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***Scientific paper***

# Variability in number of rainy days in state of Sergipe – SE

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## Abstract

Among the many factors that affect human activities, mainly agriculture, the climate is distinguished by its decisive influence on the variations presented by the irregularities in the dry and wet periods in the given region. Among the variables that make up the climate, especially for annual crops, rain is the variable that most affects the result of crop production. In this sense, the objective was to evaluate the variability of rainfall data for the State of Sergipe, SE, through the preparation of maps of the average number of rainy days, and the coefficients of variation (CV) of rainfall and the number of rainy days for annual periods, dry and rainy. In this work it was used the series of monthly total rainfall of 40 rainfall stations with at least 30 years of data, continuous and seamless. We found that the highest values of the coefficient of variation are associated with lower levels of rainfall and number of rainy days. The variability of rainfall is lower in regions with rainy periods, when compared to dry periods.

**Key word:** variation coefficient, rainy day, dry and wet periods.

## Introduction

Rainfall is one of the most important variables in the hydrological cycle, since it influences various human activities, as agriculture, fishing, livestock, and human and animal consumption of potable water. It has been extensively studied in different regions of the world as the main indicator of draught: Guiana (SHAW, 1987); Austria (EHRENDORFER, 1987); USA (GUTTMAN et al. 1993; ARNAUD et al., 2002); Sahel (GRAEF and HAIGIS, 2001); Iran (DINPASHOH et al., 2004); Brazil (SILVA, 2004).

Draughts are a serious problem to the human society and the natural ecosystems (DINPASHOH et al., 2004). In this sense, different methodologies have been used to analyze the variability of the rainfall. SILVA et al. (2003) studied the rainfall variability in the State of Paraíba based on the entropy theory. DINPASHOH et al. (2004) found coefficient of variation (CVs) from the rainfall in Iran ranging from 18% at North, where it is located the mountains and 75% at South. MODARRES and SILVA (2007) evaluated the trend of the rainfall also in Iran and verified that the CV in the region is 44.4%.

By analyzing the climate variability in the Northeast of Brazil, based on the Mann-Kendall test, SILVA (2004) observed significantly decreasing tendencies in several places of this region. He suggested that this variability may be related with climate changes in the Northeast of Brazil, which reached not only the semi-arid of the region, but also the coast area. Since the seasonal variation of the rainfall has great influence in the agricultural planning, several researches have been developing studies based on the number of rainy days (BRUNETTIA et al., 2001; SELESHI and ZANKE, 2004; ZANETTI et al., 2006; MODARRES and SILVA, 2007).

Still about this issue, HESS et al. (1995) registered that the decrease in rainfall in the Northeast of the arid zone of Niger resulted in a decrease in the number of rainy days. BRUNETTIA et al. (2001) observed that the decrease in the number of rainy days in Italy is more important in the study of the intensity of rainfall than the annual totals.

The rainfall regime of the State of Sergipe is associated with the atmospheric conditions and synoptic systems which act in the sectors North and East of the Northeast of Brazil (NEB) and it has one particular characteristic different from the other regimes of the region of NEB. Due to its spatial geographic position, Sergipe has one characteristic

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of transition between the rainfall regime of North (with maximum from February to May) and of South of the NEB sectors (December to February). This transition is observed in the beginning of the rainy season changing the rainfall and causing veranicos[1]. The maximum rainfall occurs in May, however when there is one anomalous displacement of the Inter-Tropical Convergence Zone (ITCZ) towards the South, the beginning of the rainy season of the East of the NEB sector is affected considerably, even with the existence of veranicos in May. In the end of the rainy season, end of July to September, it is seen the elevations of the rainfall in some years due to the passage of frontal systems trough the south of the NEB sectors and which reached Sergipe (KOUSKY, 1980).

