VARIABILITY OF PLUVIOMETRIC PRECIPITATION AND SPACE-TEMPORAL DYNAMICS OF PLANT COVERAGE IN THE DISTRICT OF SÃO GONÇALO - PB IN FIVE YEARS OF MONITORING

Caio Sérgio Pereira de Araujo[1], Jhon Lennon Bezerra da Silva[2], Brivaldo Gomes de Almeida[3], Lívia Maria Cavalcante Silva[4], Ceres Duarte Guedes Cabral de Almeida[5]

ABSTRACT: The objective was to analyse the temporal behaviour of the pluviometry and the spatiotemporal dynamics of the vegetation cover as a function of rainfall in the period from 2015 to 2019 in the municipality of Sousa-PB, where the São Gonçalo Irrigated Perimeter is located. The precipitation series were obtained from the database of the National Institute of Meteorology (INMET) and the images were from the MODIS sensor. The analysis of the annual data points to 708.4 mm as the average accumulated precipitation, and that, the records in the years 2016, 2017, and 2019 remained below the average, while 2015 and 2018 were above, as 2018 with higher precipitation (889.4 mm). The accumulated monthly data indicated higher incidences of rainfall in the period between January to April in five years of monitoring, with emphasis on the month of March in 2015 with 380 mm of precipitation The analysis of the Normalized Difference Vegetation Index (NDVI) allowed inferring that the vegetation of the Caatinga responds proportionally to the rain. Thus, there is a delay in vegetation in other regions of the municipality, in contrast to the District of São Gonçalo, which proved to be resilient throughout the space-time analysis.

KEYWORDS: water scarcity, semiarid, MODIS.

VARIABILIDADE DA PRECIPITAÇÃO PLUVIOMÉTRICA E DINÂMICA ESPAÇO-TEMPORAL DA COBERTURA VEGETAL NO DISTRITO DE SÃO GONÇALO – PB EM CINCO ANOS DE MONITORAMENTO

[1] Master student of Agricultural Engineering, Federal Rural University of Pernambuco (UFRPE), St Dom Manuel de Medeiros, s/n, Dois Irmãos, CEP 52171-900, Recife, PE. Fone (83) 996241861. e-mail: caiosergio.ufersa@gmail.com.
[2] PhD student of Agricultural Engineering, UFRPE, Recife - PE
[3] Associate Professor, Department of Agronomy, DEPA, UFRPE, Recife - PE
[4] Master student of Agricultural Engineering, UFRPE, Recife - PE
[5] Full Professor, Agricultural College Dom Agostinho Ikas, CODAI, UFRPE, São Lourenço da Mata - PE

RESUMO: Objetivou-se analisar o comportamento temporal do regime pluviométrico e a dinâmica espaço-temporal da cobertura vegetal em função da precipitação no período de 2015 a 2019 no município de Sousa-PB, onde encontra-se o Perímetro Irrigado São Gonçalo. As séries das precipitações foram obtidas no banco de dados do Instituto Nacional de Meteorologia (INMET) e as imagens foram do sensor MODIS. A análise dos dados anuais aponta para o valor da precipitação média acumulada em 708,4 mm, e que, os registros nos anos de 2016, 2017 e 2019 se mantiveram abaixo da média, enquanto 2015 e 2018 ficaram acima, sendo 2018 com maior precipitação (889,4 mm). Os dados mensais acumulados indicaram maiores incidências de chuvas no período de janeiro a abril nos cinco anos de monitoramento, com ênfase no mês de março de 2015 quando ocorreu precipitação de 380 mm. As análises do índice de vegetação da diferença normalizada (NDVI) permitiram inferir que a vegetação da Caatinga responde proporcionalmente à chuva. Assim, se observa um atraso da vegetação em outras regiões do município ao contrário do Distrito de São Gonçalo, que se mostrou resiliente ao longo da análise espaço-temporal.
PALAVRAS-CHAVES: escassez hídrica, semiárido, MODIS.

