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(Review Article)

Highrographic basin of the high course rio Parnaiba - Brazil and the contribution of the decade rain

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Abstract

The objective is to carry out the climatological analysis of the decadal precipitation of the hydrographic basin of the upper course of the Paraiba River and the surrounding municipalities, using a historical rainfall series between the years 1962 to 2019, which can contribute to the decisions of sectors such as socioeconomic, agricultural, irrigation, energy production, water resources and agricultural technicians and decision makers in case of extreme events that may occur. A series of monthly and annual precipitation data collected by the Northeast Development Superintendence and provided by the Executive Water Management Agency of the State of Paraiba was used, despite the variability of the observed data, the series under study between the years was unified from 1962-2014. Local contributions and the Intertropical Convergence Zone acted more intensely in the northern sector and caused most of the rain above normal levels in some decades. The municipal pluviometry information, to the man in the field, can be used by the governmental actions in the planning of the distribution of the seeds and improvement of the production, being of relevant importance to minimize the eventual losses of the planting. Consequently, agroclimatic zoning will determine the best planting time, according to the mesoregion and the specific culture. The influences and actions of large-scale phenomena El Niño, La Niña for decades in studies in the form of adverse phenomena have had their contributions in isolated decades and have left water shortages in almost all reservoirs.

Keywords: Irrigation; Factors causing and/or inhibiting rainfall; Agricultural planning; Adverse phenomena

1. Introduction

Agricultural production in the Brazilian semiarid region is highly dependent on rainfall, and, therefore, its variations cause serious damage to the state's agriculture. Paraíba with remarkable climatic characteristics, in its temporal space irregularities that affect in its rain regime. These climatic conditions directly interfere in the production of food, making it necessary to increase the production and productivity of the cultures, but for this increase, technologies already adapted for each region are indispensable, as well as, research new technologies as proposed by the authors [19; 5]. According to [24; 25; 22] living with the semiarid requires sustainable environmental management measures, with social initiatives that result in improving the living conditions of the populations, being of vital importance for the planning and development of water resources management in this region and in the region. Identification and

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characterization of periods of drought and anomalous precipitation, in a feasible way and that identifies the regional climatic nuances.

Knowledge of the climatic conditions of a given region is necessary so that strategies can be established, aimed at the most appropriate management of natural resources, thus aiming at the search for sustainable development and the implementation of viable and safe agricultural practices for the various biomes the region [26. 12] Rainfall is one of the essential elements in agricultural activities, based on the volume of precipitated rain and its distribution, it is possible to determine the types of agricultural activities in a given location [2].

In the last decades, climate change and its consequences for humanity, has been one of the biggest concerns of scientists around the world. Especially with regard to the factors responsible for climatic variability, which have been increasing since the middle of the 20th century. In the view of some researchers, human activities are responsible for part of these changes. However, a possible natural climatic variability must be taken into account, since the magnitude of the signal associated with it in the existing climate records, has not yet been well determined [8; 7].

The study of the pluviometry of a given location is generally of interest to hydrology and meteorology, but the information generated in this regard is important in many areas of Engineering such as: Environmental, Forestry, Agronomy, Agricultural, Water resources, among so many applications and uses. Other expected problems are the reduction in rainfall, which may reach a range of 60% of monthly values, with this the water storage reservoirs will become obsolete, further restricting drinking water for human, animal and plant survival, such as faunas and flora. Flora, and some species may become extinct as stated by [12].

Regarding precipitation, forecasts indicate that there should be a reduction in the tropical and subtropical regions and an increase in the average of the higher latitude regions. For the cerrado region where rainfall indexes fluctuate according to the large-scale phenomena Niño and Niña, the historical averages even in times of rainy season fluctuate within and below normality, the spatial and temporal variability is influenced by the meteorological systems operating in the time, its trend and that rainfall levels below climatology persist in future scenarios. [23] in their study in Minas Gerais in the semiarid region demonstrates that the variability of the rainy season depends solely and exclusively on the factors that cause rain.

For [15] analyzed the occurrences of extreme precipitation events in Campina Grande, with daily rainfall data covering the years 1970 – 2010. The extreme events analyzed were those with the highest intensity of daily precipitation for the years studied. The results showed that there was a change in the behavior of precipitation occurrences from the 70s in the study area. There was an intensification in maximum precipitation with a greater number of events with precipitation values greater than 80 mm. There was, in general, no direct relationship between intensification in precipitation and occurrences with ENOS events. Extreme events were evident between the months of the rainy season, with 88% of occurrences and 12% in the dry season, yet [16; 17] analyzed the climatology of precipitation in the municipality of Bananeiras - Paraíba, in the period 1930-2011 as a contribution to Agroindustry and found that rainfall indicators are essential to agro industrial sustainability.

The objective is to carry out a climatological analysis of the decadal precipitation of the municipalities surrounding the hydrographic basin of the upper Paraíba River, using a historical series of rainfall from the period 1962 to 2019, which can contribute to the decisions of sectors such as socioeconomic, agriculture, irrigation, energy production, water resources and agricultural technicians and decision makers in case of extreme events that may occur.

2. Material and methods

The Alto Paraíba River Hydrographic Basin (BHRAP), with an area of 20.071.83 km2, between latitudes 6º51'31 "and 8º26'21" South and longitudes 34º48'35 "; and 37º2'15"; West of Greenwich, it is the second largest in the State of Paraíba, o it covers 38% of its territory, housing 1,828,178 inhabitants which correspond to 52% of its total population. Considered one of the most important basins in the northeastern semi-arid region, it comprises the sub-basin of the Taperoá River and the Upper Course of the Paraíba River, the Middle Course of the Paraíba River and the Lower Course of the Paraíba River. In addition to the high population density, the basin includes the cities of João Pessoa, the state capital and Campina Grande, its second largest urban center (Figure 1).

Source: Medeiros, (2022)

Figure 1 Location of the hydrographic basin of the Alto Paraíba River

The basin is made up of regions afflicted by local, regional and large-scale synoptic events causing rain such as the Intertropical Convergence Zone and the contributions of the High Level Cyclonic Vortex systems when in activity on the NEB, in addition to the effects of the northeast trade winds in conjunction with the effects of sea breeze, aided by the formation of the South Atlantic Cyclonic vortices) and the formation of the instability lines, the Dipole Pattern in the Ocean Tropical Atlantic and wave disturbances in the field of trade winds, providing events for droughts, floods, floods, floods, overflow of rivers, dams, muds, ponds, lakes and streams; most of them, the flow of rivers at the headwaters is temporary due to poor rainfall distribution. In the region of Paraiba, the rainy season with the increase in rainfall levels causes a significant increase in runoff in which the majority are dammed in large and medium dams and their excess after the damming flows slowly into the ocean due to the relief and its basic courses of waters [13; 16].