The success of the cultures implanted in rainfed agriculture depends on the rainfall to maintain the soil humidity needed for the culture development. The irregularities in the rainfall regime are caused by changes in frequency and/or intensity of the rainfall events. The best understanding of the behavior of the rainfall, aiming at its maximum use in the agricultural activities, may be obtained with the study of the number of rainy days. Besides that, for several water appliances, as for modeling, the knowledge of the variability of the rainfall becomes essential (BUYTAERT et al., 2006).

It is important the knowledge of the distribution of the rainfall in the State of Sergipe, for the formulation of strategies and in indentifying the appropriated regions for the implantation of rainfed cultures, considering the great variation of the rainfall average in the place. Moreover, the spatial and time variability of the rainfall in the state of Sergipe is little studied even though it is very important for the purpose of formulation of strategies of combat to the effects of draught in the semi arid. Thus, the objective of the present study is to analyze the spatial variability of the rainfall in the state of Sergipe, aiming to identify the areas more susceptible to longer droughts.

## Material and methods

The studied region was the State of Sergipe located in the Northeast region of Brazil, having as limits Alagoas (NW), Atlantic Ocean (E) and Bahia (S and W). It occupies an area of 21.910 km², and it is the smallest Brazilian state. It is located between 9º 31′ S to 11º 33′ S and 36º 25′ W to 38º 14′ W, in the tropical zone and it has as main climate problem the spatial irregularity of the rainfall decreasing from the Lest Coast to the Sertão, Semi Arid.

It was used daily time series of 40 rainfall stations in all the state of Sergipe, SE, with more than 30 years of data, continuous and without failures, of rainfall and the number of rainy days. In this study it was considered as rainy days those with rainfall above 1 mm. In Table 1 it is indicated each rainfall station and its respective geographic coordinates, which are used in the work.

These rainfall stations are spatially well distributed in all the state of Sergipe and located in different climate regions, according to what is showed in Figure 1.

In order to identify the behavior of the rainfall data range which was obtained from the 40 rain gauge stations, spatially well distributed, it was calculated the values of the coefficient of variation (CVs) of the rainfall and the number of rainy days in the state of Sergipe, for the annual, dry and rainy periods. The coefficient of variation of the data set CV (%) was calculated trough the equation, indicated by JENSEN and PEDERSEN (2005):

$$CV = \frac{\sigma}{\mu} \times 100 = \frac{\left[\frac{1}{n-1}\left[\sum_{i=1}^{n} x_i^2 - \frac{1}{n}\left(\sum_{i=n}^{n} x_i\right)^2\right]\right]^{1/2}}{\frac{1}{n}\sum_{i=n}^{n} x_i} \times 100 \quad (1)$$

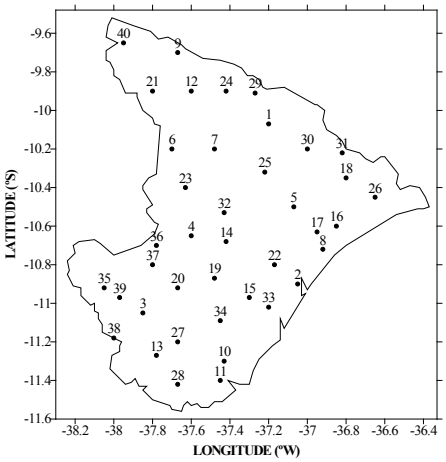


**Figure 1.** Location of the 40 rain gauge stations located in the State of Sergipe, SE.

1 'Veranico' is a Brazilian word to define dry periods during the wet season.