INTRODUCTION

The variable rainfall is the climatic unit that is the most suitable to represent the various climatic faces of Brazil and the semiarid region, due to its characteristics of temporal variability (ZAVATTINI & BOIN, 2013). Lucena et al. (2017) reinforce that this variable acts as an element that regulates agricultural and economic activities. The study of precipitation behaviour is somewhat more complex, since is inserted in the social and economic environments of a given region. The drought time interval can cause agricultural losses, besides resulting in the lack of water in the reservoirs. On the other hand, heavy rainfall can lead to soil erosion, agricultural damage, and consequently loss of inputs (ARAÚJO et al., 2008; BECKER et al., 2013).

The irrigated perimeters are areas chosen by a state agency with special geographical characteristics such as rich soils, favourable climate and large amounts of water resources, which allow to install projects related to irrigated agriculture aiming at the economic-social and rural development of agricultural production (PONTES et al., 2013). In order to promote agricultural practice without affect water supply and increasing food production (DA COSTA & ALBUQUERQUE, 2020), it was created in the period from 1968 to 1992, by the National Department of Works Against Drought (DNOCS), about 38 irrigated perimeters in the Brazilian

Northeast (RIGOTTO & FREITAS, 2014), in 1972 the São Gonçalo - PB irrigated perimeter was created.

The remote sensing techniques are useful for producing, from satellite images with combinations of multispectral bands, vegetation indexes on the surface, essential for the environmental monitoring of semiarid regions. The normalized difference vegetation index (NDVI) is widely applied in multitemporal researches since is sensitive to the conditions of green vegetation cover, specifically analysing the quantity and quality of vegetation in the environment (TOMASELLA et al., 2018).

The MODIS sensor within the TERRA satellite offers several applications for monitoring vegetation coverage, including the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI), images of reflectance and air quality (HUETE et al., 2002). This sensor provides the acquisition of annual cycles and variations in vegetation cover by temporal data, thus identifying its behaviour over the years (HMIMINA et al., 2013; BRADLEY et al., 2011).

Thus, a study in the Brazilian semiarid region has significant importance, since it is a region characterized by the water scarcity and irregularity in the distribution of precipitation and prolong droughts. This study aimed to monitor and analyse the temporal behaviour of the pluviometry and the spatiotemporal dynamics of the vegetation as a function of rainfall in the period from 2015 to 2019 in the municipality of Sousa-PB, where the São Gonçalo Irrigated Perimeter is located.

MATERIAL AND METHODS

The Perimeter Irrigated São Gonçalo is in the district of the same name, in the municipality of Sousa-PB (6º 19’ to 7º 24’ S and 37º 55’ to 38º 46’ W) (SILVA NETO et al., 2012). The perimeter has an area of 5,548.53 ha with rainfed and irrigated agriculture, where the *Rio do Peixe* watershed in the Piranhas River are used as a source of irrigation water (DNOCS, 2012). The semiarid climate of this location is of the BSh type according to Köppen, with a period of greatest rainfall intensity from January to May, and an average temperature of 27 °C, with a minimum of 22 °C and a maximum of 38 °C and with average annual evaporation 3,056 mm (DNOCS, 2012).

The series of rainfall used in this study were obtained from the database of the National Institute of Meteorology (INMET) from the rainfall station, located in the following geographical coordinates: 6° 76’ S and 38° 23’ W, in the period of 2015– 2019. The images were obtained from the MODIS sensor onboard the Terra and Aqua satellites, with a spatial resolution of 500 m and a temporal resolution of eight days. For the development of the vegetation index, to monitor land cover and use, 46 orbital images per year (2015–2019) were used, totalling 230 MODIS images. The digital processing of the images was carried out online, using the Google Earth Engine platform (GORELICK et al., 2017). This type of operation allows to analyse large-scale monitoring areas in space/time at a low cost. In addition, the MODIS sensor provides georeferenced images that are corrected to atmospheric effects, besides of the efficiency on the cloud masking or cloud shadows to avoid overestimating or underestimating of the results related to the environment (JUSTICE et al., 2002).

NDVI is determined from the multispectral bands of reflectance, in which multiplier factors (in the value of 0.0001) are assigned according to equation 1 (ALLEN et al., 2002).

$$\text{NDVI} = \frac{\text{NIR - RED}}{\text{NIR + RED}}$$

Where, *NIR* and *RED* are the reflectance bands 4 and 3 of the MODIS sensor, with spectral resolutions between 0.841 - 0.876 μm and 0.620 - 0.670 μm, respectively.

