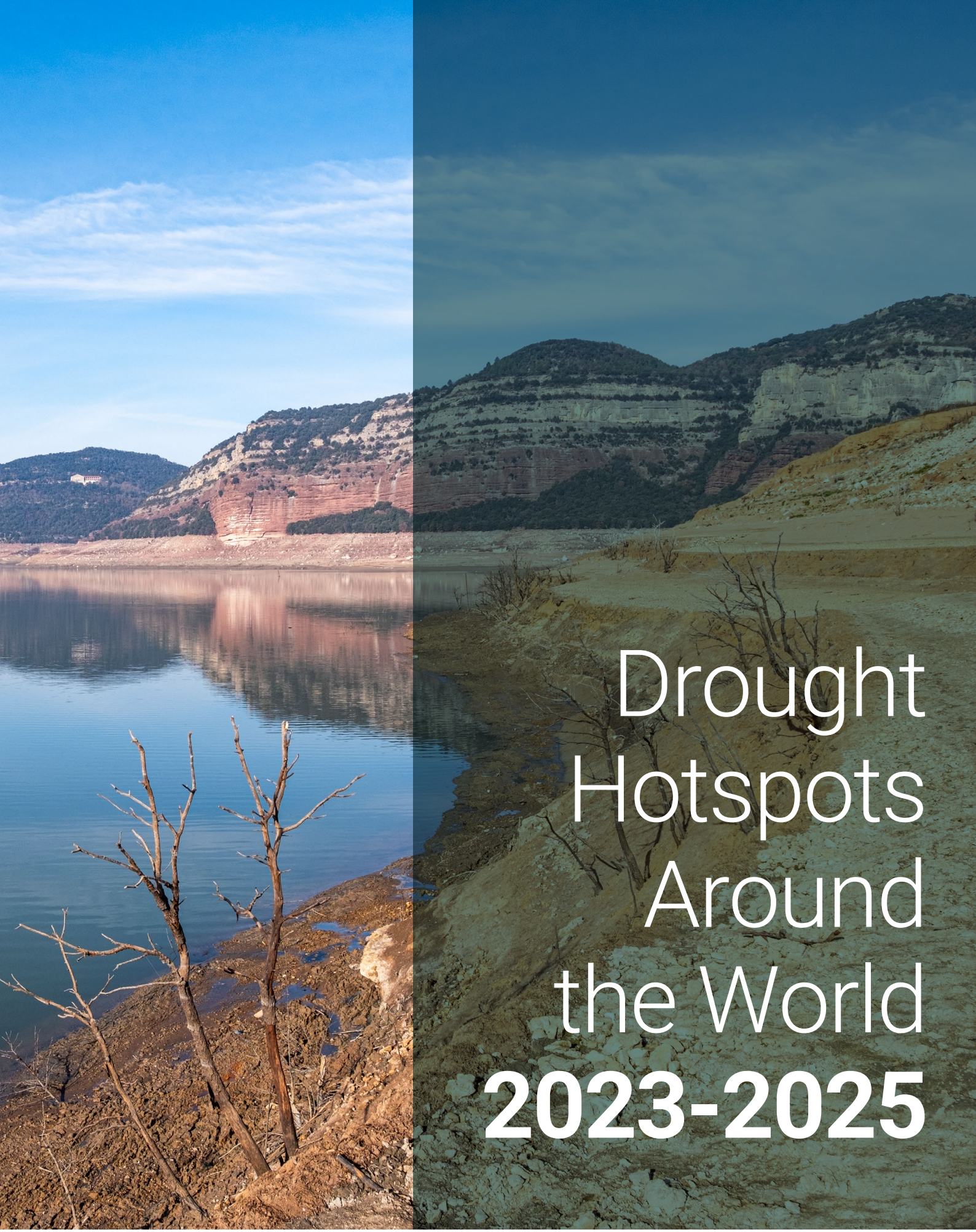

Drought Hotspots Around the World 2023-2025

United Nations
Convention to Combat Desertification

IDRA
International Drought Resilience Alliance

NDMC
National Drought Mitigation Center
University of Nebraska

Drought Hotspots Around the World **2023-2025**

Prepared by the United States National Drought Mitigation Center for the United Nations Convention to Combat Desertification

United Nations Convention to Combat Desertification

IDRA International Drought Resilience Alliance

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IDRA International Drought Resilience Alliance

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LIST OF ACRONYMS

AU	African Union
EC	European Commission
FAO	Food and Agriculture Organization of the United Nations
IDRA	International Drought Resilience Alliance
IUCN	International Union for the Conservation of Nature
NDMC	United States National Drought Mitigation Center
NOAA	United States National Oceanic and Atmospheric Administration
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
OECD	Organisation for Economic Co-operation and Development
OSS	Sahara and Sahel Observatory
WFP	World Food Programme
WMO	World Meteorological Organization
UNCCD	United Nations Convention to Combat Desertification
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development

INTRODUCTION

Global climate patterns in 2023 and 2024 set the stage for severe drought impacts worldwide that are continuing into 2025**.** According to the National Oceanic and Atmospheric Administration (NOAA), 2023 and 2024 were the two warmest years on record globally (NOAA 2025). In fact, 22 July 2024 set a record for Earth's hottest day (Goddard Digital Team 2024). High temperatures and a lack of precipitation had widespread ramifications in 2023 and 2024 such as water supply shortages, low food supplies, and power rationing. In parts of Africa, tens of millions faced food insecurity, malnutrition, and displacement as thousands of human lives were lost due to drought-induced food shortages.

This report identifies the regions of the world that were most severely affected by droughts in 2023–2024, with some continuing into 2025. It explores the impacts experienced in those areas, investigates the underlying vulnerabilities of affected populations, and examines the climatic factors that contributed to the severity of the droughts' effects. Global droughts since 2023 have had widespread impacts that exposed and exacerbated existing social, economic, and environmental vulnerabilities. Understanding which areas and populations were most affected, and why, is essential for informing future mitigation strategies, improving resilience planning, and supporting equitable policy responses.

By examining the intersection of climatic drivers and underlying vulnerabilities, this report aims to reinforce the continued importance of improving drought monitoring, planning, and response capabilities, while providing actionable insights for researchers, policymakers, and humanitarian organizations working to address the consequences of climate extremes.

DROUGHT VULNERABILITY

Drought affects people and ecosystems at different magnitudes depending on their vulnerability to impacts (Wilhelmi and Wilhite 2002). Vulnerability to drought can be seen as a product of exposure, sensitivity and adaptive capacity. Exposure is defined as the frequency and intensity with which drought occurs to people and the things they value; sensitivity is the degree to which they are affected by that exposure; and adaptive capacity is the ability to mitigate, cope with and recover from drought.

Socioeconomic factors play a large role in sensitivity and adaptive capacity (Adaawen *et al*. 2019). Communities that depend on subsistence agriculture are among the most affected by drought, risking famine, mass migration, and conflict during extremely dry conditions. Forced migration due to drought can cause financial stress, interrupt education, and disrupt healthcare, among other consequences (Andreeva *et al*. 2022).

CLIMATIC INFLUENCES

The combined effects of the El Niño Southern Oscillation and climate change intensified drought in many parts of the world in 2023 and 2024.

El Niño-Southern Oscillation

Global drought between 2023 and 2024 was influenced by the El Niño-Southern Oscillation (ENSO). A spike in global warming occurred in 2023, which one study attributed to the El Niño event occurring at the time (Raghuraman *et al.* 2024). El Niño and La Niña are opposite phases within the ENSO, a major climate phenomenon impacting global weather and climate (L'Heureux 2014). During El Niño, sea surface temperatures rise above average in the central and eastern tropical Pacific Ocean. Winds along the equator that normally blow from east to west may weaken or even blow in the opposite direction. La Niña occurs when the same region of the Pacific Ocean experiences below average sea surface temperatures. Winds along the equator blow from east to west and more strongly than normal. When Pacific Ocean temperatures are close to average and winds along the equator blow from east to west at average speeds, ENSO is in a neutral phase. Generally, sea surface temperatures in the Pacific Ocean shift from El Niño and La Niña phases every two to seven years, with a neutral phase in between. The neutral phase can be very short, as was seen in 2023: La Niña ended by 9 March that year (Becker 2023a), by 8 June El Niño had begun (Becker 2023b).

The contrasting phases of ENSO tend to have opposite effects on the regions whose climates they influence (Figures 1 and 2). El Niño typically causes dry conditions in southern Africa, south and southeast Asia, northern South America, Central America, and Australia. La Niña, on the other hand, tends to cause dry conditions in eastern Africa, western Asia, southern South America, and southern North America. The drought impacts observed during the 2023-2024 El Niño largely reflected the well-established patterns of ENSO's climatic influence.

Climate change hotspots

In addition to the effects of ENSO, drought in 2023 and 2024 affected several areas identified as climate change hotspots around the world. Climate change hotspots can be defined in two ways (Giorgi 2006). First, a hotspot may indicate a location where the climate is particularly responsive to global climate change. Alternatively, a hotspot may be a place where the effects of climate change are especially severe to the environment or human activity.

FIGURE 1 Temperature and precipitation patterns that are typical of La Niña during (top) Northern Hemisphere winters and (bottom) summers.

Map by NOAA Climate.gov, based on originals from the Climate Prediction Center.

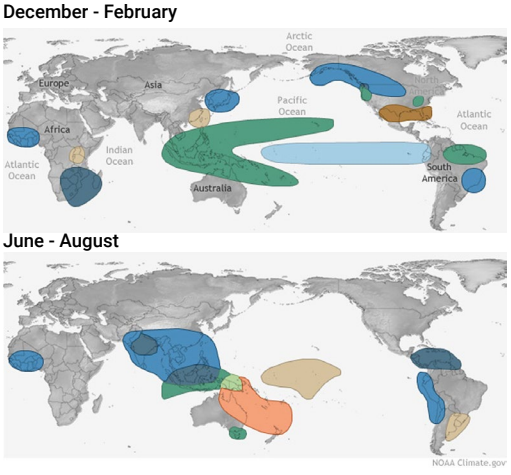
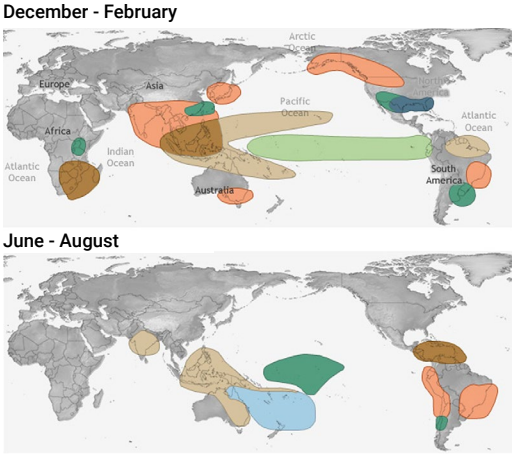


FIGURE 2 Temperature and precipitation patterns that are typical of El Niño during (top) Northern Hemisphere winters and (bottom) summers.

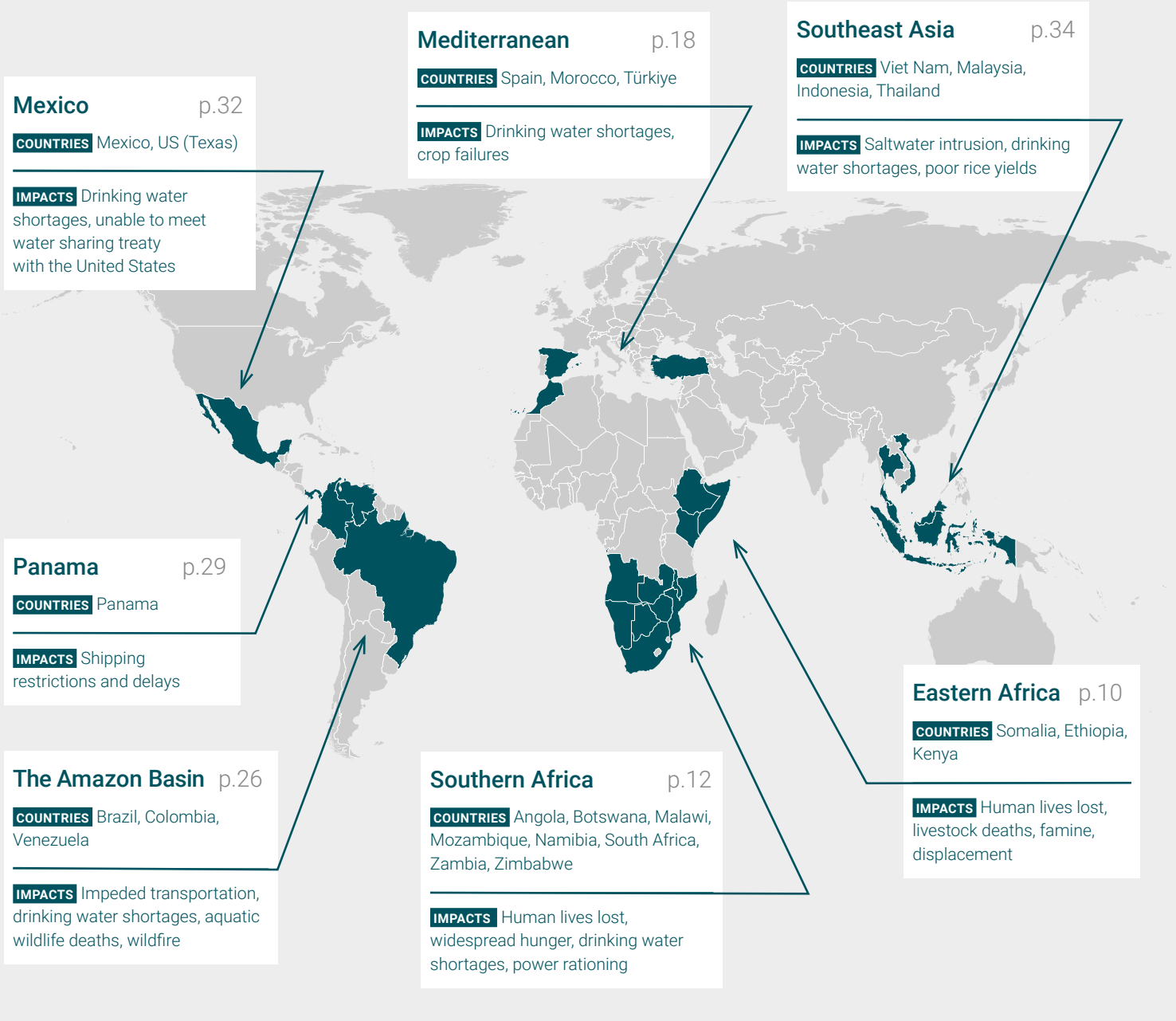
Map by NOAA Climate.gov, based on originals from the Climate Prediction Center.