**Table 1.** Geographic localization of the rainfall stations of the State of Sergipe.

| Number | Station | Code | Lat. | Long. | Alt. |
|---|---|---|---|---|---|
| 1 | AQUIDABA | 4805595 | -10.07 | -37.2 | 217 |
| 2 | ARACAJU | 4815891 | -10.9 | -37.05 | 3 |
| 3 | BONFIM | 4824131 | -11.05 | -37.85 | 230 |
| 4 | CAMPO DO BRITO | 4815501 | -10.65 | -37.6 | 180 |
| 5 | CAPELA | 4815087 | -10.5 | -37.07 | 148 |
| 6 | CARIRA | 4804761 | -10.2 | -37.7 | 351 |
| 7 | CRUZ DAS GRACAS | 4805904 | -10.2 | -37.48 | 259 |
| 8 | CURRAL DO MEIO | 4816418 | -10.72 | -36.92 | 30 |
| 9 | CURRALINHO | 3894467 | -9.7 | -37.67 | 80 |
| 10 | ESTANCIA | 4825514 | -11.3 | -37.43 | 53 |
| 11 | ESTANCIA-1 | 4825513 | -11.4 | -37.45 | 53 |
| 12 | ILHA DO OURO | 3895851 | -9.9 | -37.6 | 40 |
| 13 | ITABAIANINHA | 4824545 | -11.27 | -37.78 | 225 |
| 14 | ITABAIANA | 4815319 | -10.68 | -37.42 | 186 |
| 15 | ITAPORANGA D AJUDA | 4815942 | -10.97 | -37.3 | 10 |
| 16 | JAPARATUBA | 4816211 | -10.6 | -36.85 | 79 |
| 17 | JAPARATUBA-1 | 4816213 | -10.63 | -36.95 | 79 |
| 18 | JAPOATA | 4806741 | -10.35 | -36.8 | 89 |
| 19 | JENIPAPO | 4815705 | -10.87 | -37.48 | 100 |
| 20 | LAGARTO | 4814868 | -10.92 | -37.67 | 183 |
| 21 | LAGOA DA SERRADINHA | 4804268 | -9.9 | -37.8 | 80 |
| 22 | LARANJEIRAS | 4815667 | -10.8 | -37.17 | 9 |
| 23 | MOCAMBO | 4814174 | -10.4 | -37.63 | 204 |
| 24 | N. SENHORA DA GLORIA | 4805418 | -9.9 | -37.42 | 290 |
| 25 | N. SENRA DAS DORES | 4815057 | -10.32 | -37.22 | 200 |
| 26 | PACATUBA | 4806971 | -10.45 | -36.65 | 20 |
| 27 | PEDRINHAS | 4824467 | -11.2 | -37.67 | 170 |
| 28 | PEDRINHAS-1 | 4824468 | -11.42 | -37.67 | 170 |
| 29 | PORTO DA FOLHA | 3895848 | -9.91 | -37.27 | 45 |
| 30 | PROPRIA | 4806437 | -10.2 | -37.00 | 17 |
| 31 | PROPRIA-1 | 4806438 | -10.22 | -36.82 | 0 |
| 32 | RIBEIROPOLIS | 4815016 | -10.53 | -37.43 | 350 |
| 33 | S. CRISTOVAO | 4825062 | -11.02 | -37.2 | 20 |
| 34 | SALGADO | 4825011 | -11.09 | -37.45 | 102 |
| 35 | SAMAMBAIA | 4813892 | -10.92 | -38.05 | 250 |
| 36 | SIMAO DIAS | 4814444 | -10.7 | -37.78 | 283 |
| 37 | SIMAO DIAS-1 | 4814443 | -10.8 | -37.8 | 283 |
| 38 | TOBIAS BARRETO | 4824303 | -11.18 | -38 | 157 |
| 39 | VILA ISABEL | 4814908 | -10.97 | -37.97 | 400 |
| 40 | CAN DE S. FRANCISCO | 3894341 | -9.65 | -37.95 | 130 |

In which σ is the pattern deviation, μ the arithmetic average and n is the number of data of the time series.

According to BUSSAB (2003) the coefficient of variation, defined as the pattern deviation in percentage of the mean, is the most used statistic measure by researchers in the evaluation of data accuracy. It has the advantage of enabling the comparison of accuracy between variables, without the need of equality of units.

