Chapter 273

Quantification and study of anomalous trends of annual rainfall in the state of Bahia between 1980 and 2019

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Eulalia Pessin Silva
Federal Institute of Education, Science and Technology of Bahia, Eunápolis campus
E-mail: eulaliaps14@gmail.com

David Santiago Aquino
Federal Institute of Education, Science and Technology of Bahia, Eunápolis campus
E-mail: davi.aquino@ifba.edu.br

ABSTRACT
Water is a natural resource of extreme relevance for human activities, as well as for the maintenance of biodiversity on Earth. In the circulation of water on the planet, described by the hydrological cycle, precipitation stands out, which allows the return of part of the fresh water present in the atmosphere to the earth's surface, being, therefore, a stage of the cycle with direct implications for the availability of this resource. In the context of climate change, it is necessary to pay attention to possible trends of changes in rainfall, especially regarding the possibilities of extreme events, such as abundance of rainfall, favoring floods, or even long periods of scarcity, which can compromise the availability of water. Some studies have identified these rainfall trends in localities of the Brazilian Northeast. However, there is still no study, available in the literature, covering the entire state of Bahia. Thus, this plan estimated the occurrence of anomalies related to precipitationinthe state of Bahia. To this end, the Rainfall Anomaly Indexes (IAC) were used, which were calculated annually for 24 rainfall stations distributed in the state. We used the monthly precipitation data recorded in theseseasons for the historical series from January 1980 to December 2019. An amount of 671 anomaly indices was determined, being 338 negative results, which express drier periods or with a lack of rainfall, and 333 positive anomalies, which indicate wetter periods in relation to the historical average. The variations of these indices are described, according to the corresponding seasons, by means of a graphic study. Finally, maps of the spatial distribution of anomalies throughout the state of Bahia are elaborated.

Keywords: Rain anomaly, Hydrology, Bahia.

1 INTRODUCTION

The water that makes life possible on planet Earth, sustaining biodiversity, affecting the climate and the terrestrial landscapes, is not available statically, but dynamically. This dynamism makes thisfundamental to life present itself in various ways, sometimes in its solid form, sometimes as vapor, and sometimes in its liquid form. The circulation of water on the planet can be understood through the hydrological cycle.

For human beings, water in addition to fulfilling a physiological role, has come to be considered as a good endowed with economic value being, therefore, a natural resource on which humanity depends for the most diverse practices, such as agricultural production, industrial processes, urban supply, navigation, etc. Thus, significant changes in the hydrological cycle, such as an extreme Variability in the occurrence of a given stage may imply in the compromise of the availability of this natural resource indispensable to human activities, as well as affecting the maintenance of the various ecosystems on the planet.

Among some of the main stages of the hydrological cycle, to mention: evaporation, condensation and precipitation, the relevance of the latter stands out. According to SILVEIRA (2015) the most significant flow of water that occurs towards the atmosphere to the earth's surface worldwide is precipitation, either as rain or snow. Thus, the precipitation stage is responsible for most of the return of fresh water to the planet. (HORNINK et al, 2016). As the multiple uses of water, in general, are related to the available fresh water, precipitation becomes essential in the availability of this resource.

The water precipitated on the earth's surface is distributed in natural catchment areas where the flows produced tend to converge to a single exit point or exultory, each of these catchment areas SILVEIRA (2015) calls as Hydrographic Basin. In Brazil, the hydrographic basins are the territorial units, composed of sloped surfaces and bodies of water, on which the policies of management of water resources are applied.

According to the National Water Agency (ANA) in Brazil there are 12 hydrographic regions, these are: Amazon, Tocantins-Araguaia, Paraguay, Paraná, Uruguay, South Atlantic, Southeast Atlantic, São Francisco, Parnaíba, Atlantic Northeast West, Atlantic Northeast East, Atlantic East.

According to the Institute of Environment and Water Resources (INEMA) the state of Bahia is comprised of two hydrographic regions, being them São Francisco and Atlântico Leste. Each region is composed of several sub-basins, whose main rivers and their tributaries are fundamental for the supply of Bahian municipalities, as well as for the economic practices developed in the state.

The World Bank (2018) in the report on water resources explains that water demands have grown continuously, following the urbanization process that reached, in 2010, an average rate of 73% (IBGE, 2011). Recent studies show that the impact of climate change in the Northeast and the São Francisco River basin will result in a decrease in precipitation, intensifying droughts in the future.

Also, in the same report, it is recommended:

> [..] incorporate the probable changes in the qualitative-quantitative availability of water over time (taking into account the intensification of extreme hydrological events and climate change), in order to create more robust elements for the future scenario of management of future water supply and water security [..] (WORLD BANK, 2018)

Also in the context of climate change, the Intergovernmental Panel on Climate Change (IPCC) indicates the relevant impact that climate change causes on the regime of occurrence and distribution of rainfall, incurring an increase in extreme rainfall and drought events.

According to the scenarios presented, which describe possible rainfall changes as occurrences of extreme events, whether of abundance or scarcity of rainfall, there is a need for knowledge about possible rainfall trends, since any extreme event has a direct implication on the availability of water resources, on multiple uses, and consequently, on living beings.

Toidentify these rainfall trends, some methodologies have been developed. In Brazil, Freitas (1998) adapted, for the conditions of the Brazilian Northeast, the Rainfall Anomaly Index (RAI) developed by Van Rooy (1965), in such a way that, in possession of the rainfall heights, for a given place, it becomes possible to know the behavior of the rainfall regime throughout a predetermined historical series. As well as recognizing possible significant changes in this regime.

The RAI in Brazil is the Rainfall Anomaly Index (HAI), which has come to be considered a consistent method for rainfall studies. In the Northeast, some studies supported by this methodology were carried out, among them: (CORREIA FILHO *et al*. 2017), in Sergipe. (COSTA; RODRIGUES, 2017), in Ceará. (BROOK; MACIEL, 2018), in Pernambuco. (MANIÇOBA *et al*., 2017) in Rio Grande Norte.

It was found that, for the state of Bahia, there is no available in the literature a study that identifies the trends in the rainfall regime which covers the entire state, comprising, consequently, parts of the hydrographic regions of São Franscisco, and the East Atlantic. This research aims, therefore, to identify the rainfall trends in the state of Bahia. Thus, the main objective of the present study was to estimate the rainfall anomaly index (HAI) in 28 meteorological stations in Bahia between 1980 and 2019.

2 METHODOLOGY EMPLOYED

The methodology initially consisted of access to the portal of the National Institute of Meteorology (INMET) through the online address https://portal.inmet.gov.br/ in order to identify relevant information for the development of the inherent activities. Thus, we proceeded with the identification of conventional stations, which had monthly precipitation records covering the entire historical series of interest in this research, that is, from January 1980 to December 2019, separating them from those that did not completely fill this series. Subsequently, absences related to some of the monthly precipitation records were identified. Such absences are represented in worksheet cells by the term "null".

In the next step, the data were organized using tables, grouping the monthly data in annual records by summing the precipitation values of the months from January to December, for each of the years, in which there was no failure of monthly registration. As for the years, in which all the months presented precipitation records, these are the ones on which the rainfall anomaly indexes were calculated using the equations present in the literature, which determine the IAC admitting as reference annual precipitation values. The equations that determine the IAC are as follows:

$$IAC = 3\left(\frac{N - \bar{N}}{\bar{M} - \bar{N}}\right), \qquad para\ anomalias\ positivas\ (1)$$

$$IAC = -3\left(\frac{N - \bar{N}}{\bar{X} - \bar{N}}\right), \qquad para\ anomalias\ negativas\ (2)$$

Being
$N - \bar{N} > 0$ (positive anomalies)
$N - \bar{N} < 0$ (negative anomalies)

N: precipitação anual, em mm
$\bar{N}$: precipitação média anual da série histórica, em mm
$\bar{M}$: média das dez maiores precipitações anuais da série histórica, em mm
$\bar{X}$: média das dez menores precipitações anuais da série histórica, em mm

The positive anomalies represent occurrences of annual precipitation values higher than the average annual precipitation of the series, being, therefore, indicative of wetter periods, or with an abundance of rainfall. Negative anomalies, on the other hand, express situations in which annual rainfall was lower than the historical average, so there is the observation of drier periods, or with a shortage of rainfall.

In each year of the series, and with reference to each season, the respective IAC is obtained. Thus, with the applications of equations (1) and (2) the rainfall anomaly indices were determined.

For the study of the variability of the IAC in each season throughout the series, we proceeded with the elaboration of graphs, which describe the occurrences of the anomalies, positive and/or negative, also expressing the intensities of these, finally helping in the understanding of possible tendencies to changes in the rainfall regime, such as the occurrences of periods of rainfall scarcity, or plenty of rainfall.

After the completion of the steps related to the determination of the indices, and to the graphic studies, some of the instruments of Descriptive Statistics were used, such as mean, ordering, and standard deviation, for example, in the identification of the mean HAI in each year included in this study. This average IAC is equal to the arithmetic mean of all IAC results for the respective year.

As the average HAI was obtained for each year of the series, the average IAC of each station was calculated by applying the arithmetic mean of the resulting HAI for that station.

In addition to the arithmetic means, deviations were determined, which were calculated and indicated, in both cases, for both the average HAI per year and the average HAI per season.

As a complement to the analysis of the results, the accumulated value of IAC for each season was indicated, comprising this value in the intensity class for rainfall anomaly index. Such classes were established by Araújo et al (2009). The intensity classes considered in this study are presented in Table 1:

Table 1 - Classification of rainfall anomaly intensities

IAC Range	Intensity class
IAC > 4.00	Extremely humid
2.00 < IAC ≤ 4.00	Very wet
0.00 < IAC ≤ 2.00	Wet
- 2.00 ≤ IAC < 0.00	Dry
- 4.00 ≤ IAC < - 2.00	Very dry
IAC < - 4.00	Extremely dry

Source: Araújo et. al (2009) adapted from Freitas (2004)

Finally, in reference to the HAI accumulated for the rainfall stations distributed in the state and referenced in this study, the spatial distribution map of the rainfall anomalies in the state of Bahia is produced.