STUDY SUMMARY

In this study, we used information gathered by the National Drought Mitigation Center's weekly roundups of drought impact news to identify areas around the world that experienced the most reported drought impacts in 2023 and 2024. Evidence of the various impacts came from news reports, technical papers, and peer-reviewed studies. Areas that emerged included climate change hotspots in southern and eastern Africa, the Mediterranean, the Amazon Basin, Panama, Mexico, and southeast Asia. Impacts varied by region, but generally encompassed water supply shortages, agricultural failures, and power rationing. Figure 3 shows a summary of impacts observed by each region.

FIGURE 3 Summary of impacts observed by each region highlighted in this report.



EASTERN AND SOUTHERN AFRICA

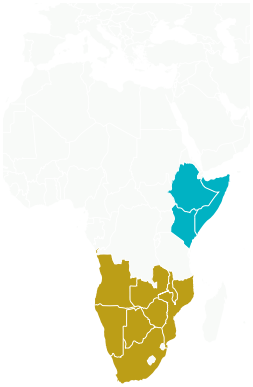


FIGURE 4
Kenya, Ethiopia and Somalia in the **east**, and Angola, Botswana, Malawi, Mozambique, Namibia, South Africa, Zambia, and Zimbabwe in the **south**.

Africa "faces disproportionate burdens and risks arising from climate change-related weather events and patterns, including prolonged droughts," noted Josefa Leonel Correia Sacko, African Union (AU) Commissioner for Agriculture, Rural Development, Blue Economy and Sustainable Development in a preface to the 2023 State of the Climate in Africa by the World Meteorological Organization (WMO). Societies and economies on the African continent are particularly vulnerable to climate extremes, despite contributing minimally to the greenhouse gas emissions driving global warming (Dhakal *et al*. 2022). Southern and Eastern Africa, in particular, have both been identified as climate change hotspots (Fan *et al*. 2021; Gebrechorkos *et al*. 2023). Both areas are prone to drought, food insecurity, and water insecurity that impact economic growth. Political conflicts, poverty, lack of infrastructure, and poor sanitation in these regions worsen the effects of climate-driven water and food shortages.

Five consecutive years of failed rainy seasons in Ethiopia, Somalia, and Kenya brought the worst drought in seventy years to the Horn of Africa by January 2023 (NASA 2022; Africanews 2023). Deadly drought likewise emerged in 2024 across southern Africa and the Zambezi basin due to a particularly strong El Niño event that began in late 2023 (Toreti *et al.* 2024a). World Food Programme's (WFP) acting regional director for southern Africa stated in a July 2024 interview that the drought was potentially the worst the region had seen in 100 years (AFP 2024a). Below average rainfall during the most critical part of the growing season led Zambia, Zimbabwe, Malawi, and Namibia to declare national disasters (Domingos 2024; Matthys 2024; Toreti *et al*. 2024a).

Millions of people across eastern and southern Africa experienced hunger, displacement, power rationing, disease, disruption to education, and even death due to the droughts (Associated Press 2023a). Women and children were particularly vulnerable due to gender-based societal inequalities (Hughes 2024). Wildlife was also affected by the drought. Figure 4 shows the countries in southern and east Africa highlighted in this report.

HUNGER

Eastern Africa

Nearly 23 million people across Somalia, Ethiopia, and Kenya were estimated to be "highly food insecure" by the Food and Agriculture Organization of the United Nations (FAO) by February 2023 (Anna 2023). The drought had already been going on for three years at that time due to an unusually long La Niña event starting in 2020 (NOAA Research 2023). Tens of thousands of people were said to have died due to drought in the region along with around 11 million livestock (Anna 2023).

Nomadic herders in the Eastern Africa region faced starvation, of both their families and their livestock (Africanews 2023). Between 2021 and January 2023, over 4.5 million livestock had died due to the drought and 30 million additional animals were at risk. Shepherds in small villages were faced with the decision of whether to continue their nomadic herding lifestyle or pursue other means of employment. By February 2025, thousands of pastoralists had left the Kotido District of Uganda with their livestock in search of food and water (Oyel 2025). Some herders expressed trepidation at the prospect of starting a new life, as they lacked education and experience in other trades (Africanews2023).

An estimated

43,000

excess deaths may have occurred in Somalia in 2022 due to the drought.

Somalia

Reports indicated that the drought was the longest on record for Somalia, starting in 2020 with the onset of La Niña (Anna 2023). Over 1 million Somalis had been displaced as of October 2022, with many crossing territory held by Islamic extremists (Anna 2022a; Anna 2022b). Fears arose of a famine worse than the one seen in 2011, during which a quarter-million people died. An estimated 43,000 excess deaths may have occurred in Somalia in 2022 due to the drought, according to the Somali government's minister of health (Cobham 2023). The WFP estimated that over 213,000 more Somalis were at "imminent risk" of dying of starvation in May 2023. Little aid had reached Somalia, as multiple crises across the globe spread resources thin. Furthermore, al-Shabab, an Islamic extremist group tied to al-Qaida, was allegedly preventing aid from reaching the parts of Somalia under its control and refusing to let people leave in search of food.

Conditions in Somalia have continued to deteriorate into early 2025 following a below-average rainy season from October to December 2024. By February, 3.4 million people were experiencing acute hunger (Mishra 2025). Between April and June this year, an estimated 4.4 million people, approximately one-quarter of the country's population, were projected to face crisis-level food insecurity (IPC Phase 3 or higher), including 784,000 expected to reach emergency levels (IPC Phase 4; IPC 2025). According to the United Nations, internally displaced persons, pastoralists with limited livestock, and farming households were likely to be most severely affected as food supplies decline amid ongoing drought and political instability (Mishra 2025). The Integrated Food Security Phase Classification (IPC) projected that 1.7 million children under five would experience acute malnutrition in Somalia between April and June, including 466,000 suffering from severe acute malnutrition (IPC 2025).

As of April 2025, more than

10 million

people, among them 4.4 million pregnant and breastfeeding women and children, remained affected by hunger and malnutrition in Ethiopia.

Ethiopia

Twelve million people in Ethiopia were experiencing "acute food insecurity" as of January 2023, according to the United Nations (Haileselassie 2023). Famine emerged in at least 12 districts of the Tigray region of Ethiopia by December 2023 due to locust infestations, the ongoing drought, and lasting effects of a two-year civil war that had officially ended a year before (Magome and Anna 2022). In just six months between July 2023 and January 2024, nearly 400 people died of starvation (Muhumuza 2024). Food aid from the WFP and the United States Agency for International Development (USAID) had been halted early in 2023 (Associated Press 2023a).

By January of 2024, four million Ethiopians were facing "crisis" or "emergency" levels of food insecurity, especially in the Afar, Amhara, Tigray, Oromia, Southern, and Southwest regions of the country (Addis Standard 2024). Over 20 million people across Ethiopia were in need of food aid, and only 14 per cent of the 3.2 million Tigrayans that humanitarian agencies had targeted had received assistance (Muhumuza 2024). Delays were attributed to technical issues, reforms to curb theft, and lack of funds.

As of April 2025, more than 10 million people, among them 4.4 million pregnant and breastfeeding women and children, remained affected by hunger and malnutrition in Ethiopia (WFP 2025). Humanitarian needs in the country continued to grow, driven by the prolonged drought from 2020 to 2023, ongoing conflict in neighboring countries, and below-average rainfall projected for this year.

Southern Africa

Drought-induced crop damage put most of the Zambezi basin in "stressed" to "crisis" levels of food insecurity by April 2024 (Toreti *et al*. 2024a). Crop failures, especially for maize, occurred in parts of Angola, Botswana, Malawi, Mozambique, Namibia, South Africa, Zambia, and Zimbabwe. Over 2 million hectares of crops had been damaged by the drought across Malawi, Mozambique, and Zambia alone by April 2024. Hunger swept across the region, with children under age five and pregnant and breastfeeding women particularly vulnerable (Mutsaka 2024a). Between January and April of 2024, at least 130 people across southern Africa lost their lives owing to the drought (Domingos 2024). By late August 2024, the Southern African Development Community announced that 68 million people across the region, or 17 per cent of the population, needed food aid (Chingono 2024).

As of March 2025, severe drought continued to affect the region when WFP announced the closure of its Southern Africa bureau due to funding constraints (Peyton 2025).

By March 2024, around

30%

of the Zambian population faced malnutrition

Zimbabwe

Nearly 20 per cent of Zimbabwe's population faced the risk of hunger due to the El Niño-induced drought by January 2024 (Mutsaka 2024a). WFP was working to provide food to 2.7 million rural Zimbabweans. Rural households in Zimbabwe often run out of food between January and March while they await the next harvest, but shortages due to drought were predicted to be particularly severe and affect 20 million people in southern Africa that season.

By early April 2024, over 9,000 cattle in Zimbabwe had died of starvation and dehydration (Gumbodete 2024). Over 1.4 million cattle across the country were at high risk, according to the Famine Early Warning Systems Network of the USAID. Pastures were in poor condition, water supplies were low, and supplementary feed prices were prohibitively high for many farmers.

Zimbabwe's 2024 corn crop was down 70 per cent compared to 2023 (Mutsaka 2024a). The price of maize doubled in Zimbabwe over a matter of months in early 2024, leaving residents in the capital city Harare to skip meals and resort to begging for food (Tok *et al*. 2024). Overall, Zimbabwe's food inflation rate reached 26 per cent by April 2024, according to the World Bank.

The number of Zimbabweans in need of aid increased as the year went on. By May 2024, the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) was requesting US$430 million in donations for 3.1 million people (Mutsaka 2024a). Donations would be distributed as food assistance, cash, and the construction of solar-powered boreholes to provide drinking water. The Zimbabwe Livelihoods Assessment Committee estimated that 6 million rural residents and 1.7 million urban residents, more than half of the country's population, would require food assistance in 2024 as the drought continued.

Zambia

By March 2024, around 30 per cent of the Zambian population faced malnutrition with the next growing season still a year away (Tok *et al*. 2024). Around one million hectares of maize, nearly half of the country's crop, was destroyed by drought in 2024. Consequently, the price of maize nearly doubled in parts of Zambia and drove up the prices of other food items as well. Six million Zambians were at risk of malnutrition and acute food shortages as of April 2024. Families in the capital city Lusaka reported skipping meals due to the price of food, with some substituting maize with beer as a meal. Impacts to Zambia's crop expanded beyond the country's borders, as Zambia is one of southern Africa's major maize exporters.

An estimated 6.6 million Zambians needed drought assistance by August 2024 (CARE 2024). In addition to skipping meals and limiting portion sizes, people had lost access to water as their sources dried up. Farmers reported running out of stored grain and livestock dying due to thirst and starvation as pastures were depleted.

By April 2024, up to

40%

of the population faced hunger in Malawi

Malawi

Maize constitutes around two-thirds of the Malawian diet, and over 90 per cent of the country's farmers rely solely on rain to water the crop (Weekes and Joseph 2024). In 2024, Malawi's President Lazarus Chakwera stated that 44 per cent of Malawi's corn crop had failed or was otherwise affected by the drought (Imray 2024). As was seen in other countries in the region, maize prices nearly doubled between 2023 and 2024 (Tok *et al*. 2024). By April 2024, up to 40 per cent of the population faced hunger and two million people needed emergency assistance. Around 600,000 metric tons of food was needed to help feed the country's 20 million people, totaling over US$200 million in humanitarian aid.

Surviving the drought

By late August 2024, the WFP had only received one fifth of the US$400 million that it needed for emergency assistance in the southern Africa region (Nyoka 2024). In the absence of sufficient aid from the government and other organizations, individuals and nations turned to a range of emergency survival tactics to mitigate hunger and thirst during the drought. Some of these measures included collecting wild plants to eat, digging holes in riverbeds for water, and culling wildlife populations for meat.

Hunger in the Sofala Province of Mozambique drove dozens of families out of their homes and into neighboring Manica province in early 2024 (BBC News 2024). People resorted to collecting wild fruits and tubers as crops in the central part of the country had been destroyed by the drought. Historically, sub-Saharan Africa provided 30,000 edible plant species, of which 7,000 were cultivated or foraged before maize, wheat, and rice came to make up 60 per cent of the continent's diet (Mabhuadhi 2024). Research indicates that many indigenous edible plants are underutilized in Africa, such as Bambara groundnut, cowpea, millet, pigeon pea, sorghum, and various leafy vegetables. These plants are nutritious and well adapted to the heat and drought that commonly occur on the continent. Increasing cultivation of these crops could provide a more stable food system, a source of income for women, and critical biodiversity to enrich degraded soils (Chivenge *et al*. 2015).

Zimbabweans in Mudzi District resorted to digging into the floor of the Vombozi River to access water for their livestock, bathing, and cleaning (Nyoka 2024). Residents dug several small holes along the riverbed, which supplied brown-colored water that gave rise to health concerns. Mudzi District was in a dire water situation, however, which affected food supplies as well. The local United Nations Children's Fund (UNICEF) kitchen had reduced their provision from three meals a week to just one as all the crops for the program had been lost to the drought; even hardy indigenous plants were not supplying fruit. As food stocks diminished, the district's medical officer stated that the UNICEF feeding program may cease altogether. One solution that emerged in September 2024 was to cull unsustainably large wildlife populations, including elephants, in Zimbabwe and Namibia to feed rural communities (Mutsaka and Magome, 2024).