Aiming to determine the regions of the State with characteristics of variability in the behavior of the rainfall data for the periods annual, dry and rainy, in each one of the rain gauge stations, it was plotted in the map of the State of Sergipe and traced isolines of the mean values of the number of rainy days, of

the coefficient of variation (CVs) of the rainfall and the number of rainy days, trough the technique of interpolation of the kriging. These isolines provide a spatial vision of the variability of dry and rainy days, and the total rainfall.

## Results and discussion

The maps of the isolines of the number of rainy days and of the coefficients of variation (CVs) of the rainfall and the number of rainy days in the state of Sergipe, for the annual, dry and rainy periods are presented in Figures 2 to 4. It can be also observed that in the places where the mean rainfall is low there are high values of CV; and for the places where the rainfall is very high, the values of CV were low. Similar results were obtained by other researchers in studies performed for Iran in which the values of the average of the rainfall are inversely proportional to the values of CV. The analysis of the results still reveals that the variability of the rainfall and of the number of rainy days in the state of Sergipe ranges according to the period of the years and the geographic localization. The analysis of each period of study is presented below.

*Annual period*

In Figure 2 it is presented the spatial variability of the mean values of the number of rainy days, of the coefficient of variation of the rainfall and the number of rainy days in the state of Sergipe referent to the annual period. In this period, the higher number of rainy days is concentrated in the mesoregion of the Litoral sergipano (Sergipe Coast), with values

