

Drought monitoring in Brazil using in situ instrumentation and remote sensing products

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National Center for Monitoring and Early Warning of Natural Disasters (Cemaden)



National Centre for Monitoring and Early Warnings of Natural Disasters

- Monitors more than 1000 municipalities in Brazil and releases alerts to local civil defence authorities.
- Maintains a large network of sensors throughout Brazil: weather stations, river level gauges and meteorological radars.
- Develops research in meteorology, hydrology, geology, sociology and **drought**. Monitors drought conditions over the Brazilian Northeast region (NEB), the most vulnerable and poor in the country.
- The bulletins of drought conditions from CEMADEN are used by the federal government to assess which municipalities can benefit from financial support or crop insurance.

DROUGHT: THE CREEPING DISASTER

Portions reprinted courtesy of the NOAA National Weather Service Office of Meteorology

While much of the weather that we experience is brief and short-lived, drought is a more gradual phenomenon, slowly taking hold of an area and tightening its grip with time. In severe cases, drought can last for many years, and can have devastating effects on agriculture and water supplies.

Nationwide losses from the U.S. drought of 1988 exceeded \$40 billion, exceeding the losses caused by Hurricane Andrew in 1992, the Mississippi River floods of 1993, and the San Francisco earthquake in 1989. In some areas of the world, the effects of drought can be far more severe. In the Horn of Africa the 1984–1985 drought led to a famine which killed 750,000 people.

by Steve Graham
August 28, 2000

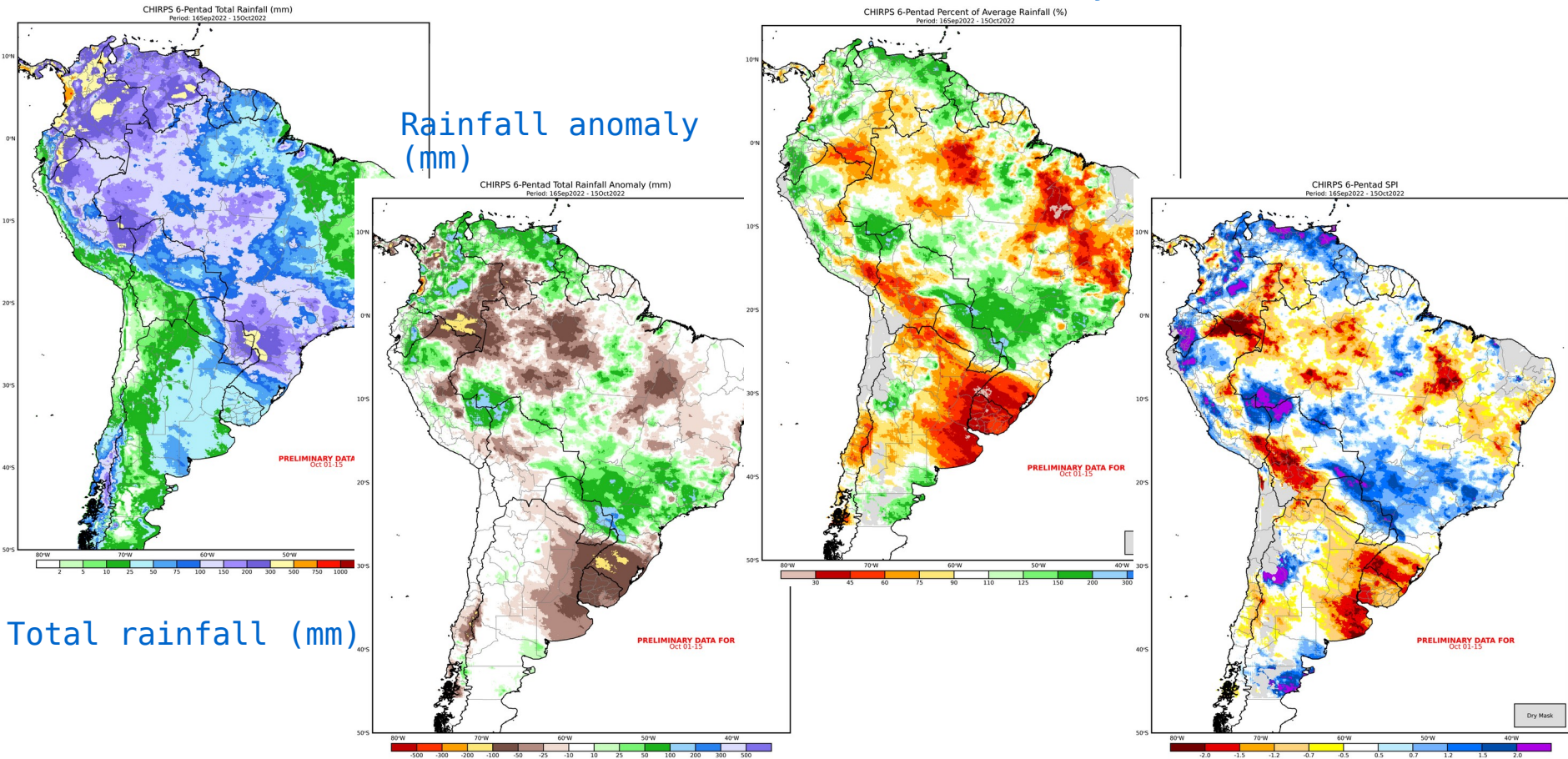
**"DROUGHT IS
DEFINED AS AN
EXTENDED PERIOD
OF DEFICIENT
RAINFALL RELATIVE
TO THE AVERAGE
FOR A REGION."**

Drought: the Creeping Disaster

Introduction
Drought Planning
and Drought Indices
Improved Monitoring
Improved
Forecasting

