Brazil is in water crisis — it needs a drought plan

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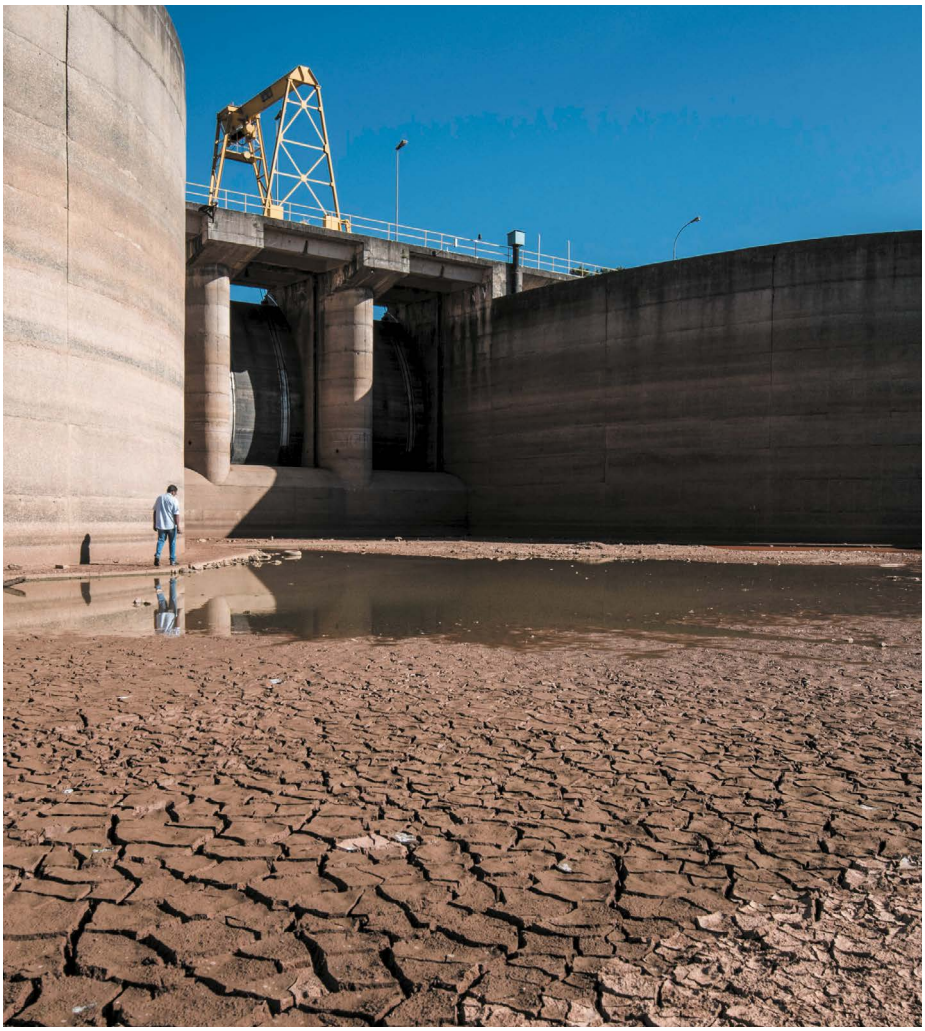
To avoid crop failures and soaring power costs, Brazil needs to diversify sources, monitor soil moisture, model local hydroclimate dynamics and treat water as a national security priority.



PAULO FRIDMAN/BLOOMBERG/GETTY

Jaguari dam is part of the Cantareira system that supplies water to São Paulo, Brazil.

Brazil has the largest amount of fresh water in the world. Two-thirds of what flows in the Amazon River alone could supply the world's demand. Yet much of the nation now faces drought.

It's the worst in many decades in a nation that grows more than one-third of the world's sugar crops and produces almost 15% of the world's beef.

This year, between March and May, dry weather in Brazil's south-central region led to a 267 km^3 shortage of water held in rivers, lakes, soil and aquifers, compared with the seasonal average for the past 20 years (see 'Brazil dries out' and 'Low water mark'). The result? Many major reservoirs have reached less than 20% capacity. Farming and energy generation have been hit. Since July, coffee prices have risen by 30% — Brazil accounts for one-third of global exports. Soya bean prices rose by 67% from June 2020 to May this year. And electricity bills have soared by 130%. Many cities face imminent water rationing.

How has this happened? And what needs to be done?

Worldwide climate change is making droughts more intense and more frequent. Deforestation in the Amazon is a contributor locally and globally. The hydroclimate in the south-central region — the engine of 70% of Brazil's gross domestic product (GDP) — is partly controlled by moisture transfer from the rainforest. Atmospheric fluxes caused by tree transpiration — also known as 'flying rivers' — might contribute as much water per day in rainfall as the Amazon River itself carries. Cutting down these trees reduces precipitation over those areas, as well as eroding a crucial global carbon sink.