Figure 1 illustrates the coverage and land use in the municipality of Sousa-PB, with emphasis on the District of São Gonçalo, based on an image from the Landsat satellite, with a spatial resolution of 30 m.

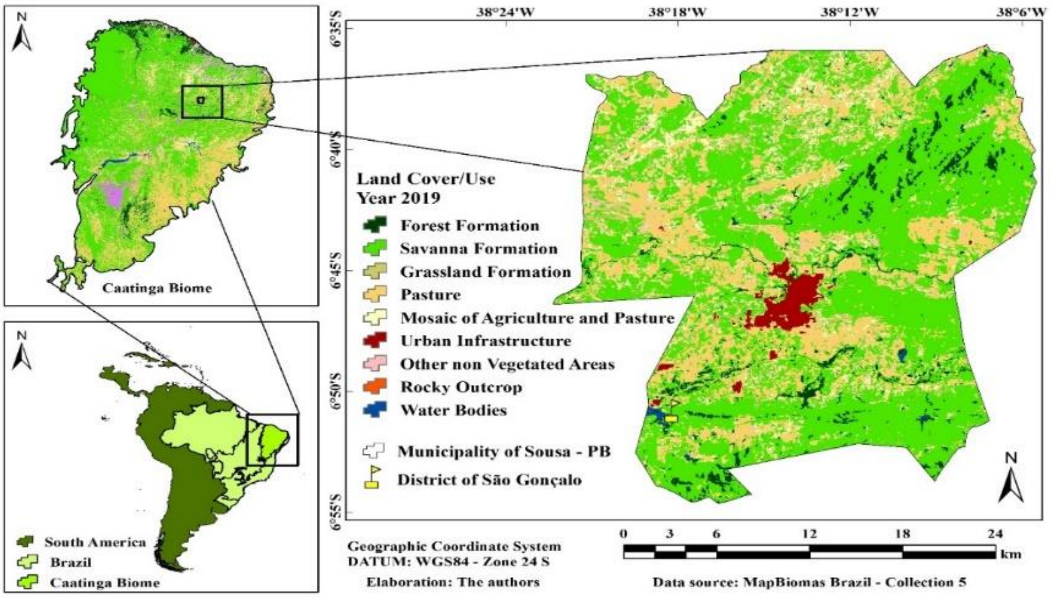

Figure 1. Spatial location of the District of São Gonçalo, Sousa, Paraíba. Adapted of Souza et al. (2020).

The annual accumulated precipitation values as well the monthly mean of the rainfall accumulated were thus obtained for the entire period studied, both parameters were evaluated by the statistical parameters: mean, standard deviation, minimum and maximum value, coefficient of variation using the Excel 2013 software.

RESULTS AND DISCUSSION

The analysis of the annual data of the pluviometric station points to the value of the average accumulated precipitation in 708.4 mm a long of the time studied in this research (Figure 2). The values recorded in 2016, 2017, and 2019 remained below average, with a lower value for 2017 (601.8 mm). The years 2015 and 2018 were above average, highlighting the data for 2018, with a precipitation of 889.4 mm.