This map was constituted through the QGis Software v3.10, which is a free and open source software, being an application of the *Geographic Information System - GIS*, which allows to perform spatial modeling, as well as queries and simulations, based on georeferenced information.

Thus, the geographical coordinates of the rainfall stations were required, allowing their location in the State. In this map we used the reference system Datum code EPSG:4674: Geographic Coordinate System SIRGAS 2000.

For each season, the accumulated IAC was used to represent the behavior of rainfall anomalies throughout the series. In order to cover the entire territory of the state of Bahia, interpolation was used following the method of Inverse Distance Weighting (IDW).

To adapt the color scale of the map, we used the intensity classes, each of which was referenced by a color specified through code, thus maintaining the standard in all the generated maps. Thus the spatial distribution map of rainfall anomalies was completed.

As a complement to the analysis of the distribution of rainfall anomalies, we sought to identify the years, between 1980 and 2019, characterized by being the wettest or driest of the entire series. In this way, new maps were produced, which represent the behavior of the IAC in the years that stood out, including 2019, the last year of the series for which the profile of the rainfall regime was determined.

3 RESULTS

Due to the large amount of data used and the spatial and temporal extension of the results obtained, a synthesis of the information for your query was performed, which can be performed by the virtual link https://1drv.ms/x/s!AsDCSjFHLZNqkBSTcp0Lrku0MvVL which does not need a login or password for access.

Table 2 presents the codes of the stations, of conventional type, for which through the INMET database rainfall data were obtained for the period covered by the predetermined historical series.

Table 2 – Organization of stations according to data availability.

CÓDIGOS DAS ESTAÇÕES CONVENCIONAIS						
SOLICITADAS			COM RETORNO DE DADOS		SEM RETORNO DE DADOS	
83249	83227	83076	82979	83249	83227	
83179	83295	83297	82985	83286	83225	
83236	83292	83344	82986	83288	83238	
83288	83186		83076	83292	83230	
83339	83242		83088	83295	83194	
83226	83225		83090	83339	83223	
83398	83090		83179	83344	83247	
82985	83184		83182	83347	83297	
83498	83549		83184	83348		
83408	83238		83186	83398		
83192	82986		83190	83408		
83286	83230		83192	83446		
83222	82979		83221	83498		
83221	83194		83222	83549		
83446	83223		83226			
83348	83247		83229			
83182	83229		83236			
83244	83088		83242			
83347	83190		83244			
TOTAL DE 41 ESTAÇÕES			TOTAL DE 33 ESTAÇÕES		TOTAL DE 8 ESTAÇÕES	

Source - Own elaboration

As shown in Table 2, although data from 41 rainfall stations were requested throughout the state of Bahia, there was only a return for 33 stations, for which the files in . CVS were generated, thus enabling access to data through Microsoft Excel software.

Among the 33 stations whose data were accessed, it is recorded that, for only 26, there are abrang andcovering data for the entire period between January 1980 and December 2019. Thus, 7 and a few stations have interrupted precipitation records on dates prior to December 2019. Thus, the stations are grouped according to Table 3.

Table 3 – Organization of the stations according to the period of coverage of the data obtained

CÓDIGOS DAS ESTAÇÕES COM RETORNO DE DADOS			
ABRANGEM TODA A SÉRIE HISTÓRICA		NÃO ABRANGEM TODA A SÉRIE	
82979	83249	82985	
83076	83286	82986	
83090	83288	83088	
83179	83292	83226	
83182	83295	83244	
83184	83344	83339	
83186	83347	83348	
83190	83398		
83192	83408		
83221	83446		
83222	83498		
83229	83549		
83236			
83242			
TOTAL DE 26 ESTAÇÕES		TOTAL DE 7 ESTAÇÕES	

Source - Own elaboration

As an example of a station not to cover the entire period of 40 years of the series, there is station 82986, referring to the city of Paulo Afonso, in which the data series is interrupted on April 30, 2015, as indicated in table 4, by means of the term "Final Date".

Table 4 – Descriptions for station 82986, including date of last record.

	A	B
1	Nome: PAULO AFONSO	
2	Codigo Estacao: 82986	
3	Latitude: -9.378106	
4	Longitude: -38.226771	
5	Altitude: 255.04	
6	Situacao: Desativada	
7	Data Inicial: 1980-01-01	
8	Data Final: 2015-04-30	
9	Periodicidade da Medicao: Mensal	

Source - Own elaboration

Among the 7 stations, which do not have data comprising the 40 years of historical series, 83244, referring to the city of Itaberaba, and 83339, referring to the city of Caetité, have data until February 2019 and July 2019, respectively. Therefore, they were excluded from the group of stations in which IAC values are determined due to the absence of precipitation records in some of the months of 2019.

Once the stations were selected, the data were organized in tables, according to the model presented in Table 5.

Table 5 – Model used for data organization.

DADOS DE PRECIPITAÇÃO MENSAL (mm) - MODELO (EST-)													TOTAL ANUAL
	JANEIRO	FEVEREIRO	MARÇO	ABRIL	MAIO	JUNHO	JULHO	AGOSTO	SETEMBRO	OUTUBRO	NOVEMBRO	DEZEMBRO	mm
1980													0
1981													0
1982													0
1983													0
1984													0
1985													0
1986													0
1987													0
1988													0
1989													0
1990													0
1991													0
1992													0
1993													0
1994													0
1995													0
1996													0
1997													0
1998													0
1999													0
	JANEIRO	FEVEREIRO	MARÇO	ABRIL	MAIO	JUNHO	JULHO	AGOSTO	SETEMBRO	OUTUBRO	NOVEMBRO	DEZEMBRO	TOTAL ANUAL
2000													0
2001													0
2002													0
2003													0
2004													0
2005													0
2006													0
2007													0
2008													0
2009													0
2010													0
2011													0
2012													0
2013													0
2014													0
2015													0
2016													0
2017													0
2018													0
2019													0

Source - Own elaboration

The "ANNUAL TOTAL" column refers to the results of the sums of the monthly precipitation records for each year. The unit of measurement being the millimeter (mm). In the same worksheet is also contained the model for the calculation of the IAC rainfall anomaly indexes, which is shown in Table 6.

Table 6 - Model used to calculate rainfall anomaly indices (HAI).

CÁLCULO DO ÍNDICE DE ANOMALIA DE CHUVAS (IAC)						
TOTAL ANUAL	MÉDIA ANUAL	ANOMALIA	ORDENAÇÃO	*MÉDIA		
mm	mm	$N - \bar{N}$	Decrescente	*10 Maiores	IAC	ANOS
0		0,0			#DIV/0!	1980
0		0,0			#DIV/0!	1981
0		0,0			#DIV/0!	1982
0		0,0			#DIV/0!	1983
0		0,0			#DIV/0!	1984
0		0,0			#DIV/0!	1985
0		0,0			#DIV/0!	1986
0		0,0			#DIV/0!	1987
0		0,0			#DIV/0!	1988
0	0,0	0,0		#DIV/0!	#DIV/0!	1989
0		0,0			#DIV/0!	1990
0		0,0			#DIV/0!	1991
0		0,0			#DIV/0!	1992
0		0,0			#DIV/0!	1993
0		0,0			#DIV/0!	1994
0		0,0			#DIV/0!	1995
0		0,0			#DIV/0!	1996
0		0,0			#DIV/0!	1997
0		0,0			#DIV/0!	1998
0		0,0			#DIV/0!	1999
TOTAL ANUAL	MÉDIA ANUAL	VARIAÇÃO		*10 Menores	#VALOR!	ANOS
0		0,0			#DIV/0!	2000
0		0,0			#DIV/0!	2001
0		0,0			#DIV/0!	2002
0		0,0			#DIV/0!	2003
0		0,0			#DIV/0!	2004
0		0,0			#DIV/0!	2005
0		0,0			#DIV/0!	2006
0		0,0			#DIV/0!	2007
0		0,0			#DIV/0!	2008
0	0,0	0,0		#DIV/0!	#DIV/0!	2009
0		0,0			#DIV/0!	2010
0		0,0			#DIV/0!	2011
0		0,0			#DIV/0!	2012
0		0,0			#DIV/0!	2013
0		0,0			#DIV/0!	2014
0		0,0			#DIV/0!	2015
0		0,0			#DIV/0!	2016
0		0,0			#DIV/0!	2017
0		0,0			#DIV/0!	2018
0		0,0			#DIV/0!	2019

Source - Own elaboration

Column 3, "ANOMALY", is the difference between "ANNUAL TOTAL" () and "ANNUĀL AVERAGE" (). The column "ORDERING" was made to facilitate the identification of the 10 highest annual rainfall values, as well as the 10 lowest. Once these values are determined, the averages are made, these are contained in the column "*AVERAGE". With this information, it becomes possible to calculate the IAC.*NN*

As an example, Table 7 shows the organization of precipitation data for station 82979, present in the city of Remanso. The sum of all monthly rainfall values for each year is also presented. From the table, it is possible to identify, that there are absences of records in a few months. For the years in which such absences occurred, the sum is not realized. It is thus indicated in the column "ANNUAL TOTAL" by the term "No data".