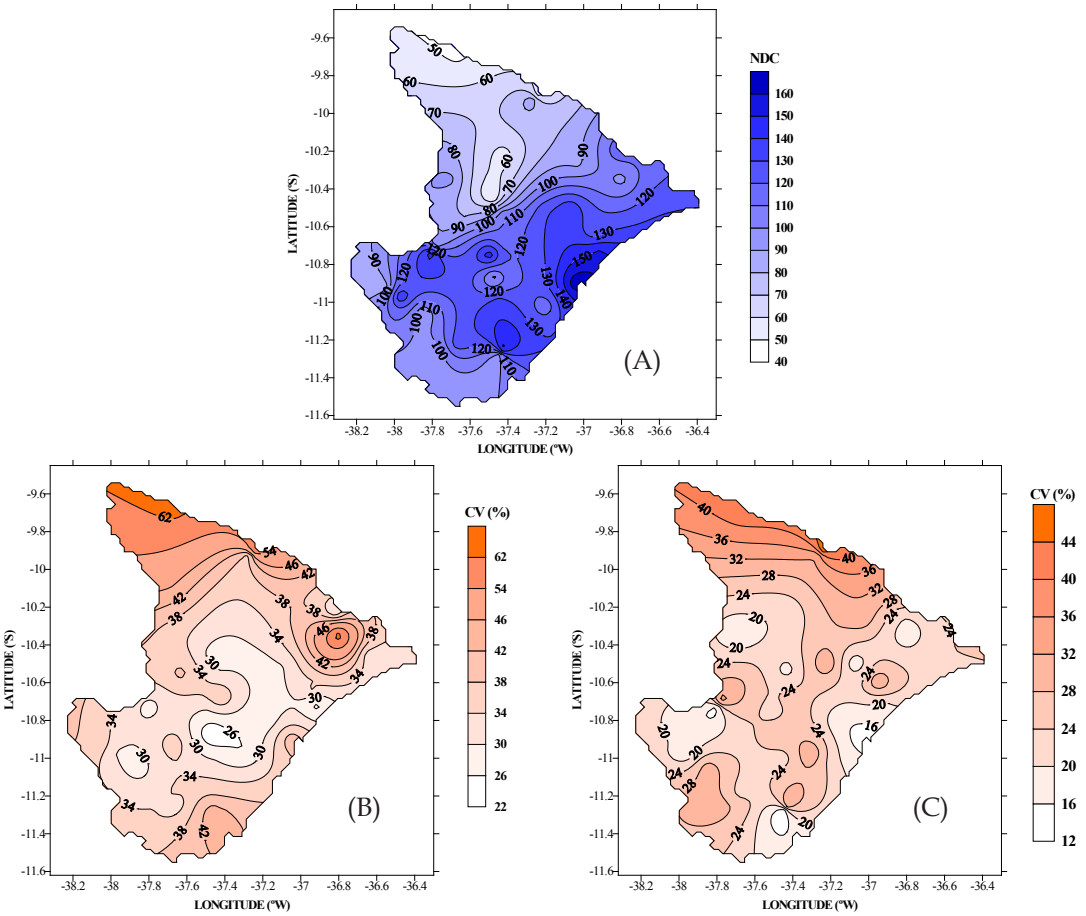


**Figure 2.** Spatial distribution of the average number of rainy days (A) CVs of rainfall (B) and numbers of rainy days (C) for the annual period in the state of Sergipe.

between 100 and 150 days; and following it decreases in towards the Agreste of the state of Sergipe with values between 90 and 110 days. The lowest values of number of rainy days were revealed in the Sertão of the State of Sergipe between 50 and 80 days.

The values of the coefficient of variation (CV) are very low in the mesoregion of the Litoral sergipano, ranging between 26 and 42% for rainfall and between 16 and 24% for the number of rainy days. In the Agreste of the State of Sergipe, the values of the CVs of the rainfall range between 25 and 34% of the number of rainy days between 20 and 28%.

In the Sertão of the state of Sergipe, it was found higher values of CV of rainfall and number of rainy days, the values of CV ranged between 38 and 62% for rainfall and between 28 and 40% for the number of rainy days.

*Rainy period*

The spatial variability of the mean values of the number of rainy days, coefficient of variation of the rainfall and of the coefficient of variation of the number of rainy days is presented in Figure 3.The higher number of rainy days in this period is concentrated in the mesoregions in Litoral and Agreste of Sergipe, with values between 12 and 18 days, and next it decreases towards the Sertão of the State of Sergipe with values between 6 and 10 days.

During the rainy period, the lowest values of CV of the rainfall and the number of rainy days are found in the mesoregions of the Litoral and Agreste of Sergipe. In the mesoregion of the Sertão of the State of Sergipe, during the rainy period, it is observed mean values of CV of rainfall very high, ranging between 60 and 90%, while for the number of rainy days they range between 42 and 62%.

