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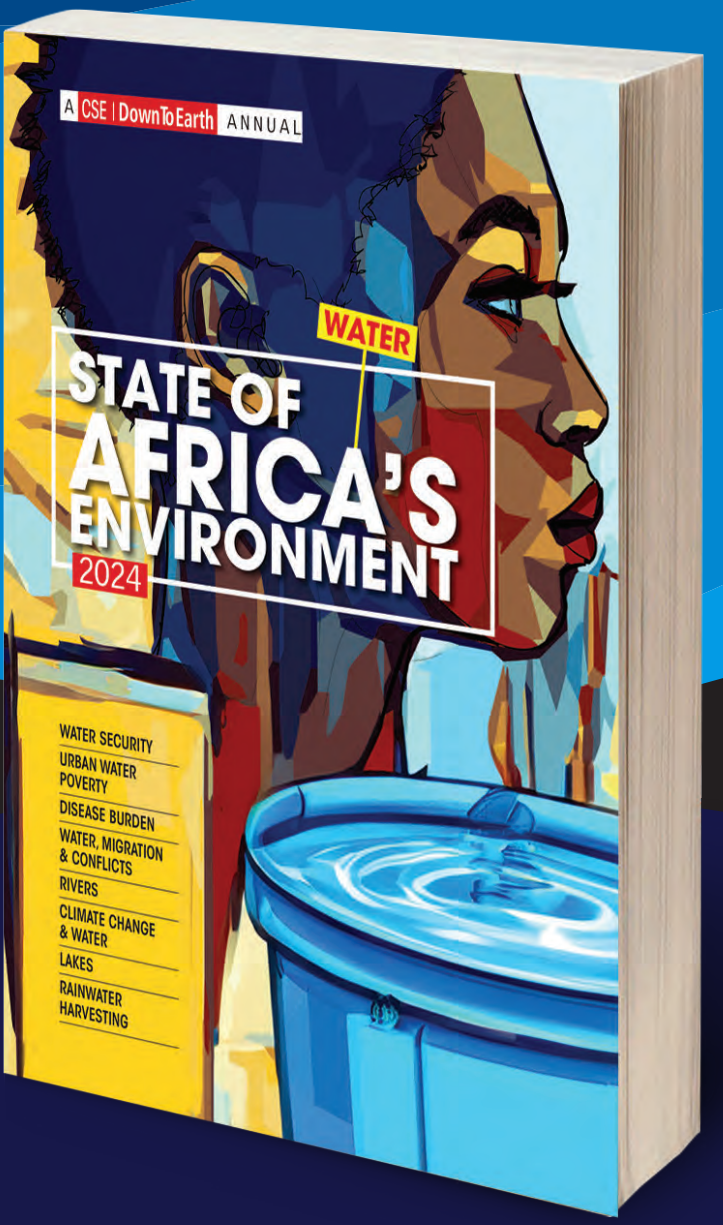

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Down To Earth is a fortnightly on the politics of environment and development. In its 34th year of publication, it continues to adhere to its founder Anil Agarwal's objective of bringing out news, perspectives and knowledge to prepare citizens to change the world.
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CONTENTS

FOREWORD

CLIMATE CHANGE IS RESHAPING AFRICA

THE WORLD changed in more ways than one in 2024. It is the year that marks the beginning of the time of climate change—when each day some part of the world is hit by extreme weather events; when a new record of heat or cold stress is made and then broken; when communities already living on the margins of survival are devastated to the point of being unable to recover from the frequent disasters. This is a different era. Scientists describe this as the Anthropocene Epoch, which in geological time is defined as the period when human activities have significant impacts on the planet's climate and ecosystems. Everything that we have done for human progress—for increased well-being and wealth generation—has breached national as well as planetary boundaries.

Africa is the hotspot of the planetary climate emergency. An analysis by Washington DC-based Brookings Institution said that seven out of the 10 most climate vulnerable nations in the world are located in Africa. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) released in August 2021 poignantly summed up, "Over the past 60 years, Africa has recorded a warming trend that has generally been more rapid than the global average... the climate has changed at rates unprecedented in at least 2,000 years." In fact, every third death (or 35 per cent) in the world from extreme weather, climate or water stress in 50 years was in Africa, according to the World Meteorological Organization (WMO).

Climate change is both figuratively and literally reshaping the continent. A churn is underway across Africa. An era of civil conflicts that followed centuries of colonial plunder across the continent seems like a thing of the past. Just as the majority of African nations were scrambling out of violent conflicts, the challenge of climate change has put the aspirations of the entire continent in serious jeopardy. The immediacy of managing disruptive climate events has displaced governance priority of bridging the development deficit.

The year 2024 was the warmest or second-warmest year on record for Africa along with devastating floods, droughts and marine heat waves, according to WMO's "State of Climate in Africa 2024" report, released in May 2025. The average annual surface temperature across Africa was around 0.86°C above the average annual surface temperature between 1991 and 2020. The strongest warming was in North Africa, which was 1.28°C above the 1991-2020 average. North Africa is the fastest warming region in the continent. The El Niño event of 2023-2024 was partly to blame for the warming and extreme weather, along with global warming and consequent climate change.

The continent in all probability will cross the guardrail of 1.5°C warming in the near future. A study published in CABI Reviews warned that the continent is "highly likely" to surpass 1.5°C of warming by 2040, accelerating devastating impacts on agriculture-based livelihoods. Africa's agriculture-dependent populations are already facing significant losses due to climate change, and these challenges will only intensify with increasing climate hazards.

People have one common query: why Africa? The irony is hard to miss. Going by each country's share of the world's cumulative CO_2 historical emissions (based on fossil emissions) for the period from 1750 to 2021, and based on fossil emissions, Sub-Saharan Africa contributed just 1.9 per cent of the world's emissions. And, it mostly came from South Africa

PHOTOGRAPH: ISTOCK PHOTO

(1.3 per cent) while 48 other African countries contributed just 0.6 per cent.

Today our world is more insecure and more anxious as each super-cycle of cataclysmic change is feeding the other. We live in an increasingly inequitable world where the rich have gotten richer and the poor poorer. In the past five years, this divide has widened as the COVID-19 pandemic devastated economies, and before they could recover the wars shaped the present, leaving countries with little financial resources to heal and to grow. This, combined with bad governance, climate change and resource squeeze, is leading to more migration, as desperate people seek new opportunities. All these add fuel to the anger and insecurity, which then make democracy prey to hateful and polarised rhetoric in this age of big technology, controlled by new business leaders with superpowers.

This anger is not confined to the poor in the world. The rich feel betrayed—or at least this is how they perceive it. When the world moved to stitch up economies in the 1990s, it was the poor that were most worried about the loss of jobs. It is the farmers in our world who took to the streets in protest of the free trade agreements that would upend their livelihoods. Today, the situation has reversed. It is the workers in the already rich world that have been left out of the new economies. They are turning against what they call the "educated elite and the experts" who have benefitted from the service and financial economy of this interconnected world. The worst outcome of this class war is the rejection of ideas. People see knowledge as tainted and compromised and feeding private interests—also an outcome of the way we have organised the world's information and business systems.

This is where the climate crisis intersects again. We know that we live in the age of climate extremes—disasters are happening all around us—but we are not doing enough to fix it. We are not in denial; but we are not designed anymore as societies to work for common causes. It is for this reason that in Baku, at the 29th Conference of Parties to the Climate Convention in November 2024, we dropped all pretence of wanting to build a cooperative world. The rich world has officially decided to throw some crumbs in the name of climate finance. This world of historical climate debtors says that the world that needs to reinvent its growth to be low-carbon, to adapt to the changing climate and to survive the loss and damages, must do with this pretend largesse. It is an insult to the change we need in the world.

This is also where economy, climate change and politics intersect. When the world moved towards interconnected economies it was believed that it would lead to a prosperous and safer world order; countries would not attack as they would be driven by the self-interest of cooperation. But the real reason for moving industry was to reduce the costs of labour and environmental safeguards. It was too expensive to manufacture if these costs had to be paid. This meant that production moved and so did emissions. We know that from the carbon dioxide balance sheet of countries as China became the world's manufacturer with others joining it. Today, as the world needs a green transition, it faces new realities. The production of all things green is still cheaper in the "other" world, China in particular. The US has promised a trade war to bring back business to his country. But this will add costs, financial and environmental, as the world is just too integrated and interconnected on its trade to disengage easily. It will also derail the momentum for a low-carbon economy as what is green is foreign-made and so must be shunned.

Just as the majority of African nations were scrambling out of violent conflicts, the challenge of climate change has put the aspirations of the entire continent in serious jeopardy

This is why at the beginning of the epoch of climate change, in the year 2024, when the world moved into a different today, we must plan for a different tomorrow. We cannot be prisoners of yesterday. We must be vanguards of a new dawn; a new promise but with the reality of the mistakes of our era. Otherwise, we will squander away coming decades to nothingness—all into a vortex of spiralling climate change impacts. This is what we must change.

Change is taking shape in Africa. It will cost around $2.8 trillion between 2020 and 2030 to implement Africa's Nationally Determined Contributions (NDCs, climate action plans submitted to the United Nations), according to the "State of Climate Finance in Africa 2022" published by the Climate Policy Initiative, an analysis and advisory organisation. Out of these identified costs, adaptation measures account for just 24 per cent. This is insignificant given the continent's high vulnerability to climate change. Irrespective of the finance crunch, countries in Africa have the responsibility and the duty to take up immediate climate change adaptation measures.

Across the continent, countries are adopting policy measures and crafting programmes to adapt to and mitigate climate change. Starting from rolling out national strategy to become net zero in carbon emission to adopting indigenous knowledge to fight impacts like drought and extreme weather events, all African nations have some adaptation programmes to showcase.

The "State of Africa's Environment 2025" report is an assessment of the climate emergency that has gripped the continent. The report also documents the many adaptation plans and policies of countries that show that the continent is bracing to tide over, sustainably. ■

CLIMATE EMERGENCY

HIGHPOINTS

Global warming causing **carbon dioxide levels** are now the **highest** than they have been in the last **800,000 years**

Year 2024 is the **first year to cross the 1.5 °C** Paris Agreement threshold annually

Last **8 years** have set the **records for the highest ocean heat** content. The ocean warming has accelerated in recent decades

Most people **born in the new millennium** have already spent **half of their lives** on an unprecedentedly **hot planet**

PHOTOGRAPH COURTESY: WMO

AN ALTERED PLANET

The world is closer to breaching a key planetary boundary on global warming

THE YEAR 2024 is a defining one for the planet Earth. Arguably, the year may be the point that divides the pre- and post-climate change eras. In March 2025, the World Meteorological Organization (WMO) released the "State of the Climate Report 2024". The WMO annual assessment revealed alarming data on global temperature, greenhouse gases (GHGS) concentrations, and rising sea levels. Global warming causing carbon dioxide (CO_2) levels are now the highest than they have been in the last 800,000 years, according to the WMO report. WMO measured the CO_2 levels at 420 parts per million (ppm) in 2023. Along with the record CO_2 levels, other GHGS such as methane (CH_4) and nitrous oxide (N_2O) were also at their highest levels in the past 800,000 years.

Human-induced CO_2 accounts the most for climate change among the GHGS. It accounts for 66 per cent of the radiative forcing by all long-lived GHGS since 1750, and around 79 per cent of

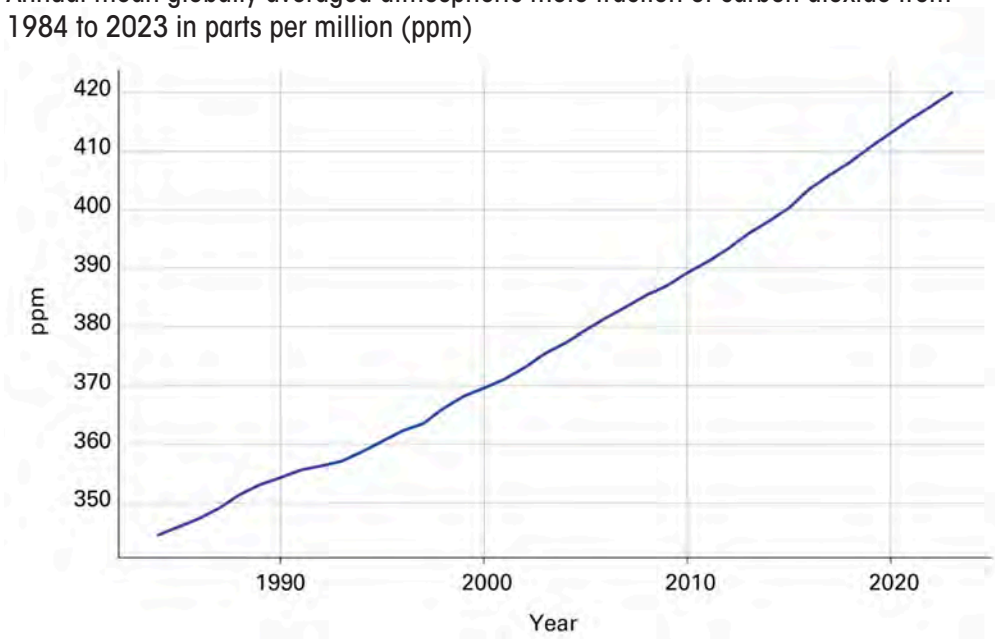
increase over the past 20 years, according to global assessments. The annual average mole fraction of CO_2 in the atmosphere was 420.0 ffl 0.1 ppm in 2023, the latest year for which data is available. This was 2.3 ppm more than in 2022 and 151 per cent of the pre-industrial concentration (in 1750), according to WMO. "Current atmospheric concentrations of CO_2 are higher than at any time in at least 2 million years. Concentrations of CH_4 and N_2O are higher than at any time in at least 800, 000 years," said the WMO.

The record levels of GHGs had resulted in record breaking temperatures in 2024 along with natural variations such as El Niño in the early part of 2024. The global mean near surface temperature was 1.55°C above pre-industrial average, according to an analysis by WMO using six international datasets with 2024 being the first year to cross the 1.5°C Paris Agreement threshold annually. Under the Paris Agreement, the world pledged to hold the rise in average temperature to well below 2°C above pre-industrial levels (1850-1900), and to mount efforts to limit warming to 1.5°C. The latter is the threshold beyond which climate change would worsen and its impacts become irreversible. Crossing this threshold in individual months or years does not imply a rise in the planet's average global temperature. However, repeated crossings bring the planet closer to the critical barrier. Darrell Kaufman, a paleoclimate scientist at Northern Arizona University, US, provided context to the current warming trend in a 2023 article published in *The Conversation*: "The last glacial episode lasted nearly 100,000 years. There is no evidence that long-term global temperatures reached the pre-industrial baseline anytime during that period. If we look even farther back, to the previous interglacial period, which peaked around 125,000 years ago, we do find evidence of warmer temperatures. The evidence suggests the long-term average temperature was probably no more than 1.5°C (2.7°F) above preindustrial levels—not much more than the current global warming level."

"While a single year above 1.5°C of warming does not indicate that the long-term temperature goals of the Paris Agreement are out of reach, it is a wake-up call that we are increasing the risks to our lives, economies and to the planet," said Celeste Saulo, secretary general of WMO. The WMO report stated that the long-term warming was between 1.34°C and 1.41°C as compared to the average in the pre-industrial period. The WMO used multiple methods to arrive at this conclusion

ATMOSPHERIC CONCENTRATION OF CO_2: HIGHER THAN ANY TIME IN 2 MILLION YEARS

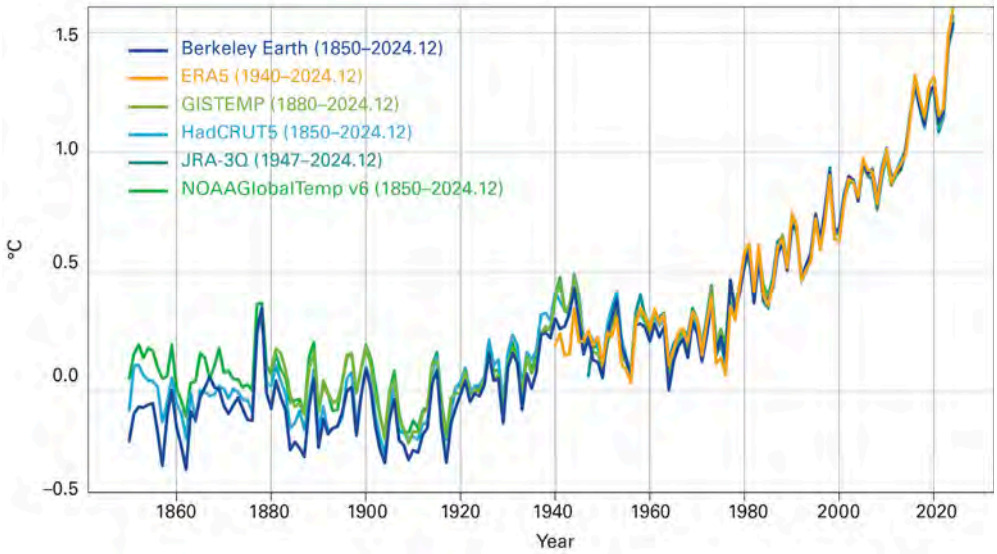
Annual mean globally averaged atmospheric mole fraction of carbon dioxide from 1984 to 2023 in parts per million (ppm)



Source: Data are from the World Data Centre for Greenhouse Gases (WDCGG)

2024: THE FIRST YEAR TO CROSS THE 1.5°C LIMIT

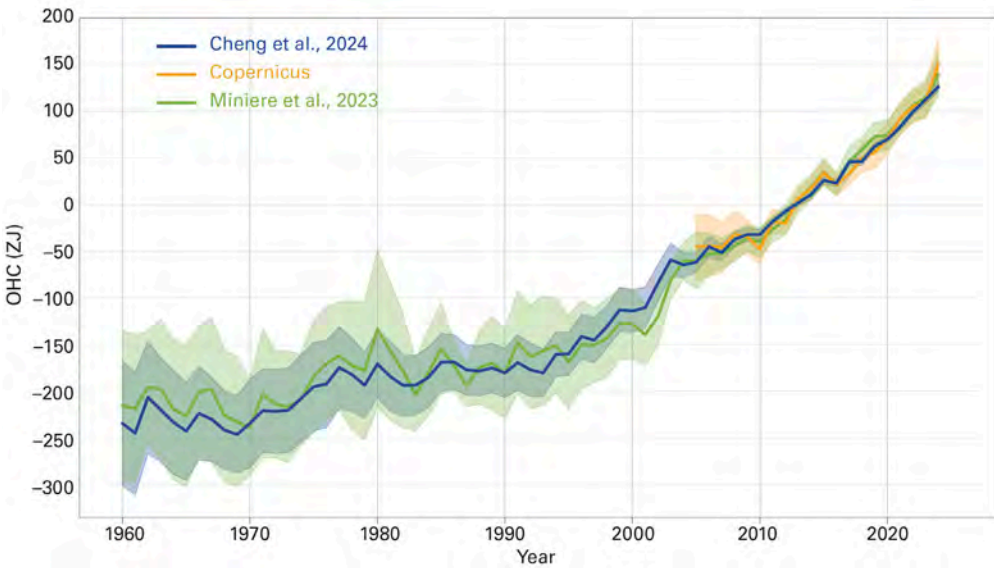
Annual global mean temperature anomalies relative to a pre-industrial (1850–1900) baseline shown from 1850 to 2024



Source: State of the Global Climate 2024, World Meteorological Organization

2024: OCEANS CONTINUE TO WARM

Annual global ocean heat content down to 2000 m depth for the period 1960–2024, in zettajoules (1021 J). The shaded area indicates the 2-sigma uncertainty range on each estimate



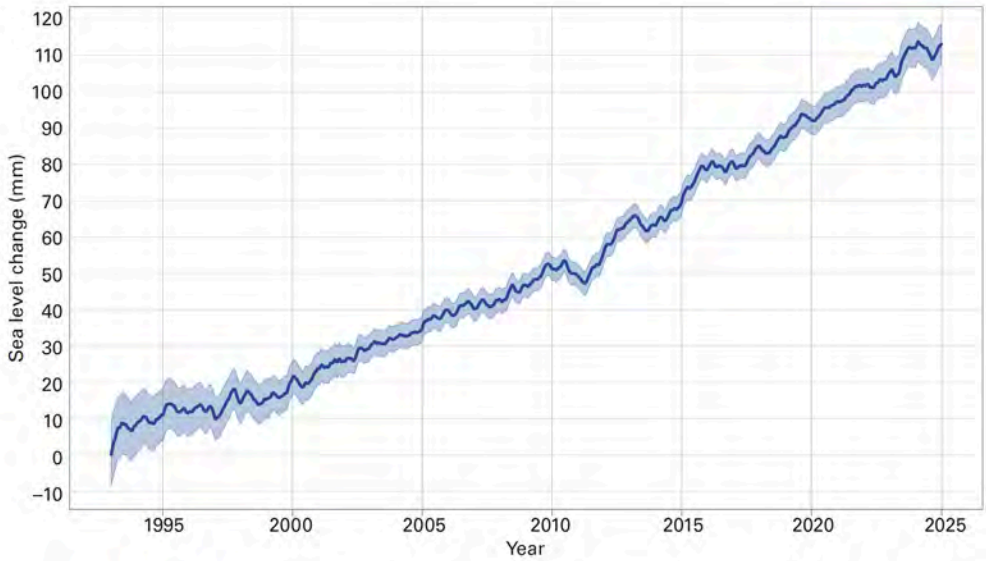
Source: State of the Global Climate 2024, World Meteorological Organization

even though it noted "the uncertainty ranges in global temperature statistics".

Recent research papers have also indicated that the world may already be in the early period of crossing the long-term threshold of 1.5°C with a recent analysis by the European Union's Copernicus Climate Change Service (C3S) stating that the threshold is likely to be crossed by September 2029, if the current temperature trend continues. The current temperature trend is dangerous one. The WMO report stated that each of the last 10 years is among the 10 warmest years on record since 1850. "This has happened for the first time since temperature records

2024: GLOBAL MEAN SEA LEVEL REACHES A RECORD HIGH

Seasonal global mean sea level change from 1993 shown for 1993–2024. The seasonal cycle has been removed from the data. The shaded area indicates the uncertainty



Source: State of the Global Climate 2024, World Meteorological Organization

began and is one of the most surprising findings of the WMO report," said Chris Hewitt, director of Climate Services branch of the WMO, during a press briefing on March 18, 2025.

The last eight years have also set the records for the highest ocean heat content. Ninety per cent of the global heat being trapped by the GHGs is absorbed by the oceans. "Data for 2024 show that our oceans continued to warm and sea levels continued to rise. The frozen parts of Earth's surface, known as the cryosphere, are melting at an alarming rate: glaciers continue to retreat, and Antarctic sea ice reached its second-lowest extent ever recorded. Meanwhile, extreme weather continues to have devastating consequences around the world," said Saulo. Seven of the last 10 years have had the highest negative mass balance of glaciers. "We also observe that the ocean warming has accelerated in recent decades and the record sea ice extent in the Arctic and Antarctica are also major concerns coming out of the WMO report. We expected the ocean warming to slow down towards the end of 2024, which did not happen. This needs to be studied further," said Karina von Shuckmann, an ocean expert with the WMO.

The record temperatures seen in 2024 could be due to El Niño, the warmer phase of the El Niño Southern Oscillation (ENSO). But global climate records had been breached so frequently in 2024 that it was untenable to hold on to a benchmark. For 16 consecutive months since June 2023, the global mean temperature "likely exceeded anything recorded before," said WMO. October 2024 was 1.65°C above pre-industrial level and the 15th month since June 2023 when the monthly global average air temperature crossed the 1.5°C limit, said C3S.

With 2015-24 being the warmest decade on record, most people born in the new millennium – also referred as the Generation Alpha - have already spent half their lives on an unprecedentedly hot planet. A report of the "The Lancet Countdown on Health and Climate Change", published in 2023 by an international collaboration of researchers that monitor the impact of climate change on health, estimated that in 2019-23, "people were exposed, on average, to 46 more days of health-threatening heat than would have been expected without climate change, a value that reached a record high of 50 more days in 2023." According to "World Cities Report 2024: Cities and Climate Action" released by UN-Habitat in November 2024, by 2040 almost 2 billion people in urban areas would see a 0.5°C rise in temperature. "Almost no urban resident will be unaffected, with billions of people subjected to hotter temperatures or exposed to the risks of flooding and other threats," said Anacláudia Rossbach, executive director, UN-Habitat.

CARBON BUDGET: HAS IT BEEN EXHAUSTED?

The distribution of historical GHG emissions between 1870 and 2030 would be nearly the same as that between 1870 and 2021

THE CONCEPT of a carbon budget in climate policy aims to quantify the amount of emissions that is permissible to stay on track towards meeting global targets. Following a series of publications in the 2000s, the Global Carbon Budget (GCB) was first quantified in the IPCC's Fifth Assessment Report (AR5). Due to difficulties in accurately quantifying the GCB, the IPCC determines the estimated GCB available to meet the 1.5°C target, with a 50 per cent accuracy being the most common. In 2018, the AR5 estimated that to have a 50 per cent chance of achieving the 1.5°C target, the GCB was 268 $GtCO_2$. Due to improvements in climate models and better and more expansive data, the budget was revised in the next cycle. In the Sixth Assessment Report (AR6) released in 2021, the available budget was revised to 500 $GtCO_2$ to have a 50 per cent chance of meeting the 1.5°C target.

If we set aside China and India's shares, the historical highest polluters, who also happen to be rich, developed countries, have constituted 45.52 per cent of the GCB space since 1900. The historical highest polluters are: USA, EU 27, UK, Japan, Russia and Canada. Today, China's swift rise in emissions places it at the same level of historical polluters. Together, these polluters and China have consumed 56.22 per cent of the GCB. Not only has this left a fraction of the GCB for the others, but these countries have also continued to expand fossil fuel dependency and emissions in the 21st century.

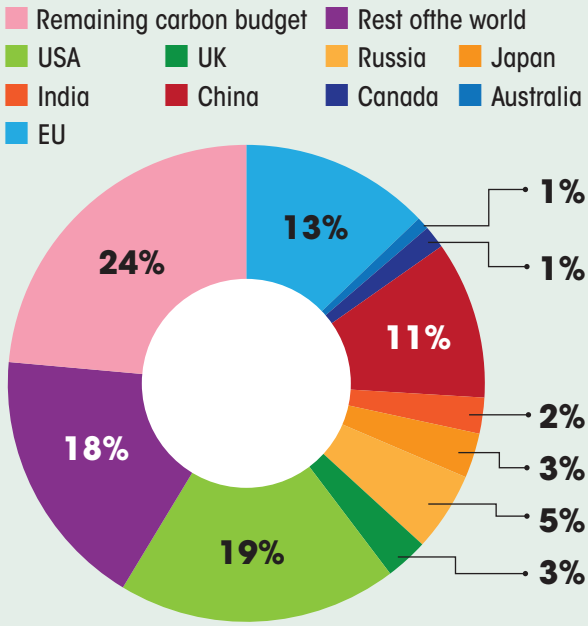
Altogether, by 2019, the world had collectively utilised 76.43 per cent of the GCB between 1900 and 2019. This aligned with a similar analysis by Carbon Brief, which concluded that 86 per cent of the GCB had been burned through since 1850.

While the GCB is used to advocate for the carbon emissions deemed necessary to aid a transition, it is critical to ensure that it is not misused to continue an inequitable sharing in the process. A recent assessment by the Delhi-based advocacy think tank Centre for Science and Environment (CSE) analysed shares in the future if the current rate of emissions continued without major interventions. It found that the distribution of historical emissions between 1870 and 2030 would be nearly the same as that between 1870 and 2021. This means that in the nine years (now six) left until 2030, which is the target year in most Nationally Determined Contributions (NDC), climate actions are not enough to bring down the emissions share of the top polluters.

The flip side of this scenario implies that, with the exception of a few countries, the rest of the world is projected to maintain their current emission levels. This implies that unless they achieve rapid decarbonisation, their industrialisation, or level of social and economic wellbeing remains stunted.

ACCOUNTING FOR THE BUDGET

Consumed vs remaining GCB for a 50% chance to meet 1.5°C



Sources: Global Carbon Project, IPCC AR6, CSE Analysis

OCEANS HEATING UP, BREWING PLANETARY DISRUPTIONS

Heat content in oceans and sea level rise are two indicators of global warming levels. The rate of sea level rise has also doubled since satellite measurements began, according to the 2025 WMO report. The long-term rate of sea-level rise has doubled since the start of the satellite record keeping: increasing from 2.1 mm per year between 1993 and 2002 to 4.7 mm per year between 2015 and 2024. "In 2024, global mean sea level reached a record high in the satellite record

(from 1993 to present)," the WMO assessed.

"In 2024, observed global ocean heat content set a record, exceeding the previous record set in 2023 by 16 ffl 8 ZJ. Over the past eight years, each year has set a new record for ocean heat content," said the WMO assessment for climate in 2024. Instrumental records start around 1960. The rate of ocean warming over the past two decades (2005–2024), 0.99–1.07 W m–2 or 11.2–12.1 ZJ per year, is more than twice that observed over the period 1960–2005 (0.27–0.34 W m–2 or 3.1–3.9 ZJ per year)," according to WMO. The WMO had in many assessments said that the current level of ocean warming confirmed that "the Earth is currently out of energy balance".

This is a perfect brew for planetary disruptions in terms of extreme weather events. According to the Clasius-Clapeyron equation, for every 1°C rise in global average temperature, there would be a 7 per cent rise in atmospheric moisture levels. The impacts of this are clearly evidenced by recent extreme weather events around the world, such as tropical cyclones, extreme rainfall, floods and droughts around the world. These events caused the greatest number of displacements in 2024 since 2008, as per the report.

The year 2024 witnessed a record number of attribution studies that show climate change as the key factor behind extreme weather events. Under the "attribution study", a new stream of climate science, scientists precisely measure the impact of climate change on a weather event, or assess if the particular event would have been different, both in frequency and intensity, without the climate change. The pioneer in rapid attribution studies is World Weather Attribution (WWA), an initiative by climate scientists from institutions across the globe. Between January and October 2024, scientists at WWA released 34 rapid attribution studies—the most in a calendar year since the initiative started in 2014. Of these, 28 studies are on significant extreme weather events—rains, floods and storms (17 studies); heatwaves

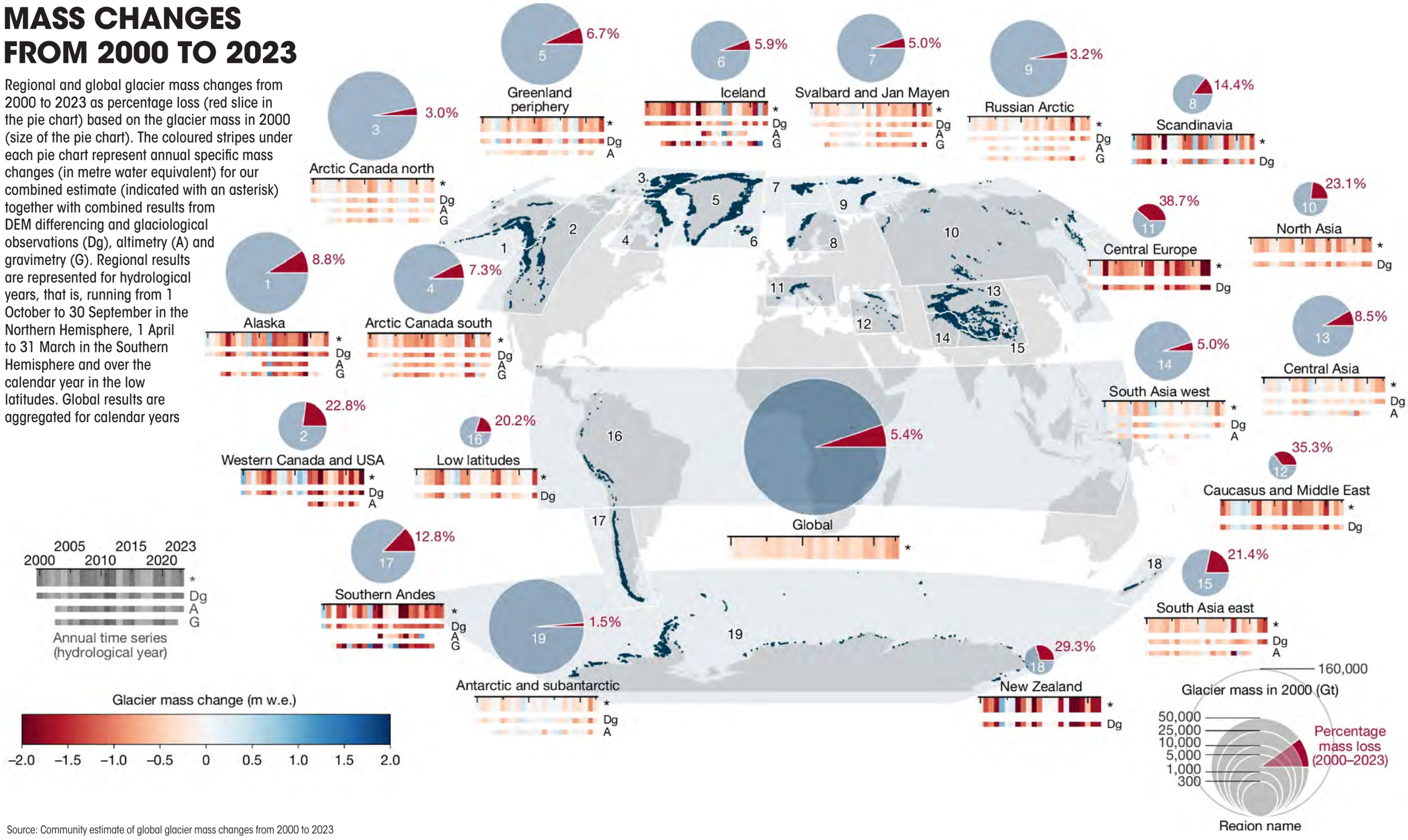
It said that in 2023, 6.3 billion people—about 78 per cent of the world's population—experienced at least 31 days of extreme heat, defined as temperatures exceeding 90 per cent of historical norms for their region (based on the 1991-2020 average)

(six studies); droughts and wildfires (two studies each); and cold spells (one study). The studies cover 26 events and show the rise in frequency and intensity of the events due to climate change. WWA attributed the May-June 2024 heatwaves in Asia and Africa's Sahel region to climate change. In a study released on May 28, 2024 WWA said that human-induced climate change has at least doubled the likelihood of such extreme heat events. It said that in 2023, 6.3 billion people—about 78 per cent of the world's population—experienced at least 31 days of extreme heat, defined as temperatures exceeding 90 per cent of historical norms for their region (based on the 1991-2020 average). The analysis also revealed that climate change contributed an average of 26 additional days of extreme heat globally, compared to conditions in a pre-industrial climate. The study stated that climate change has made such extreme temperatures nearly 0.85°C hotter than previous averages.

The world experienced a 240 per cent increase in the average number of marine heatwave (MHW) days in the summers of 2023-24 relative to the instrumental record, according to a study published in *Nature Climate Change* in March 2025. MHW, which is extreme rises in ocean temperature for an extended period of time, hit every part of the globe. Close to 10 per cent of the oceans experienced the highest sea surface temperatures (SST) ever — four times higher than the historical annual average, said the study. The global average SSTs reached record highs. "Summertime MHWs in 2023-24 were unprecedented and had wide-ranging biological, physical and societal impacts. Need to develop better response plans and adaptation and intervention approaches as MHWs intensify under climate change," said Dan A Smale, Marine Biological

GLOBAL GLACIER MASS CHANGES FROM 2000 TO 2023

Regional and global glacier mass changes from 2000 to 2023 as percentage loss (red slice in the pie chart) based on the glacier mass in 2000 (size of the pie chart). The coloured stripes under each pie chart represent annual specific mass changes (in metre water equivalent) for our combined estimate (indicated with an asterisk) together with combined results from DEM differencing and glaciological observations (Dg), altimetry (A) and gravimetry (G). Regional results are represented for hydrological years, that is, running from 1 October to 30 September in the Northern Hemisphere, 1 April to 31 March in the Southern Hemisphere and over the calendar year in the low latitudes. Global results are aggregated for calendar years



Source: Community estimate of global glacier mass changes from 2000 to 2023

EARTH IS TRAPPING MUCH MORE HEAT THAN CLIMATE MODELS FORECAST

The acceleration in heat trapping is mainly due to increased greenhouse gas emissions and changes in cloud patterns

STEVEN SHERWOOD, BENOIT MEYSSIGNAC AND THORSTEN MAURITSEN

HOW DO you measure climate change? One way is by recording temperatures in different places over a long period of time. While this works well, natural variation can make it harder to see longer-term trends. But another approach can give us a very clear sense of what's going on: Track how much heat enters Earth's atmosphere and how much heat leaves. This is Earth's energy budget and it's now well and truly out of balance.

Our recent research found this imbalance has more than doubled over the last 20 years. Other researchers have come to the same conclusions. This imbalance is now substantially more than climate models have suggested.

In the mid-2000s, the energy imbalance was about 0.6 watts per square metre (W/m2) on average. In recent years, the average was about 1.3 W/m2. This means the rate at which energy is accumulating near the planet's surface has doubled. These findings suggest climate change might well accelerate in the coming years. Worse still, this worrying imbalance is emerging even as funding uncertainty in the United States threatens our ability to track the flows of heat.

ENERGY IN, ENERGY OUT

Earth's energy budget functions a bit like your bank account, where money comes in and money goes out. If you reduce your spending, you'll build up cash in your account. Here, energy is the currency. Life on Earth depends on a balance between heat coming in from the Sun and heat leaving. This balance is tipping to one side. Solar energy hits Earth and warms it. The atmosphere's heat-trapping greenhouse gases keep some of this energy.

But the burning of coal, oil and gas has now added more than two trillion tonnes of carbon dioxide and other greenhouse gases to the atmosphere. These trap more and more heat, preventing it from leaving. Some of this extra heat is warming the land or melting sea ice, glaciers and ice sheets. But this is a tiny fraction. Fully 90 per cent has gone into the oceans due to their huge heat capacity. Earth naturally sheds heat in several ways. One way is by reflecting incoming heat off of clouds, snow and ice and back out to space. Infrared radiation is also emitted back to space. From the beginning of human civilisation up until just a century ago, the average surface temperature was about 14°C. The accumulating energy imbalance has now pushed average temperatures 1.3-1.5°C higher.

TRACKING FASTER THAN THE MODELS

Scientists keep track of the energy budget in two ways. First, we can directly measure the heat coming from the Sun and going back out to space, using the sensitive radiometers on monitoring satellites. This dataset and its predecessors date back to the late 1980s. Second, we can accurately track the build-up of heat in the oceans and atmosphere by taking temperature readings. Thousands of robotic floats have monitored temperatures in the world's oceans since the 1990s. Both methods show the energy imbalance has grown rapidly. The doubling of the energy imbalance has come as a shock, because the sophisticated climate models we use largely didn't predict such a large and rapid change. Typically, the models forecast less than half of the change we're seeing in the real world.

WHY HAS IT CHANGED SO FAST?

We don't yet have a full explanation. But new research suggests changes in clouds are a big factor. Clouds have a cooling effect overall. But the area covered by highly reflective white clouds has shrunk, while the area of jumbled, less reflective clouds has grown.

It isn't clear why the clouds are changing. One possible factor could be the consequences of successful efforts to reduce sulfur in shipping fuel from 2020, as burning the dirtier fuel may have had a brightening effect on clouds. However, the accelerating energy budget imbalance began before this change.

Natural fluctuations in the climate system such as the Pacific Decadal Oscillation might also be playing a role. Finally — and most worryingly — the cloud changes might be part of a trend caused by global warming itself, that is, a positive feedback on climate change.

WHAT DOES THIS MEAN?

These findings suggest recent extremely hot years are not one-offs but may reflect a strengthening of warming over the coming decade or longer. This will mean a higher chance of more intense climate impacts from searing heatwaves, droughts and extreme rains on land and more intense and long lasting marine heatwaves.

This imbalance may lead to worse longer-term consequences. New research shows the only climate models coming close to simulating real world measurements are those with a higher "climate sensitivity". That means these models predict more severe warming beyond the next few decades in scenarios where emissions are not rapidly reduced.

We don't know yet whether other factors are at play, however. It's still too early to definitively say we are on a high-sensitivity trajectory.

OUR EYES IN THE SKY

We've known the solution for a long time: Stop the routine burning of fossil fuels and phase out human activities causing emissions such as deforestation. Keeping accurate records over long periods of time is essential if we are to spot unexpected changes.

Satellites, in particular, are our advance warning system, telling us about heat storage changes roughly a decade before other methods. But funding cuts and drastic priority shifts in the United States may threaten essential satellite climate monitoring.

(Steven Sherwood, Professor of Atmospheric Sciences, Climate Change Research Centre, UNSW Sydney; Benoit Meyssignac, Associate Research Scientist in Climate Science, Université de Toulouse and Thorsten Mauritsen, Professor of Climate Science, Stockholm University)

Association of the United Kingdom, Plymouth, UK, and the author of the study.

The MHWs had knock-on effects. The prolonged MHWs in 2023 influenced weather patterns, for instance. It contributed to extreme air temperatures in the United Kingdom, North America and Japan, and severe flooding in Ecuador, Libya, Japan and Australia. It also "supercharged" the heat and moisture exchanges between sea and air, with a near-record number of named storms occurring through the 2023 Atlantic hurricane season and several tropical storms made landfall along the Pacific and Indian Ocean coastlines.

Previous studies had shown that the Indian Ocean warmed at a rate of 1.2°C per century during 1950-2020. Between 2020 and 2100, climate models predict warming at a rate of 1.7°C-3.8°C per century. The effects are expected to be more pronounced in the northwestern Indian Ocean including the Arabian Sea. Further, MHWs are expected to increase from 20 days per year to 220-250 days per year, pushing the tropical Indian Ocean into a near-permanent heatwave state, according to the book, "Future projections for the tropical Indian Ocean".

Overall, in 2023-2024, MHWs drove 23 records of physical impacts such as cyclones, flooding, atmospheric heatwaves, rainfall and dam collapse. The MHW events across 2023-2024 were also linked to biological impacts such as coral bleaching event, loss of vital ecosystems off Japan and Peru, and species making inroads into newer geographical locations. MHWs were also linked to damage to ecosystem services, marine industries and wider society. There were 33 records of societal impact from MHWs globally, showed the study.

ICE COVERS VANISHING, FAST

The "State of the Cryosphere 2024" report released at the 29th Conference of Parties (COP29) to the UN Framework Convention on Climate Change (UNFCCC) in 2024, said, "With rapid warming, glacier and snow loss, vulnerable mountain and downstream communities could face non-survivable conditions by 2050 due to loss of seasonal water availability, or destructive floods." The earliest ice-free day in the Arctic Ocean could occur within three years from the 2023 sea ice area (SIA) minimum equivalent conditions, according to a study published in the journal *Nature Communications* on December 3, 2024. This means that the first summer on

PHOTOGRAPH: ISTOCK PHOTO

record that melts practically all of the Arctic's sea ice could occur as early as 2027.

The study made the projection using daily output from multiple Coupled Model Intercomparison Project Phase 6 models. The researchers Celine Heuze (of University of Gothenburg, Sweden) and Alexandra Jahn (of University of Colorado Boulder, US) said that "there is a non-zero probability of an ice-free day before 2030". The primary trigger of the rapid transition to the first ice-free day within three–six years will be a warm atmosphere in the previous winter and spring, leading to a loss of sea ice mass year-round, the researchers identified. The first year with an ice-free day will have spring daily mean temperatures already in January due to heatwaves / blockings and / or warm air intrusions. In addition, the study found storms going across the Arctic in the days leading up to the first ice-free day. All these events were projected to increase in frequency as the Arctic warms, making the first ice-free day increasingly more likely. The good news is that "the first ice-free day occurs in years with a 5-year running mean global temperature at or above 1.5°C compared to the pre-industrial level". This means that if the warming levels are kept below the Paris Agreement target of 1.5 °C of global warming, ice-free days could potentially still be avoided.

Although the first ice-free day holds great symbolic importance, it doesn't signify that the Arctic Ocean will be ice-free every year thereafter. The initial ice-free day won't cause dramatic changes. "But it will show that we've fundamentally altered one of the defining characteristics of the natural environment in the Arctic Ocean, which is that it is covered by sea ice and snow year-round, through greenhouse gas emissions," said Alexandra Jahn.

However, Arctic sea ice shrank to almost record lows in the Northern Hemisphere in the summer of 2024, probably reaching its smallest size of the year on September 11, 2024, as reported by the US' National Aeronautics and Space Administration (NASA) and the National

Snow and Ice Data Center. This decrease is part of a long-term trend of diminishing and thinning ice in the Arctic Ocean. For the last 46 years, satellites have consistently recorded increased melting during the summer and reduced ice formation in the winter. Nathan Kurtz, the head of NASA's Cryospheric Sciences Laboratory, observed that sea ice is not only diminishing in size but also becoming younger. "The overwhelming majority of ice in the Arctic Ocean is thinner, first-year ice, which is less able to survive the warmer months. There is far, far less ice that is three years or older now."

In May 2025, a dire warning came. Glaciers around the world are melting faster and more extensively than previously feared, according to a study published in the journal Science. The findings, released in the first United Nations conference on glaciers held in Tajikistan, revealed that keeping global warming below 1.5°C could preserve more than twice as much glacier ice if current climate policies continue on track, pushing warming to 2.7°C. The study, conducted by a team of 21 scientists from 10 countries, used eight glacier models to simulate the long-term fate of more than 200,000 glaciers across the globe. Even if today's temperatures remain steady, glaciers are still committed to losing around 39 per cent of their 2020 ice mass over centuries. However, the research demonstrated how stark the difference becomes as warming thresholds rise.

Under current climate pledges, the world is set to warm by 2.7°C above pre-industrial levels — this would leave only 24 per cent of global glacier ice intact in the long term. By contrast, staying close to 1.5°C, the goal of the Paris Agreement, would preserve around 54 per cent of that ice. But the global average masks deeper regional crises. Some of the world's most socially and environmentally critical glacier regions — including the European Alps, the Western Rockies of

Glaciers, distinct from the continental ice sheets in Greenland and Antarctica, covered approximately 706,000 square kilometres globally around the year 2000. Their melting exacerbates local geo-hazards, impacts marine and terrestrial ecosystems and threatens regional freshwater resources

North America and Iceland — are projected to lose nearly 90 per cent of their ice at 2°C warming. Scandinavia, shockingly, could lose all its glacier ice entirely.