Table 7 – Organization of data for station 82979

DADOS DE PRECIPITAÇÃO MENSAL (mm) - REMANSO (EST-82979)													TOTAL ANUAL
	JANEIRO	*FEVEREIRO*	*MARÇO*	*ABRIL*	*MAIO*	*JUNHO*	*JULHO*	*AGOSTO*	*SETEMBRO*	*OUTUBRO*	*NOVEMBRO*	*DEZEMBRO*	mm
1980	138,1	292,3	11,1	52	0	0	0,5	0	0	1,7	79,5	179,4	754,6
1981	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1982	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1983	135,7	113,8	34,5	5,2	0	0,5	0,3	0	0	0,8	202,7	89,1	582,6
1984	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1985	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1986	26,5	198,8	190,6	87	4,4	null	0	24	null	28,3	null	94,4	Ausência de dado
1987	73,9	88,4	203,3	1	33,1	0	0,4	0	4	1,8	57,2	90,5	553,6
1988	109	37,3	173,4	105,4	0,2	3,2	null	0	0	48,4	18,4	180,2	Ausência de dado
1989	67,3	43,8	127,4	null	null	null	null	null	null	null	null	null	Ausência de dado
1990	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1991	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1992	337,2	122,4	2,2	51,8	8	0,4	1,4	0	0	0	152,4	54,6	730,4
1993	44,2	2,4	2	null	0	0,2	0	0	null	37,6	10	26,7	Ausência de dado
1994	248,9	175,3	126,5	44,8	0	0	7,4	0	null	0	3,6	93,3	Ausência de dado
1995	128,3	267,6	86,2	70,4	6,1	0	0	1,2	0	26,8	70,2	94	750,8
1996	3,1	48	258,7	81	18,8	0	0	0,2	0	0	208,4	null	Ausência de dado
1997	196,6	29,8	357,9	103,4	10,2	0	0	0	0	25,7	39,3	46,3	809,2
1998	235,1	16,2	27,3	0	8,6	0,2	0	0	0	0	124,6	98	510
1999	60,4	128	155,8	0,2	0,2	0	0,2	0,4	28,8	9,7	94,2	131,3	609,2
	JANEIRO	*FEVEREIRO*	*MARÇO*	*ABRIL*	*MAIO*	*JUNHO*	*JULHO*	*AGOSTO*	*SETEMBRO*	*OUTUBRO*	*NOVEMBRO*	*DEZEMBRO*	TOTAL ANUAL
2000	157,2	210,6	126,4	30	0,2	0,8	0	0	0,6	0	287,2	215,7	1028,7
2001	29,1	85,4	83,4	1	4,2	1,9	0,6	0	0	0,8	53,3	75,9	335,6
2002	283,2	17,2	17,6	5,8	6,4	2,8	0	0	6,9	0	35,7	141,8	517,4
2003	105,5	14,5	202,4	1,8	8	0,2	0,2	0	0,2	0	100,3	1,2	434,3
2004	350,2	159,3	70,6	0	0	1,6	0,4	0	0	40,2	71	29,9	723,2
2005	189,7	100,7	89,5	49,9	50,2	8,3	0,2	0	0	1	34	75,6	599,1
2006	0	140,7	111,6	75,3	0,6	3	0,6	0	3,8	42,2	69,4	12,9	460,1
2007	38	283,2	0,1	47,7	5,4	0	0,3	0	0	0	83,7	139,3	597,7
2008	26,6	213,9	150,8	231	2,4	0,3	0	0	0	0	34,6	46,4	706
2009	274,9	115,2	168,4	185,3	31,2	2,7	0	0	0	156,7	0	49,6	984
2010	115,2	44,9	148,7	104,1	0	17,7	3,1	0	0	28,9	5,9	170,7	639,2
2011	33,7	93,7	280,5	23,6	3,2	1,4	0	0,8	0	72,4	72,9	20,9	603,1
2012	8,2	79,3	15,6	0	0	0	0	0	0	0	106,4	16,1	225,6
2013	47,4	0	78,3	87,1	0	0	1,6	0	0	9,8	68,7	219,9	512,8
2014	0	68,2	75,4	173,7	0,4	0	3,2	3,6	0	0	61,8	151	537,3
2015	1,3	37,5	26,2	81,4	0,5	0,1	1,8	0	0	0,8	12,1	0	161,7
2016	398,5	45	7,3	0	10	0	0	0	13,5	12,1	105,9	9,8	602,1
2017	8	85,7	83,6	74,2	3,7	4,7	0	0	0	0	19	22,1	301
2018	27,9	197,1	258,7	23,6	0	0	0	0	0	24,3	1,8	94,4	627,8
2019	0	95,3	106,8	40,9	0,7	0	0	0	0	0	9,2	16,9	269,8

Source - Own elaboration

In the example of station 82979, 12 years had no precipitation records. Therefore, IAC is calculated only for 28 years belonging to the series from 1980 to 2019. The anomaly indices for these 28 years are indicated in table 8 in the "IAC" column.

Table 8 – Results of IAC values, for 28 years, at station 82979.

CÁLCULO DO ÍNDICE DE ANOMALIA DE CHUVAS (IAC)						
TOTAL ANUAL	MÉDIA ANUAL	ANOMALIA	ORDENAÇÃO	*MÉDIA		
mm	mm	$N - \bar{N}$	Decrescente	*10 Maiores	IAC	ANOS
754,6		177,2	1028,7		2,69	1980
Ausência de dado		Vazio	984			1981
Ausência de dado		Vazio	809,2			1982
582,6		5,2	754,6		0,08	1983
Ausência de dado		Vazio	750,8			1984
Ausência de dado		Vazio	730,4			1985
Ausência de dado		Vazio	723,2			1986
553,6		-23,8	706		-0,35	1987
Ausência de dado		Vazio	639,2			1988
Ausência de dado	577,4	Vazio	627,8	775,4		1989
Ausência de dado		Vazio	609,2			1990
Ausência de dado		Vazio	603,1			1991
730,4		153,0	602,1		2,32	1992
Ausência de dado		Vazio	599,1			1993
Ausência de dado		Vazio	597,7			1994
750,8		173,4	582,6		2,63	1995
Ausência de dado		Vazio	553,6			1996
809,2		231,8	537,3		3,51	1997
510		-67,4	517,4		-0,99	1998
609,2		31,8	512,8		0,48	1999
TOTAL ANUAL	MÉDIA ANUAL	ANOMALIA	510	*10 Menores	-	ANOS
1028,7		451,3	460,1		6,84	2000
335,6		-241,8	434,3		-3,55	2001
517,4		-60,0	335,6		-0,88	2002
434,3		-143,1	301		-2,10	2003
723,2		145,8	269,8		2,21	2004
599,1		21,7	225,6		0,33	2005
460,1		-117,3	161,7		-1,72	2006
597,7		20,3			0,31	2007
706		128,6			1,95	2008
984	577,4	406,6		372,8	6,16	2009
639,2		61,8			0,94	2010
603,1		25,7			0,39	2011
225,6		-351,8			-5,16	2012
512,8		-64,6			-0,95	2013
537,3		-40,1			-0,59	2014
161,7		-415,7			-6,10	2015
602,1		24,7			0,37	2016
301		-276,4			-4,05	2017
627,8		50,4			0,76	2018
269,8		-307,6			-4,51	2019

Source - Own elaboration

The calculations were performed based on equations (1) and (2) previously addressed in the methodology. For visualization, Table 9 *shows the* formula used in the worksheet.

Table 9 – Description of the formula used in the spreadsheet for the calculation of HAI.

CÁLCULO DO ÍNDICE DE ANOMALIA DE CHUVAS (IAC)						
TOTAL ANUAL	MÉDIA ANUAL	ANOMALIA	ORDENAÇÃO	*MÉDIA		
mm	mm	$N - \bar{N}$	Decre			
754,6		177,2	10			
Ausência de dado		Vazio	9			
Ausência de dado		Vazio	80			
582,6		5,2	754			
Ausência de dado		Vazio	750,8			1984
Ausência de dado		Vazio	730,4			1985
Ausência de dado		Vazio	723,2			1986
553,6		-23,8	706		-0,35	1987
Ausência de dado		Vazio	639,2			1988
Ausência de dado		Vazio	627,8			1989
Ausência de dado	577,4	Vazio	609,2	775,4		1990
Ausência de dado		Vazio	603,1			1991
730,4		153,0	602,1		2,32	1992
Ausência de dado		Vazio	599,1			1993
Ausência de dado		Vazio	597,7			1994
750,8		173,4	582,6		2,63	1995
Ausência de dado		Vazio	553,6			1996
809,2		231,8	537,3		3,51	1997
510		-67,4	517,4		-0,99	1998
609,2		31,8	512,8		0,48	1999
TOTAL ANUAL	MÉDIA ANUAL	ANOMALIA	510	*10 Menores	-	ANOS
1028,7		451,3	460,1		6,84	2000
335,6		-241,8	434,3		-3,55	2001
517,4		-60,0	335,6		-0,88	2002
434,3		-143,1	301		-2,10	2003
723,2		145,8	269,8		2,21	2004
599,1		21,7	225,6		0,33	2005
460,1		-117,3	161,7		-1,72	2006
597,7		20,3			0,31	2007
706		128,6			1,95	2008
984		406,6			6,16	2009
639,2	577,4	61,8		372,8	0,94	2010
603,1		25,7			0,39	2011
225,6		-351,8			-5,16	2012
512,8		-64,6			-0,95	2013
537,3		-40,1			-0,59	2014
161,7		-415,7			-6,10	2015
602,1		24,7			0,37	2016
301		-276,4			-4,05	2017
627,8		50,4			0,76	2018
269,8		-307,6			-4,51	2019

=SE(E(P4>0;P4<>"Vazio");3*(P4/(R4-O4));-3*(P4/(R25-O4)))

SE(teste_lógico; **[valor_se_verdadeiro]**; [valor_se_falso])

Source - Own elaboration

Following the same pattern used in station 82979, the data organization and rainfall anomaly indexes (HAI) calculations were performed for each of the 26 stations, which returned data for the entire predetermined historical series. Among them, station 83549, referring to the municipality of Mucuri, and station 83347, referring to the municipality of Itabuna, presented absences of registration for all months of the series, according to Tables 10 and 1 1, respectively.