Floods, floods and floods have already caused damage and removals to several villages and towns; historically the greatest floods occurred between the middle, low and high Paraíba stretches, the occurrence of floods is almost periodic (depending on the quality and quantity of the rainy season); it is known that in this area there are no flood containment systems and their flow rates are random, aided by relief [28].

The relief is generally quite diversified, consisting of different forms of relief worked and by different processes, acting under different climates and on rocks that are little or very different. Regarding geomorphology, there are three groups formed by the most significant climatic types: humid, sub-humid and semi-arid. Current use and vegetation cover are characterized by forest formations defined o open tree shrubbery, closed tree shrubbery, closed treehouse, coastal board, mangroves, humid forest, semi-deciduous forest, Atlantic forest and sandbank. [1]

It is noteworthy that in hydrographic basins and water sources, impacts and degradation by pollution, through sewage networks and dumps near its banks and / or even thrown by riverside populations or transported by water currents after strong events of precipitations, the intense amounts of pesticides that have been used improperly in the agricultural sector. It is observed that its surpluses are arriving directly in the areas of the basin, reservoirs, lagoon, lake, streams and streams and in the subsoil waters, contaminating them and directly affecting the human, animal and plant in accordance with [2].

The series of monthly and annual precipitation data collected by the Northeast Development Superintendence [27] and provided by the Executive Water Management Agency of the State of Paraíba [1] were used. Despite the variability of the observed data, the series under study was unified between 1962-2019, making statistical calculations for the study area in order to have more information and unify the data to better simulate and obtain accurate information about the area of study, the decade-long variability was studied between municipalities in order to understand its oscillations and variability, thus taking into account the variability of rainfall dynamics in the study area, it is assumed that for periods of less than 10 years these fluctuations must be more intense, Table 1.

Table 1 Location of the municipalities and their geographic coordinates (latitude, longitude and altitude) followed by the observation period of monthly and annual rainfall

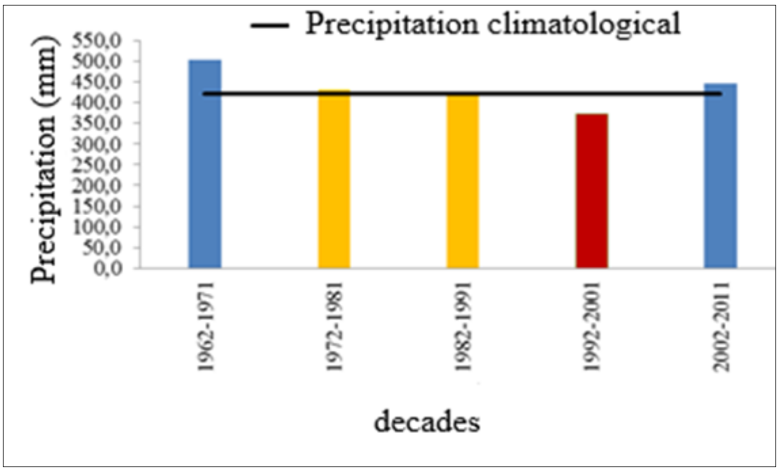
Municipalities/months	Latitude	Longitude	Altitude	Period
Barra de São Miguel	-7,45	-36,19	520	1962-2019
Cabaceiras	-7,29	-36,17	338	1926-2019
Camalaú	-7,53	-36,49	565	1962-2019
Caraúbas	-7,43	-36,29	460	1962-2019
Congo	-7,47	-36,39	500	1962-2019
Coxixola	-7,37	-36,36	465	1962-2019
Monteiro	-7,53	-37,07	590	1962-2019
Prata	-7,41	-37,04	600	1962-2019
São João do Tigre	-8,04	-36,5	616	1962-2019
São José dos Cordeiros	-7,23	-36,48	600	1962-2019
São Sebastião do Umbuzeiro	-8,09	-37,00	600	1962-2019
Serra Branca	-7,28	-36,39	450	1962-2019

Source: Medeiros, (2022)

3. Results and discussion

The decadal distributions of the 12 municipalities that surround the hydrographic basin of the upper course of the Paraíba River are illustrated between figures 2 to 13 below.

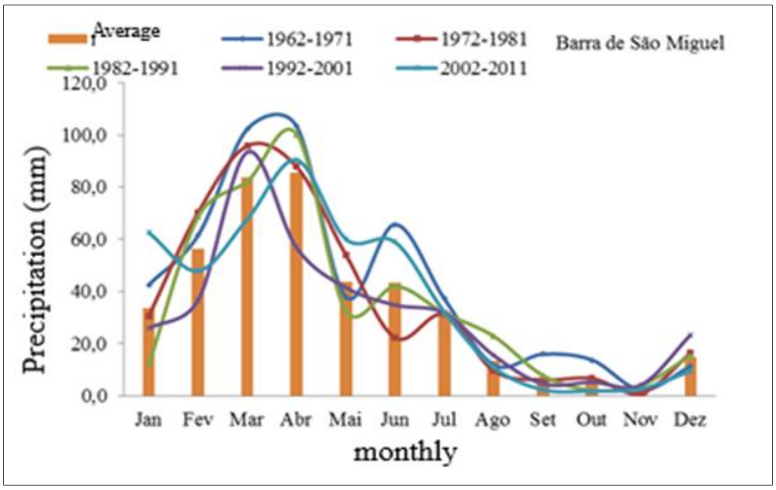
The annual distribution of precipitation for the municipality of Barra de São Miguel is shown in figure 2a. The decade of 1992-2001 with rain below the climatological stand out, the decades of 1962-1971 and 2002-2011 with rain above the climatological one and with rains between normality in the decades of 1972-1981 and 1982-1991.



Source: Medeiros (2022).

Figure 2a Precipitation (a) decade and climatological Barra de São Miguel

Figure 2b shows the fluctuations of the decades under study. The months of December to June show significant irregularities in the rainfall indexes, ranging from 15 to 110 mm. In the months of March and April the greatest intensities of rain are concentrated, with fluctuations between 60 and 110 mm, these irregular fluctuations are correlated to the local and regional effects followed by the variability in the performance of large-scale phenomena acting as El Niño/La Niña. Similar results were detected by [11; 12].

