IOSR Journal of Business and Management (IOSR-JBM)
e-ISSN:2278-487X, p-ISSN: 2319-7668. Volume 26, Issue 6. Ser. 5 (June. 2024), PP 53-61
www.iosrjournals.org

Analysis Of Drought Occurrence In The Westernmost Santa Catarina Using Precipitation Time Series And The Standardized Precipitation Index (Spi)

Gabriel Oscar Cremona Parma
University Of Southern Santa Catarina Unisul; Graduate Program In Environmental Cs. Environmental Sciences, Center For Sustainable Development - Greens. Palhoça, Sc, Brazil

Felipe Teixeira Dias
State University Of Montes Claros; Graduate Program In Social Development - Ppgds, Montes Claros, Mg, Brazil

Gabriéle Aparecida Marciano Alves
University Of Southern Santa Catarina Unisul; Degree In Mathematics. Tubarão, Sc, Brazil

Priscila Cembranel
University Of Contestado, Mafra, Sc; Educational Society Of Santa Catarina; Center For Sustainable Development - Greens. Jaraguá Do Sul, Sc, Brazil

Anelise Leal Vieira Cubas
University Of Southern Santa Catarina Unisul. Postgraduate Program In Environmental Cs. Environmental Sciences; Center For Sustainable Development - Greens. Palhoça, Sc, Brazil

Abstract
This study analyzes the occurrence of droughts in the far west of Santa Catarina using the precipitation time series and the Standardized Precipitation Index (SPI) from 2001 to 2022. Through an introduction to the phenomenon of droughts and their socio-environmental relevance, we highlight the importance of understanding regional precipitation dynamics and their implications for sustainable development. The methodology combines qualitative and quantitative analysis, using rainfall data obtained from NASA's GIOVANNI platform, and time series analysis using R to break down the rainfall series into its fundamental components and calculate the SPI on short, medium, and long term scales. The results reveal significant rainfall variation: there are periods of drought of varying intensities identified by the SPI. The temporal analysis did not indicate significant long-term trends or clear seasonality, suggesting that the variations are predominantly influenced by random factors. The discussion emphasizes the applicability of SPI as a tool for monitoring droughts, highlighting the complexity of rainfall dynamics in the region and the need for adaptive approaches to water resource management. The final considerations emphasize the relevance of this study for understanding droughts in the far west of Santa Catarina and highlight the importance of proactive strategies for mitigating aand adapting to climate change and natural variability. This work contributes to the body of knowledge on droughts in the region and offers valuable insights for planning and implementing sustainable water management measures.

Keywords: *Standardized Precipitation Index (SPI); Rainfall Time Series; Drought Analysis; Climate Variability; Water Resources Management*

Date of Submission: 07-06-2024 Date of Acceptance: 17-06-2024

I. Introduction

Climatic phenomena, especially droughts, give rise to in-depth reflections on their causes, detection, and socio-environmental impacts. This is characterized by its prolonged duration and unpredictability (MISHRA & SINGH, 2010, 2011) and presents challenges for its prediction and for managing its consequences, especially in regions with different regional characteristics. Meteorological drought is a reduction in the volume of precipitation below a specific threshold (NAUMANN et al., 2018; PAN et al., 2018); it directly affects water resource management and impacts activities such as irrigation and agricultural management, which are essential for the sustainability of river basins.

The relevance of this phenomenon extends to its direct impact on agriculture, as it compromises crop productivity (ARORA, 2019; JAVADINEJAD et al., 2021) and consequently influences the ability to meet crucial Sustainable Development Goals, including poverty eradication, food security, and health promotion (SDGs 1, 2 and 3, respectively) (YUSA et al., 2015). Evidence from global and regional climate models indicates an upward trend in the duration and extent of droughts throughout the 20th century (SPINONI et al., 2015), with studies such as Schierhorn et al. (2020) showing significant reductions in wheat and barley production due to drought in Kazakhstan between 1980 and 2015.

In the South American scenario, Brazil – with its vast ecosystem and climatic diversity – shows significant variations even between states with similar territorial extensions. Specifically, the state of Santa Catarina, located in the south of the country, is notable for its climatic diversity, influenced by air masses and ocean currents (ANDRADE et al., 1999; COAN et al., 2014). This variation is particularly evident in the far west of Santa Catarina, where the combination of different altitudes contributes to various climatic conditions (MONTEIRO, 2001).

Public policies have emerged as being fundamental in resolving local issues, especially those related to cultural, climatic, and geographical peculiarities. Milani (2008) points out that for public policies to be effective and reflect population and regional dynamics, it is essential that the community actively participates in decision-making and management.

Raeder (2014) emphasizes that, before they are launched, public policies must be based on robust preliminary studies, which often emanate from government efforts, but without neglecting the valuable contributions of technical-scientific research and analysis. The latter are vital for an in-depth understanding of the phenomena that motivate the creation of public policies. The application of indices has become the conventional approach to assessing the impact of droughts on agriculture; such indices offer a quantitative way of characterizing the main properties of drought: its intensity, duration, severity, and spatial scope, understandably and straightforwardly.

Several indices have been developed and used as tools for assessing droughts, including the Standardized Precipitation Index and the Standardized Precipitation and Evapotranspiration Index, which are widely recognized and used globally (LI et al., 2015; LEE et al., 2017; KARATAYEV et al., 2022). However, a universal method has yet to be established to assess the impact of extreme weather events such as droughts. This study aims to fill this gap by employing climatological series and adapted statistical modeling to derive the Standardized Precipitation Index (SPI) at different time scales: quarterly (short-term), semi-annual (medium-term), and annual (long-term). The comparative analysis of these scales will make it possible to determine whether there has been an increase in the frequency and duration of droughts in the region under study. This research is conducted to answer the question: "Has the frequency and duration of droughts in the far west of Santa Catarina increased?"