Table 10 – Data from station 83549 in the municipality Mucuri.

DADOS DE PRECIPITAÇÃO MENSAL (mm) - MUCURI (EST-83549)													TOTAL ANUAL
	JANEIRO	FEVEREIRO	MARÇO	ABRIL	MAIO	JUNHO	JULHO	AGOSTO	SETEMBRO	OUTUBRO	NOVEMBRO	DEZEMBRO	
1980	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1981	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1982	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1983	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1984	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1985	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1986	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1987	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1988	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1989	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1990	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1991	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1992	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1993	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1994	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1995	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1996	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1997	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1998	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1999	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
	JANEIRO	FEVEREIRO	MARÇO	ABRIL	MAIO	JUNHO	JULHO	AGOSTO	SETEMBRO	OUTUBRO	NOVEMBRO	DEZEMBRO	TOTAL ANUAL
2000	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2001	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2002	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2003	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2004	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2005	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2006	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2007	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2008	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2009	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2010	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2011	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2012	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2013	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2014	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2015	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2016	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2017	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2018	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2019	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado

Source - Own elaboration

Table 11 – Data from station 83347 in the municipality of Itabuna.

DADOS DE PRECIPITAÇÃO MENSAL (mm) - ITABUNA (EST-83347)													TOTAL ANUAL
	JANEIRO	FEVEREIRO	MARÇO	ABRIL	MAIO	JUNHO	JULHO	AGOSTO	SETEMBRO	OUTUBRO	NOVEMBRO	DEZEMBRO	
1980	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1981	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1982	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1983	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1984	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1985	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1986	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1987	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1988	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1989	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1990	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1991	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1992	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1993	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1994	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1995	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1996	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1997	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1998	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
1999	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
	JANEIRO	FEVEREIRO	MARÇO	ABRIL	MAIO	JUNHO	JULHO	AGOSTO	SETEMBRO	OUTUBRO	NOVEMBRO	DEZEMBRO	TOTAL ANUAL
2000	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2001	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2002	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2003	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2004	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2005	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2006	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2007	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2008	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2009	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2010	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2011	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2012	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2013	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2014	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2015	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2016	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2017	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2018	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado
2019	null	null	null	null	null	null	null	null	null	null	null	null	Ausência de dado

Source - Own elaboration

In the cases of the stations in Mucuri and Itabuna it was not possible to determine the IAC for any of the years of the series.

3.1 OBTAINING THE ANNUAL VALUES OF RAINFALL ANOMALY INDEX (HAI)

Table 12 shows the results of the Rainfall Anomaly indices calculated for the 24 stations, identified in the 2nd row of the table by their respective codes. The IAC values are presented according to the years, which are exposed in the 1st column on the left.

Table 12 - Results of the Rain Anomaly Indices

VALORES DE IAC CALCULADOS																								
	82979	83182	83179	83184	83186	83190	83076	83192	83221	83222	83229	83236	83242	83249	83286	83288	83398	83446	83498	83292	83344	83408	83090	83295
1980	2,69	3,83	5,14	3,77	3,18	4,97	6,06	2,49		0,62	1,11	3,60	4,84	1,26	6,43	1,79	2,25	4,72	0,99	2,26	2,81	2,49	1,29	8,07
1981																								
1982																								
1983	0,08	0,67	-1,65	-0,69		-1,07	-0,30	-2,10		-5,19	-1,79	4,42	0,20	-0,16			-0,49	2,87		1,00	0,84	3,65	-3,37	-0,98
1984																								
1985																								
1986																								
1987	-0,35	0,66	-1,50	0,58	-0,42	-2,94	-1,30	-3,05		-4,60	-2,90	0,78	-0,21	-2,07	0,24	-0,41	-2,23	-1,86	-3,63	-2,36	0,87	-0,31	0,76	-3,74
1988																								
1989																								
1990																								
1991		0,19		-0,11							-0,39													
1992	2,32										-1,88	6,22	-0,48	1,05		5,27								
1993		-3,97	-5,60		-6,50	-6,89		-5,85		-6,22	-4,72		-7,75	-4,49	-4,63	-3,86	-4,19	-2,41	-1,30		-4,22	-6,46	-5,00	-5,55
1994		-0,66	-0,68	-0,32	-0,78			-3,79			3,63	0,30	-2,29	-2,60	-1,97	0,05	-2,16	-1,59	2,03		-0,39	-0,38	-1,68	-1,87
1995	2,63	1,23	3,08	2,03	0,37	0,92	1,79	0,34		-0,29	-1,02	2,42	0,24	-2,39	5,19	3,57	-1,73	2,11	4,62		1,52	2,32	0,03	0,11
1996		-4,47	0,36	-2,68	3,80	-1,36	-0,27	-3,27		4,60	3,64	-3,73	-2,91	2,07	-5,60	-3,01	-3,50	-3,81	-2,69		-4,59	-0,64		-3,12
1997	3,51	3,97	3,88	9,32	11,56	5,16	4,21	4,55		1,90	-1,10	1,97	6,23	0,77	1,66	0,89	1,80		-3,69		4,07	0,16	4,57	
1998	-0,99	2,82	0,43	-2,25	-2,66	-0,56	0,93	-1,85		-0,08	-0,10	-1,02	-1,70	-3,87	-0,74	1,41	-2,39	-0,53	-1,64		-0,39	3,72	-1,78	-1,97
1999	0,48	1,34	0,22	0,71	0,56	1,71	1,90	-0,07	5,42	4,23	6,56	2,75	3,18	5,72	5,75	3,19	4,68	1,52	3,06		1,82	0,57	0,92	
2000	6,84	5,95	4,00	4,87	2,57	4,53	4,96	6,39	5,00	3,32	0,80	2,40	1,81	5,75		4,64	0,54	2,55	4,80	4,46	4,03	-0,48	4,04	4,03
2001	-3,55	-4,01	-1,74	-3,18	-2,50	1,69	0,00	-0,14	-1,73	2,70	-0,20	-2,59	-0,93	1,48	-1,33	-1,69		0,68	1,89	-4,36	-2,51	-2,50	-1,86	-1,48
2002	-0,88	1,65	3,09	-0,23	2,59	2,67	-6,18	-0,44	-1,04	1,25	0,17	-0,43	1,47	-0,70	-1,59	1,95	0,02	3,27	-0,16	4,24	2,34	0,89	-0,31	1,04
2003	-2,10	-2,13	-3,07	-3,48	-1,60	0,03	-3,30	-0,07		0,29	1,59	-2,11	-2,11	2,22	-1,98	-2,10	-3,79	-3,80	-3,48		-4,30	-3,13	-0,36	
2004	2,21	-0,14	0,80	0,96	0,28	0,57	-1,71	0,13	2,52	3,57	1,63	2,09	2,11	-0,67	2,51	3,79	-3,43	1,10	4,16	2,23	6,36	0,96	2,22	3,86
2005	0,33	2,87	1,27	0,50	0,71	1,86	-1,97	-0,47	2,79	3,05	3,95	-0,25	3,80	3,55		2,66	4,58	4,32	4,72	-2,21	0,23	4,81	6,17	3,53
2006	-1,72	2,72	3,20	1,83	2,94	1,11	0,20	1,54	0,95	-0,55	3,87	0,84	3,73	2,52	-0,41	-1,28	-1,11	3,05	1,63	4,58	2,63	-0,71	3,33	3,28
2007	0,31	-2,12	-2,20	2,10	-1,29	-0,01	-0,32	-0,49	2,32	-1,54	-4,00	-3,39	0,89	-1,76	-1,99	-1,11	0,88	-0,38	-1,17	3,54	1,08	-0,12	-0,01	3,16
2008	1,95	0,00	1,43	-2,51	-2,41	-2,03	1,64	1,04	3,02	-0,87	-3,78	2,00	-0,70	1,36	0,92	0,99	-2,30	-4,03	0,46	1,18	-0,94	-0,63	0,43	-1,00
2009	6,16	2,11	2,73	1,28	-1,84	-1,48	-0,19	-1,16	-2,84	-3,06	0,84		1,46	-0,73	1,34	1,72	0,32	1,92	-1,53	0,58	2,22	3,91	0,53	-1,44
2010	0,94	2,72	1,00	3,14	0,47	5,39	-1,67	6,20	4,64	0,70	0,89		-1,30	2,68		-0,24	0,69	-0,31	1,50	2,01	2,21	0,44	6,07	1,60
2011	0,39	-1,08	2,17	-2,96	-1,25	-1,93	2,43	-0,66	2,91	3,06	2,75	2,14	-0,57	2,30		1,23	1,90	3,27	-0,38	-0,53	-1,80	3,86	-0,49	0,02
2012	-5,16	-3,21	-5,15	-4,00	-5,73	-7,16	-4,46	-6,03	-8,62	-5,39	-4,48	-4,66	-4,25	-5,94	-0,89	-3,58	-0,80	-3,06	0,21	-5,22	-3,03	-2,61	-6,31	-8,84
2013	-0,95	0,35	1,11	-1,07	-0,39	-0,51	2,50	1,99	0,44	2,02	1,25	0,76	-0,50	1,27	2,06	-0,02	8,33	1,91	1,58	-1,63	-1,39	0,81	0,62	-0,76
2014	-0,59	-2,33	-3,32	0,03	-1,68	-2,40	-3,08	3,11	-0,31	-0,13	-2,11	-1,72	-0,53	-0,36	-3,65	-2,38	1,38	-1,36	-0,62	1,97	-0,74		-1,05	0,98
2015	-6,10	-3,65	-5,09	-3,81	-0,58	-1,92	-2,85	1,46	-2,77	-0,15	0,64	-3,79	-2,56	-0,01		-4,55	-1,96	-5,30	-6,43	-4,57	-3,27	-5,70	0,53	0,46
2016	0,37	-0,88	-0,41	0,26	-1,45	0,24	3,57	-0,70	-4,45	-2,30	-4,31	0,61	0,44	-2,33		-2,08		0,59	-4,43	2,47	-1,25	3,39	-1,94	
2017	-4,05	-2,52		-3,71	-3,64		-0,92	1,23	-8,48	0,90	-2,19	-3,77	-3,03	-1,66	-4,64	-3,35	0,40	-0,90	1,28	-3,69	-0,14	-4,79	-3,15	
2018	0,76	-1,59		-0,13	1,62		-1,17	-2,20	-0,20	1,56	-2,76	-1,39	1,37	-2,89	3,90	-0,66	3,52	-0,33	0,70	2,25	0,44	0,36	-3,85	
2019	-4,51	-1,58		-1,43	0,16	-1,89	-3,46	0,01		-0,27	0,70	-2,85	-2,10	1,71	-2,61	-3,40	-4,04	-2,78		-5,98	-3,64	-2,85	-0,13	