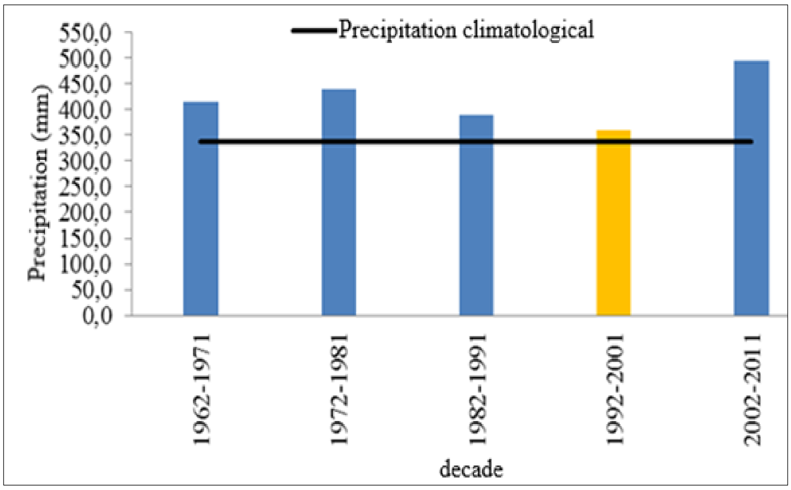


Source: Medeiros (2022)

Figure 2b Precipitation monthly for Barra de São Miguel

In the months from August to November, there is a reduction in the precipitated indexes and their fluctuation occurs in the range of 0 to 15 mm, except for the decade of 1962 to 1971, which presented values higher than the other decades in the months of September and October.

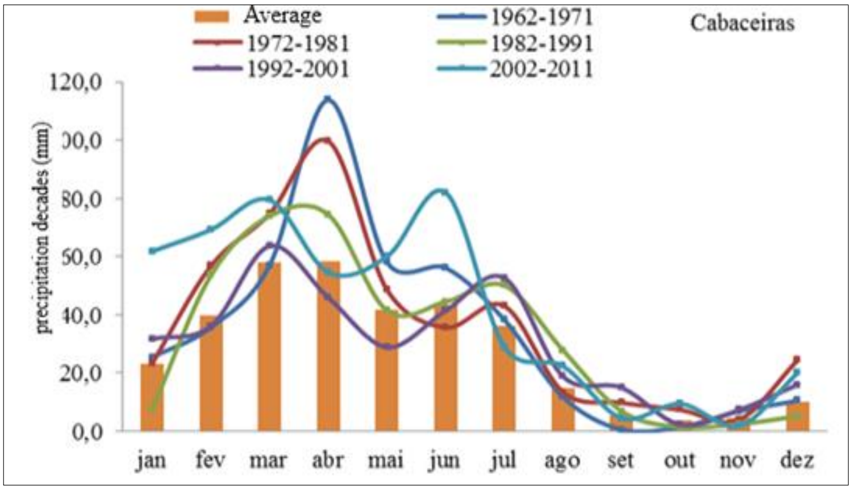
Figure 3a represents the annual totals of the decades and the climatological precipitation for the municipality of Cabaceira. In the 1992-2001 decade, there were rains between climatological normality and in the other decades, rains were above climatological (Figure 3a).



Source: Medeiros, (2022).

Figure 3a Precipitation decade and climatological for Cabaceiras

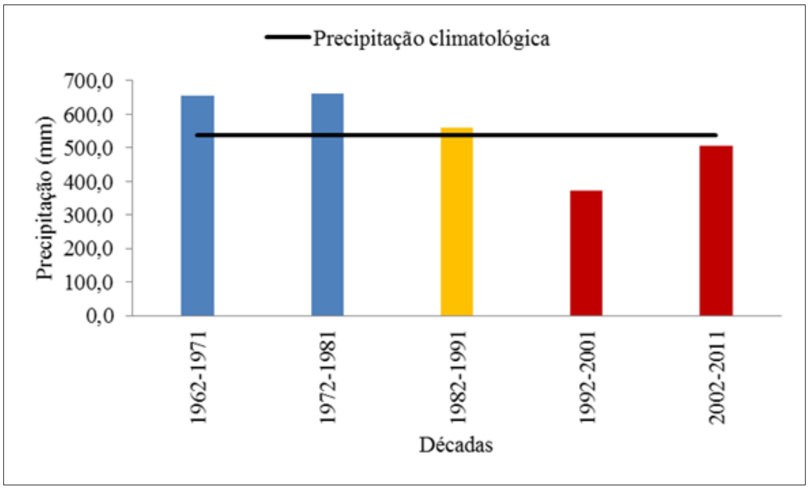
Figure 3b demonstrate the rainfall variability that occurred between the months of February to May presented with rainfall rates above normal in the decades of 1962-1971; 1972-1981; 2002-2011; between the months of august to November practically every decade kept above the climatological.



Source: Medeiros, (2022)

Figure 3b Precipitation monthly for Cabaceiras

Figures 4a and 4b show the annual, monthly oscillations and climatology of the decades under study for the municipality of Camalaú. The annual totals of the decade of 1982-1991 form the climatological precipitation in the decades of 1992-2001 and 2002-2011 the referred annual totals were below the average. In the decade of 1982-1991 the rains oscillated between the climatological normal and in the decades of 1962-1971 and 1972-1981, the registered rains were above normal.

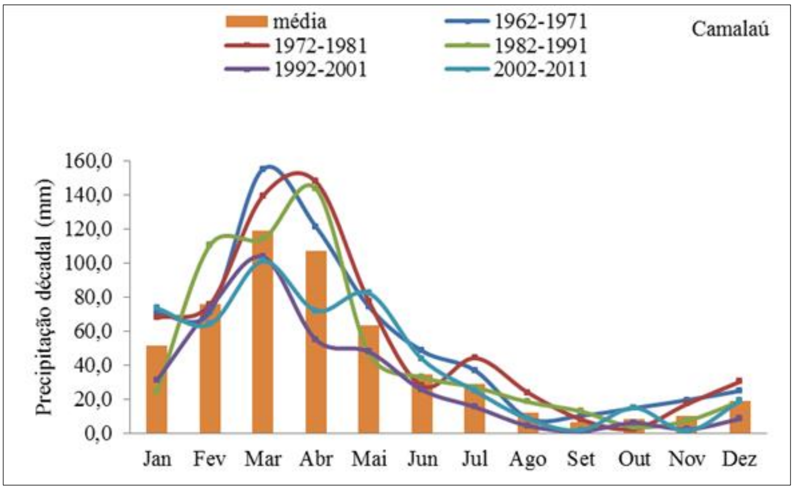


Source: Medeiros, (2022).