This work aims to analyze the occurrence and spatiotemporal variation of droughts in the far west of Santa Catarina by analyzing precipitation time series from 2001 to 2022. Additionally, using the Standardized Precipitation Index (SPI), it seeks to identify patterns of recurrence and intensity of droughts and provides subsidies for a better understanding and management of droughts in the region.

Definig of the study area

The west of Santa Catarina has been undergoing a process of accelerated industrialization, which, combined with population growth in certain cities, has intensified the degradation of natural environments, especially with regard to water resources. The region, despite having a significant volume of surface water and high annual rainfall (BACK et al., 2019), faces the constant threat of long periods of drought that negatively affect the quality of its springs (CAMPOS et al., 2018; MARINS et al., 2019; RAMBO et al., 2017).

This recurring water shortage in western Santa Catarina is exacerbated by climatic variations and unsustainable agricultural practices, such as deforestation, erosion, and silting up of rivers, which increase the severity of drought events (RAMBO et al., 2017; TERNUS et al., 2011). The region has been facing extreme weather events, including frequent and intense droughts. According to recent data from the EPAGRI/CIRAM hydrological bulletin, the beginning of 2022 marked Santa Catarina with one of the most severe droughts in its history, evidenced by a significant reduction in the volume of rainfall, particularly in the West region, where the average rainfall was between 30 and 40mm - far below the expected 150mm (EPAGRI/CIRAM, 2022).

The FAO points out that although droughts in Brazil do not directly cause immediate human losses, they degrade livelihoods by causing declines in food production and income generation (FAO, 2020). The interaction between family farming and climate extremes has increased the vulnerability of agricultural production systems to climate change (BONATTI, 2019). Subsistence farming, practiced by small producers in western Santa Catarina, is particularly at risk from climate change, partly due to the lack of financial resources to adapt or modify their production systems (GLANTZ et al., 2009; FAO, 2011).

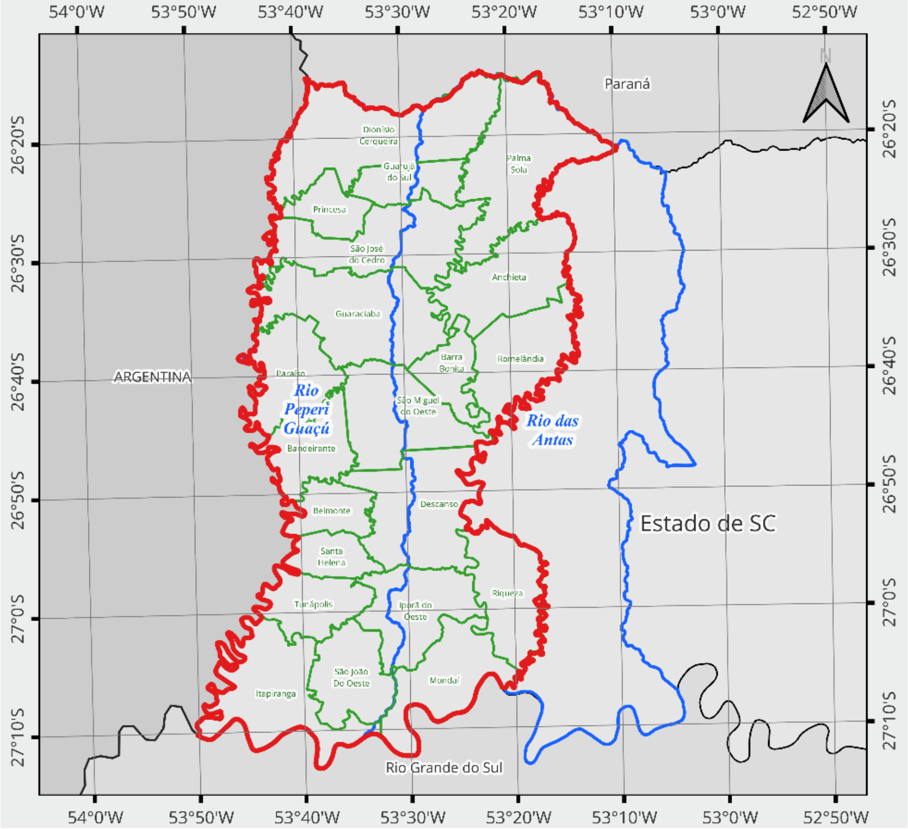
Environmental degradation in the agricultural ecosystem of western Santa Catarina is often a product of climatic and human factors, which include the unsustainable expansion of irrigation infrastructures, ineffective land use management, and inadequate drainage systems. Karatayev et al. (2022) argue that risk management strategies associated with droughts and climate change require proactive rather than reactive actions; they also highlight the need for mitigation policies to reduce dependence on fossil fuels, cut carbon emissions, and reform unsustainable agricultural practices, incorporating such measures into government mitigation programs.

The study area delimited comprises the 21 municipalities that make up the far west of the Santa Catarina micro-region, also known as the São Miguel do Oeste micro-region, in Santa Catarina, Brazil. The micro-region in focus, as illustrated in Figure 1, is covered by two important river basins: the Peperi Guaçú River basin and the Rio das Antas basin. The specific municipalities of this research include Anchieta, Bandeirante, Barra Bonita, Belmonte, Descanso, Dionísio Cerqueira, Guaraciaba, Guarujá do Sul, Iporã do Oeste, Itapiranga, Mondaí, Palma Sola, Paraíso, Princesa, Riqueza, Romelândia, Santa Helena, São João do Oeste, São José do Cedro, São Miguel do Oeste, and Tunápolis.

Figure 1 - Extremo Oeste Catarinense micro-region area.

Red: boundary of the study area. Green: 21 municipalities. Blue: river basins.

