IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Research Article
January 2021 Vol.:17, Issue:3

Susceptibility to Desertification in the Ipojuca River Basin Located in the State of Pernambuco, Brazil

IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Raimundo Mainar de Medeiros*[1], Romildo Morant de Holanda[1], Manoel Viera de França[1], Fernando Cartaxo Rolim Neto[1], Luciano Marcelo Fallé Saboya[2], Wagner Rodolfo de Araújo[3]

1 Universidade Federal Rural de Pernambuco, Brasil
2 Universidade Federal de Campina Grande, Brasil
3 Universidade Estácio de Sá, Brasil

Submitted: 01 December 2020
Revised: 20 December 2020
Accepted: 10 January 2021

HUMAN JOURNALS

www.ijsrm.humanjournals.com

Keywords: Aridity Index, Temperature, Precipitation, Evapotranspiration

ABSTRACT

Rainfall erosivity indices have been widely used for each region as erosion varies in different ways. The estimation of rainfall erosivity index defines the best time for the planning of soil management and conservation practices. Evapotranspiration is used to explain the transfer of water steam to the atmosphere and the moisture, aridity, and water indices are the basis for the climatic classification. The objective of this work was to study the oscillations of the aridity index and its vulnerability to desertification in the Ipojuca river basin located in the Pernambuco state, Brazil. The water balance, dryness index, climatic classification, and level of susceptibility were used, generating their graphs. The climates of the area were of the Arid, Semi-arid dry type with levels of susceptibility between very high and high. Areas identified with vulnerability to desertification due to the lowest aridity index may not be located in degraded areas. The areas with the highest aridity index are not allocated as vulnerability processes may be degraded to the point of being considered as desertified areas. This variation can occur due to improper use of the soil and the environment. The higher the precipitation, the greater the dryness index, and the desertification, the less susceptibility erosive. The temperature influences evapotranspiration, because the higher the temperature, the greater the evapotranspiration and, consequently, the lower the dryness index and, therefore, the greater the susceptibility to desertification.

INTRODUCTION

Among the most important consequences that can occur due to the characteristics of a region's climate are the elevation of the aridity index and the increase of desertified areas due to water déficit elevation, besides extreme events that would be associated, in the regions that are already arid or semi-arid, such as in the semi-arid region of Brazil (MMA, 2007).

It is possible that changes in climate temperature and precipitation, and an increase in the variability of precipitation events, may cause more intense and frequent flooding and droughts (Dufek *et al*., 2008). Studies have shown that the frequency and persistence of droughts should be one of the consequences of global warming (Qian *et al*., 2005). It has been seen that in the Brazilian northeast (NEB) agricultural activities are mostly based on precipitation. If these forecasts prevail, great losses will occur in the economic and social sectors of the Brazilian Northeast (NEB).

Some vulnerabilities occur because of the poor ability to resist droughts, for example, that manifest themselves as socio-economic crises. These crises have been advancing over time to a great extent, due to the rhythm and form of demographic and productive occupation of the great interior of the Brazilian semi-arid, and in particular, the Paraibano, causing serious overloads on the fragile environment and natural resources which are relatively poor (Sousa, 2008).

Medeiros *et al*. (2014) have shown that rainfall erosivity indices have been widely used in Brazil since for each region erosion varies in different ways practiced in intra-urban spaces and/or perimeters. The estimation of rainfall erosivity index defines the best time for the planning of soil management and conservation practices in the area of the Uruçuí river basin. In this area, through the equation determined by Wischmeier *et al*.(1971) and Smith (1958, 1978), the erosivity factor (R) was 28,429.1 MJ mm ha^{-1} h^{-1} year. The highest erosivity indices occurred in November to April occurring with the rainy season and the field capacity in maximum values and in May to October, the lowest indices of erosivity correspond to the dry period.