Figure 4a Precipitation decade and climatological for the municipality of Camalaú.

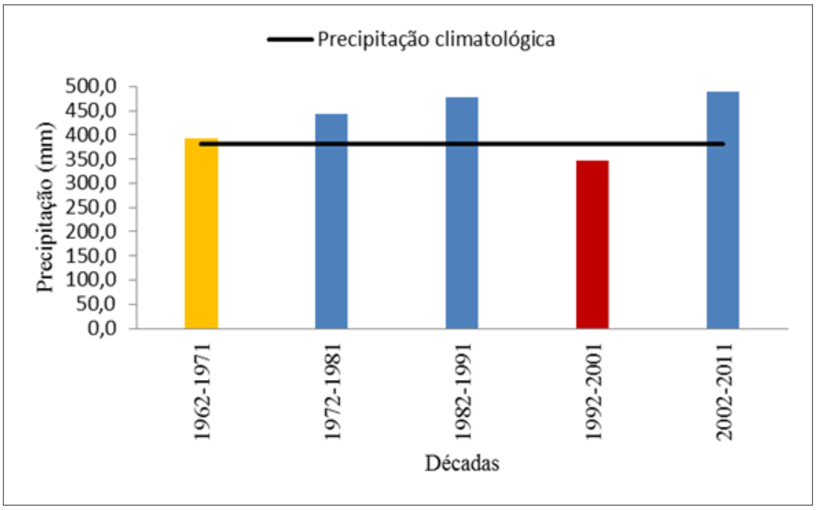
Figure 4b shows the variability of precipitation over the decades in the municipality of Camaláu. It is observed that in the months from January to May for the decades of 1962-1971; 1922-1931 and 1972-1981 the rains were above climatology and for the decade of 1982-1991 the rains were above climatology in the months of February to May. In the months of June to November, the climatology will suffer reductions in its indexes and any anomalous rain will cover its expected values.

The rainfall fluctuations between the decades 1962 to 2011 for the municipality of Caraúbas are shown in figures 5a and 5b. In the five decades studied, one had rain close to climatology, three decades with rainfall above normal climatology and a decade with rain below normal. Studies such as those by authors [10; 11; 12] corroborate the results discussed.



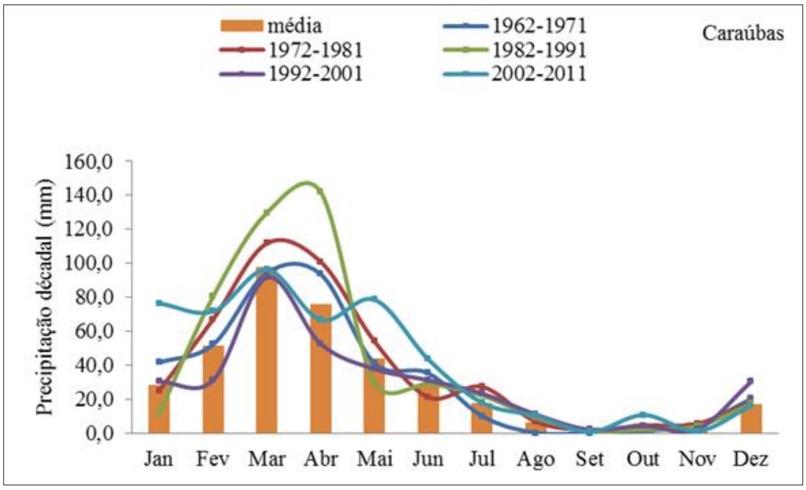
Source: Medeiros, (2022).

Figure 4b Precipitation monthly for the municipality of Camalaú



Source: Medeiros (2022)

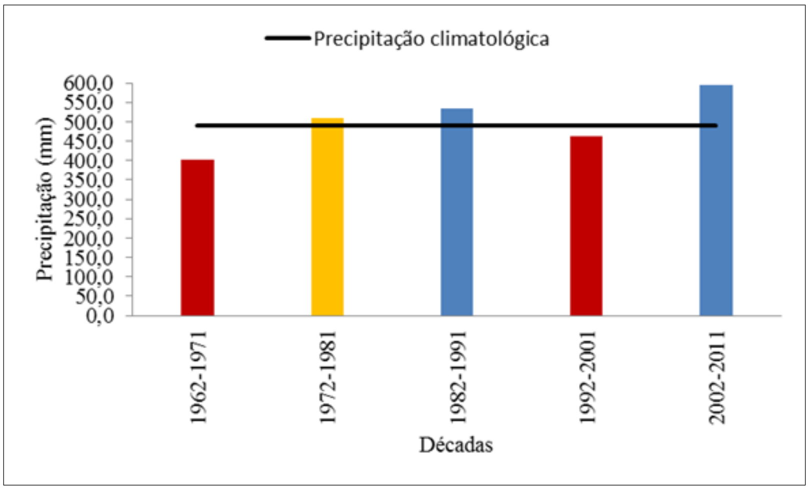
Figure 5a Precipitation (a) decade and climatological for Caraúbas



Source: Medeiros (2022).

Figure 5b Precipitation monthly for Caraúbas

Figure 6 shows the annual rainfall (a) by decade and climatological and (b) monthly oscillations for the municipality of Coxixola. In Figure 6a for the decades of 1962-1971 and 1992-2001, rainfall rates were recorded below the historical average, in the decade of 1972-1981 the rainfall occurred was equal to the average and for the decades of 1982-1991 and 2002 – 2011, the rainfall rates exceeded the historical average. Such variability in irregularities is in accordance with studies by [8; 11].

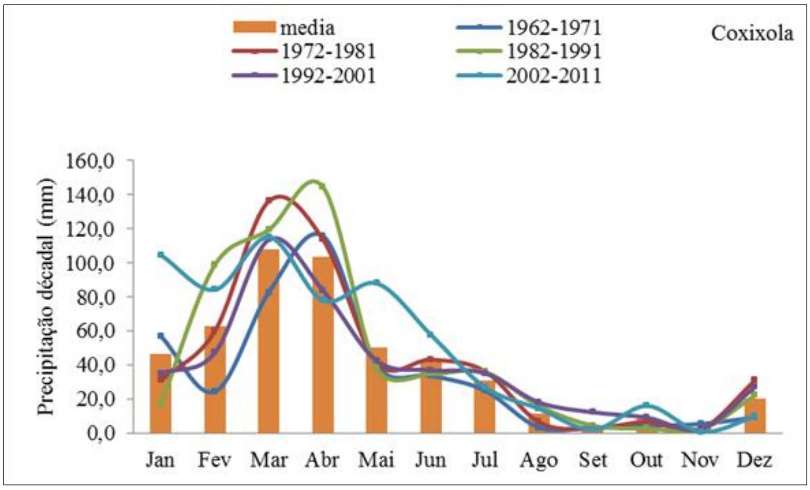


Source: Medeiros (2022)

Figure 6a Precipitation decade and climatological Coxixola

Decadal variability of rainfall for Coxixola is shown in figure 6b. In both decades between the months of August and December the rainfall rates were practically the same except for the decade of 2002-2011 for the month of October and for the decade of 1992-2001 comprised between the months of August and September that surpassed the climatology. In the months of February and March, the decades 1992-2001 stand out; 2002-2011; 1972-1981; 1982-1991 with rainfall rates above climatology. A study with [15; 16] corroborates the results discussed here.

