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Papers

Spatiotemporal Dynamics of Vegetation Cover and Drought Conditions in the Semi-Arid Region of Brazil

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Abstract
Studying a region's spatiotemporal dynamics provides essential data on changes over time, and Remote Sensing facilitates the generation of this data, offering a comprehensive view of transformations in an interest area. This work involves the use of Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI) and Standardized Precipitation Index (SPI) to provide information on spatiotemporal dynamics of vegetation and drought conditions in Brígida's River Basin, located in Pernambuco's state, Brazil, as well as Chapada do Araripe region inserted in the same basin, using nine images from TM Landsat 5 and OLI Landsat 8 satellites on different dates. Precipitation data were obtained from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) with a cutout for the Brígida basin from 1990 to 2024. The results allowed to observe temporal pattern of precipitation events every three months through SPI-3, with periods of greater intensity drought and duration for 1991-1993, 1998-1999 and 2012-2017 periods, as well as the changes in the amount of vegetative vigor studied over different dates in the basin, with the image from 06/16/1990 standing out with the highest values of vegetation indices, with results above 0.5 for NDVI and above 0.3 for EVI, especially in the Chapada do Araripe region. It was concluded that the results revealed the impact of precipitation and drought on reducing vegetative vigor over time, providing crucial data for water resource management, water security, and climate change mitigation strategies.

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INTRODUCTION

Remote Sensing has proven to be an indispensable tool in monitoring impacts of climate change, offering an efficient approach to water resource management on a global scale, enabling continuous monitoring of variables such as temperature, precipitation, and vegetation dynamics (Garajeh *et al*., 2024). The use of spectral indices has multiple uses within Remote Sensing, particularly to obtain land surface coverage information.

Studies have emerged and proved the usefulness of spectral indices, which can involve physical characteristics of the landscape, as carried out by Galvíncio *et al*. (2007) who estimated, with an index that developed spectral measures for calculate the vegetal cover fraction, named Normalized Difference Vegetation Index (NDVI), a coverage of remnant Caatinga in 42.68% of the Brígida River basin's area, which can be increased by 12% in wet periods.

However, vegetation is influenced in complex ways by drought events, which can interfere with its physiology and growth, as well as changes in temperature and humidity, which can reduce productivity and increase its vulnerability to pests and diseases. Thus, studies on the influence of drought on vegetation growth and resistance have been carried out by associating vegetation indices with drought indices to estimate the effects of different types of droughts on vegetation (Shi *et al.,* 2022). In general, drought indices are based on meteorological and hydrological factors and can be effective in analyzing dry and wet periods, such as Standard Precipitation Index (SPI), who was designed to quantify the precipitation deficit for multiple scales (WMO, 2012).

In the Brazilian Northeast region, Barbosa *et al*. (2019) sought to evaluate impacts of drought on Caatinga vegetation by comparing NDVI data with precipitation time series using SPI, and they identified a significant correlation. In addition, another study carried out by Brito *et al*. (2021) applied SPI to assess the meteorological droughts using Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data in Piranhas River basin, northeastern Brazil, between 1994 to 2017. Their study highlighted the significance of SPI to understand drought dynamics. Also in this context, the Plano Nacional de Recursos Hídricos (PNSH), or National Water Security Plan, a document that guides implementation of water resources national plans, points Brazil's Semi-arid region as being the country's most vulnerable, due to the high rainfall variability associated with absence of reservoirs or groundwater. Thus, monitoring hydroclimatic variables and their changes aggravated by climate change in historical records, offer support for an integrated management of water resources (ANA, 2019).

Therefore, the application of vegetation indices NDVI and EVI, and drought indices, SPI, enabled the analysis of the study area at this work, which focused on Brígida Basin and located in the western region of Pernambuco's state, Brazil. The indexes application generate data to investigate the spatiotemporal dynamics of vegetation cover at Brígida River basin.

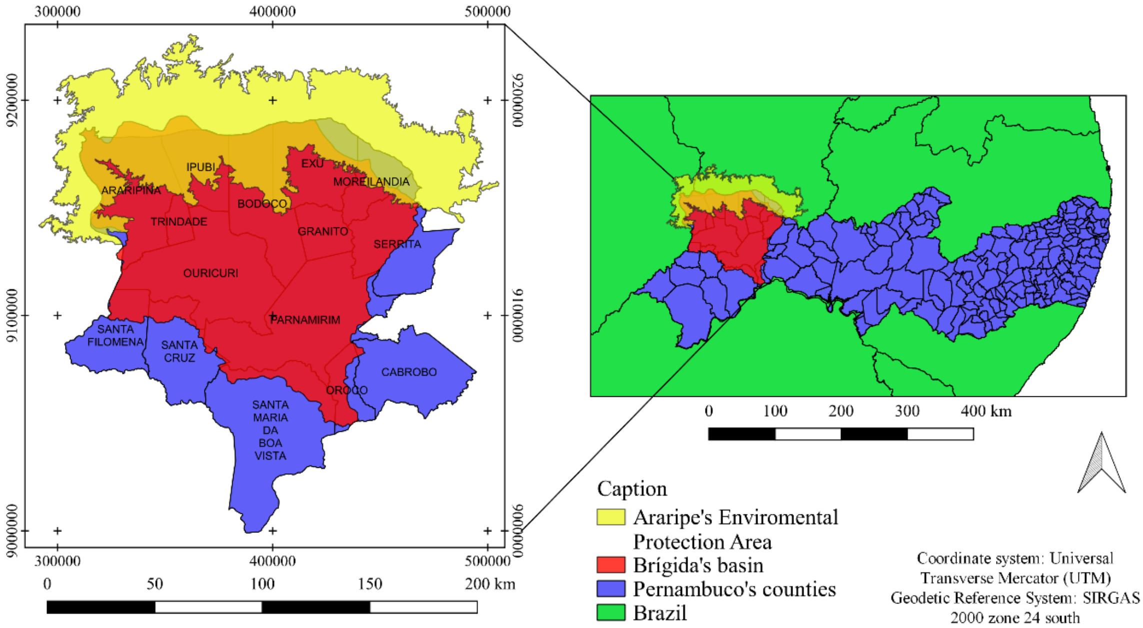
MATERIAL AND METHODS

Study area

The study area comprises the Brígida River basin, located in Pernambuco's semi-arid region, Brazil, bordered to the north by Ceará and Piauí's states. To south Brígida's basin is bordered by Bahia State, to west by Piauí's state and to east by Terra Nova's River basin. These separation on groups of basins occurred according to the Plano de Recursos Hídricos do Estado de Pernambuco (PERH/PE), or Hydric Resources State Plan of Pernambuco that has the aim to plan the use of hydric resources and assure its quality, availability and conservation. At PERH/PE, Brigida's basin is an integrant part of Planning Unit 13 (UP13) (Pernambuco, 2022).