According to Varejão-Silva (2005), another important meteorological variable is evapotranspiration, used to explain the transfer of water vapor to the atmosphere that originated from vegetated surfaces. The moisture, aridity, and water indices are the basis for the

Thornthwaite climatic classification according to Pereira *et al.*(2002), ie with a water index over 100 mm, the climate will be classified as superhuman; greater than 20mm and less than 100m is classified as humid climate; between 0mm and 20mm the climate is subhumid; oscillating between 0mm and -20mm the dry subhumid climate; between -20mm and -40mm is classified as semi-arid climate and less than -40mm as arid climate. Among other applications, these indices are also used in agroclimatic zoning and as indicators of soil water level (Teixeira *et al*., 1994).

Medeiros *et al*. (2015) evaluated the water balance and rainfall erosivity due to the climate change scenario for the municipality of Cabaceiras-PB. They used the methodology proposed by the IPCC AR4. To determine the Rainfall Erosivity Index, the Universal Soil Loss Equation was used. The results showed that the optimistic scenario and pessimistic scenario indicated critical situations of the soil conditions that will cause great losses for the water resources and rainfed crops. The pluviometric indices for the pessimistic scenario are not enough for several types of crops. Cabaceiras are classified as being a municipality of high erosivity.

Silva *et al*. (2015) studied the semi-arid region of Brazil that represents an ecologically unstable environment due to the inadequate use and overexploitation of natural resources due to the strong anthropogenic action. They found that these factors make the municipality of São João do Cariri - PB considered quite susceptible to desertification. The predominant atmospheric circulation processes in this region can also contribute significantly to desertification. The analysis of the spatial and temporal variability of rainfall provides relevant information for the diversified sectors in the use of rainwater and its storage in the economy and agriculture of the municipality. During the 99 years studied the extreme annual total rainfall precipitation was recorded in the years 1985 in which it rained 1,163.2 mm and the year 1998 when the registered annual total was 124.8 mm. It is emphasized that these extremes are due to large-scale phenomena during the studied period.

Medeiros (2014) demonstrated that the spatial variation of the meteorological variables: water deficiency, water surplus, and the Aridity, Humidity, and Water indices as a function of Available Water Capacity (AWCs) at the levels of 75, 100, 125, and 150 mm, performed by BHC method, proposed by Thornthwaite and Mather (1948, 1953), are not the same in the State of Piauí. Through this analysis it was verified that small oscillations occurred in these variables in the function of the studied AWCs, proven by the temporal space variability of the pluviometric indices together with the high oscillation of the potential evapotranspiration.

Tavares *et al*. (2016) studied desertification in the municipality of São João do Cariri - PB and analyzed socioeconomic and environmental vulnerabilities, revealing the interrelation between the vulnerability of rural families and the phenomenon of desertification. The results obtained were: social vulnerability, whose value found was 44.85%, which is considered high; economic vulnerability, whose value found was 13.05%, which is considered low. Regarding technological vulnerabilities and droughts, the values found were, respectively, 30.03% and 17.68%, which are considered moderate. The analysis of socioeconomic and environmental vulnerabilities in São João do Cariri allowed to diagnose the susceptibility of families to the phenomenon of desertification.

A reduction in the value of the aridity index means an increase in the trend of desertification. This term was defined by the United Nations since the 1980s as "land degradation in arid, semi-arid and sub-humid and dry regions, resulting from several factors, including climatic variations and human activities". This situation leads to the reduction and destruction of the biotic potential of the lands (Beserra, 2011).

The objective of this work was to study the oscillations of the inter-annual aridity index and its vulnerability to desertification for the area of the Ipojuca river basin, located in the state of Pernambuco, Brazil.

MATERIAL AND METHODS

Study área

The Ipojuca River basin is located in the state of Pernambuco, between 08º09'50 "and 08º40'20" south latitude, and 34º57'52 "and 37º02'48" west longitude. Due to its elongated conformation in the west-east direction, this basin has a strategic position in the state space, serving as a large waterway connecting the Metropolitan Region of Recife and the Sertão region of the State. The upper and middle reaches of the basin are located in the regions of Sertão (small portion) and Agreste of the State, while the lower section has the greater part of its area located in the area of Mata Pernambucana, including the coastal range of the State. Limits to the north, with the basin of the river Capibaribe, group of basins of small coastal rivers and with the State of Paraíba; limits to the south, with the basin of the Sirinhaém River; limits to the east, with the Atlantic Ocean; and limits to the west, with the basins of the Rivers Ipanema and Moxotó and the State of Paraíba (Figure 1).