In the first 23 years of the new millennium, glaciers lost an estimated 273 billion tonnes of ice annually from 2000 to 2023, making them the second-largest contributor to rising sea levels, according to a study published in journal *Nature* in February 2025. The total global glacier mass loss over this period amounted to 6.54 trillion tonnes, contributing 18 millimetres (mm) to global sea-level rise. The annual rate of sea-level rise attributed to glacier melt was 0.75 mm per year, the study noted. Furthermore, ice loss accelerated significantly in the second half of the study period (2012-2023), increasing by 36 per cent compared to the first half (2000-2011). "Our observations and recent modelling studies indicate that glacier mass loss will continue and possibly accelerate until the end of this century," Samuel Nussbaumer, a glaciologist at the University of Zurich (UZH), said in a statement. "This underpins the Intergovernmental Panel on Climate Change's (IPCC) call for urgent and concrete actions to reduce greenhouse gas emissions and associated warming to limit the impact of glacier wastage on local geohazards, regional freshwater availability, and global sea-level rise," he added.

Glaciers, distinct from the continental ice sheets in Greenland and Antarctica, covered approximately 706,000 square kilometres globally around the year 2000. Their melting exacerbates local geo-hazards, impacts marine and terrestrial ecosystems and threatens regional freshwater resources, while also influencing global water and energy cycles. To map the changing glaciers, an international team of scientists conducted the Glacier Mass Balance Intercomparison Exercise (GlaMBIE), an initiative aimed at providing a reconciled assessment of global glacier mass changes for the next IPCC report. Researchers used different field and satellite observation

WILDFIRES, EMISSIONS AND AN ACCOUNTING CHALLENGE

With increasing forest fire activities, how much of the carbon sink effect can be retained in forests

MINAL PATHAK

WILDFIRES FALL into two categories: natural and anthropogenic. The latter includes fires set deliberately for livestock or agriculture. Some global databases account for anthropogenic fires. When a fire is set, land use changes and emissions are released from burning the forest. These emissions include carbon dioxide (CO_2), methane, nitrous oxide and various air pollutants such as black carbon and carbon monoxide.

CO_2 is generally assumed to be carbon neutral, as the burnt area is expected to recover over time (resulting in net-zero forcing). However, methane, nitrous oxide and other emissions must be considered, as they contribute to radiative forcing. The assumption of "carbon neutrality" can be challenged, particularly as fires become more severe and due to time displacement. Nonetheless, fire and recovery are generally considered part of the "natural land sink."

However, wildfires can also be triggered by human-induced climate change. The wildfire emissions from Canada in 2023 and 2024 were reported as natural in inventories. The same applies to California, where fires were classified as natural in the sense that no one deliberately ignited them. However, climatic conditions played a role in triggering the fires, yet these factors are not accounted for in greenhouse gas inventories.

"The Emissions Gap Report 2024" only includes emissions directly caused by human activity. This excludes naturally occurring emissions, such as those from volcanic eruptions. This is the first time the report has included a dedicated section on wildfires, attempting to explain the challenges involved in accounting for these emissions.

There are factors that make including wildfire greenhouse gas emissions in inventories complicated. When a tree burns, CO_2 is released, but much of it is reabsorbed over time as the area regenerates. This introduces a temporal aspect to carbon accounting. That is the first problem. A second challenge arises from climate change itself, which affects how trees absorb and store carbon, adding another layer of uncertainty. It is unclear how forests will restock their carbon stores after fires.

There is also the issue of double counting. For example, some CO_2 emissions from fires in tropical regions should be excluded to avoid duplication with deforestation data, as deforestation in these areas often occurs through burning. Similarly, methane and nitrous oxide emissions from crop burning should not be counted twice if they overlap with agricultural residue burning emissions.

Also, there is a difference in how global emissions are accounted for and the way national emissions are accounted for. As always, country-level data is more uncertain than the global level. But the question is with increasing forest fire activities, how much of the carbon sink effect can be retained in forests amid increasing wildfire activity and whether these carbon stocks remain stable in the long term. The burning of annual vegetation is considered carbon neutral since it maintains equilibrium, whereas forest fires should generally be included — except in tropical areas where they overlap with deforestation. The inventories will change, I think, because of increased incidents of wildfires linked to climate change. Although accounting for these emissions remains challenging, global databases and national inventories are becoming more nuanced.

The Emissions Gap Report does not use national data. Instead, it refers to global estimates such as EDGAR (Emission Database for Global Atmospheric Research); Global Fire Emissions Database (GFED – initiated around 2000 by James Randerson (then at Caltech, now at UCI) and Jim Collatz (NASA) to estimate fire emissions and burned areas using satellite data and vegetation productivity and the global carbon budget — an international project that quantifies anthropogenic CO_2 emissions and carbon removal by land and oceans to track atmospheric CO_2 levels. The latest GFED dataset (GFED4s) includes small fire burned areas from 2017 onwards, based on the relationship between active fires and emissions. However, these estimates carry significant uncertainty, particularly when extrapolating data for regions with limited fire activity from 1997 to 2016, making them unsuitable for trend analysis.

The EDGAR database includes forest fires from boreal and temperate forests, as well as peat fires, using

a Tier 1 method to estimate net forest sink without fires. Meanwhile, GFED accounts for global tropical deforestation and Equatorial Asia peat fires, but the overall contribution is relatively small (0.03 gigatonnes of carbon dioxide equivalent). The aim is to constrain the estimates as much as possible to direct anthropogenic fires only. Unless a clear method is developed to attribute wildfire emissions to anthropogenic causes—whether directly or indirectly due to climate change — it remains difficult to include them accurately. That said, with new data emerging, I expect the situation to improve in terms of transparency and consistency from next year onwards.

(Minal Pathak is an associate professor at Global Centre for Environment and Energy, Ahmedabad University, India. She is one of the authors of the United Nations Emissions Gap report. This column is based on a conversation Minal had with Down To Earth *magazine, published from New Delhi, India)*

methods to collect, homogenise, combine, and analyse glacier mass change. They employed a range of field and satellite observation methods to collect, standardise, combine and analyse data on glacier mass changes. "We have got a wealth of satellite observations since 2000. While this allowed us to observe mass changes from all the about 275,000 glaciers worldwide, the results published did often not well agree, came with large uncertainties, or were not directly comparable due to different regional or temporal coverage," said Michael Zemp, professor at the Department of Geography at UZH.

To address this issue, the team conducted an inter-comparison study, bringing together experts and data from key observation methods. This enabled them to compare and combine results from different techniques into an annual time series of glacier mass changes for all glacier regions worldwide from 2000 to 2023. Their analysis revealed that glaciers had lost between 2 per cent and 39 per cent of their ice regionally and approximately 5 per cent globally.

Additionally, glacier mass loss was found to be around 18 per cent greater than that of the Greenland Ice Sheet (the largest ice mass in the Northern Hemisphere) and more than twice that of the Antarctic Ice Sheet (the largest ice mass on Earth). The ice sheets of Greenland and Antarctica together store about two-thirds of the world's freshwater, according to NASA. The loss has been particularly pronounced in recent years, with the period from 2019 to 2023 witnessing the highest annual ice loss — exceeding 400 gigatonnes per year (Gt/yr) — including a record 548 Gt/yr in 2023. The largest regional contributors to global glacier mass loss were Alaska (22 per cent), the Canadian Arctic (20 per cent), peripheral glaciers in Greenland (13 per cent) and the Southern Andes (10 per cent).

Glacier size also influenced mass loss, with the greatest relative ice loss occurring in regions where glaciers covered 15,000 square kilometres or less. Zemp explained that the study underscored the primary contributors to the observed global mean sea-level rise of 3.6 mm per year between 2003 and 2016. The steric component — changes in ocean temperature and salinity — accounted for 33 per cent, followed by glaciers at 20 per cent and the Greenland Ice Sheet at 17 per cent. "Smaller contributions originate from changes in land water storage and the Antarctic Ice Sheet. In view of their increasing melting, glaciers will be a main driver of sea-level rise over the coming decades. On the longer term, the ice sheets in Greenland and Antarctica will dominate sea-level rise," he added.

The researchers emphasised that glaciers are crucial freshwater resources, particularly for communities in Central Asia and the Central Andes, where glacier meltwater sustains rivers during warm and dry seasons. "But when it comes to sea-level rise, the Arctic and Antarctic regions with their much larger glacier areas are the key players. Almost one quarter of the glacier contribution to sea-level rise originates from Alaska," said UZH glaciologist Inés Dussaillant, who was involved in the GlaMBIE analyses.

MORE IN FUTURE

Global temperatures are poised to remain at or near record highs between 2025 and 2029, warned the WMO's "Global Annual to Decadal Climate Update" released on May 28, 2025. In the next five years, the global average near-surface temperature was forecast to range between 1.2°C and 1.9°C above the pre-industrial levels (1850-1900 baseline). Critically, there was an 86 per

ATMOSPHERIC RIVERS IN CHURN

Increasing load of moisture in the atmosphere is adding another layer of complexity to the climate crisis

WATER VAPOUR is one of the many gases that make up the atmosphere and is part of the hydrological cycle, which is fundamental to life on Earth. As the climate warms and air temperatures rise, more evaporation from water sources and land occurs, thus increasing atmospheric moisture content. According to the Clausius Clapeyron equation—a 190-year-old thermodynamics principle—for every 1°C rise in temperature, water holding capacity of the atmosphere increases by about 7 per cent. Scientists have established that the planet has warmed by 1.1°C since the preindustrial levels and, as per a recent analysis by EU's Copernicus Climate Change Service (C3S), is on track to breach the 1.5°C warming threshold by the end of 2024. Kevin Trenberth, scientist at US National Center for Atmospheric Research, estimates that there is now 5-15 per cent more moisture in the atmosphere compared to before the 1970s, when global temperature rise began in earnest.

This increasing load of moisture in the atmosphere is adding another layer of complexity to the climate crisis. On the one hand, it is amplifying warming caused by other greenhouse gases (GHGs) and on the other; it is intensifying extreme weather events and making them unpredictable.

A major impact of increasing moisture level in the atmosphere can be assessed through changes in atmospheric rivers—essentially, vast airborne corridors of condensed water vapour in subtropical areas that transport water from the tropics to higher latitudes. These rivers, as described by the US National Oceanic and Atmospheric Administration (NOAA), carry volumes of water comparable to that of the Mississippi river. "Atmospheric rivers transport 90 per cent of moisture from tropical areas to subtropical regions and are a major source of water for those areas," said Sara M Vallejo-Bernal, climate scientist at Potsdam Institute for Climate Impact Research, Germany. Strong atmospheric rivers can in fact carry 7.5-15 times the water volume of the Mississippi's mouth, with four to five of these systems active in the atmosphere at any given time, as per NOAA. But in a warming world, these atmospheric rivers are becoming longer, wider and more intense, primarily due to greater availability of water vapour, and can cause massive destruction and loss of life.

A 2023 study in *Nature* documented 574 atmospheric river events between 1951 and 2020, with their frequency increasing over time. The study found that 80 per cent of severe atmospheric rivers in the last two decades caused devastating floods. An October 2024 study published in Science Advances showed that atmospheric rivers had also shifted 6-10 degrees poleward over the past four decades. The scientists said that one main reason for this shift was changes in sea surface temperatures in

PHOTOGRAPH: ISTOCK PHOTO

the eastern tropical Pacific, which have had a cooling tendency since 2000, often tied to La Niña conditions that alter global atmospheric circulation. Atmospheric instability of the jet stream also allows them to curve poleward in different ways. They say a shift in atmospheric rivers can have significant effects on local climates. Subtropical regions, such as California and southern Brazil, could experience fewer atmospheric rivers, leading to prolonged droughts and water scarcity.

Conversely, higher latitudes, including the US Pacific Northwest, Europe and even the Arctic, are likely to face heavier rainfall, flooding and landslides. In polar regions, more atmospheric rivers will accelerate sea ice melting, exacerbate global warming and threaten ecosystems.

cent chance that at least one year in this period would exceed the Paris Agreement's 1.5°C warming threshold. The WMO also estimated a 70 per cent likelihood that the five-year average itself would cross the 1.5°C limit. While long-term warming averaged over decades remained below the line currently, the findings underscored how close the world was to breaching a key planetary boundary, even if temporarily. Nevertheless, this forecast underlines the dangers of the planet edging closer to irreversible climate thresholds, with the Arctic warming at more than three times the global average. The report warned that there was now an 80 per cent chance that at least one year between 2025 and 2029 would surpass 2024's record. Though extremely unlikely, there was even a 1 per cent chance of a single year exceeding 2°C of warming, a scenario that will have catastrophic consequences for ecosystems and human societies.

This is when a new assessment released in June 2025 said that the world's carbon budget was rapidly diminishing. The assessment by the Indicators of Global Climate Change (IGCC), which provides policymakers with annual updates on the latest scientific understanding of the state of selected critical indicators of the climate system, revealed that 50 per cent of the remaining carbon budget would likely be exhausted in just over three years if the global CO_2 emissions persisted at 2024 levels. The remaining carbon budget is the net amount of carbon dioxide humans can still emit without exceeding a 1.5°C global warming limit. The remaining carbon budget for 1.5°C, 1.6°C, 1.7°C and 2°C is 130 gigatonnes of carbon dioxide ($GtCO_2$), 310 $GtCO_2$, 490 $GtCO_2$ and 1050 $GtCO_2$, respectively.

The IGCC study estimated that human-induced warming for 2024 reached 1.36°C. The rate of warming has been particularly high, with a 0.27°C increase per decade between 2015 and 2024. This suggests that continued emissions at current levels could lead to human-induced global warming reaching 1.5°C in around five years. The high rate of warming, according to the study, is driven by two factors. The first is a combination of greenhouse gas emissions, which reached an all-time high of 53.6 $GtCO_2e$ per year over the last decade (2014–2023).

The second is the reduction in strength of aerosol cooling. Aerosols are small particles that can cool the atmosphere. When fossil fuel is burned, they release sulphate particles and sulphur dioxide, which can reflect sunlight and make the atmosphere cooler. However, Europe's air pollutant regulations have led to a decrease in atmospheric aerosols, thereby diminishing their cooling effect. The analysis highlighted that the average decadal greenhouse gas emissions have increased steadily since the 1970s, driven primarily by increasing CO_2 emissions from fossil fuel and industry, but also rising emissions of methane and nitrous oxide. "Global greenhouse gas emissions are at a long-term high, yet there are signs that their rate of increase has slowed," the study said. Also since the 1970s, there has been a persistent imbalance in the Earth energy system or Earth energy imbalance (EEI), a global warming indicator that provides a measure of accumulated surplus energy (heating) in the climate system. The EEI value during 1975–1994 was estimated to be 0.43 watts per square metre (W/m^2), which more than doubled to 0.89 W/m^2 during 2005–2024. ■

PHOTOGRAPH COURTESY: UNICEF

CRISIS AFRICA

HIGHPOINTS

Over the **past 60 years,** Africa has recorded a **warming trend** that has generally been **more rapid** than the global average

The year **2024** was the warmest year on **record for Africa.** Warming in the continent has exceeded the limits of natural variability

Almost the **entire ocean area around Africa** was under marine **heat waves** in 2024

The period between **2021 and 2025** is the most devastating **five-year stretch** in terms of **human toll** from weather, climate and water-related disasters

PHOTOGRAPH COURTESY: WORLD FOOD PROGRAMME

AFRICA'S TIPPING POINT

The continent's climate has changed at rates unprecedented in at least 2,000 years

WORLD'S YOUNGEST nation, South Sudan, typifies the impacts of, and the disability to fight the climate emergency in Africa. In August-October 2024 the country of 13 million faced its worst floods in six decades that affected 0.3 million people. The deluge killed over 30 million domestic animals. This meant each South Sudanese lost around two domestic animals, a critical source of food and livelihood. Going by reports of various UN and humanitarian agencies, floods affect close to 1 million people every year in the east African country in recent years. Recurring floods also mean millions remain displaced for years. Mamman Mustapha, head of mission of

Doctors Without Borders (MSF) in South Sudan, said, "People in the Old Fangak area have been displaced several times since 2022 and arable land has decreased, as have food rations provided by the World Food Programme (WFP). Communities constantly have to move to a new location, not knowing if they will be able to harvest what they have been able to sow." Old Fangak is in the Sudd marshes, one of the largest wetlands in the world spanning about 25,000 square miles.

South Sudan is facing contrasting extreme climatic events. Meshack Malo, South Sudan Country Representative for the UN Food and Agriculture Organization (FAO), said, "When South Sudan is not hit by floods, it is plagued by drought. This cyclic change between floods and drought makes the country affected for almost a good part of the year." It is widely observed that floods are becoming frequent and also more intense in recent times. "That means that any short rain then can easily trigger the flooding, because water and the soil remain quite saturated," said Malo adding, "So that intensity and frequency makes this situation worse." According to the Joint Research Center of the European Commission, "Already facing extreme food insecurity, with more than 70 per cent of the population needing humanitarian aid, South Sudan has the world's lowest level of coping capacity for climate disasters."

South Sudan is counted among the most vulnerable countries to climate change. At the same time, it is also the country with the least capacity to manage and adapt to this emergency. In the last three decades, its temperature has been rising at the rate of 0.53°C per decade, one of the world's fastest rates. Most of the country has already reported temperature rise of more than 1°C. The World Bank's Climate Change Knowledge Portal referring to the country's climate reported, "South Sudan's observed average mean temperature is 28°C (1991–2020)." The Bank said that its "seasonal mean temperatures

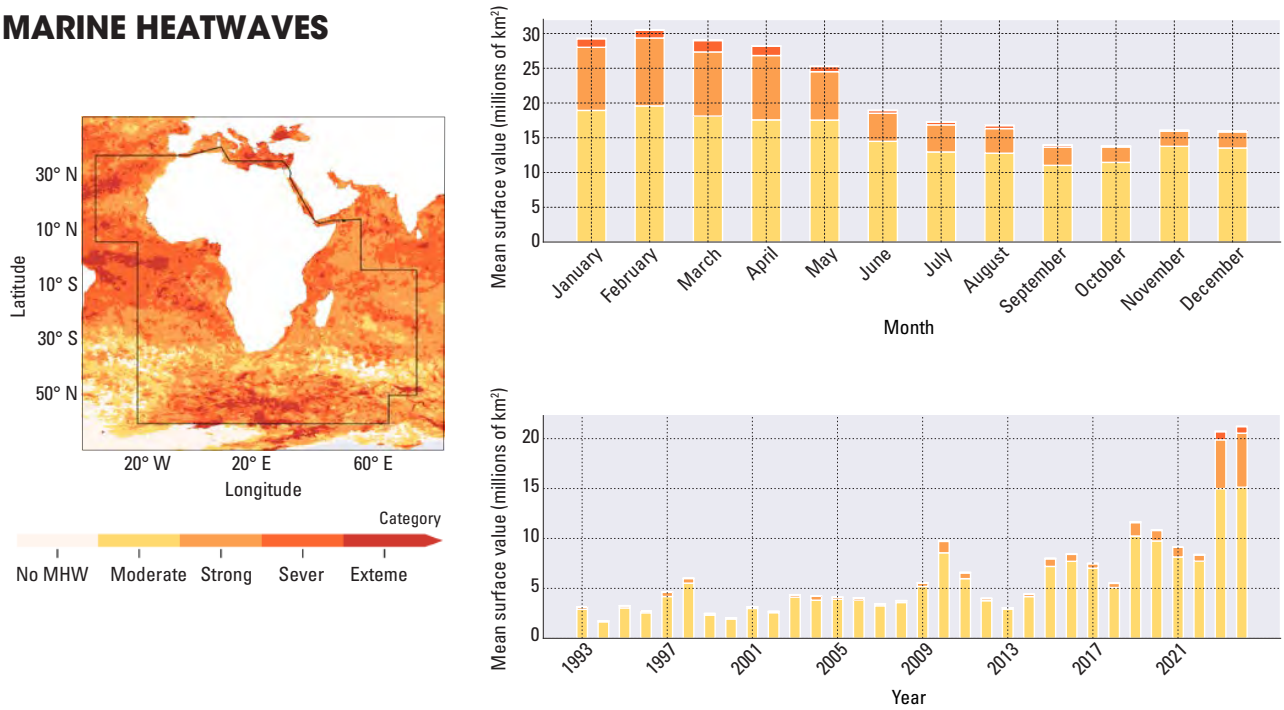
When South Sudan is not hit by floods, it is plagued by drought. This cyclic change between floods and drought makes the country affected for almost a good part of the year

have risen the most in December–February (1.15°C since 1901) and March–May (1.4°C since 1901)." And "the rainy season precipitation has increased in July–November and decreased in December–May (since 1901)." It warned, "Rising temperatures and declining dry season rainfall can decrease water availability and vegetation growth."

The contrasting extreme weather events are being attributed to the change in climate fuelled by global warming. South Sudan's extreme heat in February 2025 was at least 2°C hotter and 10 times more likely due to human-induced climate change, according to a new study by World Weather Attribution (WWA), a global consortium of climate scientists who study the role played by human-induced climate change in the occurrence, frequency and intensity of extreme weather events. With temperatures reaching 40°C, such extreme heat events are no longer rare in the country, warn 13 WWA scientists who led the study. The scientists found the period of February 22-28, 2025 the hottest week of the year. They found that climate models underestimated the actual rise in temperatures, suggesting that human-induced warming might have even greater impacts than currently projected. As global temperatures continue to rise, South Sudan is expected to face more frequent and intense heatwaves, worsening its humanitarian crisis. While the 2024 heatwave in mid-March recorded higher peak temperatures, the 2025 heatwave occurred earlier in February, raising concerns that extreme heat is becoming both more intense and shifting seasonally.

The worsening desertification has also led to a 46 per cent drop in agricultural yields, according to the FAO's March 2023-April 2024 report, compounding the humanitarian disaster. Sudan's crisis exemplifies how environmental strain can escalate existing conflicts and deepen human suffering.

MARINE HEATWAVES



Left: Map of MHWs by category for 2024 for WMO Region I Africa (black line) from Copernicus Marine Service. Right: Monthly mean surface area covered by MHWs during 2024 (upper panel), and annual mean surface area covered by MHWs over the entire record (lower panel). The categories are indicated by the colours in the bar at the bottom of the left panel.

Source: State of the Climate in Africa 2024, World Meteorological Organization

A CONTINENTAL EMERGENCY

Africa is the hotspot of the planetary climate emergency. An analysis by Washington DC-based Brookings Institution said that seven out of the 10 most climate vulnerable nations in the world are located in Africa. The Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) released in August 2021 poignantly summed up, "Over the past 60 years, Africa has recorded a warming trend that has generally been more rapid than the global average... the climate has changed at rates unprecedented in at least 2,000 years." In fact, every third death (or 35 per cent) in the world from extreme weather, climate or water stress in 50 years was in Africa, according to WMO.

According to IPCC regional projections, the average annual maximum temperature in northern and southern Africa is likely to be close to 4°C above normal. "The median temperature in these regions will rise 3.6°C when the Earth warms at 2°C above pre-industrial levels," the IPCC assessment has predicted. In some parts of north-western Africa the annual minimum temperature is projected to increase by over 2°C.

The Middle East and North Africa (MENA) are warming much faster than the global average, with notable hotspots in the Arabian Peninsula and Algeria, according to a study published in the *Journal of Geophysical Research* in November 2024. The study examined in detail the actual and projected temperature changes in the MENA region from 1850 to the end of this century. Researchers, utilising dynamically downscaled climate models, uncovered notable regional differences and biases in temperature projections for the MENA region. The temperature patterns exhibited seasonal fluctuations and distinct warming rates between coastal and inland zones throughout the MENA region.

Using the most recently available data and models, the researchers showed that the MENA

region, especially the Arabian Peninsula, was experiencing a much faster rate of warming compared to the global average. The central Arabian Peninsula's warming rate was found to be similar to that of the Arctic and is two to three times higher than the worldwide average. This discovery is alarming as the Arabian Peninsula is already among the hottest places on the planet. Other regions experiencing significant warming include Algeria, Mauritania and the Elburz Mountains in Iran.

The MENA region, known for its largely arid and semi-arid environments typical of hot desert climates, has been recognised as a major climate-change hotspot. The area faces significant threats from climatic changes due to high greenhouse gas emissions. The MENA region, which already has record-breaking summer temperatures, is currently close to exceeding 2°C of warming on average, compared to pre-industrial temperatures. Additional warming in the region could make some areas uninhabitable without adaptation measures. Warming rates are not consistent across the seasons. The researchers found summer hotspots over the central Arabian Peninsula, including the populous Riyadh Province and Algeria, and winter hotspots over Mauritania and Iran's Elburz Mountains.

By 2100, the Arabian Peninsula could warm on average by 2.6°C under low emission scenarios and by 7.6°C under high emission scenarios, according to the study. That is because the arid deserts of MENA cannot easily cool through evaporation of soil moisture, unlike their humid equatorial counterparts elsewhere in the world. Due to coastal cooling, densely populated areas along the southern and western coasts of the Arabian Peninsula, including Oman, are currently not warming as quickly as inland areas and the eastern coast of the peninsula. If the world meets low emissions targets, the pace of warming in MENA could slow by as much as 38

The average annual surface temperature across Africa was around 0.86°C above the average annual surface temperature between 1991 and 2020. The strongest warming was in North Africa, which was 1.28°C above the 1991-2020 average. North Africa is the fastest warming region in the continent

per cent. Individual cities could also try to adapt to the extreme heat through urban greening and architectural solutions.

The year 2024 was the warmest or second-warmest year on record for Africa along with devastating floods, droughts and marine heat waves, according to WMO's "State of Climate in Africa 2024" report, released in May 2025. The average annual surface temperature across Africa was around 0.86°C above the average annual surface temperature between 1991 and 2020. The strongest warming was in North Africa, which was 1.28°C above the 1991-2020 average. North Africa is the fastest warming region in the continent. The El Niño event of 2023-2024 was partly to blame for the warming and extreme weather, along with global warming and consequent climate change.

Warming in Africa has exceeded the limits of natural variability. According to the earlier IPCC report (Assessment Report 5, AR5), the near surface temperatures had risen by 0.5°C over the past century. Despite the size and geographical spread of Africa, the only exception to the observed heating trend comes from the central and interior regions of Africa. But even here, there are problems. "It is very likely that mean annual temperature has increased over the past century over most of the African continent, with the exception of areas of the interior of the continent, where the data coverage has been determined to be insufficient to draw conclusions about temperature trends," said AR5. By the end of the century, most models showed that temperatures across the continent under the "business-as-usual" scenario will be about 3-6°C higher than the average temperature observed at the end of the 20th century, which is already close to being 0.5°C more than average temperatures at the beginning. AR5 noted that the maximum change in temperature by the end of the century is likely to occur in the northern and southern parts of

PHOTOGRAPH COURTESY: UNICEF

the continent. But the fastest rate of change is expected to occur on the western side. "However, in the tropics, especially tropical West Africa, these unprecedented climates are projected to occur 1 to 2 decades earlier than the global average because the relatively small natural climate variability in this region generates narrow climate bounds that can be easily surpassed by relatively small climate changes," said the AR5.

Extreme temperatures impacted agriculture and other livelihoods in many parts of Africa in 2024. For instance in mid-March 2024, Sudan and Somalia suffered from an unprecedented heat wave with temperatures reaching above 45°C, leading to shut down of schools and impacts on food availability and livelihoods. Around the same period and in April, there were extreme temperatures in the Sahel region as well. In July, a heat dome phenomenon, or a large high pressure area, had caused record breaking temperatures in North Africa.

Sea surface temperatures around the continent, especially in the Atlantic Ocean and in the Mediterranean Sea were also record high. Alarmingly, almost the entire ocean area around Africa was under marine heat waves (MHWs) of "strong, severe or extreme intensity during 2024", according to WMO. MHWs are extended periods of extreme ocean temperatures that affect the health and productivity of marine life and also aid in the formation and intensification of tropical cyclones which frequently impact many countries of Africa, especially towards the southeast such as Malawi, Mozambique and Madagascar. A total area of 30, 00,000 square kilometres of the ocean was affected by MHWs between January and April 2024. In the latter six months of the year, the total affected area was 1.5 million square kilometres. The area affected by MHWs was the highest since records began in 1993, breaking the previous record set in 2023.

The contrasting nature of extreme weather events hitting the continent can be gauged from Tanzania's experience in 2024. Tanzania experienced its hottest year on record, marked by sharply rising night-time temperatures. The country's average annual minimum temperature, a

key indicator of night-time warmth, reached 19.3°C, which was 1.1°C higher than the long-term average. This increase outpaced the rise in maximum temperatures, which stood at 28.8°C, just 0.4°C above average, highlighting a pronounced warming trend during night-time. Across most of the country, maximum temperatures were 0°C to 1°C above average, with the exception of parts of Tabora and Shinyanga, where anomalies ranged between 0°C and -1°C.

Minimum temperatures were 1°C to 2°C higher in the northeast, including the Lake Victoria basin, northeastern highlands, northern coast, and the islands of Unguja and Pemba, as well as in the south and south western highlands. Central and western regions, along with inland areas of the northern and southern coastal belts, saw smaller increases of 0°C to 1°C. The Tanzania Meteorological Authority (TMA)'s annual climate report revealed that night-time heat exceeded long-term averages in 11 of 12 months, surpassing daytime anomalies and influencing the annual mean temperature. This trend aligns with a 2024 study published in *Nature*, which projected increasing warm days and nights throughout the 21st century under the RCP4.5 emissions scenario.

The year 2024 was also Tanzania's fourth wettest since 1970 and the wettest in two decades, with total rainfall reaching 1,307.6 mm, 285.2 mm (28 per cent) above average. The November 2023 to April 2024 rainy season was the wettest since 1970, with 1,354.6 mm of rainfall, equivalent to 172 per cent of the long-term average. January 2024, typically a dry month, became the wettest January on record, with eastern regions receiving over 200 per cent of average rainfall. April 2024 ranked as the fifth wettest April, while May was the ninth driest on record.

Warming in Africa has exceeded the limits of natural variability. According to the earlier IPCC report (Assessment Report 5, AR5), the near surface temperatures had risen by 0.5°C over the past century. Despite the size and geographical spread of Africa, the only exception to the observed heating trend comes from the central and interior regions of Africa

The other contrasting feature is intra-season variability. Many African countries suffered from either excessive rainfall or lack of rainfall throughout 2024, leading to crippling floods in many regions and debilitating droughts in others. There was excessive rainfall in large parts of the Sahel region in 2024 that led to floods. The Sahara desert, one of the driest regions on the planet, received more than five times its annual rainfall in the month of August, causing rare floods in the desert and impacting infrastructures. In eastern Africa, Kenya, Tanzania and Burundi were hit by floods from March to May affecting 0.7 million people and the deaths of hundreds of people. The same region received less than average rainfall between October and December, raising food security concerns. In western and central Africa, floods impacted four million people across Nigeria, Niger, Chad, Cameroon and the Central African Republic in 2024.

In April 2025, extreme rainfall led to destructive flooding in Kinshasa, capital of the Democratic Republic of the Congo (DRC). Such floods are expected to occur every two years in a warming world, scientists have found. Researchers from the DRC, Rwanda, Kenya, the Netherlands, Sweden, Denmark, US and the United Kingdom collaborated to assess to what extent human-induced climate change affected the likelihood and intensity of the seven-day rainfall that led to the flooding in Kinshasa. The study published by the World Weather Attribution (WWA) on April 17, 2025, found that from a hazard point of view, the event observed in 2025 is not rare. Similar periods of heavy rainfall are expected to occur on average every second year in today's climate.

CLIMATE CHANGE AND ECOLOGICAL OVERSHOOT

New economic and policy approaches will be needed to reduce consumption by the wealthy and support better social outcomes for people with low incomes

WILLIAM RIPPLE

THE GLOBAL temperature and ice extent records being broken by enormous margins are a major cause for concern because we are now leaving climate conditions associated with human civilisation. Future climate impacts will likely include substantially more frequent extreme weather events, and some regions could eventually become uninhabitable.

We are concerned that the Earth's climate is transitioning to a state that could ultimately result in many millions of deaths. Consequently, limiting future warming by reducing greenhouse gas emissions should be a top priority. We will also need more efforts to support climate change adaptations, especially in the most vulnerable regions.

As indicated by the many vital signs at record extremes, climate change is a symptom of the broader issue of ecological overshoot, wherein humanity's consumption of resources has become unsustainable. We also need to worry about related consequences of overshoot, including biodiversity loss, fresh water scarcity, pandemics, world hunger and social-economic injustice.

To address this underlying threat will require equitable policies that support the well-being of all people while curtailing overconsumption by the wealthy. An insufficient response could lead to an array of catastrophic outcomes, potentially including partial societal collapse. We believe that new economic and policy approaches will be needed to reduce consumption by the wealthy and support better social outcomes for people with low incomes. As a possible starting point, a global carbon tax could be used to effectively limit excessive consumption and emissions, while also providing funding for sustainable economic development and climate adaptation efforts, especially in the Global South.

From a policy perspective, a transition towards more plant-based diets could take many forms, including reduced meat and dairy subsidies where applicable, increased availability of plant-based options in schools and greater support for the development of environmentally-friendly meat analogues.

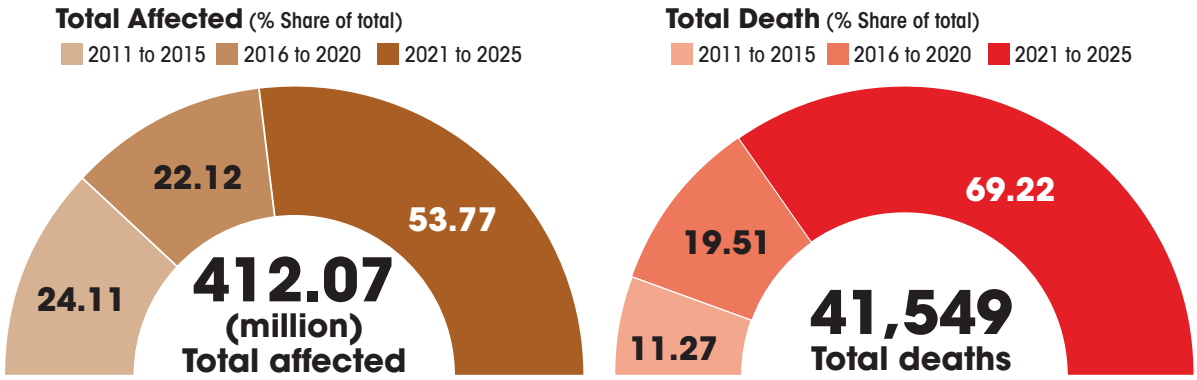
(William Ripple is a distinguished professor of ecology at Oregon State University, and the director of the Alliance of World Scientists, an independent organisation. This columns is based on a conversation with him)

Kinshasa is prone to frequent and deadly flooding during the rainy season (October to May). The analysis was focussed on the river basin where the Ndjili and the Congo rivers combine, which includes cities other than Kinshasa. While heavy rain affected large parts of the region, the impacts were concentrated in Kinshasa — a city of more than 17 million citizens. Torrential rains between April 4 and 7 triggered widespread flooding that killed at least 72 people and injured 170 more, with Kinshasa bearing the brunt of the crisis.

Several data sources including two weather stations and about half of the climate models analysed indicated a notable rise in heavy rainfall for both Kinshasa and the broader study region. "Therefore, a future increase in heavy rainfall due to climate change is a strong possibility." However, the researchers could not quantify the influence of climate change on the recent heavy rains. "Frequent spells of heavy rain are destroying homes, wiping out crops and cancelling economic gains. With every fraction of a degree of fossil fuel warming, the weather will get more violent, creating a more unequal world," said Friederike Otto, Imperial College, London and one of the authors of the study.

In southern and northern Africa, the situation was exactly the opposite with extensive drought in 2024, with some of the countries such as Morocco under a long-term drought. Morocco's agricultural output was 42 per cent below the five-year average as the country grapples with a six-year-long drought. Malawi, Zimbabwe and Zambia suffered from their worst drought

Human toll of extreme weather events in Africa: 2021–2025, the most devastating and deadliest period in 15 Years



Source: EM-DAT database

in the last two decades, with the aggregate cereal yields for southern Africa being 16 per cent below the five-year average. Zimbabwe suffered the worst, with yields 50 per cent less than the five-year average. The yields were below average by 43 per cent in Zambia.

"A stark pattern of extreme weather events (is emerging), with some countries grappling with exceptional flooding caused by excessive rainfall and others enduring persistent droughts and water scarcity," said Celeste Saulo, the WMO secretary general. And it is the new normal for the continent.

THE DEADLIEST PERIOD IN 15 YEARS

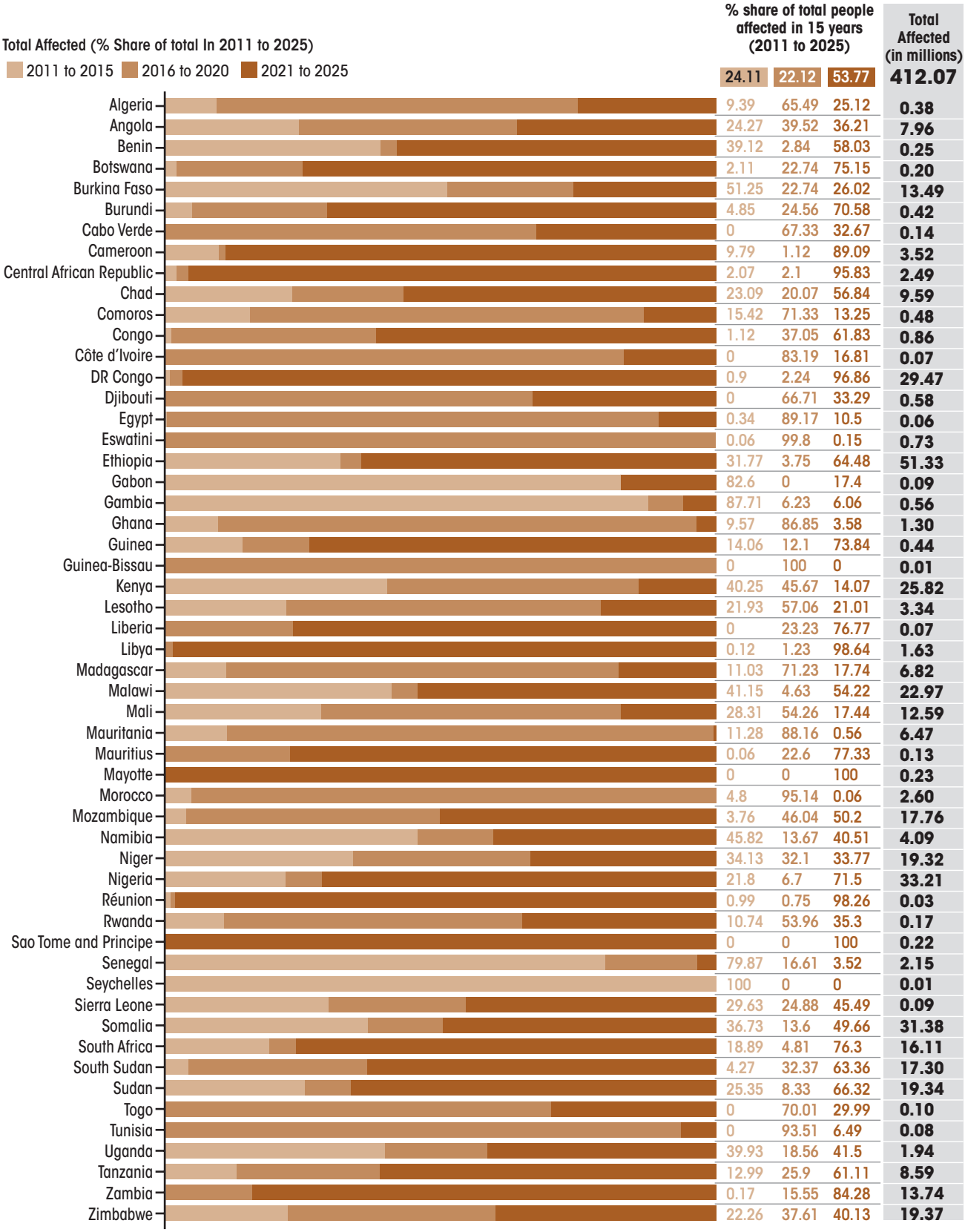
Africa is facing its deadliest climate crisis in over a decade, with the period between 2021 and 2025 emerging as the most devastating five-year stretch in terms of human toll from weather, climate and water-related disasters. An analysis by *Down To Earth* (DTE), a fortnightly published from Delhi, India, based on publicly available data from the Emergency Events Database (EM-DAT) international disaster database, showed that at least 221.57 million people were affected during this five-year period, more than the combined totals from 2011-2015 and 2016-2020 periods. Disaster-related deaths rose to 28,759 - over three times the number recorded between 2016 and 2020. These figures, based on data available up to May 2025, are likely to rise further by year-end.

The continent experienced a series of extreme weather events, including droughts, floods, cyclones, landslides, cold waves and heatwaves. These recent events alone accounted for 54 per cent of the over 412 million people impacted by such disasters across Africa since 2011.

Droughts were by far the most significant hazard, affecting 178 million people or more than 81 per cent of those impacted between 2021 and 2025. Floods affected roughly 14 per cent and storms or cyclones impacted around 4.7 per cent. The Horn of Africa bore the brunt of the crisis. Five consecutive failed rainy seasons in Ethiopia, Somalia and Kenya resulted in the worst drought in the region in 70 years by January 2023, found the report "Drought Hotspots Around the World 2023-2025", published by the UN Convention to Combat Desertification and the International Drought Resilience Alliance. The situation worsened in 2024 with another severe drought across southern Africa and the Zambezi basin, exacerbated by a strong El Niño that began in late 2023. As of May 2025, drought had affected 4.4 million people in Somalia (notably in Gedo, Hiran, Bay, Bakool, Mudug, Bari, Togdheer, Galguduud, Sool, Awdal, Nugaal, Sanaag and Woqooyi Galbeed), showed EM-DAT data. A further 2.1 million people were impacted in Kenya (including Wajir, Kilifi, Kwale, Garissa, Mandera, Marsabit, Turkana, Samburu and Baringo).

Between 2021 and 2025, just five countries accounted for over 51 per cent of all people affected by disasters in Africa, DTE analysis found. Ethiopia saw the highest numbers, with

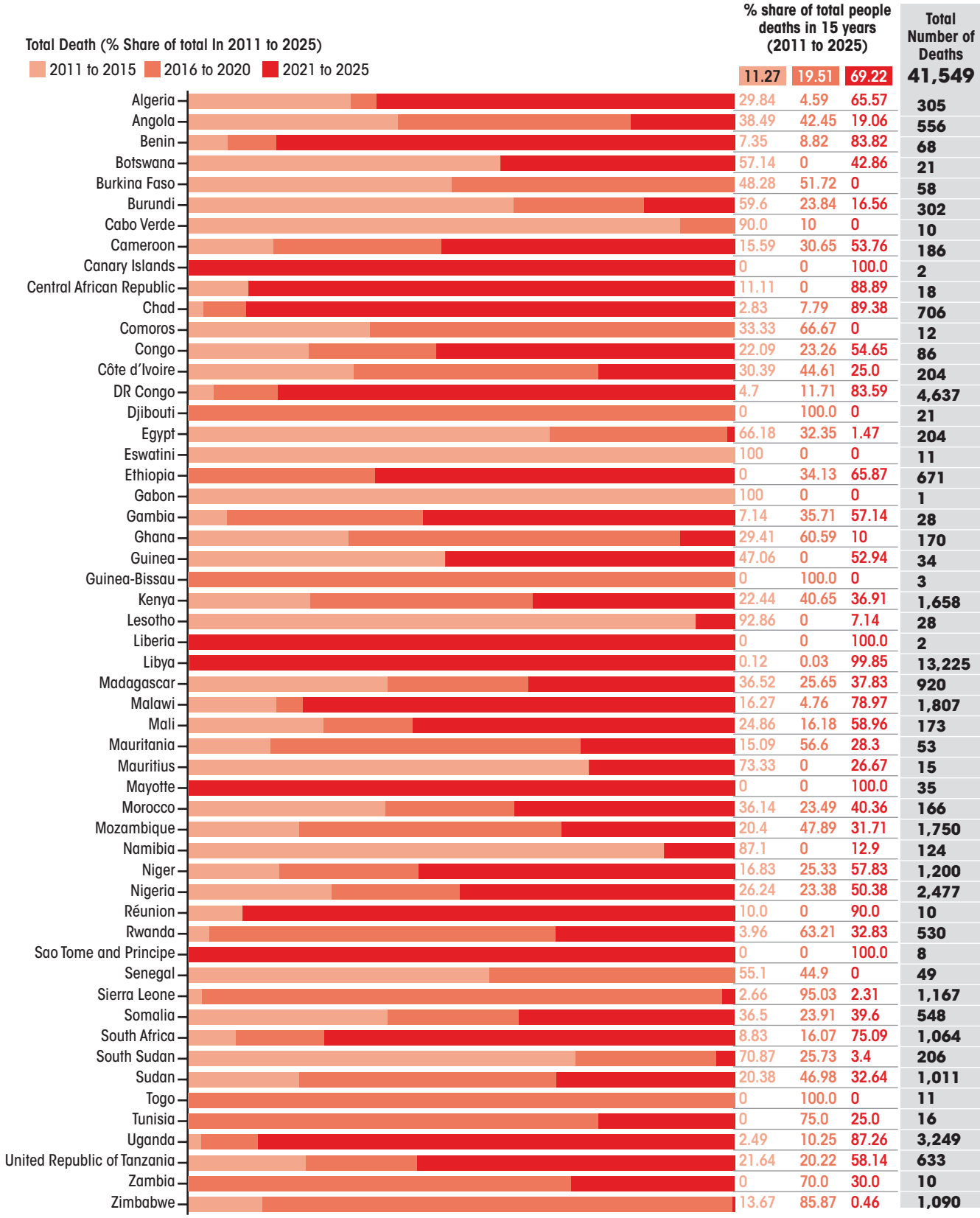
Number of people affected by extreme weather events



	% share of total people affected in 15 years (2011 to 2025)			Total Affected (in millions)
	24.11	22.12	53.77	412.07
Algeria	9.39	65.49	25.12	0.38
Angola	24.27	39.52	36.21	7.96
Benin	39.12	2.84	58.03	0.25
Botswana	2.11	22.74	75.15	0.20
Burkina Faso	51.25	22.74	26.02	13.49
Burundi	4.85	24.56	70.58	0.42
Cabo Verde	0	67.33	32.67	0.14
Cameroon	9.79	1.12	89.09	3.52
Central African Republic	2.07	2.1	95.83	2.49
Chad	23.09	20.07	56.84	9.59
Comoros	15.42	71.33	13.25	0.48
Congo	1.12	37.05	61.83	0.86
Côte d'Ivoire	0	83.19	16.81	0.07
DR Congo	0.9	2.24	96.86	29.47
Djibouti	0	66.71	33.29	0.58
Egypt	0.34	89.17	10.5	0.06
Eswatini	0.06	99.8	0.15	0.73
Ethiopia	31.77	3.75	64.48	51.33
Gabon	82.6	0	17.4	0.09
Gambia	87.71	6.23	6.06	0.56
Ghana	9.57	86.85	3.58	1.30
Guinea	14.06	12.1	73.84	0.44
Guinea-Bissau	0	100	0	0.01
Kenya	40.25	45.67	14.07	25.82
Lesotho	21.93	57.06	21.01	3.34
Liberia	0	23.23	76.77	0.07
Libya	0.12	1.23	98.64	1.63
Madagascar	11.03	71.23	17.74	6.82
Malawi	41.15	4.63	54.22	22.97
Mali	28.31	54.26	17.44	12.59
Mauritania	11.28	88.16	0.56	6.47
Mauritius	0.06	22.6	77.33	0.13
Mayotte	0	0	100	0.23
Morocco	4.8	95.14	0.06	2.60
Mozambique	3.76	46.04	50.2	17.76
Namibia	45.82	13.67	40.51	4.09
Niger	34.13	32.1	33.77	19.32
Nigeria	21.8	6.7	71.5	33.21
Réunion	0.99	0.75	98.26	0.03
Rwanda	10.74	53.96	35.3	0.17
Sao Tome and Principe	0	0	100	0.22
Senegal	79.87	16.61	3.52	2.15
Seychelles	100	0	0	0.01
Sierra Leone	29.63	24.88	45.49	0.09
Somalia	36.73	13.6	49.66	31.38
South Africa	18.89	4.81	76.3	16.11
South Sudan	4.27	32.37	63.36	17.30
Sudan	25.35	8.33	66.32	19.34
Togo	0	70.01	29.99	0.10
Tunisia	0	93.51	6.49	0.08
Uganda	39.93	18.56	41.5	1.94
Tanzania	12.99	25.9	61.11	8.59
Zambia	0.17	15.55	84.28	13.74
Zimbabwe	22.26	37.61	40.13	19.37

Data not available for Canary Islands, Eritrea and Saint Helena; Source: EM-DAT database

Deaths due to extreme weather events



Data not available for Eritrea, Saint Helena and Seychelles; Source: EM-DAT database

PHOTOGRAPH COURTESY: UNICEF

33.1 million people affected, meaning a 17-fold increase. The Democratic Republic of the Congo (DRC) followed closely, with 28.5 million affected, representing a 42-fold surge from 660,755 in the previous five-year period (2016-2020). Nigeria recorded 23.7 million affected, a nearly tenfold rise, while Somalia experienced 15.6 million affected — 3.65 times more than before. In Sudan, the number rose to 12.8 million, marking a nearly eightfold increase. Notably, three of these five most impacted countries are in East Africa. Southern African nations such as South Africa, Malawi and Zambia also recorded alarming spikes. For instance, South Africa saw 12.2 million people affected, 16 times higher than in the previous five years.