The Brígida River flows into São Francisco River and, according to Galvíncio *et al*. (2007), its source is in Chapada do Araripe, where the Exú's municipality is located. According to the Agencia Pernambucana de Água e Clima – APAC (2024), the water and climate agency, which executes the water resources policy, plans, and regulates water use in Pernambuco's state, the river has a length of 193 km, and its largest tributaries are São Pedro River, followed by Gravatá stream. Also, according to APAC (2024), Brígida River basin has an 13,495.73 km² area, corresponding to 13.73% of Pernambuco's state, covering 15 municipalities.

Figure 1 - Location of the Brígida River Basin



Source: IBGE (2023); IBGE (2024); Brasil (2024); The authors (2025).

APA da Chapada do Araripe is part of the Brígida River basin and, according to Andrade and Mota (2022), has a significant diversity of natural resources and plants, where public preservation areas coexist with interests of private properties. With the environmental legislation and conservation instruments for Áreas de Preservação Ambiental, there has been a conflict with predatory extraction resources. According to Brasil (2024), the biome of APA da Chapada do Araripe is *Caatinga*, characterized by a specific desert vegetation resilient to drought events and found only in Brazil (Araujo *et al.,* 2021). The region has an 972,605.18 hectares area, distributed between the states of Ceará, Pernambuco, and Piauí, and its southern part intersects with the northern region of Brígida's basin. According to Sousa *et al.* (2023), the north region of Brígida's basin, which encompasses Chapada do Araripe, has a high elevation and considerable spatial variability in rainfall and high vegetation density.

Data acquisition

To this research, eight different dates (Chart 1) were used over 33 years, with orbital data from Landsat 5 satellite with Thematic Mapper (TM) sensor and Landsat 8 with Operational Land Imager (OLI) sensor. The complete basin's image was found in two scenes, both in orbit 217, at points 65 and 66, obtained through the website of United States Geological Survey (USGS, 2024). Images with cloud covers less than 2% were searched, except for one case in which, due to the scarcity of available images, an image with 7% coverage was obtained, on 11/27/2009. Images were searched in the year's dry season, in accordance with a low incidence of clouds.

Chart 1 - Images dates and satellites

DATE	SENSOR/SATELITE
06/16/1990	TM / Landsat 5
11/02/1994	TM / Landsat 5
09/23/1997	TM / Landsat 5
07/06/2003	TM / Landsat 5
11/27/2009	TM / Landsat 5
09/09/2013	OLI / Landsat 8
07/15/2018	OLI / Landsat 8
10/30/2022	OLI / Landsat 8
09/17/2024	OLI / Landsat 8

Source: The authors (2025).

Precipitation data from 1990 to 2024 were obtained from the CHIRPS v2.0 dataset, developed by Funk *et al.* (2015). This dataset integrates daily rainfall observations at a spatial resolution of 0.05° × 0.05°, combining satellite imagery and in-situ station measurements to generate gridded rainfall time series for trend analysis and seasonal drought monitoring. According to Andrade *et al.* (2022), the CHIRPS dataset could adequately capture variability of precipitation in Brazilian Northeast region, in good correspondence with precipitation data from rain gauges. In this study, precipitation data from CHIRPS were extracted through Google Earth Engine (GEE).

Image preprocessing

The images preprocessing and processing were performed using the Quantum geographic information system (QGIS) software, version 3.16.1, which is a free and open-source cross-platform desktop geographic data framework application that backings survey, altering and investigation of geospatial information, according to Khan and Mohiuddin (2018). The multispectral images were downloaded in different raster bands, and those were stacked to create a single multispectral scene. Considering the size of Brígida basin, more than one Landsat scene was required to cover the entire basin. Considering this, it was necessary to mosaic two scenes, aiming to merge the scenes into a single image.

Once the scenes were stacked and mosaicked, the vector and raster images were reprojected to same Coordinate Reference System (CRS). The CRS code used was EPSG 31984, on Universal Transverse Mercator Coordinate System, and geodesic reference system was Sirgas 2000, zone 24 South. After merging, mosaicking, reprojecting and cropping the images, it was possible to perform their processing, including the images correction using addictive and multiplicative factors, according to the image's metadata.

Image processing

It calculated each image's reflectance, to process the NDVI and EVI. The procedures used involved images radiometric calibration, to compute reflectance and indices.
Reflectance is a ratio between reflected solar energy flux and incident solar energy flux in a region and must be corrected according to additive and multiplicative scale factors provided in the metadata file. The calculation of reflectance for OLI Landsat 8 and TM Landsat 5 is identified by Equation 1, according to Landsat product data, made available by the USGS (2024).

$$\rho_\lambda = M_\rho . Q_{cal} + A_\rho \quad (1)$$

Where "ρλ" is the planetary reflectance, "Mρ" is the band-specific multiplicative scale factor, "Qcal" is the calibrated and quantized pixel value, also identified by digital number (ND), "Aρ" is the band-specific additive scale factor.

The Normalized Difference Vegetation Index (NDVI), proposed by Rouse *et al.* (1973), is calculated through the ratio of the difference between near-infrared band (ρIVp) and red band (ρv) and the sum of these bands. Its equation is defined by Equation 2.

$$NDVI = \frac{\rho IV_p - \rho v}{\rho IV_p + \rho v} \quad (2)$$

Where for TM Landsat 5, near-infrared and red bands correspond, respectively, to bands 4 and 3, and for OLI Landsat 8, the near-infrared and red bands are, respectively, bands 5 and 4. For vegetated surfaces, NDVI value will be positive, while for water or cloud surfaces, it will be negative.

The Enhanced Vegetation Index (EVI), proposed by Huete *et al.* (1997), analyzes areas of denser vegetation, using the near-infrared, red and blue bands ($\rho blue$), as well as other factors and coefficients. Its processing is performed according to Equation 3.

$$EVI = \frac{G.(\rho_{IV\rho} - \rho_v)}{L + \rho_{IVp} + C1.\rho_v - C2.\rho_{azul}} \quad (3)$$

Where for TM Landsat 5, blue band corresponds to band 1 and for OLI Landsat 8 it corresponds to band 2; "G" corresponds to the gain factor (G=2.5); "L" refers to background adjustment of the vegetation canopy (L=1) and "C1" and "C2" correspond to adjustment coefficients of the aerosols influence (C1=6; C2=7.5). EVI values range from -1 to +1, and for healthy vegetation the values range from 0.2 to 0.8.

To identify correlations on results between the vegetation indices analyzed, 72 points were randomly selected in the Chapada do Araripe image's region. Values of NDVI and EVI were identified at each point, on all dates, and the coefficient of determination (R^2) between indices and trend line of their average values were found.