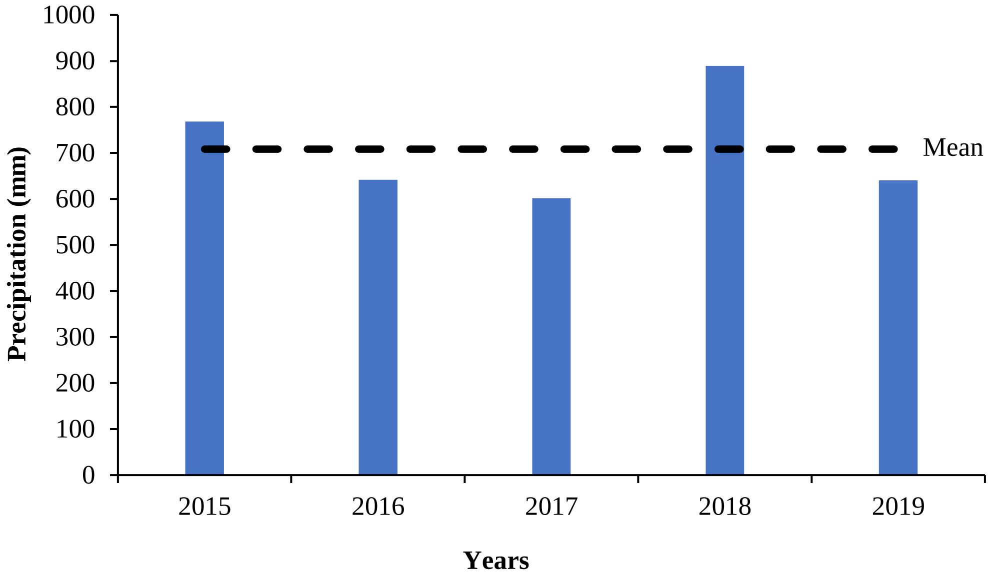

Figure 2. Accumulated rainfall, recorded annually by INMET during the period 2015 to 2019 in the district of São Gonçalo-PB

The standard deviation (SD) found in the annual series can be considered as high value (Table 1), due to the great variability of the data in the years 2016, 2017, and 2019 concerning the average of the studied period, which is a consequence of the irregularity of the rains in the region. Silva Filho et al. (2016) studied precipitation data for the municipality of Sousa-PB, and observed very high SD, confirming the values found in this research. According to the classification proposed by Gomes (1985), the coefficient of variation, resulting from the analysis of annual data, was considered average (Table 1), confirming the poor distribution of rainfall, especially in the years 2016, 2017, and 2019.

Table 1. Descriptive statistics of rainfall recorded by INMET, during the period 2015 - 2019, in the district of São Gonçalo-PB.

Annual Precipitation (mm)					
Mean	Maximum	Minimum	SD[1]	CV[2]	Classification[3]
708.4	889.4	601.8	119.1	0.17	medium

[1] Standard Deviation; [2] Coefficient of variation; [3] Gomes (1985)

The mean values of the monthly accumulated rainfall, for each year evaluated in this study, show that in the period from January to April there was a higher incidence of rain (Table 2), with emphasis in March 2015 with 380 mm of accumulated precipitation. On the other hand, the minimum values were observed for July 2018 and August and September 2016, 2017 and 2018, with September having the lowest value (0.5 mm). Silva Filho et al. (2016) identified high values for the averages of the same months, during the historical series from 1999 to 2015, which corroborates the events of the series studied in this research.

Table 2. Monthly accumulated precipitation in each year, mean, minimum and maximum values, standard deviation and coefficient of variation recorded at the São Gonçalo - PB weather station during 2015-2019.

Accumulated Precipitation (mm)												
Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
2015	56.6	160.2	380.0	37.4	8.6	45.6	62.2	0.2	2.0	5.8	0.0	9.8
2016	166.0	19.6	296.2	110.8	29.6	10.0	0.4	0.0	0.0	0.0	0.0	9.0
2017	102.4	141.2	114.2	65.8	55.4	51.2	65.4	0.0	0.0	0.4	0.4	5.4
2018	62.4	309.8	90.6	272.8	9.6	11.0	0.0	0.0	0.0	0.4	4.4	128.4
2019	70.4	21.4	225.2	136.2	144.8	7.8	22.6	6.2	0.6	0.4	1.0	4.0
Mean	91.6	130.4	221.2	124.6	49.6	25.1	30.1	1.3	0.5	1.4	1.2	31.3
Max	166.0	309.8	380.0	272.8	144.8	51.2	65.4	6.2	2.0	5.8	4.4	128.4
Min	56.6	19.6	90.6	37.4	8.6	7.8	0.0	0.0	0.0	0.0	0.0	4.0
SD	45.2	119.7	121.8	91.3	56.5	21.4	32.1	2.7	0.9	2.3	1.9	54.3
CV	0.5	0.9	0.6	0.7	1.1	0.8	1.1	2.6	1.7	1.8	1.6	1.7

Max: Maximum Value; Min: Minimum Value; SD: Standard Deviation; CV: Coefficient of variation.

Silva Filho et al. (2016) studying pluviometric regime and detailing the average, minimum, maximum values, standard deviation and coefficient of variation in the municipality of Sousa - PB, obtained results similar to those of this research, in terms of maximum values, rainiest months, and months of absence of rain, despite to evaluate different periods of this.