HYDROPOWER

At times, hospitals would go without electricity for up to **72** hours.

River flows dropped dramatically across southern Africa, threatening access to electricity in the region. The Zambezi River, the fourth longest in Africa, was at just 20 per cent of its long-term average discharge in April 2024 (Toreti *et al*. 2024). The Zambezi River is host to Zambia's largest underground power station, the Kariba dam. Zambia, which depends on hydropower for 87 per cent of its electricity, began plans to import and ration electricity in February 2024 (Reuters 2024a). To address the hydropower shortages along the Zambezi River, Zimbabwe and Zambia both increased their use of coal in 2024 (Ferris 2025).

Zambia's drought-induced energy crisis continued into September 2024, by which point millions of residents were subject to up to 21 hours without power daily (Short 2024). The Kariba dam was at just 7 per cent of its normal power generation and other smaller rivers were reduced as well. Small companies that were unable to invest in alternative sources of energy such as diesel curtailed or, in some cases, ceased manufacturing operations, while larger companies struggled with high costs of fuel.

Some hospitals in Zambia were turning away patients as the country's only public utility company was unable to supply them with power. In some instances, care for patients was compromised, as with kidney patients who were unable to receive the three hours of dialysis they needed daily. Power was only available for an hour or two at a time, often after midnight. At times, hospitals would go without electricity for up to 72 hours.

Ultimately, Zambia's economy suffered from low productivity and rising unemployment due to the drought. By September 2024, the Zambian government was actively exploring alternative energy sources to reduce dependence on hydropower. Despite government efforts to waive import taxes on solar panels, most Zambians are unable to afford them. The energy crisis hindered bakeries from operating at full capacity, limiting the production of bread and other goods, which further worsened food shortages. Additionally, widespread refrigerator failures led to significant food spoilage for individuals. The country's currency fell by nearly 15 per cent over the latter half of 2024 and had not recovered by the beginning of 2025 (Mfula 2025).

Power outages likewise hit neighboring Zimbabwe (Matiashe 2025). In 2023, residents of the Hwange area in the northwestern part of the country reportedly experienced up to 23 hours a day without electricity (Daily News 2025). Hydropower production at the Kariba South station dropped by more than 80 per cent in late 2024, and daily scheduled power outages through early 2025 could last up to 18 hours (Matiashe 2025). Although some locals were able to turn to firewood or liquefied petroleum gas to meet their basic needs, the lack of electricity limited their ability to complete work. Economic analyses showed that the power shortages had caused many job losses and cost Zimbabwe an estimated 6 per cent of its GDP each year.

Zimbabwe laid out plans in 2025 to increase the use of coal and gas to make up for the lack of hydropower (Ferris 2025). Concerns arose around the risks associated with increasing coal use, including the water needed to operate coal plants as well as contributions to greenhouse gas emissions.

VICTORIA FALLS

The Zambezi River Authority stated on 19 March 2024 that the water level at Victoria Falls, a major tourism destination on the border of Zimbabwe and Zambia, was significantly below average and 70 per cent lower than during the same period the previous year (ZRA 2024). The Zambian side of the falls went dry by October, disappointing tourists who had come to see the natural wonder and affecting local curio shops (Mweemba 2024). Many visitors to Victoria Falls were drawn to the Zimbabwean side instead, which reported a 30 per cent increase in the number of tourists at the attraction from August to October 2024 compared to the same period in 2023 (Dube 2024).

Zimbabwe-based Herald Online maintained that the falls were still flowing and attracting tourists from locally and across the world (Ncube 2024). Zimbabwean tourism experts stated that the destination is resilient to drought given the multitude of activities and sights offered in the area even during the normal seasonal low-flow period. Meanwhile, the Zambian curio industry called for the development of alternative energy sources to reduce water diversion from Victoria Falls for hydropower as local traders and tour operators struggled (Mweemba 2024).

HEALTH IMPACTS

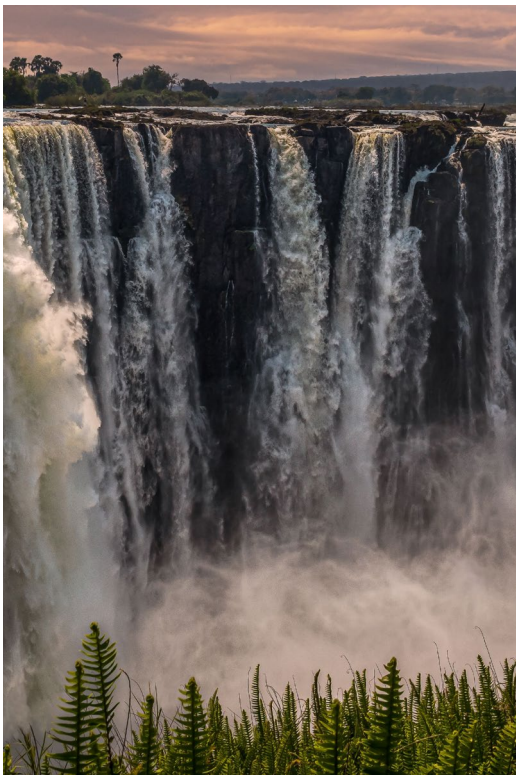
Low water levels and a lack of electricity put people in the southern and eastern African droughts at risk of disease. Often, the water that was available was unclean and shared with animals. Healthcare clinics in the Mudzi area of Zimbabwe faced significant challenges, with a quarter of them running out of water as child hospitalizations for malnutrition doubled over the course of a few months (Nyoka 2024).

43 %

of Zambians lost hydropower. Households unable to flush toilets in Oct 2024

Fears arose that the drought might prevent people from washing their hands or force them to drink from polluted wells, thereby exacerbating existing outbreaks of cholera (Mutsaka 2024a). Reservoirs at a Harare, Zimbabwe, water treatment plant were so low the plant shut down in December 2023 (IANS 2023). The city was in the midst of a cholera outbreak, a waterborne disease, which had already killed 13 individuals as food shortages began. In Zambia, which had experienced an outbreak of cholera in early 2024, some households were unable to flush toilets by October 2024 as 43 per cent of Zambians lost electricity normally provided by hydropower (Gondwe 2024).

Drought also presents substantial risks for individuals in Africa living with HIV (Project Hope 2024). Hunger and limited access to clean water can prevent people from adhering to their HIV medication programs, while food insecurity and migration can disrupt access to medical care. These challenges may lead to severe consequences, such as drug resistance and increased transmission of the virus, which affects 10 per cent of the Zambian population. The risk is further compounded by women and children being forced into marriage, exchanging sex for food and money, and the higher incidence of sexual violence during droughts.



WOMEN AND CHILDREN

During the El Niño 2015-2016 farming season

45,000

children dropped out of school, which was

3,000

more than the annual average.

In many African communities, traditional gender roles place the responsibility of gathering water on women and girls (Hughes 2024). As supplies dwindle, they must travel longer distances to find water, putting them at greater risk of sexual and gender-based violence. The prevalence of forced marriages and school dropouts further exacerbates gender disparities and increases the risk of violence against women and girls.

Desperate families in eastern Africa sought extreme, and sometimes illegal, solutions such as child marriage during the 2023-2024 drought. Although child marriage is outlawed in Ethiopia, the practice more than doubled in frequency in the four regions hit hardest by the drought (Valmary 2023). Young girls who marry can bring their family income in the form of a dowry, in one case 3,000 Ethiopian birr (US$56), while lessening the financial burden of providing food and other necessities. Forced child marriages, however, bring substantial risks to the girls. A clinic at a hospital in Gode, Ethiopia, specifically opened to help victims of the sexual and physical abuse that is common in such marriages.

ActionAid, a non-profit based in South Africa, found that families in the southern Africa region were also marrying off their young daughters in exchange for food and to relieve the financial strains on their parents during the 2023-2024 drought (Hughes 2024). In these early and forced marriages, the girls are often completely dependent on their husbands for all their basic needs and therefore vulnerable to violence, exploitation, and other forms of abuse. Girls generally leave school when they marry, further stifling their opportunities for financial independence.

Large numbers of children in Zimbabwe dropped out of school during the drought (Mutsaka 2024b). Finances were the primary reasons cited: for instance, families were no longer able to afford uniforms and tuition, which cost US$25 in the rural Mudzi district. Some children left school to work or were forced into marriage as a financial solution for their families. Others stayed home to care for their siblings while their parents went out to seek employment. Sanitation was also a concern for teenaged schoolgirls who were unable to wash during their menstrual cycles. The 2023-2024 season is not the first time El Niño has threatened education in Zimbabwe. During the previous El Niño (2015-2016 farming season), 45,000 children dropped out of school, which was 3,000 more than the annual average.

WILDLIFE

Drought impacts wildlife both directly and indirectly. Animals may die from starvation and thirst, or they may be killed by humans as a means of coping with the effects of drought. In 2023 and 2024, southern and eastern Africa saw human-wildlife conflict, the slaughter of wildlife for food, and wildlife deaths resulting from the dry conditions.

Fears of human-wildlife conflict were realized in Kenya in June 2023 when six lions were speared to death in retaliation for killing livestock (Musambi and Tiro 2023). Lions from the Amboseli National Park had wandered into a nearby farm seeking food and killed 12 goats. The Maasai owner of the goats stated that losing half of his herd was a substantial loss of income, and compensation from the Big Life Foundation conservation program would not be enough to replace them. Other locals had also lost goats to lion killings. Although the Maasai have coexisted peacefully with lions and other wild animals for centuries, droughts often drive the large predators closer to humans and fuel conflict.

Severe drought conditions in Hwange National Park, Zimbabwe's largest national park, caused the deaths of at least 100 elephants early in the austral summer of 2023-2024 (Mutsaka 2023). Some of the elephants had died due to starvation or a lack of water, while others appeared to have gotten stuck in muddy water holes. Conservationists described the importance of elephants in fighting climate change, as their waste contains plant seeds that allow trees to spread far distances.

Elephants were in the spotlight again in September 2024. Zimbabwe and Namibia decided to cull unsustainably large wildlife populations in an effort to feed needy communities while reducing pressure on the ecosystems in areas such as Hwange National Park (Mutsaka and Magome 2024). Representatives from the Zimbabwe National Parks and Wildlife Management Authority planned to allow 200 elephants to be hunted and stated that the Hwange elephant population was over three times the sustainable limit. The Zimbabwean elephant population of 100,000 was at risk of starvation and thirst as the country's summer months began. Namibia's plans to cull wildlife included 83 elephants, 300 zebra, 100 elands, 60 buffalo, 50 impala, and 30 hippos, along with other animals in five national parks.

Entire herds of hippos were stuck in mud in April 2024 as Botswana's Thamalakane River dried up during the drought (Reynolds 2024). It was unclear how many of the endangered animals had perished as they sought water and refuge from the heat and sun. Authorities called for the hippos to be relocated from the area, which was near the tourist town of Maun, to avoid human-wildlife conflict: when searching for water, hippos have been known to become aggressive to humans and approach villages. Later in the year, an additional 19 hippos died over the course of three months in Zimbabwe (AFP 2025). An investigation determined that the animals had most likely died of starvation due to the drought, as they were in poor condition and showed signs of malnutrition but no other abnormalities.

THE MEDITERRANEAN

The Mediterranean basin is home to 23 countries spanning Europe, Africa, and the Middle East (Figure 5). Immense amounts of water are abstracted from water bodies that feed into the Mediterranean Sea to meet the needs of more than 500 million people in the surrounding 1,345,000 km2 catchment (Benedini 2020). Due to population growth, urbanization, and climate change, the Mediterranean basin faces water scarcity and desertification (Lange 2020). The region has been identified as a climate change hotspot as it is particularly affected by the rising temperatures and decreased precipitation associated with global warming (Giorgi 2006; European Environment Agency 2015).

Droughts are a normal part of the Mediterranean climate, but their frequency and intensity have been increasing in the region since the 1950's (Cramer *et al*. 2018). With ongoing climate change, temperatures are expected to increase by 2–3 °C in the Mediterranean region by 2050, and by 3–5 °C by 2100 (UNEP 2020). Water availability is expected to decrease by 2-15 per cent for every 2°C of warming in the Mediterranean (Lange 2020). Sicily, Cyprus, Morocco, Algeria, Tunisia, southern Spain and Portugal, parts of Syria, and southern Türkiye are likely to become more arid and experience expansion of desert environments (Cramer *et al*. 2019).

A report from the European Environment Agency highlights the urgency of addressing climate change in the area: "The Mediterranean region is undergoing intensive demographic, social, cultural, economic and environmental changes. As Mediterranean countries are already facing important issues of water stress and extreme climate events (such as floods and droughts) climate change will most probably exacerbate issues, resulting in significant human and economic losses" (European Environment Agency 2015).

The State of the Climate in Europe 2022 report, issued by the WMO, found that Europe is warming twice as fast as the global average due to climate change (WMO 2023). In particular, the Mediterranean has been identified as a "hotspot" particularly sensitive to the effects of global climate change due to rising temperatures and decreasing precipitation (Giorgi 2006; Giorgi and Lionello 2008; Lionello *et al*. 2012). Under the RCP8.5 emission scenario, data show that heat waves will continue to increase in intensity across the Mediterranean Basin (Molina *et al*. 2020).

In this report, we highlight the recent impacts of the drought in Morocco, Türkiye, and Spain. These countries were chosen as representatives of the impact of drought across the African, Asian, and European parts of the Mediterranean based on their prevalence in the media.

FIGURE 5
Political map of the Mediterranean Basin.

MOROCCO

By January 2024, Morocco was at a **57%** water deficit.