Central coordinate of the study area: Latitude: 26°45'S Longitude: 53°30'W



Source: SEPLAN/SC, 2013. Prepared by the authors

Standardized Precipitation Index - SPI

The Standardized Precipitation Index (SPI), introduced by McKee et al. (1993), is a measure developed to quantify precipitation in a way that allows comparisons between different regions and periods of the year, regardless of climate variability. This index is widely used to monitor droughts and evaluate episodes of abundant precipitation.

The versatility of the SPI lies in its ability to monitor humidity and drought conditions on various time scales, making it applicable in multiple contexts. Drought is typically defined as a precipitation deficit resulting in insufficient water for vital societal activities. Mendes (2008) characterizes meteorological drought as a reduction in precipitation rates compared to the expected pattern for a specific area during a stipulated period. The definition of drought varies according to each region due to the different atmospheric conditions that influence precipitation. Drought analysis can be simplified by considering the beginning and end of an event and using indices that consider time series data, such as precipitation, air temperature, and soil humidity.

The SPI has been adopted by state and federal programs in Brazil to monitor drought conditions in various regions, including the São Paulo State Government's INFOSECA portal (2023). The SPI quantifies drought on different time scales, making it relevant for rainy periods and droughts (SILVA et al., 2021; BLAIN & KAYANO, 2011).

The SPI can be calculated on various time scales: the SPI-01 (monthly) reflects short-term conditions and is helpful for monitoring changes in soil humidity and impacts on agriculture. The SPI-3 (quarterly) and SPI-6 (biannual) are medium-term indicators that help analyze soil humidity and can point to trends in weather patterns. The SPI-12 (annual) and SPI-24 (biennial) scales are used to identify more prolonged impacts of droughts, especially on agriculture. Guttman (1999) and Fernandes et al. (2009) discuss SPI calculation in-depth.

SPI values are interpreted on a scale that classifies humidity and drought, ranging from extreme to normal (McKee et al., 1993): Extreme Drought (≤ -2.0 SD), Severe Drought (-1.5 to -1.99 SD), Moderate Drought (-1.0 to -1.49 SD), Normal (-0.99 to +0.99 SD), Moderate Humidity (1.0 to 1.49 SD), Severe Humidity (1.5 to 1.99 SD), and Extreme Humidity (≥ 2.0 SD). The SPI, expressed in standard deviations (SD), measures how far the observed accumulated rainfall is from the climatological average, with seven thresholds that cover the most extreme situations of deficit to those of excess rainfall.

II. Methods

The theoretical-methodological approach of this study was motivated by the need to cross-reference real observations of the phenomenon under investigation with theories capable of validating or refuting the research objective. Thus, characterized by its applicability, the research aimed at a qualitative-quantitative analysis of the phenomenon in the region in focus, adopting an exploratory-descriptive method.

The research was structured in the following stages: 1) Identification of the problem and delimitation of the study area; 2) Integrative literature review; 3) Collection of regional data; and 4) Harmonization of theoretical and practical aspects for applying statistical models.

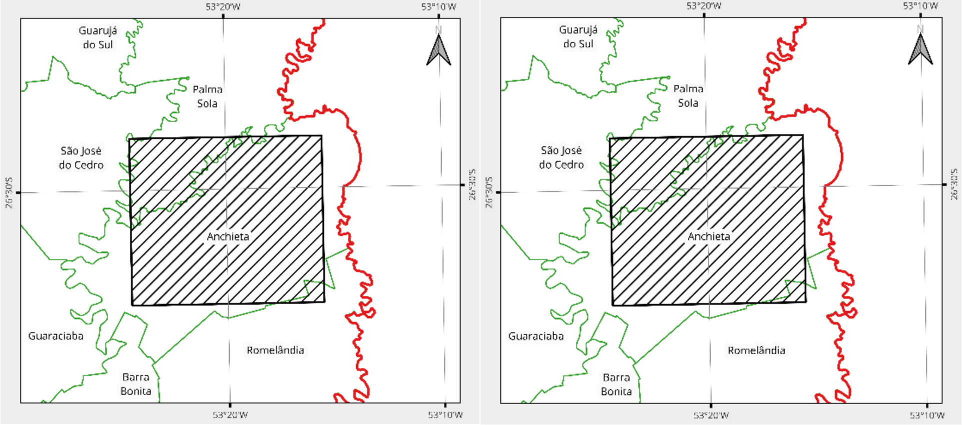
For data collection, the monthly rainfall records of all the municipalities in the micro-region under study, obtained from NASA's GIOVANNI (2023) platform, were essential. The definition of polygons within the 21 municipalities, with specific latitude and longitude coordinates, made it possible to generate accurate data on the platform.

The data used comes from the historical monthly averages generated by the "GPM IMERG Final Precipitation L3 1 month 0.1 degree x 0.1 degree V06 (GPM_3IMERGM)" model. This model stands out for its planimetric resolution of 0.1º, equivalent to an approximate area of 10 km² per quadrant, which was appropriate for this study.

This model represents the unified US algorithm that integrates precipitation products from multiple satellites. According to the GIOVANNI website (2023), the data is collected from a combination of precipitation estimates from various satellite passive microwave sensors, which are part of the Global Precipitation Measurement (GPM) constellation, intercalibrated by the CORRA algorithm (Combined Ku Radar-Radiometer Algorithm); this results in highly accurate precipitation records at half-hourly intervals. The CORRA adjustment to the monthly data is based on the Global Precipitation Climatology Project (GPCP) Satellite Gauge (SG) product. It corrects for known biases in both high latitude oceans and tropical land regions. The model's spatial coverage covers the entire planet, and for this study, the time series analyzed extended from June 1, 2000, to September 30, 2021, totaling 223 months or approximately 18 years and seven months.