The highest value of standard deviation was obtained in February and March, showing that it distanced itself a lot from the accumulated mean, which had not been observed in the other months. The coefficient of variation, according to Gomes (1985), was classified as very high for all months of the study period, associated to three years which in the August and September there was no rainfall contributing to the increase the data variability.

Figure 3 illustrates the annual spatiotemporal distribution of the NDVI vegetation index as a function of thematic maps on the surface of different land uses, between the period 2015 to 2019. This type of monitoring demonstrates the consistency of data derived from satellite since that allows observing the changing patterns of biophysical conditions.

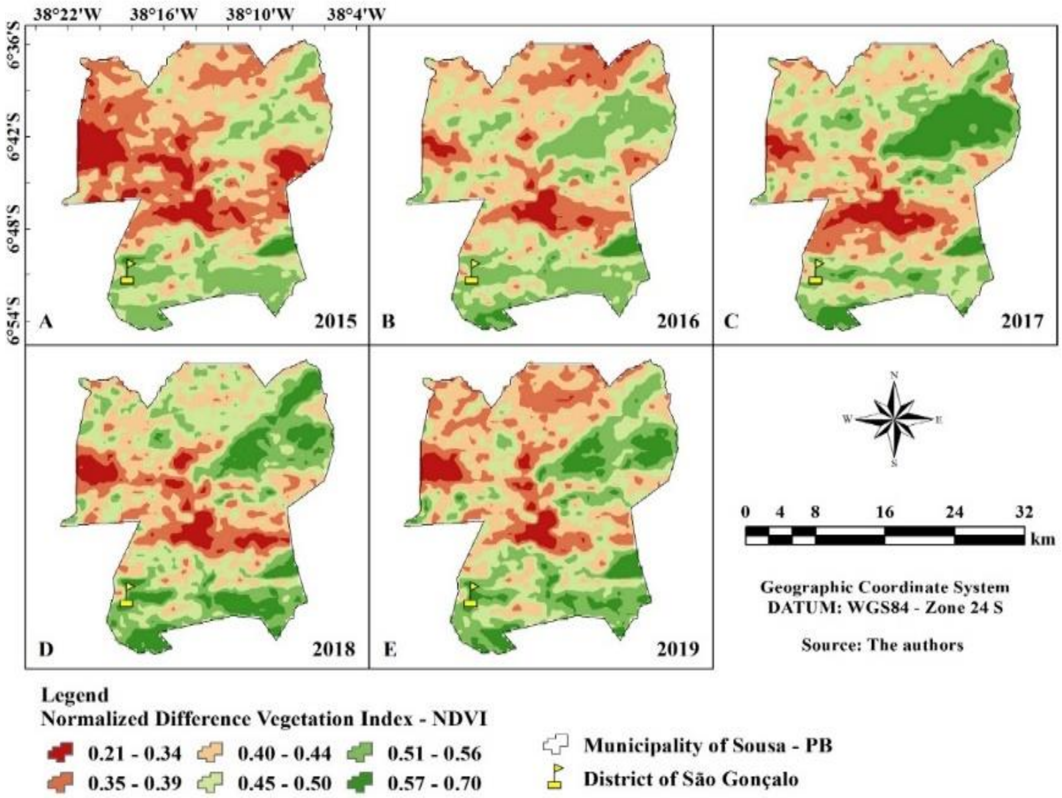

Figure 3. Spatiotemporal distribution of the NDVI vegetation index in the municipality of Sousa-PB

The areas on the maps of the north, northwest, central, and central-south regions showed low levels of vegetation over time, with NDVI values below 0.34 (Figure 3), showing the configuration of high water deficit, mainly due to the effects of drought in the semiarid. It can be noted that, according to the land use and coverage map (SOUZA et al., 2020), these are areas with pasture and urban infrastructure, which favours the changing conditions of the natural environment (Figure 1). On the other hand, the northeast, south, and southeast regions on maps presented high NDVI values over time (Figure 3).

It can be noted in the District of São Gonçalo, where the INMET meteorological station is located, rainfall ranging between 601.7 and 889.4 mm (Figure 2) was recorded for the five years studied. This fact demonstrates the effect of precipitation on the region's vegetation when it promoted adequate humidity conditions for the conservation of biomass.