Disaster-related deaths in Africa have risen dramatically over the past 15 years, highlighting the continent's growing vulnerability to climate-related and other natural hazards. Between 2011 and 2015, recorded deaths stood at 4,684. This number rose sharply to 8,106 between 2016 and 2020, a 73 per cent increase. The most recent period, from 2021 to 2025, has seen a staggering 28,759 deaths, marking more than a threefold rise compared to the previous five years. This means nearly 69 per cent of disaster-related deaths recorded since 2011 occurred in the last five years alone. The analysis confirmed not just a rise in frequency and intensity, but also the deadliness of climate-linked disasters, particularly for vulnerable populations lacking adequate resilience infrastructure.

Libya is among the 21 countries where disaster-related deaths accounted for over 50 per cent of all recorded deaths between 2011 and 2025. Libya alone accounted for 13,205 deaths, 46 per cent of the total recorded across Africa between 2021 and 2025. This was largely due to the catastrophic Derna floods of September 10, 2023, widely regarded as one of the continent's most lethal weather disasters in recent memory. The event made North Africa the region with the highest death toll during the period. The DRC also witnessed a sharp rise in fatalities, from 543 (2016-2020) to 3,876 deaths in 2021-2025, a sevenfold increase. Similarly, Malawi reported a 16-fold increase, mostly due to flooding.

This mounting toll is not merely a function of extreme weather. It signals widening gaps in disaster risk reduction, emergency response and climate adaptation planning across the continent. Despite the urgency, the latest ND-GAIN Index ranks most African countries poorly on readiness to cope with climate impacts. Among the worst performers are the Central African Republic, Chad, Congo, Zimbabwe and the DRC. The Index defines "readiness" as a country's ability to attract and deploy investments for climate adaptation, measured across economic, governance and social indicators.

CHANGING CLIMATIC CONDITIONS WILL SHAPE HUMAN EVOLUTION

Homo sapiens had all the resources to migrate long distances and adapt to changing conditions

RAJEEV PATNAIK

CHANGES IN water availability, rainfall, temperature and humidity, either globally or locally, can shape evolution. The origin and evolution of humans show many climatic changes over millions of years. Six million years ago, human ancestors separated from a branch consisting of chimpanzees and gorillas. This new branch became known as hominin, which includes humans, extinct subspecies and our immediate ancestors that could walk upright. This change corresponded to climatic changes.

This change corresponded to climatic changes. We have evolved from unicellular organisms thanks to climatic conditions. If conditions had not changed, perhaps we would have only seen microbes in the ocean. If you look at life as a tree, the branches kept changing until humans reached a particular branch. The bacteria that did not change perhaps lived in a constant environment, so they stayed the same.

If there are gradual changes in a population and a part of it lives in a region witnessing environmental changes, it gives rise to new species. There are two kinds of changes: Genetic and phenotypic [observable, physical changes]. Even now, genetic changes keep happening automatically. But they don't necessarily translate to changes in the human body or physical appearance.

Physical changes occur if there is a change in our diet or locomotion. For example, if a species ingests tough food, it will develop a heavy jaw. If it evolves to consume softer food, a heavy jaw is useless and it recedes. Simply put, if the climate does not change, humans or any living being will not evolve. When climatic conditions change, they induce vegetation changes, which have shaped human evolution.

The most dramatic change was brain size capacity. That happened with our genus, Homo. The brain size of our ancestors belonging to the genus Australopithecus, Paranthropus or Ardipithicines was ape-like. They lived in climatic conditions that did not require a big brain. Their diet and lifestyle did not need that either. Approximately two million years, there were dramatic climatic changes. The conditions were not conducive to human survival. Hunter-gatherers had to move around, change their diet, communicate and develop strategies to hunt prey.

They needed to build tools to survive. So humans began to use their brains more, which would have affected their organ size. The brain capacity almost doubled from Australopithecus. Within our genus, Homo habilis still had lower brain capacity. But the brain capacity of Homo Erectus and Homo heidelbergensis dramatically increased. We have seen this in our fossil record.

In the present day, we see genetic changes. These changes allow people living in high-altitude regions or colder climates to live in extreme conditions. For example, the Eskimos have evolved to thrive in colder conditions for thousands of years. Tibetans also have a higher capacity to retain oxygen because they live at higher altitudes with low oxygen levels.

It takes time for genetic changes to translate to changes that can be seen physically. Fossil records tell us that physical changes typically take 500,000 years to appear. Modern humans evolved somewhere around 300,000- 500,000 years ago. Around this time, we became distinct from Homo heidelbergensis. And it took almost a million years for heidelbergensis to separate from Homo erectus. Likewise, Homo neanderthalensis took hundreds of thousands of years to split from heidelbergensis. So physical changes occur gradually if climatic changes are also slow.

Drastic changes can also occur, but climatic fluctuations occur at a rate of hundreds of thousands of years. By that standard, it would take 100,000 years for changes to show physically. The human body is complex and it takes millions of years for changes to occur. In contrast, insects evolve faster, where changes in size or colour can be recorded in short periods.

New species can arise in the current period if a population become isolated. For example, if Inuit become isolated from civilisation and do not interact or interbreed, they may become physically distinct from the rest of the population. Usually, we see changes that begin with variation in a population, followed by races and sub-

species. Finally, we have new species.

In the past, we have some examples. Denisovans (who lived until 30,000 years ago from Siberia to Southeast Asia), were adapted to high altitude and low-oxygen conditions. This population gave rise to people living in high-altitude regions such as Tibet. We will see genetic changes in Europeans if hot and dry conditions become recurrent. Around 13-14 million years ago, Europe was warm and humid. Roughly 16-18 varieties of Apes lived there. And then the climate changed, transforming Europe into a cooler place. All apes disappeared from the continent. Later, it became inhabited by Neanderthals, who adapted to colder climates. Much later, Homo sapiens came in. They were smart enough to adapt to changing situations.

The climate governs every species. Homo sapiens migrated to greener pastures. Other human species died out because they could not adapt. Every species evolves in its niche. And if that niche becomes inhabitable due to climate change, the species will perish or migrate. Homo sapiens had all the resources to migrate long distances and adapt to changing conditions.

If the climate in Europe continues to remain warm and humid, we may see changes in pigmentation or skin colour. Our ancestors came from Africa. Their pigmentation was brownish. Gradually, when people migrated to cooler conditions, people evolved lighter complexion. Cooler conditions, too, can bring about changes such as a higher accumulation of fat and changes in metabolism, and increased body hair. If Europeans interbreed with others, we might not see apparent changes, but if they stay isolated, we may see changes.

Modern humans have interfered with the climate. We are to be blamed for so many drastic changes. But thanks to technology and modern medicine, humans have learned to survive. Even if something untoward were to happen due to climate fluctuations, there is every possibility that we would work around it. Humans may not go extinct. If we look at the past, we see Australopithecus thrived for millions of years. Elephants have survived for around 2.5-3 million years. Modern humans have been around only a few hundred thousand years. So, unless something dramatic happens, we won't die out. But if tomorrow, we have an asteroid impact or humans kill each other, nothing can save us.

(Rajeev Patnaik is a professor at the department of geology from Panjab University, India)

HEAT TRAP

Africa bears the brunt of the worsening global heat exposure, fuelled by global warming. This is according to the Climate Shift Index (CSI) of the non-profit Climate Central. The CSI measures how climate change alters the frequency of daily temperatures worldwide, quantifying its role in rising heat levels. Positive CSI levels 1 to 5 indicate temperatures that are increasingly likely in today's climate. A CSI level of 2 means the temperature is at least two times more likely in today's climate than in a world without human-caused climate change. The Index released in March 2025, analysed daily temperatures in 220 countries to understand where there was unusual heat and how climate change influenced those temperatures.

In 110 or half of the analysed countries, the average person experienced daily temperatures with a strong influence of climate change for at least one-third of the last three months, revealed the Index. It showed that 1.8 billion people in the world (22 per cent) — or every fifth person —experienced climate change-driven temperature increases every day between December 2024 and February 2025. In other words, they endured climate change-driven temperatures throughout the entire season. The impact peaked on February 28, 2025, when 3 billion people (37 per cent of the global population) faced temperatures strongly influenced by climate change, classified at Climate Central's CSI level 2 or higher. The average person on the planet experienced six days of risky heat during December 2024 to February 2025. The analysis showed that human-induced climate change added five risky heat days to the average person's experience during this time period. Without climate change, the average person's exposure to risky heat would have been only one day during the three months.

Of this, at least 1billion people across 36 countries in Africa experienced daily average temperatures that were strongly influenced by climate change (defined as CSI 2 or higher) for at least one-third of the season (30 or more days). Temperatures were strongly influenced by climate change in the range of 70 to 87 days in 12 of these countries. Nearly 14 million people in Rwanda experienced 87 days during the three months with temperatures strongly influenced by climate change. Ethiopia, the second most populated African country, experienced 74 days.

Climate change is intensifying heat-related health risks by increasing the frequency of "risky heat days"—days when temperatures exceed the 90th percentile of local records from 1991 to 2020. More than 394 million people experienced 30 or more days of risky heat added by climate change during the three months. Most of these people (293 million or 74 per cent) live in Africa. In other words, three of every four people exposed to 30 or more days of risky heat lived in Africa. Eight of the 10 countries with the highest number of people exposed to these extreme heat days were in Africa. These include Nigeria, the Democratic Republic of the Congo, Uganda, Ghana, Tanzania, Côte d'Ivoire, Madagascar, and Cameroon. Between December 2024 and February 2025, 10 countries across Africa and Oceania recorded the highest number of risky heat days added due to climate change. In Africa, the Comoros experienced the most, with 52 additional risky heat days, followed by Liberia (45), Equatorial Guinea (42), Ghana (40), and Mauritius (36).

Extreme heat waves will continue to increase and extreme cold waves will decrease throughout the 21st century, with additional global warming, according to IPCC. At 1.5°C global warming, heavy precipitation and associated flooding are projected to intensify and be more frequent in most regions in Africa, the IPCC projections predict. With additional increases in global warming, changes in hot and cold temperature extremes, the frequency and intensity of heavy precipitation events are projected to increase almost everywhere in Africa, warned IPCC in its projections for the continent.

While the AR5 regional profile has singled out Ethiopia and parts of eastern Africa for higher incidences of heat waves, more recent studies have suggested that the problem is likely to affect the entire continent. A study published in *Environmental Research Letters* in 2016 found that

With additional increases in global warming, changes in hot and cold temperature extremes, the frequency and intensity of heavy precipitation events are projected to increase almost everywhere in Africa

even modest warming of 2°C in global average temperatures would be enough to make heat waves a completely normal occurrence. Since Africa is situated between the Tropics of Capricorn and Cancer, it is likely to be the worst affected. In 2017, the European Commission conducted the most comprehensive analysis of the risks of heat waves in the continent. It found that equatorial and sub-equatorial Africa would be particularly badly affected. Under the business-as-usual scenario, "the Gulf of Guinea, the Horn of Africa, the Arabian peninsula, Angola and the Democratic Republic of Congo are expected to face, every 2 years, heat waves of length between 60 and 120 days. Once every 30 years heat waves are projected to be longer than 180 days over parts of central Africa and the Arabian Peninsula."

Among the regions in the world, the African continent also witnessed a phenomenon called "rapid temperature flips". Over 60 per cent of the world has likely experienced sudden swings between extreme heat and cold over the past six decades, according to a study published in journal *Nature Communications* in February 2025. These events, referred to as temperature flips, involve abrupt shifts from extreme warmth to cold or vice versa within a short period. Such rapid changes leave limited time for humans and ecosystems to respond and adapt, potentially leading to severe and even irreversible impacts on human health, infrastructure, air quality and plants.

One recent instance of a temperature flip occurred in April 2021, when Europe saw temperatures plummet from unseasonably warm to cold, resulting in widespread frost damage to crops. "Although there is a rapidly growing literature on independent extreme warm (such as heatwaves) or cold events (such as cold spells), very little is known about the rapid flips between warm and cold events, including historical occurrences, underlying processes and their responses to global warming," the study read. This knowledge gap, the researchers warned, is concerning given how human, animal and plant health is vulnerable to sudden flips in temperature extremes

PHOTOGRAPH: ISTOCK

under climate change. The researchers analysed global data from 1961 to 2023 to assess the frequency, intensity and duration of these flip events. They also used climate models to project future trends under global warming scenarios.

Their findings showed that while temperature flips occurred less frequently in the tropics and polar regions, they were widespread in mid-latitudes, including East Asia, eastern North America and parts of South America, Africa and Australia. One potential driver of this variability is the behaviour of a phenomenon called Rossby waves or planetary waves — large-scale atmospheric patterns caused by Earth's rotation. These waves help redistribute heat from the tropics towards the poles and vice versa. The study found that regions experiencing more frequent flips also tended to see stronger ones. This was particularly evident in East Asia and South America. Additionally, transition durations between warm and cold phases were shorter in mid-latitude regions.

Notably, the researchers observed that intense temperature flips may have begun as early as the early 20th century, which likely accelerated in the latter part of the century. Looking ahead, the study estimated that the frequency of flip events could increase by 7-8 per cent between 2071 and 2100 relative to the 1961-1990 baselines. Intensity was projected to rise by 7.16-7.32 per cent, while transition duration could shorten by 2.47-3.24 per cent over the same period.

Global population exposure to these events is expected to more than double, with low-income countries bearing the heaviest burden — facing exposure levels 4 to 6.5 times higher than the global average in all scenarios. Lower-middle-income nations followed closely behind, with a population exposure going up to almost 1.3 times above the global average. The researchers warn that without mitigation efforts, climate change will wreak havoc. "Climate change leads to more frequent and more severe temperature flips, such as warm winter days followed by sudden cold snaps can cause unpredictable energy demands for heating, thereby increasing unevenly across

different income-level regions and elevating the risks of energy shortages in some low-income regions," the researchers wrote, calling for effective measures to tackle and respond to rapid temperature flips.

The relative sea level around Africa has increased at a higher rate than the global mean sea level rise over the last three decades. This trend is likely to continue in the region. The rate of sea-level rise has reached 5 millimetres (mm) per year in several areas on the continent's coastline, especially along Eastern Africa, according to a WMO report. In south-western Indian Ocean from Madagascar, eastward towards and beyond Mauritius, it has even exceeded 5 mm a year. This is above the rate of average global sea-level rise of around 3-4 mm each year.

Increase in global warming will contribute to increases in the frequency and severity of coastal flooding in low-lying areas due to coastal erosion, mostly along sandy coasts, according to the IPCC assessment. Monsoon precipitation is projected to increase over Central Sahel and decrease over the far western Sahel. The monsoon season is projected to have a delayed onset and a delayed retreat, as stated in the report. At 2°C global warming, precipitation is likely to increase by 5-40 per cent in the Sahara, including parts of the Sahel. There has been an increase in monsoon precipitation during the 20th century due to warming from greenhouse gas emissions, noted the IPCC assessment. But this has been masked by the decrease due to cooling from human-caused aerosol emissions. West and Central Africa is likely to experience heavy precipitation and pluvial flooding.

The average tropical cyclone wind speeds are likely to increase in East Southern Africa, according to IPCC. This may lead to an increase in the heavy precipitation and more Category 4-5

The evidence of the negative impacts of climate change on African agriculture-based livelihood systems in the short and long term is so overwhelming that the populations should be prepared and capacitated to face the new normal of a continuously changing and varying climate

(severe) tropical cyclones in the region. Climate change is expected to make Category 5 storms stronger and more numerous in the coming decades, according to Jeff Masters, hurricane scientist with the NOAA. Marine heat waves that have become more frequent since the last century are projected to increase around the continent. With global warming of 2°C global warming and above, several regions in Africa are projected to experience an increase in frequency and / or severity of agricultural and ecological droughts. Aridity and droughts will increase across Mediterranean (Northern Africa), Western Africa, West Southern Africa and East Southern Africa, the report projected.

The continent in all probability will cross the guardrail of 1.5°C warming in the near future. A study published in *CABI Reviews* warned that the continent is "highly likely" to surpass 1.5°C of warming by 2040, accelerating devastating impacts on agriculture-based livelihoods. Africa's agriculture-dependent populations are already facing significant losses due to climate change, and these challenges will only intensify with increasing climate hazards, the study highlighted. "The evidence of the negative impacts of climate change on African agriculture-based livelihood systems in the short and long term is so overwhelming that the populations should be prepared and capacitated to face the new normal of a continuously changing and varying climate," the researchers wrote in their study. The study examined how climate change is affecting Africa's agriculture now and in the future. It assessed the risks to farming communities and food production, identified key priorities for adaptation and mitigation, and outlined necessary reforms in policies, technology, finance, and training to help African countries respond effectively. It covered all five spatial sub-regions of Africa: Central Africa, East Africa, North Africa, Southern Africa, and West Africa. ■

PHOTOGRAPH COURTESY: RICHARD ASHTON/NRC

MIGRATION

HIGHPOINTS

Africa would have the **highest rate of displacement** or migration due to impacts of the climate emergency

Nearly **222 million people** in Africa were affected by weather, climate and water-related disasters between 2021 and 2025

The number of displacements due to disasters increased from **1.1 million** in 2009 to **6.3 million** in 2023

East African countries in the Intergovernmental Authority on Development economic bloc could see up to **10.5%** of their population on the move by **2050**

PHOTOGRAPH COURTESY: GLOBAL CENTRE FOR CLIMATE MOBILITY

CLIMATE MOBILE CONTINENT

By 2050, up to 5 per cent of Africa's population of some 2 billion people could be on the move due to climate change

AFRICA IS the youngest continent having the highest population growth in the world. According to the "World Population Prospects 2022" report, some 25 per cent of the world population will be living on the continent by 2050. It is also the most climate vulnerable continent. Climate change-fuelled extreme weather events are causing unprecedented displacement across the world. The Internal Displacement Monitoring Centre (IDMC), a Norwegian non-profit that tracks internal displacement across the world, said in its report "Countdown to 2030 Disaster" disasters triggered 264.8 million internal displacements across 210 countries and territories between 2015 and 2024. Nearly 90 per cent were the result of floods and storms. Climate change is expected to increase this

risk significantly in most countries, said IDMC. The UN Refugee Agency, or the UNHCR, said over a decade weather-related disasters caused 60,000 displacements per day.

More than 216 million people across six continents will be on the move within their countries by 2050, in large part due to climate change, according to the United Nations (UN)' "World Migration Report 2024". Climate change cannot be considered the sole driver of food insecurity or migration, according to the UN report, since political power, incompetent governance, globalised food production and other social factors also play a role. What climate change does is increase the pressure on existing systems and communities. The Intergovernmental Panel on Climate Change (IPCC) assessed that 3.3 to 3.6 billion people lived in "contexts that are highly vulnerable to climate change".

Migration due to climate risks is referred to as climate mobility. The IPCC's 6th Assessment Report (AR6) recognises migration as an important coping or adaptation strategy in response to climate risks. "The outcomes of migration as an adaptation tool depend on the circumstances of the individuals or households engaging in human mobility, as well as on the involvement and agency of migrants," said the UN report. No region of the planet inhabited by humans is unaffected due to climate change and the consequent migration of people. The UN Environment Programme (UNEP)'s "Navigating New Horizons" report of 2024 said, "Climate-induced human migration and displacement affect certain regions and their populations more than others, with some countries in Africa, Central America, the Pacific Islands and South Asia more at risk than other regions."

The International Organization for Migration (IOM), a UN agency, has projected that by 2050, some 200 million additional people would be termed as "environmental migrants". These are the people who are displaced due to environmental factors, including extreme water

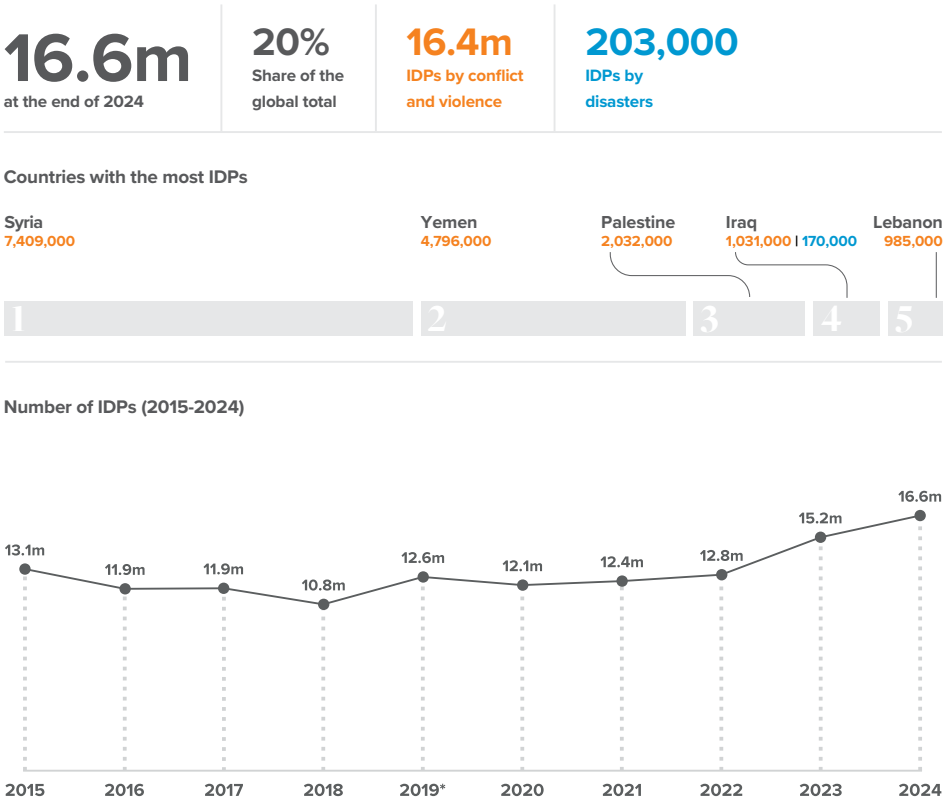
he continent would have the highest rate of displacement or migration due to impacts of the climate emergency. Or, one can say it will be the most climate mobile continent

events. After 2050, this can reach as high as one billion environmental migrants, said the UN agency. A modelling study quoted by the "Navigating New Horizons" report said, "Scientists projected that over the coming 50 years, up to three billion people could be living well outside climate conditions (and particularly temperature) that have served humanity over the past 6,000 years, and worse, that by 2070, absent climate mitigation or migration, certain regions—Northern South America, central Africa, India and northern Australia—could simply become too hot to allow human life."

Short-distance migration—accounting for the most considerable portion of global migratory movements—is very critical for climate change adaptation, according to new research from the University of East Anglia (UEA). Most migratory movements, contrary to popular belief, involved short-distance relocation caused primarily by economic, social and environmental variables such as climate change, said the research titled "The everyday mobility and changing livelihood trajectories: Implications for vulnerability and adaptation in dryland regions report". The study, published in March 2023, concentrated on those living in the drylands of India and parts of Africa.

A large number of people migrate short distances inside their own countries to harness opportunities out there or adapt to shocks and stressors in their life, said Mark Tebboth, who led the research. "Supporting and enabling this migration will help people to continue to adapt to the pressures in their lives," said Tebboth. In Africa, the drylands of Ghana, Kenya and Namibia were analysed. Arid, semi-arid, and dry sub-humid areas are collectively known as drylands—the largest global biome— covering 45 per cent of the Earth's surface and home to more than a third of the population. Such migration "is normalised within lives and livelihoods and these movements are crucial in helping people to manage different shocks and stresses

AFRICA: INTERNALLY DISPLACED PEOPLE (IDPS)



Total number of IDPs in millions; *First year disaster data is available
Source: Global Report on Internal Displacement 2025 by Internal Displacement Monitoring Centre

within their lives, including increasing climate variability," Tebboth noted. Most mobility, especially that in which environmental change is of some influence, is and will remain local, added Tebboth.

HOW CLIMATE MOBILE WILL BE AFRICA?

Several projections agree that the continent would have the highest rate of displacement or migration due to impacts of the climate emergency. Or, one can say it will be the most climate mobile continent. A majority of Africa's population is born this century – the continental median age is 19.3 years in 2025. "Many of the Africans alive today may live to see the late decades of this century," according to "It's Africa's Century — for Better or Worse" published by the Slate Group. So for the youngest continent, the majority of the population will endure the extreme climatic disruptions and resultant socio-economic impacts. Climate emergency is the neo-normal for them unlike those born in the 20th century who perceived it as a "distant scenario". A study of the charity Save the Children International said that a child born in 2020 would experience significantly more extreme climate events across their lifetime than someone born in 1960. A paper published in the journal *Nature* in 2021 estimated that those born in 2020 would be "exposed to twice as many wildfires, 2.8 times more crop failures, 2.6 times as many drought events, 2.8 times as many river floods, and 6.8 times more heatwaves".

An analysis by the fortnightly magazine *Down To Earth*, published from Delhi, India, showed that 221.56 million people in Africa were affected by weather, climate, and water-related disasters between 2021 and 2025. This was more than the combined total of the number of people affected by similar disasters in the previous two five-year periods: 2011-2015 and 2016-2020. Disaster-related deaths increased to 28, 759 — more than three times of the deaths recorded between 2016 and 2020.

Internal displacement in Africa has tripled in the 15 years (2009-2023), according to the

INTERNAL DISPLACEMENTS (MOVEMENTS)

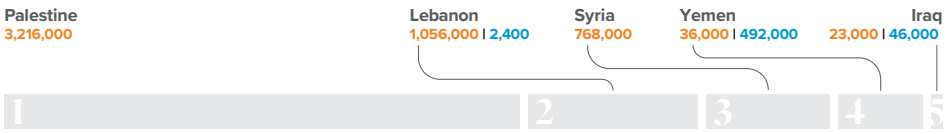
5.7m
during 2024

9%
Share of the global total

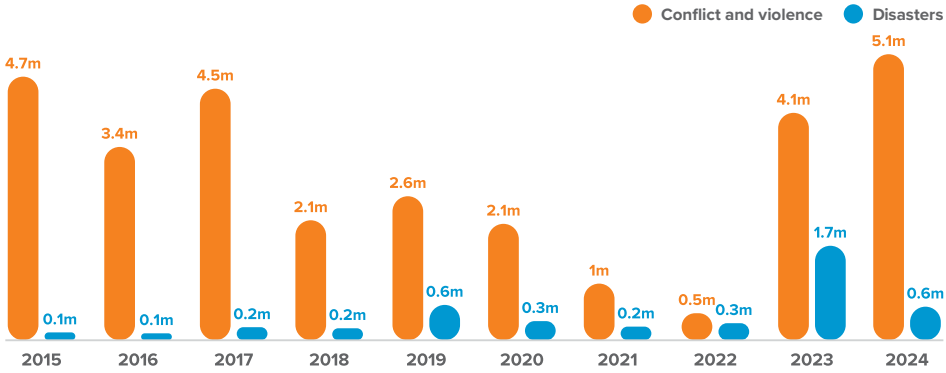
5.1m
Internal displacements by conflict and violence

599,000
Internal displacements by disasters

Countries with the most internal displacements



Internal displacements (2015-2024)



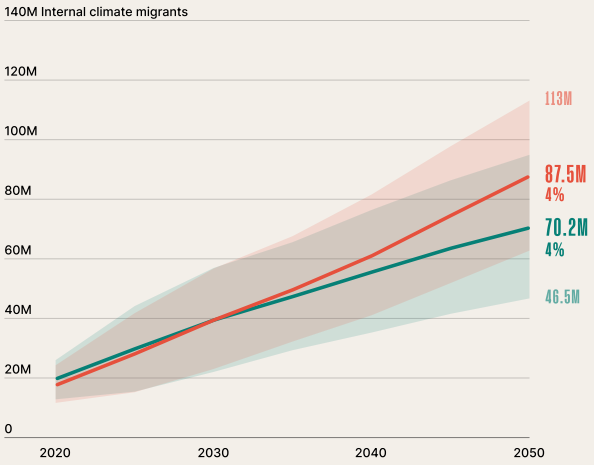
Internal displacements in millions; Numbers of IDPs are the total as of the end of 2024. Internal displacements are the total number for all of 2024. All data on these two pages is for Middle East and North Africa.
Source: Global Report on Internal Displacement 2025 by Internal Displacement Monitoring Centre

latest data released by IDMC. It is due to an increase in conflicts and violence besides the significant increase in extreme climatic events. But, during this period the number of internally displaced people due to disasters has recorded a six-fold increase. People living in internal displacement as a result of conflict and violence in Africa had increased from 10.2 million in 2009 to 32.5 million in 2023. The number of times people were forced to flee disasters each year increased from 1.1 million displacements in 2009 to 6.3 million in 2023. This surge was largely driven by climate-related events such as floods and droughts, highlighting the growing impact of environmental disasters on displacement patterns across the continent. Flooding, which impacts every region of the continent, was responsible for over 75 per cent of these displacements, while droughts contributed to an additional 11 per cent. For instance, 69 per cent of the disaster-displacements in eastern Africa were due to floods. Most of these took place during the Gu season between March and May, and the Deyr season between October and December. In western Africa, floods accounted for 99 per cent of disaster-displacements. Most of such displacements occurred between June and September.

In Africa, Cyclones Idai and Freddy were recognised as the largest disaster-related displacement events in the past 15 years. Nigeria reported the highest number of displaced people, totalling 8.7 million, with nearly three-quarters affected by two significant floods in 2012 and 2022. These events accounted for over 70 per cent of all flood-related displacements in the country. In the Horn of Africa, recurring droughts and floods led to widespread displacement, deepening the region's vulnerabilities. In the 15-year-period, the area had endured three major droughts—in 2011, 2017, and 2022—that severely disrupted agricultural production and undermined food security.

Another estimate by the Institute for Security Studies said that the number of people

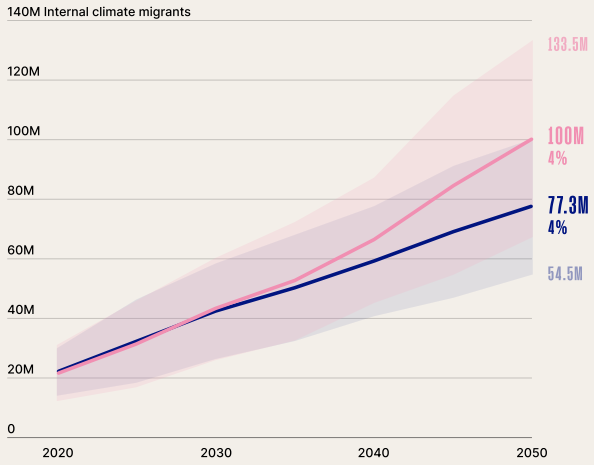
CLIMATE MOBILITY WITHIN AFRICAN COUNTRIES FROM 2020 TO 2050



Internal climate mobility in Africa under high GHG emission scenarios (and % over total population)

High Road scenario
Uncertainty (95% CI)
Rocky Road scenario
Uncertainty (95% CI)

Source: ACMI Africa Climate Mobility Model, 2022.

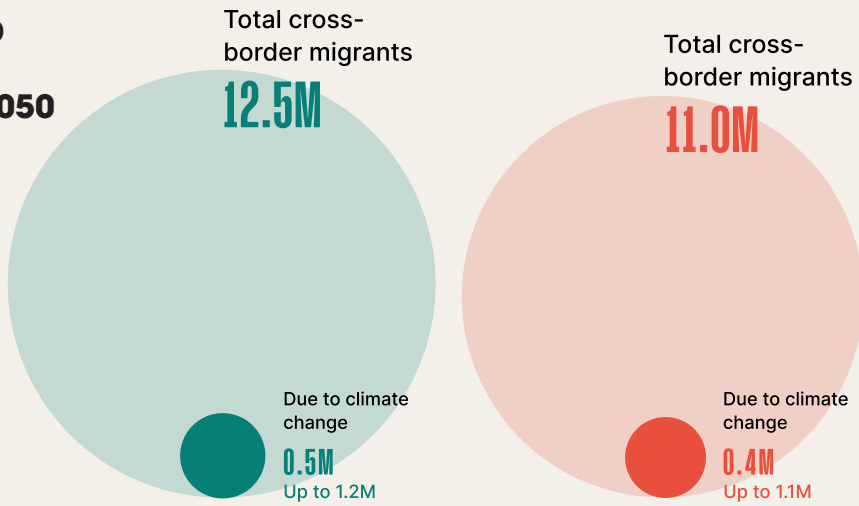


Internal climate mobility in Africa under low GHG emission scenarios (and % over total population)

High Growth & Low Emissions scenario
Uncertainty (95% CI)
Low Growth & Low Emissions scenario
Uncertainty (95% CI)

Source: ACMI Africa Climate Mobility Model, 2022.

TOTAL CROSS-BORDER MIGRATION COMPARED WITH CROSS-BORDER CLIMATE MOBILITY BY 2050



Cross-border mobility by 2050 in Africa

High Road scenario
Total cross-border migrants
Due to climate change

Rocky Road scenario
Total cross-border migrants
Due to climate change

Source: ACMI Africa Climate Mobility Model, 2022.

displaced due to extreme weather events in Africa rose by 600 per cent between 2009 and 2023. Most of these disasters were floods and storms, followed by droughts and wildfires, landslides, erosion and extreme temperatures.

Conflict situation adds another dimension to this brewing crisis. Climate change is combining with conflicts to put millions in utter distress. In November 2024, the UNHCR in collaboration with 13 expert organisations, research institutions and refugee-led groups released a report that used the latest data to show how climate shocks are interacting with conflict, pushing those who

are already in danger into even more dire situations. The report titled "No Escape: On the Frontlines of Climate Change, Conflict and Forced Displacement" said that climate change is turning out to be an additional, and growing, threat to those already suffering from war, violence, and persecution. "Of the more than 120 million forcibly displaced worldwide, three-quarters live in countries heavily impacted by climate change. Half are in places affected by both conflict and serious climate hazards, such as Ethiopia, Haiti, Myanmar, Somalia, Sudan and Syria," said the UNHRC report. The report claimed that by 2040, the number of countries facing extreme climate-related hazards might rise from three to 65, the vast majority of which would host displaced people. Similarly, most refugee settlements and camps are projected to experience twice as many days of dangerous heat by 2050.

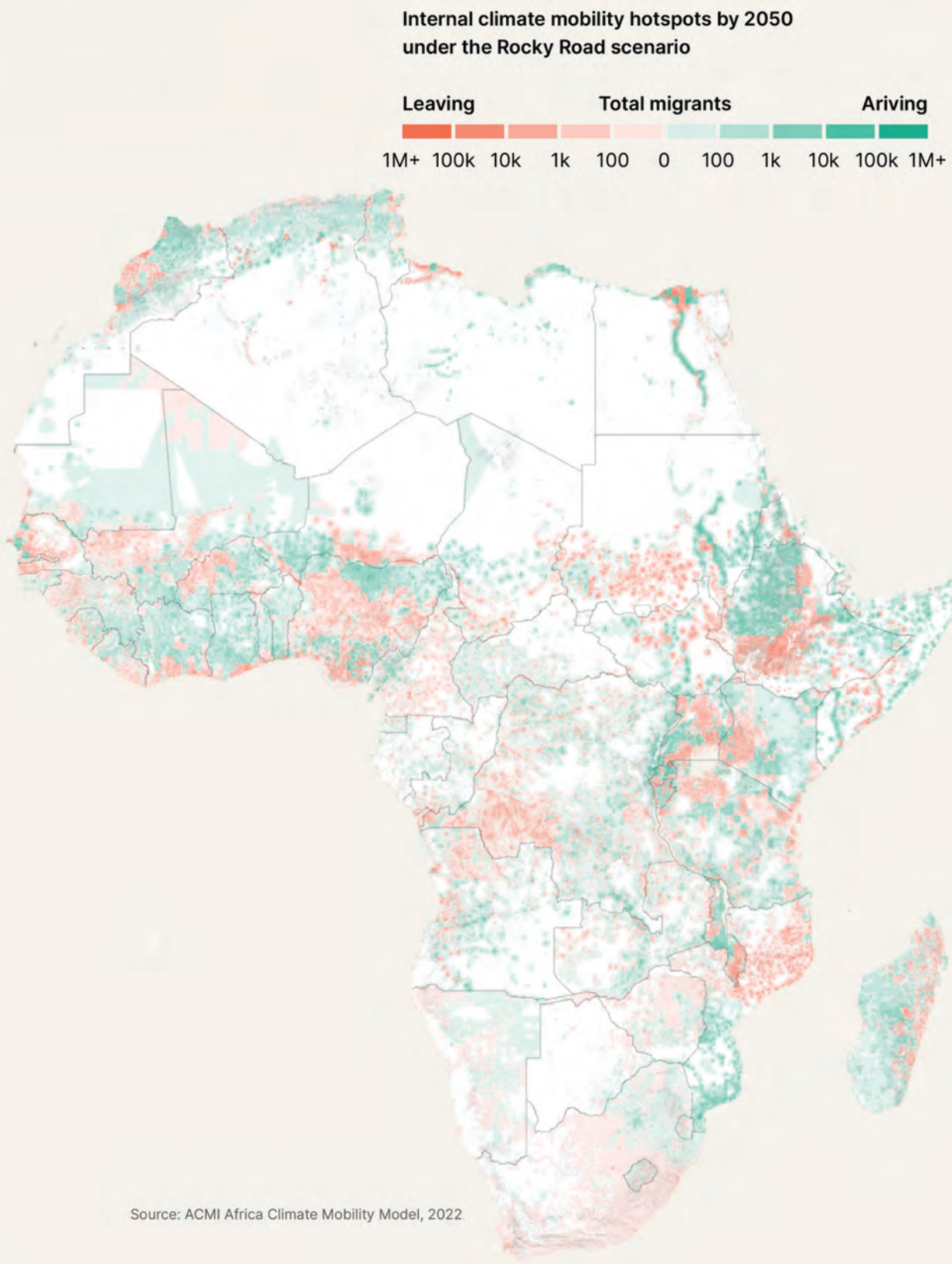
"The climate emergency represents a deep injustice ... People forced to flee, and the communities hosting them, are the least responsible for carbon emissions yet are paying the highest price. The billions of dollars in climate financing never reach them, and humanitarian assistance cannot adequately cover the ever-widening gap," said Filippo Grandi, the UN High Commissioner for Refugees. "For the world's most vulnerable people, climate change is a harsh reality that profoundly affects their lives. It is driving displacement in regions already hosting large numbers of people uprooted by conflict and insecurity, compounding their plight and leaving them with nowhere safe to go," said Grandi. It referred to the situation in Sudan. Conflicts in the country have led to massive displacement with 0.7 million crossing over to Chad, which is one of the most vulnerable countries to climate change. "At present, extremely

The climate emergency represents a deep injustice ... People forced to flee, and the communities hosting them, are the least responsible for carbon emissions yet are paying the highest price. The billions of dollars in climate financing never reach them, and humanitarian assistance cannot adequately cover the ever-widening gap

fragile states receive only around US$ 2 per person in annual adaptation funding, an astounding shortfall when compared to $161 per person in non-fragile states," pointed out Jana Birnar, an UNHCR official.

The combined impact of armed conflict and climate risks weakens people's ability to cope with disasters, the International Committee of the Red Cross (ICRC) had warned in 2024. Countries affected by conflict are also disproportionately impacted by climate change, ICRC highlighted. It studied the situations of the interior of the Central African Republic (CAR), southern Iraq and northern Mali in 2019-2020. The CAR, Iraq and Mali are all enduring protracted conflict or are in a state of fragility. These three countries are especially vulnerable to climate change, in part because of their geographical location but more importantly, because of the lasting consequences of conflicts for communities, systems, institutions and authorities. In CAR, people focused on the tensions between farmers and herders due to changing human movement patterns there and the limited capacity of authorities to regulate it. In northern Mali, pastoralists and farmers described how their ways of coping with repeated droughts and occasionally, heavy rains have been disrupted by the conflict and how that is accelerating changes to their way of life. In Mali, pastoralists were deterred from travelling with their livestock by the fear of being attacked on the road by armed groups. They gathered in certain areas — most often, close to water sources. The added pressure on already scarce resources created tensions over water with farmers and fishermen who were also trying to cope. In the interior of CAR, people who had fled the violence and settled in temporary settlements on the outskirts of urban areas endured heavy rains. Others, who had managed to stay home despite the violence or had returned from displacement, saw their shelters washed away by the floods

CONTINENTAL HOTSPOTS DEPICTING THE NUMBER OF PEOPLE MOVING OUT OF AND INTO SPECIFIC AREAS OWING TO CLIMATE IMPACTS



Source: ACMI Africa Climate Mobility Model, 2022

COST OF CONFLICTS

High-intensity conflicts result in drop of about 20% in GDP per capita after five years

"IN DEVELOPING economies in general, the extreme-poverty rate has been whittled down to single digits — just 6 per cent. In economies facing conflict or instability, however, the rate is nearly 40 per cent," the World Bank noted in the assessment. The Bank had assessed these 39 countries/territories in long-standing fragile and conflict situations. Though most of the countries are in sub-Saharan Africa, they are also in East Asia and Pacific and the Middle East (West Asia) and North Africa regions.

"Once they get started, conflicts tend to be persistent — and their economic effects are both grave and long-lasting, the research shows. Half of economies facing conflict or instability today have faced those conditions for 15 years or more," said the Bank assessment. These countries — grouped by the Bank as economies in fragile and conflict-affected situations (FCS) — reported increasingly more conflicts with higher severity since the 2000s. The number of individual conflict events and conflict-related fatalities had more than tripled since the turn of the millennium, with most of the increase having occurred since around 2010.

Some notable in this group are countries / territories like Ethiopia, Sudan, Ukraine and the West Bank and Gaza. Indermit Gill, chief economist of the World Bank Group, said while the world attention is on Ukraine and the Middle East, "Yet, more than 70 per cent of people suffering from conflict and instability are Africans. Untreated, these conditions become chronic." In the near future, this group of countries would be home to the largest portion of the world's extreme poor. "By 2030, FCS economies are projected to account for nearly 60 per cent of the world's extreme poor," the Bank observed in the assessment. Currently, FCS countries have 421 million people living in extreme poverty, which is more than the rest of the world combined. Nearly 40 per cent of the population in these countries are extremely poor, or live on less than $3 per day.

According to the Bank's assessment, 1 per cent increase in conflict-related fatalities per million population will wipe off around 3.7 per cent of per capita GDP after five years. "High-intensity conflicts — those that kill more than 150 out of every 1 million people at onset — are typically followed by a cumulative drop of about 20 per cent in GDP per capita after five years, relative to pre-conflict projections," said the Bank. "Food insecurity has also surged alongside worsening conflict, with about 18 per cent of the FCS population — around 200 million people — currently experiencing acute food insecurity, compared with just 1 per cent in other emerging markets and developing economies." It means food insecurity in FCS countries is 18 times that of developing countries.