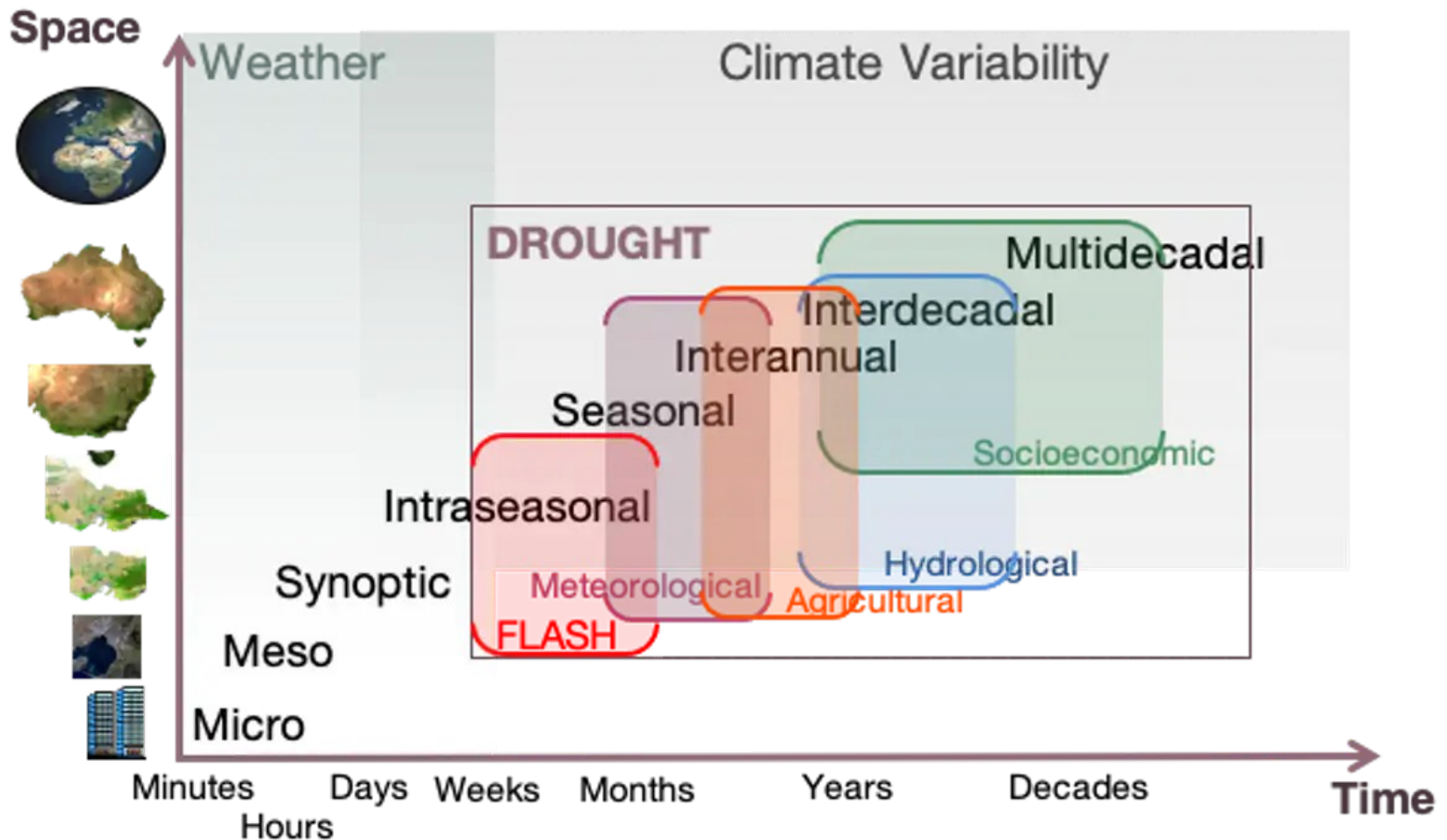
How to measure meteorological drought?

Rainfall anomaly (%)

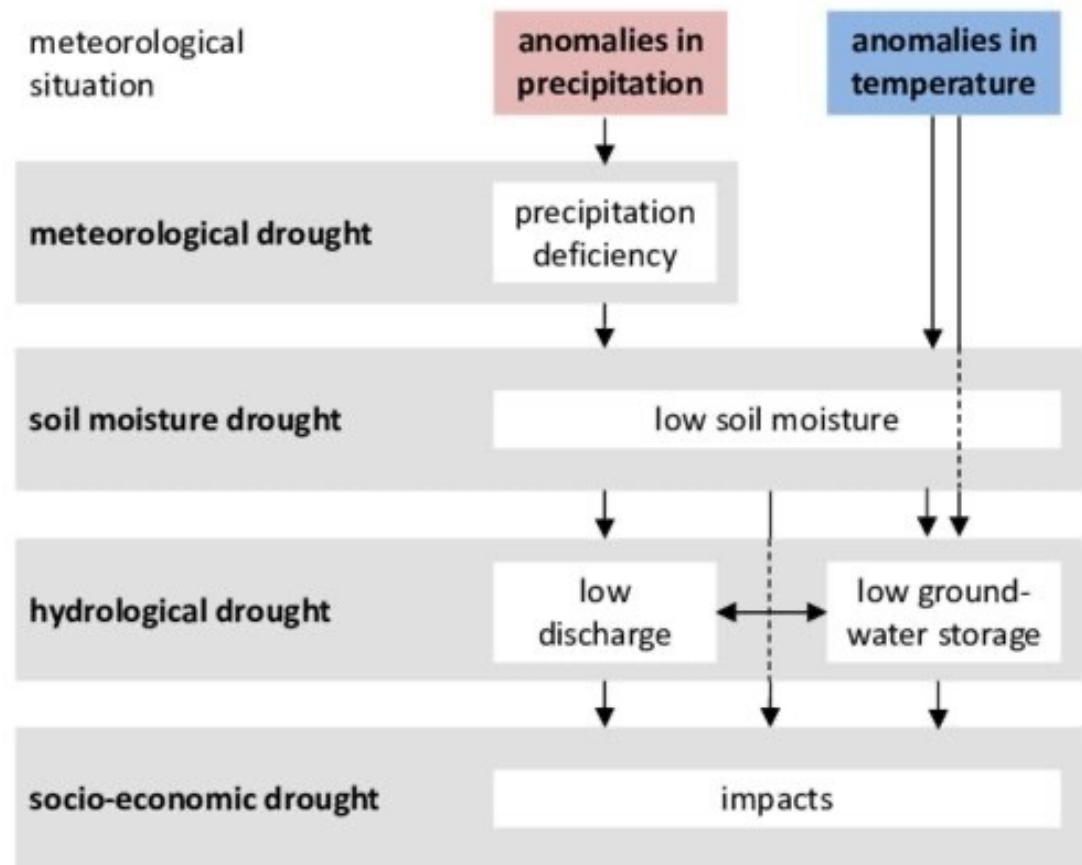


Standardized Precipitation Index (SPI)

Droughts in space and time



Drought propagation



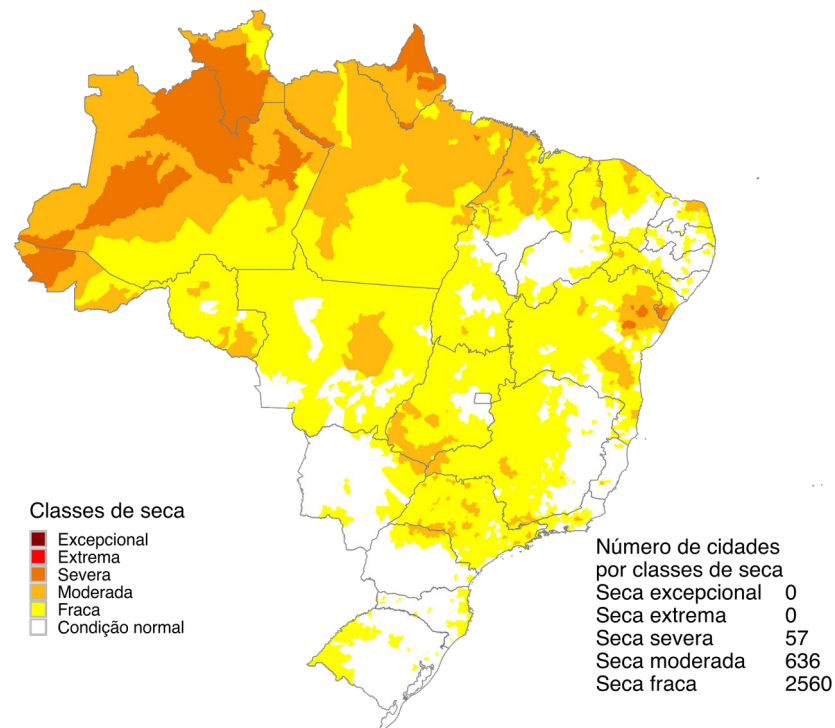
Drought monitoring at Cemaden: past and present