The Ipojuca River basin covers an area of 3,435.34 km^2, corresponding to 3.49% of the area of the State. A total of 25 municipalities are included in this basin, of which 14 have their headquarters located in the basin. The Ipojuca River route, with approximately 320 km, is predominantly oriented in the west-east direction, and its river system is intermittent. Is perennial from its middle course, in the vicinity of the city of Caruaru. Its main tributaries, on the right bank, are the streams: Liberal, Taquara, and Mel, and, on the left bank, the streams of Coutinho, Mocós, Muxoxo, and Pata Choca. The Liberal stream, its most important tributary, has its sources in the Municipality of Alagoinha. It drains, along its 47 km of extension, areas of the municipalities of Alagoinha, Pesqueira, and Sanharó, and flows into the Rio Ipojuca. Its estuary has been greatly altered in recent years, due to the installation of the Suape Port Complex.

Figure 1 - Outline of the Ipojuca river basin and its tributaries next to the municipalities of the environment. Source: Adapted by Medeiros (2020).

Concern to relief in the eastern portion of the study area, two distinct forms of relief are observed, namely: the coastal plain, with altitudes always lower than 100m; And a set of hillshaped hills and hills - "sea of hills" - located on the lens, with altimetric heights of less than 300m, found in the vicinity of the Borborema Plateau. In the western portion of the basin, in the areas belonging to the municipalities of Poção, Pesqueira, Sanharó, and Belo Jardim, there are the oldest and highest surfaces, already well worked by the erosive process, with altitudes varying between 800 and 1,000m(APAC, 2020).

In terms of geology, most of the area of the Ipojuca River basin is represented by pre-Cambrian crystalline and crystalline rocks, whose dominant lithostratigraphic unit is the Migmatitic-Granitoid Complex - pCmi, where granites and granodiorites predominate over the migmatites, Stromal, nebulous and epibolytic. Throughout the entire hydro unit, following the east-west direction, there is an extensive transcurrent fault of the right, called the Pernambuco Lineament. Another massive, granitic-diorite occurs south of the fault, going from the municipality of São Caetano to areas of the municipality of Chã Grande. Concerning the sediments that occur in a small area of this hydrographic basin, it is possible to see that recent alluvial deposits dominate, followed by outcrops of the Cabo Formation, that presents through conglomerates, argillaceous with silty matrix, siltstones and clays, besides Vulcanites in the form of sills, necks or spills, of an acidic constitution (rhyolites) to basic (trachyte and basalt) (CPRM, 1995).

The dominant vegetation presents physiognomic differences as a consequence of the edaphoclimatic factors, and can generally be considered as an "agrestina" caatinga, characterized by the presence of xerophilous, deciduous species, in large numbers composed of thorns and abundance of Cactaceae and Bromeliaceae. In the higher areas and exposed to the humid winds (the southeastern alísios), the "brejos de elevação" occur (being distinguished as areas of springs), being considered ecosystems differentiated from those predominant in the lower or less exposed areas. In these marshes, the presence of the mountainous forest is observed, at the moment with a high state of degradation being replaced by the polyculture. In the more humid areas of the basin, the vegetation is of the Atlantic Tropical Perennial Forest type, which today is greatly reduced by the devastating action of man. Mangroves are found on the coast, some in great devastation (CPRM, 1995).

Methodological procedures

The methodology used mean monthly and annual precipitation data acquired from the database of the Northeast Development Superintendency (SUDENE) and the Weather and Climate Agency of the State of Pernambuco (APAC) for the period from 1962 to 2015.