Source: Own elaboration

In the first ten years belonging to the historical series, 1980 to 1989, a higher frequency was identified in the absence of results for HAI, this was verified, because it is in this period, in which there were no precipitation records, and it is not possible to determine HAI in these cases.

In total, 671 Rain Anomaly Indices were determined, of which 333 are positive results, which indicate wetter periods. Already 338 are indices, whose negative values express occurrences of drier periods.

Among the results, the highest HAI determined was 11.56 for the year 1997 with rainfall data from station 83186 in the city of Jacobina. While the lowest result of IAC was -8.84 in the year 2012 with data from station 83295 in Itiruçu.

3.2 GRAPHICAL AND ANALYTICAL STUDY, FOR EACH SEASON, OF THE BEHAVIOR OF THE IAC OVER TIME

The results presented in Table 12 were organized in graphs that describe the variation of rainfall anomaly indices (HAI) in the period from 1980 to 2019. In total, 24 graphs have been elaborated (Figures 1 to 24), each referring to the study with data from a rainfall station. The graphs show the respective station codes.

Figure 1 – Graphic study of the IAC determined with data from station 82979 in Remanso - BA

Source: Own elaboration

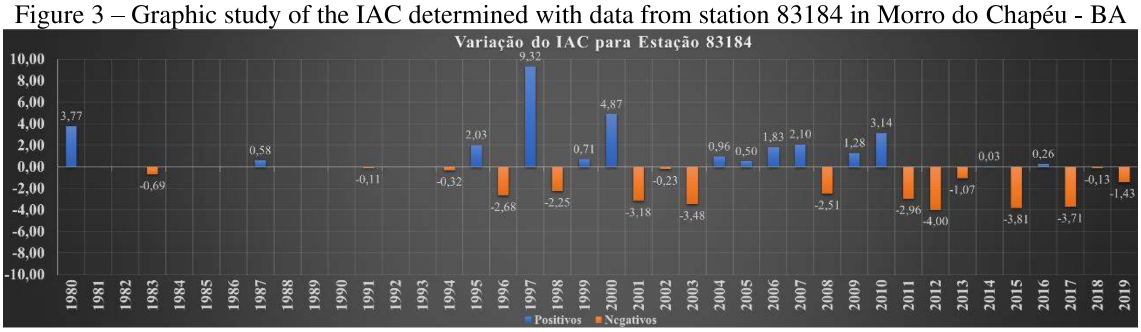
Figure 2 – Graphic study of the IAC determined with data from station 83182 in Irecê - BA

Source: Own elaboration

Figure 2 – Graphic study of the IAC determined with data from station 83179 in Barra - BA

Source: Own elaboration

Figure 3 – Graphic study of the IAC determined with data from station 83184 in Morro do Chapéu - BA



Source: Own elaboration

Figure 4 – Graphic study of the IAC determined with data from station 83186 in Jacobina - BA

Source: Own elaboration

Figure 5 – Graphic study of the IAC determined with data from station 83190 in Serrinha - BA

Source: Own elaboration

Figure 6 – Graphic study of the IAC determined with data from station 83076 in Sta. Rita de Cássia - BA

Source: Own elaboration

Figure 7 – Graphic study of the IAC determined with data from station 83192 in Cipó - BA

Source: Own elaboration

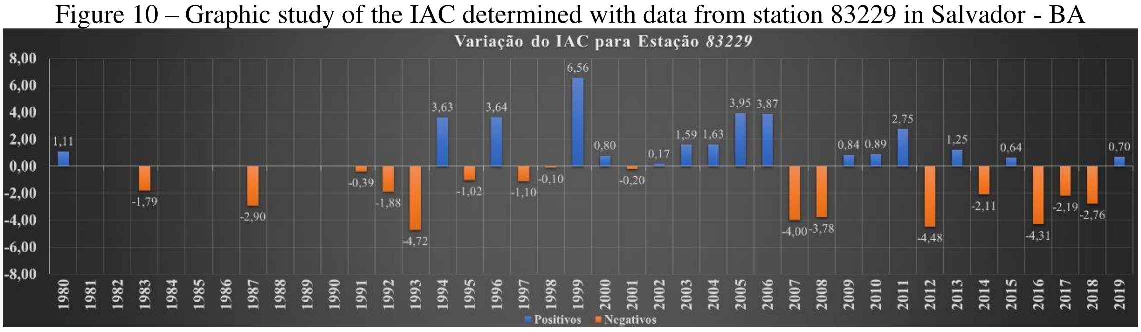
Figure 8 – Graphic study of the IAC determined with data from station 83221 in Feira de Santana - BA

Source: Own elaboration

Figure 9 – Graphic study of the IAC determined with data from station 83222 in Cruz das Almas - BA

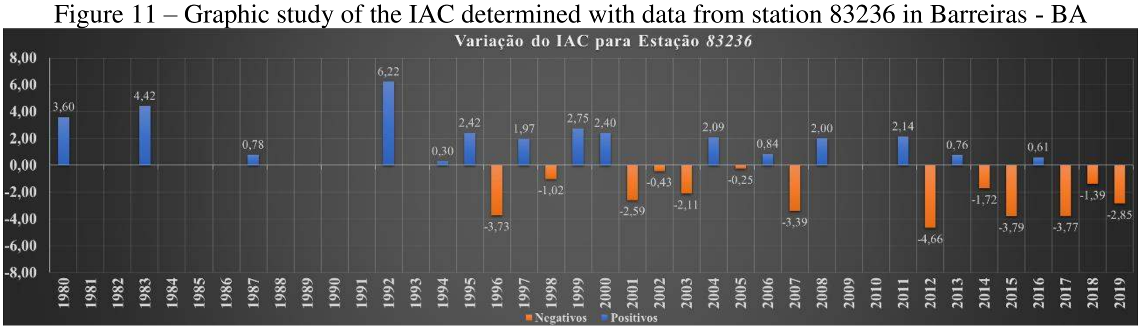
Source: Own elaboration

Figure 10 – Graphic study of the IAC determined with data from station 83229 in Salvador - BA



Source: Own elaboration

Figure 11 – Graphic study of the IAC determined with data from station 83236 in Barreiras - BA

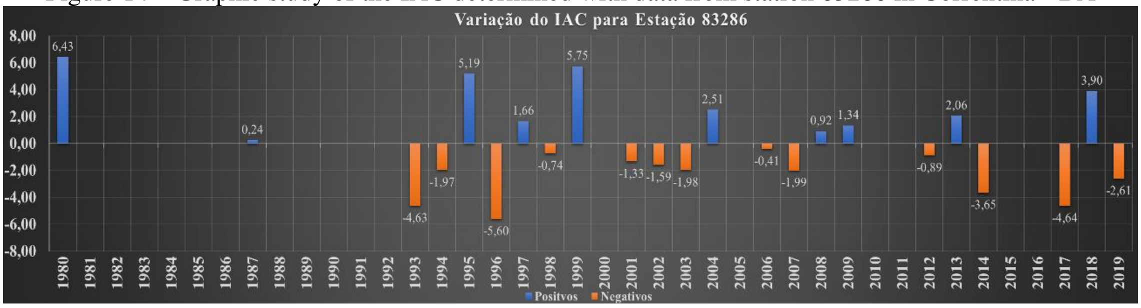


Source: Own elaboration

Figure 13 – Graphic study of the IAC determined with data from station 83242 in Lençois - BA

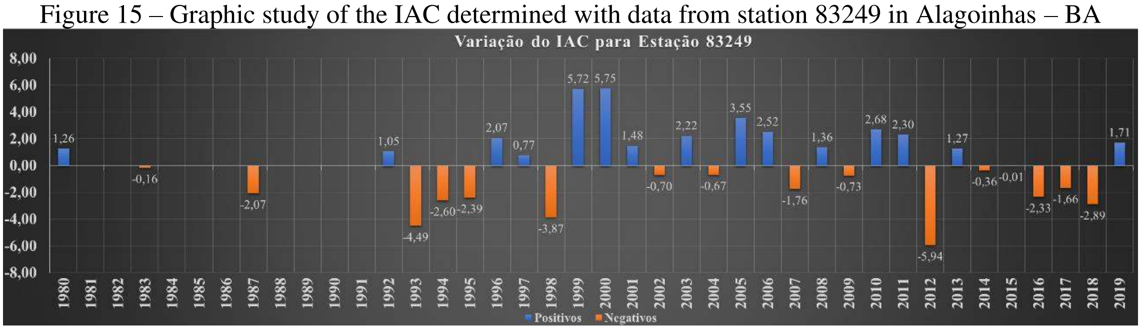
Source: Own elaboration

Figure 14 – Graphic study of the IAC determined with data from station 83286 in Correntina - BA



