

# Novel socio-environmental vulnerability index pinpoints sustainability issues in Brazilian river basins

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Woman washing clothes in the Parnaíba River near Nazária, Piauí state, Brazil.  
Credit: Wilson Dias/Agência Brasil

Brazilian researchers combined environmental physical, social and economic indicators to create an index that measures a region's vulnerability and used it to analyze the basins of the Parnaíba River and São Francisco River in the Northeast of Brazil. The index is named

SEVI (for Socio-Environmental Vulnerability).

The Parnaíba and São Francisco basins are considered crucial to agricultural expansion and [biodiversity conservation](#). They contain more than 780 municipalities and part of the semi-arid Caatinga and savanna-like Cerrado biomes, which are threatened by deforestation as well as adverse effects of climate change.

The study shows that the main obstacles to improving the socio-environmental vulnerability of the Parnaíba basin, the second largest river basin in the Northeast, are deficits in infrastructure, income, and conditions for [human development](#), all of which impair adaptive capacity, defined by the researchers as "the ability of a system to evolve in order to accommodate [environmental hazards](#) or anthropogenic impacts."

In the São Francisco basin, the most significant causes of vulnerability are population density, soil degradation/desertification, and climate factors, especially temperature and precipitation.

These findings are reported in an article on the study published in the journal *Sustainability*. The authors are affiliated with the National Space Research Institute (INPE) and the National Disaster Surveillance and Early Warning Center (CEMADEN).

"The study showed that sustainable development projects should take specific characteristics of each region into consideration and brought to light the deficiencies of some public policies. We analyzed a problem that affects [agricultural areas](#) in several countries, especially in the developing world," biologist Rita Marcia da Silva Pinto Vieira, first author of the article, told Agência FAPESP. She was at INPE when the study was conducted.

Including socio-[economic indicators](#) allowed the researchers to strengthen the argument that sustainability is not linked only to climate, environmental factors and soil degradation but also to human activity and biodiversity.

"Vulnerability indicators typically focus on one factor in isolation. By integrating environmental and socio-economic data, we showed that vulnerability has as much to do with exposure to environmental, social and political stress as it does with the system's capacity to adapt. The index highlights areas where vulnerability is particularly acute," said Lincoln Muniz Alves, a climatologist at INPE and penultimate author of the article.

The last author is Jean Pierre Ometto, a senior researcher in the Impact, Adaptation and Vulnerability Division of INPE's Department of Earth Sciences (DIIAV-CGCT).

## **Methodology**

The SEVI index resulted from a combination of indicators relating to adaptation (human development, infrastructure and income), sensitivity (days without rain, land use and cover, temperature, and soil type), and exposure (population density and soil degradation or desertification).

The methodology was based on the environmentally sensitive areas (ESA) approach developed by MEDALUS (Mediterranean Desertification and Land Use), a project conducted in eight European Union countries in the late 1980s and early 1990s. The indicators and overall index were weighted from very low to very high.

The area of the regions analyzed totaled about 962,000 square kilometers (km<sup>2</sup>), with a population of some 20 million, mostly urban. Sixteen million people live in the São Francisco basin. The river runs

through six states from Minas Gerais to the Alagoas-Sergipe border. Four million live in the Parnaíba basin.

According to the SEVI index, vulnerability levels were "very high" and "high" in 53% of the São Francisco basin, pointing to 337,569 km<sup>2</sup> with socio-environmental fragilities, partly coinciding with desertification hotspots officially recognized by the Environment Ministry. In the Parnaíba basin, the proportion was 37% (121,990 km<sup>2</sup>).

Adaptive capacity was "very low" and "low" in 57% of the area analyzed (549,830 km<sup>2</sup>). Exposure was "very high" and "high" in 62.8% and 30.7% of the São Francisco and Parnaíba basins respectively. Sensitivity was also high in a significant proportion of both (341,726 km<sup>2</sup> and 123,666 km<sup>2</sup>). These results mainly reflected population density, soil degradation, desertification, and the number of days without rain, which directly influences the risk of wildfires during the dry season.

The authors of the article expect these problems to become steadily worse as a consequence of climate change. Previous research using global models projected a drop of 46% and 26% in streamflow in the São Francisco and Parnaíba rivers respectively in the decades ahead, and socio-environmental vulnerability is set to increase significantly, especially in areas where the population is poor, as extreme weather becomes more frequent.

Furthermore, deforestation has hit the region hard in recent years. In the Cerrado, it affected 10,689 km<sup>2</sup> in 2022, more than in any year since 2015 (11,129 km<sup>2</sup>), and in the Caatinga, it increased 25% compared with 2021, according to INPE's monitoring program (PRODES).

This year, the number of deforestation alerts for the Cerrado jumped 35% in the first five months compared with the corresponding period of 2022, according to INPE's early warning system (DETER).

## Protected areas

The researchers also analyzed conservation units located in both basins, concluding that units in the Parnaíba basin were less vulnerable. In the São Francisco basin, 32.4% of the area (12,477 km<sup>2</sup>) was highly vulnerable within a 5 km buffer zone, indicating human pressure from deforestation and burning in fully protected areas.

On the upside, Lapa Grande State Park in Minas Gerais was the most well-preserved conservation unit in the region, with low vulnerability in 84.6% of its area.

"The study pinpointed the areas with high vulnerability and emphasized the importance of conservation units. In our recommendations, we stress that the [sustainable practices](#) used in these units can also be implemented in adjacent areas," Alves said.

For the authors, it is critically important to extend conservation units, introduce sustainable land management practices in adjacent buffer zones, and develop strategies for the protection of ecosystem services and local vegetation.

These management practices and their modernization should be shared with farmers in the region, according to the article. Many smallholders located in the areas with high socio-environmental vulnerability lack funds, and their traditional [land-use](#) practices deplete natural resources and aggravated poverty.

## Contributions

According to the authors, the information on socio-environmental vulnerability with regional characteristics provided by the SEVI index

contributes to support for programs such as the National Climate Change Adaptation Plan (PNA), as well as public policies aimed at rehabilitating degraded areas.

"We used specific variables for the Caatinga and Cerrado, but the methodological framework we developed for SEVI can certainly be applied elsewhere, using the peculiarities of each region and biome," Vieira said.

**More information:** Rita Marcia da Silva Pinto Vieira et al, Socio-Environmental Vulnerability to Drought Conditions and Land Degradation: An Assessment in Two Northeastern Brazilian River Basins, *Sustainability* (2023). [DOI: 10.3390/su15108029](https://doi.org/10.3390/su15108029)

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