Index for drought monitoring

To monitor severity and extent of drought during the adopted time series, Standardized Precipitation Index (SPI) was applied from 1990 to 2024. This is one of the drought monitoring and forecasting tools most recommended by the World Meteorological Organization (WMO) that can be applied to different time scales, whose input data is precipitation (WMO, 2012).

In its original formulation, precipitation data are adjusted to Gamma distribution to define a relationship between data and probability of occurrence. This probability is then combined with an estimate of inverse normal distribution to calculate the deviation of precipitation amount from a zero mean and a standard deviation of unity. Thus, SPI can be used to monitor both dry and wet periods, allowing this variation to be represented in a similar way. In this study, SPI was calculated from the R software version 2023.12.1 with SCI package. The R software is a open-source software for data science, scientific research, and technical communication (RSTUDIO TEAM, 2025).

In SPI calculation, monthly precipitation data were used, with a 3-month time scale (SPI-3), which is commonly used in studies of vegetation's initial vulnerability, in a way that the precipitation's effects anomalies in study region and their short-term distribution could be observed (Rad *et al.*, 2017; Ortega-Gómez *et al.*, 2018), and the classification is made according to Table 1 (McKee *et al.*, 1993). The 3-month time scale for several drought indices, including the SPI, was found to be the most proper for identifying the influence of agricultural drought on vegetation health, according to a study conducted by Javed *et al.* (2021) in China, since the SPI-3 reflects short to medium term soil moisture, and it gives an indication of available moisture conditions at the beginning of growing season. Due to the basin's climatic characteristics, only drought events were considered (negative SPI).

Table 1 - Description of SPI in class interval

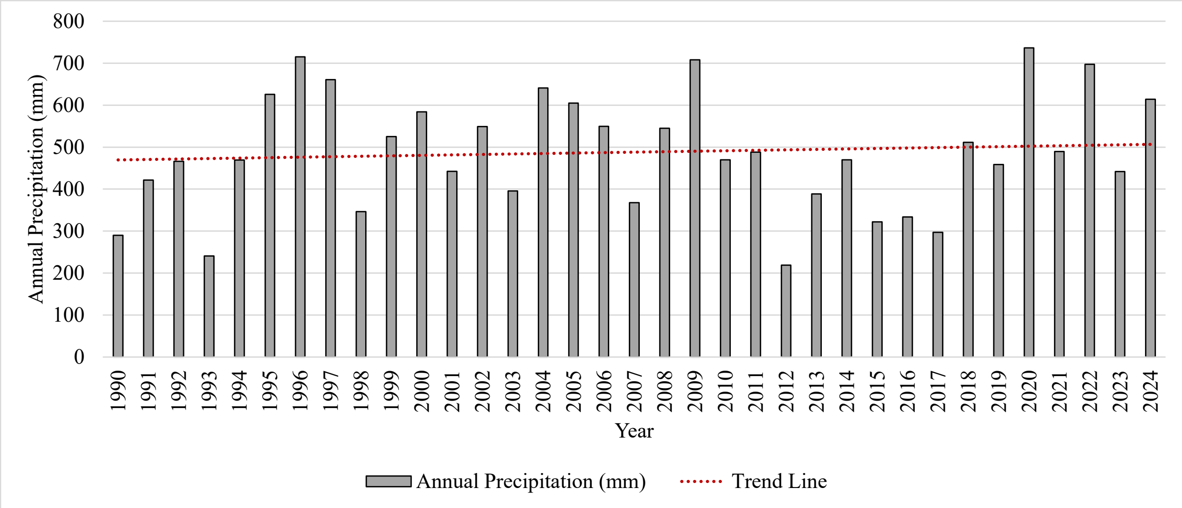
CLASS	SPI	P_{lower}	P_{top}
Extreme Drought	< -2.0	0.0%	2.28%
Severe Drought	-1.99 to -1.5	2.28%	6.68%
Moderate Drought	-1.49 to -1.0	6.68%	15.9%
Near Normal	-0.99 to 0.99	15.9%	50.0%

Source: The authors (2025). Adapted from McKee *et al.* (1993).

RESULTS AND DISCUSSION

Figure 2 shows the total annual precipitation values for each year in the period from 1990 to 2024.

Figure 2 - Total annual precipitation in the period from 1990 to 2024

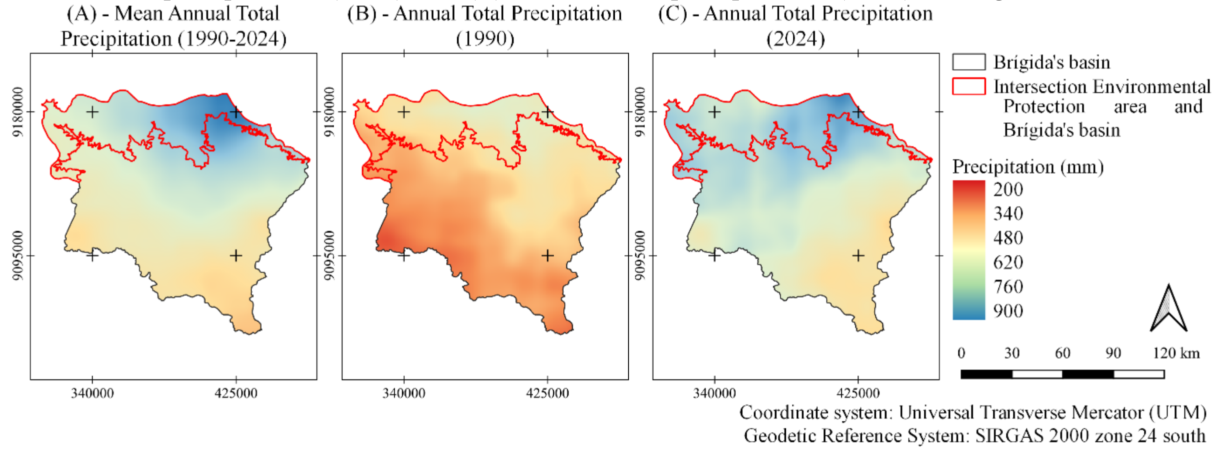


Source: The authors (2025).

According to data, there's a great annual variability throughout the studied period, with a slight tendency for precipitation to increase. The years 1993 and 2012 stand out as being the years with the lowest total precipitation due to critical drought events, also shown in Marengo *et al.* (2018), that cited the extreme drought years based on El Niño and a warmer tropical North Atlantic Ocean, that were responsible for circulation changes, reducing rain fall over Northeast Brazil, while the years 1996, 2009, 2020 and 2022 were years with high precipitation. The average precipitation for 1990 to 2024, as well as annual precipitation for 1990 and 2024 were spatially distributed, seen in Figure 3.