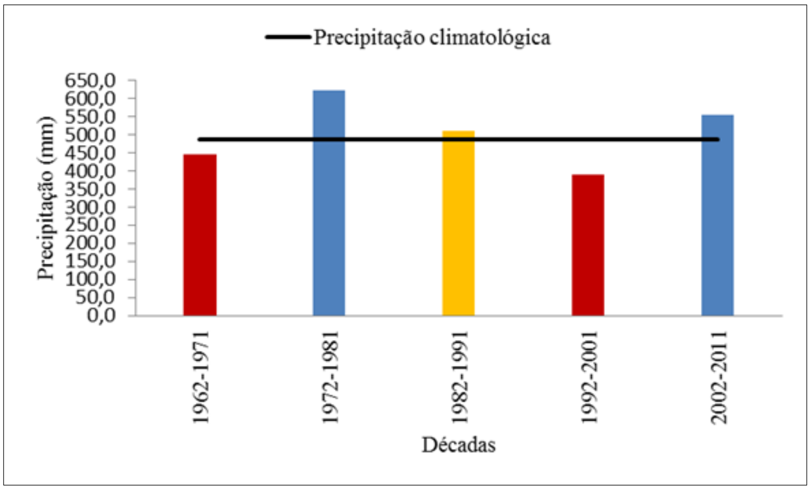
For [3; 22 and 18] in their studies four decades ago, they realized that the finitude of natural resources accompanied by the fragility of the planet's ecosystems would not support the pace of socioeconomic increase imposed by humanity. This statement corroborates the results discussed in this article.



Source: Medeiros (2022).

Figure 6b Precipitation monthly Coxixola

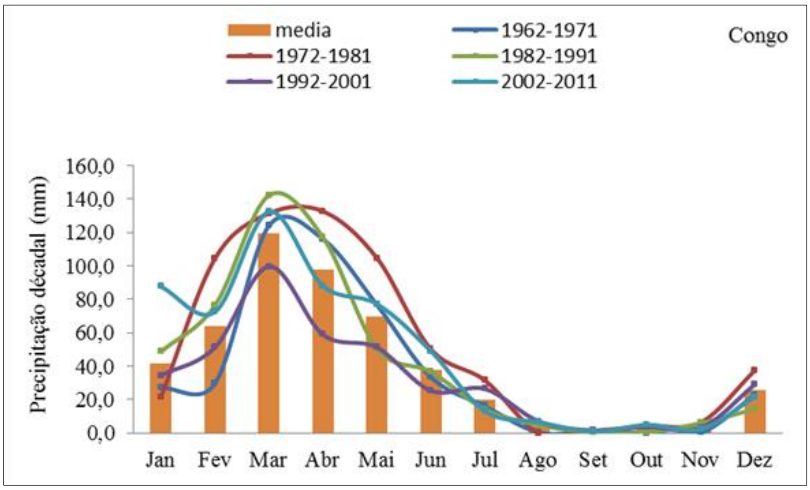
Decadal oscillations for the municipality of Congo are shown in figures 7 a, b. In Figure 7a, the decades of 1962-1971 and 1992-2001 precipitated below normal, in the other decades worked, the rains were above normal, and these results corroborate the study by [9; 21].



Source: Medeiros (2022)

Figure 7a Precipitation decade and climatological Congo

In figure 7b between the months of August and November the rainfall rates were equalized, in the months from February to April there were irregularities in the rainfall rates in the municipality of Congo and the decades 1992-2001, 2002-2011 presented as the lowest rainfall rates these irregularities are in accordance with the studies of [16; 14 and 4].



Source: Medeiros (2022).

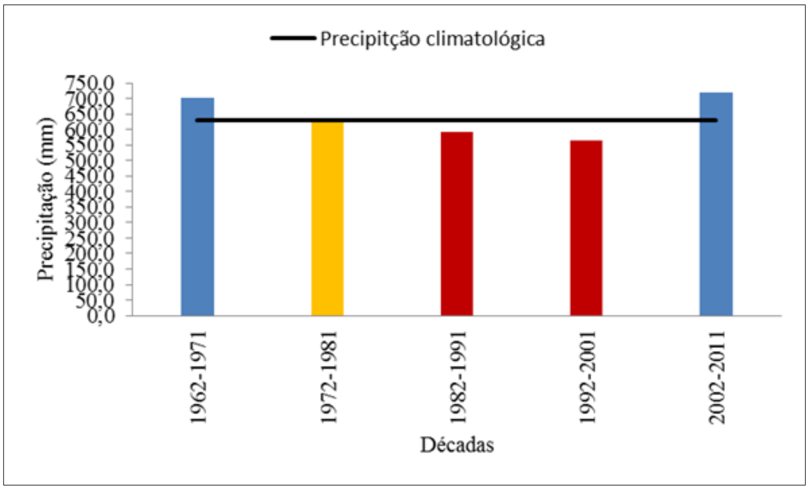
Figure 7b Precipitation monthly Congo

Figure 8 shows the rainfall fluctuations for (a) decade and climatological and (b) monthly for the municipality of Monteiro. With two decades above and below the historical average and a decade between normality (Figure 8a).

The rainfall irregularities recorded in figure 8a with emphasis on the decade 1992-2001 and 1962-1971 where their decadal rainfall rates were below normal.