Further, infant mortality rates are more than twice as high, showed the Bank assessment. Expectedly, these countries report low life expectancy in comparison to others. The Bank assessment attributed this to the lingering fragility and conflict situations. "At 64, average life expectancy in economies suffering from conflict or instability is seven years lower than in other developing economies," the Bank said.

and ended up being displaced.

According to Amnesty International, government failures in tackling inequality, climate breakdown, and gender-based violence across Africa are putting future generations at risk. Amnesty's "State of the World's Human Rights 2024/25", documented unlawful attacks and killings by state forces and armed groups in numerous African nations, including Burkina Faso, Cameroon, the Central African Republic (CAR), the Democratic Republic of the Congo (DRC), Ethiopia, Mali, Mozambique, Niger, Nigeria, Somalia, South Sudan, and Sudan. Disturbingly, conflict-related sexual violence saw a sharp rise, with over 11,000 cases of gender-based violence reported in CAR in just the first half of 2024. Similar patterns of sexual violence were prevalent in Somalia and South Sudan.

A worsening cost-of-living crisis compounded these challenges, as soaring prices for food, fuel, and basic necessities pushed millions deeper into poverty. High taxes, unsustainable debt, widespread corruption, ongoing conflicts, and extreme weather events further aggravated the situation. Food insecurity reached alarming levels, particularly in Southern Africa, where Angola, Botswana, Lesotho, Malawi, Namibia, Zambia, and Zimbabwe suffered their worst

PHOTOGRAPH COURTESY: GLOBAL CENTRE FOR CLIMATE MOBILITY

drought in a century due to El Niño. Several governments declared states of emergency as crops failed and livestock perished, threatening famine. Severe hunger also persisted in CAR, Somalia, and South Sudan.

Conflict and climate disasters continue to displace millions, with Sudan remaining home to the world's largest displaced population. The DRC, Burkina Faso, South Sudan, Somalia, CAR, and Mali also saw massive internal displacement. In southern Madagascar, authorities neglected hundreds displaced by drought, denying them basic rights and humanitarian aid. South Sudan, meanwhile, lacked any meaningful policies to address climate risks despite facing severe threats.

In the coming decades, climate mobility in the continent will peak. The Africa Climate Mobility Initiative (ACMI), a joint undertaking of the African Union Commission, the World Bank, UN Development Programme, the International Organization for Migration and the UN Framework Convention on Climate Change, studied the displacement due to climate disruptions. In its report "The Africa Climate Mobility Report", it said, "By 2050, up to 5 percent of Africa's population of some 2 billion people could be on the move due to climate impacts, up from 1.5 percent today. The overwhelming majority of this movement will happen within countries rather than across borders." The ACMI assessment said that climate displacement will be more for some countries than others in the continent. "East African countries in the Intergovernmental Authority on Development (IGAD) economic bloc could see up to 10.5 percent of their population on the move by 2050." ■

PHOTOGRAPH: ISTOCK PHOTO

FOOD SECURITY

HIGHPOINTS

Global warming of 2°C would put over **50%** of the continent's population at risk of undernourishment

Climate change is likely to affect **cocoa production** in West and Central Africa. The area is responsible for over **70%** of the world's cocoa production

Climate change combined with land degradation causing a decline of **18%** in agricultural production

Climate change is leading to widespread outbreaks of **plant diseases**. This has the potential to not just wipe out livelihoods but also can trigger hunger and death

PHOTOGRAPH: ISTOCK PHOTO

SHRINKING FOOD BASKET

Cropping systems across Africa are incredibly stressed and are slated for significant declines in production

AFRICA's MOUNTAIN regions have the second highest population density in the mountain regions of the world, after Asia. There are not many studies on how climate change would impact these regions. The Intergovernmental Panel on Climate Change (IPCC) estimated that risks to livelihoods and economy from changing mountain water resources are low in Central Africa and moderate in East Africa. But a study published in *Nature Climate Change* in January 2025 found out a less known phenomenon. Farmers in seven out of 10 African mountain sites reported seeing reduced fog, an important source of water for plants. The seven regions include Kilimanjaro and Udzungwa in Tanzania, Kigezi in Uganda, Mount Kenya and Aberdare in Kenya, Nyungwe in Rwanda and Itombwe in the Democratic

Republic of the Congo. Further, all 10 sites, including Bale (Ethiopia), Kibira (Burundi), and Bamboutos (Cameroon), saw fewer foggy days.

Reduced fog can be driven by increased temperatures, which, in turn, causes rising cloud base or overall reduced cloud incidence in mountain regions, the study highlighted. It also called for further investigation of the reported widespread reduction in fog. The authors of the study explained that IPCC did not consider fog in their assessment of Africa's mountain regions with a 228 million population. The study pointed out that nearly all sites experienced other climatic changes also, including increased temperatures, changes in rainfall amount and distribution, an increase in extreme droughts, fewer hailstorms and increased wind strength during the rainy season.

Studies have reiterated that mountain regions need urgent adaptation measures due to rising temperatures and changing rainfall. "Yet knowledge of where and how climate change adaptation is happening in African mountain regions remains extremely limited," the researchers wrote. So the team conducted the survey of 1,500 farmers across the 10 African mountain regions on the perceived climate change impacts and adaptation responses. Farmers from nearly all sites reported climate change-related impacts such as reduced stream flow, crop yields and cow milk production, increased soil erosion, crop and livestock diseases and reduced human health. Farmers in Kibira, Burundi reported an increase in malaria prevalence and influenza. In Aberdare, Kenya, farmers claimed more respiratory diseases, while waterborne diseases like cholera, typhoid, and dysentery were reported in Udzungwa, Tanzania. These results require further investigation, the researchers wrote.

However, farmers in nearly all sites were adapting to the changing climate by changing planting dates, sowing seeds again if a batch doesn't germinate, changing to improved crop varieties, and increasing use of soil conservation techniques, irrigation, fertiliser, pesticide and veterinary care. They were also diversifying into off-farm labour. "Overall, results show that African mountain farmers respond to climate change impacts by using multiple adaptation responses, most of which focus on intensifying farming practice," read the study. The researchers noted that most adaptation practices by farmers were more behavioural rather than technological, infrastructural or ecosystem-based.

At least half of the global crop production in low latitude areas could be jeopardised as global warming surpasses the threshold of 1.5°C and climate conditions become unsuitable for food production

FOOD SECURITY THREATENED

Climate change's impacts on the land system, agriculture and food security are going to be severe. At least half of the global crop production in low latitude areas could be jeopardised as global warming surpasses the threshold of 1.5°C and climate conditions become unsuitable for food production, a global analysis published in *Nature Food* in March 2024 warned. At the same time, there is also a threat to crop diversity as it is projected to decline on 52 per cent of global cropland in a scenario of global warming exceeding 2°C and on 56 per cent if warming exceeds 3°C. Researchers from Aalto University, Finland, University of Göttingen, Germany, and University of Zürich, Switzerland, studied 30 major crops under four scenarios of global warming levels ranging from 1.5-4°C and found a considerable increase in the share of agricultural areas shifting to unprecedented climatic conditions if global warming exceeds 2°C.

Around 10-31 per cent of current production would shift outside the "climate niche" to areas where none of the 30 crops were currently grown. This would increase to 20-48 per cent in a 3°C warming scenario. The authors of the study defined "climatic niche" for each crop based on the current climate conditions in their current production areas. For this purpose, the research applied the "safe climatic space" (SCS) concept, in which they mapped the current

PHOTOGRAPH COURTESY: WORLD FOOD PROGRAMME

climatic space of the major production areas of each crop using three climate parameters: annual precipitation, bio-temperature and aridity. "This means that when cropland shifts outside of the SCS, globally, there is no reference of, for example, agricultural management practices that would support continuing crop production under these novel climate conditions," said the study. Further, the researchers examined which locations would fall outside these SCSS under future climate conditions.

In the Middle East and North Africa (MENA), the current crop production would be at considerable risk on nearly 50 per cent of cropland area already under 1.5°C global warming. In MENA, these areas with considerable risk to current production would cover 69 per cent of the cropland area under 3°C global warming and in South Asia and in sub-Saharan Africa (SSA), 60 per cent. In contrast, especially in the Northern Hemisphere, there are large areas where the current production would not face considerable risk under any studied warming level. These lower risk areas cover 80 per cent of the croplands in North America and 77 per cent of those in Europe and Central Asia.

In terms of decline in potential crop diversity, the most spatially extensive decline was observed near the Equator, for example, in SSA and South Asia, where the diversity of food crops would decrease on more than 70 per cent of the current cropland area if global warming exceeds 2°C. Previous research estimated that by 2100, up to 30 per cent of global food crop production could experience climate conditions that currently do not host major crop production anywhere across the globe. Therefore, the risk of reduction in croplands, especially for major crops like wheat, rice, maize, and soybean was likely to exacerbate the already insufficient food supply and "threaten the livelihoods of agricultural households in several countries".

The study pointed out that it was unlikely that the adverse effects on crop production in low-latitude regions could be offset by incremental adaptations in agricultural management practices. "Therefore, in addition to climate change mitigation efforts, it is critical to support the food supply in these regions by strengthening national and international climate governance, for

example, by creating trade arrangements and financing for innovative adaptation in low-income countries," it said.

DRYING AFRICA

There is another dire warning. Scientists with high confidence have warned of a widespread increase in dry areas across the globe. The landmark report "The Global Threat of Drying Lands" from the UN Convention to Combat Desertification (UNCCD) released in December 2024 quantified both historical and projected future dryland expansions, offering critical insights into their impacts worldwide. This is for the first time, scientists from the UNCCD's Science-Policy Interface, which works to bridge the gap between science and policy, clearly documented current and future drying trends and impacts.

Its findings said that 77.6 per cent of the Earth's land likely became permanently drier in the three decades leading up to 2020, compared to the previous 30-year period (1961-1990). This meant 4.3 million square kilometres of previously humid landscapes had transitioned into drylands — areas where precipitation is less than 65 per cent of the atmospheric evaporative demand. This transition has dire implications for agriculture, ecosystems and the livelihoods of those dependent on these regions, as reduced rainfall affects crops, pastures, people and nature. Such lands now account for 40.6 per cent of the Earth's total land area (excluding Antarctica). To put this into perspective, this expanse is nearly a third larger than India, the world's seventh-largest country. Further, if the world fails to curb greenhouse gas emissions, another 3 per cent of the world's humid areas will become drylands by the end of this century.

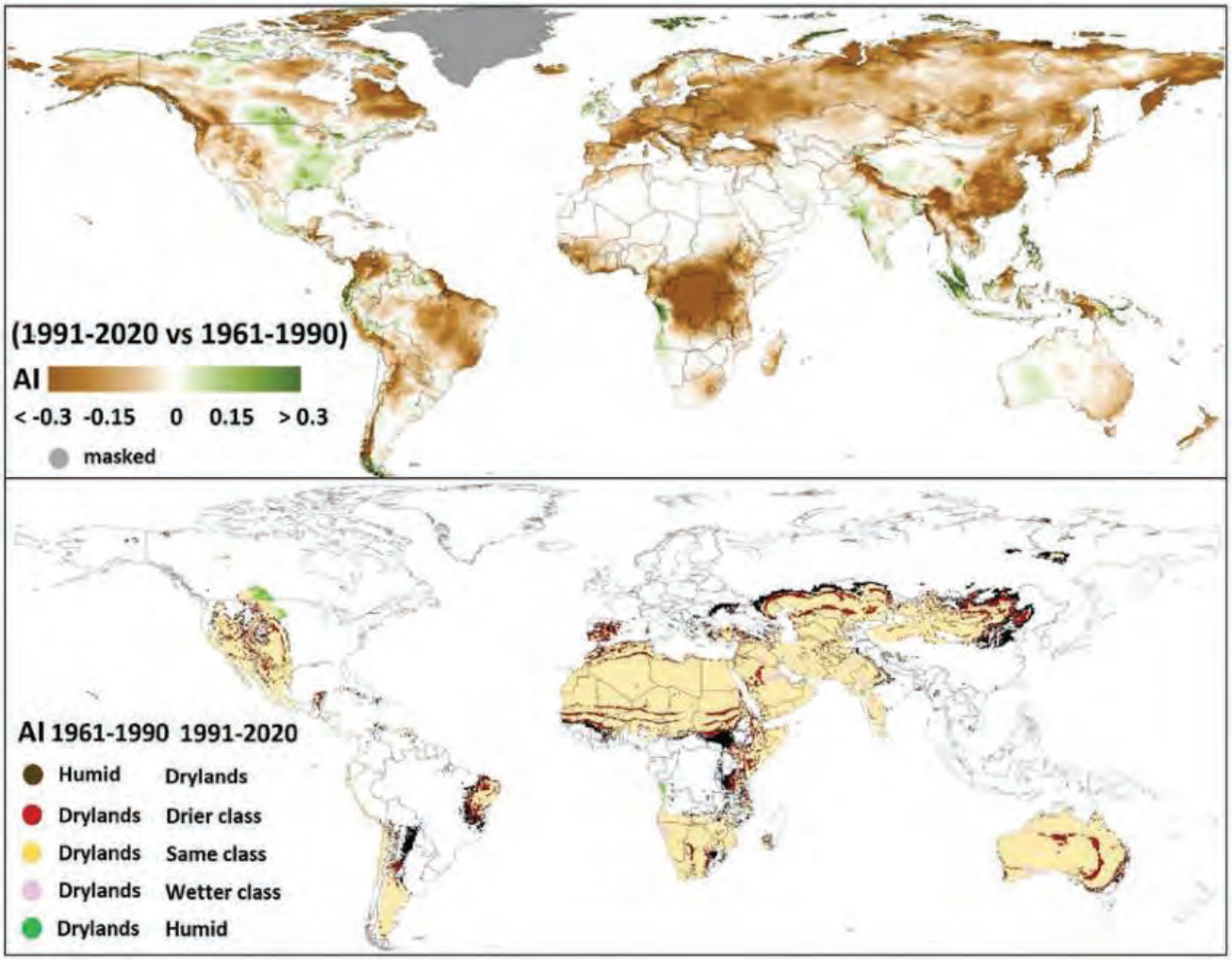
Between 1990 and 2015, African nations recorded a 12 per cent decline in gross domestic product (GDP) due to aridity. While few climate-model projections directly linked future aridity to poverty, climate drying was expected to exacerbate poverty, resulting in gdp growth losses of approximately 16 per cent and 6.7 per cent

Increasing aridity threatens people and ecosystems in nearly every global region. Aridity differs from drought in its nature and duration and is considered the world's largest single driver behind the degradation of agricultural systems. Droughts are short-term anomalies characterised by periods of low rainfall, often linked to high temperatures, low precipitation and reduced air humidity. In contrast, aridity reflects a persistent, long-term lack of available moisture needed to sustain most terrestrial life. A harsh differentiation is that while droughts also cause massive losses, those ends and recovery is possible. But "when an area's climate becomes drier, however, the ability to return to previous conditions is lost. The drier climates, now affecting vast lands across the globe, will not return to how they were and this change is redefining life on Earth," said Ibrahim Thiaw, executive secretary of UNCCD.

The report pointed out that much of aridity's recent rise can be attributed to human-caused climate change and that no region on the planet was projected to transition from historical drylands to future wetlands. Currently, 2.3 billion people inhabit drylands — a figure that has doubled over the past three decades. In a worst-case climate scenario, this number could rise to 5 billion by 2100. "These billions of people face even greater threats to their lives and livelihoods from climate-related increases in aridification and desertification," the report warned. Asia is home to 1.35 billion dryland inhabitants, more than half the global total.

Nearly half of Africa's population (620 million people) also lives in these arid regions. Rising aridity has already taken a toll on economies. Between 1990 and 2015, African nations recorded a 12 per cent decline in gross domestic product (GDP) due to aridity. While few climate-model projections directly linked future aridity to poverty, climate drying was expected to exacerbate

TRENDS IN ARIDITY



Upper panel: the difference between AI values over 1961–1990 and 1991–2020. Green means wetter conditions, brown drier conditions (Greenland is masked in the upper panel as the AI shows large variations due to snow, with no shifts from cold AI class). Lower panel: the shifts between AI classes in the above-mentioned periods. Black areas are the hotspots exposed to aridification

Source: The Global Threat of Drying Lands: Regional and global aridity trends and future projections, a report by United Nations

poverty, resulting in GDP growth losses of approximately 16 per cent and 6.7 per cent in Africa and Asia, respectively, according to the analysis.

Increasing aridity is expected to play a role in larger and more intense wildfires in the climate-altered future, with a 74 per cent expected increase in wildfire-burned areas in California and 40 per cent additional annual high fire danger days in Greece by 2100 compared to late 20th century levels. At least 55 per cent of species (mammals, reptiles, fish, amphibians, and birds) were at risk of habitat loss from aridity in hotspots like arid regions in West Africa, western Australia, Iberian Peninsula and humid regions of southern Mexico and northern Amazon rainforest.

THREAT TO FOOD SECURITY

There are eerie signs of climate change impacts on food security in Africa. Global warming of 2°C would put over 50 per cent of the continent's population at risk of undernourishment. Projections estimate that climate change will lead to an equivalent of 2 to 4 per cent annual loss in GDP in

the region by 2040. Over the past decade or so, warnings of possible famines in parts of eastern and southern Africa following long periods of protracted droughts have become common. In 2017, such warnings were issued for several nations in eastern and southern Africa. Ocean warming and acidification are depleting marine ecosystems, which provides nutrition to millions of inhabitants living on Africa's large coast. An analysis of fisheries in 132 countries by Edward H Allison et al in 2009 revealed that about two-thirds of the most vulnerable countries are situated in Africa. The worst affected are likely to be coastal countries in West Africa where value of fish is expected to decline by more than 20 per cent, equivalent to an annual loss of US $310 million per year by mid-century, according to IPCC AR5. The problem of nutrition depletion is not limited to marine ecosystems.

Cropping systems across Africa have been found to be incredibly stressed and are slated for significant declines in production in the coming decades. About 70 per cent of Africa is dependent on small and rain-fed agriculture that is expected to be badly hit by a changing climate. IPCC noted that maize yields are likely to reduce by about 22 per cent across sub-Saharan Africa, while Zimbabwe and South Africa are likely to experience yield declines of over 30 per cent by the mid-century. In the same period, wheat production would drop by as much as 35 per cent. Though some produce might show modest increases in the immediate future, this is likely to be offset by declines in the production of most cereals and horticultural crops. The food shortage is linked inextricably with the availability and access to water. Satellite images of the receding Kilimanjaro glaciers or of rapidly shrinking major lake systems like Victoria, Chad or Turkana have in recent years gone viral on the social media. These images are representative of the widespread shortages

About 70 per cent of Africa is dependent on small and rain-fed agriculture that is expected to be badly hit by a changing climate. ipcc noted that maize yields are likely to reduce by about 22 per cent across sub-Saharan Africa, while Zimbabwe and South Africa are likely to experience yield declines of over 30 per cent by the mid-century

of freshwater and surface water sources across the African landscape. Combined with an increasing population, which will see Africa's population nearly quadruple in a little more than 100 years, climate change is likely to put added stress on the availability and access to freshwater (Read "State of Africa's Environment 2024: Water" here: https://www.cseindia.org/state-of-africa-s-environment-2024-12364). There are already numerous reports of clashes and conflicts between different communities on access to water.

POVERTY AND CLIMATE

According to the World Bank, most of the shocks caused by climate change are also the causes for poverty in the continent. "The consequences of climate change for Africa are devastating and threaten to push millions of people into extreme poverty by 2030, largely due to lower crop yields and higher food prices, and negative health impacts," said Benoit Bosquet of the World Bank.

For instance, a study published in the journal *Agricultural and Forest Meteorology* in February 2025 suggested that ongoing climate change is likely to affect cocoa production in West and Central Africa. The area is responsible for over 70 per cent of the world's cocoa production. The study was conducted in the four main cocoa producing countries — Ivory Coast, Ghana, Nigeria (west Africa) and Cameroon (central Africa). Ivory Coast and Ghana are the largest producers followed by Nigeria and Cameroon. The research replicated both the mean and variability in yield over a 30-year period in the past (1980–2010) and in the future (2030–2060). The scientists employed a mechanistic cocoa crop model known as CASEJ, which replicates the

A NEW KAMPALA DECLARATION

After two decades, the Comprehensive Africa Agriculture Development Program shifts from narrow focus on agriculture-led growth to a broader agri-food systems approach

THE EXTRAORDINARY African Union Summit on the Comprehensive Africa Agriculture Development Program (CAADP) in January 2025 adopted the transformative Kampala Declaration for Africa's agri-food systems from 2026 to 2035. The new declaration is the successor to the Malabo Declaration, whose implementation period concludes in 2025.

During the summit, African leaders also endorsed the groundbreaking ten-year CAADP action plan (2026–2035), which outlines a detailed roadmap for transforming agriculture across Africa, a sector deeply vulnerable to climate change impacts. This plan specifies the steps required to achieve the declaration's goals, including clear implementation and monitoring strategies. The CAADP's vision, "Sustainable and Resilient Agri-food Systems for a Healthy and Prosperous Africa," aligns with Agenda 2063's goal of achieving "The Africa We Want" and the Africa Common Position on Food Systems. This was also reiterated in the first Africa Climate Summit Declaration of 2023. After two decades, there is a shift from the narrow focus on agriculture-led growth to a broader agri-food systems approach.

The CAADP was officially launched in July 2003 during the Second Ordinary Session of the AU Assembly in Maputo, Mozambique, in response to challenges such as low agricultural productivity, food insecurity, and under-investment in Africa's agriculture. At this session, African Heads of State and Government adopted the Maputo Declaration on Agriculture and Food Security, urging AU Member States to allocate at least 10 per cent of their national budgets to agriculture and rural development and to achieve annual agricultural productivity growth of at least 6 per cent. The declaration underscored the importance of enhancing agricultural productivity through increased investment in the sector.

In 2014, the Malabo Declaration expanded the CAADP framework by reaffirming its principles and targets while introducing ambitious new goals, such as eradicating hunger and malnutrition, tripling intra-African trade, enhancing resilience, and strengthening accountability for actions and results. However, according to the fourth Biennial Review Report released by the African Union in February 2024, the continent remains off-track in achieving the commitments outlined in the Malabo Declaration. Notably, ending hunger by 2025, one of the declaration's seven key commitments, has not been met by any Member State, as highlighted in the report. While there has been progress in reducing stunting rates, malnutrition remains a critical concern, contributing to higher mortality rates and hindering development.

PHOTOGRAPH COURTESY: CAADP

Meanwhile, rising obesity and related health issues are adding to the continent's economic and health burdens. Without urgent and intensified efforts, Africa is unlikely to meet its goals of ending hunger and malnutrition by 2025 or 2030.

Africa's agricultural sector has been severely impacted by recent shocks, including the COVID-19 pandemic, internal conflicts, the Russia-Ukraine war, climate change, and corruption. These disruptions underscored the urgent need for a renewed CAADP agenda to transform the continent's agri-food systems beyond 2025. In response, the Thirty-Seventh Ordinary Session of the African Union Assembly, held in February 2024, called for the development of a post-Malabo CAADP agenda for 2026-2035. This new framework aims to build resilient agri-food systems capable of addressing these complex challenges and ensuring sustainable growth.

Building on the Maputo and Malabo phases of the CAADP, the post-Malabo agenda adopted in Kampala on January 11, 2025, introduces an agri-food systems approach. This approach empowers stakeholders to tackle challenges across the entire food value chain while aligning policies with broader development objectives.

This strategic shift is based on recognising the complex connections between agriculture, nutrition, economic development, and other sectors. To address trade-offs and inter-linkages, policies must be better integrated, considering sustainable practices from farm to fork, value chain complexity, and the impact on diets and nutrition. The agri-food systems approach prioritises environmental sustainability to protect future food production and combats all forms of malnutrition—such as under-nutrition and micronutrient deficiencies—by promoting diverse, nutritious, and affordable diets.

Building resilience is crucial for adapting to and recovering from shocks like climate change, pandemics, conflicts, and economic disruptions. While there has been some progress, Africa is facing challenges in this area, with only two countries on track to meet resilience-building targets in 2023. The slow pace of progress in strengthening resilience hinders the achievement of other key goals, including ending hunger, eradicating malnutrition, and reducing poverty.

While Africa is currently the hardest hit by climate change and also has the widest agricultural productivity gaps to close, the 10-year CAADP has set the stage for a new era in African agriculture. It advocates for adoption of climate-smart innovations and technologies to ensure food-security for Africa's population which is projected to double by 2050, reaching approximately 2.5 billion people.

key physical and biochemical processes occurring in the plant and their reactions to varying climate conditions. The CASEJ model predicts cocoa growth and production under both water-limited and non-limited scenarios and is designed to simulate the impacts of warming and increased CO_2 levels on cocoa yield. The researchers simulated potential water-limited cocoa yields to evaluate effects of warming and precipitation changes based on five plausible general circulation models climate-change scenarios, with and without elevated CO_2.

The findings indicated that temperature and rainfall changes are rendering some regions less ideal for cocoa farming, whereas other areas might gain advantages from the changing climate. The effects are expected to differ by region, with changes in the climate suitability of production areas and a possible reduction of 50 per cent in the currently suitable climatic area by 2050. The northern edge of the cocoa-production zone in Ivory Coast and Ghana are projected to suffer the worst reduction (12 per cent) in yield. These areas have already become marginal for producing cocoa. They are estimated to be followed by Nigeria (10 per cent) and Cameroon (2 per cent).

The study's findings indicated that with future climate changes, cocoa production (suitable growing regions) might move more from Ghana and Ivory Coast, which currently account for over 60 per cent of the world's cocoa production, towards eastern countries such as Nigeria and Cameroon. This change in production could greatly impact countries such as Cameroon, as potential rises in cocoa production in this new region could severely affect forest areas. Cameroon is among the African nations where a significant portion of rainforest and related biodiversity remains intact. Managing the adaptation of cocoa production to climate change, while avoiding deforestation caused by cocoa expansion, will be a major challenge both now and in the future.

CLIMATE AND LAND DEGRADATION

Climate change is just precipitating the planet's land degradation crisis. Land degradation impacts 15 million sq km of the planet. This is more than the area of Antarctica or almost equal to the size of the Russian Federation. Population-wise, most of the world's poor reside in areas impacted by degradation. UNCCD data suggests some 1.2 billion people are affected by land

degradation. Even more worryingly, UNCCD estimated that the global area impacted by land degradation is expanding each year by about 1 million km^2.

Land-system is one of the nine planetary boundaries that set a threshold level beyond which there would be catastrophic environmental impacts and its reversal could be difficult. Maintaining these boundaries effectively means a stable planetary system. "The aim of the planetary boundaries framework is to provide a measure for achieving human wellbeing within Earth's ecological limits," said Johan Rockström, who introduced the concept in 2009. Recent assessments said that six of these boundaries have already been breached.

The land-system planetary boundary is widely believed to have been breached since 1990. The key benchmark for gauging the land-system boundary is land use; and for this, the key indicator is forest cover of the planet. Ideally, maintaining 75 per cent of the original forest cover is estimated to keep us within this particular planetary boundary. But currently, we have been just left with 60 per cent of the planet's original forest areas (before human intervention periods).

Breaching the land-system boundary has ramifications on other such ones. This is because land is a central aspect in seven of the nine planetary boundaries: land-system change, climate change, change in biosphere integrity, freshwater change, biogeochemical flows, novel entities and atmospheric aerosol loading. The UNCCD earlier said that "Unabated land degradation will directly or indirectly lead to further pressure on these planetary boundaries, whereas sustainable land management can lead to greater systems resilience."

Land degradation has primarily been attributed to agriculture. "Conventional agriculture is the leading culprit of land degradation, contributing to deforestation, soil erosion and pollution. Unsustainable irrigation practices deplete freshwater resources, while excessive use of nitrogen- and phosphorus-based fertilizers destabilizes ecosystems," said a special report titled "Stepping back from the precipice: Transforming land management to stay within planetary boundaries" published by UNCCD and the Potsdam Institute for Climate Impact Research in December 2024. Close to 90 per cent of direct deforestation has been caused by cropland expansion. "If we fail to

More than 40 per cent of East Africa's soils are degraded, with climate change and soil erosion posing a major threat to agriculture and food production in the already food-insecure region

acknowledge the pivotal role of land and take appropriate action, the consequences will ripple through every aspect of life and extend well into the future, intensifying difficulties for future generations," said Ibrahim.

Agriculture contributes one-fifth of Africa's GDP and employs nearly two-thirds of the workforce. So, the forecast of climate change combined with land degradation causing a decline of 18 per cent in agricultural production is worrying. This is because the continent's food supply demand will triple by 2050. According to the World Meteorological Organization (WMO), "Projected annual food imports by African countries are expected to increase by about a factor of three, from US$ 35 billion to US$ 110 billion by 2025." "Climate change and the diminishing natural resource base could fuel conflicts for scarce productive land, water, and pastures, where farmer-herder violence has increased over the past 10 years due to growing land pressure, with geographic concentrations in many sub-Saharan countries," said WMO.

A scientific report published in *Nature* in May 2025, by scholars from Shantou University and Jiangsu University of China and Kwame Nkrumah University of Science and Technology Kumasi, Ghana, studied the moderating role of climate change on food security-health outcome nexus in 46 African countries. "Climate change is a moderator that affects the health outcomes linked to poor nutrition and exacerbates food insecurity. Agriculture systems are under stress as a result of increasingly unpredictable climate conditions, which lowers food output, raises food prices, and makes it harder to obtain wholesome food. The most vulnerable and impoverished groups, who are least equipped to cope with climate shocks, are disproportionately affected by

PHOTOGRAPH COURTESY: FAO

these effects," they concluded in the paper.

More than 40 per cent of East Africa's soils are degraded, with climate change and soil erosion posing a major threat to agriculture and food production in the already food-insecure region. As per Soil Atlas Kenya Edition, the case in Kenya is worse, with only a fifth of the croplands arable. The Atlas described it as a silent crisis in East Africa, saying, "Soil degradation poses a global crisis as it jeopardises food security, livelihoods and ecosystem health. The situation is worse in East Africa, where over 40 percent of soils are degraded, threatening the region's agricultural foundation and resilience." In some cases, like Kenya, the situation is worse. Croplands lose an average of 26 tons of soil per hectare annually to water-induced erosion, with some areas experiencing losses exceeding 90 tons. Joachim Paul, the director of Heinrich Boll Foundation, said, "Soil is the foundation of life, yet it remains one of the most overlooked and undervalued resources. Its health influences the food we eat, the water we drink and the air we breathe. Protecting soil is not just an agricultural concern, it is essential for sustaining ecosystems, food security and climate resilience particularly in Africa."

By 2040, it is projected that due to climate-change, there could be an expansion in the global arid area by 3.9 per cent and this would translate as losses of an estimated 20 million tonnes of maize, 19 million tonnes of rice, eight million tonnes of soybeans and 21 million tonnes of wheat, according to the "The Global Threat of Drying Lands" report. At a global scale, a country's proportion of hyper-arid, semi-arid and arid land was negatively correlated with its output of major crops, highlighting the fact that, even in regions where precipitation has increased, a higher atmospheric evaporative demand may negatively affect crop yields.

The widespread increase in drylands would eventually lead to countries dependent on food imports to ensure food security, further aggravating socioeconomic impacts. "These countries face additional food security risks when increases in food prices make imports prohibitive or

when food production crises, such as those during severe droughts, make these imports unavailable," it added. Scientists warned that the problems faced by agricultural systems due to aridity were expected to worsen into the future — especially in sub-Saharan Africa, North Africa and the Middle East and South Asia. In sub-Saharan Africa, for example, between 17 and 22 per cent of current crop production could be lost by mid-century due to the impacts of increasing aridity and temperatures in a moderate emissions scenario. Rainfed agriculture in the region will be specifically affected. Yields of millet have been projected to decline by a quarter within the same time frame, if greenhouse gas emissions continued to be high, and in Kenya, maize production was projected to fall by as much as half by 2050, due to increased atmospheric evaporative demand across the country.

PLANT HEALTH AND CLIMATE

Climate change is also leading to widespread outbreaks of plant diseases. This has the potential to not just wipe out livelihoods but also can trigger hunger and deaths. For instance, take the recent disease outbreaks in the continent, widely attributed to changing climate. Cassava holds the solution to Africa's struggle with food insecurity, poverty and malnutrition. The tuber is a staple food in many African countries. It is drought-tolerant and grows well even on poor soil. However, cassava brown streak disease is fast eliminating that possibility. First spotted in Tanzania in 1935, the disease has spread from eastern Africa to central and southern Africa. Its spread has been particularly aggressive in recent years.

In Rwanda, export earnings from roots declined by 40 per cent from $7.9 million in 2016 to $4.7 million in 2017, largely because of a severe outbreak of the disease. Geofrey Ng'andu,

A plant pandemic could provoke a humanitarian crisis—a crisis that could deprive people of livelihood and lead to widespread hunger. The world has witnessed such crises in the past

agriculture extension officer of Kanchibiya district in Zambia, said the disease entered the country in 2017 and had since spread rapidly. "In 2022, about 500 ha were affected by the disease. In 2023, it increased to 700 ha. This year, close to 1,000 ha stands are affected," said Ng'andu. Slyvester Mulenga, a farmer from Kanchibiya district. "We would eat maize mealie meal for three months in a year and cassava mealie meal for the rest of the year. It has been our staple food, but not anymore." The disease infected 97 per cent of the plants and can lead to hunger and death of many cassava-dependent families, Mulenga said.

"One can safely assume that multiple plant diseases are going to spread across the world because of globalisation and climate change impacts. This is devastating as climate change is already exacerbating the food crisis across the world," said Nick Talbot of The Sainsbury Laboratory, UK that conducts research on plant diseases and resistance. What's alarming is that these pathogens are fast mutating to invade previously untouched geographies, infect new hosts and evade resistant varieties.

A plant pandemic could provoke a humanitarian crisis—a crisis that could deprive people of livelihood and lead to widespread hunger. The world has witnessed such crises in the past. Between 1845 and 1852, Phytophthora infestans wiped out potato crops in Ireland, resulting in the Great Famine and mass migration. The UK government estimated that 1 million people were affected either by disease or hunger. Similarly, during the 1943 Bengal famine, Cochliobolus miyabeanus that causes brown spot disease in rice led to the death of over 2 million people. In recent years, 400,000 coffee workers in central America lost their livelihood and had to migrate after coffee leaf rust disease infected plantations, stated a 2021 study published in Agricultural Sciences. "The war between Russia and Ukraine has shown us how vulnerable we are to perturbations in the global supply of wheat and how shortages can lead to rapid increases in price affecting trade," warned Paul Nicholson, professor at the John Innes Centre in the UK.

COWS HELP FARMS STORE ONE-THIRD MORE CARBON IN SOIL

Livestock is critical to healthier, carbon-rich soils

WHILE LIVESTOCK is known to be one of the major sources of methane emissions, new data suggested it plays a crucial role in enhancing soil carbon storage. A report by Soil Association Exchange, an organisation promoting sustainable farming and assessing its impacts, found that farms with a mixed enterprise system, combining both arable crops and livestock, hold a third more soil organic carbon compared to those with arable crops alone. Researchers gathered data from 685 farms covering a total area of 238,000 hectares across the United Kingdom over two years (2022-2024) and found compelling evidence that integrating livestock into arable systems improves soil health, particularly in terms of organic matter and carbon levels.

Across all surveyed farms, soils had an average of 5.74 per cent organic matter and 3.34 per cent soil organic carbon (SOC). Arable-only cropping, including potatoes, averaged 2.54 per cent SOC, while mixed farms with cows and sheep had 3.47 per cent SOC, and farms with only cows and sheep had 4.92 per cent SOC. Mixed enterprise farms with livestock also tended to support greater plant diversity compared to those without.

The researchers measured outcomes across six impact areas: Soil health, carbon, biodiversity, animal welfare, water, and community and societal impacts. "Farming contributes 11 per cent of our UK greenhouse (GHG) emissions, and the National Farmers Union (NFU) has a 2040 industry goal to become Net Zero. It is still rare to find a farm that has achieved Net Zero status, and there are no doubts some have large hurdles to overcome. Livestock in particular play a large role in our emissions, but are also pivotal to not only our soil health but to overall biodiversity and the rural community," the report said.

PHOTOGRAPH: ISTOCK

PHOTOGRAPH COURTESY: ZARI

Similarly, soybean and wheat are extensively grown in high-density monocultures, and their yields are compromised by a plethora of pests and pathogens. Soybean rust caused by the fungus Phakopsora pachyrhizi and wheat blotch caused by the fungus Zymoseptoria tritici are among the most destructive diseases on these crops, and yield losses of more than 50 per cent have been documented during severe epidemics, according to a review article published in *Nature Reviews Microbiology* in May 2023.

An overhaul of the way we grow food is pertinent because plant pathogen loads and disease pressure are likely to change under future climate scenarios. Nick Talbot of The Sainsbury Laboratory, UK, said extreme weather events such as tropical storms had shown potential to spread diseases. Wheat blast outbreaks in Bangladesh, for example, have often followed tropical storms and heavy rains. A May 2021 study, "The persistent threat of emerging plant disease pandemics to global food security", published in *Agricultural Sciences*, noted that extreme weather events like hurricanes could transport pathogen spores over continents. It said Hurricane Ivan in 2004 caused soybean rust movement from Brazil to the US. Another research, published in *Scientific Reports* in April 2024, concluded that a rise in global warming from 1.5°C to 4°C is expected to increase the risk of Pierce's disease (a bacterial disease that affects grapevines) epidemics in vineyards of southern Europe, particularly in France, Italy and Portugal. A 3°C increase indicates expansion of disease to the Mediterranean region and beyond. In a warming climate, wheat blast will spread to countries that so far remain untouched.

To aggravate the matter, elevated temperatures can suppress plant immunity, leading to increased pathogen infection, stated the article in *Nature Reviews Microbiology*. For example, prolonged drought causes water stress in plants, which results in increased susceptibility to infection by pathogens. Climate change can also facilitate the emergence of new strains of

Multiple plant diseases are going to spread across the world because of globalisation and climate change impacts. This is devastating as climate change is already exacerbating the food crisis across the world

pathogens, which in turn can break down resistance of the host plant, notes the article. Elevated carbon dioxide levels in the atmosphere are also seen to increase the severity of certain pathogens like powdery mildew that infects gourds.

Mitigating the future risks also requires effective monitoring and management of plant diseases. Scientists suggest taking a leaf out of the COVID-19 pandemic, by using genomic surveillance to help control the spread of diseases. For example, researchers recently conducted a genomic surveillance of wheat blast fungus. In a 2023 study, published in *PLOS Biology*, they noted that the technique enabled rapid and accurate pathogen identification and allowed tracing of the outbreak origin, which could direct preventive measures. Scientists from Bangladesh used a similar disease surveillance and monitoring mechanism, Open Wheat Blast, to share genomic data and analysis related to wheat blast and could track down its origin to South America.

The International Maize and Wheat Improvement Center (CIMMYT), Mexico, has also formed a Wheat Disease Early Warning Advisory System (Wheat DEWAS), which has introduced new analytic and knowledge systems capacity to one of the world's largest and most advanced crop pathogen surveillance systems. The project allows researchers to build an open and scalable system to prevent disease outbreaks from novel pathogen strains threatening wheat productivity and food security in South Asia and East Africa. Talbot said scientists in Japan, UK, and other countries are working on surveillance of the spread of wheat blast disease and identifying potential mutations. "There are about a handful of strains identified by scientists that work against the wheat blast. The Rmg8 gene developed is the strongest thus far. But more efforts are needed to identify resistance genes and add multiple protection layers to the crop to safeguard against wheat blast," he added. Coordinated effort and active surveillance are the only ways to beat pathogens in this warming and globalised world. ■

PHOTOGRAPH: ISTOCK PHOTO

WATER

HIGHPOINTS

Current world water gaps of nearly **458 billion cubic meters/year** is projected to increase by 6% under the 1.5°C warming scenario

High water stress caused by global warming will displace up to **700 million Africans** by 2030

Countries need to integrate the **water and climate agendas** at a national level through national adaptation and resilience planning and at the regional level, through transboundary cooperation

PHOTOGRAPH: ISTOCK PHOTO

A FOUNDATIONAL SHRUG

For the first time in history, human activity is pushing the global water cycle out of balance

THE WORLD has currently water gaps amounting to nearly 458 billion cubic meters per year. These are projected to increase by 6 per cent under the 1.5°C warming scenario and by 15 per cent under 3°C warming according to an analysis published in *Nature Communications* in January 2025. Water gaps are defined as the difference between renewable water availability and water consumption while maintaining adequate flows in aquatic environments. Researchers Lorenzo Rosa of the Carnegie Institution for Science and Matteo Sangiorgio of Politecnico di Milano used climate outputs from five climate models from the CMIP6 archive to quantify water gaps under baseline, 1.5°C, and 3°C warming scenarios.

These gaps occur on every continent. Global warming is increasingly exacerbating water gaps. Regions currently experiencing water gaps are expected to face more severe conditions under 1.5°C warming, with even worse outcomes at 3°C warming. This trend is particularly evident in the eastern US, Chile, the Mediterranean region, south and east India, and the North China Plain. Additionally, some regions that were relatively unaffected in the baseline climate, such as Italy, Madagascar, and some US states on the East Coast (North Carolina and Virginia) and in the Great Lakes region (Wisconsin, Minnesota, Illinois), are projected to see worsening conditions. Saudi Arabia is projected to experience decreased water scarcity under the 1.5°C warming scenario, but substantial increases in water gaps under the 3°C warming scenario.

Global warming and the resultant change in climate are having profound impacts on the water resources and distribution in the world. The circulation of water in the Earth-Atmosphere system has been significantly impacted by climate change and human activities, according to the World Meteorological Organization (WMO). The effects on the hydrological cycle are leading to droughts and extreme rainfall events and the erratic water cycles unleashed widespread disruption, burdening livelihoods and economies. The ongoing melting of snow, ice and glaciers compounded the threat, exacerbating the risk of extreme weather events such as floods. These events cast long-term consequences on the water security of millions, warned WMO's "State of Global Water Resources 2022" report. The findings of the report are critical, as nearly 4 billion people are already experiencing severe water scarcity for at least a month every year. High water stress caused by global warming will displace up to 700 million Africans by 2030. It will also aggravate conflicts on the continent, according to "State of the Climate in Africa 2021" published jointly by WMO and

Global warming and the resultant change in climate are having profound impacts on the water resources and distribution in the world. The circulation of water in the Earth-Atmosphere system has been significantly impacted by climate change

the African Union Commission. The warming is causing extreme weather events such as lingering droughts and devastating floods that is hitting African communities, economies and ecosystems hard.

The "2024 Global Water Monitor Report" released in January 2025 said that climate change significantly disrupted the global water cycle in 2024, resulting in devastating water-related disasters that caused over 8,700 deaths, displaced 40 million people and led to economic losses exceeding $550 billion. The report highlighted the most damaging water-related disasters of 2024, which included flash floods, river floods, droughts, tropical cyclones and landslides. Some of the other events that made it to the list were flooding in Afghanistan-Pakistan, heavy flooding in East Africa, Rio Grande do Sul floods in Brazil and the severe drought and bushfires in the Amazon basin. The report attributed all these events to climate impact.

Rising sea surface temperatures, linked to climate change, were a key factor behind prolonged droughts in the Amazon Basin and Southern Africa as well. Global warming also intensified heavy rainfall events. 2024 saw the highest average land temperatures ever recorded globally. The frequency of record-warm months was the highest since 1979, the "2024 Global Water Monitor Report" highlighted. As many as 34 countries experienced record-high annual maximum temperatures and annual minimum temperatures also increased, particularly in tropical regions. There are also fewer frost days. Thirteen countries experienced an unusual but not record low number of frost days, including 10 in Europe and India, showed the report. In terms of precipitation, the record-breaking monthly rainfall total was 27 per cent higher in 2024

PHOTOGRAPH: ISTOCK PHOTO

than at the beginning of the century. New records were set in West Africa, Europe and Asia. Extreme rainfall events occurred 52 percent more frequently. The number of record maximum rainfall events worldwide has increased by 4 per cent per decade.

The report warned that 2025 could bring further extreme weather events. Northern South America, southern Africa, northern Africa, Central Asia, parts of North America and Western Australia are likely to experience intense droughts. In contrast, regions such as the Sahel, Horn of Africa, Europe and most of Asia face heightened risks of flooding. “Ongoing climate change increases the potential for extreme weather events, including flash floods, flash droughts, intense storms, and heatwaves across many regions in 2025,” read the report.

The warming has caused a disruption in the pattern of rainfall. Glaciers too are disappearing, the report said. Mount Kenya, Mount Kilimanjaro (Tanzania) and the Rwenzori mountains (Uganda) are retreating at a faster rate than the global average. Kilimanjaro could vanish by 2040 due to climate change, the WMO had warned in the “State of the Climate in Africa 2020”. But, the existence of these glaciers in east Africa depends on the amount of future precipitation that falls on the region. Africa’s freshwater lakes have shrunk. The total surface area of Lake Chad shrunk to 1,350 square kilometres in the 2000s, from 25 000 sq km in the 1960s. Lake Chad, which is located in the Sahel region at the conjunction of Nigeria, Niger, Chad and Cameroon, is home to 17.4 million people. These countries of the Lake Chad basin are among the 10 least peaceful countries in Africa, according to the "Global Terrorism Index" report, 2020. “The drying up of continental water bodies like Lake Chad has significant adverse impacts on the agricultural sector,

ecosystems, biodiversity and socioeconomic development," said Petteri Taalas, secretary-general of WMO. In West Africa, the WMO report of 2020 has attributed long-term decline in river flow to increase in temperature, drought, and increased water demand. Four out of five African countries are unlikely to have sustainably managed water resources by 2030, the report, which has a special focus on water, noted. Increasing demand and decreasing supply of water might worsen conflict, it said. This will result in Africa not being able to meet the United Nations mandated Sustainable Development Goals (SDG) by 2030. Going forward, it will be very difficult for the continent to achieve goals on sustainable development unless actions are taken to address water-related concerns, the report said. Poor progress on water security will impact at least three SDG goals — poverty alleviation (SDG 1), green energy (SDG 7) and disaster risk reduction (SDG 11).