The accumulated monthly rainfall data for the study area is calculated from the GIOVANNI website (2023) and adjusted to the model grid using the extreme coordinates defined for each municipality (Figure 2). This data is available in a text file containing a spreadsheet, which includes eight initial header lines with information about the product obtained. These are followed by two columns with monthly data: the "TIME" column indicates the period to which the data refers, and the "MEAN" column shows the average rainfall for that period.

Figure 2 - Example of a polygon for capturing data on the GIOVANNI



Source: the authors

The R statistical programming language (R Core Team, 2020) and the RStudio development environment (RStudio Team, 2020) were used in the time series analysis phase. The analysis steps included:

- Basic Descriptive Analysis: Descriptive analyses were conducted to obtain an overview of the collected data.
- Time Series Decomposition: Additive models were applied to decompose the time series into its fundamental components: trend, seasonality, stationarity and random component. For trend analysis, the moving averages method was applied; it is a technique that smoothes the series, facilitates the removal of outliers, and helps identify trends.
- Autocorrelation and Partial Autocorrelation Analysis: These analyses were fundamental to understanding the temporal dependence between the points in the series.
- Analysis of Residuals and Normality Tests: After the general analyses, the random part of the time series was examined using tests to verify the normality of the residuals.

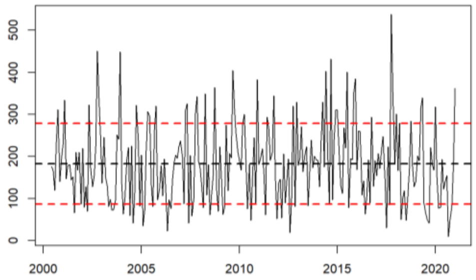
Based on these preliminary analyses, statistical modeling of the time series was carried out to calculate the Standardized Precipitation Index (SPI) on the short-term (3 months), medium-term (9 months), and long-term (12 months) scales. The aim was to analyze the periods of drought on these different time scales and determine whether there was an increase in the frequency or duration of droughts on any of these scales.

III. Results And Discussion

The analysis of the rainfall time series focused on droughts revealed insights into three main segments: the statistical description of the series, the additive decomposition of the time series, and the interpretation of the Standardized Precipitation Index (SPI).

In describing the time series, the average rainfall was 182mm with a standard deviation of 96mm over the period analyzed. The median was 177mm, with an interquartile range of 105 to 235mm, suggesting significant variation in monthly rainfall, ranging between the 9mm and 538mm extremes. The non-normal distribution of the data (Shapiro test: p-value < 0.001) and the presence of higher outliers highlight the inherent variability of this type of environmental data (Figure 3).

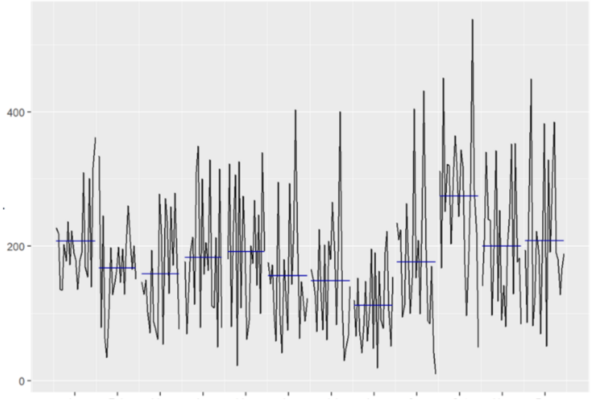
Figure 3: Time series indicating the mean and standard deviation



Source: The authors

The monthly averages over the study period showed minimums in August, close to 110mm, and maximums in October, around 280m. The existence of extreme peaks that exceed the monthly averages both by excess and defect indicates the complexity of the rainfall pattern, as shown in Figure 4. These extremes demonstrate that the isolated use of monthly averages provides a limited view, underlining the need for more in-depth analysis to understand the dynamics of droughts in the region.

Figure 4 - time series, from January to December, with monthly average values (blue lines)

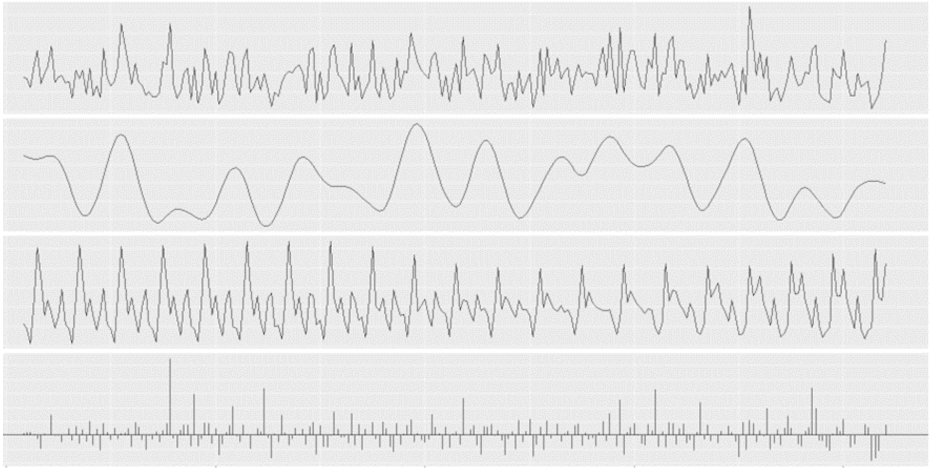


Source: The authors

The autocorrelation analysis revealed a p-value < 0.001, which indicates the absence of autocorrelation and the lack of obvious seasonal patterns. This finding is fundamental, as it suggests that the variations observed in the time series are predominantly random, without a clear trend of seasonal repetition or predictable long-term patterns (Figure 5).