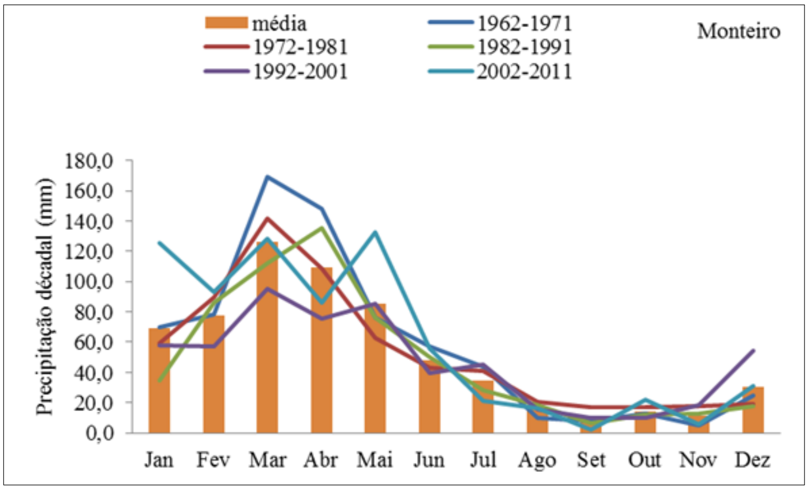
The rainfall irregularities caused by El Niño (a) were not the cause of the variability in Monteiro. Studies like that of [14; 4] corroborates the discussions presented here. These irregularities are linked to the rain-causing systems in the study area, followed by local and regional contributions that cause irregular and moderate intensities of rainfall (Figure 8 a,b). In figure 8a, it records three decades with rainfall above climatology and two decades with rainfall levels below normal.

Figure 9 shows rainfall fluctuations for (a) decade and climatological and (b) monthly for the municipality of Prata. With two decades above and below the historical average and a decade between normality (Figure 9a).



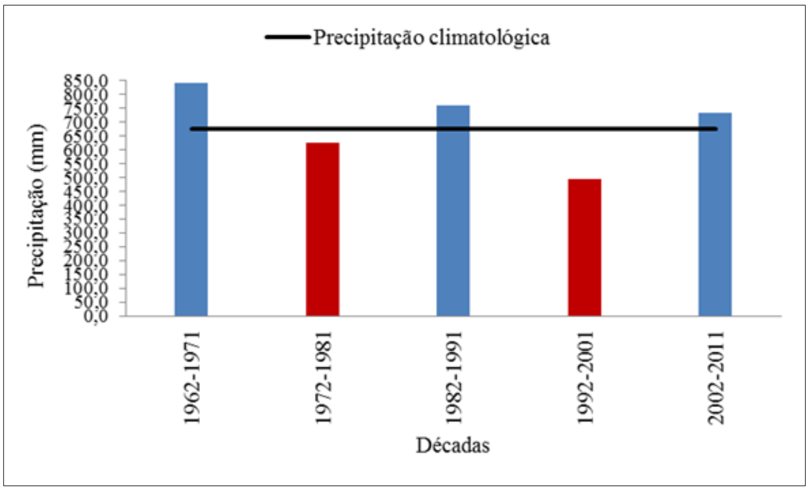
Source: Medeiros (2022)

Figure 8a Precipitation (a) decade and climatological for Monteiro



Source: Medeiros (2022).

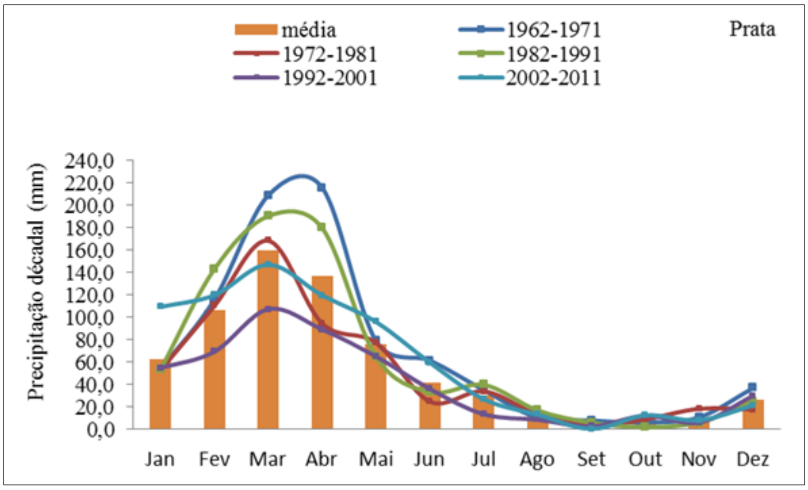
Figure 8b Precipitation (b) monthly for Monteiro



Source: Medeiros (2022).

Figure 9 (a) Precipitation decade and climatological for Prata

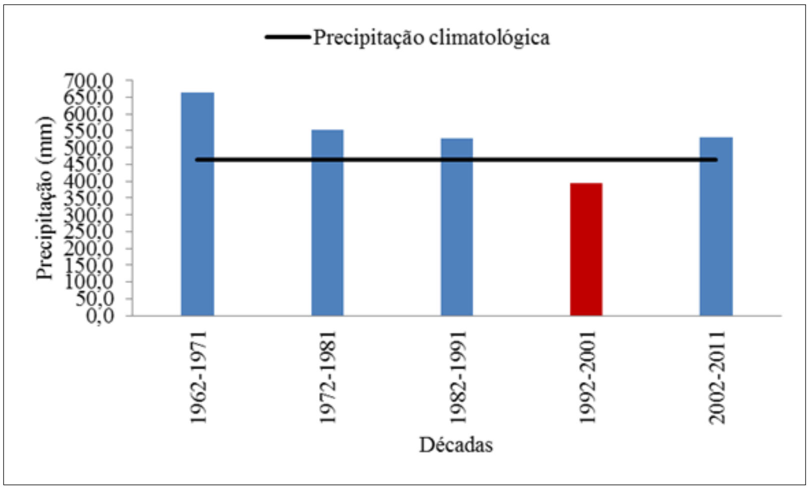
The irregularities observed in figure 9b and with emphasis on the1992-2001 decades; 2002-2001 and 1972-1981, which registered rainfall levels below the historical average.



Source: Medeiros (2022).

Figure 9 (b) Precipitation monthly for Prata.

The five decades of rainfall recorded in the municipality of São João do Tigre with rainfall above the climatological normal in four of them, as shown in figure 10a. In Figure 10b, the decades of 1962-1971 stand out; 1972-1981 for the months of February to May with rain above normal and the decade of 1982-1991 in the months of February, April and May, the remaining decades see the temporal space irregularities with indexes below the average. These variability are in accordance with the studies of [9; 10].