In this sense, it is observed that the Caatinga vegetation responds proportionally to the rain and the region of Sousa-PB presents pluviometry variability and poorly distributed rainfall annually. As a result, there is a delay in vegetation for other regions of the municipality, contrasting with the District of São Gonçalo, which has proved resilient throughout the space-time analysis.

CONCLUSIONS

The results showed variability in the precipitation caused by the unstable regime, where there was a greater concentration in the year 2018 and lower in the years 2016, 2017, and 2019, contributing to the classification of the coefficient of variation as medium.

The accumulated monthly rainfall showed similar variability, with greater concentration in January, February, March and April in the five years analysed, resulting in high coefficients of variation (0.5, 0.9, 0.6, and 0.7, respectively), as well as with high values of deviation standard (45.2, 119.7, 121.8 and 91.3, respectively). This study pointed out the months of August, September, October and November as those with the lowest concentrations of rain, resulting also in higher values for the variation coefficient.

Geospatial estimates of physical-hydric and agricultural environmental conditions in space and time were important for effective interpretations of the land cover and use changes, providing information for the planning and management of water and natural resources in the Brazilian semiarid region.

The NDVI analysis allowed to infer that the Caatinga vegetation responds proportionally to the rain, observing a delay in the vegetation in other regions, contrasting with the District of São Gonçalo, which proved to be resilient throughout the space-time analysis.

REFERENCES

ALLEN, R. G.; TASUMI, M.; TREZZA, R.; BASTIAANSSEN, W. G. M. SEBAL (Surface Energy Balance Algorithms for Land). **Advance Training and Users Manual** - Idaho Implementation, v.1. 97p. 2002.

ARAÚJO L. E.; SOUSA, F. A. S.; RIBEIRO, M. A. F. M.; SANTOS, A. S.; MEDEIROS, P. C. Análise estatística de chuvas intensas na bacia hidrográfica do rio Paraíba. **Revista Brasileira de Meteorologia**, v. 23, n. 2, p. 162-169, 2008.

BECKER, C. T.; MELO, M. M. M. S.; COSTA, M. N. M. Desempenho temporal de séries pluviométricas no estado da Paraíba: uma análise comparativa. **In: Workshop Internacional sobre Água no Semiárido Brasileiro**, Campina Grande, v. 1, n. 1 p. 01-05, 2013.

BRADLEY, A. V.; GERARD, F. F.; BARBIER, N.; WEEDON, G. P.; ANDERSON, L. O.; HUNTINGFORD, C.; ARAGÃO, L. E. O. C.; ZELAZOWSKI, P.; ARAI, E. Relationships between phenology, radiation and precipitation in the Amazon region. **Global Change Biology**, v. 17, n. 6, p. 2245-2260, 2011.

DA COSTA, F. R.; ALBUQUERQUE, B. C. D. Perímetros irrigados, comunidade e sustentabilidade: uma revisão de literatura. **Cadernos Cajuína,** v. 5, n. 3, p. 498-513, 2020.

DNOCS –Departamento nacional de obras contra as secas. **Perímetros Irrigados**. Disponível em: https://www.dnocs.gov.br/~dnocs/doc/canais/perimetros_irrigados/. Acesso em: 16 out. 2020, 2012.

GOMES, F. P. **Curso de estatística experimental**. Nobel, São Paulo p. 467, 1985.

GORELICK, N.; HANCHER, M.; DIXON, M.; ILYUSHCHENKO, S.; THAU, D.; MOORE, R. Google Earth Engine: Planetary-scale geospatial analysis for everyone. **Remote Sensing of Environment**, v. 202, p. 18-27. 2017.

HMIMINA, G.; DUFRENE, E.; PONTAILLER, J. Y.; DELPIERRE, N.; AUBINET, M.; CAQUET, B.; GRANDCOURT, A.; BURBAN, B.; FLECHARD, C.; GRANIER, A.; GROSS, P.; HEINESCH, B.; LONGDOZ, B.; MOUREAUX, C.; OURCIVAL, J. M.; RAMBAL, S.; SAINT ANDRE, L.; SOUDANI, K. Evaluation of the potential of MODIS satellite data to predict vegetation phenology in different biomes: An investigation using ground-based NDVI measurements. **Remote Sensing of Environment**, v. 132, p. 145-158, 2013.