The additive decomposition of the time series made it possible to isolate and examine the trend, seasonality, and randomness components. The analysis revealed no significant upward or downward trends in rainfall over time, suggesting stability in the rainfall series. Likewise, due to the absence of repetitive patterns, the seasonality component corroborated the idea that no marked seasonality affects the rainfall pattern in the region. The randomness of the rainfall data, as evidenced by the random component, reaffirms the unpredictable nature of the natural variations in the rainfall time series (Figure 5).

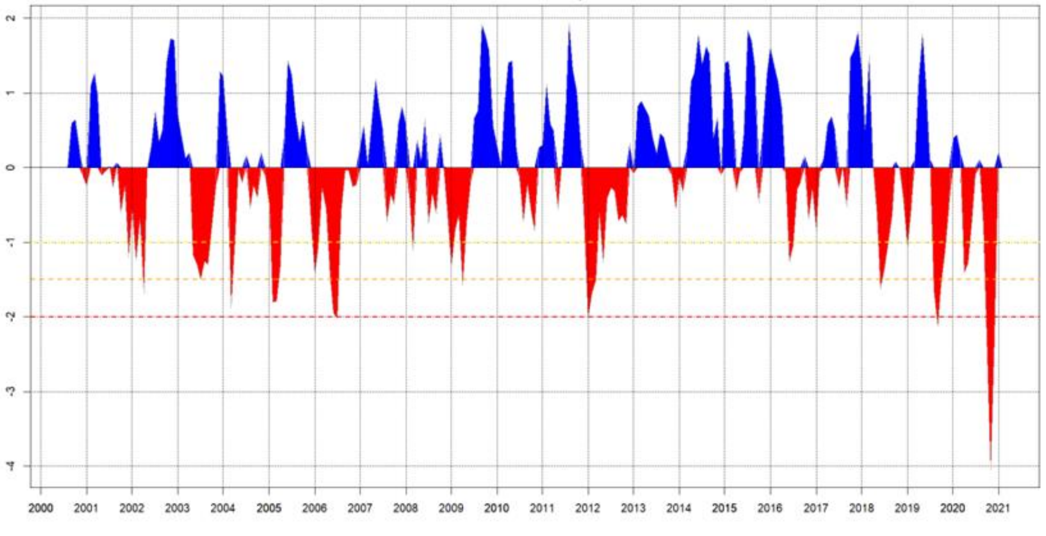
Figure 5: components of the additive decomposition of the rainfall series. A: original series, B: time trend, C: seasonality, D: randomness.