The water balance used calculates the availability of water in the soil for the different types of crops. It counts the rainfall before evapotranspiration potential, taking into account the capacity of the field of soil water storage. The model used to determine the water balance was the one proposed by Thornthwaite (1948; 1955) and its calculation structure was carried out by spreadsheets following Medeiros (2015). The BHC method calculation was performed only with mean precipitation data and average monthly air temperature with an available water capacity (AWC) of 100 mm.

Calculation of potential evapotranspiration (ETP)

The estimated potential evapotranspiration (ETP) used in the methodology requires only monthly average air temperature and maximum sunshine expressed in mm/month. ETP is defined as follows, according to Thornthwaite and Mather (1948, 1953).

$$(\mathrm{ETP})\mathrm{j} = \mathrm{Fj}\,.\mathrm{Ej}$$

At where:

Represents potential evapotranspiration (mm / day) not adjusted and summarized as follows:

$$Ej = 0{,}553\ (\frac{10.Tj}{I})^{a}$$

On what:

Tj represents the monthly average air temperature of the month (°C); I am the annual heat index defined by:

$$\mathrm{I} = \sum_{j=1}^{12} ij$$

Being, the thermal index of heat in the month given by:

$$ij = (\frac{Tj}{5})^{1,514}$$

Finally, the exponent "a" is a cubic function of this annual heat index, expressed as follows:

$$a = 6{,}75x10^{-7} - 7{,}71x10^{-5}I^2 + 1{,}79x10^{-2}I + 0{,}49$$

The correcting factor is defined as a function of the number of days of the month Dj (in January, Dj = 31, in February Dj = 28, etc.) and maximum insolation on day 15 of month J (Nj), considered representative of the average This month, defined by:

$$Fj = \frac{Dj.Nj}{12}$$

For the calculation of the maximum insolation of day 15, the following expression was used:

$$Nj = \left(\frac{2}{15}\right)[\text{arc.cos}(-tag\emptyset.tag\delta)]$$

At where:

Ø Location latitude;

δ Declination of the Sun in degrees, for the day, considered; defined by:

$$\delta = 23{,}45^0 sen[360(284 + \text{d})/365]$$

On what,

"D" is the order number, in the year of the considered day (Julian day).

The estimate of potential evapotranspiration is only valid for the mean air temperature of the month below 26.5 °C. When the average temperature of that month is equal to or greater than 26.5 °C, Thornthwaite and Mather (1948, 1953) assume that is independent of the annual heat index and an appropriate table is used for its estimation.

Aridity index (AI)

The aridity index (AI) was calculated using the formula suggested by the United Nations Environment Program (UNEP, 1992), which has been used for the classification of lands susceptible to desertification processes. The equation is given by:

$$AI = \frac{Pr}{ETP}$$

At where:

Pr is the mean annual precipitation (mm year^{-1}) and ETP is the mean annual evapotranspiration (mm year^{-1}).

Thus, the AI was calculated for the municipality understudy with the monthly and annual rainfall data and the mean air temperature data, and the mean monthly ETP was calculated by the climatic water balance method according to Thornthwaite (1948,1953). The spreadsheet developed by Medeiros (2015) was used to calculate the water balance. The climatic classification of a given locality has to agree with the values of the AI shown in Table 1.

Table No.1: Climate classification according to values of aridity index (AI)(Author, 2020).

Climate Types	Aridity Index (AI)
Hyperarido (H)	AI ≤ 0.03
Arid (A)	0.03< AI ≤ 0.2
Semi-arid (SA)	0.2< AI ≤ 0.5
Dry subunit (SUS)	0.5< AI ≤ 0.65
Subunit (SU)	0.65 < AI ≤ 1.0
Wet (U)	AI > 1.0

The degree of desertification is associated with susceptibility according to index AI, added by the rigor of the dry season, demographic pressure and type of natural resource use, as well as the country's level of development and the quality of preventive measures (FAO, 2000). Knowing the historical meteorological series of precipitation and the average temperature and the AI, one can characterize the water availability and the planning for the use. It is also possible to highlight the annual periods that will be critical, with water losses or surpluses following Souza *et al*. (2014).