Monitoring since 2013

Attendance to the demands and actions of the federal government

Identification of municipalities affected by drought to support the Ministry of Agrarian Development's Crop Guarantee program

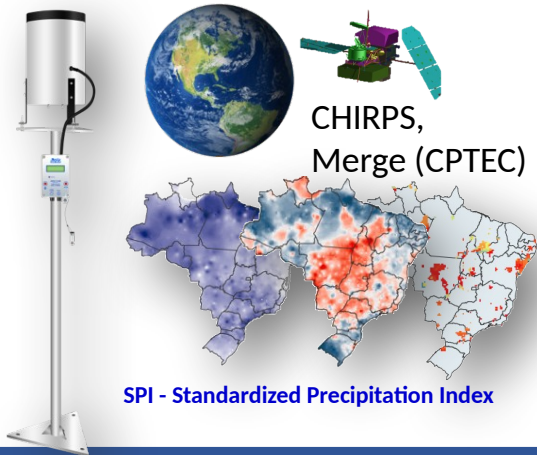
Support for National Water Agency (ANA) crisis rooms for southern, northern, northeastern regions, basins and biomes



Agricultural drought monitoring

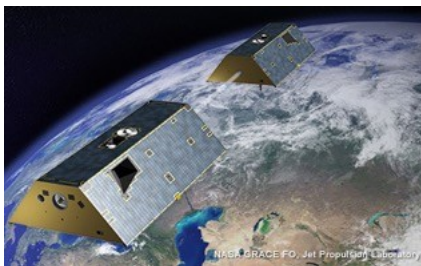
Integrated Drought Index (municipality level and raster)

Precipitation (in situ + satellite)

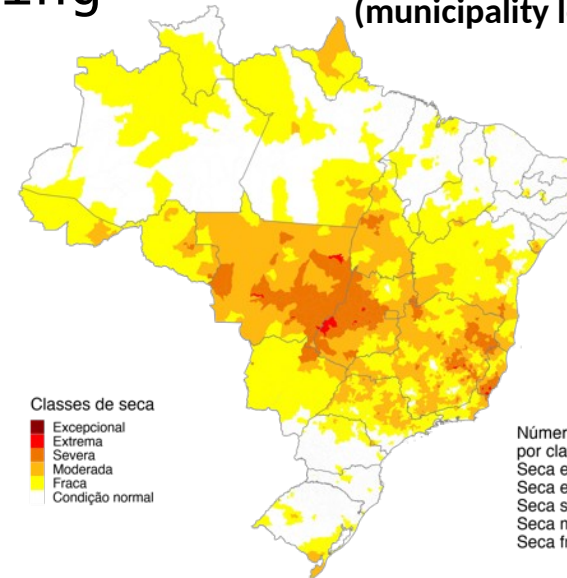


Soil moisture (satellite)

GRACE



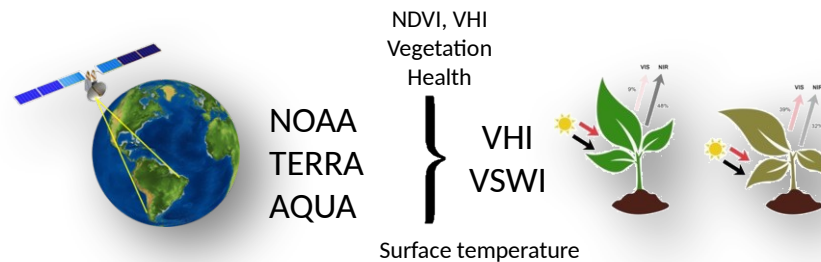
Classes de seca



Número de cidades
por classes de seca
Seca excepcional 0
Seca extrema 22
Seca severa 306
Seca moderada 1080
Seca fraca 1693

Junho 2022
Índice Integrado de Seca (SPI3, VHI, AUS)
Dados: CPTEC/INPE - NOAA - NASA / Preparação: Cemaden/MCTI

Water stress in plants (satellite)



Standardized Precipitation Index (SPI)

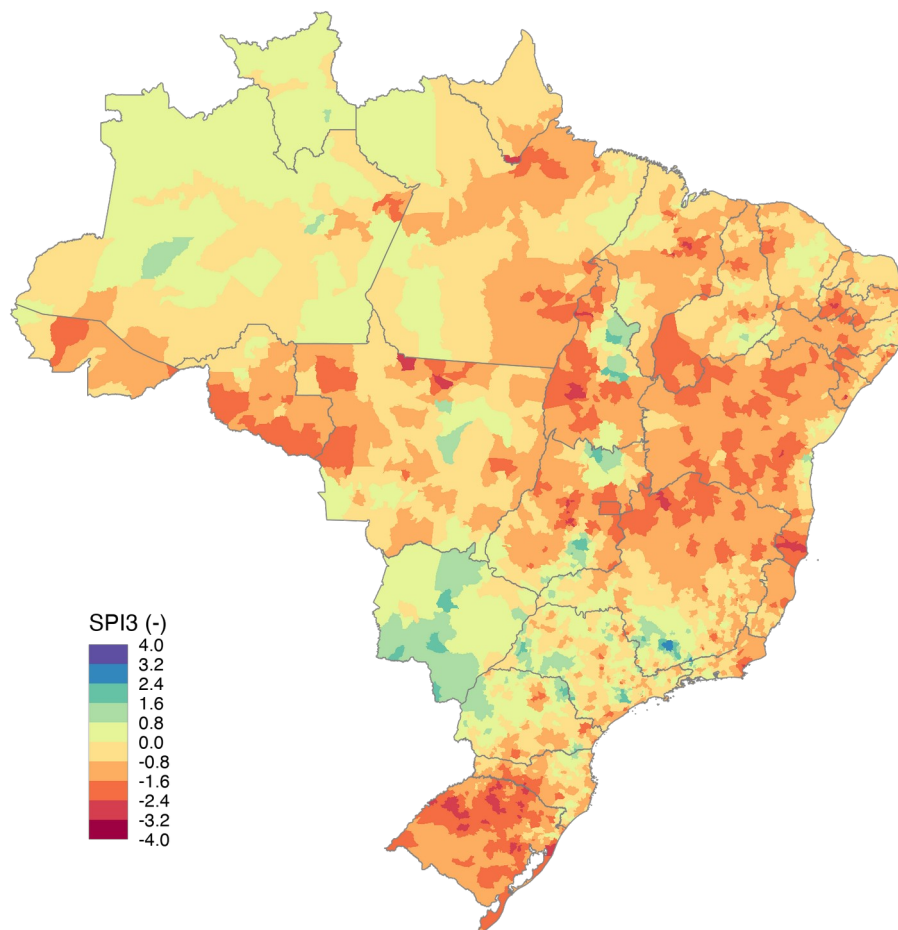
Status of the monthly
accumulated rainfall

Above average (positive)

Below average (negative)

Requires long series of rain (30
years)