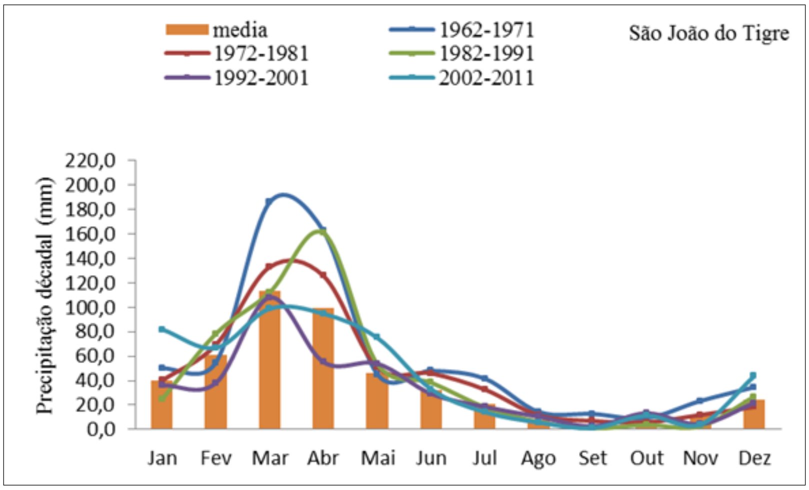
Source: Medeiros (2022).

Figure 10a Precipitation (a) decade and climatological for São João do Tigre

In figure 11 Annual precipitation (a) per decade and climatological and (b) monthly for the municipality of São José Cordeiro. In the decades 1962-1971, 1982-1991 and 1992-2001 the rainfall rates were below normal in the 1972-1981 and 2002-2011 decades the rainfall rates surpassed climatology (Figure 11a). Figure 11b shows rainfall fluctuations well above the historical between February and April except for the decade 2002-2011. Between the months of July and December, the rainfall indexes were the same except for the decade of 2002-2011 for the month of October.

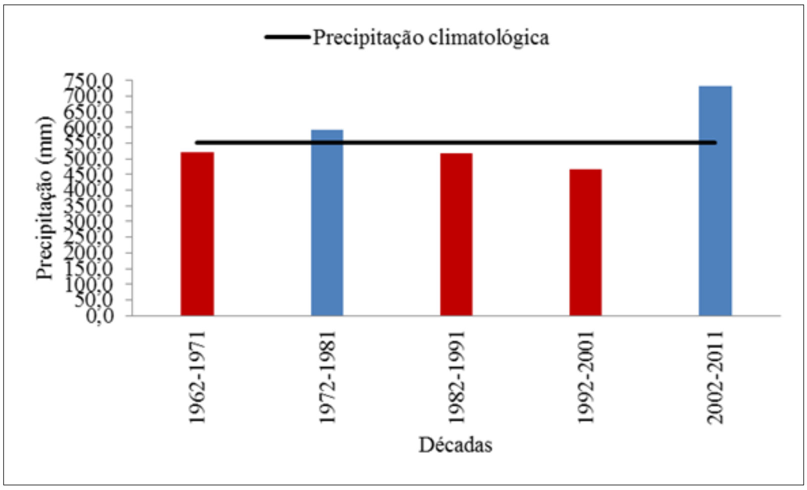
A study like those of the Authors (Medeiros et al., 2016) corroborate the results in discussions (França et al., 2018).

Figures 12 (a, b) show annual rainfall fluctuations (a) per decade and climatological and (b) monthly for the municipality of São Sebastião do Umbuzeiro.



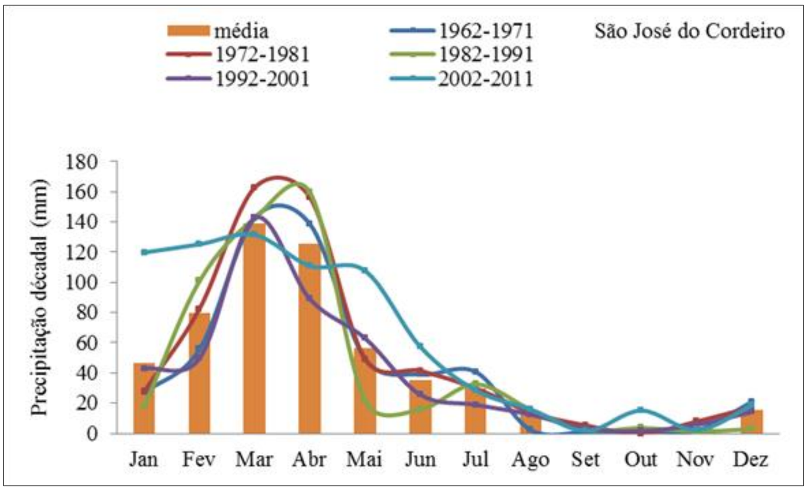
Source: Medeiros (2022)

Figure 10b Precipitation monthly for São João do Tigre



Source: Medeiros (2022)

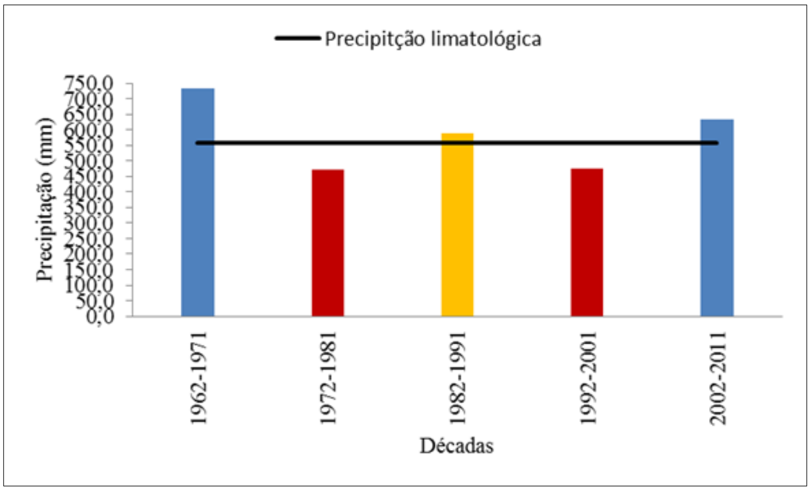
Figure 11a Precipitation (a) decade and climatological for São José Cordeiro



Source: Medeiros (2022)