For decades there has been a governmental failure to recognize drought as a matter of national and international security. Brazil's water crisis is a world crisis. What's needed is a coordinated nationwide drought-mitigation plan crafted by researchers, policymakers, industry, the public sector and civil society. Here are some key points that such a plan should address; these points are supported by 95 Brazilian and international water and climate scientists (see Supplementary information for list of co-signatories).

Vast reserves

About 20% of all global inland water flowing to the oceans is generated in Brazilian territory[1]. This fuels the country's welfare and economic growth. About 85% of the nation's fresh water needs are supplied by surface waters — rivers and lakes[2]. In the United States, that figure is 75%; in India, it is 60%.

Brazil has the world's second-largest installed hydropower capacity, at 107.4 gigawatts (GW); it produces 65% of the country's electricity. Two-fifths of this is generated in the Paraná River Basin, where river discharges have fallen to their lowest levels in 91 years. The country has had to revert to burning fossil fuels and biofuel, passing the higher costs onto consumers. Thermal power produced 13.2% of the nation's electricity in July 2021, the highest in its history.

In a nation dependent on agriculture for almost one-quarter of its GDP, crops such as soya, coffee and sugar cane, and livestock use much of the water. Irrigation feeds about 13%

of the cultivated land[3], drawing down 68% of total water consumption — some 68.4 billion litres per day[4].

But water is not equally available across the country, nor over time.

Different droughts

Water crises can originate from many types of drought: meteorological, hydrological, agricultural and socio-economic.

Meteorological droughts are dry weather patterns due to periods of little rainfall or high temperatures, which increase evaporation rates. These can cause hydrological droughts, water shortages on land surfaces such as rivers and lakes.

Agricultural droughts — a decline in soil moisture levels — can result. These can jeopardize crop yield and increase food insecurity. Shortages to the domestic and industrial supply — socio-economic droughts — can also follow. This might lead to rationing, disease, conflict and migration. It could also bring water-intensive processes such as concrete and steel production to a halt.

These different droughts can interact in complex and non-linear ways. Hydrological droughts, for example, are intensified when prolonged periods of low soil moisture begin to dry out shallow aquifers. This can drop their levels below riverbed elevations, interrupting river–groundwater connectivity. Depleted rivers or lakes can then have a knock-on effect on reservoir levels, triggering a socio-economic drought.

Human fingerprint

The 2021 Intergovernmental Panel on Climate Change (IPCC) report highlighted that unabated regional land-cover change and global warming are causing a cascade of persistent dry conditions around the globe[5]. Studies suggest an extended dry season in most of central South America under an extreme, but not unlikely, scenario[6].

Decades of deforestation of the Amazon has led to vast knock-on effects. Cutting down trees, as well as slashing the amount of moisture transported from the rainforest towards central-southern Brazil[7], is the main driver of fire[8]. The particulate matter released into the upper air alters the formation of rain clouds[9].

Improper land use can worsen droughts, too, and even cause rivers to run dry. Intensive cattle farming leads to unvegetated land and compacted soils. As well as decreasing the amount of moisture given off by plants, it limits the soil's capacity to retain water and recharge aquifers.

But droughts alone don't explain the recurrence of water crises in Brazil. Failure to treat water as an essential national resource has led Brazil to a long history of mismanagement. Science denialism is now promoted at the highest levels around the country[10,11]. And national policies have driven increasingly erratic land occupation by agribusiness and mining interests, increasing deforestation and wildfires and undermining climate mitigation[12–14].

As the country plunged into severe water shortages in 2014 and 2015, the Brazilian Academy of Sciences upbraided state authorities for failure to take swift, bold actions and for a lack of transparency about the gravity of the situation[15].

Six years have passed and not much has changed. This time around, the country's economy is recovering to pre-pandemic levels. Economic growth requires extra energy to power production. With the current hydropower situation, this demand might have to be met by burning biofuel or fossil fuel.