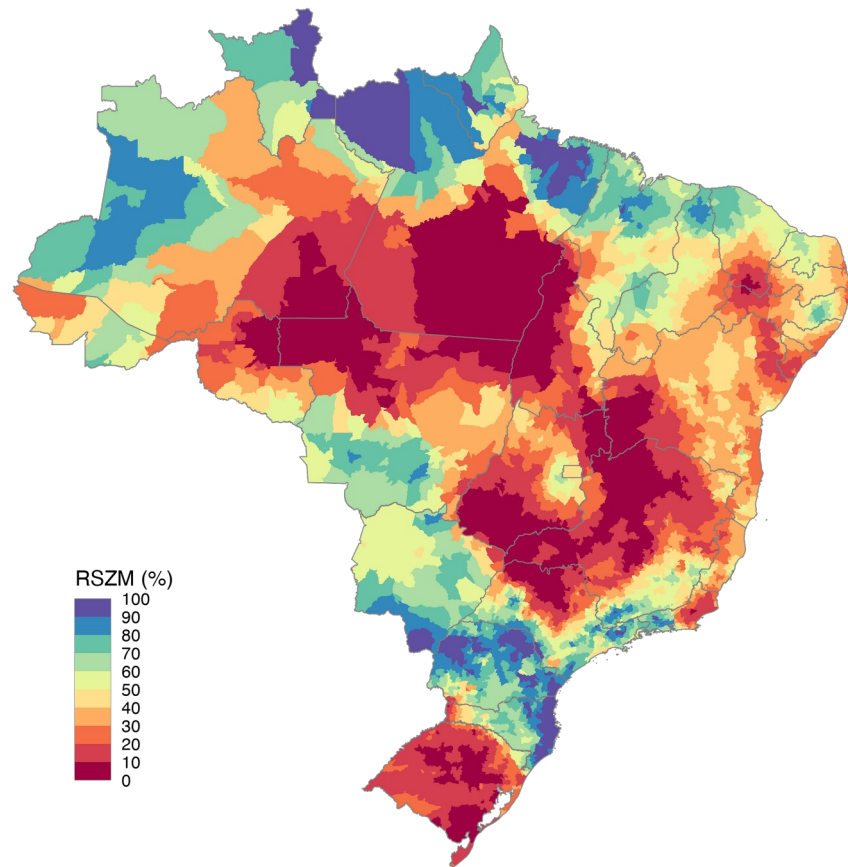
- Calculated in windows of 1 to
12 months, or more



Root Zone Soil Moisture

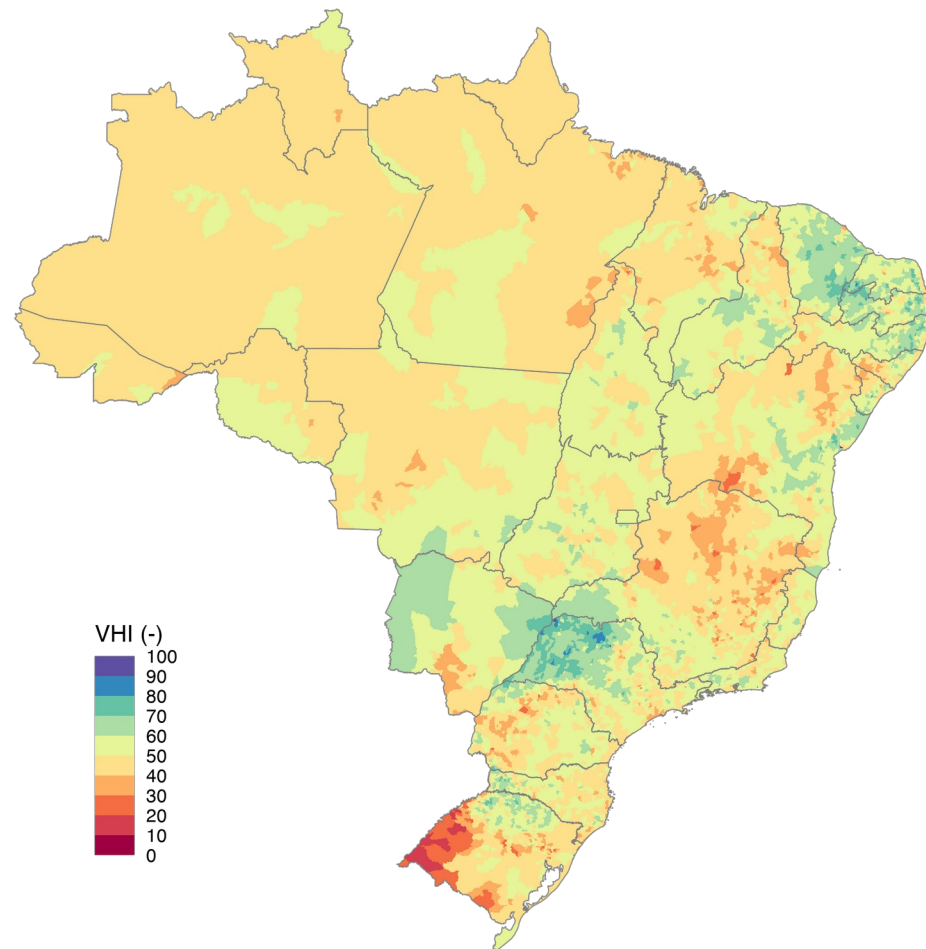
Soil moisture at root depth (1 m)
GRACE Satellite (NASA)
Spatial resolution of 25 km

- Available every 7 days



Vegetation Health Index (VHI)

- Measures humidity and
temperature conditions of
vegetation
Values below 40 indicate water
stress
NOAA satellites
Spatial resolution of 4 km
- Available every 7 days



Integrated Drought Index

Diagnostics of average
drought conditions

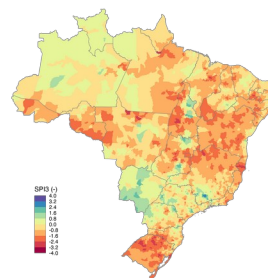
Rainfall, soil moisture and
vegetation health with the
same weight

Quantification of drought
intensity

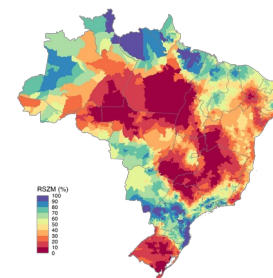
- Updated monthly/biweekly

IIS processing steps:

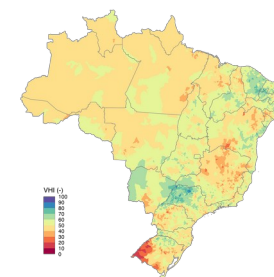
- Spatial uniformization
- Conversion to drought classes
- Calculation by municipalities
- Preparation of maps and reports
- Updating online platforms