The years shown in Figure 3 were chosen because they are, respectively, the first and last of the adopted time series. The average precipitation for the period from 1990 to 2024 was 488.18 mm, with the highest average precipitation values in the northern and northeastern regions of the basin, where Chapada do Araripe is located.

Figure 3 - Spatial distribution of (A) average annual total precipitation (1990-2024), (B) annual total precipitation (1990) and (C) annual total precipitation (2024) in Brígida basin



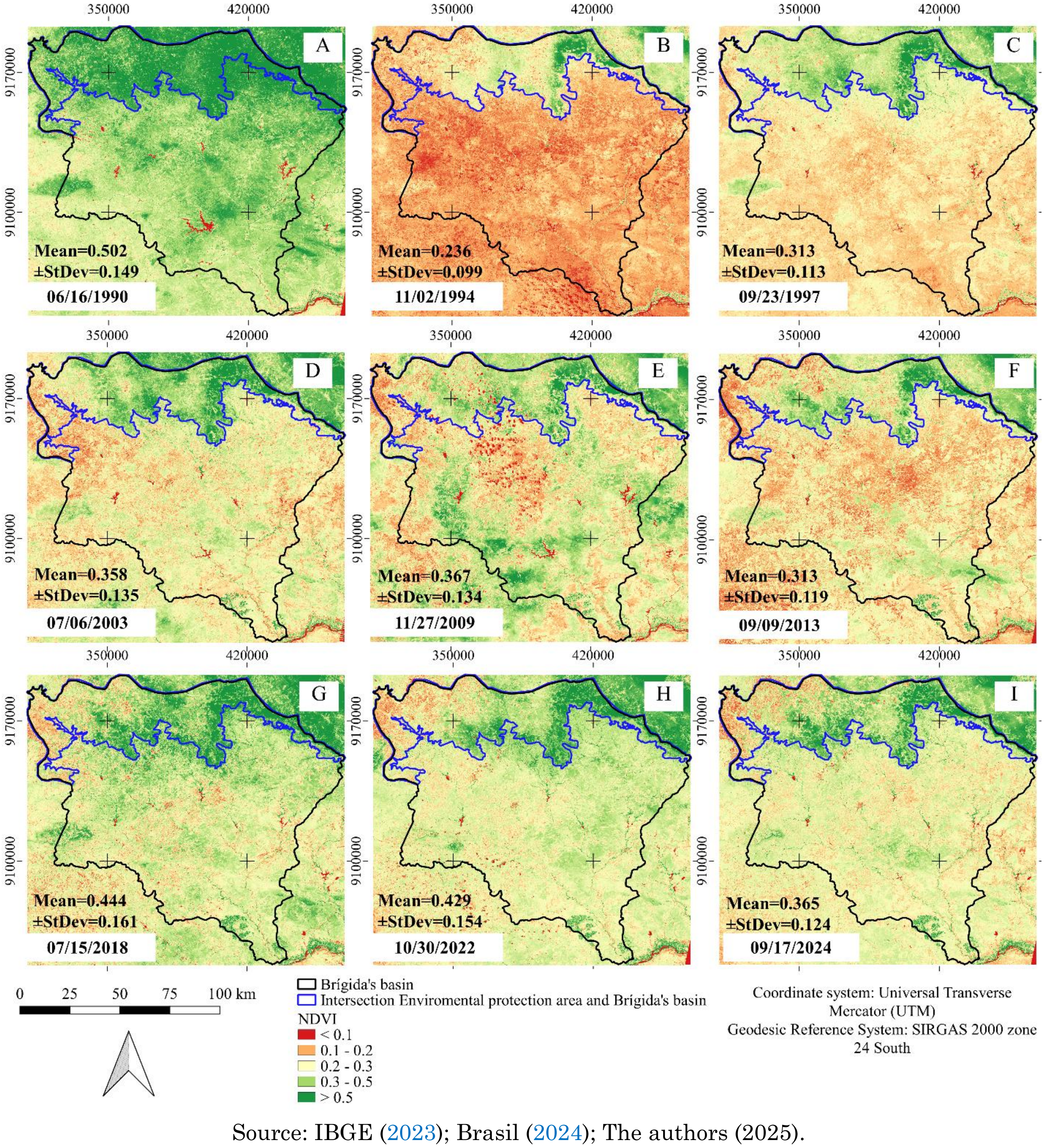
Source: IBGE (2023); Brasil (2024); The authors (2025).

Figure 3-b suggests a negative precipitation anomaly, with a value lower than historical average, observed for the period studied, with a reduction of 40.55% in the average precipitation in 1990. For 2024 (Figure 3-c), the calculated precipitation anomaly was positive, indicating that there was precipitation higher than the average precipitation for the period considered, with an increase of 25.82%. These results can be confirmed by Figure 2, which suggests below-average precipitation for 1990 and high precipitation for 2024. These results are also in line with the latest Full Report on the Situation of Water Resources in Brazil (ANA, 2022), which indicated an increase in precipitation records in northeastern Brazil from 2018 onwards, that can be seen by comparing Figure 2 (precipitation above trend line) and Figure 3-c (precipitation

varying between 620 and 900 mm, approximately).

According to spatiotemporal dynamics of NDVI, it was noticeable that on dates from 1994 to 2013 (Figure 4-b-f) there was less vegetation coverage, with 1994, 1997 and 2013 images standing out. Although the years 1997 and 2009 recorded annual precipitation above the average for the study period (Figure 2), the highest rainfall volumes were concentrated in the early months of the year, having limited influence on the conditions observed on the image acquisition date.

Figure 4 - Classification of the NDVI vegetation index in the Brígida River Basin



Source: IBGE (2023); Brasil (2024); The authors (2025).