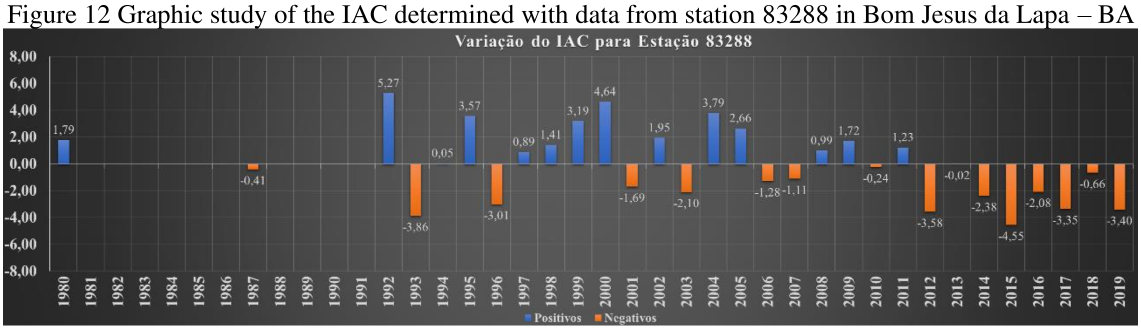
Source: Own elaboration

Figure 15 – Graphic study of the IAC determined with data from station 83249 in Alagoinhas – BA



Source: Own elaboration

Figure 12 Graphic study of the IAC determined with data from station 83288 in Bom Jesus da Lapa – BA

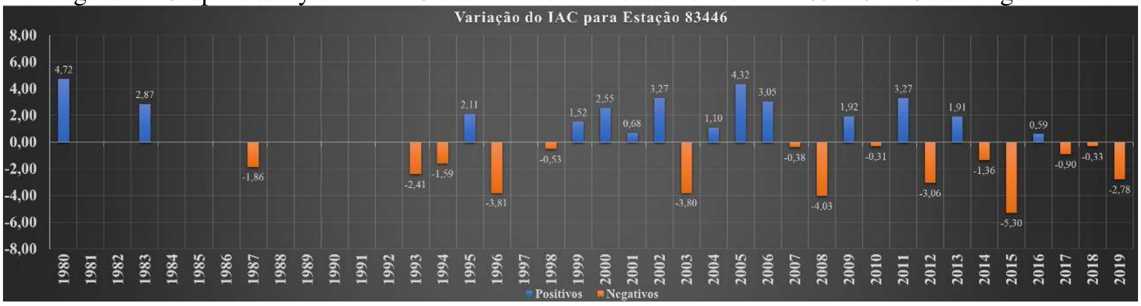


Source: Own elaboration

Figure 13 Graphic study of the IAC determined with data from station 83398 in Canavieiras – BA

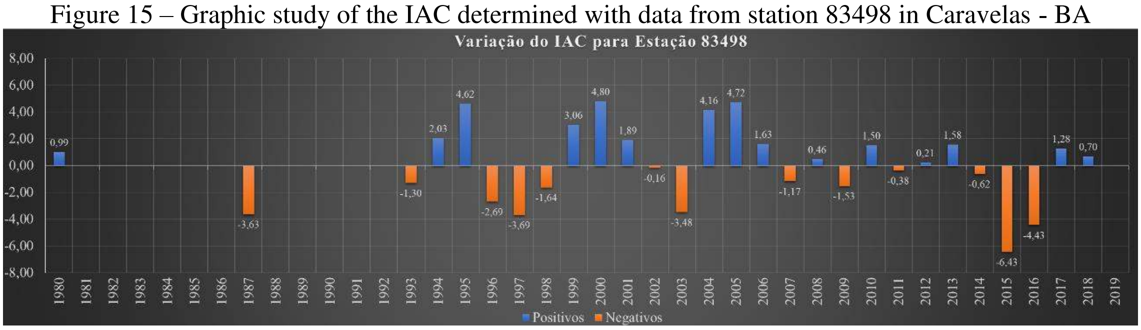
Source: Own elaboration

Figure 14 Graphic study of the IAC determined with data from station 83446 in Guaratinga – BA



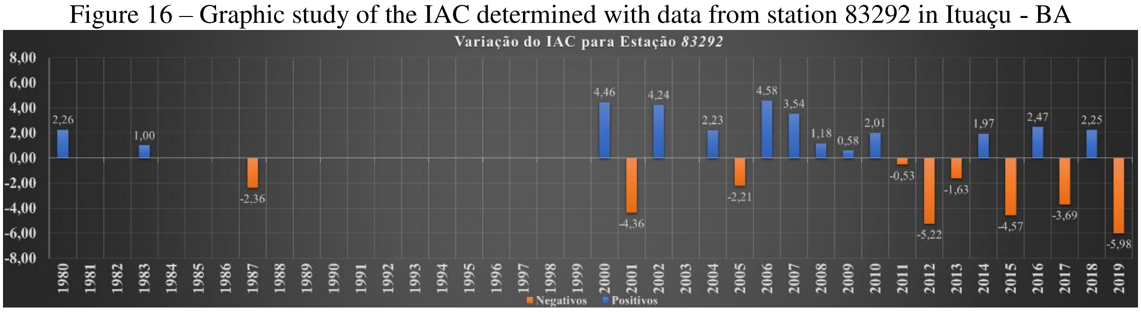
Source: Own elaboration

Figure 15 – Graphic study of the IAC determined with data from station 83498 in Caravelas - BA



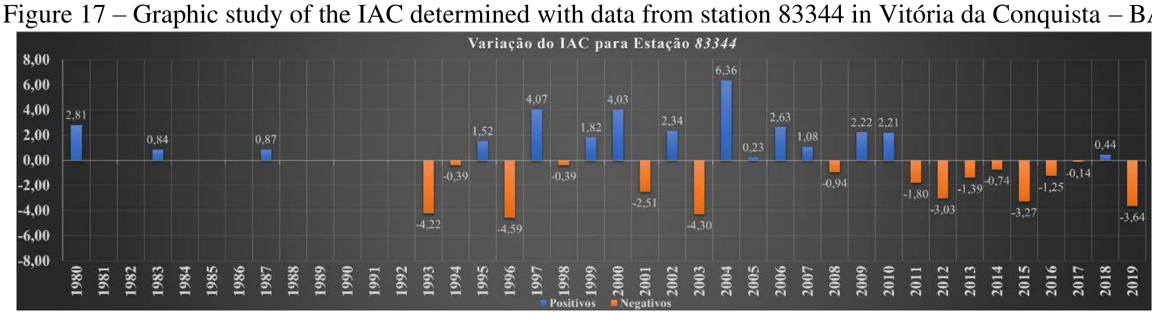
Source: Own elaboration

Figure 16 – Graphic study of the IAC determined with data from station 83292 in Ituaçu - BA



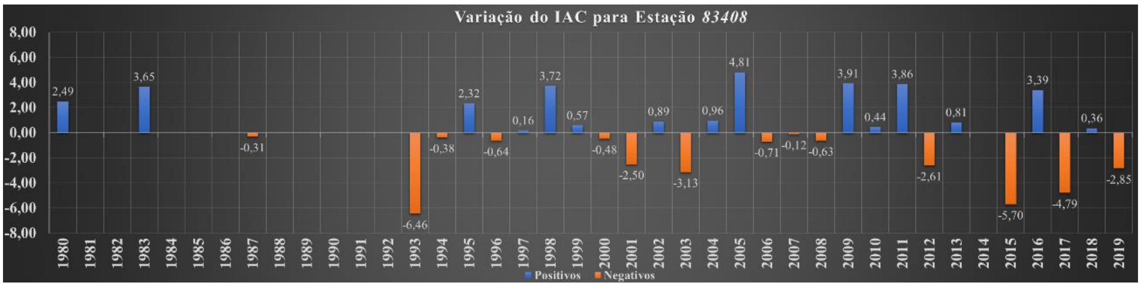
Source: Own elaboration

Figure 17 – Graphic study of the IAC determined with data from station 83344 in Vitória da Conquista – BA



Source: Own elaboration

Figure 18 – Graphic study of the IAC determined with data from station 83408 in Carinhanha - BA

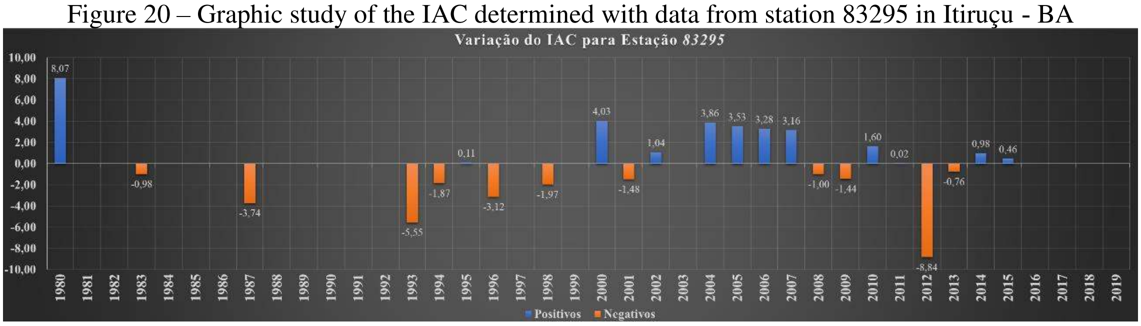


Source: Own elaboration

Figure 19 – Graphic study of the IAC determined with data from station 83190 in Serrinha - BA

Source: Own elaboration

Figure 20 – Graphic study of the IAC determined with data from station 83295 in Itiruçu - BA



Source: Own elaboration

3.3 CALCULATION OF THE AVERAGE IAC OF THE SEASONS FOR EACH YEAR

For each year belonging to the historical series, IAC results were obtained in different seasons. From these annual results, the average IAC for that year was determined based on up to 24 IAC data, corresponding to the 24 stations. Table 13 shows the average annual HAI. In the years, in which for no season it was possible to determine the Rain Anomaly Index, the average annual IAC was not obtained.