HUETE, A.; DIDAN, K.; MIURA, T.; RODRIGUEZ, E. P.; GAO, X.; FERREIRA, L. G. Overview of the radiometric and biophysical performance of the MODIS vegetation indices. **Remote Sensing of Environment**, v. 83, n. 1-2, p. 195-213, 2002.

JUSTICE, C. O.; TOWNSHEND, J. R. G.; VERMOTE, E. F.; MASUOKA, E.; WOLFE, R. E.; SALEOUS, N.; MORISETTE, J. T. An overview of MODIS Land data processing and product status. **Remote Sensing of Environment**, v. 83, n. 1-2, p. 3-15, 2002.

LUCENA, J. A.; NÓBREGA, R. S.; WANDERLEY, L. S. A. Aspectos temporais, espaciais e rítmicos da variabilidade pluviométrica no Núcleo de Desertificação de Cabrobó/PE. **Revista Brasileira de Geografia Física**, Recife, v. 10, n. 6, p. 1784-1801, 2017.

PONTES, A. G. V.; GADELHA, D.; FREITAS, B. M. C.; RIGOTTO, R. M.; FERREIRA, M. J. M. Os perímetros irrigados como estratégia geopolítica para o desenvolvimento do semiárido e suas implicações à saúde, ao trabalho e ao ambiente. **Ciência & Saúde Coletiva**, Rio de Janeiro, v. 18, n. 11, p. 3213-3222, 2013.

RIGOTTO, R. M.; FREITAS, B. M. C. Perímetros irrigados e a expansão do agronegócio no campo: quatro décadas de violação de direitos no semiárido. **Dossiê perímetros irrigados.** Disponível em: https://dossieperimetrosirrigados.wordpress.com/. 2014.

SILVA FILHO, J. A.; ARAUJO, S. C.; NOGUEIRA, V. F. B. Análise temporal do regime pluviométrico no município de Sousa – PB. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, v. 11, n. 1, p. 08-13, 2016.

SILVA NETO, M. F.; MACEDO, M. L. A.; ANDRADE, A. R. S.; FREITAS, J. C.; PEREIRA, E. R. R. Análise do perfil agrícola do perímetro irrigado de São Gonçalo-PB. **Revista Brasileira de Tecnologia Aplicada nas Ciências Agrárias**, v. 5, n. 2, p. 155-172, 2012.

SOUZA, C. M. Z.; SHIMBO, J.; ROSA, M. R.; PARENTE, L. L. A.; ALENCAR, A.; RUDORFF, B. F. T.; HASENACK, H.; MATSUMOTO, M. G.; FERREIRA, L.; SOUZA-FILHO, P. W. M.; OLIVEIRA S. W.; ROCHA, W. F.; FONSECA, A. V.; MARQUES, C. B.; DINIZ, C. G.; COSTA, D.; MONTEIRO, D.; ROSA, E. R.; VÉLEZ-MARTIN, E.; WEBER, E. J.; LENTI, F. E. B.; PATERNOST, F. F.; PAREYN, F. G. C.; SIQUEIRA, J. V.; VIERA, J. L.; NETO, L. C. F.; SARAIVA, M. M.; SALES, M. H.; SALGADO, M. P. G.; VASCONCELOS, R.; GALANO, S.; MESQUITA, V. V.; AZEVEDO, T. Reconstructing three decades of land use and land cover changes in Brazilian biomes with Landsat archive and earth engine. **Remote Sensing**, v. 12, n. 17, 2020.

TOMASELLA, J.; VIEIRA, R. M. S. P.; BARBOSA, A. A.; RODRIGUEZ, D. A.; OLIVEIRA SANTANA, M., SESTINI, M. F. Desertification trends in the Northeast of Brazil over the period 2000–2016. **International Journal of Applied Earth Observation and Geoinformation**, v. 73, p. 197-206. 2018.

ZAVATTINI, J. A.; BOIN, M. N. Climatologia geográfica: teoria e prática de pesquisa. **Editora Alínea**, Campinas – SP, p. 01-152, 2013. ISBN 978-85-7516-611-6.