TOP THREAT

The 20th edition of the World Economic Forum (WEF)'s annual Global Risks Report released in January 2025, identified India alongside Mexico, Morocco, Tunisia, and Uzbekistan as the five countries where water supply crises rank as the top immediate or short-term risks. The report highlighted that water supply shortage, whether for human, industrial, or ecosystem needs, lead to water insecurity at local, regional, and global levels. These shortages were driven by factors including human overexploitation, mismanagement of critical natural resources, climate change, and insufficient infrastructure. The number of countries identifying water supply shortages as a top-five risk has surged from seven in 2024 to 27 in

Water supply shortage, whether for human, industrial, or ecosystem needs, lead to water insecurity at local, regional, and global levels. These shortages were driven by factors including human overexploitation, mismanagement of critical natural resources, climate change, and insufficient infrastructure

2025, reflecting the growing global crisis and the increasing significance of this issue. In North Africa, Morocco and Tunisia had seen water concerns rise from the third-most severe risk in 2024 to the foremost challenge in 2025.

The UN-led "Global Water Security 2023 Assessment", released during the UN 2023 Water Conference, found that all African nations were "water insecure" accounting for nearly half of the 114 such nations in the world. Three of the five "critically water insecure" countries in the world are in Africa - Eritrea, Sudan and Ethiopia. Africa accounts for 22 per cent of the world's critically water insecure population. Around 6.3 billion people (or 78 per cent of the world's population) live in countries experiencing critical water insecurity or general water insecurity. Of this, 4.3 billion reside in the Asia-Pacific, followed by Africa (1.4 billion), Americas (415 million people) and 65 million in Europe. In the African continent, 13 African countries have been assessed to be in the critically insecure category.

For many countries, it is a double whammy: most climate change vulnerable countries are also water-stressed. Africa is the world's second driest continent, after Australia and also the most water-stressed one. Sub-Saharan Africa was the world's most water-stressed region between 2020 and 2021, found a survey published in the *Lancet Planetary Health* journal in November 2022. Nearly 36 per cent of the people surveyed in the region were water insecure, according to the report. Overall, some 14.2 per cent of the respondents were water stressed; while countries in Sub-Saharan Africa, such as Cameroon (63.9 per cent) and Ethiopia (45 per cent), experienced the highest rates of water insecurity, those in Asia, like China (3.6 per cent), experienced the least.

LAKES ARE AT STAKE

Lake Victoria will have a prolonged period of low-oxygen levels

SHORT-TERM heat waves, along with long-term global warming, are reducing the levels of dissolved oxygen (DO) on the surface of lakes across the globe according to a study published in *Science Advances* in March 2025. The average deoxygenation rate in global lakes is faster than that observed in the oceans and in rivers. The analysis indicated a continuous deoxygenation in 83 per cent of the studied lakes.

Decreasing solubility due to global warming accounted for 55 per cent of surface oxygen loss in global lakes, while eutrophication is responsible for 10 per cent of surface oxygen loss. As temperatures continue to increase, surface DO is projected to decrease by 0.34 and 0.76 mg/litre by 2100 under SSP2-4.5 and SSP5-8.5 respectively. As the frequency and impact intensity of heat waves increase, the future impact of heat waves on lake deoxygenation may intensify, particularly in North America and Europe.

Researchers led by Yibo Zhan from the Chinese Academy of Sciences used model-derived DO estimates for 15,535 lakes to investigate the extent to which long-term climate warming and short-term heat waves contribute to surface DO dynamics on a global scale. The study predicted that stressed lakes will primarily be in tropical regions. There are 238 (SSP2-4.5 scenario) and 279 (SSP5-8.5 scenario) lakes that are projected to experience stress conditions in the future. The predictions for Lake Victoria, Africa's largest lake by area indicate a prolonged period of low-oxygen levels.

On the basis of ERA5 reanalysis data, the researchers identified atmospheric heat wave events over global lakes during the period of 2003–2023. The average duration of heat waves over global lakes was 15 days per year. Globally, 85 per cent of the studied lakes have experienced a gradual increase in the number of heat wave days per year. The number of heat wave days has increased across all six continents over the past two decades, with an increase rate of 1.2 days/year in Africa, 0.7 days/year in Asia, 0.6 days/year in Europe, 0.5 days/year in North America, 1.4 days/year in Oceania, and 0.6 days/year in South America respectively.

Deoxygenation is projected to occur more rapidly in Europe and North America compared to Africa, Asia, Oceania and South America. Under SSP5-8.5, projected DO rates are approximately 2.3 times higher than those in SSP2-4.5. Long-term projections suggest that the global mean DO will decrease to 9.11 and 8.70 mg/litre by 2100

PHOTOGRAPH: ISTOCK PHOTO

under SSP2-4.5 and SSP5-8.5, respectively. Heat waves can result in a reduction in DO solubility and lead to rapid and substantial fluctuations in DO concentration over short durations. The analysis demonstrated that heat waves negatively affect DO concentrations in lakes worldwide.

A decrease in DO concentrations results in substantial consequences: Reduced nitrogen fixation, increased emissions of N2O (a potent greenhouse gas), limitations on habitat suitability and productivity for oxygen-demanding organisms as well as having adverse impacts on food security, livelihoods and coastal economies. "The declining oxygen could lead to species extinction, aquatic organism kills and the collapse of commercial fishing industries," said co-author Zhang Yunlin, Chinese Academy of Sciences.

UNICEF has been highlighting the links between climate vulnerability and water scarcity. Lack of monitoring of water, sanitation and hygiene (WASH)-related programmes, projects and policies in a third of the developing nations is a major factor driving water insecurity in the world's worst-impact countries, said UNICEF's report "Triple Threat", released in March 2023. It analysed 10 African countries where children were most affected by the convergence of three water-related threats: Inadequate water, sanitation and hygiene; related diseases; and climate hazards. The report released during the UN Water Conference (March 22-24, 2023), called for urgent investment in WASH services to protect children. The 10 African countries facing this triple burden are Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger, Nigeria and Somalia — all in sub-Saharan Africa — with a combined population of 190 million children, according to the Children's Climate Risk Index 2021 by UNICEF. They are the world's most water-insecure and climate impacted countries, experiencing water scarcity and conflicts, heat waves, flooding and cyclones. They are within the top 25 per cent of the developing countries in terms of exposure to climate and environmental hazards, shocks and stresses. They are also not on track to meet the SDGs target of universal access to basic wash services by 2030.

OUT OF BALANCE

The ongoing water crisis across the globe is likely to worsen and is predicted to cause financial losses in lower-income countries amounting to an average GDP loss of up to 15 per cent by 2050. This is around twice the estimated global average GDP loss of about 8 per cent, according to the "Global Commission on the Economics of Water" report released in October 2024. The Commission attributed this crisis to a combination of factors such as weak economic practices, unsustainable land use and persistent mismanagement of water resources — all exacerbated by the adversely changing climate.

For the first time in history, human activity is pushing the global water cycle out of balance, compromising the very foundation of human well-being and economic stability. According to the Commission, the water crisis demanded a reworking of policy frameworks — in other words, a new economics of water. The report emphasised the necessity to manage water resources as a global public good rather than personally owned commodity. "The new economics of water begins by recognising that the water cycle must now be governed as a global common good, that can only be fixed collectively, through concerted action in every country, collaboration across boundaries and cultures, and for benefits that will be felt everywhere," said Henk Ovink, Executive Director, Commissioner, Global Commission on the Economics of Water.

The water challenge becomes even more pressing when we recognise how much water each person needs daily to live a dignified life. The Global Commission offered a new perspective on just access to water — while 50 to 100 litres per day is required to meet essential health and hygiene needs, a dignified life — including adequate nutrition and consumption — requires a minimum of about 4,000 litres per person per day. As this vital resource becomes scarcer, food security and human development are at risk. But while the global water crisis is a tragedy, it is also an opportunity to transform the economics of water, noted the report and called for a shift in perspective to properly recognise water scarcity and the benefits it provides. The report

highlighted a critical distinction between "green water" which refers to moisture in soils and vegetation, and "blue water" encompassing surface and groundwater.

The Global Commission emphasised that reliable supplies of green water are vital for generating rainfall, as well as for mitigating climate change and ensuring economic stability. To address these challenges, the report underlined the need to redefine water governance. For this, it called for a fundamental shift in how water is perceived and managed globally, advocating for a collective, mission-driven approach that engages all stakeholders. The five missions it proposed include: revolutionising the Food Systems, conserving natural habitats, establishing a circular water economy, enabling sustainable innovation and ensuring clean water access. As the world struggles to find solutions to looming water crisis, the report provided a framework along with a roadmap with challenging goals stated under the five missions.

For instance, the mission for new revolution in food systems includes three goals and includes improving the water productivity by reducing water usage in agriculture by a third, while increasing crop yields. Accelerating the shift to regenerative agriculture systems from 15 per cent of global cropland to 50 per cent by 2050 is another significant goal that the world should strive and work towards, suggests the report. The world should also act seriously to meet the 30% target for the restoration of degraded forests and inland water ecosystems. This will encourage the regeneration of green water flows and stocks through precipitation and soil moisture retention, says the commission. The emphasis on "green water" conservation and restoration is significant when climate change is a short-term and long-term risk. "A stable supply of green water is linked inextricably to stable patterns of rainfall, itself critical to economies and livelihoods. It also provides crucial support for the natural storage of carbon dioxide in the soil and mitigation of climate change," the report stated.

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If blue and green water remain threatened, the aims of the Global Biodiversity Framework to protect and restore biodiversity will be undermined. The value of green water can be recognised and incorporated in Payment for Ecosystem Services (PES) schemes, stated the report while citing the strategic catchment assessment undertaken by the Mhlathuze municipality in South Africa to estimate in monetary terms the value its ecosystem provides. As the majority of the global population resides in urban areas facing unstable and declining water resources, one of the missions emphasised the importance of promoting circular economy solutions. According to the report, approximately 8 per cent of current freshwater withdrawals—roughly equivalent to the total amount distributed by municipalities worldwide—can be reclaimed from wastewater each year.

To secure a just and sustainable water future for everyone, the ultimate ambition for global water governance should be the establishment of a "Global Water Pact". The report called for a strategic focus on securing funding through innovative "Just Water Partnerships" and enhancing the global water data infrastructure to support the mission-driven approach. "We can only solve this crisis by thinking broadly about how we govern water, recognizing its interactions with climate change and biodiversity, and mobilising all our economic tools," Tharman Shanmugaratnam, president of Singapore and co-chair of the Commission, was quoted. The commission also noted that at a time when the world is not on track to achieve the SDGs, the impact of water scarcity on both people and nature now jeopardises virtually each of the sustainable development goals as chartered by the United Nations.

PHOTOGRAPH: ISTOCK PHOTO

WATER CENTRAL TO FIGHT CLIMATE CHANGE

In October 2021, various United Nations bodies made an urgent appeal to countries to make water an integral part of the fight against climate change on the wake of the Conference of Parties (COP 26) to the UN Framework Convention on Climate Change (UNFCCC) in Glasgow. A letter addressed to heads of countries by agencies like World Meteorological Organization, World Health Organization, Food and Agriculture Organization, IFAD, UNESCO, UNICEF, United Nations Environmental Programme, UN University, the UN Economic Commission for Europe and the Global Water Partnership (GWP), said: "Accelerated action is urgently needed to address the water-related consequences of climate change that impact people and the planet."

The UN agencies quoted an earlier UNICEF report that over one-third of the world's child population were severely exposed to water scarcity. It added, "The UN World Water development Report 2020 emphasises that water is the 'climate connector' that allows for greater collaboration and coordination across the majority of targets for climate change (Paris Agreement), sustainable development (2030 Agenda and its SDGs) and disaster risk reduction (Sendai Framework)." The UN agencies appealed to countries to "address more effectively, the water dimensions of climate change adaptation and mitigation, as provided for in an UN-agreed framework to accelerate progress towards Sustainable Development Goal 6." They said as a priority countries should "integrate the water and climate agendas at a national level through national adaptation and resilience planning and at the regional level, through transboundary cooperation." This is one of the seven "urgent priorities" that the UN agencies have flagged for countries to take up. As weather-related disasters strike countries with greater frequency due to climate change, the lack of meteorological infrastructure like early warning systems add to the woes. One of the seven priorities suggested in the letter is to "encourage universal access to timely warnings about water-related disasters to help save lives and protect livelihoods." ■

HEALTH

HIGHPOINTS

A 14% rise in malaria transmissions in 2023, putting an additional **147-171 million** people at risk by 2030

Infants exposed to tropical cyclones either in the womb or within their **first year of life** are more likely to die

Global burden of cholera has shifted to Africa, where there was a **125% increase** in cases in 2023 compared to the previous year

Thawing risks **reawakening dormant viruses**, bacteria and fungi, some tens of thousands of years old

PHOTOGRAPH COURTESY: CHAC

PUBLIC HEALTH EMERGENCY

Africa faces an escalating burden of climate-sensitive diseases

IN NOVEMBER 2024, the inaugural Climate and Health Africa Conference (CHAC 2024) ended in Zimbabwe with the adoption of a landmark declaration to enhance climate resilience within health systems and address the profound health impacts of climate change on the continent. Health ministers, scientists, policymakers and other delegates from 51 countries adopted and endorsed the Harare Declaration, a blueprint that will guide African countries going forward. The declaration acknowledges the critical link between changing climate and health.

"As a continent on the frontlines of climate change, Africa should no longer be a passive recipient of global solutions, but a proactive architect of its own future systems for better

health and wellbeing, shaped by further prioritised role given to scientific, local and traditional knowledge generation, scale-up of innovative solutions, and policy leadership," read the Harare Declaration. The declaration calls for immediate and collaborative action from a wide array of stakeholders — including governments, academic institutions, funding agencies and civil society — to combat the detrimental health effects of climate change and improve the well-being of African populations. Recognising the disproportionate burden of climate-related health risks faced by African populations, the declaration presents a comprehensive strategy to address these challenges. It is a collective voice outlining high-level priorities and offering recommendations towards equitable strategies that will help build resilience and people-oriented systems for health. It calls on policymakers to prioritise climate change as a public emergency while reinforcing the health sector institutional frameworks for increased ability to protect, capacitate and involve health workers. It emphasises the need to strengthen research and knowledge generation by investing in studies that assess the specific impacts of climate change on health in Africa and identify effective interventions. It also seeks to promote inclusive dialogue between science, policy and communities. The declaration also highlights the importance of improving surveillance and early warning systems to track climate-related health risks, enabling timely and effective responses.

It recommended the establishment of equitable research partnerships and the reinforcement of capacities of African researchers and called for increased funding for these programmes. Additionally, it calls for building climate-resilient health systems by enhancing the capacity of health infrastructures to adapt to and mitigate the impacts of climate change, including through necessary upgrades and workforce training. The declaration also emphasises the importance of

Africa CDC recognises the urgent need for collective action to mitigate the impact of climate change on human health noting that climate change is not just an environmental issue, indeed it is also a health matter

community engagement and participation in climate and health initiatives and recognises the crucial role of local knowledge and traditional practices in building resilience.

The declaration, which aligns with the framework for building climate-resilient and sustainable health systems in the African region newly adopted by the World Health Organization (WHO), was endorsed by health ministers and representatives from countries engaged in the WHO-led Alliance for Transformative Action on Climate and Health Initiative (ATACH) and over 500 participants at CHAC 2024. "Our region deals with multiple climate-induced emergencies every year. I applaud the commitments taken by health policy makers to build climate-resilient health systems that can adapt to and mitigate the impacts of climate change," said Matshidiso Moeti, WHO Regional Director for Africa. Lul Pout Riek, Regional Director, Africa Centre for Disease Control (CDC) Southern Africa Regional Coordinating Centre that endorsed the declaration, said, "Africa CDC recognises the urgent need for collective action to mitigate the impact of climate change on human health noting that climate change is not just an environmental issue, indeed it is also a health matter." CHAC 2024 chairperson Fortunate Machingura said the conference had served to debunk the general belief that there is not enough research evidence coming out of Africa. She said 573 research abstracts were submitted for the consideration, of which the organisers had to accommodate just 244 of these for the purpose of the conference.

Officially opening the conference earlier on, Zimbabwe's president Emmerson Mnangagwa said Africa must not wait for others to act on its behalf in issues to do with climate change and health but must share ideas and make bold decisions that protect its citizenry against the negative impacts of climate change. "Climate change is not merely an environmental disaster. It is a public health emergency," Mnangagwa said.

PHOTOGRAPH: UNICEF

CLIMATE-HEALTH NEXUX

It is indeed. Various research findings have established that climate change is directly and indirectly linked to human health, including through access to treatment and care. For instance, consider drought. Drought is regarded as a major consequence of anthropogenic climate change, with severe impacts on human health. These droughts have affected most people living in the Horn of Africa, the Sahel region, and southern regions of Africa with increasing frequency and duration and impact on health, exacerbated by these regions' low adaptive capacity.

A study done by researchers from the University of the Witwatersrand, South Africa, University of Eswatini, Eswatini, and Stanford University School of Medicine, USA established that the HIV crisis in Eswatini (formerly Swaziland) persists alongside the climate emergency, increasing poor health outcomes in individuals living with HIV. It was established that although there is no clinical evidence of a direct influence of climate change on the biological effect of HIV, changing weather patterns have an effect on the livelihoods and sustenance of children, adults, and caregivers, which may consequently increase the likelihood of HIV transmission and disrupt HIV care.

According to WHO, Africa faces an escalating burden of climate-sensitive diseases, with increasing transmission of vector and waterborne illnesses. Recent statistics revealed a 14 per cent rise in malaria transmissions in 2023, potentially putting an additional 147-171 million people at risk by 2030. Additionally, 18 African countries reported cholera outbreaks linked to natural disasters, contributing to a staggering 836,600 cases between January 2023 and March 2024, alongside widespread malnutrition and population displacement.

The majority of African Union (AU) member states are not on track to achieve the continent's target of eradicating malaria by 2030, according to the 2024 Africa Progress Report, unveiled at the 38th AU Summit in Addis Ababa, Ethiopia in February 2025. Despite the ambitious goals set under the AU's Catalytic Framework, progress has stalled. Malaria incidence has only

decreased by four per cent and mortality by just 15 per cent since 2015. These figures fall significantly short of the interim targets of a 40 per cent reduction by 2020 and a 75 per cent reduction by 2025. Of the 46 AU Member States reporting malaria cases, only six have reached a 40 per cent reduction in incidence, while just seven have met the 75 per cent reduction target for mortality.

The report, which was jointly prepared by the African Leaders Malaria Alliance (ALMA), the African Union Commission, and the Roll Back Malaria Partnership to End Malaria, identified significant challenges including funding deficits, climate change, and biological resistance as key obstacles to progress. The report highlighted that funding shortages remained a major obstacle to malaria eradication. WHO stated that global funding for malaria control reached only $4 billion in 2023, far short of the $8.3 billion required. This funding gap had grown from $2.9 billion in 2019 to $4.3 billion in 2023. The "Africa Progress Report" warned that an additional $1.5 billion was needed in 2025-2026 to maintain the current, though inadequate, coverage of malaria interventions. To meet the global malaria targets by 2025, around $6.3 billion in annual funding is necessary.

Climate change is exacerbating malaria transmission, particularly in Africa's highland areas, where the number of months suitable for malaria transmission has already increased by 14 per cent. By the 2030s, an additional 147–171 million Africans could be at risk and climate-driven transmission is expected to result in 775,000 additional deaths by 2050. Extreme weather events, such as floods and prolonged rainy seasons, are accelerating mosquito breeding, while

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humanitarian crises disrupt healthcare systems and hamper malaria control efforts. The spread of invasive mosquito species presents another challenge. *Anopheles stephensi*, an urban-adapted mosquito capable of transmitting malaria in densely populated areas, has now been found in eight AU Member States, including Kenya. This species poses a threat of malaria outbreaks in cities and economic centres, where transmission had previously been low.

If malaria funding remains stagnant between 2027 and 2029, Africa could face an estimated 112 million additional cases and up to 280,700 more deaths due to surges and outbreaks. The economic burden of malaria is also considerable. "In malaria-endemic regions, the disease reduces GDP growth by up to 1.3 per cent annually and contributes to the loss of up to half a billion workdays each year. However, investing in malaria elimination brings substantial economic returns. The eradication of malaria could increase Africa's GDP by $127 billion by 2030," stated H.E. Moussa Faki, Chairperson of the African Union Commission.

With distinct white bands on their bodies and legs, *Aedes* mosquitoes are originally found in tropical and subtropical parts of the world. Though most serious diseases such as dengue, chikungunya, yellow fever and Zika are transmitted by just two species— *Aedes aegypti* and *Aedes albopictus*—these are fast emerging throughout the world as a public health threat. *A aegypti* is native to sub-Saharan Africa, and in its native environment it lives in tree holes and small pools of water and bites non-human primates. It is believed that these mosquitoes first moved to nearby human habitations during droughts when the tree holes dried up. The mosquitoes then moved out of Africa during the transatlantic slave trade. The first case of yellow fever was reported outside Africa in Yucatan, Central America, in 1648. Similarly, *A albopictus* is native to

tropical Southeast Asia, where it was originally a forest species that fed on wild animals. It first spread to the islands in the Indian and Pacific Oceans and then during the 1980s extended its range across temperate regions in Europe, Africa and the Americas.

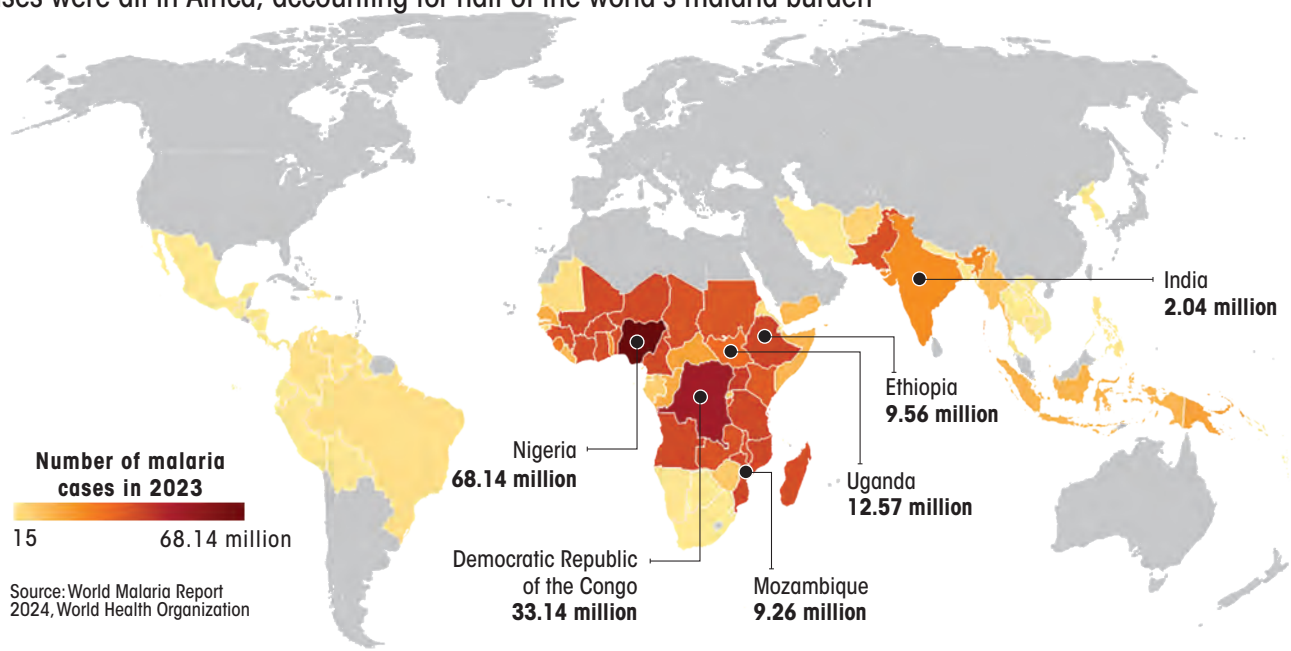
While human-made conditions have made it easy for the mosquitoes to spread over larger areas, global warming has further aided in their proliferation as warm and wet environments are excellent places for mosquitoes to breed. A modelling study published in *Nature Communications* on May 1, 2020, showed that the world became about 1.5 per cent more suitable per decade for the development of A aegypti during 1950-2000. It predicted that the trend was likely to increase to 3.2-4.4 per cent per decade by 2050. By 2050, 49 per cent of the world's population would live in places where *A aegypti* and *A albopictus* are present if greenhouse gas emissions continued at the current rates. This was explained by researchers in *Nature Microbiology* on March 4, 2019 using historic data on the distributions of these two mosquito species over time in Europe and the US.

Under current climate conditions and population densities, both mosquito species will continue to spread globally over the coming decades. *A aegypti* is predicted to spread within its current tropical range, but also in new temperate areas in the US and China, reaching as far north as Chicago and Shanghai, respectively. *A albopictus* is forecast to spread widely throughout Europe and reach large areas of France and Germany over the next 30 years. It would establish itself in the northern US and the highlands of Latin America and East Africa. The researchers of the study published on *Nature Microbiology* pointed out the importance of curbing climate change considering that after the next five to 15 years, expansion of these mosquito species would be driven by changes in climate, temperature and urbanisation that create new and favourable habitats for them to breed.

Climate change increases the vector population too, as mosquitoes are now able to breed through the year. For instance, at present most of the predicted transmission risk of Zika virus occurs in the tropics. A study published in *Global Change Biology* on October 9, 2020, showed that if climate change remained unmitigated, as many as 1.3 billion new people could be living in areas with temperatures suitable for Zika transmission by 2050. Most regions in South and East Asia and sub-Saharan Africa could face year-round outbreaks of Zika infection. A

COUNTRIES WHERE MALARIA STINGS

In 2023, at least 80 countries reported malaria cases. The five countries with the highest number of cases were all in Africa, accounting for half of the world's malaria burden



Source: World Malaria Report 2024, World Health Organization

A NEW ORDER

There is a need for a fundamental paradigm shift toward an equitable and just public health landscape through the New Public Health Order for the continent

TAKING LESSONS from the recent deadly disease outbreaks, the African Union (AU) through Africa Centres for Disease Control and Prevention (Africa CDC), announced a new framework in October 2024 to address deeper structural public health deficiencies. The framework, named as "New Public Health Order for Africa" focuses on five key strategic pillars — strengthening public health institutions, strengthening public health workforce, manufacturing of vaccines, diagnostics and therapeutics and increasing domestic resources for health security as well as engaging in respectful and action-oriented partnerships.

Jean Kaseya, Director General of Africa CDC, said, "Existing global mechanisms, policies and interventions have consistently failed in addressing Africa's health security priorities, as recently highlighted by the COVID-19 pandemic, Mpox, and Ebola." "There is a need for a fundamental paradigm shift toward an equitable and just public health landscape through the New Public Health Order for the continent. The continent must take control of its health security through strong local leadership, innovation and investment in public health infrastructure and systems," he added, expressing optimism towards the new framework that has been in the works for three years before being rolled out.

The AU and Africa CDC called upon governments, multilateral organisations, philanthropies, the private sector and civil society organisations to support the full implementation of the framework to drive global health security. "The New Public Health Order envisages strengthened National Public Health and Research Institutes, working with local universities, providing expertise in Emergency Operating Centres (EOCs) and genomic sequencing capabilities. It is geared to develop and expand local manufacturing that will see vaccines, diagnostics, therapeutics, and medical supplies all manufactured from the continent. There is a need for respectful action-oriented partnerships that will ensure long-term engagement, alignment on priorities by African countries with Member States in the driver's seat," read in part a communique from Africa CDC.

Africa has responded to multiple public health-related emergencies with moderate success, but a host of lessons have been learnt. The COVID-19 pandemic, in particular, offered numerous insights and underscored the importance of regional coordination in addressing health crises. Many initiatives emerged in response to the pandemic, marking critical milestones in Africa's health security infrastructure.

The Africa Joint Continental Strategy for COVID-19 provided a comprehensive approach to containing the virus, while initiatives like the African Vaccine Acquisition Task Team (AVATT) and the Africa Medical Supplies Platform (AMSP) demonstrated Africa's capability to mobilise resources in real time. The Africa Pathogen Genomics Initiative and the Partnership to Accelerate COVID-19 Testing (PACT) were

PHOTOGRAPH: ISTOCK PHOTO

instrumental in enhancing diagnostic capabilities and genomic surveillance, essential for understanding virus mutations and managing the spread of COVID-19. "Most member states still rely on indicator-based surveillance systems with limited implementation of event-based or advanced processes. The over 160 disease outbreaks reported annually have revealed gaps in Member States' abilities to prepare for and respond to emergencies," said Kaseya, adding that only 5 per cent of laboratories are equipped to diagnose priority diseases in their countries and meet international standards. "Africa relies heavily on imports; only 1% of vaccines and 30-40 per cent of therapeutics are manufactured on the continent," Kaseya said.

Over the past two years, countries such as Egypt, Kenya, Morocco, Senegal, South Africa, Uganda, and Rwanda have taken significant steps to establish domestic vaccine manufacturing capabilities. These efforts represent a paradigm shift in Africa's vaccine landscape, as the continent aims to ensure more equitable access to vaccines and medical supplies during future health crises. The lessons learned from COVID-19, Ebola and Mpox have shown that while Africa has made progress in public health preparedness, addressing the continent's long-standing structural gaps will require sustained efforts, investments, and partnerships.

The initiative could be well-meaning, but faces a couple of challenges, in addition to the lack of political goodwill from top politicians and enforcement mechanisms for non-compliant state members, according to experts. For a continental entity that heavily relies on external donors for financial support or doesn't fully roll out some of its key initiatives due to financial constraints, full implementation might be problematic.

Inadequate funding from member states limits the AU's capacity to sustain long-term programs, making it difficult to implement ambitious projects effectively, even as Africa CDC asks member states to adhere to the Abuja Declaration of 2001, which says "African countries should allocate 15 per cent of their budgets to health".

Yet, many hurdles are likely to be winding protocol which results in slow and uncoordinated decision-making. Multiple governance experts have also expressed concern that uniform implementation across member states with diverse political and economic circumstances may be problematic. Some countries may prioritise national agendas over continental goals, making cooperation inconsistent.

Lastly, many AU member states lack the institutional and technical capacity to implement continental initiatives effectively. Weak public institutions, insufficient expertise, and lack of infrastructure hinder the ability of countries to adopt and adapt to such AU programmes and directives.

mathematical model published in *Frontiers in Public Health* on June 12, 2019 indicated that while global abundance of *A aegypti* over the last century till now increased by 9.5 per cent, it was expected to increase by 20 per cent under low carbon emission and 30 per cent under high carbon emission scenarios by the end of this century.

Climate change has also affected the disease carrying capacity of mosquitoes. A review paper published in *The Lancet* on October 30, 2021 assessed the influence of temperature and rainfall on the capacity of the mosquito to spread the disease. The researchers overlaid it with human population density data to estimate the reproductive number (R0; the expected number of secondary infections resulting from one infection). Their findings showed that the R0 for all arboviral diseases tracked had increased since 1950-54; in 2020, the number of infections transmitted by *A aegypti* was 13 per cent higher than the 1950-54 baseline years and those spread by *A albopictus* was 7 per cent higher. Some studies also showed that the mosquitoes were turning into more efficient vector. For instance, *A aegypti* has two subspecies: the original African subspecies A aegypti formosus and *A aegypti aegypti* that evolved to specialise in biting humans. The latter can thus transmit infectious diseases among humans more easily.

A group of researchers led by Louis Lambrechts of the Insect-Virus Interactions Unit of Institut Pasteur in France tested 14 mosquito colonies developed from field samples collected in Asia, Africa and the Americas, and found that the African mosquitoes were less likely to acquire Zika virus in their blood meals. Mouse infection experiments showed that African subspecies transmitted a smaller virus inoculum than the human specialist. Genetic differences located on the mosquito chromosome 2 were likely the cause of the increased susceptibility to Zika virus found in *A aegypti* outside of Africa, they concluded in their study published in the journal *Science* on November 20, 2020.

The virus also affects the behaviour of the mosquitoes. Researchers from Australia reported in the journal *Emerging Microbes and Infections* on April 25, 2018, that Zika virus targeted *A aegypti*'s neurons and induced changes in its behaviour. Zika virus-infected females showed significantly increased movement compared to uninfected females during the egg-laying phase. The team showed a spike in the activity of mosquito's primary neurons after infections.

A study published in the *BMJ Global Health* journal in June 2024 revealed that the geographical range of Rift Valley fever disease clusters was expanding across eastern Africa. Rift Valley fever (RVF), a mosquito-borne viral disease caused by Rift Valley fever virus (RVFV), is known for extreme weather-associated large epidemics characterised by abortions and perinatal mortalities in livestock. It also causes fever, jaundice, encephalitis, retinitis and haemorrhagic syndrome in humans. Since its first recorded identification in 1930 in Kenya, RVF outbreaks have been reported throughout Africa with subsequent epidemic deaths in humans and livestock losses.

The *BMJ Global Health* study challenges previous beliefs about RVF, revealing that it predominantly occurs in small clusters rather than large outbreaks and its association with El Niño is not as pronounced as previously thought. The study, titled "Widening geographic range of Rift Valley fever disease clusters associated with climate change in East Africa", was conducted in the East Africa region - Kenya, Uganda and Tanzania. The region is characterised by a diverse ecosystem ranging from agriculturally productive highlands to semiarid and arid lands inhabited

The geographical range of Rift Valley fever disease clusters was expanding across eastern Africa. Rift Valley fever (RVF), a mosquito-borne viral disease caused by Rift Valley fever virus (RVFV), is known for extreme weather-associated large epidemics characterised by abortions and perinatal mortalities in livestock

by nomadic pastoralists. Regional climatic conditions in eastern Africa are not uniform. Kenya, Uganda and northeastern parts of Tanzania witness bimodal rainfall (two wet and two dry seasons annually), with long rains occurring from March to May and short rains from October to December. In contrast, central and southern Tanzania experience unimodal rainfall (one wet and one dry season) from November to May. Most of the region experiences substantial levels of rainfall in at least one season, except the northern and eastern parts of Kenya. Temperatures in most areas range from a moderate 15 to 25°C, except in coastal belts characterised by humidity and higher temperatures.

The researchers collected data on 100 RVF disease events in eastern Africa from 2008 through 2022. Of the 100 events, 44 were reported in Uganda, 41 in Kenya and 15 in Tanzania. Among the 100 events, 91 were classified as "small clusters" with a median of one human and three livestock cases, with minimal human mortality occurring primarily in highlands (67 per cent). Thirty-five per cent of the clusters occurred in regions that had never reported RVF cases before. The study modeled against possible geo-ecological risk factors of occurrence including altitude, soil type, rainfall, temperature, normalised difference vegetation index (NDVI), livestock production system, land-use change and long-term climatic variations. A positive NDVI change one month prior to RVF occurrence was observed in 51 per cent of the small clusters. The small RVF clusters were situated in areas with notable land use changes, particularly those leading to significant water accumulation such as rice farming, mining and irrigation. A °C increase in temperature and a 1-unit increase in NDVI, one month prior, were associated with increased RVF incidence rate ratios of 1.20 and 1.93 respectively.

The study findings on climatic trends analysis revealed a significant decadal increase in annual mean temperature, associated with decreasing rainfall in arid and semi-arid lowlands but increasing rainfall trends in highlands. These hotter and wetter highlands showed

PHOTOGRAPH: ISTOCK PHOTO

increasing frequency of RVF clusters, accounting for 76 per cent and 43 per cent in Uganda and Kenya, respectively.

With ongoing heating of the planet, eastern Africa is projected to undergo changes in temperature and precipitation patterns with continued increases in seasonal and annual mean temperatures, especially in highland areas. The study highlighted the increasing frequency of small RVF clusters in previously unaffected areas, associated with a combination of higher temperature and rainfall. The widening geographic range of disease is associated with climatic variations, with the likely impact of wider dispersal of the virus leading to the creation of new regions with virus endemicity.

WARMING AND HEALTH RISKS

Warming has other health impacts as well. A study published in journal *Nature Medicine* in September 2024 revealed a significant link between high temperatures in the final week of pregnancy and an increased risk of perinatal death in sub-Saharan Africa. The study found that babies whose mothers were exposed to extreme heat the week before childbirth faced a 34 per cent higher risk of stillbirth or neonatal death within 24 hours of birth.

Extreme heat has been previously associated with adverse pregnancy outcomes, including preterm birth, low birthweight and stillbirth. Heat stress on mothers can disrupt foetal development and increase complications during labour. Additionally, heatwaves can indirectly impact perinatal health by straining healthcare systems, causing delays in care and reducing access to essential services. Sub-Saharan Africa already bears the highest burden of neonatal mortality worldwide, with 27 deaths per 1,000 live births in 2022, followed by central and southern Asia with 21 deaths per 1,000 live births. Despite this, there has been little research examining the relationship between temperature in the final week of pregnancy and perinatal mortality in the region.

The study analysed 138,015 births across 16 hospitals in Benin, Malawi, Tanzania and Uganda between July 2021 and December 2023, observing the effects of rising temperatures on perinatal outcomes. The largest sample size came from Malawi, while Tanzania contributed the smallest sample. The researchers from Karolinska Institute and others defined high temperatures as an increase from a typically warm week (22-28 °C) to an exceptionally warm week (24-29°C), depending on the country. The study also found that the risk of perinatal death was notably higher during the six hottest months of the year, with stillbirths being more strongly associated with heat exposure. A significant finding was that 44 per cent of stillbirths in the study occurred during labour. The research, however, only represented 30-40 per cent of hospital births. Poorer women in remote or rural areas, who may be more vulnerable to heat stress, were underrepresented in the sample. The findings underscored the urgent need for interventions to protect pregnant women in sub-Saharan Africa from the dangers posed by rising temperatures, as climate change continues to exacerbate extreme weather patterns.

A study published in *Science Advances* in May 2025 revealed a significant rise in infant mortality in low- and middle-income countries following exposure to tropical cyclones, including those below hurricane or typhoon strength. The findings highlighted an urgent need for stronger disaster response measures and child health protections, particularly as climate change increases the frequency and intensity of severe weather events.

The study found that infants exposed to tropical cyclones either in the womb or within their first year of life were markedly more likely to die. On average, infant mortality rose by 11 per cent compared to baseline levels — an increase of 4.4 deaths per 1,000 live births. The elevated risk was most acute within the first year after a storm and appeared to subside after two years.

Babies whose mothers were exposed to extreme heat the week before childbirth faced a 34 per cent higher risk of stillbirth or neonatal death within 24 hours of birth

However, the precise reasons behind the mortality rise remain unclear. "The fact that health care use and undernutrition were not affected by tropical cyclone exposure suggests that the mortality effects are driven by other factors that we could not directly study," said lead author Dr Zachary Wagner, associate professor (research) of economics at the USC Dornsife College of Letters, Arts and Sciences, and senior economist at its Centre for Economic and Social Research.

The research team, which included academics from the RAND Corporation, Stanford University, Johns Hopkins University, and UCLouvain in Belgium, also noted that the mortality increase was linked not only to major storms but to more frequent, lower-intensity tropical storms. "Some of the countries had only a few Category 3 or higher storms during the period we studied," said Zetianyu Wang, a PhD student at RAND and the report's first author. "But that doesn't mean the impact of larger storms is absent. As the planet warms, we risk more tragedies across the globe if measures aren't taken to protect children in the poorest countries."

Researchers analysed nearly 1.7 million child health records across seven low- and middle-income countries: Bangladesh, India, Madagascar, Cambodia, the Philippines, the Dominican Republic and Haiti. While the average increase in infant mortality was 11 per cent, the effects varied widely between countries. Bangladesh, Haiti and the Dominican Republic experienced increases of more than 10 deaths per 1,000 births following cyclones. In contrast, little to no increase was recorded in India, Madagascar, Cambodia and the Philippines.

Dr Wagner suggested these differences could stem from disparities in geography, housing, and public health systems. "Some countries may be helped by mountainous terrain, while others have more flood-prone areas," he explained. "Disaster preparedness, evacuation efforts, the sturdiness of housing, and pre-existing child health conditions all likely play a role." Understanding why some countries are more resilient than others will be a major focus of further investigation. "If we want to protect children from the growing threat of climate-linked disasters," Wagner added, "we need to understand not just where the risk is greatest, but why."

PHOTOGRAPH: IWHO

CHOLERA PANDEMIC AND CLIMATE LINK

The fast spread of cholera is also linked to the changing climate. South 24 Parganas stretches from the urban fringe of Kolkata to the riverine villages in the Sundarbans—the vast delta spanning India and Bangladesh. Known for vast tracts of mangrove forests and saltwater swamp, the delta is formed in the Bay of Bengal, often considered the "homeland" of cholera. Studies in fact suggest that the Sundarbans could be the ground-zero of cholera, which has caused seven pandemics in the past 200 years. According to the book "Pandemic", it all began in the 1760s, when the East India Company ordered felling of the mangroves in the Sundarbans, building embankments and growing rice in the region. Over 2,000 sq km of mangroves were felled. As people moved into the Sundarbans, the bacteria, which were until then largely hitchhiking on crustacean copepods, found a new host: humans. "A splash of water on the face, or intrusion of that salty water into the well, or water or food contamination is all it takes for an infection," said Sonali Shah, author of the book. Its spread was probably local until the first pandemic took off in 1817 in Jessore (now in Bangladesh), some 250 km from the Sundarbans. Over the next 60 years, Vibrio cholerae quietly seeded five pandemics until the 1880s, when Robert Koch, a German physician, identified the bacteria from the intestines and stool samples of infected patients, and described its role in causing the disease.

Scientists have so far recorded over 200 serogroups (groups that share a common antigen, which triggers an immune response in the body) of *Vibrio cholerae*. Only two of these serogroups—O1 and O139—are known to produce the cholera toxin and are responsible for major epidemics. Scientists have also deciphered the bacteria's infection pathway and developed approaches to prevent or treat the illness, with hydration being the mainstay of treatment. Yet, the world has largely failed to contain the pathogen.

We are currently in the midst of the seventh pandemic, which has been spreading since 1961

and has even secured a spot in the Guinness World Records as the "longest-enduring pandemic disease outbreak". What's worse is that according to WHO, cholera cases were on the wane in the 1990s, but show a significant uptick since 2017. According to WHO's global cholera statistics for 2023, the outbreaks were spreading globally and were becoming deadlier. The number of cholera deaths reported globally in 2023 increased by 71 per cent from the deaths in 2022, while the number of reported cases rose 13 per cent. As many as 45 countries reported cases of cholera infection, up from 44 the previous year and 35 in 2021. "Preliminary data show that the global cholera crisis continued into 2024, with 22 countries currently reporting active outbreaks," noted the WHO report, adding that 38 per cent of the reported cases were among children under five years of age.

The WHO analysis further showed that the global burden of the disease has shifted from the Middle East (West Asia) and Asia to Africa, where there was a 125 per cent increase in cases in 2023 compared with the previous year. "Conflict, climate change, inadequate safe water and sanitation, poverty, underdevelopment, and population displacement due to emerging and re-emerging conflicts and disasters from natural hazards all contributed to the rise in cholera outbreaks last year (2023)," WHO stated.

Climate change may be increasing the impact of cholera in African countries. The continent is likely to see its worst cholera crisis this decade, driven by extreme weather events and poor water supply and sanitation infrastructure, according to WHO. "The common denominator for many of these outbreaks is climate-related events, such as storms, floods and droughts," alerted WHO Director-General Tedros Adhanom in a media briefing on January 11, 2023.

Most of the larger outbreaks, which are also simultaneously occurring, are a direct impact of

Climate change may be increasing the impact of cholera in African countries. The continent is likely to see its worst cholera crisis this decade, driven by extreme weather events and poor water supply and sanitation infrastructure, according to World Health Organisation

the increase in adverse climate troubles, said Philippe Barboza, WHO team lead for Cholera and Epidemic Diarrhoeal Diseases. "The cholera crisis has been playing out across the Horn of Africa and the Sahel accompanied by major floods, unprecedented monsoons (and) a succession of cyclones," said Philippe.

While cholera cases globally stunted in 2021, Africa ditched the trend, with confirmed cases reaching the 2017 levels. The case fatality ratio (CFR) or deaths per 100 confirmed cases more than doubled from less than one in 2020 to almost 2 in 2021. The average cholera CFR reported globally in 2021 was 1.9 per cent and 2.9 per cent in Africa. The average CFR in Africa was almost at three per cent as of January 29, 2023, which was above the 2.3 per cent reached in 2022 and far exceeded the acceptable level of below one.

Malawi was among the worst-affected countries, with 36,943 cases and 1,210 associated deaths reported from all 29 districts since March 3, 2022. The situation worsened in January 2023, when the country registered a 143 per cent increase in the number of cases since December 2022. These outbreaks had taken place following two major disasters — tropical storm Ana (January 2022) and cyclone Gombe (March 2022). Since January 2022, when tropical storm Ana was declared a national disaster, Malawi had registered polio and cholera outbreaks.

Cholera has been endemic in Malawi since 1998. The outbreaks are usually reported during the rainy season from November to May. But in 2022, the cholera outbreaks were reported earlier in March 2022. The outbreak extended through the dry season, with cases being reported since March 2022 as per the WHO statement. Tropical storm Ana and, subsequently, Gombe caused extensive destruction of infrastructure. The disruption of water and sanitation systems was a recipe for cholera, said WHO Africa region.

PHOTOGRAPH: ISTOCK PHOTO

So, lack of access to safe water, sanitation, and hygiene following these disasters has been a significant driver for cholera, a water-borne disease. Besides Malawi, cases had been reported in neighbouring Mozambique and Zambia, as well as in Burundi, Cameroon, the Democratic Republic of the Congo (DRC) and Nigeria. In Nigeria, too, the worst floods in a decade that struck between June and November 2022 and attributed to climate change have been the driver behind cholera outbreaks. Cholera cases spiked across the flood-hit Cameroon following heavy rains with repeated floods observed since August 2022. Conflicts and large population movements in many regions of the country created a suitable environment for the outbreak.

Ethiopia, Kenya and Somalia also responded to outbreaks amid the historic drought in the Horn of Africa, which left millions in dire need of humanitarian assistance. Prolonged drought in Kenya resulted in acute water shortage and rationing, leading to poor sanitation and cholera outbreaks in major cities/towns, including Nairobi. “Diminishing water resources due to severe drought in parts of the country are likely to lead to an outbreak of other diseases associated with poor sanitation,” warned Francis Kuria, head of public health at Kenya’s ministry of health.