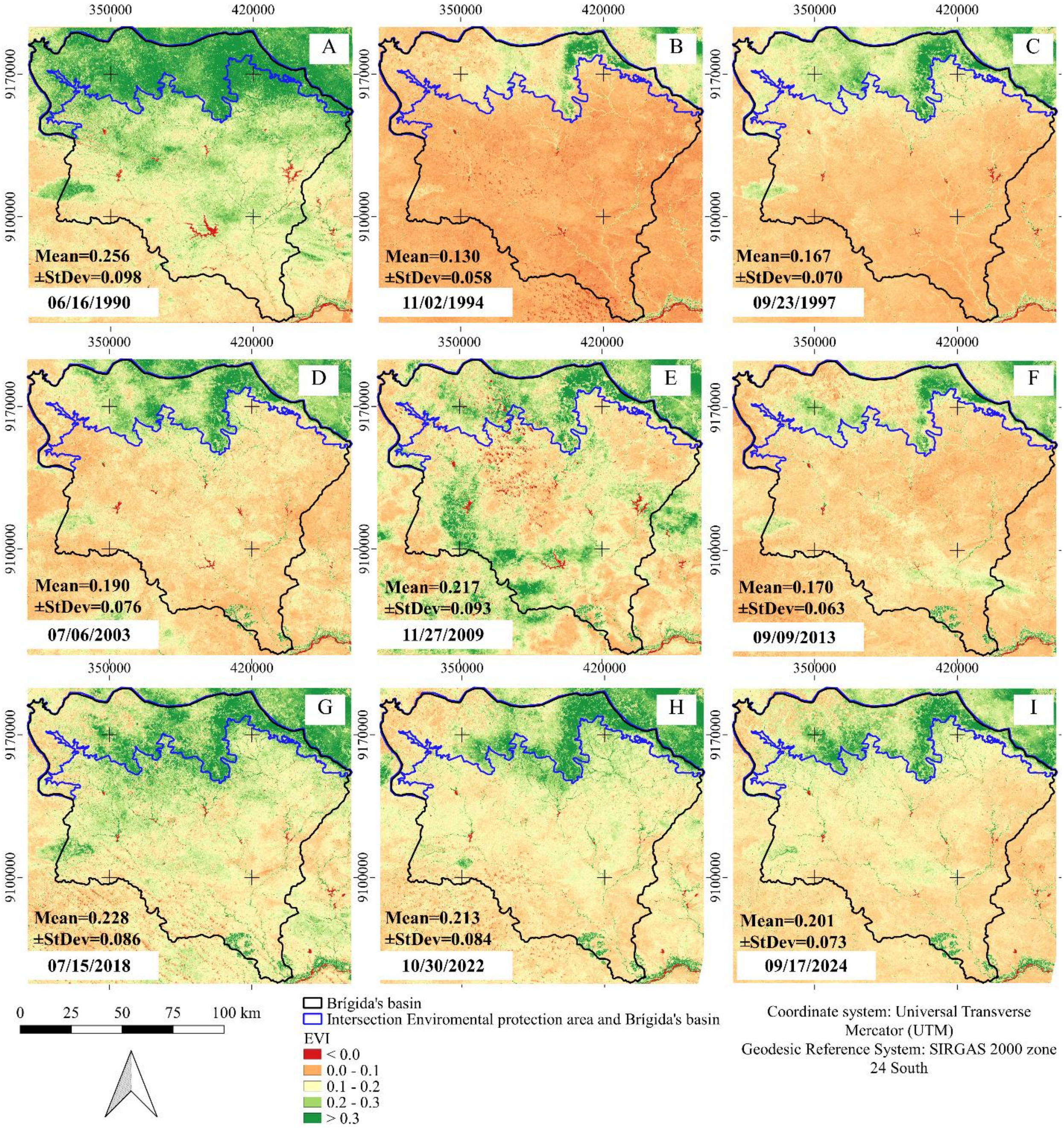
In images from 1990, 2018, 2022 and 2024 (Figure 4-A, 4-G, 4-H and 4-I) there was greater vegetation coverage, with the date from 1990 standing out positively. The northern part of the basin, identified as the southern area of the Área de Preservação da Chapada do Araripe, or Chapada do Araripe Preservation Area, in Pernambuco, consistently showed more vegetation, highlighted by a blue outline in the images. This pattern appears to be closely related to precipitation distribution, as this northern region also presents the highest rainfall values across the three analyzed maps (Figures 3).

In the analyzed image, dated 06/16/1990 (Figure 4-A), a strong intensity of vegetation, identified through the highest mean, can be seen in the northeast region of the Brígida basin, where the municipalities of Exú and Moreilândia are located. Sousa *et al.* (2023), also studying the same basin, found a spatial increase in the amount of precipitation, proportional to the increase in the elevation of the basin. The northern region, which includes Chapada do Araripe, has higher elevations and a greater vegetative density.

Also in Sousa *et al.* (2023), they performed a spatiotemporal analysis of precipitation and droughts in the Brígida basin, and its land use and coverage dynamics, also using NDVI and ground reference data from 40 climate stations for a 55-year time series. In their study, the vegetation index properly detected environmental degradation that occurred during a period of severe drought dated between 2012 and 2013, where the annual precipitation was 272.97 mm in 2012 and 416.69 mm in 2013. Additionally, in a study carried out with NDVI in the Brígida river basin dated 09/13/2002, according to Galvíncio *et al.* (2007), the remaining coverage of *Caatinga* in the basin was evidenced in 42.68% of its area, in the dry season, with approximately 50% of its area covered by vegetation (including forests, crops etc.).

In the analysis of EVI (Figure 5), a correlation with the result of NDVI was noticeable when considering both indices. The dates of 06/16/1990 and 11/02/1994 were consolidated as having the highest and lowest vegetative vigor, respectively. However, for EVI, it is possible to note that the results of the classifications were more pronounced, which is consistent with Huete *et al.* (2002), who stated that EVI presents greater emphasis on structural variations in the canopy, including the leaf area index, canopy type, plant physiognomy and canopy architecture.

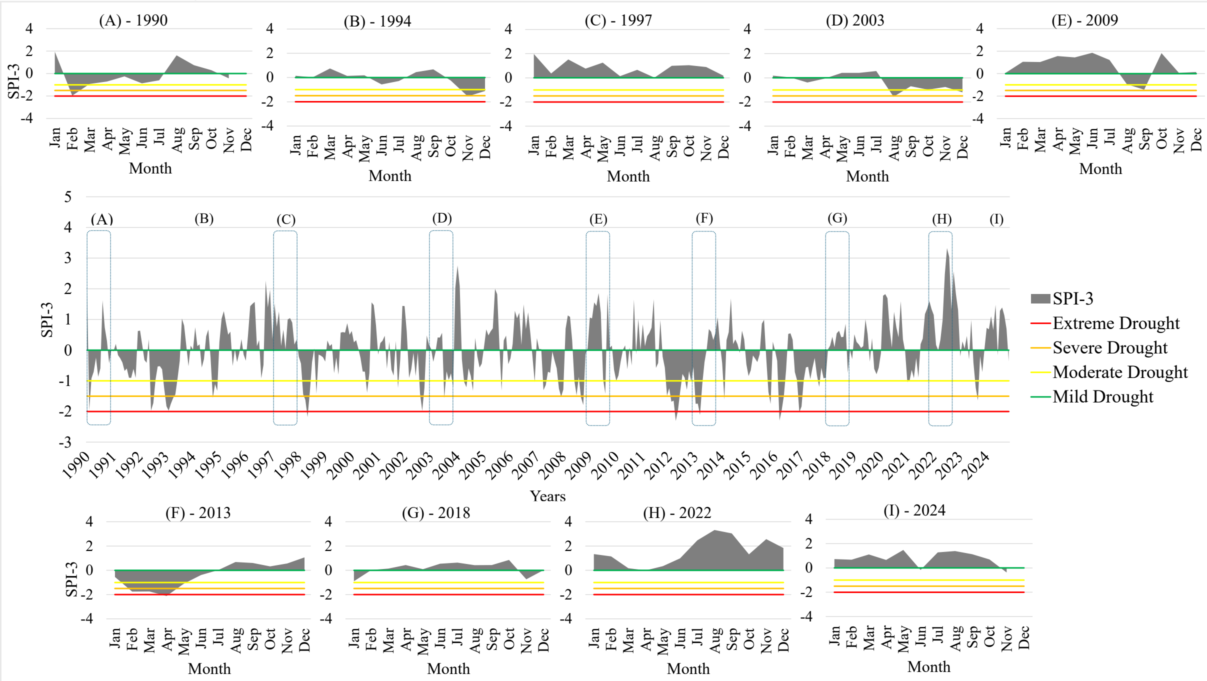
Figure 5 - Classification of the EVI vegetation index in the Brígida River Basin