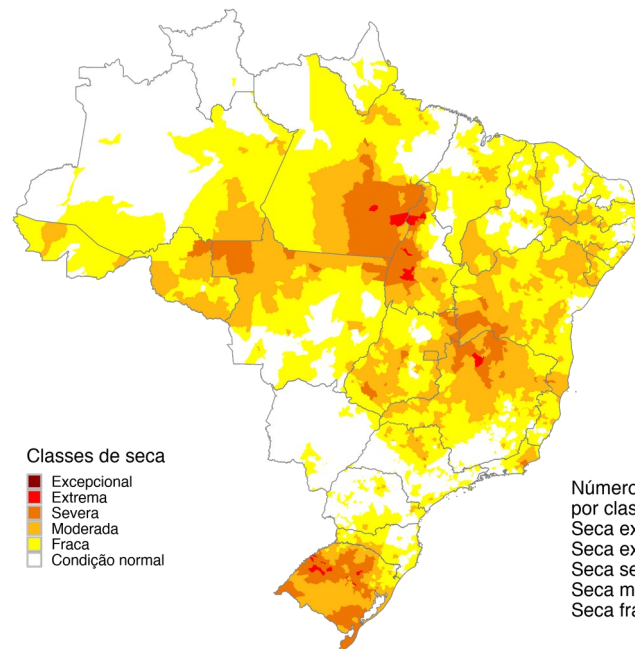
Rainfall
anomaly



Soil
moisture



Vegetation
health



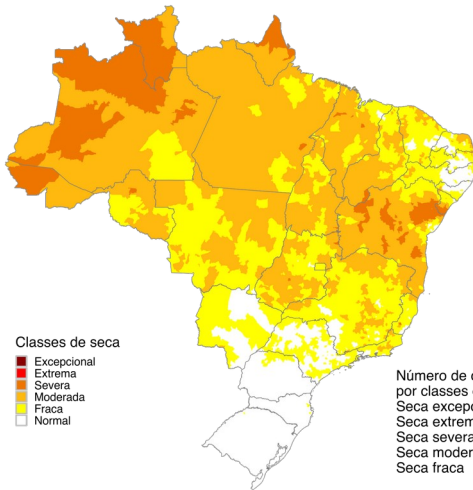
Classes de seca

- Excepcional
- Extrema
- Severa
- Moderada
- Fraca
- Condição normal

Número de cidades
por classes de seca
Seca excepcional 0
Seca extrema 34
Seca severa 352
Seca moderada 1250
Seca fraca 2418

INTEGRATED DROUGHT INDEX SCENARIOS - NOVEMBER/2023

Rainfall 40% below the mean



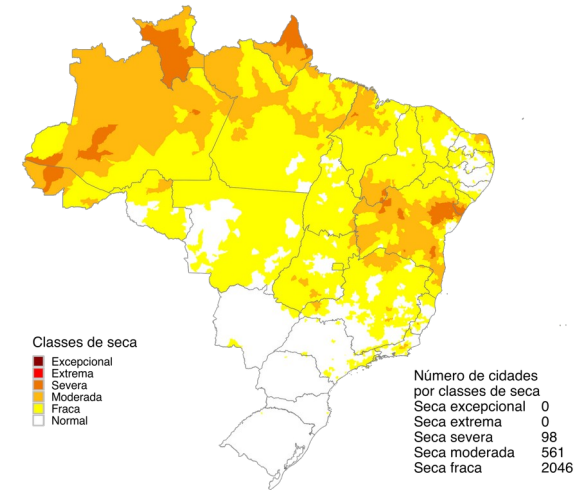
Novembro 2023
Índice Integrado de Seca (SPI6, VHI, AUS)
Cenário: Chuva -40%
Dados: CPTEC/INPE - NOAA - NASA / Preparação: Cemaden/MCTI

NOVEMBER/2023

IIS

- Secca Excepcional
- Secca Extrema
- Secca Severa
- Secca Moderada
- Secca Fraca
- Normal

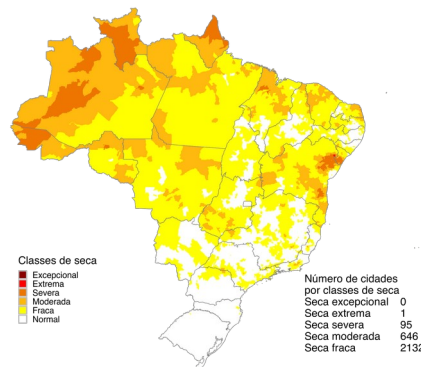
Rainfall 40% above the mean



Novembro 2023
Índice Integrado de Seca (SPI6, VHI, US)
Cenário: Chuva +40%
Dados: CPTEC/INPE - NOAA - NASA / Preparação: Cemaden/MCTI

IIS OBSERVADO (IIS6)

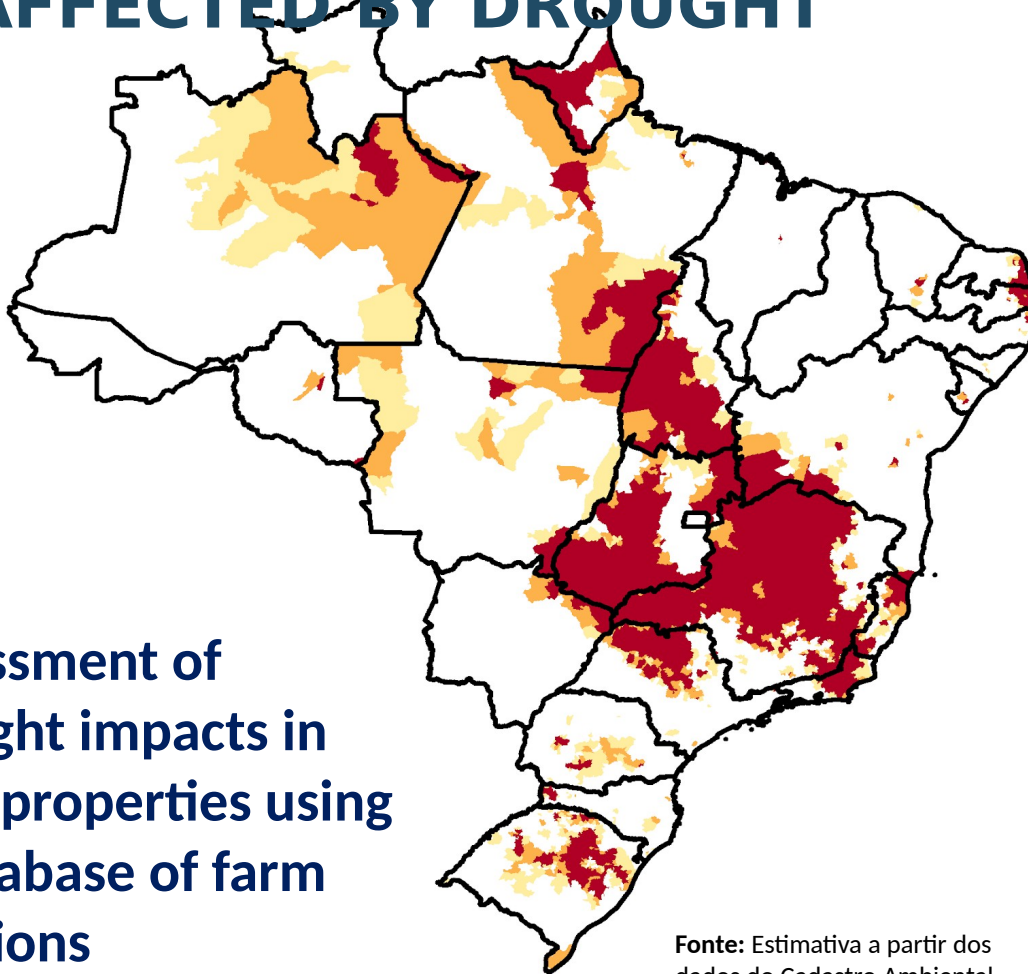
October/23



Outubro 2023
Índice Integrado de Seca (SPI6, VHI, US)
Dados: CPTEC/INPE - NOAA - NASA / Preparação: Cemaden/MCTI

PASTURES AND FARMS AFFECTED BY DROUGHT

Assessment of
drought impacts in
rural properties using
a database of farm
locations