CLIMATE AND NEW VIRUSES

As the planet warms, Earth’s ice masses are vanishing at an alarming rate. This rapid thaw is not only rising sea levels but also reactivating ancient and modern microorganisms, some of which could alter ecosystems and intensify the threat of antimicrobial resistance (AMR), said the United Nations (UN)’s "Frontiers 2025: The Weight of Time" report released by the UN Environment Programme (UNEP) in July 2025. It warned that the cryosphere — the planet’s frozen regions — is at the frontline of climate change. The impacts of a 2 °C rise in global temperatures would include irreversible sea-level rise and the dramatic loss of glaciers, sea ice and permafrost, the report state.

The cryosphere includes the Antarctic and Greenland ice sheets, ice shelves, mountain

glaciers on every continent, permafrost and seasonally frozen ground. It covers 52 per cent of the Earth's land surface and 5 per cent of ocean area, making it one of the most affected zones among terrestrial and aquatic ecosystems. It directly supports 670 million people and billions more who depend on freshwater from these frozen reserves.

According to UNEP, Arctic sea ice is shrinking so rapidly that the Arctic Ocean may become seasonally ice-free before 2050. Even if warming is limited to 1.5°C, projections show world's glaciers could be halved by the end of the century. Between 24 per cent and 69 per cent of near-surface permafrost could thaw by the end of the century, the UNEP report said.

Such thawing risks reawakening dormant viruses, bacteria and fungi, some potentially tens of thousands of years old. While some cryospheric microorganisms may not survive thawing, many others are likely to interact with present-day microbes and multi-cellular organisms, potentially infecting plants, animals and humans. According to the UNEP report, specific populations of re-emerging micro-organisms could thrive in these new environments, profoundly altering the structure and function of existing microbial communities and surrounding ecosystems. One cited example is the anthrax outbreak in Russia's Yamal Peninsula in 2016. Exceptionally high summer temperatures caused permafrost to thaw, reactivating Bacillus anthracis spores long frozen in the soil. The outbreak killed over 2,000 reindeer and infected about 90 herders.

Another consequence of opening this Pandora's Box is the rise of antimicrobial resistance genes, driven by changes in cryospheric microbial communities. The report also warned that the acquisition of virulence-related genes by bacteria may give rise to more potent pathogens, capable of causing disease more efficiently. Researchers recently detected thousands of virulence factors in microorganisms recovered from 21 Tibetan glaciers. In addition, scientists have documented a variety of bacteria and fungi preserved in ice cores across regions including Greenland, Denmark, Ellesmere Island (Canada), South America, the Qinghai-Tibetan Plateau, Alaska, the Himalayas, Siberia and Antarctica.

In 2023, some researchers revived a female roundworm — a previously unknown species — that had been dormant in Siberian permafrost for nearly 46,000 years. Remarkably, the organism resumed life and began reproducing asexually.

Some cryospheric microorganisms, known as psychrophiles — species that thrive at near-freezing temperatures — have evolved a range of strategies to survive harsh conditions. These include the production of antifreeze proteins, compounds that aid membrane fluidity and pigments that act as natural sunscreen. Many are also capable of long-term dormancy. Psychrophiles also produce cold-active enzymes that function at low temperatures and these have found commercial applications in the food and beverage industry, pharmaceuticals, detergents and biotechnology.

Despite these adaptations, scientists emphasise that global cryosphere loss is potentially irreversible if greenhouse gas emissions continue unchecked. Even if emissions were halted immediately, the report warned, it could take centuries for the cryosphere to return to mid-20th century conditions. To reduce further loss, the report urged an urgent crackdown on short-lived climate pollutants — particularly black carbon — that accelerate glacier melt. These dark particles reduce the reflectivity (albedo) of ice surfaces, causing them to absorb more heat. Primary sources of black carbon include emissions from diesel engines, open-field crop burning and wildfires. Tackling these at the source is essential, the report said. Other recommendations include regulating tourism in fragile cryospheric areas and deploying reflective geotextile sheets over glacier surfaces to reduce seasonal melt. However, the report notes that scaling up such methods, currently used on ski slopes, to cover entire glaciers would be prohibitively expensive and could introduce plastic pollution through material degradation.

UNEP concluded the report by warning that rapidly melting glaciers and thawing permafrost are stark indicators of the world's failure to adequately mitigate greenhouse gas emissions over the past three decades — a failure with increasingly ominous consequences. "By failing to avoid the unmanageable, we now must manage the unavoidable, witnessing the loss of stable ecological systems that our species evolved with and struggling to preserve samples of those systems' diversity and unimaginable value," it said. ■

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CLIMATE DEBT

HIGHPOINTS

Rich countries have achieved up to **70% of their economic growth** by appropriating more than their fair share of the **atmospheric commons**

The world's **1% super rich** accounts for **16% of global carbon emissions**, the same caused by the world's poorest 66%

African nations are projected to spend close to **30% of their revenue servicing debts in 2025;** leaving no funds to spend on climate loss and damages

In Zambia, Ghana and Cameroon, the external **public debt service exceeds** the losses from climate **by over 50 times**

PHOTOGRAPH: ISTOCK PHOTO

DEBT'S CLIMATE TRAP

Africa's debt burden limits its capacity to finance climate adaptation and mitigation plans

CLIMATE DEBT and carbon inequality are the global talking points. "Climate debt is based on an idea that wealthy nations have polluted more than their fair share of the atmosphere with greenhouse gases. This is known as atmospheric appropriation," according to Astrid R.N. Haas, Research associate at African Centre for Cities, University of Cape Town. An estimate by non-profit Actionaid concluded that "rich countries have achieved up to 70 per cent of their economic growth by appropriating more than their fair share of the 'atmospheric commons'."

The Intergovernmental Panel on Climate Change (IPCC) defines carbon budget as "the total net amount of carbon dioxide (CO_2) that can still be emitted by human activities while limiting

global warming to a specified level (e.g., 1.5°C or 2°C above pre-industrial levels)." A 2018 IPCC report titled "Global warming of 1.5°C" has estimated the amount of CO_2 the world can emit to stay below 1.5°C global warming over pre-industrial levels. The world had already emitted about 2,200 Gt of CO_2 from the dawn of the industrial revolution till 2017. To remain below 1.5°C rise, only 420–570 Gt more can be emitted till the end of this century. Together, past emissions and tolerable future emissions of CO_2 feed into the carbon budget of the world. Past emissions have consumed over four-fifths of the 1.5°C budgetary carbon allocations. At the current rate of global emissions, these allocations are set to be exhausted in 12 years.

The US, constituting 4.3 per cent of the world's population in 2018, has been responsible for over a quarter of the world's total CO_2 emissions during 1751-2017. The EU, accounting for 22 per cent of historical emissions with just 6.8 per cent of the population, is not far behind. Other voracious consumers of the historical carbon pie include Russia and Japan, responsible for 6 per cent and 4 per cent of global emissions respectively, but having less than 2 per cent of the global population. Together, these top four, with less than 15 per cent of the world's population, have devoured 57 per cent of the carbon pie. This is in sharp contrast with developing countries, which have more population, but account for insignificant portions of the carbon budget.

Thus, the historical division of the carbon pie has been extremely iniquitous. A Centre for Science and Environment (CSE) analysis, an advocacy institution based in Delhi, India, revealed that even if historical responsibility is overlooked by focusing exclusively on future emissions, the division of the carbon pie would continue to be grossly unfair. Accounting for 9.2 per cent of all GHG emissions between 2019 and 2030—and despite the assumptions of the analysis tilting in its favour—the US would still consume over double the fair share of its population. Thus, inequity is likely to persist in the future, albeit with a new big boy (China) joining the high table as its

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leader. China, the EU and the US, along with Japan and Russia, with 33 per cent of the world's population, will consume nearly half of the future emissions pie. Poor countries will not be able to satisfy the hunger of development needs with a just share as the world's biggest polluters continue to feast on a gluttonous amount of the future carbon pie.

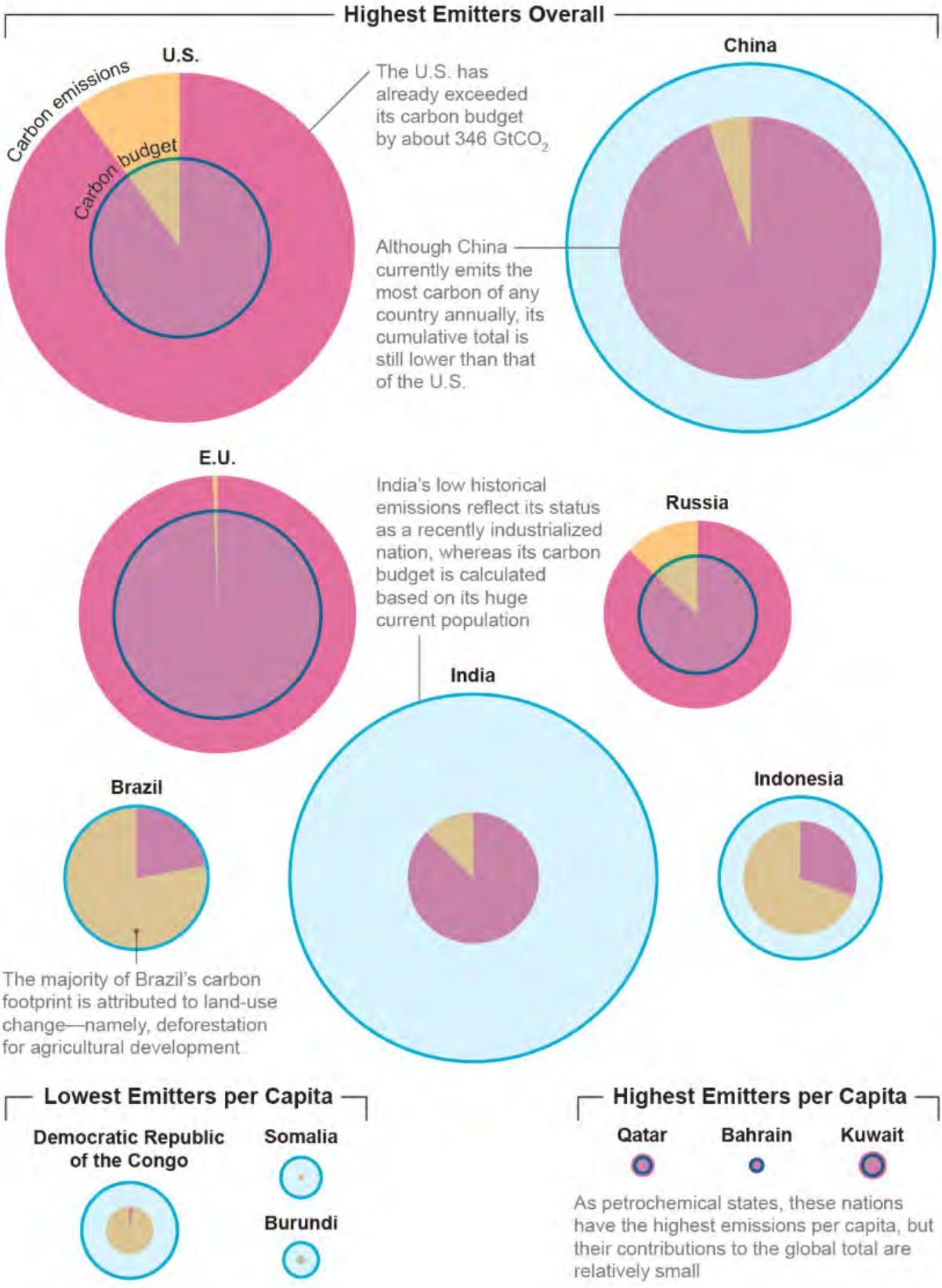
Going by each country's share of the world's cumulative CO2 historical emissions (based on fossil emissions) for the period from 1750 to 2021, and based on fossil emissions, Sub-Saharan Africa contributed just 1.9 per cent of the world's emissions. And, it mostly came from South Africa (1.3 per cent) while 48 other African countries contributed just 0.6 per cent. The total CO_2 emissions for 2024 were projected to be a whopping 41.6 billion tonnes, up from 40.6 billion tonnes in 2023, according to the Global Carbon Budget (GCB). The figure of 41.6 billion tonnes of CO_2 included fossil CO_2 emissions of 37.4 billion, and the rest from land-use change (deforestation). Both fossil and land-use change CO_2 emissions are set to rise in 2025 as well.

CARBON INEQUALITY

Carbon inequality is at its peak. The world's richest 1 per cent of people emitted as much carbon as the poorest 5 billion who make up 66 per cent of the global population, according to an assessment by non-profit Oxfam in 2023. Its report "Climate Equality: A Planet for the 99%", stated that in 2019, the world's 1 per cent super rich accounted for 16 per cent of global carbon emissions, the same caused by the world's poorest 66 per cent. The analysis found that it would take about 1,500 years for someone in the bottom 99 per cent to produce as much carbon as the richest billionaires do in a year.

The super-rich are key to the climate story due to the carbon they emit in their daily lives,

REPRESENTATION OF REMAINING CARBON BUDGET SPACE FOR COUNTRIES



Source: Scientific American

from their consumption and lifestyles to their investments and shareholdings in heavily polluting industries, which is much bigger than the rest of the population. Similarly, the countries that are least responsible for global warming, the low-emitting nations, are suffering the worst consequences of the climate crisis. They are also the least able to respond and recover. More than 91 per cent of climate-related disasters of the past 50 years occurred in developing countries. The death toll from floods is seven times higher in the most unequal countries as compared to more equal countries. The most vulnerable countries in the world are located in Africa, South Asia, Central and South America, Small Island Developing States and the Arctic.

A joint research report by the Stockholm Environment Institute (SEI) and Oxfam, released in September 2020, examined the different contributions of different income groups to carbon emissions from 1990 to 2015. During this period, carbon dioxide emissions rose by roughly 60 per cent (13.5 billion tonnes of carbon dioxide). Nearly half of the total growth in absolute emissions was due to the richest 10 per cent, with the richest 5 per cent alone contributing over a third (37 per cent). The impact of the poorest half of the world's population was practically negligible.

In July 2025, SEI and Oxfam revealed in another assessment that the richest in the Middle East and North Africa (MENA) region produced a shockingly disproportionate share of consumption-based emissions with their massive super yachts and private jets. According to this assessment "Not Everyone is in the Same Boat; Climate and Inequality in the Middle East and North Africa", within the MENA region, the wealthiest and most resource-rich

Going by each country's share of the world's cumulative CO_2 historical emissions (based on fossil emissions) for the period from 1750 to 2021, and based on fossil emissions, Sub-Saharan Africa contributed just 1.9 per cent of the world's emissions. And, it mostly came from South Africa (1.3 per cent) while 48 other African countries contributed just 0.6 per cent

countries were disproportionately responsible for most consumption-based emissions, relative to their population.

As of 2022, the richest 10 per cent were responsible for 60 per cent of emissions, while the poorest 50 per cent of the region contributed only 10 per cent. The pattern for big-emitting countries is the same as for individuals—the richest 0.1 per cent emitted 437.5 times more per capita than the bottom 50 per cent in 1999, a disparity that grew to 465 times by 2022. The high emission shares and global rankings of Saudi Arabia, the UAE, Egypt, Iraq, and Algeria highlighted their significant role in global emissions, driven by their oil and gas-reliant economies. Overall, the region registered stark levels of climate inequality as emissions were concentrated in the hands of the super-rich. The richest 0.1 per cent (496,000 people) emitted as much as the poorest 50 per cent (248 million people).

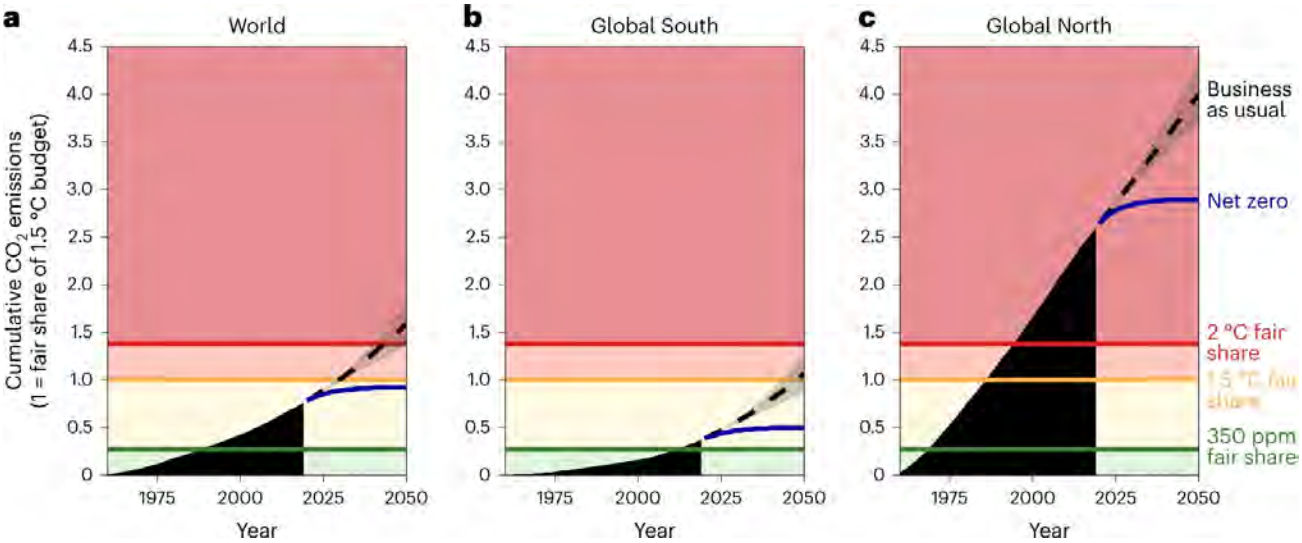
These emissions disparities are driven by the staggering economic inequalities in the region. The MENA region is one of the most unequal regions in the world in terms of wealth and income. Half of the countries with the most significant growth in wealth inequality worldwide are in MENA. The region stands at the crux of two interlinked and inseparable crises — skyrocketing inequality and climate breakdown. The region faces extreme climate vulnerabilities, including record-breaking heat waves, droughts, desertification, and worsening food insecurity. The inequalities have made it even more difficult for the rest of the population to navigate the climate crisis, as they often lack the resources to adapt to and mitigate the impact of extreme weather events, water scarcity, and food insecurity.

So, carbon inequality is further deepening. Experts have measured this inequality's monetary values – how much the developed countries that have appropriated the carbon space should compensate the developing countries? "The global North would overshoot its collective equality-based share of the 1.5 °C carbon budget by a factor of three, appropriating half of the global South's share in the process. We calculate that compensation of US$192 trillion would be owed to the undershooting countries of the global South for the appropriation of their atmospheric fair shares by 2050, with an average disbursement to those countries of US$940 per capita per year," read a research paper published on *Nature Sustainability* in June 2023. Its authors Andrew L. Fanning, Doughnut Economics Action Lab, Oxford, UK and Jason Hickel, Institute of Environmental Science and Technology, Autonomous University of Barcelona, Barcelona, Spain said, "There are 129 countries from the global South in our analysis, which are home to more than 80 per cent of the total population, but their aggregate cumulative emissions surpassed fair shares of the 350 ppm carbon budget only in 2012—more than two decades after the world as a whole. If this group of countries collectively pursued ambitious mitigation following our net-zero scenario between 2020 and 2050, it would use only 50 per cent of its 1.5 °C fair share. Our business-as-usual projections suggest this group of global South countries would likely remain within its fair share of the 2 °C carbon budget by 2050 but would likely overshoot its fair share of the 1.5 °C carbon budget in 2048 (2043–2053), judging from historical trends."

BUDGET FOR CARBON, AND LOSS AND DAMAGE

Notwithstanding the shrinking carbon budget and the appropriation of the atmospheric commons, the Africa continent will endure disproportionate loss and damage due to climate impacts. The mid to long-term effects of climate change are expected to drag down the gross domestic product (GDP) of most African nations by 2-5 per cent annually by 2030. The GDP of 65 countries in Asia, Africa and Latin America that are vulnerable to climate change may reduce by 19.6 per cent by 2050 and 63.9 per cent by 2100 with current climate policies, according to a

WORLD AND REGIONAL CUMULATIVE CO2 EMISSIONS WITH RESPECT TO FAIR SHARES OF GLOBAL CARBON BUDGETS, HISTORICAL TRENDS (1960–2019) AND SCENARIO TRENDS (2020–2050)



a, World. b, Global South region. c, Global North region. The historical emissions (black area), business-as-usual projected pathway (dashed line) and net-zero pathway (blue line) show cumulative emissions relative to fair shares of the 1.5 °C carbon budget (yellow line), with fair shares of 350 ppm (green line) and 2 °C budgets (red line) also shown. World and regional totals are aggregated from national values. Likely (66%) prediction intervals are shown in lighter tint around the business-as-usual projections. See Extended Data Figs. 1 and 2 for results with cumulative emissions starting from 1850 and 1992, respectively.

Source: Compensation for atmospheric appropriation, an article published on *Nature Sustainability* journal

report published by Christian Aid, a non-governmental organisation in 2021. The damage to the economy of these countries will reduce but remain significant even if global temperature rise at the end of the century is limited to 1.5 °C over pre-industrial levels. In this scenario, their GDP will hit 13.1 per cent by 2050 and 33.1 per cent by 2100.

Eight of the top 10 most affected countries are in Africa and the other two in South America. All the 10 countries — Sudan, Mauritania, Mali, Niger, Burkina Faso, Chad, Djibouti, Suriname, Guyana, Guinea — face GDP damage of over 70 per cent by 2100 under our current climate policy trajectory and of 40 per cent even if the world keeps to 1.5°C. Sudan topped this list with 83.9 per cent loss of GDP by 2100 under current policies. Even with a Paris Agreement-aligned 1.5°C rise, it will see a climate-induced GDP hit of 51.6 per cent. In 2020, Sudan's GDP per capita was under $600 per person — a large share of the population living in extreme income poverty of under $2 a day.

The average per capita carbon dioxide emissions of the top 10 most-impacted countries is 0.45 tonnes. An average American, on the other hand, is responsible for more CO_2 (16.1 tonnes per capita) than 36 people from these 10 countries. The World Meteorological Organization had warned that sub-Saharan Africa could see a 3 per cent drop in GDP by 2050 as a result of climate change. Sub-Saharan Africa has lost over $520 million in direct economic damages annually as a result of climate change since the beginning of this century, the International Monetary Fund (IMF) estimated.

Many of these are low-income countries, which struggle to provide basic public services. All eight of the African countries in the top 10 list of most-affected countries spend under

The world must reach Net Zero emissions by 2050. This target has become a new marker of climate "ambition", with the world now divided into countries with net zero targets, and those without. Africa has the potential to reach Net Zero carbon emissions and climate resilience within the timelines proposed

$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. Africa will require $50 billion a year to survive the onslaught of extreme weather events, diseases and loss of livelihood sources in case the global temperature rise does not exceed 2oC, said the World Bank's Africa Climate Business Plan. The amount will rise to a humongous US $200 billion if global warming continues unabated over the next few decades. But just the way world leaders show no commitment to contain the temperature rise; there is no commitment as to who will bear the cost.

Africa is ambitious in its emission reduction, or going "Net Zero" on emissions. The IPCC's "Special Report on Global Warming of 1.5°C" says "Net Zero" is – conceptually – a state in which "human activities result in no net effect on the climate system". This will involve balancing all residual emissions with emission (carbon dioxide) removal. This will also involve accounting for regional or local bio-geophysical effects of human activities that affect local climate or surface albedo (light reflected by a surface). The IPCC says the world must reach Net Zero emissions by 2050. This target has become a new marker of climate "ambition", with the world now divided into countries with net zero targets, and those without. Africa has the potential to reach Net Zero carbon emissions and climate resilience within the timelines proposed by IPCC. Countries in the continent increased their target to reduce GHGs by 1-54 per cent in comparison to their earlier Intended Nationally Determined Contributions. These have also taken into account more sectors and are inclusive of women and youth, said Africa NDC Hub citing Namibia's NDC, 2021. Most countries have improved adaptation targets through quantitative analyses, increased the sectoral scope and aligned targets with national climate policies.

CLIMATE'S DEBT LINK

African nations, like other developing and poor countries, face another debt crisis that limits their capacity to finance their climate adaptation and mitigation plans. Amid the escalating climate crisis, these countries are grappling with severe economic and financial hardships. This is making them dependent on borrowings from foreign countries and multilateral institutions, creating a vicious circle that hinders their ability to invest in climate resilience, adaptation and the low-carbon transition. Often, this cycle is forcing these countries to borrow further for disaster recovery, mounting their debt burden. This has dire consequences. The UN Conference on Trade and Development (UNCTAD), in a 2024 report, warned that the global public debt stock—money borrowed by governments worldwide, from within their country or from abroad—reached record levels of US $97 trillion in 2023. This means that while the average income of an individual in the world has grown by 22 per cent to $13,065 between 2013 and 2023, the individual's share in global debt has increased by an astounding 61 per cent during the same period, reaching $12,034. This unequal growth between public debt per capita and gross national income per capita is troubling, because it means that a significant portion of income is likely to be spent on debt repayment, leaving little room for financing developmental and climate priorities in line with countries' NDCs to reduce GHGs emissions and adapt to climate change impacts. While the climate finance needs of a citizen of the developing world (low- and middle-income countries excluding China) stands at about $488 annually till 2030, developing countries are also often the most vulnerable to climate change impacts and will require the lion's share of increased investment for climate action.

This reality has grave implications when examined against the current political headwinds, particularly with respect to aid cuts and reduced international cooperation from the developed world. The US' withdrawal from the Paris Agreement has weakened global climate action. The outcome of the New Collective Quantified Goal (NCQG) on climate finance at the 29th Conference of the Parties to the UN Framework Convention on Climate Change (COP29) in Baku, Azerbaijan, in 2024 has been a failure, especially for developing countries seeking climate justice through

the provision of public finance from developed nations. Meanwhile, international financial institutions are quietly stepping away from net-zero alliances and scaling back climate pledges. Major donors, including the US, UK, Belgium, France, Netherlands and Sweden, are slashing their foreign aid budgets, implying a possible 22 per cent decrease in foreign aid (relative to 2023 levels) in the coming year, as per "A generational shift: The future of foreign aid", released by global management consultancy McKinsey and Company in May 2025.

To add to this, public climate finance from developed nations continues to fall short. For much of the Global South, the financial landscape for development and climate looks bleak. One crucial piece of this stalled progress is the growing external debt crisis. The Fourth International Conference on Financing for Development (FfD4), held between June 30 and July 3, 2025 in Seville, Spain, brought renewed attention to the critical issue of sovereign debt in the context of global development. A key focus was on scaling international financing for the Sustainable Development Goals (SDGs), including climate action (SDG13), and advancing reforms to the global financial architecture to make it more equitable and responsive to the needs of developing countries.

African nations are projected to spend close to 30 per cent of their revenue servicing debts in 2025, according to the report titled "World Economic Situation and Prospects" released in January 2025, and published by the United Nations Department of Economic and Social Affairs (UN DESA) in partnership with the United Nations Conference on Trade and Development (UNCTAD) and the five United Nations regional commission. Close to 25 countries in Africa have

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net interest payments exceeding 10 per cent of revenue, the report highlighted. This came against subdued growth prediction, with 1.4 per cent growth expected in 2025 from 0.7 per cent in 2024. "Rising debt-servicing burdens are diverting resources away from vital public services and investment, especially in Africa," said Nagesh Kumar, former director, United Nations Economic and Social Commission of Asia and the Pacific.

For a growing number of developing countries, debt and climate crises are coming together in a vicious circle. A study by United Nations Environment Programme (UNEP) and School of Oriental and African Studies, UK, found that climate change has already raised the average cost of debt by 117 basis points (1 basis point is equal to 0.01 per cent) for a sample of developing countries. For several of the most vulnerable countries, the costs of addressing climate change, as reported by them, amount to costs of damages for isolated climate-induced/climate-worsened weather events. More recently, several small island countries, at greatest risk of sea level rise caused by climate change, have rallied together to call for debt relief in the face of mounting physical and economic impacts of climate change. Haiti, among the most vulnerable and severely indebted, faced damages of at least $432.38 million in 2023 alone from "climatological" natural disasters alone. These vulnerabilities reinforce each other, demanding that debt and climate finance be addressed together.

CLIMATE-DEBT OVERLAP

To understand the overlap of debt and climate vulnerability, it is important to examine countries most at risk from climate impacts and most burdened by debt. Over half of the low- and middle-income countries (LMICs) with high climate vulnerability, or 36 countries, are either already in debt distress or at high risk of it. Their experiences offer a sharp lens into how debt burdens

REDEMPTION

The climate change treaties set forth binding obligations for States parties to ensure the protection of the climate system and other parts of the environment from anthropogenic greenhouse gas emissions

ON JULY 23, 2025 the International Court of Justice (ICJ), the principal judicial organ of the UN, passed an "advisory opinion" stating that government actions driving climate change are illegal and that countries should be held legally responsible for their emissions. "The climate change treaties set forth binding obligations for States parties to ensure the protection of the climate system and other parts of the environment from anthropogenic greenhouse gas emissions," the world court said, because, climate change "imperils all forms of life". Dire Tladi, one of the court's 15 judges, said it was one of the most consequential matters ever brought before ICJ. "It is an existential crisis that potentially threatens the future of humanity," Tladi said.

The first-ever ruling of ICJ on climate change traces its origin to a classroom discussion among 27 law students at the University of the South Pacific's campus in Port Vila, the capital of Vanuatu, one of the world's most climate vulnerable countries. In 2019, the students, grouped as the Pacific Island Students Fighting Climate Change, launched a campaign called "#Climateicjao". The campaign seeks climate justice as "for too long, those most responsible for the climate crisis have ignored their obligations". The group seeking climate justice lobbied with Pacific countries. Ultimately, Ralph Regenvanu, Vanuatu's minister for climate change, declared the country's support. Vanuatu campaigned alongside youth groups from across the world. In 2023, it reached a milestone: 123 countries agreed to co-sponsor a resolution in the UN General Assembly to "request for an advisory opinion of the ICJ on the obligations of states in respect of climate change". That year, on April 12, the UN Assembly resolution sought advisory opinion from ICJ on two questions: what obligations do states have to tackle climate change under international law; and what are the legal consequences if they fail to do so?

According to ICJ's advisory opinion, the obligations of countries include "to adopt measures with a view to contributing to the mitigation of greenhouse gas emissions and adapting to climate change". It reminds that "States parties listed in Annex I (36 countries, mostly developed ones) to the UN Framework Convention on Climate Change (UNFCCC) have additional obligations to take the lead in combating climate change by limiting their greenhouse

PHOTOGRAPHS COURTESY: PACIFIC ISLANDS STUDENTS FIGHTING CLIMATE CHANGE

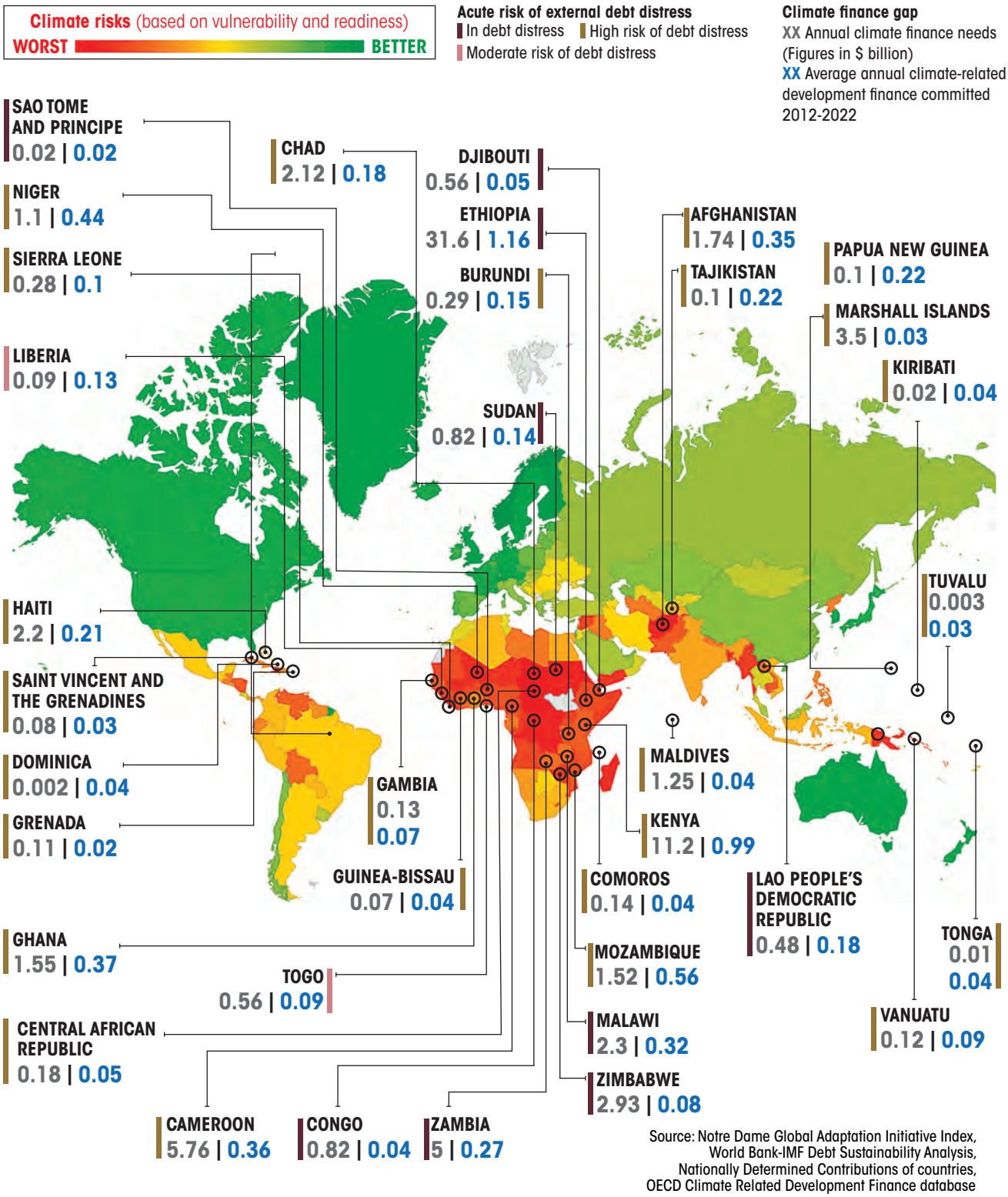
gas emissions and enhancing their greenhouse gas sinks and reservoirs". The second part of the order is particularly telling as it has brought back the issue of historical responsibility of developed countries to the fore, which was almost put on the backburner when all countries in 2025 agreed to the Paris Agreement, which diluted the responsibility of the Annex 1 countries. The order says the member-countries of UNFCCC "have a duty to co-operate with each other in order to achieve the underlying objective of the Convention". This wording is expected to put pressure on the US; even though the historically biggest emitter withdrew from the Paris Agreement after Donald Trump assumed power, it has not withdrawn from UNFCCC.

Responding to the more contentious question of legal implications of violating the Agreement, as posed by the UN General Assembly, the world court ruled that "A breach by a State of any obligations… constitutes an internationally wrongful act entailing the responsibility of that State". Further, it states that "the legal consequences resulting from the commission of an internationally wrongful act may include the obligations of: (a) cessation of the wrongful actions or omissions, if they are continuing; (b) providing assurances and guarantees of non-repetition of wrongful actions or omissions, if circumstances so require; and (c) full reparation to injured States in the form of restitution, compensation and satisfaction, provided that the general conditions of the law of State responsibility are met, including that a sufficiently direct and certain causal nexus can be shown between the wrongful act and injury."

The last part directly syncs with the loss and damage component of UN negotiations that has only been formalised in the last few years but has hardly been implemented on the ground. Kenya, Ghana, Madagascar, South Africa, Cameroon, Sierra Leone, Mauritius, Burkina Faso and Egypt made submissions about climate change damage. ICJ accepted their argument that developing countries have disproportionately suffered the effects of climate change, more than the developed nations, despite contributing minimally to greenhouse gas emissions.

THREAT FROM ALL CORNERS

While most low- and middle- income countries are climate-vulnerable, at least 36 of them also face acute external debt and a severe climate finance gap. Together, they need $79 billion annually, but received just $7.17 billion a year in commitments between 2012 and 2022



Source: Notre Dame Global Adaptation Initiative Index, World Bank-IMF Debt Sustainability Analysis, Nationally Determined Contributions of countries, OECD Climate Related Development Finance database

shrink fiscal space, deepen climate vulnerability, and how international climate finance still falls short of addressing this imbalance.

Developing countries need scaled-up finance to enable climate action. Those most vulnerable—to both climate and economic shocks—need non-debt climate finance. The countries in this analysis have together received $78 billion over 11 years (2012-2022) as development finance with a climate component. This is a generous estimate, given the varying degrees of actual climate aspects at the project level, and the fact that the figures are only available for the commitments made by donor countries—actual disbursements might vary. It has been noted in the past that climate finance has a much lower disbursement ratio than overall development finance; sometimes, even as much as only half the amount being disbursed. On an annual basis, they have together received $7.17 billion per annum. The total costed needs for implementing these countries' national climate plans per year, on the other hand, amounts to $79 billion—the gap is massive.

All the while, damages from climate related disasters continue to pile up. When we add the lens of sovereign debt to this situation, the picture becomes murkier. These countries are either already at high risk of debt distress or in debt distress. The World Bank and IMF explain debt distress as a situation where a country is "unable to fulfil its financial obligations and debt restructuring is required." In the event of a sovereign debt default, countries lose market access and face even higher borrowing costs. These 36 countries spent a total of $13.24 billion on

Chad, one of the world's most climate vulnerable countries, faces a stark imbalance between its climate needs and financial realities. With over $2.1 billion needed annually to implement its climate plans, it has received just $177 million per year in committed climate-related development finance over the past decade— barely 8 per cent of its actual requirements

external public debt service payments in 2022 alone. This is 1.8 times more than what they have received as climate-related development finance in a year—they have spent nearly double the amount of what has flowed in for climate action on servicing external public-private-government debt alone. Of the 36 countries highlighted in this analysis, one-third has the highest vulnerability to climate change with the least preparedness. Examining the climate finance needs, flows and external public debt service, it is revealed that climate vulnerable countries are under-supported on finance, yet overburdened with debt servicing, often spending more on debt than on education or health.

While the situation varies given the unique circumstances of each country, it is reflective of the broader debt-development-climate nexus. In many countries, external public debt service outweighs either climate finance received or basic social spending as a share of GDP. For instance, debt service is higher than climate-related development finance flowing in Chad, Guinea-Bissau, Haiti and Sierra Leone. In Chad, Guinea-Bissau and Haiti, debt service also exceeds social spending.

Of the 36 countries in this sample, reliable data on losses from climate related disasters was available for 25. For these 25 countries, nearly 70 per cent have paid more in external public debt service in 2022 than the average annual losses from climate disasters. In four of these countries, Zambia, Ghana, Cameroon and Tajikistan, the external public debt service exceeds the losses from climate by over 50 times. It comes as no surprise that two of these, Ghana and Zambia are also countries that have attempted to have their external debts restructured under the G20 Common Framework—to limited avail. While climate-related losses may be episodic and debt service is a recurring fiscal obligation, this contrast reveals the structural imbalance in how public

PHOTOGRAPH: ISTOCK PHOTO

finances are allocated. It underscores that even without a disaster occurring, a significant portion of a vulnerable country's fiscal space is already pre-committed to creditors—often far exceeding what they typically lose from disasters. This leaves little-to-no room to respond when an actual climate crisis strikes. The comparison is not to equate the two, but to expose how rigid and unfair financial commitments can crowd out the capacity to prepare for or recover from the far less predictable—but potentially catastrophic—shocks of climate change.

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FUTURE IMPLICATIONS

The debt crisis can threaten sustainable development prospects in Africa. "When a developing country like Nigeria borrows, the term at which the money is made available to them becomes onerous. That is what leads to debt burden for countries that need that money the most," Kumar said. Claver Gatete, the United Nations Under-Secretary-General who is also the ECA Executive Secretary, said that estimates by the Group of 20 (G20) economic bloc were that for Africa to make meaningful progress, it needed an additional spending of $1.8 trillion for climate action and $1.2 trillion for development financing by 2030. "Yet, shrinking fiscal space is now the single

most important issue for African ministers of Finance, Planning and Economy," Gatete pointed out. "Debt has increased by over 180 per cent since 2010, and 21 countries are now at risk of, or in, debt distress. This is notwithstanding the annual loss of at least 5 per cent of GDP because of climate change. In addition, the private sector is being squeezed out. Therefore, the natural question that confronts us is 'where will all these resources come from?'"

As the sovereign debt crisis spreads across Africa, some of the countries have resorted to seeking debt relief or loan restructuring. Others have gone for swapping debt and climate finance or green investments. For instance, last year Cape Verde struck a debt-for-climate deal with Portugal, with the former colonial master agreeing to write off an initial $13 million the African nation owed it. Media reports also noted that Ghana has also sought and won a moratorium on debt payments with official creditors until May 2026, as it simultaneously seeks to finalise a deal with Eurobond investors to restructure its $13 billion debt by the end of March 2025. Ghana's public debt has more than doubled since 2012 and amounts to 85 per cent of GDP. Zambia's debt stood at 98 per cent of GDP as of 2022. At 74 per cent and 70 per cent of GDP, South Africa and Kenya are also considered to be on the edge of financial distress as their foreign debts have been growing steadily over the years.

Several countries delineate the requirement of international assistance for climate finance in their NDCs, ranging from 75 per cent to 90 per cent of overall needs. The Organisation of Economic Cooperation and Development (OECD) collates data on flows of Climate Related Development Finance (CRDF), of which Official Development Assistance (ODA) towards

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developing countries is a large part. These flows comprise the bulk of tracked international assistance for climate finance flowing to developing countries around the world. Though it is important to note that CRDF is closely related but distinct from the flows that comprise climate finance, tracked as part of the erstwhile $100 billion goal.

The growing share of non-concessional, less development-focused climate related development finance suggests a shift away from equitable, need-based support. The data shows around 2015, the share of non-concessional flows overtook concessional flows, and the trend continues till 2022. The gap may be reducing, but for countries with small economies, the need for majority concessional finance, particularly for climate, is imperative. OECD's report tracking overall climate finance flows highlighted that of the $115.9 billion provided/mobilised by developed countries in 2022, some 69 per cent were in the form of loans.

For countries grappling with climate shocks, low readiness, and high debt, this triple bind leaves little space for investment in adaptation or recovery. These are not isolated or theoretical mismatches—they are systemic and structural failures of the global financial system. The analysis underscores the need for a justice informed lens on climate and debt to ensure that those facing the brunt of climate breakdown are not punished twice. ■

PHOTOGRAPH: ISTOCK

CARBON MARKET

HIGHPOINTS

By 2024, Africa had about **one-fifth of the carbon credit projects** listed in top carbon market registries

Between 2013 and 2023, **about 14% of the world's total or $5.9 billion** was invested in carbon **projects in Sub-Saharan Africa**

Most of the **carbon credit projects** in Africa are concentrated in two main areas: **forestry and land use, and community-based** projects like improved cookstoves

Although Africa doesn't have compliance carbon markets, the **voluntary carbon market has grown significantly** on the continent

PHOTOGRAPH: ISTOCK

CARBON CAPTURE

Carbon offset projects boom in Africa. Are they effective?

JOSEPH OLE Parsaloi moved slowly across the sun-scorched plains of northern Tanzania, his cattle grazing lazily on the arid landscape. Dust swirled around their hooves, catching the fading sunlight in a golden haze. The 56-year-old Maasai herder, accompanied by his children, guided his 143 cattle, sheep, and goats across several kilometres in search of pasture and water before returning to their *boma* — a traditional thorn-fenced enclosure. Armed with a club and a spear, Parsaloi skillfully navigated the rugged terrain. A sharp whistle kept strays in line as he led the herd through the dry savanna, following rhythms passed down for generations.

"This land is essential for cattle grazing, but we have been instructed to change our grazing methods to help store carbon in the soil. I worry this will disrupt our feeding plans," said Parsaloi.

Like thousands of other Maasai pastoralists, Parsaloi finds himself entangled in the growing global carbon credit industry. Foreign companies, backed by wealthy investors, are securing deals that allow them to claim carbon stored in Tanzanian soil as offsets for pollution elsewhere.

This is the new age fast breeding carbon market. While these initiatives are touted as climate solutions, the Maasai see them as a direct threat to their way of life. Carbon markets are systems that price carbon emissions and create economic incentives for governments and businesses to either reduce their own emissions or pay for reductions made by others. Essentially, buyers—including countries, companies, or individuals—purchase certificates that represent financial support for activities that reduce carbon emissions, such as growing trees. These certificates are used by buyers to "offset" their own emissions. Buyers are matched with sellers who perform the activities that reduce emissions, generating sellable certificates that are quantified based on the amount of emission reduction achieved.

Over the last two decades, these carbon markets—shifting, growing, and changing—have diversified into various kinds and become more complex. However, they can be divided into two main categories: compliance markets, where industries participate to meet government emission standards and are structured and enforced by legislation; and voluntary markets, where participants choose to engage in carbon trading beyond regulatory requirements and the market is largely unregulated. Voluntary carbon markets, in particular, have proliferated with little standardised design or guiding principles, resulting in a fragmented and often opaque system. There is also a new form of market currently under development: markets based on Article 6 of the Paris Agreement. These markets are structured and enforced by the United Nations Framework Convention on Climate Change (UNFCCC) and national governments in some form, but they involve voluntary participation.

A DISGUISED LAND GRAB?

