	2050	~1.5°C	-9.9
Mauritius	2050	Current policies	-14.8
Mauritius	2100	~1.5°C	-25.7
Mauritius	2100	Current policies	-52.3
Kenya	2050	~1.5°C	-9.1
Kenya	2050	Current policies	-13.7
Kenya	2100	~1.5°C	-23.9
Kenya	2100	Current policies	-50.3
Papua New Guinea	2050	~1.5°C	-9.2
Papua New Guinea	2050	Current policies	-13.8
Papua New Guinea	2100	~1.5°C	-24.1
Papua New Guinea	2100	Current policies	-50.1
Madagascar	2050	~1.5°C	-8.8
Madagascar	2050	Current policies	-13.3
Madagascar	2100	~1.5°C	-23.2
Madagascar	2100	Current policies	-48.8
Fiji	2050	~1.5°C	-8.5
Fiji	2050	Current policies	-12.8
Fiji	2100	~1.5°C	-22.4
Fiji	2100	Current policies	-46.7
Cape Verde	2050	~1.5°C	-7.6
Cape Verde	2050	Current policies	-11.5
Cape Verde	2100	~1.5°C	-20.3
Cape Verde	2100	Current policies	-43.6
Morocco	2050	~1.5°C	-6.7

Morocco	2050	Current policies	-10.3
Morocco	2100	~1.5°C	-18.2
Morocco	2100	Current policies	-41.7
Lebanon	2050	~1.5°C	-2.2
Lebanon	2050	Current policies	-3.7
Lebanon	2100	~1.5°C	-6.6
Lebanon	2100	Current policies	-19.4
Afghanistan	2050	~1.5°C	-0.6
Afghanistan	2050	Current policies	-1.5
Afghanistan	2100	~1.5°C	-2.3
Afghanistan	2100	Current policies	-11.7
Liberia	2050	~1.5°C	-13.9
Liberia	2050	Current policies	-20.6
Liberia	2100	~1.5°C	-35
Liberia	2100	Current policies	-66
Bhutan	2050	~1.5°C	-0.2
Bhutan	2050	Current policies	-0.4
Bhutan	2100	~1.5°C	-0.6
Bhutan	2100	Current policies	-5.3

Appendix 2

There is no consensus so far in economics and statistics on the “right” theoretical approach to estimate economic damages of climate change and the numbers vary widely depending on the initial specification and the modelling approach. One of the most prominent sources of differences stems from the choice between estimating damage to the level of output in an economy (i.e., impact on GDP in a single year or at a point in time) or whether it impacts economic growth (i.e., impact on GDP growth via damages to natural and human capital, under-investment, etc.). Resulting estimates from the two approaches vary primarily because the growth effects accumulate over time and are, by definition, substantially larger than level effects. Growth-based effects from prominent global assessments based on top-down econometrics vary between 7% (Kahn et al. 2019) and 23% (Burke et al. 2015) globally, while the level-based effects are centered around 1-2% of GDP reduction globally (Newell et al., 2021).

The analysis here is based on an econometric approach proposed in prominent papers of Marshall Burke and colleagues published in Nature magazine in 2015 and 2018.

Historical relationship between per capita GDP growth, temperature and precipitation is estimated using a fixed effects model with the following equation:

$$\Delta \ln GDP_{i,t} = \beta_1 T_{it} + \beta_2 T_{it}^2 + \beta_3 P_{it} + \beta_4 P_{it}^2 + \mu_i + \upsilon_t + \theta_{1i} t + \theta_{2i} t^2 + \varepsilon_{it}$$

where the dependent variable is GDP growth of country i in year t, T and P are the average temperature and precipitation in year *t*, μ_i represents country-fixed effects that control for heterogeneity between countries that do not vary over time (e.g. historical legacy, institutions or culture), υ_t are year-fixed effects that account for common global shocks in a given year (e.g. financial crisis), and $\theta_{1i} t + \theta_{2i} t^2$ are country-specific linear and quadratic time trends, which allow GDP and temperature to evolve flexibly (e.g. account for positive growth trends of both variables without confounding the relationship). Inclusion of the three types of fixed effects means that the estimated coefficients β_1 - β_4 can be interpreted as actual impacts of temperature and precipitation that are independent of non-climate related confounding factors. Only temperature variable (coefficients β_1 and β_2) is statistically significant in different specifications tested and this relationship holds robustly across alternative models. The non-linear (quadratic) relationship between GDP and climate variables allows the effect of warming to differ depending on the country's average temperature.

Several bootstrapping techniques (by country; by year; by five-year blocks) have been used to quantify uncertainty in coefficient estimates β_1 and β_2. Bootstrapping uses different sampling methods to derive improved estimates of standard errors and confidence intervals.

Coefficient estimates obtained from the historical regression model are used in the second step of the analysis in combination with climate model projections of temperature to obtain projected future per capita GDP growth. Here we present two scenarios of global warming: a Paris Agreement-compatible pathway of the global mean temperature (GMT) increase limited to 1.5°C in 2100 and the "current policy" pathway that results in the median increase of 2.9°C in 2100 compared to the pre-industrial period based on the latest update of the Climate Action Tracker (CAT) from May 2021.[13]

Future GDP growth in the climate change scenarios is compared to the "baseline" scenarios available from the socio-economic scenario framework – the Shared Socioeconomic Pathways (SSPs) (O'Neill et al. 2017) – which are the basis for climate impact assessments in the 6th Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC). The SSPs are meant to represent a range of plausible futures of socio-economic components in a hypothetical world without climate change. They are used as baselines in comparisons to scenarios with climate change. Here we use the SSP1 scenario which is meant to be most compatible with the 1.5°C-consistent pathway. Baseline SSP scenarios can also be explored here.[14]

Although the majority countries from the LDC, AOSIS and CVF blocs are included, not all countries could be added due to a lack of data regarding their historical GDP. The countries not included in the report are: Antigua and Barbuda, Barbados, Cook Islands, Dominica, Grenada, Jamaica, Kiribati, Lesotho, Maldives, Marshall Islands, Myanmar, Nauru, Niue, Palau, Palestine, Saint Kitts and Nevis, Saint

Lucia, Seychelles, Singapore, Somalia, South Sudan, Timor-Leste, Tonga and Tuvalu.

End notes

[1] https://climateactiontracker.org/press/global-update-projected-warming-from-paris-pledges-drops-to-two-point-four-degrees/

[2] These three groups include 89 nations (there is some crossover between membership). The analysis presented here is for 65 of them – the remaining 24 were not included due to a lack of high-quality data on historical GDP

[3] https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=SD

[4] https://www.pnas.org/content/116/20/9808

[5] https://unfccc.int/documents/4309 A/AC.237/WG.II/CRP.8

[6] https://unfccc.int/documents/7643#beg FCCC/CP/2012/8/Add.1

[7] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

[8] https://reliefweb.int/report/sudan/sudan-floods-flash-update-no-15-30-september-2021-enar

[9] https://www.reuters.com/business/environment/un-blames-worst-south-sudan-floods-since-1962-climate-change-2021-10-19/

[10] https://www.africanews.com/2021/09/22/more-than-288-000-affected-by-sudan-floods-un/

[11] https://www.theguardian.com/environment/2020/nov/15/scientists-link-record-breaking-hurricane-season-to-climate-crisis

[12] https://gain.nd.edu/our-work/country-index/

[13] https://climateactiontracker.org/global/cat-thermometer/

[14] https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about