Table 13 – Results of average annual HAIs

Year	Average IAC	Standard deviation	No IAC data
1980	3,33	1,95	23
1981	-	-	0
1982	-	-	0
1983	-0,21	2,28	19
1984	-	-	0
1985	-	-	0
1986	-	-	0
1987	-1,30	1,67	23
1988	-	-	0
1989	-	-	0
1990	-	-	0
1991	-0,10	0,29	3
1992	2,09	3,18	6
1993	-4,98	1,59	18
1994	-0,84	1,72	18
1995	1,32	1,91	22
1996	-1,56	3,01	20
1997	3,27	3,41	20
1998	-0,69	1,78	22
1999	2,56	2,04	22
2000	3,82	1,89	23
2001	-1,21	1,94	23
2002	0,61	2,13	24
2003	-1,85	1,82	21
2004	1,59	2,06	24
2005	2,21	2,27	23
2006	1,59	1,84	24
2007	-0,32	1,91	24
2008	-0,20	1,90	24
2009	0,56	2,19	23
2010	1,81	2,19	22
2011	0,73	1,96	23
2012	-4,52	2,23	24
2013	0,82	2,00	24
2014	-0,91	1,69	23
2015	-2,69	2,39	23
2016	-0,69	2,27	21
2017	-2,42	2,39	21
2018	-0,03	2,04	21
2019	-2,05	1,95	20

Source - Own elaboration

3.4 CALCULATION OF THE AVERAGE IAC OF EACH STATION OVER THE 40 YEARS OF MONITORING

With the available rainfall data, it was possible to determine up to 40 IAC results for each season, these being relative to the 40 years belonging to the historical series, 1980 to 2019. From these results, the average IAC for the respective station was determined. Table 14 shows the Mean Anomaly Indices.

Table 14 - Results of Average HAIs for each season

Station code	Average IAC	Standard deviation	Number of IAC data
82979	0,04	3,05	28
83182	-0,04	2,66	31
83179	0,13	2,93	27
83184	-0,04	2,92	30
83186	-0,13	3,31	29
83190	-0,05	3,12	27
83076	-0,11	2,90	28
83192	-0,06	2,92	30
83221	-0,02	4,08	19
83222	0,11	2,90	29
83229	-0,11	2,81	32
83236	0,06	2,79	28
83242	-0,07	2,82	31
83249	0,10	2,75	31
83286	-0,09	3,33	23
83288	-0,02	2,69	30
83398	-0,10	2,99	28
83446	0,05	2,73	29
83498	0,09	2,90	28
83292	0,10	3,33	22
83344	0,03	2,74	30
83408	0,04	2,91	29
83090	0,01	2,98	29
83295	-0,03	3,57	23

Source - Own elaboration

3.5 CALCULATION OF THE ACCUMULATED IAC OF THE STATIONS OVER THE 40 YEARS OF MONITORING

The IAC represents a deviation from the average annual rainfall, so the average of the indices for each season approached 0. In such a way, that it was verified the relevance of the analysis of the accumulated HAIs to proceed with the classification of the period covered, following the classification established by Araújo (2009), in adaptation to the works of Freitas (2004). The results of these accumulated indices are shown in Table 15.

Table 15 – Cumulative IAC corresponding to the rainfall season

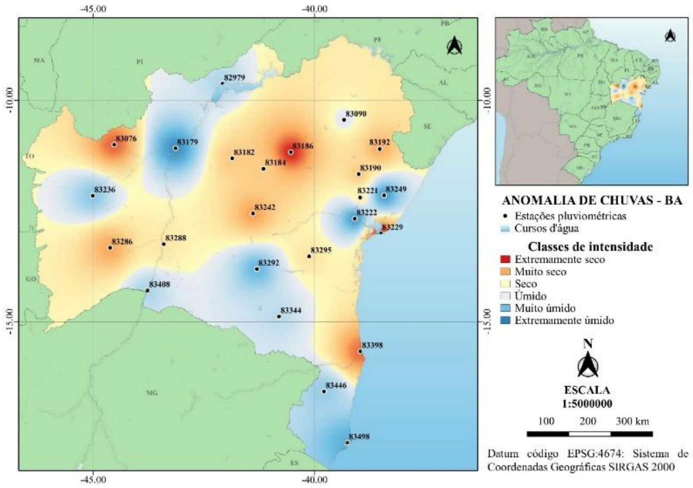
Station code	Cumulative IAC	Intensity class
82979	1,02	Wet
83182	-1,25	Dry
83179	3,51	Very Wet
83184	-1,17	Dry
83186	-3,91	Very Dry
83190	-1,29	Dry
83076	-2,96	Very Dry
83192	-1,86	Dry
83221	-0,44	Dry
83222	3,13	Very wet
83229	-3,67	Very Dry
83236	1,59	Wet
83242	-2,15	Very Dry
83249	3,07	Very Wet
83286	-2,04	Very Dry
83288	-0,56	Dry
83398	-2,85	Very Dry
83446	1,43	Wet
83498	2,49	Very Wet
83292	2,21	Very Wet
83344	0,85	Wet
83408	1,06	Wet
83090	0,21	Wet
83295	-0,62	Dry

Source - Own elaboration

3.6 GENERATION OF A SPATIAL DISTRIBUTION MAP OF THE ANOMALIES OBSERVED FOR EACH STATION

In possession of the anomaly indices accumulated throughout the historical series, for each of the 24 stations in the state of Bahia, we proceeded with the elaboration of the map of spatial distribution of the rainfall anomalies, explaining the identifications of thecorresponding intensity classes. Thus, the result is shown in Figure 25.

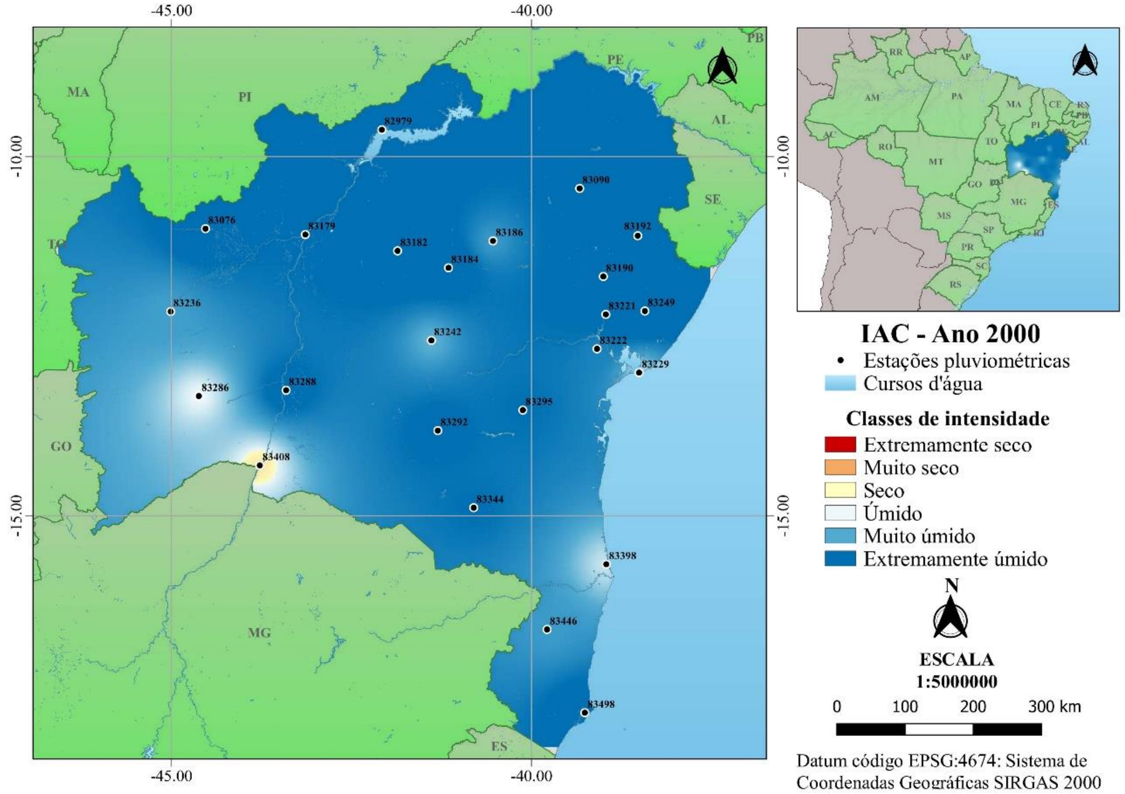
Figure 21 – Spatial distribution of Rainfall Anomalies in Bahia, related *to* the entire series from 1980 to 2019.



Source: Own elaboration

A spatial distribution map of rainfall anomalies was also elaborated for the year identified as the wettest of the entire historical series, this being the year 2000. The corresponding distribution is shown in Figure 26.

Figure 22 – Spatial distribution of rainfall anomalies in the year 2000.