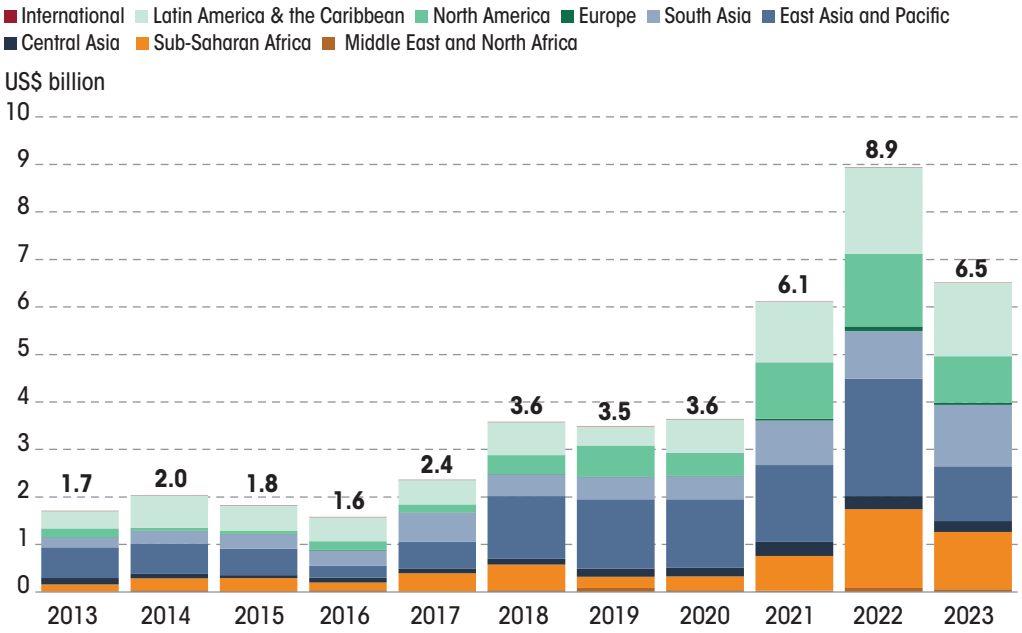
In recent years, carbon offset projects have targeted nearly 2 million hectares of Maasai grazing land. Two major initiatives — the Longido and Monduli Rangelands Carbon Project,

This is the new age fast breeding carbon market. While these initiatives are touted as climate solutions, the Maasai see them as a direct threat to their way of life

funded by Volkswagen ClimatePartners and The Resilient Tarangire Ecosystem Project, backed by The Nature Conservancy — have promised financial and environmental benefits for local communities. However, many Maasai fear history is repeating itself. Their traditional system of communal grazing and seasonal mobility is being upended by structured rotational grazing models imposed by these projects. Under the new system, cattle must be moved in strict cycles every 14 days to maintain soil carbon levels — a radical departure from practices honed over centuries.

Village residents said the deals had been pushed through without proper consultation, leaving communities bound by long-term contracts — some lasting up to 40 years — with little understanding of their implications. "Most people don't even know what they signed up for," said Na Nalichilichi, a researcher at the Maasai International Solidarity Alliance (MISA), a coalition advocating for Maasai land rights. "Women and young people—who will inherit these contracts—were completely left out of the discussions." On the other hand, project organisers insisted the carbon credit programmes would benefit local communities. "Carbon markets can provide a new source of income," said Lucy Magembe, country director for The Nature Conservancy. "These projects help communities adapt to climate change while preserving biodiversity." But the Maasai remain skeptical. They have heard similar promises before—when their land was taken for wildlife tourism, trophy hunting, and conservation zones. Many fear they are being lured into agreements that benefit outsiders

ANNUAL VOLUNTARY CARBON-CREDIT PROJECT CAPITAL EXPENDITURE BY REGION



Data as of Sept. 30, 2024. Source: MSCI Carbon Markets

while leaving them with little in return. "The biggest problem is control," said Parsaloi. "The contracts dictate how we use our land for decades. If we want to leave the deal, we have no clear exit." Maasai community members also reported receiving meager compensation. Some communities had been offered one-time payments of just a few thousand dollars, with no clear long-term benefits. Critics likened these payments to a "dowry," offering temporary financial relief while locking communities into restrictive land-use agreements.

The Tanzanian government is intensifying efforts to expand carbon credit schemes, framing them as a tool for both environmental conservation and economic growth. During a recent climate meeting in Dar es Salaam, Vice President Philip Mpango outlined plans to streamline the sector, calling for greater transparency and faster approvals from the National Carbon Monitoring Centre (NCMC). As Tanzania enters international carbon markets, officials anticipate significant financial gains — projected at $1 billion annually from carbon credit sales. Yet, critics argue that local communities are being sidelined in the rush for profits.

Tanzania is not alone in facing controversy over carbon trading. A 2023 investigation by *The Guardian* found that more than 90 per cent of rainforest carbon offsets sold by a leading certifier were effectively worthless. Soil carbon offsets, such as those in the Maasai rangelands, are even more uncertain. "The idea that you can capture carbon in Maasai rangelands and sell it to polluters is based on flawed assumptions," said Henry Kileo, an environmental researcher specialising in carbon storage. "In semi-arid climates like northern Tanzania, soil carbon levels are highly variable and difficult to measure accurately. There's no guarantee these projects actually help fight climate change."

Faced with growing opposition, the Maasai are organising. Across villages, elders gather to discuss their options. Young warriors, once trained to defend cattle from lions, are now preparing to defend their land through legal battles and advocacy. The crisis has deep roots. In 2022, Maasai communities in Ngorongoro and Loliondo faced violent evictions under the guise of conservation. In response, Joseph Oleshangay, a Maasai lawyer and other activists formed MISA to defend pastoralist rights. "MISA started as a response to the crisis in Ngorongoro and Loliondo," said Oleshangay. "But as we dug deeper, we realised the same challenges were spreading across the Maasai region, driven by conservation policies and

now carbon credit projects."

A January 2024 study by MISA uncovered troubling details about carbon credit deals in Maasai villages. Nalichilichi, who led the research in Longido and Monduli districts, found widespread violations of "Free, Prior and Informed Consent (FPIC)".

"Our research showed that most villagers didn't understand what they were signing," she said. "Village meetings were rare, and women were excluded from discussions." Some villages received small "engagement payments," which Nalichilichi argued were used to coerce leaders into signing deals. "They were framed as goodwill gestures, but in reality, they pressured communities into agreements without genuine consent."

Legal experts are also questioning the fairness of carbon credit contracts. "The contracts last for 30 years, but village land-use plans are reviewed every 10 years," said Yonas Masiaya, a lawyer who has reviewed the agreements. "Locking communities into such long-term commitments undermines their ability to adapt."

Another major concern is financial secrecy. "Nowhere in the contracts does it specify how much revenue villages will receive," Masiaya added. "The actual buyers of these credits are unknown—only intermediary companies appear in the paperwork."

For Maasai rights activist Saitoti Parmelo, the most alarming impact is the disruption of traditional pastoralism. "The Maasai way of life depends on flexible grazing patterns that adapt to unpredictable weather," he said. "Forcing us into a fixed system designed for carbon markets, not for our survival, is a recipe for disaster." For Maasai pastoralists like Timan Tina, the stakes could not be higher. "Land is everything to us," she said. "Without it, pastoralism is impossible."

Africa's role in the carbon market began with hosting projects that issued carbon credits traded on the global market. Some of the earliest carbon market projects in Africa emerged in the late 1990s, beginning with forest conservation initiatives in East Africa

Tina feared carbon credit schemes would lead to land loss, similar to past conservation projects controlled by outsiders. "Our land is not just a place to graze livestock," she explained. "It holds deep cultural and spiritual significance." As the battle over land rights continues, the Maasai remain determined to resist. "We do not want carbon credit projects to become another way for outsiders to take our land and profit at our expense," Tina declared.

CARBON MARKET IN AFRICA

Africa's role in the carbon market began with hosting projects that issued carbon credits traded on the global market. Some of the earliest carbon market projects in Africa emerged in the late 1990s, beginning with forest conservation initiatives in East Africa. One of the first REDD+ projects in the voluntary carbon market was initiated during this period: the Kasigau Corridor REDD+ Project in Kenya. Another notable project in Kenya, the Mikoko Pamoja project, was among the first in the world to issue carbon credits from mangrove conservation.

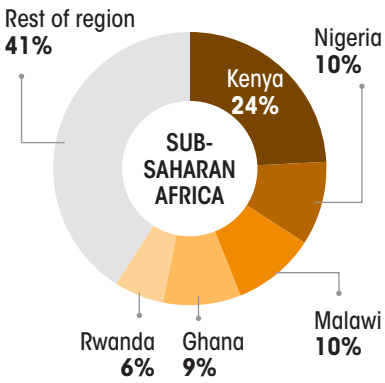
Despite its early initiatives, Africa historically had a minimal presence in the carbon market. As of March 2022, the Clean Development Mechanism (CDM), a market established under the Kyoto Protocol and led by the UNFCCC, saw only approximately 3 per cent of its carbon credit projects originating from Africa. This limited involvement was primarily due to insufficient investment in projects such as Solar PV and Wind Energy, which were prevalent in other regions like China and India and limited institutional capacity to host these projects.

As the Voluntary Carbon Markets developed and businesses started investing more in forestry and community projects, Africa's presence in the carbon market grew too. By 2024, the region was responsible for about one-fifth of the projects listed in top carbon market registries. Investment in these projects also went up, making up nearly 17 per cent of the total investment

in voluntary carbon projects, according to Trove Research's "Investment Trends and Outcomes in the Global Carbon Market" report. Between 2013 and 2023, about 14 per cent of the world's total or US$ 5.9 billion was invested in carbon projects in Sub-Saharan Africa, according to MSCI Carbon Markets. The largest share of investment in carbon credit projects in Africa went to Kenya, which received about US$ 1 billion between 2013 and 2023, with 70 per cent of that amount coming after 2020.

In addition to the voluntary carbon market, recent bilateral deals signed by African countries with non-African countries to cooperate on market mechanisms based on Article 6 of the Paris Agreement are leading to new frameworks being put forward by governments in African countries for issuing carbon offsets. These frameworks are intended to supply offsets to partnering countries. In some cases, offsetting activities have already begun.

TOP FIVE COUNTRY SHARE OF REGIONAL PROJECT CAPITAL EXPENDITURE



Data as of Sept. 30, 2024. Data for project capital expenditure between 2013 and 2023.
Source: MSCI Carbon Markets

As the carbon offset market diversifies, the ecosystem surrounding it is also developing in Africa. The West African Alliance on Carbon Markets and Climate Finance, an alliance of several West African countries, was formed at the Conference of Parties to UNFCCC (COP22) held in Marrakech, Morocco in November 2016 to enhance the engagement of West African nations in market mechanisms, particularly through Article 6 of the Paris Agreement. The African Carbon Market Initiative (ACMI) was launched at COP27 held in Sharm el-Sheikh, Egypt, in November 2022, sponsored by the Global Energy Alliance for People and Planet, Sustainable Energy for All, The Rockefeller Foundation, and the UN Economic Commission for Africa, to promote carbon markets in Africa.

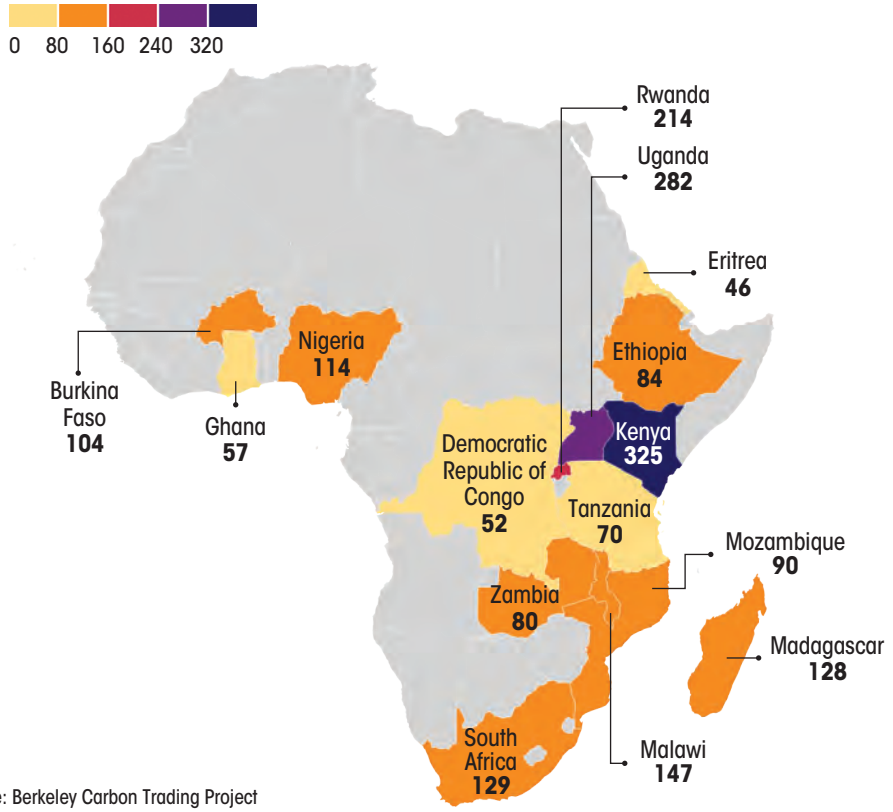
Although Africa does not have compliance carbon markets, the voluntary carbon market has grown significantly on the continent. Key registries of the voluntary carbon market, such as Verra's VCS and the Gold Standard, which together account for over 95% of Africa's voluntary carbon market projects, reflect this growth. As of July 2024, 2227 projects across Africa were listed on these two leading voluntary carbon market registries. Of these, 1,020 projects had been issued carbon credits, totaling approximately 341 million. Of these, 185 million carbon credits had been retired. Another six projects are listed under the ART registry (Architecture for REDD+ Transactions) all of which are REDD+ projects.

Most of the carbon credit projects in Africa are concentrated in two main areas: forestry and land use, and community-based projects, particularly those involving household devices like improved cookstoves. These sectors are the leading carbon credit issuers across the continent. A study by the Delhi-based advocacy group Centre for Science and Environment (CSE) has explored projects in these two sectors in detail, shedding light on how they work and their relevance for both the community and the climate.

COOKSTOVE PROJECTS

Clean cookstove projects in the voluntary carbon market (VCM) involve partnerships between carbon credit project developers and manufacturers or distributors of energy-efficient cookstoves. These stoves are provided to communities, often at a subsidised price or sometimes for free. The idea is that these cookstoves use less fuel and produce fewer emissions compared to traditional stoves, reducing the amount of carbon released into the atmosphere. Project developers then calculate the amount of carbon emissions avoided by using these cleaner stoves and claim carbon offsets for the reduction. These offsets are certified by voluntary carbon offsetting standards and can be sold in the voluntary carbon markets. The revenue generated from selling these offsets helps fund the project and also generates profits for the developers.

CARBON CREDIT PROJECTS IN AFRICAN COUNTRIES LISTED IN THE VOLUNTARY CARBON MARKET



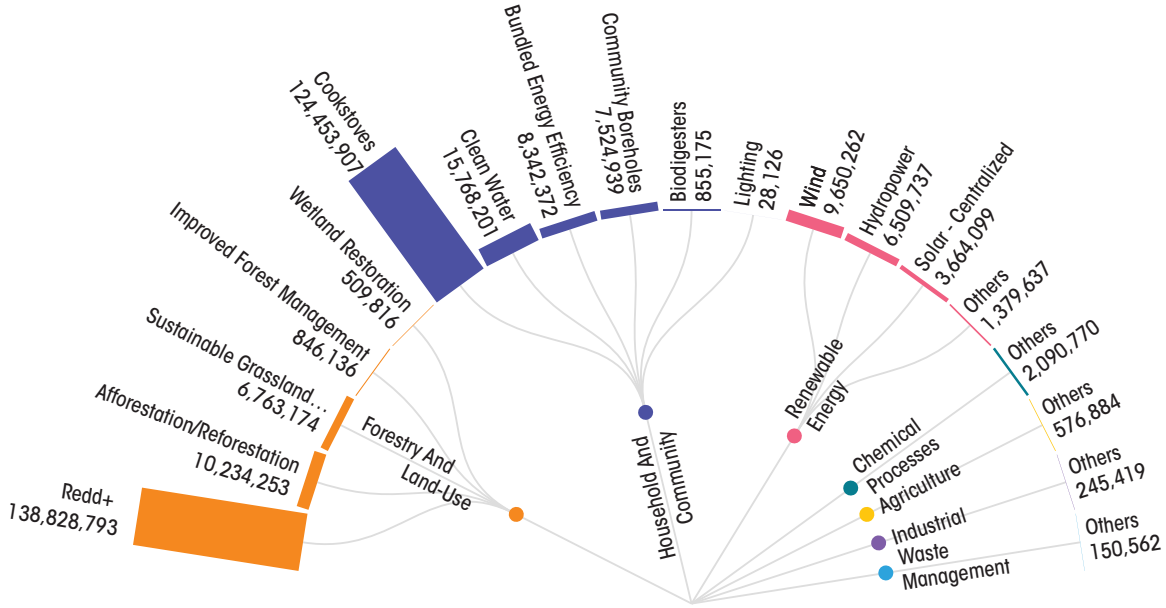
Source: Berkeley Carbon Trading Project

Typically, a "clean cookstove" costs anywhere between US $2–100. Each cookstove is reported to offset between 2–4 tCO_2e per year. Carbon credits are given for a typical period of 5–7 years considering the cookstove's life. Considering these figures, in a five-year lifetime, a cookstove could generate 10–28 carbon credits. Current prices in the market are between US $7–10 per credit for cookstove projects. Thus, US $70–280 could be earned per cookstove. Therefore, the cookstove distribution industry is thriving in the carbon market with lucrative returns for developers and their investors. According to the Clean Cooking Alliance, the for-profit clean cooking industry saw an investment of US$ 215 million in the year 2022. This was 80 per cent higher than the investment in 2021. 97 per cent of this investment was return-seeking capital – equity or debt. Two-thirds of the investment in three years (2020-2022) went to companies that were involved in the carbon credit business.

Until May 2025, 124 million carbon credits had been issued to 444 cookstove-based carbon credit projects in Africa. The total number of listed projects, including those in the pipeline for registration across VCS and Gold Standard - the two standards that almost entirely represent the cookstove voluntary carbon market (VCM) in Africa, amounted to 935, according to the Berkeley Carbon Trading project, University of California, California. Cookstove projects in Ghana, Mali, and Uganda were among the first to be registered under the voluntary registries starting in 2007. Since then, such projects have been undertaken in more than 37 countries across the continent.

A CSE study on cookstove projects in India in 2023 identified several issues in the design and implementation of these initiatives. First, the study highlighted flaws in the baseline assumptions used to estimate greenhouse gas reductions. Many projects assumed that the target population relied primarily on non-renewable biomass, neglecting the fact that many households were already using cleaner sources of cooking. The projects assumed that once the cookstoves were provided to beneficiary households, they would exclusively use them. However, this was far from

TYPE OF CARBON CREDITS ISSUED TO VOLUNTARY CARBON MARKET PROJECTS IN AFRICA



Source: Berkeley Carbon Trading Project

what was observed on the ground. Village households typically used multiple sources of cooking fuel for cost convenience, and in many cases, the new cookstoves had fallen into disuse or were being used sparingly. This miscalculation inflated the projected carbon savings.

Second, the study pointed to a lack of transparency regarding the ownership of carbon credits. Villagers were often unaware that they had signed over their carbon rights to project developers. The third issue was that in some cases, households had even made payments to receive the cookstoves, unaware that the cookstoves were generating carbon credits for the project developers. The fourth issue involved inadequate monitoring and verification. Despite claims of regular surveys, many households reported minimal or no follow-up from the project developers. The study also criticized the role of third-party validators, who appeared to give projects a clean chit despite apparent discrepancies in their field visits.

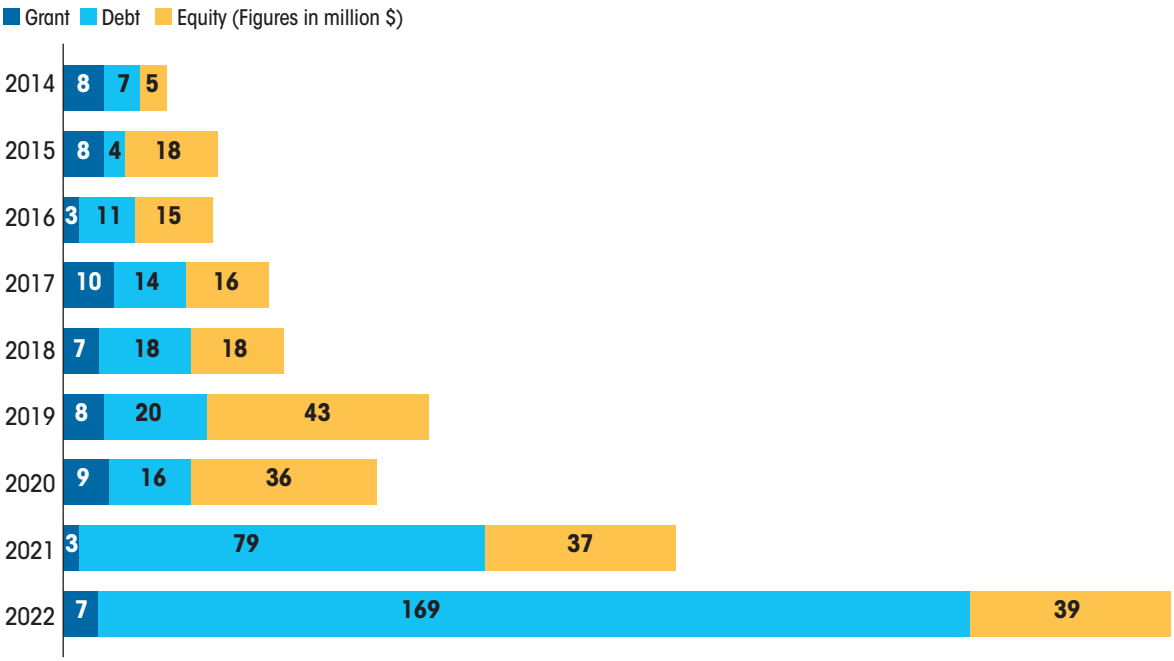
Finally, the study questioned whether these projects genuinely benefited the communities involved. Many villagers found the improved cookstoves inconvenient or infrequently used, undermining the projected environmental benefits. Moreover, the financial benefits derived from carbon credits appeared to disproportionately favor project developers over local communities.

Other studies offer similar insights on such projects. A study conducted by researchers from UC Berkeley echoed these concerns, highlighting the overestimation of carbon savings by a factor of 10 in cookstove projects. Exaggerated claims about carbon savings were made based on unrealistic assumptions of stove usage and fuel type. Much like in India, the study found that households continued to use traditional stoves alongside the new ones, significantly diluting the expected emissions reductions. Moreover, the supposed health benefits from reduced indoor air pollution were often not realized, as the new stoves did not perform as effectively as advertised.

FORESTRY AND LAND-USE PROJECTS

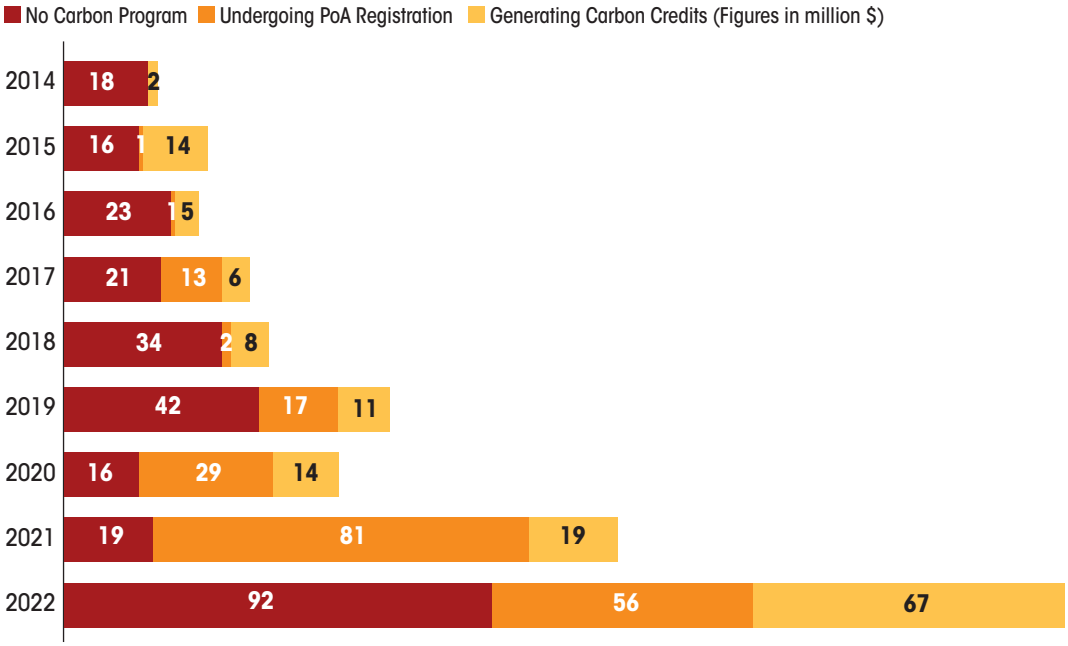
Forestry and land use carbon credit projects are designed to sequester carbon dioxide (CO_2) from the atmosphere through changes in land management practices. Forestry and land-use based projects make-up about 1/5th of all projects in the voluntary carbon market. About 38 per cent of the carbon credits issued have been to these projects. According to the World Bank, the average price for forestry and land-use carbon credits for emission removal was $15.5 and

CAPITAL RAISED BY CLEAN COOKSTOVE DEVELOPERS



Source: Clean Cooking Alliance

CAPITAL RAISED BY CLEAN COOKING COMPANIES BY CARBON PROFILE

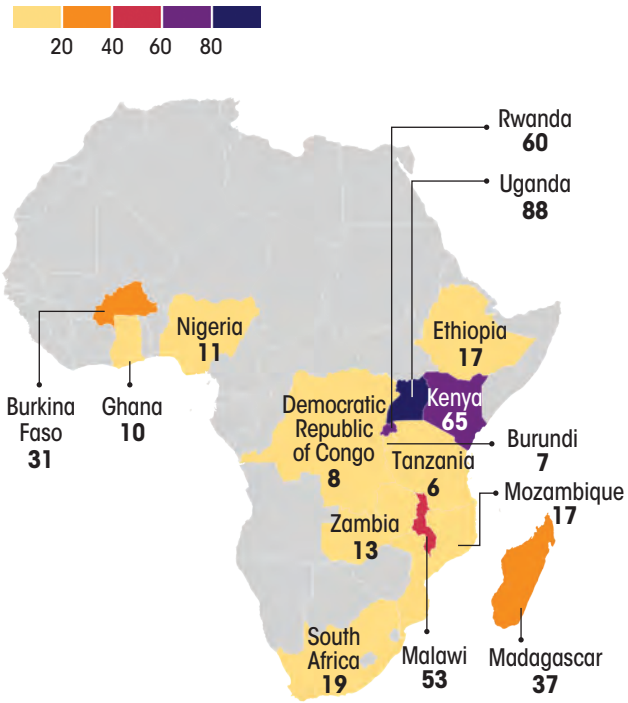


Source: Clean Cooking Alliance

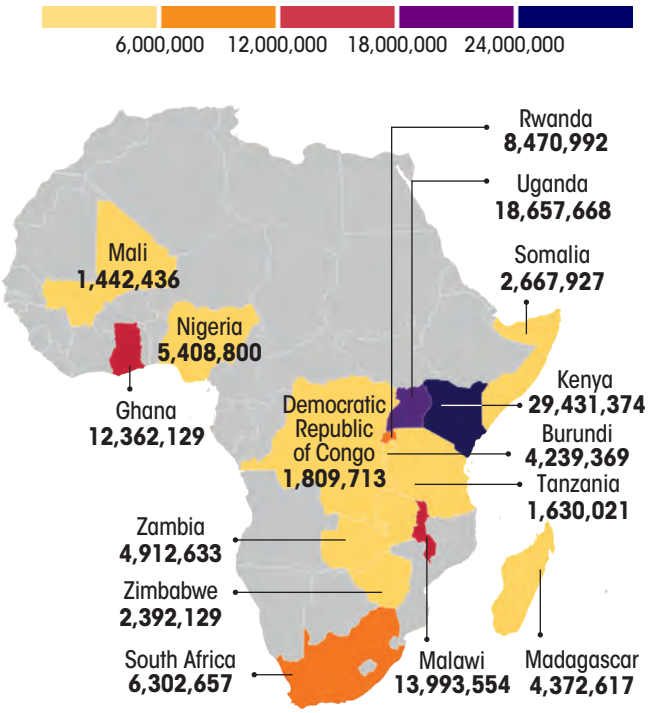
emission avoidance projects were $5.3 in 2024.

Forestry and land-use-based projects have included 192 projects across Africa in four voluntary carbon market registries - Verified Carbon Standard (VCS), Gold Standard, Architecture for REDD+ Transactions (ART) The REDD+ Environmental Excellence Standard (TREES), and American Carbon Registry (ACR) - as of July 2025, of which 56 have issued a total of 153 million

REGISTERED COOKSTOVE PROJECTS IN AFRICA REGION



COOKSTOVE PROJECTS CREDITS ISSUED IN AFRICA REGION



Data source: Berkeley Carbon Trading Project

carbon credits. 141 million credits from 153 have been issued by REDD+ projects – mostly in Democratic Republic of Congo, Kenya, Zimbabwe, Zambia and Ethiopia.

One of the largest carbon credit projects registered in Africa was the Kariba REDD+ project in Zimbabwe, reported to have encompassed an area of 747,801 hectares. By early 2023, the project, which was registered in 2011, had sold 28.8 million credits to companies like Gucci, Volkswagen, Porsche, Nestlé, Delta Air Lines, and others. In March 2023, Bloomberg investigated the project and found that, while the project fetched over €100 million, most of the money had gone to the project developers, South Pole, and its partner, Carbon Green Investments, rather than to the community undertaking efforts to prevent deforestation. Moreover, the project was found to have vastly overestimated gains and consequently over-issued credits. Verra, the registry where the project was registered, launched an investigation in October 2023, putting the project on hold. South Pole, the Swiss developer, pulled out of the project soon after, and the project was finally withdrawn in mid-2024.

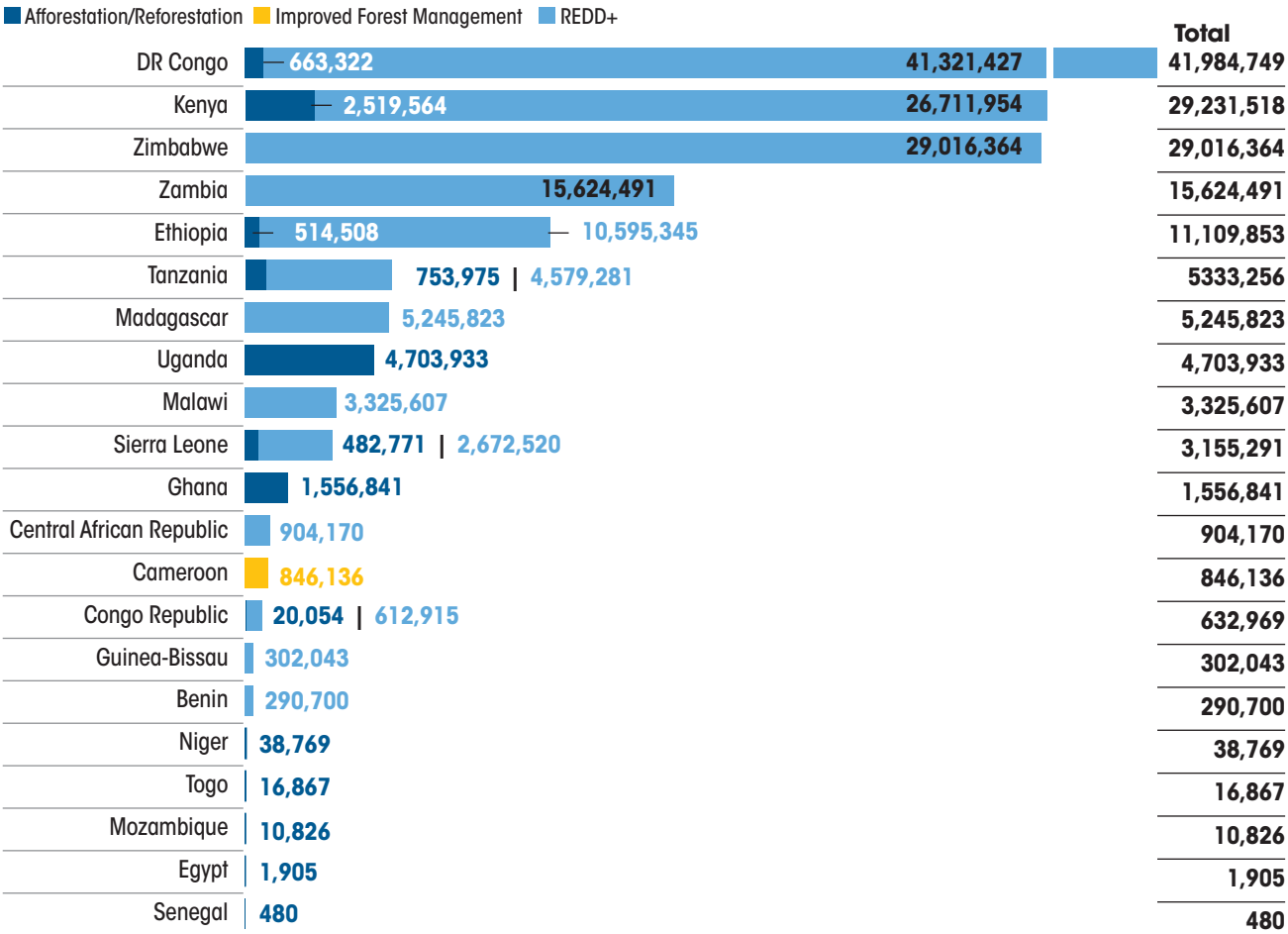
But the case is far from unique and vast regularities have been uncovered in FOLU projects in Africa and elsewhere – the reported issues are more severe for REDD+ projects that also generally cover vast swathes of land, involving communities, administration, national and international organizations.

In some cases, carbon credit projects have led to the displacement of communities, either through direct eviction or by restricting access to lands they traditionally use.

Another issue is the inequitable distribution of benefits. Despite being the custodians of the land, communities often receive either a small portion or nothing out of the financial benefits generated by carbon credit projects. This has led to concerns about fair compensation and benefit-sharing. The complexity of carbon markets and the involvement of multiple intermediaries often obscure the flow of funds, making it difficult for local stakeholders to understand how much they should rightfully receive.

The complexity of the market is compounded by the lack of transparency in the activities conducted, deals signed, and transactions occurring within these projects. For example,

TOP 15 COUNTRIES BY CREDITS ISSUED IN THE FORESTRY AND LAND-USE SECTOR



Data: Carbon Plan

there is a lack of transparency in how Blue Carbon LLC has secured large tracts of land in African countries and how activities are being done, measurements made on the activities and other important details.

Another important aspect is the environmental integrity of the projects, especially the difficulty of accurately establishing baselines in forestry and land-use projects. Determining accurate baselines can be difficult due to limited historical data and uncertainties in future projections. There's also the risk of baseline manipulation, where developers set artificially low baselines to inflate reported carbon savings.

ARTICLE 6 BASED CARBON PROJECTS IN AFRICA

Article 6 of the Paris Agreement provides guidelines for international cooperation to achieve climate targets through carbon markets and non-market approaches. Under Article 6.2, countries can enter into partnerships with other countries and transfer emission reductions, known as Internationally Transferred Mitigation Outcomes (ITMOs), among themselves or to other international mechanisms, such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). In this mechanism, one country pays for an emission reduction project in another country in exchange for emission reduction units or carbon offsets (ITMOs), which can then be used by the paying country to meet its own Nationally Determined Contributions (NDCs). Article 6.4 establishes a centralised mechanism run by the UNFCCC to certify projects that issue emission reduction units that can be traded internationally, similar to the Clean Development Mechanism under the Kyoto Protocol, but with new rules.

Several governments and private entities have started working on their infrastructure and projects to support the issuance and transaction of Article 6-based credits. Until July 2025, at least 11 African countries had signed 28 bilateral agreements or MOUs with other countries to host projects based on Article 6.2 and supply ITMOs (emission reduction units) to partnering countries.

Ghana signed a cooperation agreement with Switzerland in 2022. This serves as a legal framework for the transfer of ITMOs. It provides information on the eligibility of mitigation outcomes, authorization, monitoring and reporting processes, and the registry. An important recognition the agreement makes is that the transaction under this approach would not count as support provided under Article 9 (climate finance), Article 10 (technology transfer), and Article 11 (capacity building) of the Paris Agreement.

Mitigation outcomes achieved from 2021 onwards would be eligible for transfer. The first set of activities agreed upon under this cooperative approach were non-utility scale solar systems, agriculture, clean cookstove distribution, and waste management projects. The first authorization provided under this cooperative approach was in 2022 itself with Ghana authorising UNDP Ghana for transfer of ITMOs from a project named "Promotion of climate-smart agriculture practices for sustainable rice cultivation in Ghana. The authorisation statement cannot be changed after 30 days of issuance. Since the issuance of the first authorisation statement, a number of activities are being considered under the cooperative approach, totaling over 20 million tonnes of CO_2e.

One of the projects authorized between the countries is the "Transformative Cookstove Activity in Rural Ghana." The project plans to distribute 180,000 improved cookstoves in rural

Despite being the custodians of the land, communities often receive either a small portion or nothing out of the financial benefits generated by carbon credit projects

Ghana in three phases. These cookstoves are claimed to reduce biomass usage by 60 per cent. The project is supported by the Klik Foundation's financing, which will ultimately receive the ITMOs from the project. The cookstoves will be provided to households at a subsidized price. The estimated annual ITMOs from the project is 403,896, which will cumulatively add up to 3.2 million over eight years. The project uses a methodology from the Gold Standard program, which is applied in the voluntary carbon market. This methodology has also been approved by the Integrity Council for the Voluntary Carbon Market (ICVCM).

End-beneficiaries will still need to purchase the cookstoves, but at a reduced price. For beneficiaries who may not have the means to pay for the subsidized cookstove, a fund has been created to provide loans. For a traditional firewood stove, the average monthly savings from fuel reduction is claimed to be 40.32 Ghanaian Cedi (US$ 2.62). These savings are expected to help households recover their investment in about six months, making the total investment around 180 Ghanaian Cedi (US$ 11.72).

Envirofit Ghana will manufacture the cookstoves, which will be distributed with the help of local organizations. Envirofit is also the project developer, responsible for day-to-day operations, as well as the monitoring, reporting, and verification processes. Other entities involved in the project include the Transformative Technology Access Fund, the microfinance institution responsible for disbursing loans to beneficiaries in need, and a village-level association called the VLSA, which will manage the loans and serve as collateral. In addition to Envirofit, another company called Act Commodities will serve as the "activity supervisor," the "legal owner of the environmental attributes," and Klik's counterparty in the MOPA (Mitigation Outcome Purchase Agreement).

It remains to be seen how Article 6-based projects differ from carbon credit projects in the voluntary market in terms of framework, process, methodologies, and other requirements, and how they address concerns prevalent in the voluntary market. Since the Article 6.2 framework

BILATERAL AGREEMENTS ON ARTICLE 6.2 BETWEEN COUNTRIES

provides flexibility for countries to bilaterally agree on their own models of engagement, ensuring that the activities are transparent and well-governed becomes important.

The Malawi Dairy Biogas Programme in partnership with the Klik Foundation will install 10,000 systems in the country. Sistema.bio and EcoGen are two private entities working on identifying the farmers, installing the systems, and providing after-sales services. The project will issue around 500,000 carbon credits until the end of 2030, the cutoff date at which KliK Foundation has agreed to buy credits.

REGULATORY INTERVENTIONS BY GOVERNMENTS IN AFRICA

In recent years, several African nations have introduced carbon market regulations. For example, Kenya's Climate Change (Amendment) Act of 2023 established a National Carbon Registry and mandates environmental impact assessments for carbon projects. This has been further elaborated in the Draft Climate Change (Carbon Registry) Regulations, 2025.The Climate Change (Carbon Trading) Regulations, 2025 (Draft) will place voluntary and compliance credits under a licensed framework, trading via a regulated exchange. Ghana has introduced a detailed framework for participation in Article 6-based market mechanisms and launched the Ghana Carbon Registry to track emissions reductions. South Africa's Johannesburg Stock Exchange has also launched a voluntary carbon market to facilitate the local trade of carbon credits.

Zimbabwe replaced its 2023 regulations with the Carbon Trading (General) Regulations, 2025, setting up the Zimbabwe Carbon Markets Authority, a national registry, and clearer benefit-sharing: 1% of credits for NDCs, 2 per cent for a buffer, 30% to a national transaction account, with the remainder going to project developers. ■

PHOTOGRAPH: ISTOCK PHOTO

ADAPTATION

HIGHPOINTS

Africa nations Nationally Determined **Contributions will cost $2.8 trillion** between 2020 and 2030

Out of the **identified costs,** adaptation measures **account for just 24%**

A survey finds 50% of respondents

believe their own **governments bear the primary responsibility** for fighting the climate emergency

Nations across the continent have **rolled out** innovative and ambitious **climate adaptation programmes**

PHOTOGRAPH COURTESY: ISOE WIKOM

AFRICA ADAPTING

Across the continent, countries are rolling out climate change adaptation and mitigation programmes and plans

IT WILL cost around $2.8 trillion between 2020 and 2030 to implement Africa's Nationally Determined Contributions (NDCs, climate action plans submitted to the United Nations), according to the "State of Climate Finance in Africa 2022" published by the Climate Policy Initiative, an analysis and advisory organisation. Out of this identified costs, adaptation measures account for just 24 per cent. This is insignificant given the continent's high vulnerability to climate change. Irrespective of the finance crunch, countries in Africa have the responsibility and the duty to take up immediate climate change adaptation measures.

Almost half of Africans who are aware of climate change believe that their own governments bear the primary responsibility for addressing the crisis and reducing its impacts, according to a survey published in *Nature* in April 2025. The survey was based on an analysis of Afrobarometer, Africa's largest public opinion survey. Conducted across 39 countries, the study drew on responses from 53,444 individuals. Of these, 26,735

respondents said they had heard of climate change, and it was their views that the analysis focused on. Among this group, 45 per cent placed primary responsibility for climate action on their national governments. A further 30 per cent believed ordinary Africans themselves must take the lead. Comparatively fewer respondents pointed to historical emitters such as rich countries (13 per cent), or business and industry (8 per cent), as being primarily responsible. Only 4 per cent named traditional leaders.

The survey results showed stark regional variations. In West Africa, more than half of respondents across countries including Nigeria, Liberia, Niger, The Gambia, Guinea, Mauritania, Sierra Leone, Mali and Senegal believed their governments should take the lead. In Nigeria, this figure increased to 76 per cent — the highest of any country surveyed. By contrast, in countries such as Uganda, Benin, Ethiopia, Ghana and Kenya, views were more evenly split between governments and everyday citizens. All four small island states surveyed — Cabo Verde, Mauritius, Seychelles, and São Tomé and Príncipe — ranked among the top 10 where citizens attributed primary responsibility to historically high-emitting countries. This may reflect growing awareness of the existential threat posed to low-lying coastal nations by rising sea levels. In Malawi and Zimbabwe, a notable 9 per cent of respondents believed traditional leaders are primarily responsible, underlining the importance of incorporating indigenous knowledge and local leadership in climate policy.

The study also found that belief in the need for both individual and government action on climate change is linked to lower levels of poverty, higher education levels, and greater access to new media. Additionally, respondents who perceived local government services as more accessible and less corrupt were more likely to hold their governments accountable on climate action. This measure of "professionalism" was based on individual reports of service quality and integrity, aggregated at a regional level.

African nations urgently need substantial climate finance to implement their ndcs. However, corruption, including misappropriation, theft and misallocation of funds, poses a significant threat to these efforts

A report by Transparency International, released in February 2025, highlighted how systemic corruption in sub-Saharan Africa undermines climate action. Titled "2024 Corruption Perceptions Index: Corruption is Playing a Devastating Role in the Climate Crisis", the report revealed that weak anti-corruption measures hinder efforts to mitigate climate change. African nations urgently need substantial climate finance to implement their NDCs. However, corruption, including misappropriation, theft and misallocation of funds, poses a significant threat to these efforts, the analysis illustrated. The Corruption Perceptions Index (CPI) underscored that corruption is a global challenge obstructing effective climate action.

CPI ranked 180 countries based on perceived levels of public sector corruption, using a scale from 0 (highly corrupt) to 100 (very clean). The highest-scoring sub-Saharan African countries were Seychelles (72), Cabo Verde (62), Botswana (57) and Rwanda (57). Notable improvements included Ivory Coast (45), up 10 points since 2019 and Tanzania (41), up 10 points since 2014. Conversely, Lesotho (37) dropped 12 points since 2014, while Eswatini (27) fell by 16 points. Countries most affected by climate change, such as Equatorial Guinea, Eritrea, Somalia and South Sudan, also ranked among the most corrupt, the authors of the report pointed out.

Corruption weakens governance, undermines law enforcement and diverts crucial climate funds meant to reduce emissions and enhance resilience, the researchers noted in the report. In nations with high corruption levels, environmental decision-making lacks transparency, leading to unfair policies and environmental destruction. Libya, for example, faces extreme heat, declining rainfall, rising sea levels and prolonged droughts. Corruption and the absence of a

WASTE NOT THE OPPORTUNITY

Circularity in waste management can reduce carbon emissions

AFRICA'S INDUSTRIES generate millions of tonnes of waste every year and are responsible for 30-40 per cent of the continent's greenhouse gas emissions. The volume of emissions is likely to double by 2050 in a business-as-usual scenario.

Circularity is the answer. Instead of dumping or burning this waste, it can be used as a resource in manufacturing that can not only boost growth but significantly cut down emissions. Complete recycling of just four types of industrial waste — lead acid battery, glass waste, cashew waste and e-waste — could reduce 8.7 million tonne of carbon dioxide, which is a 2 per cent reduction in total GHG emissions from the continent, a report by Delhi-based think tank Centre for Science and Environment (CSE) indicated. By using industrial waste, Africa's industries can lower raw material costs, improve energy efficiency, reduce emissions and create job opportunities, said Ishita Garg, programme manager, industrial pollution, CSE.

Yet, in efforts to facilitate a circular economy in the continent, industrial waste is often overshadowed by its more popular cousins — household waste and plastic. Industrial waste needs to be treated as a development opportunity, the report emphasised. It demonstrated how circular solutions can drive both economic growth and environmental sustainability, Garg said. For industrial circularity to become a reality, regulatory frameworks need to evolve, said Christopher N Beka, director-inspection and enforcement, National Environmental Standards and Regulations Enforcement Agency, Nigeria.

The path to industrial circularity is not without hurdles. Absence of comprehensive waste inventories on the type and quantity of industrial waste generated is a major roadblock, according to the CSE report. Numerous African nations undergoing rapid industrialisation lack data on industrial waste generation, including statistics on recycling, reuse and disposal. This absence of information makes it challenging to monitor material flows and pinpoint opportunities for circularity. "The absence of such information has resulted in dumping of waste like slag, fly ash, plastic, glass, paper, etc which are otherwise easily recyclable," said Garg.