Research priorities

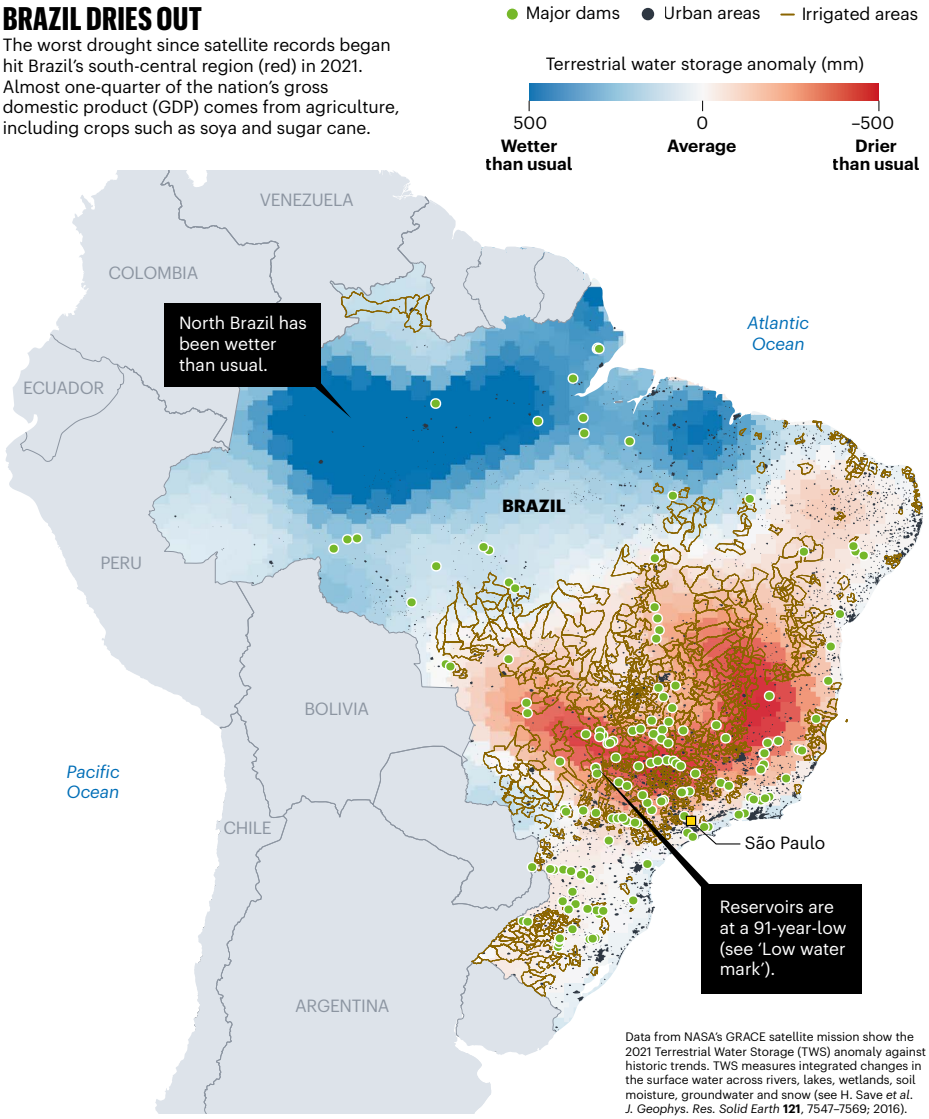
The nation's groundwater and meteorological monitoring is sparse and insufficient to properly track water variability and availability across the country. Brazil monitors groundwater at 409 sites nationwide; to put that into perspective, the North American and Indian networks have more than 16,000 and 22,000 sites, respectively. There are no nationwide systems in place to track soil moisture in Brazil, and monitoring of water use is patchy.

Governance of these networks must be strengthened, and more effective guidance on how to respond to future crises is needed. Monitoring networks are currently operated across different national agencies and departments, often leading to duplicated efforts and inefficient data access. Drought monitoring initiatives developed in Brazil through international partnerships, such as the Monitor de Secas, have been emerging in recent years. However, reducing delays to the availability of data, and improving accuracy and inaccessibility for end-users, such as farmers and local water departments, would make these initiatives more useful.

There needs to be more investment into high-quality, readily available data and computing power — the key ingredients for multidisciplinary drought research. Tupã — Brazil's most powerful supercomputer at the Brazilian National Institute for Space Research (INPE) is nearing the end of its life.

BRAZIL DRIES OUT

The worst drought since satellite records began hit Brazil's south-central region (red) in 2021. Almost one-quarter of the nation's gross domestic product (GDP) comes from agriculture, including crops such as soya and sugar cane.



Data from NASA's GRACE satellite mission show the 2021 Terrestrial Water Storage (TWS) anomaly against historic trends. TWS measures integrated changes in the surface water across rivers, lakes, wetlands, soil moisture, groundwater and snow (see H. Save *et al. J. Geophys. Res. Solid Earth* **121**, 7547–7569; 2016).