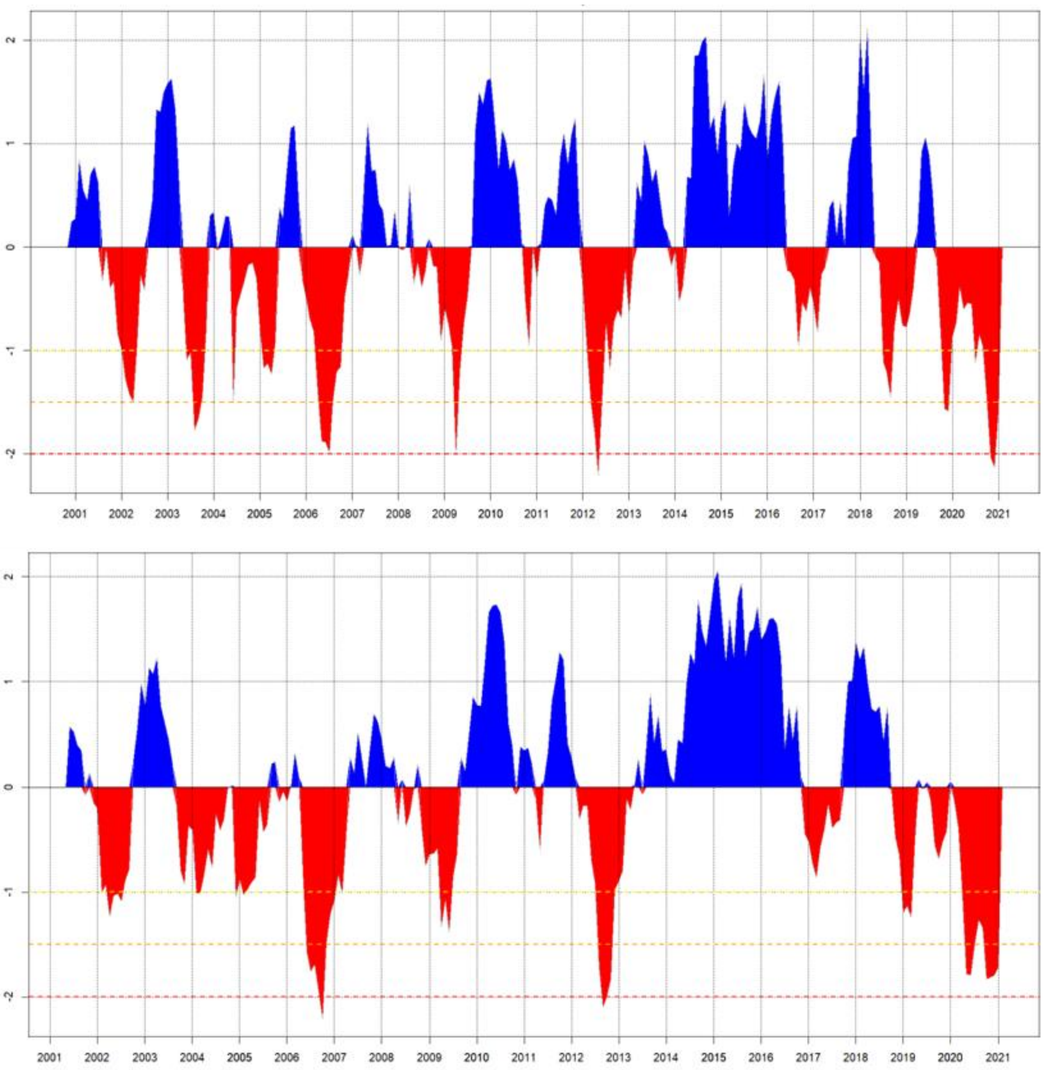


Source: The authors

The generation and analysis of SPI graphs are crucial for identifying the severity and duration of droughts on different time scales, as well as providing a comparative tool for assessing drought variations over time. The 3-month SPI (Figure 6A), focused on short-term conditions, is particularly relevant for analyzing soil humidity and its immediate impacts on agriculture. The 6-month scales (Figure 6B) provide a medium-term perspective that is useful for assessing longer-term agricultural impacts and water management. Finally, the 12-month SPI (Figure 6C) reflects long-term impacts on water resources, including availability in reservoirs and aquifers.

Figure 6: SPI. A: 3 months, B: 6 months, C: 12 months
Thresholds: Extreme Drought (≤ -2.0 SD), Severe Drought (-1.5 to -1.99 SD), Moderate Drought (-1.0 to -1.49 SD)





Source: The authors

The SPI graphs illustrate different drought intensities over the time scales analyzed, allowing a detailed understanding of the evolution of drought conditions in the region. This analysis, complemented by classifying droughts into intensity categories based on standard deviations, provides a solid basis for interpreting the severity of observed droughts and anticipating possible future trends. These characteristics have been summarized in the table in Figure 7.

Figure 7: Summary of drought events by year, period and intensity.
Bold underlined years: major drought events

Prazo	Intensidades	01	02	03	04	05	**06**	07	08	**09**	10	11	**12**	13	14	15	16	17	**18**	**19**	**20**	Num.
curto	moderada	X	X	X	X	X	X		X	X			X				X		X		X	12
	severa				X	X	X			X			X						X	X		7
	extrema												X							X	X	3
médio	moderada		X		X	X											X		X			5
	severa		X	X						X			X							X	X	6
	extrema						X			X			X								X	4
Longo	moderada		X			X				X									X	X		5
	severa						X														X	2
	extrema						X						X									2

Source: The authors

Detailed analysis of the SPI summary table (Figure 7) offers profound insights into the frequency and intensity of droughts over the years, which shows significant patterns. The year 2006 is notable for the occurrences of extreme droughts on all time scales. In 2009, there was a return of severe and extreme events, especially in the short and medium term, as well as in 2012, when moderate, severe, and extreme drought events were identified on all the time scales studied.

The period from 2018 to 2020 deserves special attention. Compared to the analysis from 2001 to 2017, which recorded severe drought events in only three non-consecutive years (2006, 2009, and 2012), there has been an increase in the recurrence of drought events in more recent years. The SPI data indicates that drought events of various intensities have occurred consecutively in the region under study.

In 2018, the highlight was events of moderate intensity on all time scales, including a short-term severe event. In 2019, severe events were recorded in the short and medium term, with extreme events in the short term and moderate events in the long term. In 2020, the situation was intensified by severe events on all time scales and extremes in the short and medium term, while moderate or severe events were observed in the long term.

This longitudinal analysis indicates increased recurrence and continuity of droughts in recent years. The tendency for droughts to intensify will be better understood over time and with further analysis of the time series in this region of Santa Catarina.

IV. Concluding Remarks

This study offered a comprehensive analysis of rainfall variability and the occurrence of droughts in the far west of Santa Catarina, using a qualitative-quantitative approach and exploring the Standardized Precipitation Index (SPI) on various time scales. The results highlight the complexity and variability of rainfall in the region and show periods of drought of different intensities and durations.

Statistical analysis revealed a rainfall distribution with significant variation, characterized by a wide range of monthly precipitation and outliers, reflecting rainfall's unpredictable and non-uniform nature. The additive decomposition of the time series did not identify significant long-term trends in rainfall or clear seasonal patterns, underlining the predominance of random factors in the found rainfall variations.

The SPI graphs, at different time scales, provided valuable insights into the severity and timing of droughts, allowing for a more detailed understanding of how these events affect the region. The absence of clear trends in the time series suggests that although droughts do occur, they are influenced by a complexity of environmental factors that vary over time.

The application of the SPI was an effective tool for monitoring and evaluating droughts and provided a quantitative basis for comparing the severity of droughts between different periods and regions. This analysis is fundamental for planning water resources and implementing mitigation strategies that can minimize the adverse impacts of droughts on agriculture, water supply, and the region's natural ecosystems.

Faced with the challenges posed by climate change and natural climate variability, this study underlines the importance of continuing to research and monitor droughts in the far west of Santa Catarina. Future initiatives should seek to improve understanding of the mechanisms underlying rainfall variations and develop predictive models based on machine learning that can anticipate drought events and help make proactive decisions for managing water resources and adapting affected communities.

References

[1] Andrade, A. R. D., Baldo, M. C., Nery, J. T. Variabilidade Sazonal Da Precipitação Pluviométrica De Santa Catarina. Acta Scientiarum 21 (4), 923–928. 1999.

[2] Back, A.J., Gonçalves, F.N., Fan, F.M. Spatial, Seasonal, And Temporal Variations In Rainfall Aggressiveness In The South Of Brazil. Eng. Agrícola 39, 466–475. 2019. Doi: Https://Doi.Org/10.1590/1809-4430-Eng.Agric.V39n4p466-475.

[3] Blain, G. C.; Kayano, M. T. 118 Anos De Dados Mensais Do Índice Padronizado De Precipitação: Série Meteorológica De Campinas, Estado De São Paulo. Revista Brasileira De Meteorologia, V.26, N.1, 137 - 148, 2011. Disponível Em: Https://Www.Scielo.Br/J/Rbmet/A/Mn4xkpqnjvfwrnzqc6mntqs/?Lang=Pt Acesso Em 05 De Agosto 2022.