Source: IBGE (2023); Brasil (2024); The authors (2025).

In the results shown in Figure 5, it was observed that a low response to vegetation cover was noticeable on 1994 (B), 1997 (C) and 2013 (F) dates, with the date of 11/02/1994 standing out, having the lowest vegetative vigor, with a 0.130 mean. On 06/16/1990 and 11/27/2009, there was a well-distributed response among the vegetation level classes, apparently, with their regions varying considerably between exposed soil and vegetative vigor. There were similarities between the NDVI and EVI indexes results about the greatest vegetative vigor on 06/16/1990, with 0.502 mean for NDVI and 0.256 for EVI, and lowest vigor on 11/02/1994 with 0.236 for NDVI and 0.130 for EVI, (Figure 4-A, 4-B and Figure 5-A, 5-B), which represented, respectively, the highest and lowest values for 1990 and 1994's images. This variation in spectral vegetation response aligns with the SPI-3 values for Brígida River basin (Figures 6-A and 6-B), which effectively capture drought periods corresponding to the image acquisition dates, particularly the dry conditions in late 1994 and wetter context observed in mid-1990.

Figure 6 – SPI series for 3 months for the time series from 1990 to 2022



Source: The authors (2025).

The SPI-3 values for the periods 1991-1993, 1998-1999 and 2012-2017 shown a great severity and duration of drought for the study region, classified according to Table 1 as periods of Extreme Drought. These results were also observed in the study carried out by Marengo *et al.* (2018), who identified records of intense droughts caused by the intense El Niño phenomenon in the years 1997, 1998 and 2015 in several locations in the Brazilian Northeast region. According to Marengo *et al.* (2016), the period from 2012 to 2013 was marked by changes in atmospheric circulation and precipitation, causing a subsidence anomaly in the Northeast of Brazil, which resulted in periods of drought. This phenomenon may have influenced the result obtained for the images processed for NDVI and EVI on 09/09/2013 (Figures 4-F and 5-F), which showed reduced vegetative vigor. For the selected dates, the most critical years, according to SPI-3, were 1990, 2003 and 2013, with the highest drought intensity being observed in 2013 (Figure 6-F). For NDVI and EVI on 11/2/1994, results showed low values of vegetative vigor among the dates between the years 1990 and 2000, which is consistent with the result obtained for the same year through SPI-3, which indicates the occurrence of mild to extreme drought from September onwards, for that time. However, it is noteworthy that from 1994 onwards, the intense drought scenario that extended from 1991 to 1993 began to slow down, which may have reflected in low values obtained for vegetation indices on 11/2/1994.

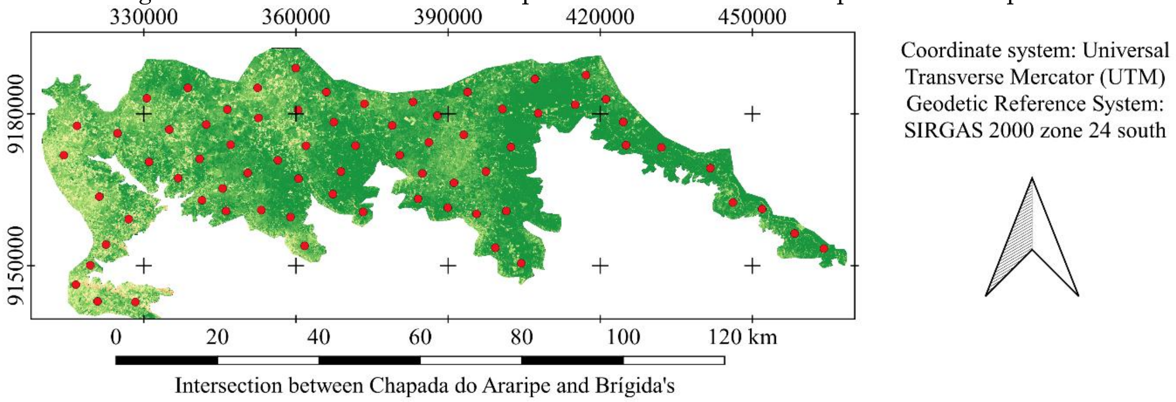
The years 1997, 2009, 2022 and 2024 can be considered wet years according to SPI-3 results, but the dates of 09/23/1997 (Figure 5-C) and 11/27/2009 (Figure 5-E) presented low values of vegetation cover for both vegetation indices processed. However, also for northeast areas, changes in land use, poor agricultural practices, and the presence of pests or plant diseases can also cause index anomalies like those induced by drought (Heim, 2002; Cunha *et al.,* 2015). Furthermore, the images represent only one day of the year, whereas the SPI is representative of an entire year. Therefore, precipitation dynamics from days or weeks prior to data acquisition may influence image visualization.

Although the June 16, 1990, date (Figure 5-A) shows high vegetative vigor according to NDVI and EVI, it is important to highlight that in that year, the total annual precipitation of 440.73 mm was below the average of 577.63 mm (Figure 2), and a dry period was identified that extended from January to April through SPI-3 (Figure 6-A). However, the first months of the year were marked by low rainfall, followed by an atypical precipitation event in April of 146.80 mm, which may have contributed to SPI-3 results observed for the following months. Furthermore, it was found that until 1990, there were still considerable areas of primitive vegetation in the Chapada do Araripe region. Comparing visually the north part of Brigida's basin, it was represented by the greener areas, and it was evidenced specifically by high indexes values, above 0.5 for NDVI and above 0.3 for EVI. It began to be modified for cassava cultivation, agriculture, and use of wood for firewood and charcoal, and extended to adjacent areas. From the 1990s onwards, measures were taken to restore the region's vegetation cover (Silva Neto, 2013).