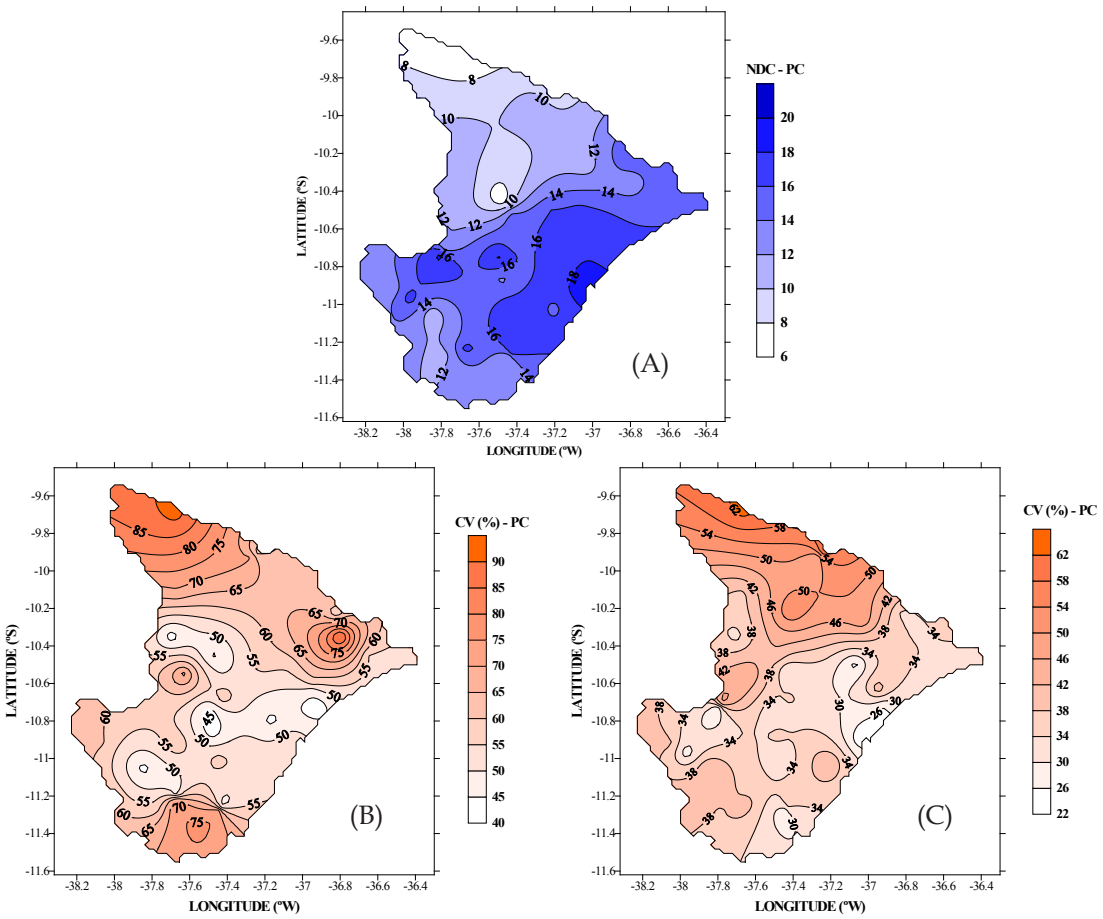


**Figure 3.** Spatial distribution of the average number of rainy days (A) CVs of rainfall (B) and numbers of rainy days (C) for the rainy period in the State of Sergipe.

*Dry period*

In Figure 4 it is presented the spatial variability of the mean values of the number of rainy days, coefficient of variation of the rainfall and of the coefficient of variation of the number of rainy days referent to the dry period in the state of Sergipe. In this period, the higher number of rainy days is concentrated in the mesoregions in the Litoral and Agreste Sergipano, with isolines between 6 and 10 days. The mesoregions of the Litoral and Agreste presented isolines of CV lower than 100%, both for the rainfall and the number of rainy days.

Tables 2 to 4 present the values of numbers of rainy days, coefficient of variation of rainfall, and coefficient of variation of number of rainy days in the state of Sergipe.

In the month of January, the mesoregion of the Sertão sergipano presented the lower number of rainy days, with values of approximately 2.87 days. The highest values of the mean number of rainy days in this month were in the mesoregions of the Litoral and Agreste, reaching until 5.45 days (Table 2). This result indicates that the high number of rainy days in these microregions may be associated with the omnipresence of cyclone vortex in this period of the year in the cost of the Northeast of Brazil.

In the Mesoregion of the Sertão sergipano, the number of rainy days increased considerably from the month of March, as consequence of the acting of the Zone of Intertropical Convergence (ITCZ). This phenomenon is responsible for the increase of the rainfall in this region of the state due to its movement in this period for the south hemisphere.

In Table 3, the highest and lowest values of CV of the rainfall obtained ranged from 144.53 to