[4] Bonatti, M. Et Al. Social Representations Of Climate Change And Climate Adaptation Plans In Southern Brazil: Challenges Of Genuine Participation. Urban Climate. 2019. Doi: Https://Doi.Org/10.1016/J.Uclim.2019.100496.

[5] Bracesco, N. Et Al. Recent Advances On Ilex Paraguariensis Research: Minireview. Journal Of Ethnopharmacology. Volume 136, Issue. 2019. Doi: Https://Doi.Org/10.1016/J.Jep.2010.06.032.

[6] Bryan, E., Deressa, T.T.; Gbetibouo, G.A., Ringler, C. Adaptation To Climate Change In Ethiopia And South Africa: Options And Constraints. Environmental Science & Policy 12, 413–426. 2009.

[7] Campos, S. A. B., Dal-Magro, J., Souza-Franco, G. M. De Metals In Fish Of Different Trophic Levels In The Area Of Influence Of The Ahe Foz Do Chapecó. Reservoir, Brazil. Environ. Sci. Pollut. Res. 25. 2018. Doi: Https://Doi.Org/10.1007/S11356-018-2522-0.

[8] Coan, B. D. P., Back, A. J., Bonetti, A. V. Precipitação Mensal E Anual Provável No Estado De Santa Catarina. Revista Brasileira De Climatologia 15, 122–142. 2014.

[9] Epagri/Ciram Boletim Hidrológico, Disponível Em: Https://Ciram.Epagri.Sc.Gov.Br/Index.Php/2020/08/28/Boletim-Hidrologico-Jacutinga/ Acesso Em 11 De Mar. 2022.

[10] Fao – Food And Agriculture Organization Of The United Nations. Overcoming Water Challenges In Agriculture. Rome. 2020. Doi: Https://Doi.Org/10.4060/Cb1447en.

[11] ______. The State Of Food Insecurity In The World How Does International Price Volatility Affect Domestic Economies And Food Security?. Rome. 2011

[12] Fernandes, D. S. Et Al. Desempenho De Índices Quantitativos De Seca Na Estimativa Da Produtividade De Arroz De Terras Altas. Pesquisa Agropecuária Brasileira, Brasília, V. 45, N. 8, P. 771-779, 2010.

[13] Fontana, C., Sevegnani, L. Quais São As Espécies Arbóreas Comuns Da Floresta Estacional Decidual Em Santa Catarina? Rea – Revista De Estudos Ambientais (Online) V.14, N.1, Esp. 2012.

[14] Gasper, A. L. Et Al. Inventário Florístico Florestal De Santa Catarina: Espécies Da Floresta Ombrófila Mista. Rodriguésia. V. 64, N. 2. 2013. Doi: Https://Doi.Org/10.1590/S2175-78602013000200001.

[15] Glantz, M.H., Gomes, R., Ramasamy, S. Coping With A Changing Climate: Con- Siderations For Adaptation And Mitigation In Agriculture. Food And Agriculture Organization Of The United Nations, Rome. 2009.

[16] Ibge – Instituto Brasileiro De Geografia E Estatística. Manuais Técnicos Em Geociências Divulga Os Procedimentos Metodológicos Utilizados Nos Estudos E Pesquisas De Geociências. 2009. Disponível Em: Https://Www.Terrabrasilis.Org.Br/Ecotecadigital/Pdf/Manual-Tecnico-Da-Vegetacao-Brasileira.Pdf Acesso Em 21 De Ago. 2022.

[17] Giovanni. Giovanni The Bridge Between Data And Science. Disponível Em: Https://Giovanni.Gsfc.Nasa.Gov/Giovanni/. Acessado Em 12 De Ago. 2022.

[18] Guttman, N.B. Accepting The Standardized Precipitation Index: A Calculation Algorithm. Journal Of The American Water Resources Association, V. 35, N. 2. 1999.

[19] Cptec/Inpe - Centro De Previsão De Tempo E Estudos Climáticos / Instituto Nacional De Pesquisa Espaciais. Índice De Precipitação Padronizado. 2023. Disponível Em: Http://Clima1.Cptec.Inpe.Br/Spi/Pt Acesso Em 12 De Ago. 2022.

[20] Infoseca – Centro De Monitoramento E Mitigação Se Deca E Adversidades Hidrometeorológicas. Standardized Precipitation Index (Spi). 2022. Disponível Em: Http://Www.Infoseca.Agricultura.Sp.Gov.Br/ Acesso Em 11 De Ago 2022.

[21] Karatayev, M. Et Al. Monitoring Climate Change, Drought Conditions And Wheat Production In Eurasia: The Case Study Of Kazakhstan. Heliyon, Volume 8, Issue 1, Issn 2405-8440, 2018. Doi: Https://Doi.Org/10.1016/J.Heliyon.2021.E08660.

[22] Lee, S.H. Et Al. Assessment Of The Impact Of Climate Change On Drought Characteristics In The Hwanghae Plain, North Korea Using Time Series Spi And Spei: 1981–2100. Water, 9 (8). 2017.

[23] Li, X. Et Al. Use Of The Standardized Precipitation Evapotranspiration Index (Spei) To Characterize The Drying Trend In Southwest China From 1982–2012. Rem. Sens., 7 (8). 2015.

[24] Marins, K., Et Al.; Iron And Manganese Present In Underground Water Promote Biochemical, Genotoxic, And Behavioral Alterations In Zebrafish (Danio Rerio). Environ. Sci. Pollut. Res. Doi: Https://Doi.Org/10.1007/S11356-019-05621-0. 2019.