Limited financial support for circular practices, insufficient industrial waste management infrastructure and gaps in the policy framework also hinder large-scale adoption of the practice. The challenge is compounded by an absence of industrial waste targeted goals and actions in circular economy polices of many African countries.

The CSE report has a prescription for implementation of circularity in the continent. Some of them include:

- Create a national waste inventory to track industrial waste generation, recycling, and disposal.
- Develop waste mapping and cross-industry waste exchange to repurpose waste as raw materials.
- Develop and implement industrial waste-focused policies that establish sector-specific guidelines.
- Introduce targeted financial mechanisms and invest in recycling infrastructure to make circular waste practices viable and scalable.
- Provide technical guidance and capacity building to help industries transition to circularity.

Amid the challenges, the report recorded solutions successfully adopted by some African countries. Nigeria, Rwanda and Ghana have already developed their roadmaps while Uganda, Chad and other African countries are in the process of drafting theirs, according to the report.

cohesive adaptation strategy have worsened the situation. On September 10, 2023, Hurricane Daniel devastated Derna, causing two dams to collapse — an incident linked to corruption and poor infrastructure maintenance. In Eswatini, unauthorised government spending and the Anti-Corruption Commission's inaction continue to hinder anti-corruption efforts, the report stated. Climate change is intensifying extreme weather events, but securing climate finance remains a challenge due to governance failures.

In South Africa, the first country to sign a just energy transition partnership deal, corruption concerns persist. The former chief executive of Eskom, a South African electricity public utility, alleged that over a billion rand ($56 million) is stolen monthly from the state-owned energy provider, raising doubts about the government's ability to combat climate-related corruption.

According to the report, corruption correlates with weaker environmental policies and inadequate environmental protection. In Zambia, corrupt networks, including senior government officials, facilitated illicit trade in Mukula wood, a protected rosewood species. This

illegal trade generated an estimated $7.5 million annually in bribes and informal fees. Moreover, corruption makes it dangerous for environmental activists to speak out. Land and environmental defenders, often at the forefront of climate advocacy, face violence, intimidation and even murder in highly corrupt countries, the report highlighted. In 2023, two environmental defenders were killed in the Democratic Republic of Congo, one in Rwanda and one in Ghana. Between 2012 and 2023, 116 environmental defenders were murdered in Africa, most of them park rangers in the Democratic Republic of Congo. Urgent action is needed worldwide to root out corruption that undermines climate action through theft, misuse of funds and undue influence, said Maira Martini, chief executive of Transparency International. "Governments and multilateral organisations must embed anti-corruption measures in climate efforts to protect funding and rebuild trust," she added.

Some African nations have made notable strides in tackling corruption, according to the report. Seychelles has prosecuted high-profile cases, improved inter-agency information exchange, and was removed from the EU blacklist for non-compliance. The country has also been recognised for innovative approaches to reducing emissions, including circular economy initiatives and greater civic participation.

Tanzania has gained 10 points on the CPI since 2014, reflecting stronger anti-corruption enforcement. High-ranking officials suspected of corruption are now swiftly removed from office and a specialised court has been established to prosecute corruption and economic crimes.

However, across the continent, countries are adopting policy measures and crafting

The Minawao refugee camp is slowly turning green again. Since 2018, refugees and host communities have planted over 360,000 trees — including edible species like neem, moringa, acacia, and leucaena — as part of a large-scale reforestation campaign

programmes to adapt to and mitigate climate change. Starting from rolling out national strategy to become net zero in carbon emission to adopting indigenous knowledge to fight impacts like drought and extreme weather events, all African nations have some adaptation programmes to showcase. Some of such examples follow.

CAMEROON

Smart greenhouses to hyper local weather forecast: Cameroon's plan to be climate-resilient is taking shape in an unusual place – a refugee camp in the Far North arid areas of the country. Nearly a decade ago, the camp started hosting refugees escaping a deadly insurgency in neighbouring Nigeria. The demand for fuelwood and clearing for settlements led to severe deforestation. Climate change is adding to this crisis. The region has witnessed a 30 per cent decline in rainfall over the past three decades further exacerbating food insecurity and land degradation, according to the Cameroon's National Observatory on Climate Change.

It called for not just a reforestation drive but also to regenerate the land ecology for sustaining climate resilient agriculture. This gave shape to the country's climate adaptation plan, responsive to local threats and putting the communities in charge of the plan to sustain it.

The Minawao refugee camp is slowly turning green again. Since 2018, refugees and host communities have planted over 360,000 trees — including edible species like neem, moringa, acacia, and leucaena — as part of a large-scale reforestation campaign supported by foreign donors. Using "cocoon" technology that helps seedlings retain water, they are restoring degraded land and reviving the ecosystem in one of the country's driest zones. Refugees now care for tree nurseries, monitor survival rates, and train new volunteers.

Alongside the trees, another solution focused on fuel has taken root. With firewood becoming scarce, more than 8,000 households have been trained to produce eco-charcoal briquettes from

PHOTOGRAPH: ISTOCK PHOTO

agricultural and household wastes like corn cobs, peanut shells, rice husks, and dry leaves. The process is impressively simple and low-tech: organic material is toasted in a barrel, ground, and mixed with water, compressed into briquettes and sun-dried.

Today, the facility turns out about 200 kilograms of briquettes a day, and the dual approach has reduced pressure on local forests as well as provided camp residents with a renewable source of cooking fuel. It has also eased tensions between refugees and host communities, created new sources of income, and given local women leadership roles in climate action. What was once seen as an environmental burden has become a living blueprint for sustainable adaptation in a fragile region.

Cameroon, often celebrated as "Africa in miniature" thanks to its ecological diversity spanning from dense equatorial rainforests in the south to arid Sahelian plains in the north, is the 56th most vulnerable country to climate change in the world and amongst the least ready, according to Notre Dame Global Adaptation Initiative ranking. According to the World Bank, about 70 per cent of the country's roughly 28 million people are highly vulnerable to climate-related shocks, primarily because their livelihoods, notably agriculture, are directly exposed to extreme weather events.

The Minawao reforestation and sustainable fuelwood development is the outcome of the country's National Adaptation Plan adopted a decade ago. The plan has 12 priority sectors, including agriculture, water, forestry and biodiversity that have been earmarked for taking up specific projects to adapt to and mitigate climate impacts.

Thus, reforestation and climate-secured agriculture have been identified as an adaptation strategy in the Far North region. Non-profits like Environmental Protection and Development Association are helping farmers adopt drought-resistant crops, build water retention pits, and

join savings groups to buffer against crop failure. A recent collaboration with the Pan-African Climate Justice Alliance trained over 300 farmers on how to produce organic fertiliser from local materials — cutting costs while improving soil resilience.

Innovative projects are being rolled out aimed at specific needs of local communities facing the climate threat. In the northern city of Garoua, an ambitious climate adaptation plan is unfolding. In 2022, the city launched Cameroon's first inter-communal Sustainable Energy Access and Climate Action Plan (SEACAP), in partnership with the EU's Covenant of Mayors in Sub-Saharan Africa (COM SSA). The plan is bold: reduce emissions by 25 per cent by 2030, boost access to clean energy, and protect the city from flooding and heat stress.

What makes the Garoua initiative stand out is its inter-communal approach. Surrounding rural districts are involved in the planning process, ensuring that urban climate strategies are not developed in isolation. Local officials, community leaders, and youth groups have been trained on climate-smart planning, resulting in green corridors, waste-to-energy pilot projects, and flood management zones.

In the country's humid tropical zones, hundreds of kilometres from the dusty Sahel, Cameroonian entrepreneur Roland Fomumdam is confronting a different side of the climate crisis: seasonal food scarcity and volatile prices. His response? Low-cost climate-smart greenhouses designed and built locally to grow fresh produce year-round, independent of rainfall patterns or rising temperatures.

Since 2013, his company, Greenhouse Ventures Cameroon, has pioneered precision farming techniques that allow crops like bell pepper, tomatoes, and strawberries to be grown year-round. Unlike earlier state-led greenhouse efforts, Fomumdam's innovation is tailored to Cameroon's

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five ecological zones and built using local materials. At one of his farms in Bangue, 35 km from the port city of Douala, weekly harvests now reach over 160 kg of bell peppers — sold at less than half the price of imported ones. "We've been able to substitute importation of bell peppers by over 90 per cent," he says. "And we can keep prices steady from January to December."

Beyond production, Fomumdam's Greenhouse Academy is training a new generation of precision farmers to expand climate-resilient practices. Students like Godwill Angereh have moved hundreds of kilometres to learn the techniques, motivated by the technology, to address food insecurity while building sustainable livelihoods. The academy, along with farms in Yaounde, Bafang, Bali, and Dibombari, reflects a growing local movement toward adaptive, tech-driven agriculture.

Adaptation relies on access to timely and reliable climate information. A grassroots innovation led by young Cameroonian mathematician and computer scientist Paul Ghislain Poum is helping bridge that gap. Poum has developed a mobile weather forecasting system that delivers hyper-local weather forecasts to smallholder farmers—many of whom are at the mercy of climate instability. The app provides localised weather alerts to over 200 districts, especially in regions where traditional meteorological data is scarce. For farmers without smart phones, the alerts are rebroadcast via local radio in local languages. "This information is crucial for the population in general," he says, "but particularly for rural farmers who suffer from production deficits due to climate fluctuations and lack of access to quality weather reports."

PHOTOGRAPH :EMILIA GANKAMA

CONGO

Reforestation and raising edible caterpillar: The Democratic Republic of Congo (DRC) is often talked about in terms of how climate change can cripple a country. The country situated at the heart of the Congo Basin is facing rising sea levels, severe floods, soil erosion, drought, and biodiversity loss. It ranks 169th in the Climate Vulnerability Index of the University of Notre Dame, one of the most vulnerable countries in the world.

Nearly 70 per cent of its population depends on agriculture and other natural resources, thus, making them vulnerable to climate change. In 2021, DRC adopted its inaugural "National Adaptation Plan to Climate Change 2022-2026". At the core of this plan is to fortify its over two-thirds population from climate change.

One of the key adaptation activities is to regenerate forests to ensure people's livelihood security. Its dense tropical forests account for 47 per cent of Africa's total.

For instance, the province of South Kivu that has the country's highest density of population and 80 per cent of its population are poor. Once it had dense forests that ensured food security. But in recent decades deforestation nearly stripped the province of its green cover. This led to land degradation while agriculture intensity is increasing. This leads to loss of livelihood forcing people to exploit the forests more causing deforestation, particularly in the Kahuzi-Biega National Park (KBNP), a UNESCO World Heritage Site.

A local non-profit PIFEVA, under the country's climate adaptation plan, is reforesting 440 hectares spread over 22 villages. Its aim is two-fold: regeneration of the local ecology and the restoration of food and livelihood security. It is funded by the Adaptation Fund, which supports climate innovation in developing countries through the UNDP-Adaptation Fund Climate Innovation Accelerator (AFCIA).Under the project, it is planting indigenous trees, and particularly those that host the edible caterpillars. The caterpillars are a protein-rich food and also a source

of income for local communities. As the reforestation picks up, it has opened up opportunities for income as well. The initiative has trained 660 women and young people to raise nurseries, to sell and also to be in managing the new forests.

Involving women has been deliberate. They usually don't own assets even though they play a key role in agriculture. They don't get a share in the earnings. "Empowering women enhances biodiversity outcomes and fosters community-wide transformation, as women gain confidence and leadership experience," says Veronique Bulaya, PIFEVA's project coordinator. "The indigenous women and men have naturally adopted a sustainable lifestyle. They have given up deforestation, embraced and applied the entire project for forest management. Each time an individual cuts down a tree, s/he plants 10 others," she says.

The DRC government has launched several frameworks to address climate risks, including the National Climate-Biodiversity Policy, which is currently being finalised. The country has also been accredited with the Green Climate Fund, which will make it easier to access international funding.

On the ground, several projects are underway, focusing on climate-smart agriculture, agro-forestry, community reforestation and green infrastructure. These include the Capacity Building Project for Climate Change Adaptation, which promotes resilient activities in vulnerable areas and an agro-forestry programme to reduce deforestation. Congo's vast tropical forest is at the heart of the Biodev 2030 programme, which integrates multi-stakeholder dialogue, biodiversity certificates and payments for ecosystem services.

TANZANIA

Adaptation must be everyone's business: In Jangwani, Dar es Salaam, an impoverished neighbourhood where the Msimbazi River snakes through crowded shacks and tangled mangroves, heavy rains routinely trigger floods and mass displacement.

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Jangwani resident Teresia Katimba shuddered with horror on revisiting the events of a humid night when the swollen Msimbazi River had breached its banks again, turning her cramped house, perched precariously near the riverbank, into a pool of misery. Murky floodwater — mixed with sewage, plastic bottles, and garbage — poured in relentlessly into her house, soaking mattresses and spoiling everything from maize flour to charcoal and dried sardines, as her children huddled around her in prayer.

"I don't want to remember the suffering we went through. We survived by the grace of God. The loss was unspeakably heavy," Katimba recalled. For years, slum dwellers in Dar es Salaam lived in fear of rain. With every downpour came disease, displacement and despair.

But today, Katimba breathes easier. In 2024, she was among hundreds of residents relocated to Madale, a higher-ground neighbourhood, under the $200 million World Bank–funded Msimbazi Basin Development Project. She received compensation and built a modest home in the dry, forested area about 39 kilometres from the city centre. "We're very happy to be here," she says, smiling outside her new home. "There's no floodwater to worry about. We have peace now."

The city is tackling the menace head-on. The Msimbazi Basin Development Project, running through 2028, targets the city's lower river basin — home to 330,000 people — and seeks to transform one of Africa's most flood-vulnerable zones into a green, climate-resilient

PHOTOGRAPH :KIZITO MAKOYE

urban park. The initiative includes river dredging, terracing, new drainage infrastructure and a complete overhaul of the Jangwani Bridge and bus depot. Displaced residents like Katimba are being resettled on safer land with compensation. "This project was conceived after the floods in February 2018, which were very devastating," says John Morton, a project manager at the World Bank.

Tanzania is on the frontlines of the climate crisis, grappling with rising temperatures, erratic rainfall and more frequent floods that threaten food security, infrastructure and lives. With over 70 per cent of the population relying on rain-fed agriculture, the country's economic backbone is increasingly exposed to climate shocks. In cities like Dar es Salaam, flash floods routinely displace thousands, while rural communities endure prolonged droughts and shrinking water sources.

As these impacts intensify, the government is ramping up climate adaptation efforts — from relocating flood-prone residents to scaling up resilient farming and securing international climate finance. But limited resources, weak coordination, and capacity gaps continue to hinder progress.

In the parched village of Ikungi, Singida, 54-year-old maize farmer Baraka Mussa squints at the sky, waiting for clouds that never come. "We used to know when to plant," he says. "Now the rains play tricks on us." "As rivers dry up and soils erode, our livelihoods hang by a thread," says Fatma Sudi, a climate governance expert at the environment division in the Vice President's Office. "We are facing more frequent and intense floods, erratic rainfall, and rising temperatures," she said. "Our economy is bleeding from climate shocks."

In response, Tanzania has adopted a range of adaptation initiatives. The National Climate Change Response Strategy (2021-2026), paired with updated Nationally Determined

Contributions, aims to integrate climate action into every development sector. "We're embedding climate action into all major development plans," says Sudi. "From agriculture to infrastructure, the aim is climate-proofing our economy."

A key effort is the Tanzania Agriculture Climate Adaptation Technology Deployment Programme, supported by the Green Climate Fund. It has reached over 1.24 million smallholder farmers with drought-tolerant seeds, conservation agriculture, and water-saving irrigation. The Local Climate Finance Initiative (LOCAL) by UNCDF is channeling performance-based grants to district councils to support climate-resilient infrastructure — from livestock shelters to improved water systems. Along the coast, ecosystem-based adaptation efforts in Zanzibar, Pangani and Bagamoyo have restored mangroves, built seawalls and relocated salinised wells to help thousands cope with erosion and rising seas.

"We don't just sit and wait for rain anymore," says Gloria Meena, a farmer in Ruvu. "We listen to the radio and learn what to do." Meena is among thousands of farmers tuning into Heka-Heka Vijijini, a weekly programme on Moshi FM radio station. It educates onion and rice farmers on how to adapt to erratic weather using crop rotation, irrigation and soil conservation.

"This programme changed how I farm," says Paulina Ndauka. "Before, I didn't know how to prevent soil erosion. Now, my farm is safer." For extension officers like Onesmo Mbaga, the radio

In 2009, Sylverster co-founded Mitao Forecast Africa, an early warning system innovation meant to make realistic and simple climate information — derived from complex science-based evidence — available even to illiterate residents

show is a game changer. "It allows us to reach thousands of farmers at once," he says. "People now build reservoirs and time their planting better."

Despite strong national policies, execution remains uneven. "We still fly blind in many areas," says Edmund Mabhuye, head of the Centre for Climate Change Studies at the University of Dar es Salaam. "Even the best policies are useless without local knowledge and commitment." In rural wards, climate planning often takes a back seat to immediate political or economic concerns. "We need to change mindsets from the village up," he says. "Adaptation must be everyone's business."

MADAGASCAR

Before the voyage, be climate-wise: People living in Madagascar's coastal areas face multiple challenges daily due to lack of meteorological information. This knowledge gap has left some villages with very few men, as most of the traditional male fishers continue to die at sea.

A single coastal village might simultaneously lose many fishers, leaving numerous children orphaned and only a handful of women married in the areas most susceptible to disasters. Eventually, these children grow up to become fishermen themselves, perpetuating the cycle. In the country, women and children are the most vulnerable.

The poor communication of such vital information also creates a spiral of poverty and ecological destruction that they are unable to avoid. But there are solutions that local innovators are exploring.

"The situation is common in the south-eastern and southern coasts of the island, and we have to find solutions," says Toky Hasina Sylverster, an oceanographer and president of non-profit Aquatic Service. In 2009, Sylverster co-founded Mitao Forecast Africa, an early warning system innovation meant to make realistic and simple climate information — derived from complex science-based evidence — available even to illiterate residents. "My relatives from my grandmother on my paternal side — all fishers — are victims as well," he says.

The innovation is part of efforts to reduce community vulnerability to climate change

AFRICANS SURVIVED 10,000 YEARS OF CLIMATE CHANGES BY ADAPTING FOOD SYSTEMS

By blending herding, farming, fishing and foraging, they developed flexible strategies tailored to local conditions

LEANNE N PHELPS AND KRISTINA GUILD DOUGLASS

IMAGINE LIVING in a place where a single drought, hurricane or mudslide can wipe out your food supply. Across Africa, many communities do exactly that – navigate climate shocks like floods, heatwaves and failed harvests. What's often overlooked in the development policies to tackle these threats is a powerful source of insight: Africa's own history.

Around 14,700 to 5,500 years ago, much of Africa experienced wetter conditions – a time referred to as the African Humid Period. As wet conditions declined around 5,500 years ago, major social, cultural and environmental changes ensued across the continent.

We're part of a multidisciplinary team of scientists who recently published a study about how diverse African communities adapted to climate variability over the past 10,000 years. This is the first study to explore thousands of years of change in people's livelihoods across the continent using isotopic data. This continent-wide approach offers novel insights into how livelihoods formed and evolved across space and time.

Prior theories often assumed that societies and their food systems evolved in a linear way. In other words, they developed from simple hunting and gathering communities to politically and socially complex societies practising agriculture. Instead, what we see is a complex mosaic of adaptable strategies that helped people survive.

For 10,000 years, African communities adapted by mixing herding, farming, fishing and foraging. They blended different practices based on what worked at different times in their specific environment. That diversity across communities and regions was key to human survival. That has real lessons for food systems today.

Our research suggests that rigid, top-down development plans, including ones that privilege intensifying agriculture over diversified economies, are unlikely to succeed. Many modern policies promote narrow approaches, like focusing only on cash crops. But history tells a different story. Resilience isn't about choosing the "best" or most "intensive" method and sticking with it. Rather it's about staying flexible and blending different strategies to align with local conditions.

We were able to develop our insights by looking at the clues left behind by the food people ate and the environments they lived in. We did this by analysing the chemical traces (isotopes) in ancient human and domestic animal bones from 187 archaeological sites across the African continent. We sorted the results into groups with similar features, or "isotopic niches". Then we described the livelihood and ecological characteristics of these niches using archaeological and environmental information.

Our methods illustrated a wide range of livelihood systems. For example, in what are now Botswana and Zimbabwe, some groups combined small-scale farming with wild food gathering and livestock herding after the African Humid Period. In Egypt and Sudan, communities mixed crop farming – focused on wheat, barley and legumes – with fishing, dairy and beer brewing.

Herders, in particular, developed highly flexible strategies. They adapted to hot plains, dry highlands and everything in between. Pastoral systems (farming with grazing animals) show up at more archaeological sites than any other food system. They also have the widest range of chemical signatures – evidence of their adaptability to shifting environments.

Our study also used isotopic data to build up a picture of how people were using livestock. Most animal management systems were reliant on grasses (plants such as millet and tropical pasture) and adapted to diverse ecological conditions. Some systems were highly specialised to semi-arid and mountainous environments. Others included mixed herds adapted to wetter or lower elevation regions. In other cases, animals were kept as stock in small numbers to supplement other livelihoods – providing milk, dung and insurance against crop failure. This adaptability helps clarify why, over the past millennium, pastoral systems have remained so important,

especially in areas with increasing aridity.

The study also provides strong evidence for interactions between food production and foraging, whether at community or regional level. Dynamic, mixed livelihood strategies, including interactions like trade within and between communities near and far, were especially apparent during periods of climatic stress. One of these periods was the end of the African Humid Period (from about 5,500 years ago), when a drier climate created new challenges.

In south-eastern Africa, from 2,000 years ago, there was a rise of diverse livelihood systems blending herding, farming and foraging in complex ways. These systems likely emerged in response to complex environmental and social change. Complex changes in social networks – especially around sharing land, resources and knowledge – likely underpinned the development of this resilience.

Ancient livelihood strategies offer a playbook for surviving climate change today. Our analysis suggests that over thousands of years, communities that combined herding, farming, fishing and gathering were making context-specific choices that helped them weather unpredictable conditions. They built food systems that worked with the land and sea, not against them. And they leaned on strong social networks, sharing resources, knowledge and labour.

Past responses to climate shifts can inform current and future strategies for building resilience in regions facing socio-environmental pressures.

(Leanne N Phelps is associate research scientist and Kristina Guild Douglass is associate professor, Columbia University)

impacts and to empower people. After years of trials at small scale, its large-scale use started in 2014. There are currently around 750,000 users across the country, and their number is expected to grow further in the future. Some African coastal countries are set to import the Malagasy innovation.

The Mitao Forecast is a last-kilometre solution that uses satellite meteorological data. The process relies on software using artificial intelligence to convert complex evidence into simple, useful information that is valid for four days for any geographic point, with accurate Global Positioning System coordinates.

It is up to community relays in the villages who serve as local focal points, to timely forward the produced SMS to any phone numbers on their registers. "They also have the responsibility to display coloured-code tokens — green, yellow, orange, red — on the bulletin boards which the users constantly consult. Green means safe climate conditions, while red indicates total interdiction," explains Sylverster.

The alert system is not only a life-saving tool but also a financial planning one for poor households. "It helps the fishermen's wives to manage their revenue well. When their husbands gain Ar100, 000, for example, and they are aware of bad meteorological patterns for the next two or three days, they can manage their income accordingly to avoid eventual paucity. Previously, they tended to spend the whole sum as soon as they earned it," the expert affirms. The innovation also benefits fish collectors. "It allows them to decide whether it is necessary to go into the field with amounts of money and ice to secure the products," he adds.

Better still, the Mitao Forecast innovation appears to be a realistic tool for income-generating activities and conservation management. Data collected from sites across the territory, stored in databases, help communities plan timely activities. By studying historical data regarding an area, for example, users become aware of any changes over time and can adjust their interventions accordingly.

KENYA

From energy transition to seed tweaking: When she planted her maize crop at the end of April 2022, Catherine Wanjiku, a farmer in Mathioya constituency of central Kenya was already concerned that the seasonal rains were late but was grateful they had finally come.

She had planted the "624 hybrid" maize variety as per her usual practice, with the hope of harvesting enough to feed her family of five at the end of the four-month period to maturity. But it was not to be. That year Kenya experienced its worst drought in 40 years. While her area being among the wetter parts of the country did not experience severe

drought, the rains ended two months after they started, meaning that she could only harvest a quarter of his usual amount grain.

"I learnt my lesson the hard way. I no longer plant maize varieties that mature in four months. I shifted to fast-maturing varieties whether or not the rains are promising or inadequate. That way, I'm assured of a good yield," she says of the coping mechanism she had adopted without prompting from anyone.

Kenya has been exposed to horrific floods, crushing droughts and erratic weather patterns over the last two decades. In the past four years alone, the country has witnessed flooding and droughts, with hundreds of lives lost, livelihoods for millions destroyed and infrastructure severely damaged in what's now a dangerous cycle of annual extreme weather events, says Mohamed Adow, director, Nairobi-based think tank, Power Shift Africa, adding, "More than 20 million Kenyans live below the poverty line, which heightens their climate vulnerability." "While these losses and damages have been life-changing, scientific projections show the climate situation will only worsen in the coming years, and it doesn't help that we've crossed the 1.5°C mark that the world could have avoided," he says.

Kenya has elaborate institutional, policy and statutory frameworks to address climate change and its impacts, and even though implementation has been slow, the country has mainstreamed these by integrating mitigation and adaptation interventions in its budgeting and development planning through the Kenya National Adaptation Plan. Institutions such as the National Drought Management Authority provide support to drought-impacted communities by promoting sustainable agriculture practices, including through irrigation, agro-ecology and the introduction of drought-resistant crops to enhance food security.

Kenya has elaborate institutional, policy and statutory frameworks to address climate change and its impacts, and even though implementation has been slow, the country has mainstreamed these by integrating mitigation and adaptation interventions in its budgeting and development planning through the Kenya National Adaptation Plan

One major intervention has been the adoption of clean energy, which has made it a leader in Africa, with more than 92 per cent of its electricity tapped from geothermal, hydro, wind and solar. Renewable energy sources not just reduce greenhouse gases emissions, but also support agriculture, powering businesses and improving livelihoods. By solarising community boreholes, communities can have improved access to water for their households, livestock and farms. This eliminates their reliance on rain-fed agriculture and the need to cover long distances in search of water, minimising communities' climate vulnerability.

At the regional level, the Climate Prediction and Applications Centre (ICPAC), a specialised regional climate platform by the Intergovernmental Authority on Development (IGAD), has been instrumental in supporting Kenya's efforts to adapt to and mitigate the impacts of climate change. The IGAD is a horn-of Africa eight-member states organisation created in 1996 to address priority areas of food security and environmental protection, economic cooperation, regional integration and social development, peace and security. ICPAC is one of its key organs.

The centre works closely with national institutions including the Kenya Meteorological Department (KMD), on programmes to build resilience and support adaptation across sectors. According to Calistus Wachana, an expert on climate services user engagement at ICPAC, the regional centre has supported Kenya in establishing the National Framework for Climate Services (NFCS), whose aim is to bridge the gap between climate information providers and users across key sectors. The framework complements Kenya's Climate Change Act (2016), which while it's a law does not explicitly detail mechanisms for delivering climate services, he notes.

The centre has also partnered with KMD to facilitate the National Climate Outlook Forums

PHOTOGRAPH: MAINA WARURU

(NCOF), which are aligned with Kenya's main rainfall season of March-May and October-December. The forums support national and county-level climate adaptation, providing consensus forecasts and advisories that guide agricultural planning, water management, hydropower generation plans and disaster preparedness, the official explained.

As a result, user engagement with ICPAC's climate services has grown, particularly through digital tools such as the East Africa Hazard Watch, which enable monitoring of extreme events including droughts, cyclones, desert locust infestations, heavy rainfall, floods and crop failure.

"Despite the challenges the programmes have led to improved access to and use of climate information, especially in agriculture and disaster risk management, extension officers report more confidence in advising farmers, while county governments have begun integrating forecasts into local development plans," he adds.

Wambua Kituku, development practitioner, environmental lawyer & scholar at the University of Nairobi, singles out the Financing Locally-Led Climate Action Program (FLLOCA), a programme financed by the World Bank to enhance the capacity of both county and national governments to manage climate risks and implement climate resilience actions at the local level. This, he says, is one of the few successful adaptation and mitigation initiatives at least in terms of implementation.

NAMIBIA

Rainwater harvesting to conservation agriculture: Namibia stares at a reversal of its developmental progress made over decades. Sion Shifa, a senior official in the Ministry of Environment, Forestry and Tourism, attributes this to the impacts of climate change. Namibia's arid and semi-arid landscapes, combined with its heavy dependence on rain-fed agriculture,

make it one of the most climate vulnerable countries in the world. With 92 per cent of the country's land area very-arid, arid or semi-arid, it ranks second in aridity after the Sahara Desert. But it is an upper middle-income country with half of its population residing in urban areas. The rest half in rural areas are mostly poor, and the most vulnerable to climate change impacts.

"This vulnerability has the potential to reverse the country's development gains," says Shifa. Prolonged droughts and creeping desertification are already reshaping the country's landscapes and rural livelihoods. Climate-smart agriculture expert Axel Rothauge says traditional coping methods have become less effective. "For generations, Namibians have survived extreme weather through local knowledge," he says. "But times are changing fast. Traditional methods are fading and new techniques are not always adapted to our environment."

But, the country's response to this threat has been preemptive. Nearly 25 years ago, Namibia established a multi-sectoral National Committee on Climate Change to advise the government. This was followed by the National Policy on Climate Change for Namibia in 2011, which identified priority areas for adaptation and mitigation, including public awareness, institutional strengthening and research. To put the policy into action, the National Climate Change Strategy and Action Plan (2013-2030) was launched to reduce climate impacts on vulnerable communities and integrate climate considerations into development planning.

On the ground, interventions focus on food security, sustainable water use, biological resource management, agro-forestry, rainwater and flood harvesting and climate-smart agriculture. Farmers are encouraged to plant drought-resistant crops, rear hardy livestock and adopt drip irrigation systems to conserve water. In 2015, the Namibian government rolled out one of its earliest climate-resilient farm projects called "Comprehensive Conservation Agriculture Programme 2015-2019". Conservation agriculture involves very less mechanical soil disturbances, encourages permanent soil cover and crop rotation. This method is being popularised given the arid nature of the country's landscape. The country's agriculture extension services have been deployed to help farmers adopt this method.

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Shetuuka Shetuuka, chair of the Olushandja Horticulture Producers Association, says local innovation like the above has been proving effective. "Our members are conserving water through drip irrigation and rainwater harvesting, planting drought-resistant crops such as carrots, beetroots, sweet potatoes and peppers and using organic fertilisers to revive the soil," he says. Community members receive training on sustainable farming techniques and advocate for policies to support small producers. Many rural households have established small to medium-sized gardens to boost food production and contribute to national food security.

MOZAMBIQUE

Social protection and resilience to early warning: Fifty-year old Marta Sigauque stands outside her flooded home thinking how to scoop up the water that has flooded her home in the outlying suburb of Ferroviario das Mahotas, a sprawling suburb just outside the Mozambican capital of Maputo. That is a daunting task made all the more difficult because it is not the first time. Buckets are all over her home, rooted in the stagnant green water surrounding it.

"I'm struggling to get this water out of my house, but in a few days, it could rain again. I'll have to go back to the same situation," she says, pointing to the water that has been stagnant for

PHOTOGRAPH: CHARLES MANGWIRO

almost a week. Her neighbourhood is suffering the impact of two back-to-back flash floods that together drove close to 2,000 families away from their homes in mid-April.

Marta Sigauque's situation has prompted the Mozambican government to anticipate that climate change will exacerbate the country's development challenges by 2050, under the worst-case climate projection. Projections indicate that this will increase Mozambique's poverty level by 5 per cent, pushing an additional 1.6 million people into poverty if no significant structural transformation occurs.

In view of this, the government has partnered with Save the Children Mozambique (SCIMOZ) to implement the LINK Project, which seeks to strengthen climate resilience and adaptive social protection in the country. With a budget of over US$28 million, financed by the United Nations Green Climate Fund (GCF), the LINK Project is one among many other initiatives that will be implemented in nine districts in the provinces of Manica, Tete and Gaza.

Mozambique is one of the poorest countries in the world and ranks third on global weather-related damage, following Bangladesh and Ethiopia. Natural hazards such as droughts, floods, cyclones and related disasters have all been part of Mozambican history and have had an impact in shaping the country's poverty and vulnerability situation.

The LINK Project is aimed at strengthening climate resilience and adaptive social protection in Mozambique. The five-year initiative will also reduce the adverse impacts of climate change on the most vulnerable communities, in addition to promoting an integrated approach to adaptation and social protection. MAAP and SCIMOZ say the project prioritises nature-based solutions for economic empowerment of vulnerable groups, especially youth, and emphasises linking with the private sector.

According to Emília Fumo, MAAP permanent secretary, the Mozambican government's

participation is to implement activities with concrete actions in beekeeping, livestock and agriculture and other activities that will ensure that the impact of climate change is minimised and communities can continue to guarantee their development and well-being. "The project's main activities are centered on strengthening institutional and community capacity for climate resilience, implementing locally led adaptation actions and integrating climate change adaptation into district development planning and budgeting," says Fumo.

More than 415,000 people will benefit directly from the project and another 933,000 will be reached indirectly, says Carla Landeiro, director of the LINK Project, noting that the actions are to be implemented with the aim of preparing vulnerable communities to face and adapt to climate impacts. "The essential concept of the project is to 'marry' actions to combat climate change in the arid and semi-arid zones of Mozambique and social protection mechanisms," says Landeiro. She adds, "It's not about giving the fish, it's about giving the hook and this will also help to create activities that later generate income to lift out of poverty those who are now in the worst conditions."

The southern African nation is particularly vulnerable to floods, cyclones, and droughts, with cyclones occurring approximately five times yearly. Northern Mozambique was ravaged by Cyclone Chido in December 2024 and again by Cyclone Dikeledi in January 2025, leaving many people in need of assistance, especially food supplies. Mozambique is placing special emphasis on the prevention of natural disasters and improving early warning systems. Adaptation measures are being implemented in the agricultural, fisheries, energy, environmental and water sectors, with particular attention being paid to the coastal zones and erosion control.

To address these risks, Ethiopia has developed a comprehensive climate policy framework, aligning itself with international agreements such as the Sendai Framework for Disaster Risk Reduction

ETHIOPIA

In a renewable grid: Ethiopia's mountainous and highland terrain makes it particularly vulnerable to the growing impacts of climate change, with severe weather events — floods, droughts and landslides — now affecting communities across the country. The World Bank estimates annual climate-related losses to gross domestic product or GDP at 1-1.5 per cent, with projections suggesting these could rise to 5 per cent by the 2040s, pushing millions more Ethiopians into poverty. The Woodwell Climate Research Center's National Climate Risk Assessment of Ethiopia (April 2025) projects a 20-30 per cent increase in historically extreme rainfall by 2050 and up to 40 per cent by 2070 across much of the country.

"Flood risk is generally concentrated within the central Rift Valley and in Somali, where communities have developed within the floodplain," the Centre notes. "We estimate that the 100-year flood will impact more than 840,000 structures and cause greater than $1.2 billion 2020 USD ($1.47 billion in 2025 USD), or more than 47 billion 2020 Birr (192 billion in 2025 Birr), in building damages."

Temperature increases of around a degree Celsius (°C) since the 1960s and erratic rainfall patterns have compounded Ethiopia's climate vulnerability, says Dessalegn Atnafu, head of the biosafety and regulation desk at the Ethiopian Environmental Protection Authority (EPA). Droughts and floods, he adds, have become alarmingly frequent.

To address these risks, Ethiopia has developed a comprehensive climate policy framework, aligning itself with international agreements such as the Sendai Framework for Disaster Risk Reduction. The country submitted its first updated Nationally Determined Contributions (NDC) in 2020, with a target to cut emissions by 68.8 per cent by 2030. It is now preparing its next NDC submission for the 2031-2035 period.

Ethiopia's climate ambitions are underpinned by a series of national strategies, including its Ten-Year Development Plan (2021-2030), the Long-Term Low Carbon Emission Development

PHOTOGRAPH: ISTOCK PHOTO

Strategy (2020-2050), the Climate Resilient Green Economy Strategy and the National Adaptation Plan.

Ethiopia's National Adaptation Plan (NAP), adopted in 2019, outlines strategic actions to boost climate resilience. Earmias Masresha, a senior environmental risk assessment expert at the EPA, explains that the plan identifies 18 adaptation options and five strategic priorities to be pursued until 2030. These span vulnerable sectors such as agriculture, forestry, health, transport, energy, industry, water and urban development.

"The plan seeks to mainstream climate change adaptation into long-term national development," he says.

Ethiopia's Climate Resilient Green Economy (CRGE) strategy, first unveiled at 27th Conference of Parties (COP27) to the United Nations Framework Convention on Climate Change in Durban, South Africa in 2011, sets the goal of achieving middle-income status by 2025 without increasing net greenhouse gas emissions. Ahead of the Second Africa Climate Summit to be held in Addis Ababa from September 8-10, 2025, Planning and Development Minister Fitsum Assefa says Ethiopia's landmark Green Legacy Initiative, through which over 40 billion seedlings were planted between 2019 and 2023.

Flagship programmes including renewable energy expansion, electric mobility, climate-smart urban planning, watershed restoration and sustainable land use have further supported Ethiopia's adaptation agenda. As the current chair of the African Ministerial Conference on the Environment, Ethiopia is also advocating for Africa's equitable share of international climate finance.

Through its Long-Term Low Emission and Climate Resilient Development Strategy, Ethiopia aims to achieve net-zero emissions by 2050. The NDC Implementation Plan requires an

estimated $316 billion for the 2030 goals. The government has pledged to fund 20 per cent of this cost, with the remainder dependent on external support.

The Health National Adaptation Plan II (2024-2028) identifies Ethiopia as highly vulnerable to climate-related hazards. Climate impacts range from direct exposure to heatwaves and extreme weather to indirect effects on food, water, disease transmission and infrastructure. The plan estimates that by 2030, an additional 248,200 people per year could be at risk of flooding. Heat-related deaths among the elderly (65+) may rise to over 65 per 100,000 people annually by 2080 — up from fewer than three per 100,000 today.

Agricultural productivity is also at risk. According to Earmias Masresha of the EPA, rainfall variability and rising temperatures — especially a 20 per cent decrease in rainfall in south-central Ethiopia — have already taken a toll. Major droughts in recent years have slashed GDP by 1-4 per cent, while soil erosion from intense rains has cost the economy around 1 per cent of GDP.

Messay Emana Getu of the Ethiopia Biotechnology Institute warns that low adaptive capacity, coupled with climate-sensitive agriculture, makes Ethiopia especially vulnerable. Around 97 per cent of rural households depend on farming or livestock, cultivating an average of just 1.1 hectares each, mostly for their own consumption. "Most cereals — 55 per cent to 80 per cent — are consumed by the households themselves, with sales accounting for only 15 per cent or less," said Messay. He noted that smallholders are poorly equipped to cope with climate shocks and emphasised the need for soil and water conservation, agro-forestry, irrigation and diversified livelihoods.

Ethiopia's energy strategy plays a central role in its climate ambitions. Under the CRGE, the country plans to generate electricity using 70 per cent hydropower, 20 per cent wind and solar

Ethiopia's energy strategy plays a central role in its climate ambitions. Under the CRGE, the country plans to generate electricity using 70 per cent hydropower, 20 per cent wind and solar and 10 per cent geothermal

and 10 per cent geothermal. According to the Ethiopian Energy Outlook 2025, the country's national grid is already powered entirely by renewables, with hydropower dominant. The Grand Ethiopian Renaissance Dam (GERD), which is partially operational, now generates 2,350 megawatts (MW), with six of the 13 planned turbines commissioned. Once completed in September 2025, GERD will become Africa's largest hydroelectric project with a capacity of over 5,000 MW.

To complement its renewable generation, Ethiopia is also promoting electric vehicles (EV). The government aims to raise the number of EVs from 15,000 today to 148,000 by 2030. High import duties are being imposed on internal combustion engine vehicles to encourage the shift.

ZIMBABWE

Vulnerable to climate change: Until the late 1990s, Zimbabwe would have to deal with the logistical nightmares involved in handling its bountiful maize, cotton and tobacco produce. Today, it struggles to ensure that there is just enough grain to feed the 16 million citizens of this southern African country. Climate change has gradually wiped off the surplus from the country's rainfed agriculture. Realising that the good old times are gone for good, the African country is now racing to implement an array of climate adaptation strategies.

Zimbabwe is particularly vulnerable to climate change because of its geographic location, heavy reliance on rainfed agriculture and susceptibility to extreme weather events, according to the World Bank. As a result, the country's food security, water resources and overall economic stability are threatened.

Ranked among the top 20 countries most affected by extreme weather between 2000 and 2019 by the Global Climate Risk Index, Zimbabwe is experiencing an increasingly warming trend, with more frequent and intense heatwaves, and longer, more severe droughts. The

PHOTOGRAPH: CYRIL ZENDA

country's mean annual temperature rose by about 0.03°C per year from 1970 to 2016 and is expected to rise by 1- 1.5°C by 2040, potentially exceeding 3°C by 2050, a United Nations Environment Programme report shows.

With 80 per cent of the country's agriculture reliant on rain, increasingly frequent and longer droughts, shorter rainy seasons and hotter temperatures, cyclones and floods have turned this landlocked African country that was once considered the continent's bread basket into one that increasingly relies on food imports and donations. Experts also trace the increase in pests and diseases affecting crop yields to the warmer conditions related to climate change.

The government has started promoting irrigation, conservation farming and water-harvesting to ensure the survival of the agriculture sector, on which 70 per cent of the population depends for employment and sustenance. "A comprehensive irrigation development strategy is being implemented," says Professor Obert Jiri, permanent secretary, ministry of lands and agriculture. The strategy targets irrigation development using idle waterbodies (existing dams) and dams under construction. "Zimbabwe is currently the most dammed country in sub-Saharan Africa, with more than 10,700 dams already storing water, most of which is underutilised," he says. A total of 221,000 hectares is currently under irrigation. "But this includes about 100,000 hectares under plantation crops, leaving about 120,000 hectares for cereal production."

Jiri says for the country to return to its former glory of being the bread basket of the region, some 350,000 hectares of farmland have to be put under irrigation, and this is what the government is working towards.

Zimbabwe is not the only country that was late to adopt irrigation to climate-proof farming — the problem is felt across the continent. Only six per cent of Africa's cultivated land is under irrigation, which poorly compares with other regions such as Latin America (14 per cent) and Asia (37 per cent), according to a 2018 report "Water-wise: Smart Irrigation Strategies for Africa

by the Malabo Montpellier Panel of Agricultural Experts".

The government is also establishing 900 pilot and learning sites to promote integrated rainwater harvesting. This follows a study by a local university that proved the technique to be an effective climate change adaptation and mitigation strategy, especially for smallholder farmers who constitute the bulk of the farmers in Zimbabwe. Because of colonial land distribution patterns, most of the country's 1.5 million small-holder farmers — those with less than 10 hectares of land — are largely found in arid and semi-arid parts of the country.

For over a decade, George Nyamadzawo, professor of soil and environmental science at Bindura University of Science Education in Zimbabwe, worked with smallholder farmer communities in the Marange area, an arid area on the eastern part of the country, to study water harvesting techniques. From their research, Nyamadzawo and his team established that contour ridges and infiltration pits can reduce soil and water loss from runoff by more than 50 per cent and 75 per cent respectively, while increasing crop yields by up to seven times from 0.4 tonnes / hectare to 3 t / ha. "We were promoting tied contours, infiltration pits and other water harvesting technology as methods that can be used by farmers in dry regions such as these," Nyamadzawo explains.

"After integrating tight contours and infiltration pits, we managed to increase crop yields to at least three tonnes per hectare," he says. Some of the farmers realised maize yields of 4-6 t / ha, while vegetable production increased 10 times.

This water-harvesting strategy is being implemented together with a conservation farming method that is called pfumvudza, a concept that emphasises efficient use of resources on small plots, aiming for optimal management and increased productivity.

To improve the water supply situation, the government is currently undertaking an ambitious programme to drill 35,000 solar-powered boreholes in both urban and rural areas

Climate change expert Peter Makwanya says that as water becomes increasingly scarce due to climate change, the future of farming is in irrigation, conservation farming and improved disease and pest management. "This makes water harvesting and conservation fundamental."

Climate change is also having an effect on the country's health outcomes, particularly for vulnerable populations. Vector-borne diseases like malaria are becoming more prevalent due to shifting climate patterns, while others like cholera, typhoid and dysentery easily flourish in conditions of limited water supplies.

"Harare (City Council) is producing around 320 megalitres of water per day and demand on a daily basis is 1,200 megalitres, leaving most residents without water, resulting in a situation where some of them resort to unsafe water sources," Community Water Alliance (CWA) coordinator Hardlife Mudzingwa told DTE.

To improve the water supply situation, the government is currently undertaking an ambitious programme to drill 35,000 solar-powered boreholes in both urban and rural areas. "The boreholes are helping improve access to water for many people," Mudzingwa says.

In addition to agriculture, water and health, other sectors such as electricity, forestry and biodiversity, as well as infrastructure and human settlements are also highly exposed to the depredations of climate change.

It is also causing grazing and water shortages as well as the heat stress that threaten the survival of the country's wildlife species, especially those sensitive to heat, such as elephants, of which the country already has an oversized population.

A 2020 study in Hwange National Park projected a reduction of 40 per cent of elephant habitat by 2050 and a change in elephant population distribution because of climate change. The Hwange National Park, home to the bulk of Zimbabwe's 100,000-plus elephants, is now increasingly relying on boreholes for water, and some of the boreholes have to be deepened regularly as the water table drops further. ■

Centre for Science and Environment (CSE) is a non-governmental, independent policy research institution based in Delhi that was started in 1980 by the late Anil Agarwal, a leading figure in India's environment movement.

For more than three decades now, CSE has helped shape policies and build public awareness to bring change in areas of pollution mitigation and public health security, low carbon development, natural resource management and livelihood security to make growth sustainable and inclusive.

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