Source: Own elaboration

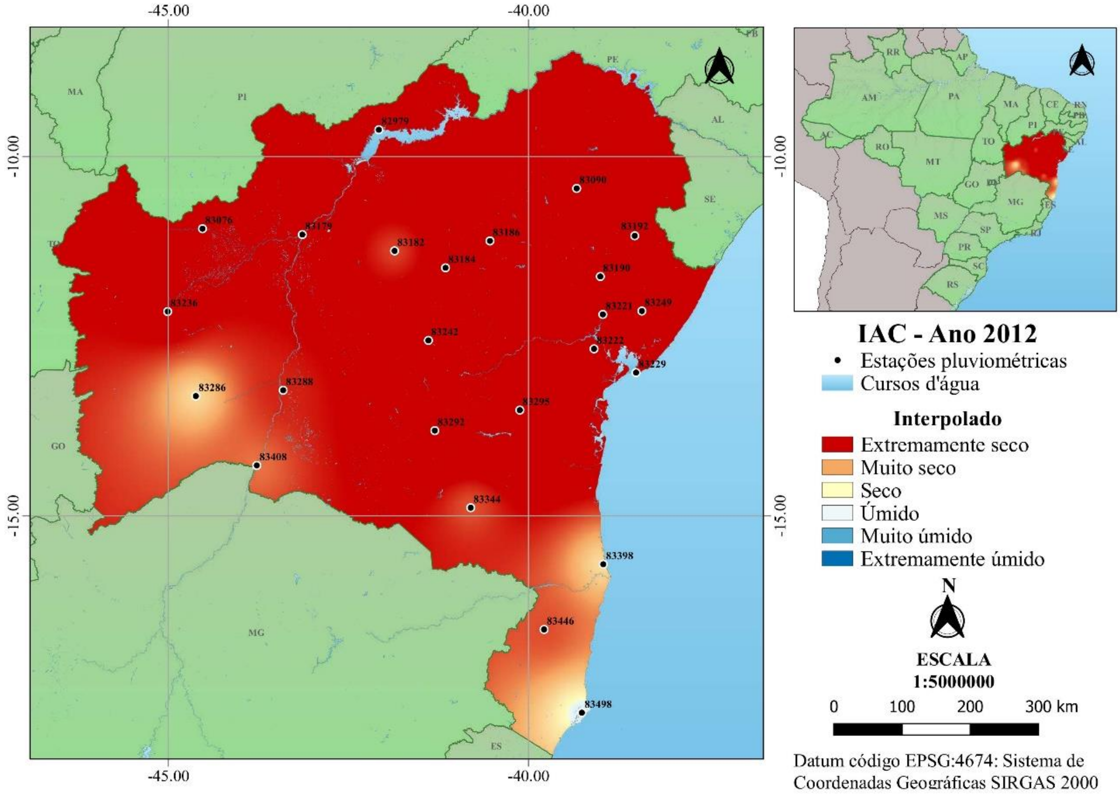
In the year 2000, with the exception of station 83408 in the municipality of Carinhanha, for which the anomaly determined was equal to -0.48 comprised in the "dry" class, in other 22 stations positive indices were obtained, which indicated the year 2000 as the wettest period of the entire historical series studied from 1980 to 2019.

The average IAC for this year was 3.82 ± 1.89 with 23 IAC results available. For station 83286 it was not possible to determine the IAC due to the absence of rainfall data.

The highest value of IAC determined for this year was equal to 6.84 with data from station 82979 in the municipality of Remanso, this result corresponds to the intensity class "Extremely humid". Among the 22 positive results, 15 are contained in the "Extremely Humid" class, 4 in "Very wet" and 3 belong to the "Humid" class.

As illustrated the distribution of rainfall anomalies, through the elaboration of the map, for the wettest year, it was also done for the second driest year of the series studied, this year 2012. The corresponding distribution is shown in Figure 27.

Figure 23 - Spatial distribution of Rain Anomalies in 2012.



Source: Own elaboration

In 2012, of the 24 indices calculated, there were 23 negative, and only 1 positive, among the negatives the most expressive was -8.84, relative to station 83295 in the municipality of Itiruçu. Still related to the 23 negative results, 16 are contained in the "Extremely Dry" class, 5 in "Very dry" and 2 belong to the "Dry" class.

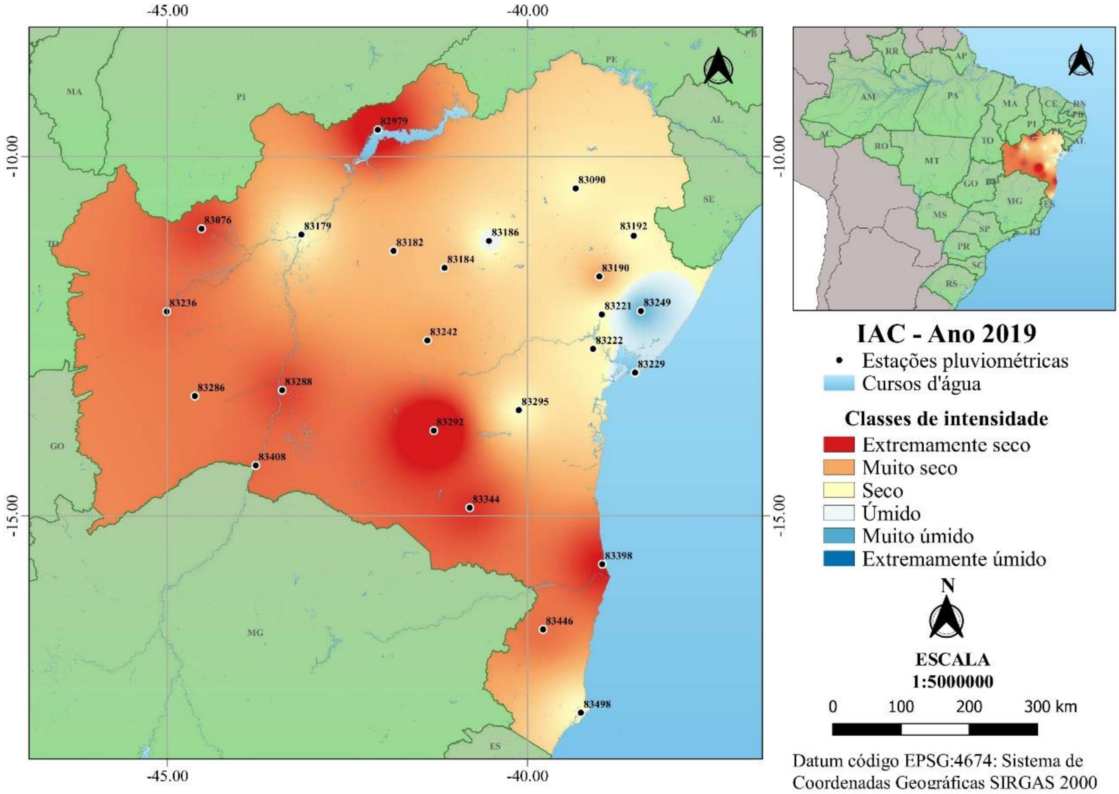
The average IAC for this year was -4.52 ± 2.2 3 with 24 IAC results available. This average IAC corresponds to the "Extremely dry" class.

As for the only positive rainfall anomaly result, this was equal to 0.21, and contained in the "Wet class" being determined with the data from station 83498 in the municipality of Caravelas.

The spatial distribution of rainfall anomalies in the last year belonging to the series studied, 2019, was also indicated on a map.

The result for the spatial distribution of rainfall anomalies in 2019 is shown in Figure 28.

Figure 24 - Spatial distribution of Rain Anomalies in the year 2019.



Source: Own elaboration

With the help of this distribution it was possible to identify that this was a predominantly dry period.

For the year 2019, 20 anomalies were determined, of which 16 are negative and 4 positive. Among the negatives, 3 in the "Extremely Dry" class, 8 in "Very Dry" and 5 identify the period as "Dry". Among those 4 positives, all are contained in the "Wet" class.

The average IAC for this year was -2.05 ± 1.95 with 20 IAC results available. For stations 83179, 83221, 83498 and 83295 it was not possible to determine the IAC due to lack of rainfall data.

4 CONCLUSIONS

As for spatiality, the24 stations that returned monthly rainfall data for the series from 1980 to 2019 are spatially distributed in such a way that it was possible to represent the rainfall anomalies in several regions throughout the state of Bahia.

Regarding temporality, it was found that, for the first 10 years of the historical series, that is: 1980 to 1989, there was a higher incidence of failures of precipitation records, implying the impossibility of determining the HAI in those years, this condition was repeated in several rainfall stations consulted. Thus, it is from 1990 onwards that the indices are determined with significant frequency. The graphic and analytical study contributed to the identification of this aspect.

The rainfall data obtained allowed the calculation of 671 annual values of rainfall anomaly indices (HAI), of which 338 are indices whose negative results express the decrease in rainfall in the respective localities and periods analyzed. On the other hand, the 333 indices with positive values indicate an increase in the occurrence of rainfall for the corresponding places and periods.

Although it presents a relative quantitative balance for positive and negative indices, the frequencies of occurrences of these are affected by temporality. Forexample, there is a higher frequency of positive anomalies predominantly recorded in the 1990s and 2000s, being scarcer in the 2010s.

As of 2010, in general, the driest periods are predominant, and in some cases, successive. For example, at station 83182 in Irecê, and at station 83288 in Bom Jesus da Lapa, the last 6 years of the series are all represented by negative anomalies. However, there are exceptions, such as station 83192 in Cipó and station 83398 in Canavieiras, where there are more expressive wet events even from 2010.

Thus, the spatial distribution of rainfall anomalies accumulated in the seasons, throughout the state of Bahia, helped in the verification that the rainfall trends are not uniform throughout the state territory. These trends can be better understood from local perspectives and aspects.

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