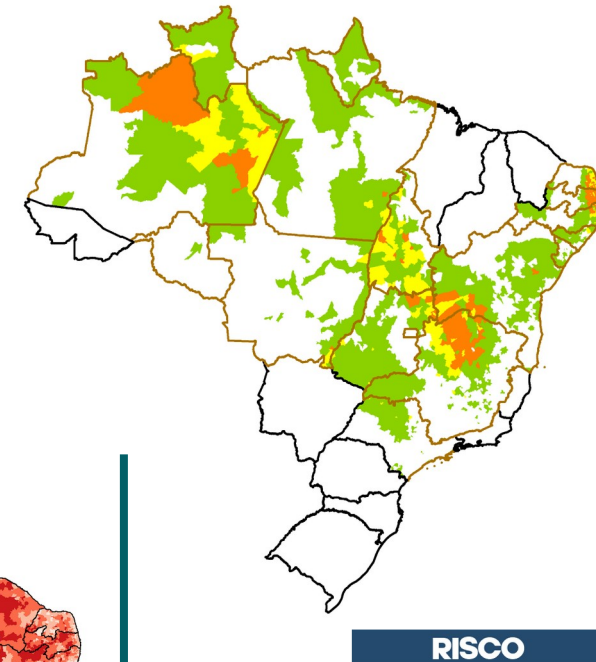
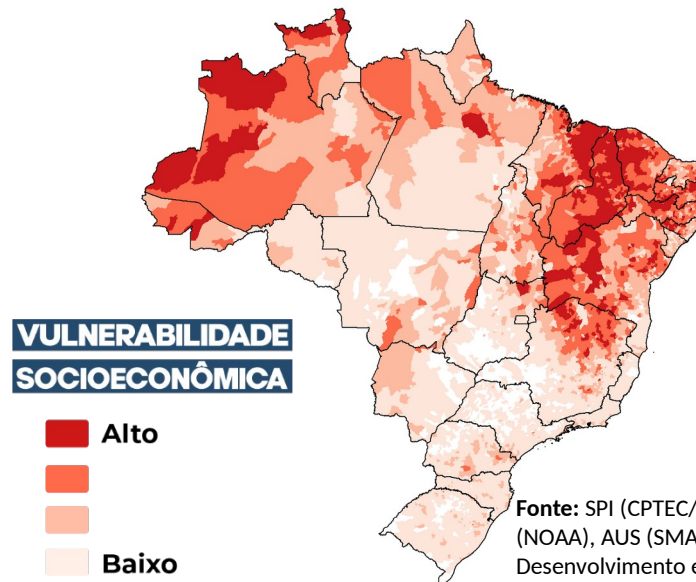
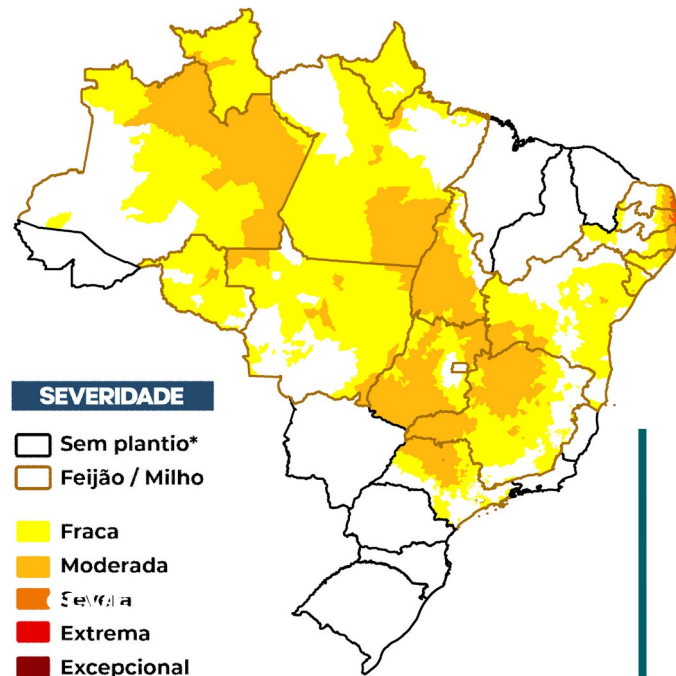


Fonte: Estimativa a partir dos dados do Cadastro Ambiental Rural para minifúndios, pequenas e médias propriedades e IIS-3,, Desenvolvimento e Processamento (CEMADEN).

UF		40 a 60%	60 - 80%	> 80%
N	AM	8	25	4
	AP	1	4	5
	PA	13	12	22
	RO		2	2
	RR	1		
	TO	8	9	69
NE	AL	3	1	
	BA	14	9	18
	CE	4	3	1
	MA	1		2
	PB	4	2	55
	PE	5	6	12
	RN	6	2	35
CO	SE		1	3
	GO	9	15	170
	MS	1	4	4
	MT	15	10	13
SE	ES	11	6	29
	MG	44	41	468
	RJ	5	4	40
	SP	33	37	171
S	PR	26	9	9
	RS	70	61	152
	SC	18	7	15

DROUGHT RISK MONITORING AND FORECASTING

Drought risk depends on the intensity of the physical drought event and the interactions between the vulnerabilities and capabilities of the exposed systems.



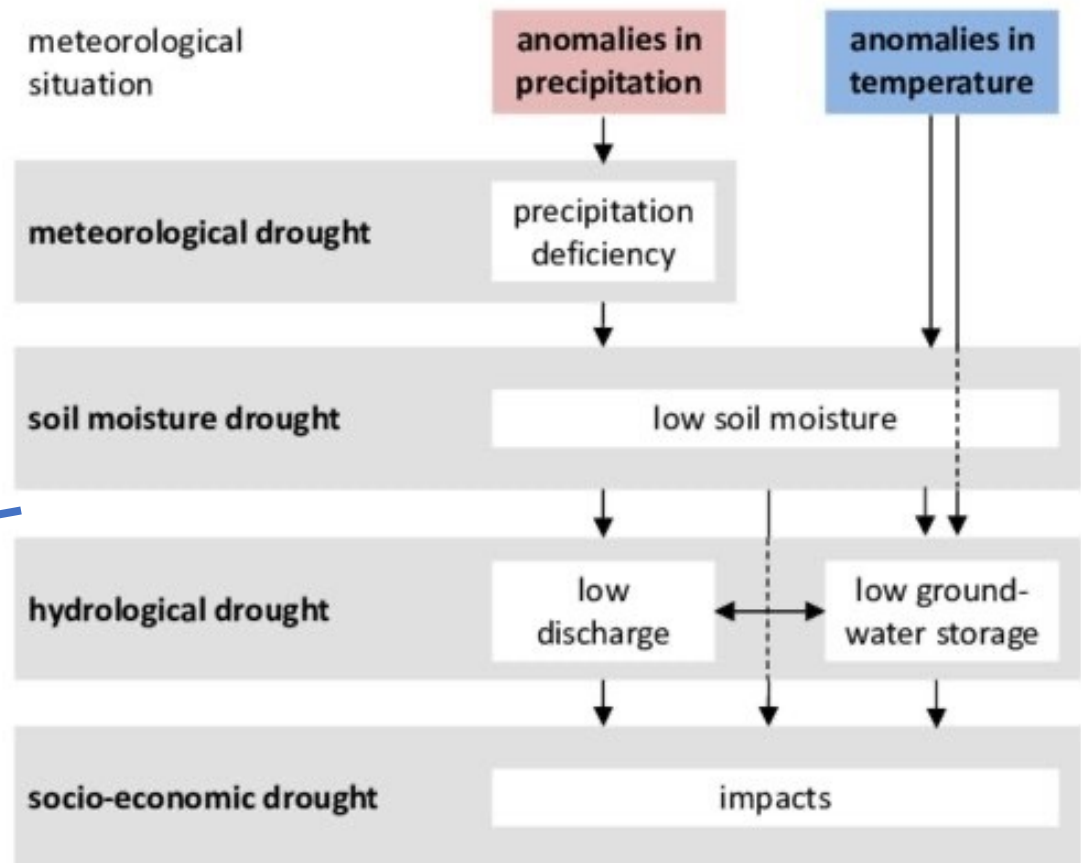
Fonte: SPI (CPTEC/INPE), VHI (NOAA), AUS (SMAP/NASA), Desenvolvimento e Processamento do Risco (CEMADEN).