Table No. 2: Classification of the level of susceptibility to desertification with the use of the Aridity Index, adapted from the methodology of Matallo Júnior (2001).

Level of susceptibility to desertification	Aridity index
Upper to moderate (SM)	AI > 0.65
Moderate (M)	0.51< AI <0.65
High (AL)	0.21<AI <0.50
Very high (MA)	0.05<AI <0.20
Below very high (IMA)	AI <0.05

RESULTS AND DISCUSSION

Table 3 shows the period the years 1962 to 2019, the aridity indices, the climatic classifications, and the level of susceptibility for the area of the Ipojuca river basin. With the calculated AI, it was possible to classify the level of susceptibility to desertification, adapted from the classification (Table 2) proposed by Matallo Júnior and Schenkel (2003).

Table No. 3: Annual Representativeness; Aridity indices (AI); Climate classification (CC); Susceptibility Level (SL) for the area of the Ipojuca River basin.Source: Medeiros (2020).

Município	Latitude	Longitude	Altitude	AI	SL	CC
Arcoverde	-8,4336	-37,0556	794	0,358	M	AS
Belo Jardim	-8,3333	-36,4208	727	0,347	M	AS
Bezerros	-8,2433	-35,7528	553	0,385	M	AS
Caruaru	-8,2383	-35,9158	539	0,492	M	AS
Chã Grande	-7,7211	-39,2361	466	0,259	AL	AS
Escada	-8,3667	-35,2333	145	0,216	AL	AS
Gravatá	-8,2006	-35,5431	460	0,316	M	AS
Ipojuca	-8,5144	-35,0058	62	0,178	MA	A
Pombos	-8,1386	-35,3961	341	0,259	AL	AS

Porção	-8,1836	-36,7053	904	0,295	AL	AS
Primavera	-8,3483	-35,3475	367	0,193	MA	A
Sanharó	-8,3639	-36,5664	726	0,316	M	AS
São Caitano	-8,3283	-36,1375	639	0,467	AL	AS
Tacaimbó	-9,1089	-38,1533	621	0,426	AL	AS
Agrestina	-8,4578	-35,9536	458	0,341	AL	AS
Alagoinha	-8,4661	-36,7739	717	0,392	AL	AS
Altinho	-8,4906	-36,0597	530	0,409	AL	AS
Amaraji	-8,3778	-35,4472	386	0,190	MA	A
Cachoeirinha	-8,4839	-36,2375	572	0,439	AL	AS
Pesqueira	-8,3531	-36,6972	791	0,309	AL	AS
Riacho Almas	-8,1381	-35,8592	443	0,478	AL	AS
Sairé	-8,3267	-35,7089	628	0,274	AL	AS
São Bento Una	-8,5281	-36,46	662	0,361	AL	AS
Venturosa	-7,9286	-38,9694	638	0,447	AL	AS
Vitória S Antão	-8,8383	-35,6347	253	0,254	AL	AS

Legend: AI = Aridity indices; SL = Susceptibility Level; CC = Climate Classification; MA = Very high; AL = High; M = Moderate; IMA = Below very high; SM = Greater than moderate; H = hyperarid; A = Arid; AS = Semi-arid; SUS = Dry sub-humid; SU = Subhumid; U = wet.

In Susceptibility levels, there were two types Moderate and High and in the climatic classification occur the climates Semiarid and the Arid climate.

Figure 2 shows the distribution of the mean annual temperature and the average historical temperature of the period 1962-2019 for the area of the Ipojuca river basin. The interannual fluctuation with irregularity and oscillation between 20.6 and 25.6 °C are observed. It is also worth noting that between the years 1962 to 2019 the annual temperatures were below normal in the following municipalities: Arcoverde, Alagoinha, Belo Jardim, Poção, Saharé, Sanharó, São

Caitano, São Bento do Uno, Tacaimbó, and Venturosa. The municipalities of Bezerros, Cachoeirinha, and Caruaru remained with temperatures near the average. In other municipalities, the temperature fluctuation was above normality.