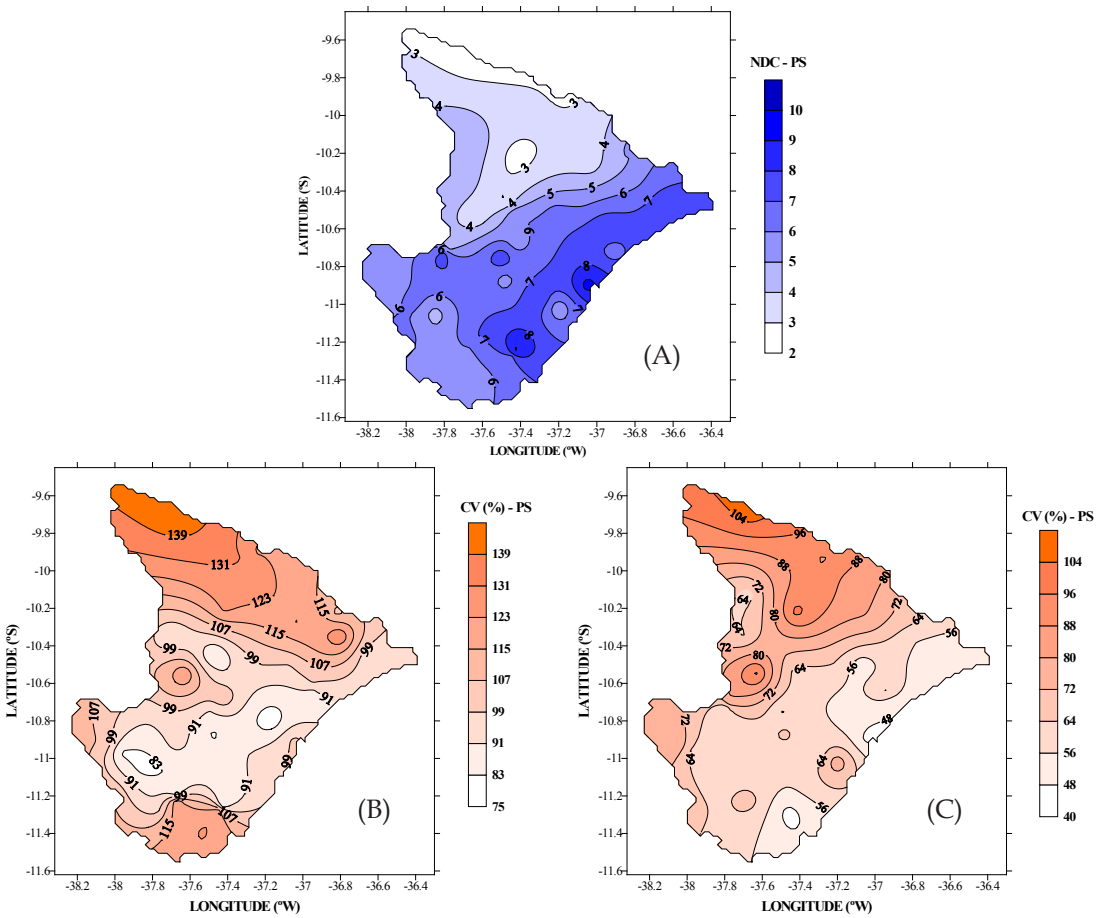


**Figure 4.** Spatial distribution of the average number of rainy days (A) CVs of rainfall (B) and numbers of rainy days (C) for the dry period in the State of Sergipe.

**Table 2.** Average monthly and annual number of rainy days in each of Sergipe State Mesorregion.

| Months | Mesorregion the State of Sergipe | | |
|---|---|---|---|
| | Coast | Agreste | Interior |
| January | 5.45 | 4.31 | 2.87 |
| February | 6.32 | 5.97 | 3.34 |
| March | 9.45 | 7.73 | 4.75 |
| April | 13.16 | 11.23 | 7.31 |
| May | 17.05 | 15.48 | 10.33 |
| June | 16.69 | 15.91 | 10.57 |
| July | 17.55 | 16.80 | 10.87 |
| August | 14.32 | 13.35 | 7.91 |
| September | 9.60 | 9.10 | 4.61 |
| October | 6.24 | 5.08 | 2.28 |
| November | 4.61 | 4.39 | 2.21 |
| December | 4.80 | 4.32 | 2.75 |
| Annual Average | 125.21 | 113.05 | 69.30 |

48.64%, respectively, and occurred around the driest period and mesoregion (October in the mesoregion of Sertão) and rainy (June in the mesoregion of Litoral). The annual average of the CV of rainfall ranged from 32.52% in the mesoregion of Litoral, to 45.86% in the mesoregion of the Sertão sergipano. The annual average of CV of rainfall was also maximum in the driest mesoregion and minimum in the rainiest mesoregion. Therefore, the variability of the CV of rainfall is higher in the driest periods and regions, inversely; this variability is lower in the rainiest periods and regions.