Droughts are a typical part of the Moroccan climate, but they have become more frequent and severe since the 1900's (Gumus *et al*. 2024). Morocco is expected to become more arid during the 21st century, with drought occurrence and severity continuing to increase over time. Modeling based on the RCP 4.5 and 8.5 emission scenarios indicates that precipitation in the High Atlas basins of Morocco may decrease by up to 65 per cent, compared to historical averages, by 2100. Severe droughts (SPI below -2) would consequently increase in frequency (Zkhiri *et al*. 2018). As of 2015, Morocco had around 645 m3 of water resources per capita, compared to 10,000m3 in "water rich" countries, but that number is expected to decline to 500 m3 by 2050. At that point, Morocco will be at risk of "extreme water scarcity" (Verner *et al.* 2018).

Water supply

Morocco had faced six consecutive years of drought as of 2024 (phys.org 2024a). Rain early in 2023 helped replenish water reserves in parts of the country, with dams reaching up to 55 per cent capacity by February in some regions. Other areas, such as the Sharq region, were below 25 per cent reservoir fill at that time. Many reservoirs were lower in February 2023 than they had been in February 2022, which was also a drought year.

Reservoirs were still low in 2024, averaging 25 per cent full across the country early in the year (Figure 6; Earth Observatory 2024). January of 2024 was the hottest on record in Morocco since measurements began, reaching as high as 37°C (phys.org 2024b). Rainfall from September 2023 to February 2024 was down 70 per cent compared to a normal year and dry conditions were widespread (Valo 2024). By January 2024, Morocco was at a 57 per cent water deficit (Morocco World News 2024a). Morocco's second-largest reservoir, Al Massira Dam near Casablanca, was down to 1-2 per cent full by February (Earth Observatory 2024). Water restrictions prohibiting car washing, cleaning roads, and planting grass in Casablanca extended to public hammams, which were required to close on Mondays, Tuesdays, and Wednesdays (Morocco World News 2024b).

Morocco turned to desalination to supplement its dwindling water supplies (Martin 2024). Desalination is very energy-intensive, however, and Morocco imports 90 per cent of its energy. The desalination process is therefore particularly costly in Morocco (Morocco World News 2023a). As of January 2024, eleven new desalination plants were planned for construction in 2024 and 2025 (Morocco World News 2024b) Another 23 mobile desalination stations were also in planning stages in addition to brackish water processing stations around the country.

Cloud seeding was another tool employed to mitigate Morocco's water shortages. The process has been shown to increase precipitation in targeted areas by more than 10 per cent per year (Desert Research Institute, n.d.). The Moroccan government invested nearly €15 million in cloud seeding between 2021 and 2023 (Martin 2024).

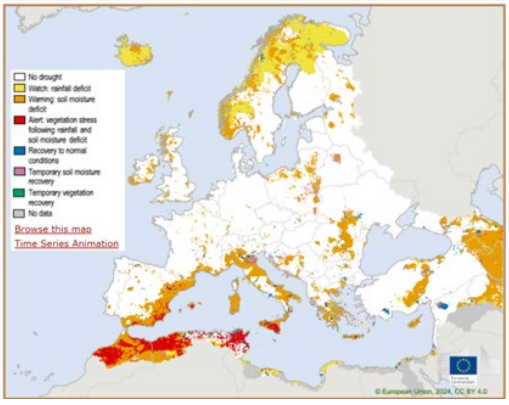
FIGURES 6A AND 6B

Much of northern Morocco was under drought warning or alert conditions in January and February 2024.

Source: European Drought Observatory.

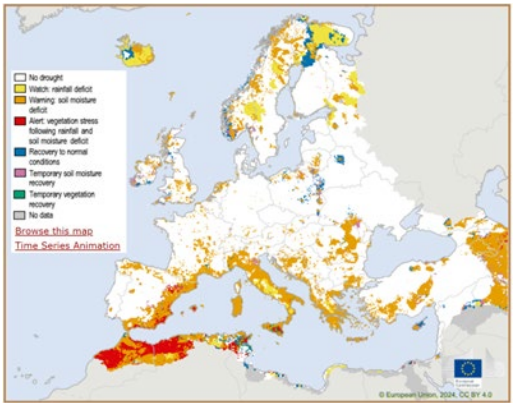
Situation of Combined Drought Indicator in Europe - 2nd ten-day period of January 2024

According to the latest map of the **Combined Drought Indicator 16.1%** of the EU-27 territory (without Madeira, Azores, Canary Islands) plus the United Kingdom is in **Warning** conditions and **1.2%** is in **Alert** conditions



Situation of Combined Drought Indicator in Europe - 1st ten-day period of February 2024

According to the latest map of the **Combined Drought Indicator 19.6%** of the EU-27 territory (without Madeira, Azores, Canary Islands) plus the United Kingdom is in **Warning** conditions and **0.9%** is in **Alert** conditions



Years of drought severely impacted Morocco's sheep population, which in early 2025 had declined by

38%

compared to 2016.

Estimates indicate that cloud seeding could increase the country's precipitation rates by 4 per cent and enhance agricultural production by up to 20 per cent (Lechheb 2024).

Concerns exist, however, about the ecological implications of cloud seeding. For instance, some question whether the silver iodide used to induce precipitation may be toxic to aquatic and terrestrial organisms. According to the Desert Research Institute, Nevada, USA, "Silver iodide exists naturally in the environment at low concentrations and is not known to be harmful to humans or wildlife" (Desert Research Institute, n.d.). Indeed, some studies have indicated that the small amounts of silver iodide used in cloud seeding are too small to be toxic (Williams and Denholm 2009). Other studies, however, suggest that there may be some ecological risk to the practice, particularly if it is performed repeatedly in the same area and the silver chloride accumulates in the environment (Fajardo *et al.* 2016).

Agriculture

Meat and cereal grain production suffered as Morocco's drought stretched across sixth consecutive years. In 2023, shortly before the annual feast of Eid al-Adha, meat prices were at a record high (Morocco World News 2023b). The price increase was due in part to drought-induced shortages, but also to international inflation and lasting impacts of the COVID-19 pandemic. Morocco, in response, had increased the importation of live animals for consumption fivefold since the beginning of the year. The government also implemented incentives for importing livestock, such as cutting customs duties and some taxes, to further decrease the price of meat in preparation for Eid.

Morocco's agricultural sector experienced a substantial loss of jobs in 2024 due to the drought, bringing the country's unemployment rate up from 13 per cent in 2023 to 13.3 per cent (Reuters 2025a). In January 2024, a report from Rabat indicated that low water supplies had led farmers to irrigate around half of the amount of land they had before the dry spell began (Eljechtimi 2024). Many wells had dried up near Taroudant, compelling locals to dig at least 400 meters in search of water. Across the country, only 2.5 million hectares of crops were planted in 2024, compared to the normal 4 million. By mid-April, it was evident that, of those planted hectares, around 20 per cent of the crop yield would be lost to the drought, according to the Minister of Agriculture, Fisheries, Rural Development and Water and Forests (Middle East Monitor 2024).

Wheat and barley production in Morocco was forecast to be nearly 30 per cent below average for 2024, according to the Joint Research Commission's Monitoring Agricultural Resources report released on 27 May (Manfron *et al.* 2024). Drought conditions across North Africa had reduced cereal crop yields across Algeria, Tunisia, Libya, and Egypt, as well (Suharskaya 2024). The Moroccan government implemented subsidies to help farmers afford food, while other organizations helped advise farmers on drought mitigation procedures (Metz 2024). In March 2025, the Moroccan state grain agency announced that it would continue subsidizing soft wheat imports until the end of the year amid the ongoing drought (Reuters 2025).

Years of drought severely impacted Morocco's sheep population, which in early 2025 had declined by 38 per cent compared to 2016 (Daoudi 2025). As part of Eid al-Adha, which will occur in June this year, Muslims traditionally slaughter sheep or goats, with the meat shared and donated to the poor. However, in February 2025, King Mohammed VI urged Moroccans to forgo the ritual (Eljechtimi 2025). Shortly afterward, an official ban on slaughtering female sheep and goats was enacted through March 2026 in an effort to rebuild national herds.

TÜRKIYE

Türkiye is semi-arid and prone to land degradation, with 88 per cent of the country's territory at risk of desertification (Uzuner and Dengiz 2020). Precipitation in Türkiye is expected to decrease by 30 per cent by the end of the 21st century (Philandras *et al.* 2011). Simultaneously, temperatures are rising, particularly in the western and southwestern parts of the country (Apak and Ubay 2007). By 2100, coastal regions of Türkiye are expected to see temperatures rise by 4–5 °C relative to the 1961-1990 average, while inland regions will likely experience a 5–6 °C temperature increase (Demir *et al*. 2008).

Türkiye is semi-arid and prone to land degradation, with

88%

of the country's territory at risk of desertification.

According to the Organisation for Economic Cooperation and Development (OECD), Türkiye is considered a "water-stressed" nation as of 2019 (OECD 2019). Currently, 1,350m3 of freshwater is available per capita, compared to the 10,000m3 in "water-rich" countries (Republic of Turkiye, n.d.). By 2030, Türkiye anticipates having only 1,000m3 per capita, pushing the country into a "water-poor" classification due to drought, population growth, and industrialization (Daily Sabah 2023a). Türkiye's Agriculture and Forestry Minister stated that half of Türkiye's population and 80 per cent of the country's irrigated agriculture could be at risk of water shortages at that point (Duvar English 2023).

Drought was widespread in Türkiye in 2023, following an extremely dry year in 2022. Most of the country, aside from the Black Sea Region, was under drought conditions by July 2023 (Daily Sabah 2023). The Aegean, central and southeastern Anatolia, Mediterranean, and Thrace regions were the most affected, according to the General Directorate of Meteorology. Water supply and agricultural production were among the most prominent concerns in the media.

Water supply

During the 2023 water year, precipitation nationwide across Türkiye was only 6 per cent below the long-term annual average (Duvar English 2023). Regional differences existed, however: Hatay province experienced a 55 per cent decrease, while precipitation in the Edirne and Tekirdağ provinces fell by 40 per cent. In the Marmara Region, a 25 per cent decrease in precipitation was recorded for the year. Shrinking lakes and groundwater depletion were cause for concern across Türkiye due to the drought and pre-existing inefficiencies in water use.

Istanbul, in the Marmara Region of western Türkiye, faced dwindling water supplies in 2023 (Daily Sabah 2023c). The three primary reservoirs serving the city of over 15 million residents shrank to an average of 43.81 per cent capacity by July that year. The lowest reservoir was just 3.91 per cent full. A local professor of engineering cited acute drought as the primary cause of the low water levels but emphasized the importance of improving water management in Türkiye in light of climate change.

Water levels in Istanbul's reservoirs remained low through September 2023 and were not expected to rise before winter (Daily Sabah 2023d). Plans to access water from the "dead volume" of the reservoirs raised concerns for the Water Policies Association. According to the association's director, the water at the bottom of the dam would likely be of low quality and difficult to purify. The director insisted that Istanbul's water use needed to become more efficient and stated that it may be time to encourage reverse migration from the ancient city, which is Türkiye's largest.

Ongoing drought also contributed to a rapid increase in the number of sinkholes across Türkiye, especially in the Konya Closed Basin (Daily Sabah 2023e). There are over a thousand sinkholes caused by groundwater depletion in the country, and drought is the primary contributor to their formation. In Konya, groundwater levels recede by approximately two meters per year due to an annual water deficit of around 500 million cubic meters. Aksaray, Ankara, Eskişehir, Karaman, Nevşehir, Niğde, and the Sakarya Basin have also been affected. The sinkholes present hazards to human life and infrastructure while permanently reducing aquifer storage capacity.

Agriculture

Dry reservoirs outside of Istanbul provided reprieve for farmers in the midst of the drought (Kucukgocmen 2023). As normal agricultural fields in the region became unsuitable for grazing and planting in 2023, soils along depleted reservoirs retained enough moisture to grow grass and sunflowers. Local farmers had not been able to sow most of their rice due to the lack of rain, and alternative crops likewise failed in the dry paddies. In the preceding 11 months, northwestern Türkiye had only received 77 per cent of its normal precipitation, according to the Turkish State Meteorological Service. August precipitation in the region was only 26 per cent of average.

Given that around 75 per cent of Türkiye's water use goes to agriculture, investment in efficient irrigation systems is a critical part of water management, according to the director of Boğaziçi University's Climate Change and Policy Application and Research Center (Republic of Turkiye, n.d.). Turkish farmers pursued water-saving measures such as night irrigation and rainwater harvesting to mitigate the effects of the 2023-2024 drought (Devami 2024). These methods have proven effective in Türkiye, both in terms of conserving water and increasing crop production, according to a professor from Adıyaman University's School of Technical Sciences. Still, according to the Turkish Statistical Institute, cereal and field crop production declined by 5 per cent in 2024 compared to 2023 due to ongoing drought conditions.

Türkiye's water crisis persisted into early 2025, with the driest January in 24 years (Hurriyet Daily News 2025). Southeastern Anatolia received just 6 per cent of its usual rainfall, while central regions saw only 30 per cent of the average. The Turkish Grain Board warned of likely low crop yields and potentially reduced quality, particularly in wheat-producing areas threatened by agricultural drought.

SPAIN

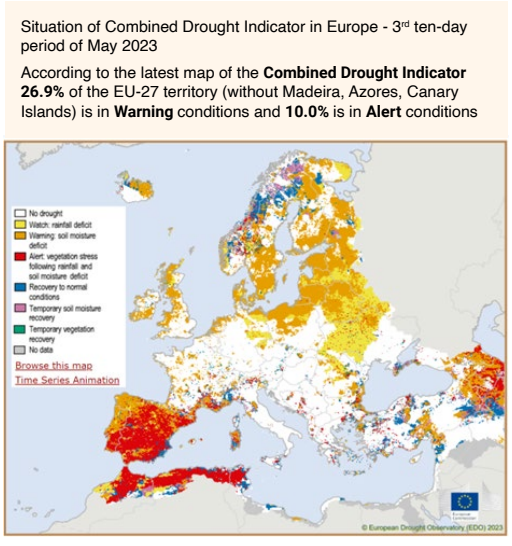
Spain is expected to be amongst the areas in the Mediterranean experiencing the most intense heat waves under climate change modeling (Molina *et al*. 2020). If current warming trends as seen between 1973-2022 continue in Spain, the country is predicted to experience a 14-20 per cent decrease in precipitation compared to the 2000-2022 average by 2050 (Roca *et al*. 2024). Such a drastic reduction would cause parts of Spain's climate to change from Mediterranean to warm steppe, as defined by the Koppen classification system.