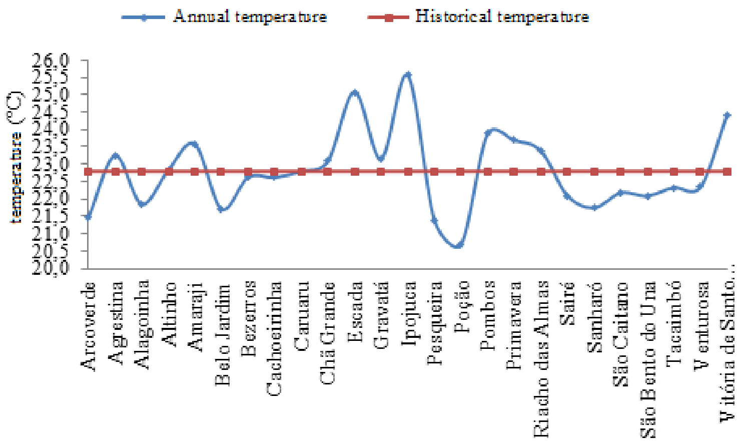

Figure No. 2: Distribution of mean annual and historical temperature for the Ipojuca river basin - PE in the period 1962-2019. Source: Medeiros (2020).

The Figure 3 shows the distribution of precipitation from the period 1962-2019 in the area of the Ipojuca river basin. The monthly fluctuation of precipitation varies from 3.5 mm in October to 64.5 mm in April with an average annual precipitation of 354 mm. The municipality of Caruaru has the lowest annual rainfall (565.5 mm). The largest annual precipitation record occurred in the municipality of Ipojuca with 1,946.3 mm.

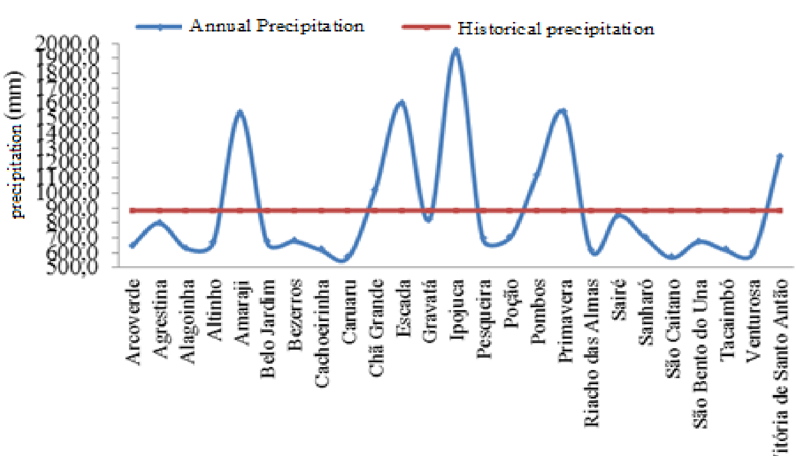

Figure No. 3: Distribution of annual and historical mean precipitation for the Ipojuca river basin - PE in the period 1962-2019. Source: Medeiros (2020).

The months of greatest pluviometric fluctuation occur between January and July corresponding to 88.19% of the annual value and in August to December, there is 11.81% of the expected rainfall (Figure 4).

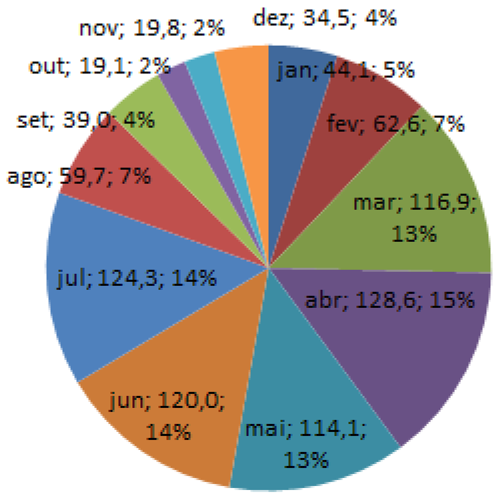

Figure No. 4: Monthly and percentage representation of precipitation for the Ipojuca river basin - PE in the period 1962-2019.Source: Medeiros (2020).