The combination of short-term drought indices SPI-3 with the vegetation index NDVI, demonstrated greater capacity for detecting early droughts compared to other indices studied by Ortega-Gómez *et al.* (2018) in a hydrographic basin with a humid to semi-arid climate located in Spain.

To compare the processed vegetation indices (Table 2), 72 randomly selected points were used in Área de Preservação Ambiental da Chapada do Araripe, in order to obtain a comprehensive coverage of the evidence area, as shown in Figure 7. These points were selected using QGIS and stored in a shapefile, the data of vegetation indices values were used for the comparison between them. The same method using points and coefficient of determination (R^2) was used by Macandza (2022), who used logistic regression and GIS techniques in the dynamic analysis of forest cover in Mabote and Funhalouro, Inhambane, southern Mozambique.

Figure 7 - Location of the chosen points in the APA da Chapada do Araripe area



Source: Brasil (2024); The authors (2025).

Table 2 - Coefficient of determination (R^2) for comparing values between EVI and NDVI

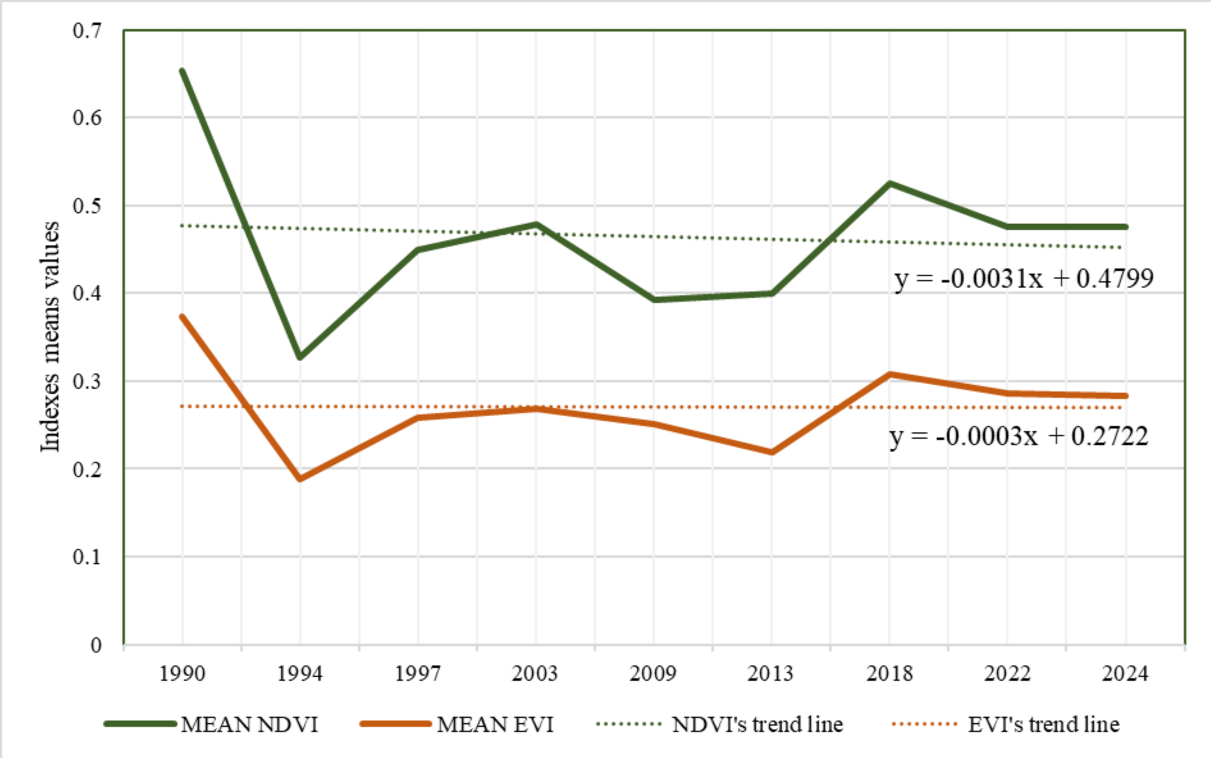
Date	06/16/1990	11/02/1994	09/23/1997	07/06/2003	11/27/2009	09/09/2013	07/15/2018	10/30/2022	09/17/2024
R^2	96.0%	95.4%	92.8%	91.6%	99.0%	90.6%	92.8%	92.7%	83.6%

Source: The authors (2025).

It was possible to see that the values of the coefficient of determination (R^2) were above 80%, demonstrating a good correlation between the NDVI and EVI values, with the date of 2024 having the lowest correlation, at 83.6%.

In addition, the average of two indices was sought in the 72 points, and it was observed that NDVI showed a slight tendency for its values to decrease over the dates, as shown in the trend line equation, with -0.0031 decline on NDVI and -0.0003 for EVI values (Figure 8). This decrease shows that, over the analyzed periods, there is a smaller quantity of pixels with high vegetative vigor over the dates or there is a possible increase in deforested areas, since the lower the EVI value, the less healthy the vegetation or the greater the amount of exposed soil. Over the years, it was observed that the average EVI values also indicated a reduction, although less explicit, with an almost horizontal trend line.

Figure 8 - Comparison of average values between NDVI and EVI on the dates analyzed