Hot, dry conditions emerged in Europe in 2022, setting the stage for a severe drought affecting crops and the water supply through 2024. According to the European Union's Copernicus Climate Change Service, 2022 was Europe's hottest summer ever recorded, edging out the record set in 2021 (Copernicus 2023). The Global Drought Observatory, run by the European Commission's Joint Research Centre, reported in July 2024 that southern and south-eastern Europe were suffering the greatest impacts to water resource availability (European Commission JRC 2024).

Spain was among several European Union Mediterranean countries that experienced poor harvests, heatwaves, and domestic water restrictions due to the drought. Low precipitation and high temperatures that started in 2022, the warmest year on record for Spain (Copernicus 2023), extended into the new year. Spain received just 36 per cent of its average March rainfall in 2023, while record-breaking April temperatures reached nearly 39°C (Pleitgen *et al*. 2023). By late May 2023, most of Spain was under "Alert" conditions as defined by the European Drought Observatory's Combined Drought Indicator (Figure 7).

FIGURE 7
Drought alert conditions covered most of Spain in May 2023.

Source: European Drought Observatory.



Severe drought continued across the Mediterranean region into 2024 with precipitation deficits and record-high temperatures in January (Toreti *et al*. 2024b). As a result, 45 per cent of southern Europe experienced low soil moisture early in the year. Areas of southern Spain were particularly hard hit, and water shortages and poor harvests were seen across the country due to the drought.

Water shortages

Concerns about water supplies in 2023 prompted the Spanish government to invest €22.84 billion into a project involving 6,500 measures modernizing irrigation and improving their water supply, among other water management and conservation goals (Council of Ministers 2023). The average amount of available water in Spain had decreased by 12 per cent between 1980 and 2023, with predictions of a further decrease of 14-20 per cent by 2050. Desalination plants, irrigation efficiency programs, and water reuse plans were among the strategies implemented to mitigate the effects of dwindling water supplies. Catalonia and the southern coast of Spain were two of the regions most affected by water shortages between 2023 and 2024.

Catalonia

Northern Spain began 2023 with a winter heatwave amid a historic drought—Catalonia's worst since 1905 (Edwards and Gretener 2023). With minimal rainfall over 25 months, the Ter-Llobregat water system dropped to 27 per cent capacity.

Pre-existing water restrictions in Catalonia consequently escalated in February 2023, affecting nearly six million people (McMurty 2023). Agricultural producers were required to reduce by 40 per cent while domestic users were restricted to 230 liters of drinkable water daily, which still exceeded the average daily use of 116 liters (Wilson and Morenatti 2024). By April, several villages needed water trucked in as reservoirs averaged an unusually low level of 25 per cent full (Pleitgen *et*

Some communities were losing **70%-80%** of their water due to leaks.

Only **25%** of municipalities with more than 20,000 residents had a drought plan in place.

al. 2023). The Sau reservoir, which is a major source of drinking water for Barcelona, was at just 7 per cent capacity.

By February 2024, Catalonia's reservoirs dropped below 16 per cent of capacity, triggering a drought emergency declaration (LeMonde with AFP 2024). On average, the reservoirs are normally maintained at 70 per cent full (Wilson and Morenatti 2024). Catalan residents were limited to 200 liters of water per day at home. Crop irrigation was to be reduced by 80 per cent, while industrial users were required to cut 25 per cent of their consumption.

Residents of Barcelona were largely unaffected by Catalan water use restrictions, as the city benefits greatly from desalination and water purification systems that provide 55 per cent of the water used (Wilson and Morenatti 2024). Residents in smaller communities across Catalonia, however, struggled with dry wells and difficulties obtaining drinking water. The Catalan government stated in an interview that pipes in the areas needed to be modernized, as some communities were losing 70-80 per cent of their water due to leaks. Drinking water in the town of Ripoll, in northern Catalonia, was also found to contain excessive concentrations of arsenic (Catalan News 2024a).

To meet the area's water needs, Catalonia began shipping in desalinated water from neighboring Valencia (Macedonio Vega 2024). The water was not viewed as a viable long-term option, as it was expensive and would make up only 2 per cent of Barcelona's needs. Instead, environmental groups suggested increasing restrictions on agricultural water use in Catalonia and improving drought preparedness in the region. For instance, only 25 per cent of municipalities with more than 20,000 residents had a drought plan in place as of February 2024. As the drought continued through spring, Catalonia decided to temporarily install a second desalination plant in the Barcelona port (Associated Press 2024a). The new plant would support 6 per cent of Barcelona's water consumption, whereas the main desalination plant accounted for nearly 25 per cent.

Tourist industries adapted to the drought using several innovations. Several hotel owners along the Catalan coast joined together to purchase a €1.5m mobile desalination plant during the restrictions (Catalan News 2024b). The plant would be used to draw water from a well in the sand to fill pools and supply drinking water during the tourist season. Other hotels opted to use saltwater in their swimming pools instead of freshwater, while one in Barcelona mixed more air with its shower water to reduce consumption from 40 liters per minute to nine (Fruhbeck 2024). Guests also voluntarily reduced water consumption in response to education about water use but still averaged 163.5 liters per day.

Restrictions in Catalonia were eased in May after rainfall raised reservoir levels to 25 per cent (Associated Press 2024b). Farmers were still required to reduce their average use by 40 per cent, and industrial users needed to cut 15 per cent. Residents were allowed to use 230 liters per day at home, compared to the previous 200 liters.

Southern Spain

Drinking water shortages emerged in southern Spain by May 2023 (Euronews 2023). As drinking water reservoirs north of Córdoba dried up, local water companies began sourcing water from a lake contaminated with dairy manure. Residents of the nearby villages resorted to having their water trucked in to avoid the health risks associated with the tap water.

In December 2023, authorities in the Province of Málaga began putting plans for shipping in fresh water, activating the city's unused desalination plant, and repairing pipelines (Lillo 2023). Several reservoirs in the area were at record low levels, and authorities were concerned about the price of desalination, which was estimated at €10 million monthly. Fuengirola, on Málaga's Costa del Sol, turned off water completely for most homes between midnight and 7 AM starting 15 January (Trelinski 2024a). The local water company also reduced water pressure for the entire city, jeopardizing water availability for those at higher elevations. Residents were encouraged to use cisterns to store water for overnight use.

Potable water restrictions were put in place in the Campo de Gibraltar, Province of Cádiz, in early January (Gibraltar Chronicle Staff 2024). About 278,000 people were affected by the

limitations, which included drops in water pressure and nearly no water supply between 11 PM and 6 AM. Various outdoor water uses were regulated as well, with the goal of cutting water consumption by 20 per cent as the reservoirs reached critically low levels.

Along the Costa Blanca, a segment of the Province of Alicante's Mediterranean coastline, dropping water levels made tap water unsuitable for consumption as salinity increased (Manez 2024). Distribution points were set up in August 2024 for tourists and residents to receive free bottled water for cooking and drinking. Locals were prohibited from filling swimming pools, washing cars, or watering gardens due to the water shortages.

Rain in January 2025 failed to relieve southern Spain of the drought (Bostyn 2025). Málaga and Alicante still reported having critically low water reserves, while northern Spain had largely emerged from the drought by that time. The Public Sanitation and Supply Association of Andalucía warned that the Costa del Sol would need to increase its water-saving measures and continue operating under "emergency" conditions as the southern half of the country remained in a drought.

In April 2023, around **60%** of Spain's agricultural land was under drought conditions.

Agriculture

Severe drought took hold of the Iberian Peninsula in 2023 (Toreti *et al*. 2023a), causing poor crop yields, early wildfires, spikes in the price of olive oil, and layoffs in the wine industry. As part of Spain's 2023 plan for water conservation, farmers in the southeastern part of the country were subject to irrigation cuts meant to improve the ecological value of the Tagus River (Reuters 2023a). The Tagus River supplies irrigation for 70 per cent of Spain's fruit and vegetable exports. Thousands of farmers gathered in Madrid to protest the plan as an estimated 25,000 jobs were at stake. The government's solution to offset the reduced irrigation was to invest €8 billion into water recycling and desalination.

In April 2023, around 60 per cent of Spain's agricultural land was under drought conditions and 3.5 million hectares of crops had been destroyed. Wildfires started unusually early that spring, bringing fears that the season would be reminiscent of the 306,000 hectares that burned in summer of 2022 (O'Mahony and Wilson, 2023). Unusually high temperatures combined with a long-term lack of precipitation led to delayed crop sowing and forecasts of low yields for the year (Toreti *et al*. 2023a). Signs of severe vegetation stress emerged across the western Mediterranean, including failed crops and small fruits. Poor yield forecasts led some farmers to reduce the amount of land sown with summer crops.

Two years of drought and a record heatwave resulted in a 50 per cent decrease in Spain's olive crop, causing olive oil prices to double by September 2023 (Macias 2023). Olive oil thefts consequently increased 29 per cent over the 2022-2023 season in southern Spain (Wilkinson 2023). One producer near Córdoba reported that over 50,000 liters of olive oil had been stolen from their mill (El Mundo 2023).

The olive harvest for the 2023-2024 season was similarly poor, with Málaga producing even less than the year before (Stuber 2024). Málaga normally produces over 50,000 metric tons of oil but only managed 28,390 metric tons in the spring of 2024. Sunflower oil began to replace olive oil as the most popular cooking oil in Spain due to rising costs (Pons 2024). Spain is the largest producer of olive oil in the word, supplying 45 per cent of the global supply and 70 per cent of Europe's. Thus, disruptions to the Spanish olive crop can have rippling effects on food prices around the world (El Mundo 2023).

Cava wine yields in Catalonia totaled just 230 million kilos in 2023, compared to 300 million in 2021 (Waterworth 2025). Industry experts expected the 2024 yield to be even lower. In late April 2024, a producer of Spanish cava wine in the Penedes region announced plans to temporarily lay off 80 per cent of its workforce, totaling 615 people (Reuters 2024). Some of the grapevines in the affected regions were 30 years old, with their roots dying in the ground due to the drought. Wine grape production was also low in Valencia. Estimates predicted the 2024 harvest in the region to be 42 per cent below average, the smallest harvest in 30 years (Trelinski 2024).

THE AMAZON BASIN

The Amazon rainforest covers about 40 per cent of South America (Figure 8) and has been described as the lungs of the planet due to its role in removing carbon dioxide from the atmosphere. It plays a critical role in global carbon storage, hosts a wide range of biodiversity, supplies natural resources to the world, and is home to around 45 million people (Quijano Vallejos *et al*. 2020). Furthermore, moisture from the rainforest is critical to form precipitation for the rest of the South American continent (Flores *et al.* 2024).

Drought in the Amazon rainforest can have lasting impacts on the global carbon cycle. During the 2015-2016 El Niño, drought in the Amazon drastically reduced aboveground vegetation in the area, resulting in nearly 1 gigaton of carbon being released into the atmosphere (Liu *et al*. 2024). Carbon stocks in belowground biomass and the soil were still below predrought levels at the end of 2018, while the aboveground biomass took over a year to recover. The northeastern region of the Amazon, which was hit hardest by drought, was still at a cumulative loss of 0.6 gigaton of carbon in December 2018. The deficit was primarily attributed to low photosynthesis as vegetation in the area was water-stressed. In other regions of the Amazon, carbon loss was due in part to fire. Researchers raised the concern that ongoing drought could change the Amazon rainforest from a net carbon-neutral state to a carbon source.

FIGURE 8
The yellow line shows the Amazon Basin as delineated by the World Wide Fund for Nature. National boundaries are in black.

Figure via Wikimedia Commons, using NASA's Blue Marble imagery, modified by Pfly.

The Amazon serves as a critical carbon sink and a buffer against climate change (Heinrich *et al*. 2021), yet it has also been identified as a climate change hotspot (Fan *et al*. 2021). Temperatures in the region have been increasing while the amount of rainfall has simultaneously decreased. Droughts are expected to worsen in the Amazon basin as climate change continues: Recent estimates found that, by the year 2050, up to 47 per cent of the Amazon rainforest will be threatened by drought and wildfire (Flores *et al*. 2024).

Recent drought has exacerbated the ongoing deforestation and ecosystem degradation in the Amazon rainforest (Lapola *et al*. 2023). The drought of 2023-2024 was considered unprecedented and possibly the most severe, widespread drought on record for the region. Nine countries in the Amazon basin experienced extremely high temperatures and their lowest rainfall in 40 years during 2023 (Toreti *et al*. 2023b). That year, the Brazilian Amazon biome lost 3.3 million hectares of surface water relative to 2022 (Souza *et al*. 2024). The Amazon river lost nearly 60 per cent of its surface water, the most of any Brazilian state. The drought was attributed to a combination of El Niño, which commonly causes severe droughts in the Amazon, and human-induced climate change.

By September 2023, fifteen municipalities in the Amazon were in a state of emergency and around 110,000 people were experiencing the impacts of drought (Associated Press 2023c; Reuters 2023b). Drought continued through 2024 with impacts accumulating over time. Primary impacts were related to low water levels, fires, and aquatic wildlife deaths.