The Figure 5 shows the occurrence of the arid climate (A) in the municipalities of Ipojuca, with a very high susceptibility level, Primavera and Amarají. The semi-arid climate (AS) was registered in the other municipalities of the studied area with a level of susceptibility ranging from high to moderate.

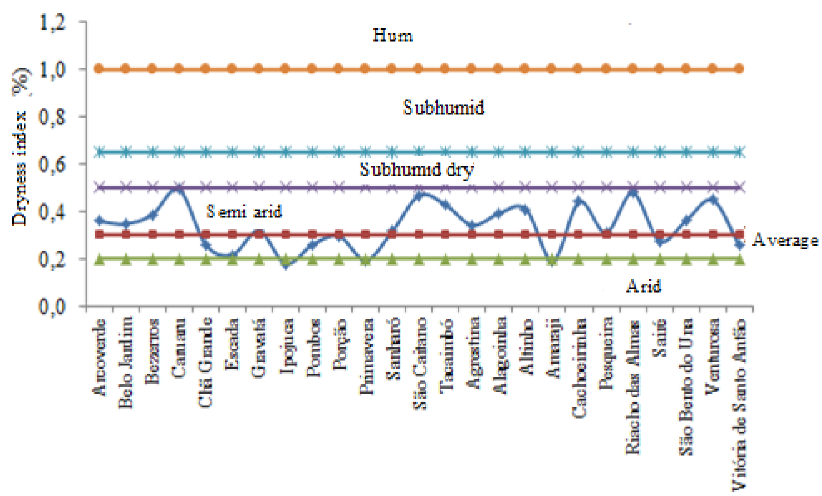

Figure No. 5: Annual variability of aridity indices for the Ipojuca river basin - PE in the period 1962-2019. Source: Medeiros (2020).

CONCLUSIONS

The aridity index calculated in the water balance shows a wide interannual and inter-municipal spatial oscillation, however, the aridity indices are above the values established for the desertification.

Areas identified with vulnerability to desertification due to the lower aridity index may not be located in the degraded area, and areas that have a higher aridity index and are not warned as vulnerability processes may be degraded to the point of being considered Desertified areas. This variability may occur due to improper use of the soil and the environment.

The period from 1962 to 2015 was studied to determine with greater certainty the data of the levels of susceptibility and climatic classifications with more precision determine the existence or not of areas with desertification. In this sense, the higher the precipitation.

The temperature influences evapotranspiration, that is, the loss of water to the atmosphere, because the higher the temperature, the greater the evapotranspiration and, consequently, the lower the dryness index and, therefore, the greater the susceptibility to desertification.

The spatial distribution of rainfall occurs irregularly and with high monthly and annual variability, as well as the annual temperature distribution making the semiarid climate predominate in most of the studied years.

REFERENCES

1. APAC. Pernambuco Water and Climate Agency of the State of Pernambuco. Recife, 2015.
2. Dufek, AS.; Ambrizzi, T. Precipitation variability in São Paulo State, Brazil.Theoretical and Applied Climatology, 2008. v. 93, p.167-178.
3. FAO. Foad and agriculture organization of the United Nations. La erosion del suelo por el água: Algumas medidas para em las tierras de cultivo. Roma: Organization de Las Nacioes Unidas, p.207. 1967,
4. Matallo Junior, HA. desertification in the world and in Brazil. In: SCHENKEL, C.S. e Matallo JR, H Org). Desertification. Brasilia: 2003.UNESCO,
5. Matallo JúnioR, H. Desertification indicators: history and perspectives. - Brasília:2001.UNESCO,
6. Medeiros, RM, Matos, RM, Silva, PF, Saboya, LMF.Calculation of water balance and erosivity for the municipality of Cabaceiras-PB. Biosphere Encyclopedia Magazine, Scientific Center Knowing - Goiânia, 2015.v.11 n.21; p. 2894-2907.
7. Medeiros, RM. Elaboration of a computer program in electronic spreadsheets of the water balance. 2016.
8. Medeiros, RM. Agrometeorological study for the State of Pernambuco. 2017. p.145. Single Edition.
9. Medeiros, RM. Characterization of climate changes through meteorological series for the municipality of Teresina / Piauí. Pernambuco Magazine of Technology. 2014. v.2, p.6 - 17,