Drought propagation

Agricultural drought:
Evolution from negative
rainfall anomalies to soil
water deficits and impacts
on vegetation health



How to measure
drought propagation?



Combined Drought Indicator (CDI)

This Factsheet provides a detailed technical description of the Combined Drought Indicator (CDI) as implemented in the Copernicus European Drought Observatory (EDO), and which is used for detecting and monitoring areas that either are affected or have the potential to be affected by agricultural drought. The meteorological, hydrological and satellite-derived biophysical variables upon which the CDI indicator is based, as well as the indicator's temporal and spatial scales and geographic coverage, are summarized below. An example of the CDI indicator is shown in Figure 1.

Variables	Temporal scale	Spatial scale	Coverage
Precipitation, soil moisture, and vegetation response.	10 days (= 1 dekad)	5 km	Europe

The Combined Drought Indicator (CDI) is derived by integrating the following three main drought indicators, which are implemented operationally within EDO:

- **Standardized Precipitation Index (SPI):** The SPI indicator measures precipitation anomalies at a given location, based on a comparison of observed total precipitation amounts for an accumulation period of interest (e.g. 1, 3, 12, 48 months), with the long-term historic rainfall record for that period (McKee et al., 1993; Edwards and McKee, 1997).
- **Soil Moisture Anomaly (SMA):** The SMA indicator is derived from anomalies of estimated daily soil moisture (or soil water) content - represented as standardized soil moisture index (SMI) - which is produced by the JRC's LISFLOOD hydrological model (de Roo et al. 2000), and which has been shown to be effective for drought detection purposes (Laguardia and Niemeyer, 2008).
- **FAPAR Anomaly:** The FAPAR Anomaly indicator is computed as deviations of the biophysical variable Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), composited for 10-day intervals, from long-term mean values. Satellite-measured FAPAR represents the fraction of incident solar radiation that is absorbed by land vegetation for photosynthesis, and is effective for detecting and assessing drought impacts on vegetation canopies (Gobron et al., 2005).

Example of implementing a drought propagation index

Table 2: Classification scheme used for computing the Combined Drought Indicator. Note that the delta symbol (Δ) is used as a prefix to indicate anomalies, and "m-1" is used as a suffix to indicate the month previous to the current one.

LEVEL	COLOUR	CLASSIFICATION CONDITION
Watch		$SPI-3 < -1$ or $SPI-1 < -2$
Warning		$SMA < -1$ and ($SPI-3 < -1$ or $SPI-1 < -2$)
Alert		$\Delta FAPAR < -1$ and ($SPI-3 < -1$ or $SPI-1 < -2$)
Partial recovery		($\Delta FAPAR < -1$ and ($SPI-3_{m-1} < -1$ and $SPI-3 > -1$)) or ($\Delta FAPAR < -1$ and ($SPI-1_{m-1} < -2$ and $SPI-1 > -2$))
Full recovery		($SPI-3_{m-1} < -1$ and $SPI-3 > -1$) or ($SPI-1_{m-1} < -2$ and $SPI-1 > -2$))

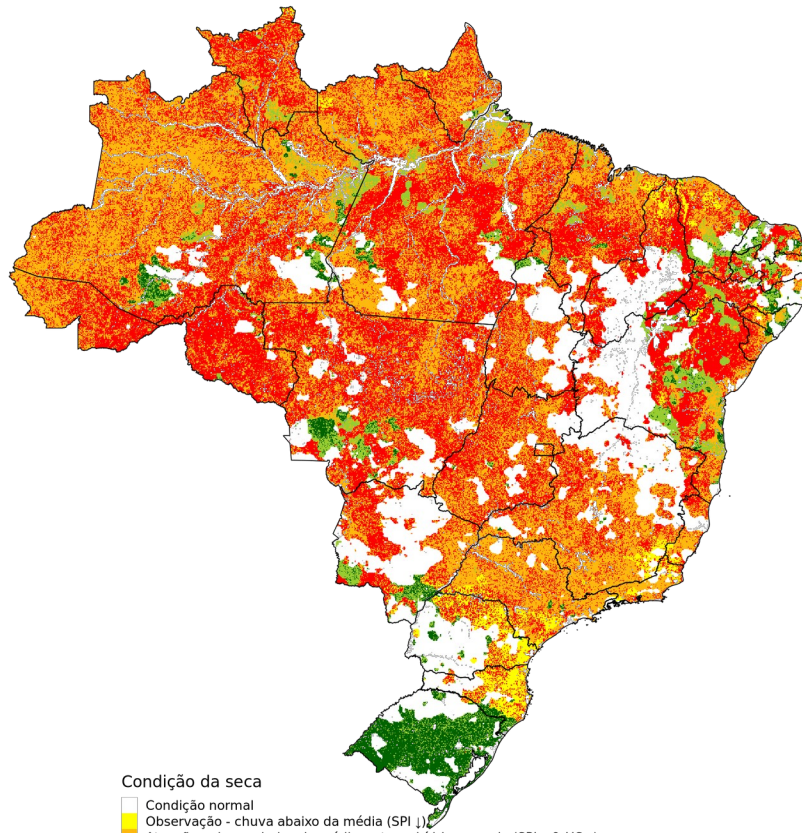
Implementation of the Drought Conditions Propagation Index

Available data:

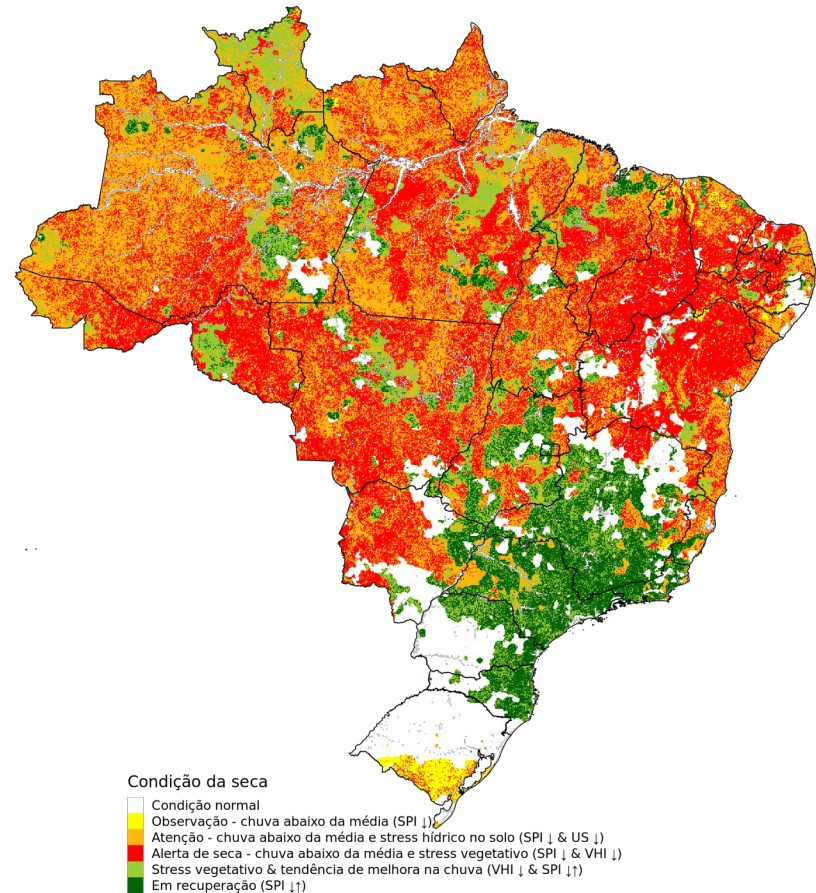
- SPI1, SPI3 (current and previous month), monthly, 4 km resolution
- Soil moisture (GRACE/NASA satellite), weekly, 25 km res.
- Vegetation Health Index (NOAA), weekly, 4 km res.

Propagation of Drought Conditions

Propagação Incremental das Condições de Seca (PICS)
Setembro 2023

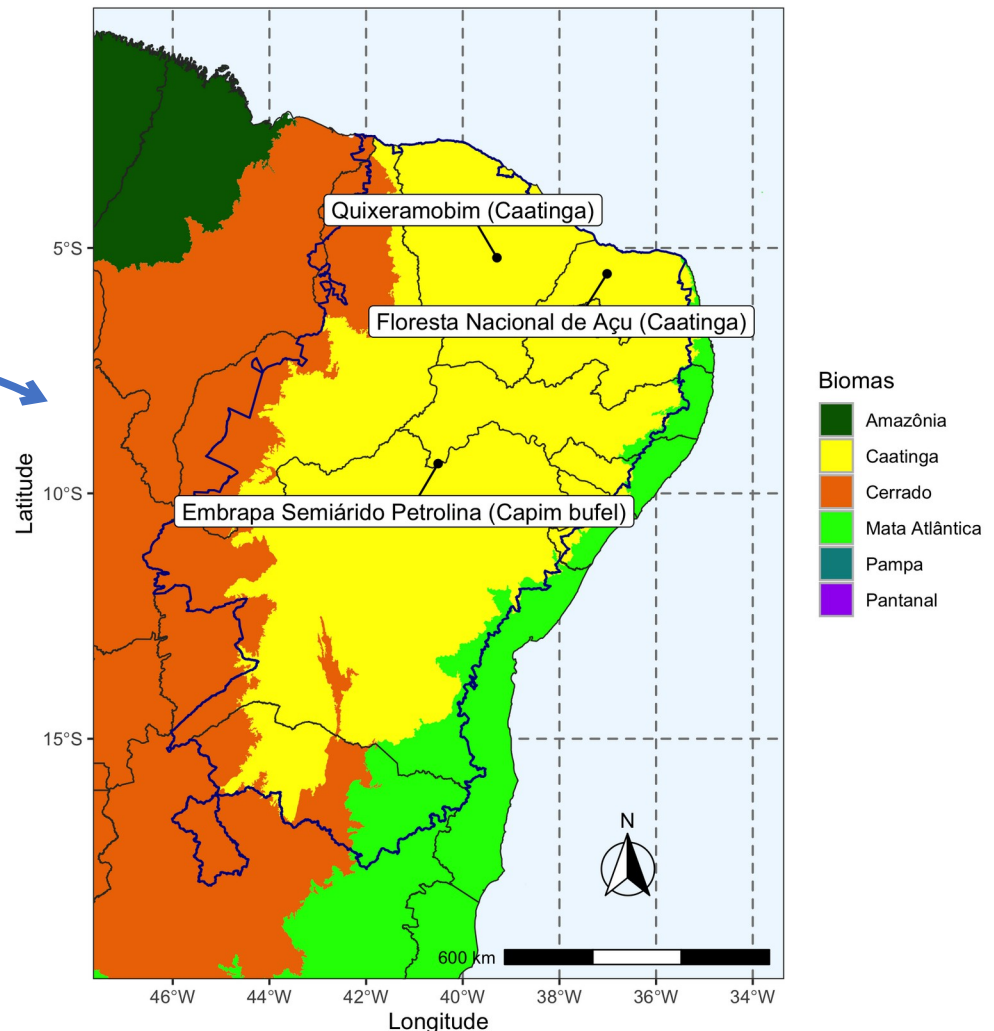


Propagação Incremental das Condições de Seca (PICS)
Outubro 2023



Future steps: flux towers, flash droughts

- Installation of flux towers in the semiarid region
 - Real-time measurements of evapotranspiration, air temperature, soil moisture, precipitation
- Assessment of trends and flash droughts
- Composite drought events (rainfall and temperature)
 - How do the rainfall and temperature anomaly are related in time? (cross-wavelet)



Drought monitoring at Cemaden: past, present and **future**

Past and present

Monitoring since 2013

Attendance to the demands and actions of the federal government

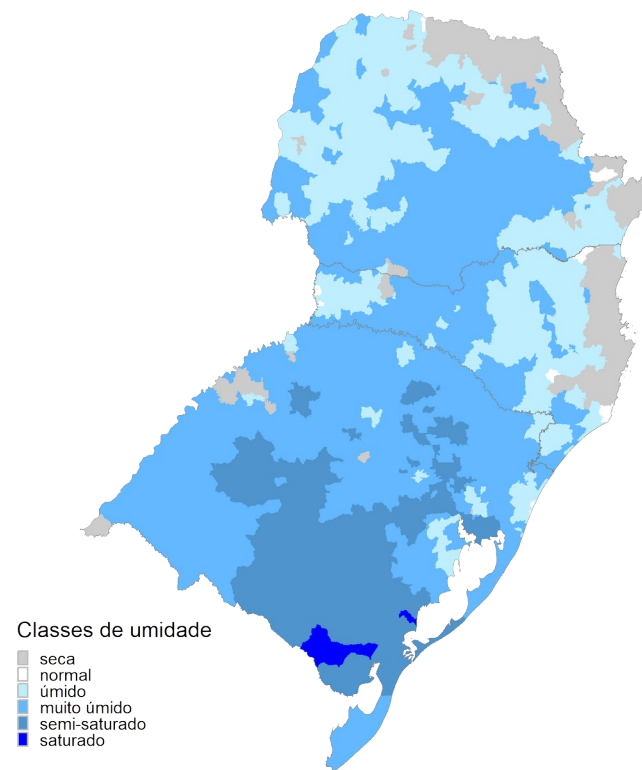
Identification of municipalities affected by drought to support the Ministry of Agrarian Development's Crop Guarantee program

Support for National Water Agency (ANA) crisis rooms for southern, northern, northeastern regions, basins and biomes

Future

- Integration of sub-seasonal forecasts
- Identifying patterns using AI
- Testing of new indices: Aggregate Water

Resources Index (IARA)





Obrigado!

Contact: marcelo.zeri@cemaden.gov.br