RIVERS AND STREAMS

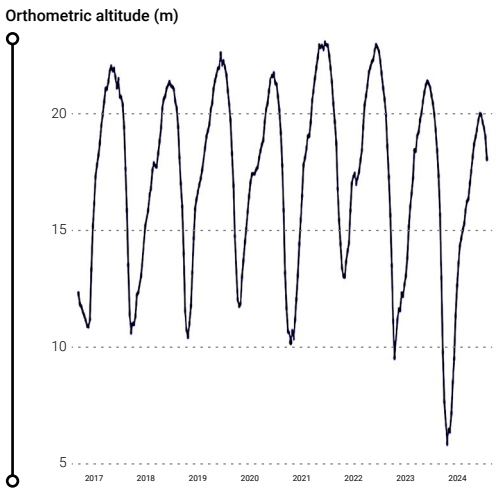
Drought impacts people in the Amazon in unique ways due to the range of purposes its rivers and streams serve. Small, isolated municipalities are particularly vulnerable (De Souza *et al.* 2024). Many communities in the Amazon are limited in their ability to access basic services during droughts as hundreds of thousands of Amazonians depend on waterways for transportation, food, and income (Hughes 2023; Santos de Lima *et al*. 2024). There are few roads in the rainforest: over 60 per cent of non-indigenous localities and 66 per cent of indigenous localities are closer to major water bodies than roads, and only 38 per cent of non-indigenous and 33 per cent of indigenous communities are within one kilometer to the nearest road (Santos de Lima *et al*. 2024). Most transportation in the Amazon is therefore conducted by boat, leaving many isolated and struggling to obtain supplies during droughts. Many residents also depend on fishing for sustenance and employment, which can be drastically affected by low water levels and high temperatures.

Waterways were at historically low levels in September 2023, impeding food and water shipments (Associated Press 2023c). Drinking water became contaminated by mass die-offs of fish that occurred because of the low water levels, particularly affecting communities that depend on fishing for subsistence. Transportation of supplies was also greatly hindered by low river levels due to high dependency on boats. The Brazilian Air Force was employed to supply food and water to the states of Amazonas and Acre (Reuters 2023b).

FIGURE 9

Orthometric altitude of the Rio Negro at the Manaus, Brazil, monitoring station. The water level dipped far below normal seasonal lows in 2023, hitting its lowest point on 27 October. Data from 30 July 2014 to 30 July 2024.

Source: HidroSat Version 2.3.0.



Some residents of the Amazon basin, such as in the town of Serafina, Brazil, were able to dig wells on their own properties to replace water from the Rio Negro they would normally depend on for drinking, cooking, and cleaning (Hughes 2023). The river was at its lowest level since records began over 100 years ago. Figure 9 shows a substantial dip in the Rio Negro's water levels at Manaus in the late 2023 beyond normal seasonal lows, reaching a low point on 27 October.

Locals reported experiencing gastrointestinal upset when they drank from the river at such low water levels. With the waterways too low to navigate, the journey to the nearest hospital increased to hours. In remote jungle villages, pregnant women were stranded and depended on traditional midwives as travel became impossible (Olivares and Andreoni 2025). Disruptions to drinking water and food supplies due to low river levels continued through late 2024 as the drought went on (Kelly 2024a).

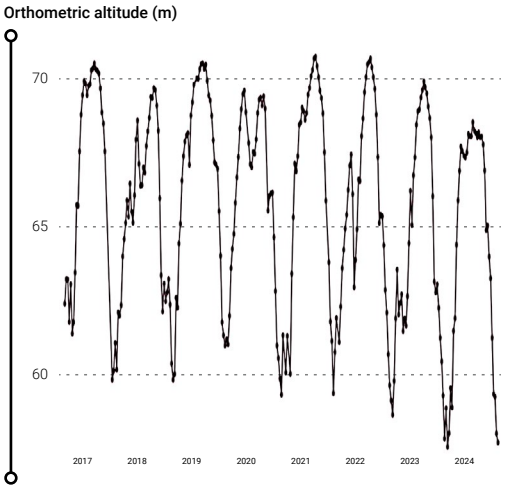
Transportation difficulties caused by the drought prompted calls for the Brazilian government to start paving roads in the Amazon (Fabio 2024). Particular attention was given to highway BR-319, which Brazilian President Luiz Inácio Lula da Silva planned to repave as part of his 2023 campaign. Researchers were concerned that paving, repairing, and maintaining roads would contribute to deforestation in the Amazonas state. Deforestation and drought interact in a positive feedback loop: deforestation decreases the amount of evapotranspiration generated by photosynthesis, which reduces the amount of rainfall both locally and across the South American continent (Staal *et al*. 2020). The resulting drought stresses plants and increases the risk of fire, further driving deforestation. Environmentalists also raised concerns about illegal side roads being built off developed highways. Their concern was not unfounded, as the previous year 5,092 km of such illegal roads were discovered along the BR-319 highway alone (Observatorio BR-319, 2023).

Drought continued to plague the Amazon region through 2024. By September, some waterways that had previously been navigable were completely dry (Silva and Benassatto 2024). Others, such as the Negro River and the Solimões River,

FIGURE 10

Orthometric altitude of the Amazon River at the Tabatinga Montante monitoring station, upstream of Leticia, Colombia. Water levels dropped well below normal seasonal lows in the spring seasons of 2023 and 2024, hitting their lowest point on 9 October 2024. Data from 12 April 2014 to 04 March 2025.

Source: HidroSat Version 2.3.0



were at historically low levels (Barros and Biller 2024; Kelly 2024b). Both the Negro and the Solimões are major tributaries of the Amazon River, which was reduced by up to 90 per cent in Colombia (Science X Network 2024). Around Leticia, the capital of Colombia's Amazonas state and a critical trade hub, boats were stranded along dry riverbed in the Amazon River. Figure 10 shows notably low water levels in the Amazon River in the spring seasons of 2023 and 2024, with the lowest point occurring on 9 October 2024.

AQUATIC WILDLIFE

Low water levels had significant effects on aquatic wildlife in the Amazon basin as well. Over 200 endangered Amazonian River dolphins and thousands of fish died over the course of a few days in September 2023 due to excessively warm water in Lake Tefe (Watts 2023). Temperatures in the lake had reached up to 39°C. September 2024 saw a repeat of the previous year, with juvenile river dolphins washing up on the shores of Lake Tefe as water levels dropped and temperatures rose once again (Reuters 2024c). Long term, these deaths may affect the species composition and functional types of fish in the Amazon basin, as was seen after the 2005 drought (Arantes *et al*. 2017).

Native Amazonian manatees were exposed to poachers due to low river levels in 2024 (Brown 2024). Manatees generally stay deep beneath the water's surface, but in shallow water they are more visible to poachers. Manatee poaching was outlawed in Brazil in 1967, but the meat is still commonly consumed in small Amazonian towns. Law enforcement and changing cultural perceptions of manatee meat have reduced the incidence of poaching and helped restore manatee populations, but the species is still vulnerable and the ease of poaching during drought threatens their numbers.

FIRES

Fires were another concern in the Amazon region during the 2023-2024 drought. A record number of wildfires, nearly 3,000, took hold in the Brazilian state of Amazonas in October 2023 (Hughes 2023). The largest city in the region, Manaus, Brazil, was affected by thick smoke from the fires. The municipality of Curralinho, Brazil, also experienced large fires in fall of 2023.

Venezuela likewise broke wildfire records in 2024, with 30,200 fire points emerging between January and March (Spring *et al*. 2024). An additional 11,434 fire spots emerged in the Brazilian Amazon in July 2024 alone (Eschenbacher 2024). Many of the fires in that area were caused by small-scale farmers who routinely use fire as an inexpensive way to manage soil acidity and prepare fields for planting (Hughes 2023). Though fire is a normal part of agriculture in the Amazon, dry conditions allowed the intentional fires to grow out of control.

PANAMA

Central America has been identified as a climate change hotspot (Fan *et al.* 2021), and Panama made headlines as the El Niño event of 2023 and 2024 worsened the effects of existing drought. Before the onset of El Niño, 2023 had been Panama's driest year on record since 1950 (Bloomberg 2023). The emergence of El Niño further reduced rainfall in the country by 8 per cent (World Weather Attribution 2024). Dry conditions impacted the Panama Canal, which is a vital part of the world's economy. The Panama Canal's toll revenues dropped by about US$100 million per month between October 2023 and January 2024 as traffic dropped by 36 per cent due to the restrictions (Reuters 2024d; Associated Press 2024c).

PANAMA CANAL OPERATIONS

The Panama Canal, an artificial waterway that transects the Isthmus of Panama, connects the Atlantic and Pacific Oceans and is critical for 5 per cent of annual international maritime trade (UN Trade and Development report 2023). Drought in the region reduced precipitation to 50 per cent of normal from February to April 2023 (Bloomberg 2023). Consequently, Lake Gatun, the main waterbody feeding the canal, dropped to exceptionally low levels (Figure 11). By May of that year, shipping restrictions due to shallow water in the canal required ships to reduce their cargo by up to 40 per cent. Water levels continued to drop throughout the summer of 2023, resulting in more weight limits and fines for those violating restrictions (John and Ward 2023; Moreno 2023). By September of 2023, Panama began seeking new sources of water for the canal to continue operating (Jara 2023).

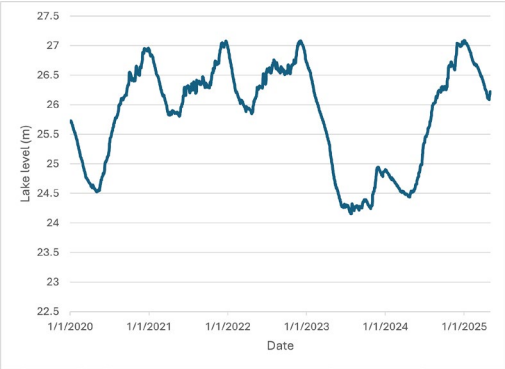


FIGURE 11
Water levels in Lake Gatun, which supplies the Panama Canal. Data from 1 January 2020 to 2 May 2025.

Source: Meteorology and Hydrology Branch, Panama Canal Authority, Republic of Panama.

International repercussions of the Panama Canal drought began in earnest in December 2023 as major holidays approached (Patrick 2023). Shipments that normally would take eight to 10 hours to pass through the canal took one to two weeks as only 24 ships were allowed per day, compared to the normal 38 ships. Some shippers began paying millions of dollars to hasten their deliveries, while other vessels were rerouted to the Suez Canal in Egypt or around South Africa's Cape of Good Hope. One Greek tanker became stuck in the shallow waters of the Panama Canal in December 2023, further exacerbating delays (Dixon 2023).

Fuel tankers out of Houston eventually began to take the long route to Chile due to the restrictions, increasing their journey from 23 days to 32 days (Somasekhar 2023). Likewise, grain shipments from the United States to Asia started to take longer in December 2023, with shipments delayed into 2024 as shippers avoided the Panama Canal due to record-high transit fees and the risk of vessels becoming stuck (Plume 2023). In the United Kingdom, fruits, vegetables, and other fresh produce increased in price and became scarcer (Milmo 2023). United States soybean shipments also slowed down due to the delays (Braun 2023). As shipping difficulties continued in the Panama Canal, a Danish company began using trains across Panama for transport (Rosen Fondahn 2024).

Rain in December 2023 allowed the Panama Canal to suspend plans to impose further restrictions the following year (Moreno 2024). In February 2024, the Panama Canal Authority confirmed that limits on daily number of vessel transits would remain through April 2025 (Prensa Latina 2024). Gatun and Alajuela, the two artificial lakes that feed the canal and provide drinking water for 4.2 million people, were still at low levels. In June 2024, the draft limit was restored to normal, and 32 vessels were allowed to pass daily (Safety-4Sea 2024).

Transits through the Panama Canal rose steadily throughout 2024, with traffic from October 2024 to January 2025 up 25 per cent compared to the same period the previous year (Labrut 2025). Following a slight dip in January 2025 (Parraga 2025), the Panama Canal Board of Directors approved funding for a new reservoir in the Río Indio basin (Schuler 2025). The six-year project aims to expand water storage capacity to better withstand droughts like the 2023–2024 event, benefiting both local communities and canal operations. The funding package includes compensation and resettlement for those affected by the development.

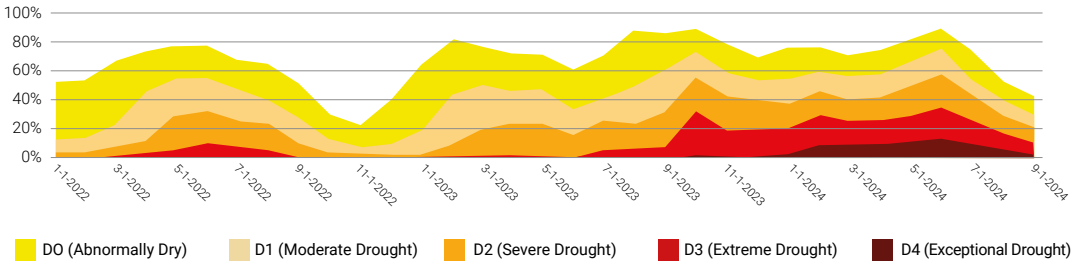
MEXICO

Dry conditions throughout 2022 and historically low rainfall in early 2023 put most of Mexico's 210 reservoirs below 50 per cent capacity by June 2023 (MND 2023). Drought affected 67 per cent of the country by September that year (Figure 12; Rainsford 2023). Above-average rainfall in December gave Mexico some reprieve, but 55 per cent of its territory remained under drought conditions in January 2024 (MND 2024). By June 2024, nearly 90 per cent of the country was in some level of drought (Reuters 2024e). The states of Chihuahua, Durango, Guanajuato, Hidalgo, Querétaro, San Luis Potosí, Sinaloa, and Tamaulipas were in "extreme" or "exceptional" drought at that time. Impacts were felt across the country, with Mexico City's water supply and Mexico's agreement to share water from the Rio Bravo/Rio Grande with the United States dominating headlines.

FIGURE 12

Percent area of Mexico in various categories of drought from January 2022 to September 2024.

Retrieved from the North American Drought Monitor 13 October 2024.