10, Medeiros, RM, Gomes Filho, MF, Costa Neto, FA. Rain erosivity in the area of the hydrographic basin of the Uruçuí Preto-PI, Brazil aiming at the development of soil management. 9th congress on higher agricultural education Areia-PB - 27 a 30 de outubro de 2014 Nº ISSN / 0101-756X.

11. Millennium Ecosystem Assessment, Ecosystems and Human well-Being: Desertification synthesis, 1 ed. World resources Institute, Washington. 2005.

12. Ministériodo Meio Ambiente. Atlas of areas susceptible to desertification in Brazil. Water Resources Secretariat, Brasília: 2007.MMA,

13. Nicholson, SE, Tucker, CJ, BA, MB. Desertification, Drought, and Surface Vegetation: An Example from the West African Sahel. Bulletin of the American Meteorological Society, 1998. v.79, n.5, p.815-829,.

14. Pereira, APA,angelocci, LR, Sentelhas, PC. Agrometeorology: fundamentals and practical applications. Guaíba - RS: Agriculture, 2002.478p.

15. Silva, VMA, Medeiros, RM, Arauju, SMS. Desertification and rainfall variability in São João do Cariri - PB in the period 1911-2010. I International Workshop on Water in the Brazilian Semiarid Region. Campina Grande - PB. 2013.

16. Sousa, RF. Vulnerability, Semiaridity and Desertification: risk scenarios in Cariri Paraibano. OKARA Magazine: Geography in debate. 2008. p.128-206.

17. SUDENE. Northeast Development Superintendence. Monthly rainfall data from the Northeast - Paraíba. (Pluviometry series, 2). Recife. 1990.

18. Tavares, VC, Ramos, NZ. Desertification in São João do Cariri (PB): an analysis of vulnerabilities. Brazilian Journal of Physical Geography 2016. v.09, n.05. p.1384-1399.

19. Teixeira, H.C.T.; Azevedo, P.V. Agroclimatic potential of the State of Pernambuco for the cultivation of acerola. Brazilian Journal of Agrometeorology, Santa Maria, 1994. v.2, n.1, p.105-113,

20. Thornthwaite, C.W. An approach toward a rational classification of climate. Geographic Review, 1948.38, p.55-94.

21. Thornthwaite, C.W.; Mather, J.R. The water balance. Publications in Climatology. New Jersey: Drexel Institute of Technology, 1955. 104p.

22. UNEP. United Nations Envionment Programme. Disponível: http://www.unep.org/sgb/prev_docs/78_05_GC6_report_k7803325.pdf. 1978.

23. Varejão-Silva, MA. Meteorology and Climatology. Digital Version. Recife, 2005. 516p.

24. Wischmeier, WH, Johnson, CB, Cross, BV. A soil erodibility nomograph for farmaland and construction sites. Journal of Soil and Water Conservation, Ankeny, 1971. n.26, p.189-193,

25. WischmeieR, WH, Smith, DD. Rainfall energy and its relationship to soil loss. Transactions of the American Geophysical Union, Washington, 1958. v.39, n.2, p.285-291,

26. Wischmeier, WH, Smith, DD. Predicting rainfall erosion losses: a guide to conservation planning. Washington: USDA, 1978. 58p.

27. Beserra, EA. Aridity Projections in Northeast Brazil for the 21st Century in a Global Warming Scenario. 93f. Master's Dissertation (National Institute for Space Research).São José dos Campos-SP. 2011.