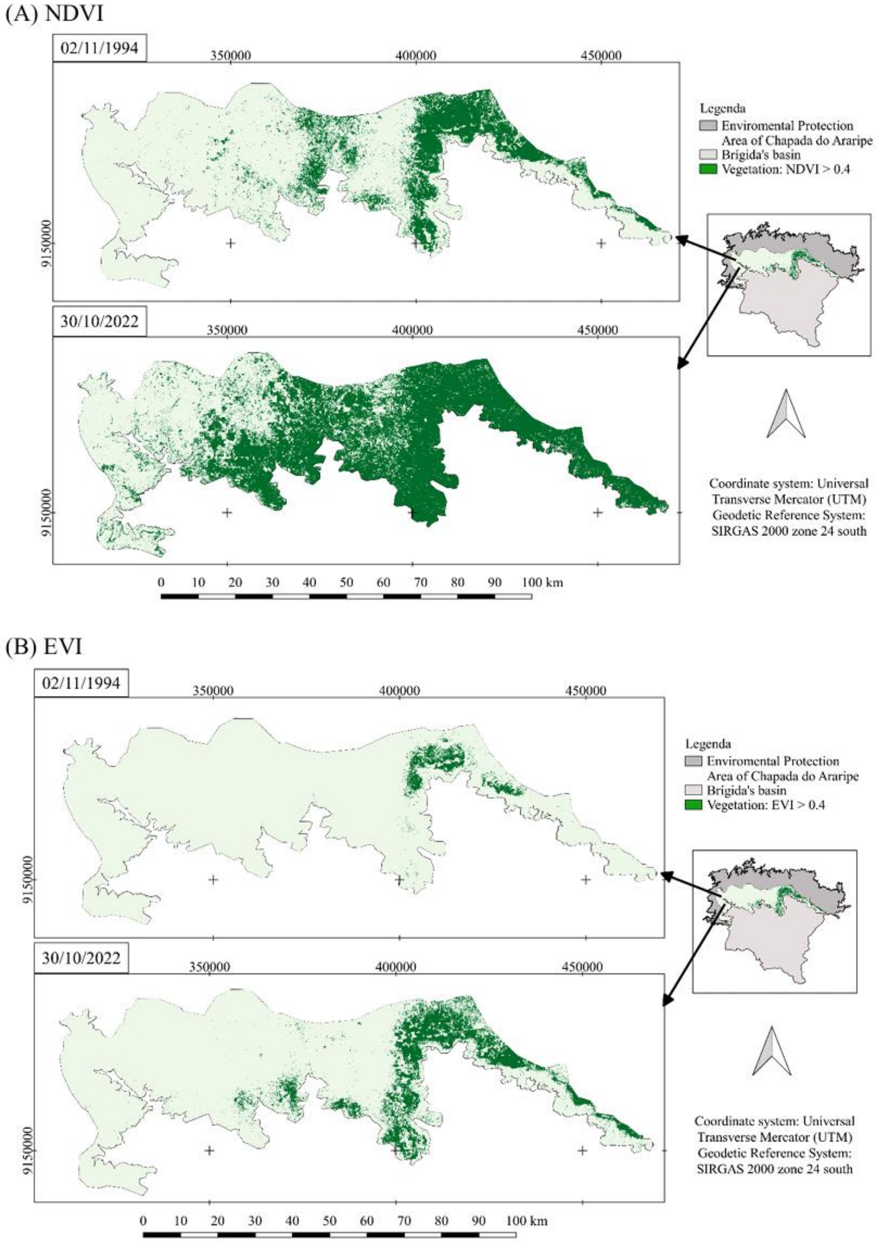


Source: The authors (2025).

In the work carried out by Ribeiro *et al.* (2016), which used the EVI to assess vegetation in the Pajeú river basin in 2003, 2005, 2007, 2012, 2013 and 2014, the year 2012 stood out, in which there was a loss of vegetation cover due to the lack of rainfall, demonstrating lower EVI values, followed by the recovery of vegetation in 2014.

Among the years used here, the two closest dates were selected between the different years evaluated to make a comparison between the vegetation regions of the intersection between Área de Preservação Ambiental da Chapada do Araripe and Brígida's Basin. The dates refer to the months of November and October of 1994 and 2022, respectively, with a time difference of 28 years and 3 days, and were sought index values that represented the vegetation with the greatest vegetative vigor, classified in the EVI and NDVI with values greater than 0.4. Given the results (Figure 9), it was identified that there was an increase in vigor between the dates of 1994 and 2022, according to the indexes applied.

Figure 9 - Comparison of (A) NDVI and (B) EVI for the period of 1994 and 2022 in the region of the Chapada do Araripe APA



Source: Brasil (2024); The authors (2025).

Figure 9-A shows greater vegetative vigor in eastern region of the APA-basin intersection on both dates, with a broader vegetative distribution toward the center in 2022. This pattern may be related to rainfall in the five days preceding 10/30/2022 image, which helped to increase vegetative vigor for the date.

The sum of the rainfall obtained through CHIRPS for the 5 days prior to the images is shown in Table 3. For most dates, there was a small amount of rain in the days prior to the sensor overpass on Brigida's basin; however, it's observed that there was a considerable precipitation between 10/25/2022 and 10/30/2022, with total accumulated value of 19.39 mm. This precipitation may have caused increase in green's regions highlighted, identified by NDVI classification, since the *Caatinga* vegetation has a rapid response rainfall event, as shown in Figure 9-A.

Table 3 – Accumulated precipitation 5 days before the date of each image adopted

DATE	ACCUMULATED PRECIPITATION (mm)
06/16/1990	0.00
11/02/1994	0.06
09/23/1997	0.00
07/06/2003	0.94
11/27/2009	0.00
09/09/2013	0.00
07/15/2018	0.02
10/30/2022	19.39
09/17/2024	0.93

Source: The authors (2025).

The difference between the results of the EVI and NDVI may be due to the fact cited by Huete *et al*. (2002), who stated that the EVI highlights structural variations in the canopy, canopy type and vegetation canopy architecture. However, the rain in the previous 5 days was not enough to cause changes in the canopy, but it was a reason for the improvement in vegetative vigor demonstrated by the NDVI.

FINAL CONSIDERATIONS

After observing the NDVI and EVI, it is possible to conclude that, according to the dates sought, the amount of vigor in the studied area has been constantly decreasing. This result was identified through the trend lines of the index values obtained punctually, indicating a reason to pay attention about vegetation regions in Brígida River basin. There's the possibility of vegetation variations due to land's use changes.

The SPI analysis indicated that these results can be explained based on the region's; rainfall regime, which resulted in some periods of high intensity and duration of drought events, especially in 2003, 2013 and 2018.

For vegetation indices, the results with the EVI were more sensitive to changes in the canopy, mainly for the Área de Preservação Ambiental da Chapada do Araripe region, while for the NDVI, the vegetative vigor was consolidated with changes in rainfall indices.

The results obtained provided data for understanding vegetation dynamics and its relationship with prolonged drought periods in the Brígida River basin. These data can support the development of environmental management measures, public policies for climate adaptation, and forest recovery initiatives, promoting a more sustainable and climate-resilient approach. Future research can incorporate modeling and forecasting methods for future impacts in the study area, such as machine learning algorithms, that uses Artificial Intelligence to analyze data and predict patterns, allowing more efficient management of natural resources and mitigation of the adverse effects of climate change in the long term, also providing the analysis of vegetative changes on the brazilian semiarid region, using spectral indices with more than 30 years of observation.

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Débora Soares: Conceptualization; Methodology; Software; Validation; Formal analysis; Investigation; Writing - Review & Editing. Juliana Moraes: Methodology; Software Validation; Formal analysis; Writing - Review & Editing. Diego Araújo: Supervision; Formal analysis; Validation; Anderson Paiva: Supervision. Leidjane Oliveira: Conceptualization; Supervision; Validation.