[25] Mckee, T. B., Doesken, N. J. E Kleist, J.; The Relationship Of Drought Frequency And Duration To Time Scales, In: Eighth Conference On Applied Climatology, Anaheim, California, 1993.

[26] Mendes, J. Linhas Para A Elaboração De Um Plano De Minimização Dos Riscos De Seca Em Zonas Com Escassez De Recursos Hídricos: O Caso Da Margem Esquerda Do Guadiana. Tese (Doutorado Em Engenharia Civil), Feup, Porto, 2008.

[27] Milani, C. R. O Princípio Da Participação Social Na Gestão De Políticas Públicas Locais: Uma Análise De Experiências Latino-Americanas E Europeias. Revista De Administração Pública, 42(3). 2008

[28] Monteiro, M. A. Caracterização Climática Do Estado De Santa Catarina: Uma Abordagem Dos Principais Sistemas Atmosféricos Que Atuam Durante O Ano. Geosul, 16(31). 2001.

[29] Mishra, A.K., Singh V.P. A Review Of Drought Concepts. J. Hydrol., 391 (1-2). 2010.

[30] ______ . Drought Modeling - A Review. J. Hydrol., 403 (1-2). 2011.

[31] Naumann, G. Et Al. Global Changes In Drought Conditions Under Different Levels Of Warming. Geophys. Res. Lett., 45 (7). 2018.

[32] Pan, X., Chin, M., Ichoku, C.M. Connecting Indonesian Fires And Drought With The Type Of El Niño And Phase Of The Indian Ocean Dipole During 1979–2016. J. Geophys. Res. Atmos., 123 (15). 2018.

[33] R Core Team (2020). R: A Language And Environment For Statistical Computing. R Foundation For Statistical Computing, Vienna, Austria. Url Https://Www.R-Project.Org/.

[34] Rstudio Team (2020). Rstudio: Integrated Development For R. Rstudio, Pbc, Boston, Ma Url Http://Www.Rstudio.Com/

[35] Raeder, S. T. O. Ciclo De Políticas: Uma Abordagem Integradora Dos Modelos Para Análise De Políticas Públicas. Perspectivas Em Políticas Públicas, 7(13). 2014.

[36] Rambo, C.L. Et Al. Hydropower Reservoirs: Cytotoxic And Genotoxic Assessment Using The Allium Cepa Root Model. Environ. Sci. Pollut. Res. 24. 2017. Doi: Https://Doi.Org/10.1007/S11356-017-8509-4.

[37] Salerno, A.R.; Muller, J.J.V. Mata Atlântica Catarinense. Agropecuária Catarinense, V.24, N.2, 2011. Disponível Em: Https://Publicacoes.Epagri.Sc.Gov.Br/Rac/Issue/Download/76/152 Acesso Em 10 De Ago. 2022.

[38] Silva, G. K. Da Et Al. Análise Da Variabilidade Espaço-Temporal Do Spi: Um Estudo De Caso Para A Sub-Bacia Choró, Ceará, Brasil. Revista Brasileira De Meteorologia, V. 36, N. 3 (Suplemento). Doi: Http://Dx.Doi.Org/10.1590/0102-77863630005. 2021

[39] Schierhorn, F., Et Al. Spatially Varying Impacts Of Climate Change On Wheat And Barley Yields In Kazakhstan. J. Arid Environ, 178. 2020.

[40] Schons, C.T. Et Al.; Índices De Competição Em Nível De Árvore Individual Para Espécies Da Floresta Ombrófila Mista. Scientia Forestalis, 48(128), E3275. Doi: Https://Doi.Org/10.18671/Scifor.V48n128.13. 2020.

[41] Seplan/Sc – Secretaria De Planejamento De Santa Catarina. Limites Municipais. Sigsc: Sistema De Informações Geográficas Do Estado De Santa Catarina. 3023. Disponível Em: Http://Sigsc.Sc.Gov.Br/Download/ Acesso Em 12 De Mai. 2022.

[42] Silva, K.P., Tavela, A.D.O., Santos, K.L. Predação De Frutos De Hovenia Dulcis Em Fragmento De Floresta Estacional Decidual. Revista Multidisciplinar De Educação E Meio Ambiente, 2(2), 56. 2021. Doi: Https://Doi.Org/10.51189/Rema/1072.

[43] Sousa, M. De A. Jr.; Sausen T. M. Lacruz, S. P. Monitoramento De Estiagem Na Região Sul Do Brasil Utilizando Dados Evi/Modis No Período De Dezembro De 2000 A Junho De 2009. In: Anais Xv Simpósio Brasileiro De Sensoriamento Remoto - Sbsr, Curitiba, Pr, Brasil, 30 De Abril A 05 De Maio De 2011. Disponível Em: Http://Marte.Sid.Inpe.Br/Col/Dpi.Inpe.Br/Marte/2011/07.20.12.38/Doc/P0795.Pdf Acesso Em 15 De Set. 2022.

[44] Termus, R.Z. Et Al. Influence Of Urbanisation On Water Quality In The Basin Of The Upper Uruguay River In Western Santa Catarina, Brazil. Acta Limnol. Bras. 23. 2011. Doi: Https://Doi.Org/10.1590/S2179-975x2011000200009.

[45] Wolff, W., Duarte, S.N., Fernandes, R.D.M. Spatialization Of The Annual And Seasonal Average Precipitations In The State Of Santa Catarina, Brazil. Journal Of South American Earth Sciences. 2020. Doi: Https://Doi.Org/10.1016/J.Jsames.2020.102735.

[46] Yusa, A.P Et Al.; Climate Change, Drought And Human Health In Canada. Int. J. Environ. Res. Publ. Health, 12 (7). 2015. Doi: Http://Doi.Org/10.3390/Ijerph120708359.