SOURCE: H. SAVE *ET AL. J. GEOPHYS. RES. SOLID EARTH* **121**, 7547–7569 (2016)

Funds from the United Nations have provided temporary access to alternative computers, but these are not powerful enough to perform hydrometeorological forecasts and climate predictions. US$20 million of federal funds should be put aside for a new supercomputer. Instead, the science and technology ministry's budget for 2022 has been reduced by 87% (see *Nature* https://doi.org/g77w; 2021).

Many processes that affect south-central Brazil's water availability are not well understood. These need more research to best inform policy. They include:

Climate feedbacks. Deforestation, land use, biomass burning and global warming interact to determine water availability. Fresh approaches should exploit emerging knowledge and computational tools to better incorporate small-scale and fast processes, such as vegetation, land cover, clouds and aerosol feedback effects in climate models. This will need higher-resolution simulations, more computational power and reliable *in situ* and satellite-based observations.

Compound events. Hazards such as droughts, heatwaves and fires can have devastating impacts beyond an area related to an isolated event. Risk-assessment approaches should consider how the co-occurrence of multiple and dependent hazards affect models. Climate, health and social scientists, as well as engineers and modellers, should work to improve predictions.

Groundwater. Intensive pumping, especially combined with droughts, has led to severe depletion in regions such as the western and central United States, northern India and the Middle East[16]. More research, along with groundwater and soil-moisture monitoring, is needed to understand how Brazilian aquifers respond to pumping, as well as climate variability and change.

Migration and health. Climate change could intensify migration from the northeast, Brazil's driest and poorest region, to the southeast. Other movements of people could be triggered across the country as longer, more frequent and severe droughts arise. Massive climate migrations might result in an increase of water insecurity, as well as unemployment and poverty in major Brazilian cities. Social, political and economic scientists should work to identify the drivers of climate migration to guide policymaking. Research initiatives should also consider the long-term effects of drought on human health, such as malnutrition and mental health.

Diversify sources

Stable, long-term investment is needed to upgrade the nation's water and power system. Hydropower has a small carbon footprint once installed, despite its initial high environmental and social impacts. When there isn't enough water to generate electricity, however, expensive and more-polluting fossil-fuel-based thermal power currently picks up the slack.

Instead, Brazil could diversify by amplifying wind and solar capacity. This could be supported by an existing system of contract auctions, providing a mechanism to gather funds for clean energy. The success of such a mechanism in Brazil is demonstrated by recent investments totalling nearly $8 billion over the past 5 years, mostly from the private sector. An estimated 300 GW could be generated from clean energy sources by 2050 – 3 times the nation's current demand[17].

> **"Worldwide climate change is making droughts more intense and more frequent."**

Brazil lies on major aquifers – valuable and underused resources. The agricultural sector should build climate resilience by using this groundwater, especially during extreme hydrological droughts. This needs to be done sustainably, to avoid the depletion experienced by other countries[16]. A clear picture of the spatial distribution and temporal variability of aquifers could guide farmers towards appropriate locations and rates of extraction.

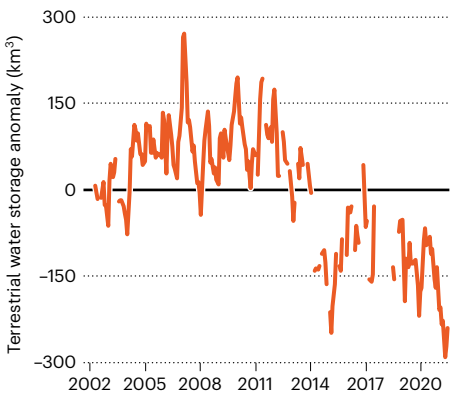
In November, Brazil promised to end illegal deforestation and cut emissions from 2005 levels by 50% by 2030 at the 2021 United Nations Climate Change Conference (COP26) in Glasgow, UK. However, such measures are not ambitious enough and would not bring the country in line with green policies, such as the European Green Deal and the US Green New Deal.

There might be short-term economic harm from stemming deforestation, especially among farmers and landowners. But the costs of doing nothing are too extreme to ignore. The World Economic Forum has classed water crises as a top global risk, owing to their impact on food production, human health, conflict, ecosystem function and extreme weather (see go.nature.com/3lwow7x).

Brazil has the expertise and motivation to mitigate this risk. The research community must work with governments to craft laws, policies and investments that enforce optimal water practice – preventive and adaptive. With political willpower, funding and infrastructure to match, the country could become a world leader in hydroclimate resilience.

LOW WATER MARK

Water storage levels are at their lowest across south-central Brazil since satellite records began.



Gaps in the data are months in which the GRACE satellite mission did not acquire data.

SOURCE: H. SAVE *ET AL. J. GEOPHYS. RES. SOLID EARTH* **121**, 7547–7569 (2016)

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