Similarly, the values of the CV of the number of rainy days are higher in the driest regions and lower in the rainiest ones (Table 4).

The mesoregion of Litoral, in which the annual average of rainfall may reach more than 1800 mm, reveals that CV of number of rainy days for the annual mean presents values lower than 50%. On the other hand, the mesoregion of Sertão, in which rainfall has annual average of until 500 mm, the values of CV of number of rainy days range from 46.02 to 103.82% (mesoregion of Sertão) and between 31.15 to 71.13% (mesoregion of Agreste). As for the CV of the number of rainy days, the rainiest months presented the lower values of CV and the dry months presented the highest values of coefficient of variation as it can be seen in Table 4.

The Easterly Waves Disturbances (EWD) are also frequent in this period of the year and mesoregion of the state. On the other side, the highest averages of number of rainy days is in the mesoregion of Litoral and Agreste with values of 125.1 and 113.05 days, respectively; while the lowest annual average is in the mesoregion of the Sertão sergipano.

This result was also found trough the analysis of the space distribution of the number of rainy days, which suggests the inadequacy of the implantation of crops of long cycle in these microregions facing the low number of rainy days and the high variability of the rainfall during the cultivation season.

**Table 3.** Average monthly and annual CV (%) of rainfall in each of Sergipe State Mesorregion.

| Months | Mesorregion the State of Sergipe | | |
|---|---|---|---|
| | Coast | Agreste | Interior |
| January | 95.85 | 98.22 | 118.03 |
| February | 109.19 | 91.77 | 106.71 |
| March | 87.42 | 90.85 | 106.37 |
| April | 70.72 | 64.50 | 94.50 |
| May | 66.62 | 61.51 | 71.04 |
| June | 51.72 | 48.64 | 74.99 |
| July | 55.61 | 48.64 | 77.68 |
| August | 59.18 | 50.94 | 68.84 |
| September | 75.64 | 71.56 | 100.63 |
| October | 105.36 | 96.13 | 140.98 |
| November | 129.68 | 109.52 | 144.53 |
| December | 127.70 | 107.74 | 128.39 |
| Annual Average | 32.52 | 37.42 | 45.86 |

**Table 4.** Average monthly and annual CV (%) number of rainy days in each of Sergipe State Mesorregion.

| Months | Mesorregion the State of Sergipe | | |
|---|---|---|---|
| | Coast | Agreste | Interior |
| January | 57.54 | 71.13 | 86.49 |
| February | 63.24 | 60.32 | 79.00 |
| March | 51.11 | 56.13 | 70.22 |
| April | 38.26 | 43.51 | 57.47 |
| May | 31.89 | 39.19 | 51.22 |
| June | 32.00 | 31.56 | 46.66 |
| July | 30.06 | 31.15 | 46.02 |
| August | 36.54 | 36.93 | 50.31 |
| September | 49.06 | 51.22 | 72.75 |
| October | 65.17 | 66.82 | 96.12 |
| November | 64.47 | 66.59 | 103.82 |
| December | 63.75 | 70.09 | 90.44 |
| Annual Average | 21.86 | 24.41 | 32.51 |

## Conclusion

The variability of the rainfall is not uniform in all the state of Sergipe;

It was observed that the highest values of number of rainy days occurred in the Litoral and Agreste;

The highest values of CV are associated to the lowest values of rainfall and of the number of rainy days;

The variability of the rainfall in the state of Sergipe is lower in the rainy period than in the dry period;

The rainiest period generally is concentrated in the first semester of the year, due to the action of the ITCZ and of the Easterly Waves Disturbance (EWD), while the driest period occurs in the second semester of the year.

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