MEXICO CITY

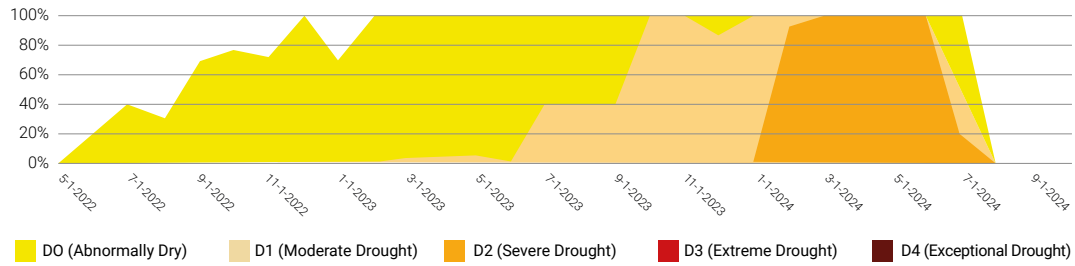
Mexico City spent over two years under drought conditions, leaving residents without reliable running water for several months in late 2023 and early 2024 (Figure 13; Paddison *et al.* 2024a). The rapidly growing city, currently home to around 22 million people, has dealt with abnormally low rainfall and high temperatures in addition to leaky water infrastructure for several years. Mexico City's water system has substantial existing troubles: Over-extraction of the Mexico City's aquifer, which supplies residents with 60 per cent of their water, has caused the city to sink 50 cm per year since at least 1950 (Chaussard et al. 2021). The remaining water supply is gathered through system that loses about 40 per cent to leaks (Dirección General de Comunicación Social - UNAM, 16 December 2022).

The recent drought in Mexico City amplified the ongoing effects of climate change and leaky infrastructure in the area. Fears of "day zero," a point at which the city would run out of water, emerged as Mexico City's water supply system reached a record low of 39 per cent capacity and 90 per cent of the city was in a severe drought (Bnamericas 2024). Officials criticized predictions of a June 26th "day zero," while some emphasized that the use of the term was effective in accomplishing water conservation during a similar situation in South Africa in 2018 (Bittle 2024).

FIGURE 13

Percent area of the Distrito Federal, Mexico, in various categories of drought from May 2022 to July 2024.

Retrieved from the North American Drought Monitor 3 May 2025.



WATER-SHARING TREATY

Mexico's struggles to obtain sufficient water for its inhabitants, livestock, and crops were exacerbated by an upcoming deadline on a water-sharing treaty with the United States. Under the 1944 Treaty, Mexico is obligated to share 1.75 million acre-feet of water from tributaries of the Río Bravo del Norte (known in the United States as the Rio Grande) with the United States every five years (Pskowski 2023). The next deadline is October 2025.

Water shortages along the Rio Grande basin have become more common due to drought and climate change, however. The United States Bureau of Reclamation reported in 2021 that temperature increases in the basin since 1970 have been twice the global average (USBR 2021). Temperatures are expected to rise by another 2.2 to 5.5°C by the end of the 21st century. By 2050, regional changes in precipitation and temperature could cause annual runoff in the Conchos basin, the largest tributary to the Rio Grande, to decline by up to 25 per cent.

With less than a year and a half remaining until the 2025 deadline, Mexico had delivered less than 30 per cent of the required water and was in the midst of a drought in May 2024. La Niña conditions from 2022 to 2023 had caused a precipitation deficit to the northwest region of Mexico (Thiem 2024) and nearly the entire state of Chihuahua had been in a state of drought since August 2023 (Figure 14). Mexico's major tributary to the Rio Grande, the Río Conchos, runs through Chihuahua and was affected by the dry conditions. At the end of May, 40 per cent of the state was in "exceptional drought," the most severe designation. Texas farmers dependent on the water had to either reduce their irrigated acreage or purchase water from other sources.

Local politicians and farmers expressed concern over how the 1944 Treaty obligations would be filled, given the ongoing drought in northern Mexico (Pskowski 2023). Farmers on both sides of the river are highly dependent on irrigation to make a living in the Chihuahuan desert. In 2020, the last time the five-year deadline came,

FIGURE 14

Percent of Chihuahua, Mexico, in various categories of drought from May 2023 to March 2025.

Retrieved from the North American Drought Monitor 3 May 2025.

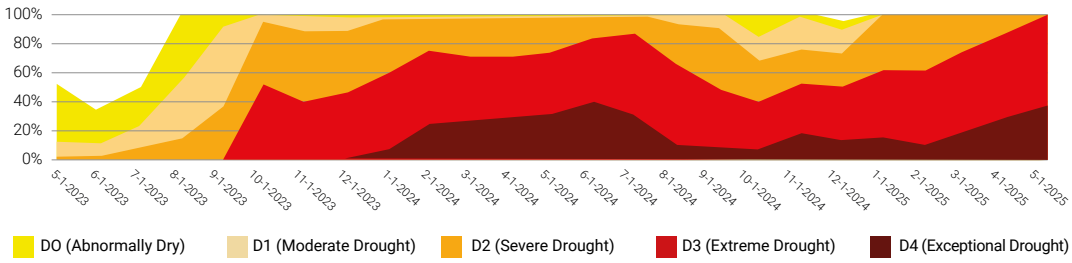


FIGURE 15

Reservoir storage in Falcon Reservoir from 1956 to May 2025.

Retrieved from https://waterdatafortexas.org/reservoirs/individual/falcon

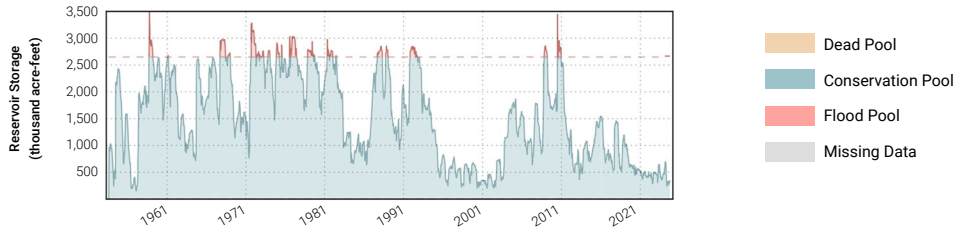
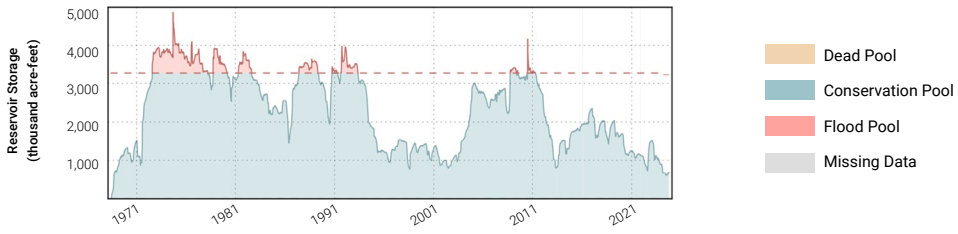


FIGURE 16

Reservoir storage in Amistad Reservoir from 1971 to May 2025.

Retrieved from https://waterdatafortexas.org/reservoirs/individual/amistad



protests erupted in Mexico as the government sent reservoir water to the United States instead of keeping the supply for Mexican farmers. Thousands of Mexican farmers and their supporters gathered at the dam, pushing out the National Guard who had been sent to protect it. One demonstrator was killed in the process.

Texans felt the effects of Mexico's delayed water payments in 2024. Due to a lack of irrigation water from the Rio Grande, Texas's only sugar mill announced in February that it would close that year (Del Valle 2024). The closure cost 500 people their jobs and cut around US$100 million a year from the Rio Grande Valley's economy. Several Texas towns enacted Stage 2 water restrictions, while Laredo entered Stage 3 restrictions in June (Sanchez 2024). Both major international reservoirs along the Rio Grande were extremely low in 2024: Falcon Reservoir was just over 9 per cent full in May (Figure 15; Water Data for Texas, n.d.); Meanwhile, Amistad Reservoir was historically low at less than 25 per cent full on July 17 (Figure 16; Water Data for Texas, n.d.).

Northwest Mexico's exceptional drought persisted into early 2025 (MND 2025), intensifying tensions as the deadline for the1944 United States–Mexico water-sharing treaty approached.

As of April, Mexico still owed the United States roughly two-thirds of the required 1.75 million acre-feet due by October. While President Claudia Sheinbaum of Mexico pledged immediate deliveries to avoid sanctions, governors of three Mexican border states—Coahuila, Chihuahua, and Tamaulipas—opposed fulfilling the water payments. The governors insisted that domestic needs must take priority as water was drawn from the Amistad Dam. They argued that meeting the treaty's obligations was unfeasible under current drought conditions and noted that the agreement includes provisions for waiving debt during such emergencies.

Mexico was not solely responsible for dwindling water supplies in the Rio Grande, as reported by the International Boundary and Water Commission in August 2024 (Garcia 2024). Inflow from the United States to the Amistad International Reservoir was 33 per cent lower from 2011 to 2020 than it had been from 1981 to 1990. Likewise, the Falcon International Reservoir received 21.5 per cent less water between 2011 and 2020 from the United States than it had in the 1980's. The United States commissioner for the International Boundary and Water Commission stated that the Rio Grande provides 90 per cent of the region's water supply. To ensure water in the future, both sides of the border would need to build drought resilience and seek alternate sources of water. To that end, the United States pledged to dedicate US$60 million to projects along the Rio Grande in New Mexico and Texas (Montoya 2024).

An expert who studied the 1944 Treaty urged both countries to seek solutions to the heart of the problem: the overuse of and dependence on irrigation in the Rio Grande and Río Conchos basins (Pskowski 2023). The Río Conchos had been overallocated by Mexico's National Water Commission and could not meet the needs of all farmers and businesses who had been promised water. Environmental groups and other researchers likewise stressed the importance of transitioning away from irrigation agriculture in the desert climate so basic human needs could be met. Other experts highlighted the importance of altering the water sharing agreement to adapt to the current climate, which has changed drastically since the treaty's inception eighty years ago (Paddison and Gutierrez 2024b).

SOUTHEAST ASIA

Asia's climate is warming faster than the global average, and southeast Asia has been identified as being one of the most vulnerable regions to climate change (Sentian *et al*. 2022; WMO 2024); Southeast Asia has a large population that is highly dependent on agriculture and is subject to severe precipitation extremes. Under climate change, temperatures are expected to increase in southeast Asia, while precipitation is expected to decrease. El Niño events are associated with temperature increases and drought in southeast Asia, which can have devastating impacts on the region (Thirumalai *et al*. 2017). The strong El Niño that emerged in 2023 affected water supply and agriculture in southeast Asia. Viet Nam, Thailand, Malaysia, and Indonesia were prominent in news headlines during the 2023-2024 drought.

RICE, COFFEE, AND SUGAR SUPPLIES

Drought conditions due to El Niño in Southeast Asia had widespread impacts on food prices and supplies, including rice, coffee, and sugar. Warnings of a global rice shortage emerged in April 2023, when industry analysts noted decreasing production around the world (Thornton 2023). By November that year, reports emerged stating that Indonesia, the largest economy in Southeast Asia, was importing rice from Thailand, Viet Nam, Pakistan, and Myanmar to make up for its deficit that resulted from extreme El Niño-related drought conditions (Xinhua News Agency 2023; Pattaya Mail 2023).

Statistics Indonesia reported that the price of rice was the largest contributing factor to inflation in Indonesia from August to October 2023 (Xinhua News Agency 2023). Around 21.3 million families were expected to receive rice assistance in addition to 18.8 million who would receive financial aid. Rice prices stayed high throughout the rest of 2023 and into early 2024 (Barends 2024). To help curb prices, support farmers' income amidst low exports, and stabilize the food supply, Indonesia's military helped plant rice in December 2024 (Christina 2023).

Robusta coffee futures set a record high price in April 2024 (Asplund 2024). Dry conditions in Viet Nam drove robusta prices up due to concerns about a poor harvest. Viet Nam is the world's largest producer of robusta coffee, and their agriculture department expected the 2023-2024 crop to be 20 per cent lower than average - the smallest in four years - due to drought. Warning signs of a poor robusta harvest emerged again in June 2024 as Viet Namese coffee trees were stunted by heat, drought, and a pest that thrives in such conditions (AFP 2024b). Viet Nam's Coffee and Cocoa Association expected the 2024-2025 crop to be 15-20 per cent lower than normal when harvesting started in October.

Sugar supplies likewise fell due to the 2023-2024 El Niño as drought hit the Thai sugar industry. Thailand is the second-largest producer of sugar worldwide, and farmers in the region experienced a 12.4 per cent decrease in harvest in the 2023-2024 crop year compared to 2022-2023 (Apisitniran 2024). Global sugar prices in January 2024 had risen to their highest since 2011 due to dry conditions in both Thailand and India, triggering an 8.9 per cent increase in the price of sweets and sugar in the United States in the previous year (Millman 2024; USDA, n.d.).

SALINITY IN THE MEKONG DELTA

Saltwater intrusion plagued the Mekong Delta area of Viet Nam in early 2024 (Nam 2024). In February, tap water in the Ben Tre Province was too saline for drinking or cooking, a phenomenon seen previously during the 2019-2020 drought. Some households had obtained cement ponds and plastic reservoirs to store freshwater to last through the dry season. Freshwater was also available through local services in case water factories were unable to provide enough by the time families' private storage contains ran out. At the time, 13,000 families served by the Ben Tre Center for Clean Water and Rural Environmental Sanitation were using water with salinity levels above 1/1,000. The usual standard salinity level is 0.5/1,000.

By April, around 30,000 families in the Go Cong Dong District of the Tien Giang Province were short of water for domestic use due to the drought and saltwater intrusion (Tung 2024). Water was brought from Ho Chi Minh City and the Long An Province and distributed for free among residents of Tan Phuoc Commune. More than 60 public water taps were available in the province, but demand was so high that trucks had to be dispatched to provide additional free water to locals. The Tan Phuoc Commune, home to thousands of families, does not have tap water, so residents normally drink rainwater and use a canal for other purposes. Thus, ongoing drought and the lack of rain left the commune with no water. The province planned to install 50 more public taps in the coming months.

Drought and salinity in the Mekong Delta had wide-ranging implications for food security in Viet Nam (Binh 2024). Over 20 million people depend on the rice grown in the Mekong Delta, garnering the region the nickname "the rice bowl." Dams built upstream on the Mekong River in China, Lao, and Cambodia limit the amount of water that reaches the delta, allowing saltwater to intrude during drought years. During previous droughts, hundreds of thousands of hectares of rice and other crops were lost to dryness and salinity.