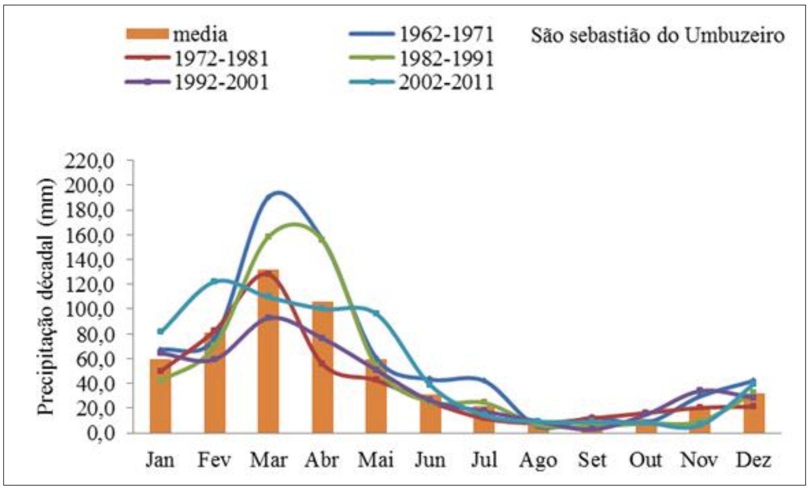
Figure 11b Precipitation monthly for São José Cordeiro

Figure 12a shows the decadal rainfall fluctuations and their irregularities. In the decade 1972-1981 and 1992 and 2001 the rainfall indexes flowed below climatology, the decades 1962-1971 and 2002-2011 registered rainfall indexes higher than climatology, in the decade 1982-1991 the rainfall indexes were equal to climatic intensities. The rainfall variability recorded in the months of March and April for the studied area show irregularities for both decades. Between the months of July and December the rainfall rates were practically equal (Figure 12b). The rainfall irregularities caused by El Niño (a) were not the cause of their variability. Studies like that of [4; 7 and 13] corroborates the discussions presented here.



Source: Medeiros (2022).

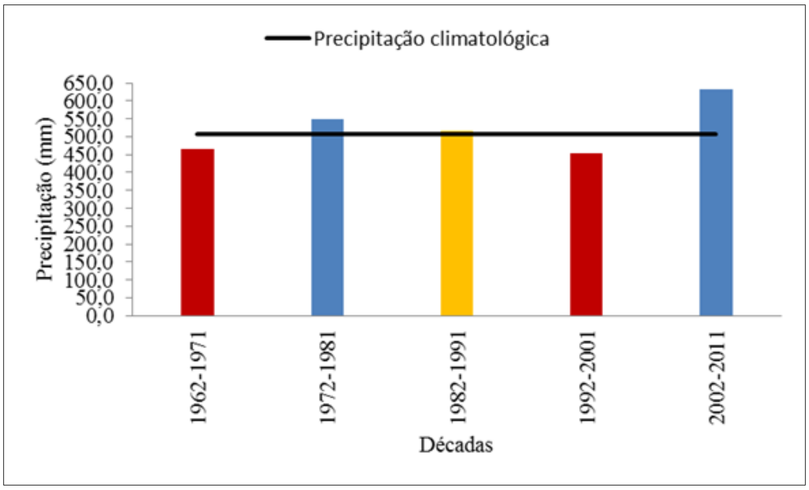
Figure 12a Precipitation decade and climatological for São Sebastião do Umbuzeiro.



Source: Medeiros (2022).

Figure 12b Precipitation monthly for São Sebastião do Umbuzeiro

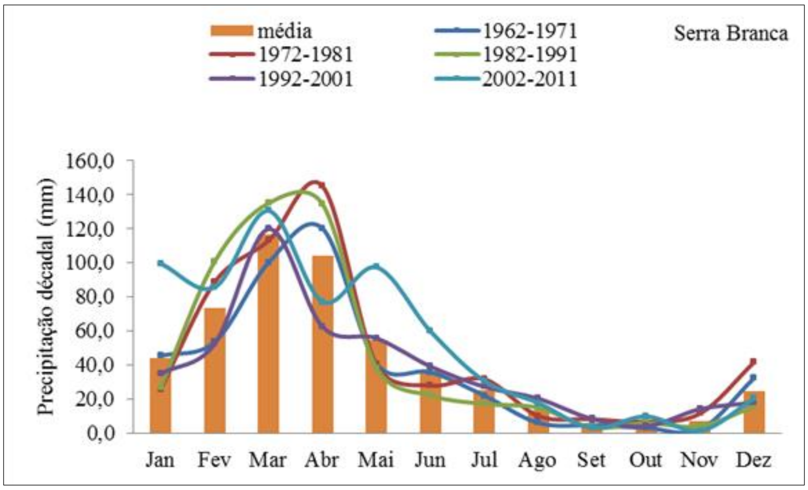
The decades under study for the municipality of Serra Branca show two decades with rainfall below normal, two decades with rainfall above the historical average and the decade of 1982-1991 with rainfall between normal (Figure 13a).



Source: Medeiros (2022).

Figure 13a Precipitation decade and climatological for Serra Branca**.**

Figure 13b shows the inter-irregular irregularities that occurred in the municipality under study. In the months of May to January the decade precipitation flowed close to or below the climatological average, except the decade of 1962-1971. In the months of February to April, the 1972-1981 decades stand out; 1982-1991 and 2002-2011 with rains above normal. These variabilities are linked to large-scale phenomena, local effects and heat exchange.



Source: Medeiros (2022).

Figure 13b Precipitation monthly for Serra Branca

4. Conclusion

The municipal fluviometric information, to the man in the field, can be used by the governmental actions in the planning of the distribution of the seeds and improvement of the production, being of relevant importance to minimize the eventual losses of the planting. Consequently, agroclimatic zoning will determine the best planting time, according to the mesoregion and the specific culture.

The influences and actions of the large-scale El Niño/La Niña phenomena for decades in studies in the form of adverse phenomena had their contributions in isolated decades and left water shortages in almost all reservoirs.

Irregularity between Niño and La Niña active in the world and especially in the state of Paraíba between decades and years has its local and regional variations caused by environmental, regional and local disasters such as prolonged droughts, extreme rains in short intervals causing flooding, floods of streets, neighborhoods and towns, floods, slope collapse, silting of streams, streams, rivers, lakes and ponds overflow and drying of medium to large dams, affecting the water tables of lakes and ponds, losses and overcrowding, altering human and animal thermal comfort, causing disruption in agribusiness, farming, pasture and urban and rural afforestation, reduction or total drought of streams, rivers, streams, ponds and lakes and the lack of water and its shortages for survival. Traffic disorder, the general population and the municipal and state economy.

Local contributions and the Intertropical Convergence Zone acted more intensely in the northern sector and caused most of the rain above normal levels in some decades.

Compliance with ethical standards

Disclosure of conflict of interest

The authors' participation was equal in the development of the article.

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