Brazil is in water crisis – it needs a drought plan

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

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Brazil has the most freshwater in the world. Two thirds of what flows in the Amazon River alone could supply the world's domestic demand. Yet much of the nation now faces drought.

The worst in several decades. In a nation that grows over a third of the world's sugar, and produces almost 15% of the world's beef.

This fall, between March and May, dry weather in Brazil's South-central region led to a 267km^3 shortage of water held in rivers, lakes or underground, compared with the seasonal average for the past twenty years (see Figures 1 and 2). The result? Many major reservoirs are at less than 20% capacity. Farming and energy generation have been hit. Since July, coffee prices have risen 30% -- Brazil accounts for one third of global exports. Soybean prices rose by 67% – this crop makes up 70% of animal feed globally. And electricity bills have soared 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 -- engine of 60% of Brazil's GDP -- is partly controlled by moisture transfer from the rainforest. Atmospheric fluxes caused by tree transpiration – also known as 'flying rivers' – may 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.

The World Economic Forum have classed water crises as a top global risk, due to their impact on food production, human health, conflict, ecosystem function, and extreme weather[1]. Brazil's water crisis is a world crisis. Droughts must be recognized as a matter of a national and international security. What's needed is a coordinated nationwide Drought Mitigation Plan crafted by researchers, policymakers, industry, the public sector and civil society. Here below are some key points that such a plan should address; these points are supported by xx *<subs: number TBC by authors]* Brazilian and international water and climate scientists (see list of co-signatories attached).

Vast reserves

About 20% of all global inland water flowing to the oceans is generated in Brazilian territory[2]. 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[3]. In the US, that figure is 75%; in India, it is 60%.

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

In a nation dependent on agriculture for almost a quarter of its GDP, crops such as soy, coffee and sugar cane, and livestock use much of the water. Irrigation feeds about 13% of the cultivated surface[4], drawing down 68% of total water consumption -- some 68.4 billion liters daily[3].

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

Different droughts

Water crises can originate from many types of droughts: meteorological, hydrological, agricultural, and socioeconomic.

Meteorological droughts are dry weather patterns due to periods of little rainfall or high heat, 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 – may result. These can jeopardize crop yield and increase food insecurity. Shortages to the domestic and industrial supply – socioeconomic drought – can also follow. This may lead to rationing, disease, conflict and migration. It may also bring water-intensive processes such as concrete and steel production to a halt.

These different processes 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 socioeconomic drought.

Human fingerprint

The 2021 IPCC report highlighted that unabated regional landcover 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 "although-reachable" 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. 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 recognize 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]. And national policies have driven increasingly erratic land occupation by agribusiness and mining interests, increasing deforestation and wildfires and undermining climate mitigation[11–13].

As the country plunged into a severe shortages in 2014, 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[14].

Seven 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 may have to be met by burning bio 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 over 16,000 and 22,000 sites, respectively. There are no nationwide systems in place to track soil moisture, and water use monitoring 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, many times leading to duplicated efforts and inefficient data access. Drought monitoring initiatives through international partnerships, such as the *Monitor de Secas* (http://monitordesecas.ana.gov.br/), have been emerging in recent years. However, the system needs to reduce delays to the availability of data, and improve accuracy and accessibility to end-users, such as farmers and local water departments, in order to optimize its usefulness.

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 Institute for Space Research (*Instituto Nacional de Pesquisas Espaciais; INPE)* is nearing the end of its lifecycle. UN funds have provided temporary access to alternative computers, but these are not powerful enough to perform hydrometeorological forecasts and climate predictions. 40 million USD 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%[15].

Many processes which impact south-central's 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. New approaches should exploit emerging knowledge and computational tools to better incorporate small-scale and fast processes, such as vegetation dynamics or 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 those related to an isolated event. Risk assessment approaches should consider how the co-occurrence of multiple and dependent hazards affects models. Climate, health and social scientists, as well as engineers and modelers, should work to improve predictions.

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

Migration and health. Climate change can 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 could 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 policy making. Research initiatives should also consider long-term drought effects on human health, such as malnutrition and impairments in mental health.

Diversify sources

Stable, long-term investment is needed to upgrade the nation's water and power system. Hydropower has a very 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 pick up the slack.

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

The Brazilian territory lies on major aquifers - valuable and underused resources. The agricultural sector should build climate resilience by using this groundwater, especially during extreme hydrological drought. 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.

This month 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). 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 U.S. Green New Deal.

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 -- preventative and adaptive. With political willpower, funding, and infrastructure to match, the country could become a world leader in hydroclimate resilience.

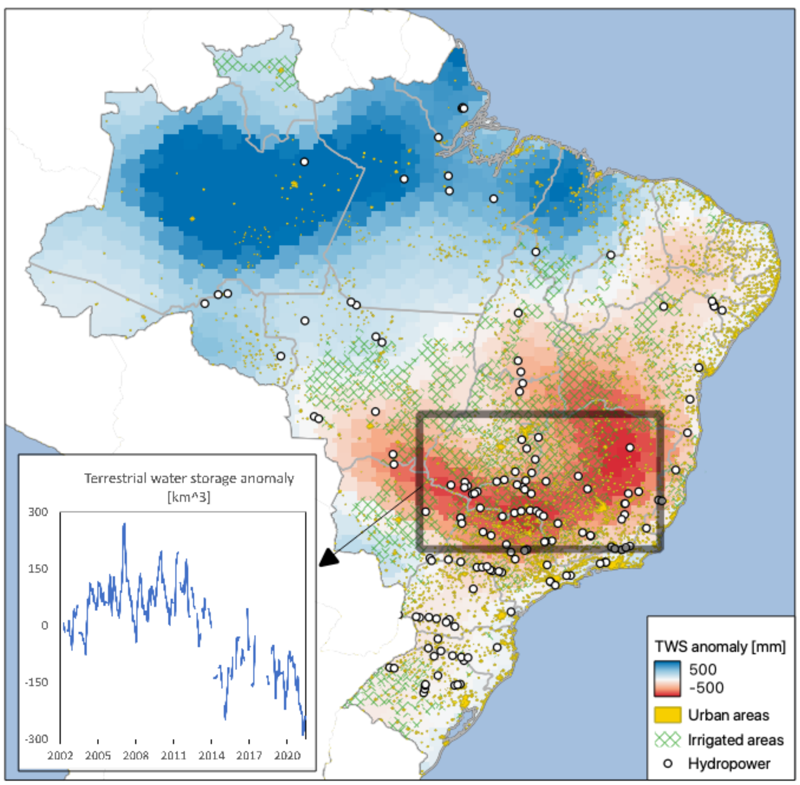

Figure 1. Brazil's terrestrial water storage (TWS) anomaly for the 2021 Austral fall season (April, May and June), urban and irrigated areas, and location of major hydropower stations. TWS is derived from NASA's GRACE mission[9] data and represents the integrated change in surface waters (e.g., rivers, lakes, wetlands), soil moisture, groundwater, and snow. Red tones indicate extreme drought conditions in the 2021 Austral fall season.

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