An early heatwave in southern Viet Nam saw February temperatures reach 38°C, which normally does not occur until April or May (AFP 2024). Viet Nam was in the grips of an abnormally long dry spell due to the combined effects of El Niño and climate change when the unusual heatwave emerged. A farmer in Ca Mau province stated that he was unable to transport his rice crop as more than 80 canals had dried up in the Tran Van Thoi district. In addition, around 340 cases of subsidence and landslides occurred due to farmers pumping water for irrigation.

The Mekong Delta drought impacted shrimp farmers as well (SGGP 2024). Heat, lack of water, and salinity contributed to the deaths of many shrimps, despite the farmers' efforts to pump freshwater to save them. Some of the shrimps perished in the saline tap water caused by the saltwater intrusion, while other farmers were unable to obtain water at all. The Agriculture and Rural Development Department of Kien Giang Province was helping farmers sell their healthy, mature shrimp quickly to minimize the financial damage caused by the weather. Farmers were also provided with chlorine to clean ponds that had been affected by the die-offs.

The dry season arrived early in 2025 in Viet Nam's Mekong Delta, bringing drought and salinity intrusion to the region again (SGGP 2025). Although authorities and local communities acted on early meteorological warnings, February 2025 salinity levels surpassed those of 2024. Residents undertook measures such as renovating ditches, constructing temporary reservoirs, digging wells, and storing fresh water in an effort to reduce losses compared to last year. Despite these efforts, an estimated 90,000 to 110,000 hectares of fruit crops, rice fields, and aquaculture were expected to be affected by drought and salinity in 2025.

WATER SUPPLY SHORTAGES

Indonesia encountered severe water shortages in 2023, leading to desperate conditions. After four months without rainfall in Karanganyar village, Central Java province, wells had dried so locals resorted to digging in dry riverbeds to obtain water for drinking, washing, and irrigation (Purwanto and Purnomo 2023). Many residents gathered to collect water in this way, which took one to two hours. The water they took away was salty, muddy, and less than ideal for the purposes for which it was needed, but it allowed locals and their crops to survive the extreme circumstances.

By October 2023, 113 traditional villages in the province of Bali, Indonesia, were faced with severe shortages of clean water due to the extreme drought in addition to forest fires (Coconuts Bali 2023). The governor of the province implemented a two-week state of emergency. Meanwhile, the Bali Provincial Disaster Management Agency submitted a request to implement weather modification technology like cloud seeding to help alleviate the effects of the drought (Daily Sabah 2023c).

Around 150,000 residents from 40 villages in Papar, Malaysia, experienced water shortages as well in March 2024 (Daily Express Malaysia 2024). A drought emergency was declared in the district as businesses and residents lacked clean water amid high temperatures. Although El Niño and its associated drought were largely to blame for the water supply issues, failing water infrastructure in the region exacerbated the situation, leading to weeks of dry taps in Papar (Sipalan 2024).

High-end tourist areas of Thailand also began experiencing water shortages and rationing in spring 2024, shortly before the hottest part of the year. Phi Phi Island, Thailand, faced such an extreme water shortage over several months that large businesses and hotels considered shutting down as their supplies emptied (Boyle 2024). Households and businesses were unable to attain tap water from the local private company, leading them to rely on wells or purchase raw, or untreated, water.

Water service was interrupted for several days across Hua Hin Municipality, a beach resort town and popular tourist destination near Bangkok, in April 2024 (Hua Hin Today 2024).

The waterworks department restored water service, but limited distribution to 5:00 a.m. to 10:30 a.m. The town's mayor coordinated with local agencies to distribute additional water supplies to residents through water trucks, but the municipality urged residents to conserve water as nearly 7,000 households faced acute water shortages.

Another Thai tourist destination, Koh Larn Island, experienced water shortages as a surge of tourists arrived on the island amidst the prolonged drought (Pattaya Mail 2024). The island hosted an average of 10,000 visitors daily since reopening after COVID-19 restrictions, and businesses and hotels were faced with high water prices to meet the needs of their customers. Pattaya City coordinated distribution of water to inhabitants of the island using mainland water supplies and made plans for piping water to residents in addition to increasing seawater desalination.

CONCLUSIONS AND POLICY RECOMMENDATIONS

Drought during 2023 and 2024 affected a wide range of climate change hotspots from southern and eastern Africa to the Mediterranean, the Amazon Basin, Panama, Mexico, and southeast Asia. The El Niño–Southern Oscillation (ENSO) played a role in the drought's severity in many of the areas we identified. Despite El Niño's official end in May 2024 (NASA Earth Observatory 2024b), the impacts of the droughts continue to affect these regions into 2025.

Water supply shortages, agricultural failures, and power rationing were common impacts seen around the world. Global trade and education were disrupted as well, while in southern and eastern Africa thousands of people lost their lives to drought-induced famine. In many of the drought news stories, failing infrastructure and inefficiencies in water delivery systems were cited as critical contributors to water shortages. Women and girls, indigenous populations, and isolated or rural communities emerged as being particularly vulnerable to drought impacts due to cultural norms, limited access to aid and other resources, and financial dependence on agriculture.

RECOMMENDATIONS

Future drought risks will be shaped by environmental and societal changes, including trends in sustainability, globalization, demographics, and innovation. Without major reductions in greenhouse gas emissions, rising temperatures will lead to more frequent and severe droughts by increasing heat, evaporation, and shifting precipitation patterns. Meanwhile, urbanization, land use changes, and population growth will further strain water resources and alter which assets and regions are most exposed to drought impacts. Societies' vulnerability to drought and their resilience to impacts will depend on their ability to strengthen ecosystems, implement changes in water management, and ensure equitable resource access.

As water shortages grow more frequent and severe, addressing drought effectively will require immediate action that involves systemic, cross-sectoral solutions and international cooperation. Decision-making must be iterative, continuously informed by monitoring and learning, and engage diverse stakeholder values. Investments in early warning systems, knowledge-sharing, sustainable water management, innovative agriculture, and community engagement are critical for building resilience. Effective drought mitigation strategies will involve reducing water demand and preparing for drought, while ensuring underserved communities are included in decision-making to address inequalities.

Reducing demand

Efforts to reduce water demand should prioritize equitable, sustainable strategies rather than punitive measures like tariffs, which often disproportionately harm underprivileged communities (Bruhl and Visser 2021). Agriculture, hydropower, and water transport systems are major sectors where policymakers and stakeholders can focus on substantially reducing water demand.

Agriculture is the largest global consumer of freshwater, so reducing agricultural water demand is critical. Governments and farmers are encouraged to identify high-water-use crops and promote alternatives that are more water efficient, including indigenous plants, which also support soil health, biodiversity, and economic opportunities for women (Chivenge *et al*. 2015). As conditions deteriorate, migration from drought-affected areas may increase. Countries that rely on hydropower are highly vulnerable to devastating impacts during severe droughts. As seen during the 2023-2024 El Niño, losing power can threaten healthcare, small businesses, hygiene,

and education. Diversifying renewable energy sources can help improve drought resilience by reducing dependence on hydropower (Luo and Kiwara 2025). Transitioning to solar, wind, and geothermal power can increase energy security while simultaneously making more water available for agriculture, drinking, and sanitation. Kenya is provided as an example of a country that has improved its drought resilience by diversifying its energy sources away from hydropower dependence (Heinrich Boll Stiftung 2012).

Inefficient water transport systems lose substantial amounts of freshwater and represent an opportunity for governments and individuals to maximize the water resources available to them. As much as 40 per cent of water in Mexico City (DGCS-UNAM 2022), 60 per cent in parts of the U.S (Webber 2024), and 80 per cent in small Catalan communities (Wilson and Morenatti 2024) is lost to leaks. Investing in repairs, replacing toxic pipes, and employing innovative solutions can drastically reduce waste and ensure water quality.

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Preparing for drought

Recognizing and planning for the inevitable impacts of droughts, especially under climate change, is essential for effective drought planning. Governments are encouraged to develop and maintain drought plans that include proactive mitigation measures, clearly defined roles and responsibilities, and action triggers based on continuous monitoring. Vulnerability assessments, early warning systems, and improved data collection are crucial tools for water resource planning and effective responses to shortages. For instance, many localities currently do not monitor groundwater abstractions, and implementation of programs to measure aquifer levels and groundwater use would help produce a more accurate depiction of water use (UN WWDR 2022).

Part of planning for future droughts should include re-evaluating the feasibility of current practices. Water sharing treaties, such as the 1944 Treaty between Mexico and the United States, that seemed viable when they were created may no longer be sustainable due to climate change, population growth, and increases in water needs where they were implemented (Paddison and Gutierrez 2024). Likewise, the sustainability of current agricultural practices in some regions should be re-evaluated. Arid regions that previously employed extensive irrigation may need to adjust their agricultural operations to better suit modern climate patterns.

Nature-based solutions can offer proactive, sustainable ways to manage drought risks while supporting biodiversity and community well-being (EC JRC and UNCCD 2024; Magero *et al*. 2024). Strategies such as agroforestry, soil management, wetland restoration, and urban green infrastructure can enhance water conservation and reduce vulnerability while generating US$27 for every US$1 invested (Thomas *et al*. 2024). Nature-based solutions that prioritize land restoration should be integral to broader adaptation strategies alongside existing drought planning and resilience frameworks (EC JRC and UNCCD 2024; Magero *et al*. 2024). A comprehensive guide to nature-based solutions to drought can be found through the International Union for Conservation of Nature and Natural Resources (IUCN) (Magero *et al.* 2024), and a detailed analysis of the economic benefits of these strategies, including case studies, is available from the website of the United Nations Convention to Combat Desertification (UNCCD) (Thomas *et al*. 2024).

Managing drought under climate change demands integrated approaches that combine land and water management with governance reforms, such as community-based water management, insurance schemes for farmers, and water trading programs (EC JRC and UNCCD 2024). The timing of actions taken may depend on the severity of drought conditions, but early implementation and proactivity, as opposed to reactivity, will be key to minimizing damage. For instance, early actions include improvements in water resource management, conservation practices, and land-use planning. As conditions deteriorate, measures such as migration from drought-affected areas may be necessary.

Ultimately, all strategies will face limits under severe climate warming, leading to unavoidable losses and trade-offs, particularly regarding water allocation. Section 4.4 of the World Drought Atlas, produced by the

European Commission (EC) and UNCCD, offers detailed management strategies for reference, encompassing major themes of water resource management, land-use management, and policy.

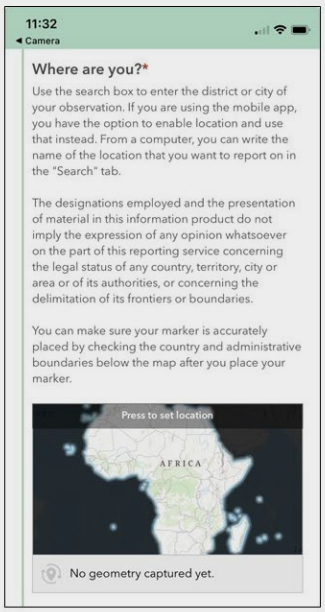
Community engagement

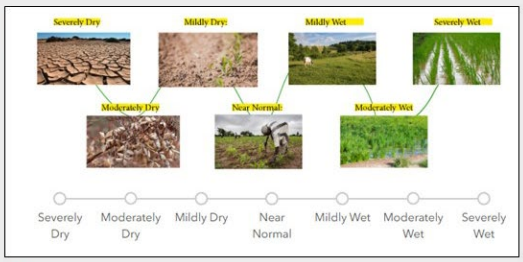
Throughout all steps of the drought planning, mitigation, and response processes, clear communication and engagement with the community are necessary. Public education and awareness campaigns are vital to foster support for drought resilience and water-saving initiatives. Importantly, women, indigenous and rural communities, and other underserved populations must be actively engaged in water policy decisions and drought impact monitoring to ensure equitable, comprehensive, and effective drought solutions.

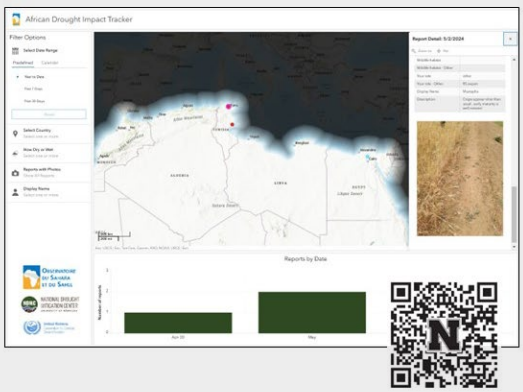
The Drought Impact Tracker

Technological advancements provide new opportunities for farmers, herders and other people on the land to share information and experiences. In December 2024 the UNCCD, the United States NDMC and the Sahara and Sahel Observatory demonstrated a prototype system for crowdsourcing landscape observations related to drought impacts in Africa. The Drought Impact Tracker, Figure 17) is based on the Condition Monitoring Observer Reports system in the United States Each dot on the map represents a report submitted by an observer. Observers can submit reports from a mobile device or computer. Observations include date, location, a seven-point dry-to-wet assessment, checklists of possible conditions grouped by sector, and the opportunity to upload up to five photos and a description.

In many ways, deploying the technology is the easier part of the challenge. The more intensive work is in forging understanding between the people on the ground who are contributing their time and energy, and the decision makers or audience for the map. Observers need to know and experience the benefits of their contributions. By using the Drought Impact Tracker, individuals affected firsthand by droughts can play an active role in informing scientists and policymakers of conditions and impacts in real-time.







The Drought Impact Tracker is a prototype system for collecting drought-related observations from farmers, herders, and others on the land. Their observations appear immediately on a map.
The prototype was unveiled in December 2024 by the UNCCD, the NDMC, and the Sahel and Sahara Observatory.

https://go.unl.edu/droughtimpacttracker

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