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ESTIMATE OF THE INTENSITY-DURATION-FREQUENCY PARAMETERS OF INTENSE RAINFALL FOR THE STATE OF ALAGOAS, BRAZIL

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ABSTRACT

The study of the rainfall characteristics is of fundamental importance since the frequency of floods has increased in several parts of Brazil due to anthropic impacts of climatic changes. Thus, this study aimed to determine the parameters of the intense rainfall equation (K, a, b, c) for 52 municipalities in the State of Alagoas using data from 164 rain gauges ta available from the National Water Agency (ANA). The data series were subjected to consistency analysis and further desegregation of maximum daily rainfall to durations of the 5; 10; 15; 20; 25; 30; 60; 360; 480; 600; 720 and 1,440 minutes and return period of 5; 10; 25; 50 and 100 years according to different probabilistic models. The adjustment of the parameters was carried out by means of non-linear regression, with R^2 greater than 0.949 for all the stations, considering for this purpose one station per municipality, totaling 51 municipalities of study. It was obtained that the maximum rainfall intensity predicted increases with the increase in the return period and decreases with the increase of the duration of the rain. The greater intensities were detected in the mesoregion of Eastern Alagoano and the lowest intensities in the mesoregion of Sertão Alagoano.

Palavras-chave:
Equações IDF
Hidrologia
Precipitação Pluviométrica

ESTIMATIVA DOS PARÂMETROS DE INTENSIDADE-DURAÇÃO-FREQUÊNCIA DA CHUVA INTENSA PARA O ESTADO DE ALAGOAS, BRASIL

RESUMO

O estudo das características das chuvas é de fundamental importância, uma vez que a frequência de inundações tem crescido em diversas partes do Brasil, devido a impactos antrópicos ou de mudanças climáticas. Neste sentido este estudo teve por objetivo determinar os parâmetros da equação de chuvas intensas (K, a, b, c) para 52 municípios de estado de Alagoas, por intermédio de 164 estações pluviométricas com dados disponíveis na Agência Nacional das Águas (ANA). As séries de dados foram submetidas a análise de consistência e posterior desagregação das chuvas máximas de um dia em durações de 5; 10; 15; 20; 25; 30; 60; 360; 480; 600; 720 e 1.440 minutos para cada duração e período de retorno de 5; 10; 25; 50 e 100 anos conforme diferentes modelos probabilísticos. O ajuste dos parâmetros foi realizado por meio de regressão não linear, com R^2 superior à 0,949 para todos as estações estudadas, considerando-se para tanto uma estação por município do estado, totalizando 51 municípios de estudo. Identificou-se que a intensidade máxima prevista de precipitação pluviométrica eleva com o aumento do período de retorno e reduz com o aumento da duração da chuva, com maiores intensidades detectadas na mesorregião do Leste Alagoano e as menores intensidades na mesorregião do Sertão Alagoano.

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INTRODUCTION

Known as extreme rainfall, heavy rainfall is that with a high precipitated depth in a short period (ARAÚJO, 2008). The lack of information about this type of rainfall increases the uncertainties of projects related to water resources, resulting in poorly sized designs. Thus, the quantification of extreme rainfall is paramount as when combined with the knowledge of the temporal and spatial distribution of the behavior of rainfall, it supports the correct decision-making to studies related to the dimensioning of hydraulic projects, such as irrigation projects, water flood and soil erosion (CECÍLIO, 2009).

In the context of urban and agricultural development in addition to the anthropic actions that affect the intensity of the rainfall and the runoff generated, it is essential to understand the dynamics of the hydrological cycle, particularly evidenced by the intense rainfall effects, which occurs in a torrential manner in the tropics. These effects directly affect the ability of soils to resist the physical aggressions imposed on them due to the action of the impacts of raindrops and consequently the erosion they are susceptible due to the effective absence of vegetation cover especially caused by deforestation, by the overexposure to excesses of solar radiation and the inadequate management of its use and occupation, which resulted in an increase in the number and frequency of floods in urban and rural areas in several parts of Brazil and the world (ARAGÃO *et al*., 2013) providing destruction of property and human lives (MCT / CGE, 2002).

Considering the Brazilian agricultural capacity, data from the Ministry of Agriculture, Livestock, and Supply (MAPA, 2012) disclose that many of the agricultural losses that occurred in the past decade in the country were due to the farmer's lack of knowledge about the behavior of rain distribution as well as the performance of extreme events. As a consequence, projects and studies are currently being implemented to expand information about different study areas with different agricultural aptness, with special regards to cropping regions with low climatic risks as well as the adoption of measures to prevent drought and excessive rain, allowing forecasts that help in the guiding and optimization of the cultural treatments to be implemented and the behavior to be expected in the productivity of the developed crop.

In this context, the quantification of extreme rainfall can be performed by means of equations characterized by their intensity (I), duration (D) and frequency (F), denominated IDF Equations, which relate such parameters of occurrence of an event with a determined return period (SOUZA *et al*., 2012). The parameters of these equations are based on values extracted from rainfall time series, which can be adjusted through the use of statistical methods, such as linear regression or non-linear regression (ARAGÃO *et al*., 2013).

The classic paper of intense rainfall studies in Brazil was published by Pfafstetter (1957). Currently, several studies on changes in rainfall patterns have been developed on all continents, primarily evidenced by the extreme occurrences observed in the last decades, as well as due to changes in climates with evident losses (SALGUEIRO *et al*., 2014). In this context, authors deploy their studies in different locations to adjust the IDF equations, in which can be quoted the city of São Paulo (SCHARDONG and SIMONOVIC, 2013), the state of Santa Catarina (BACK *et al*., 2012), the city of Porto Alegre (WESCHENFELDER *et al*., 2015) and the Northeast region, the state of Sergipe (ARAGÃO *et al*., 2013), the state of Piauí (CAMPOS *et al*., 2014), the state of Maranhão (CAMPOS *et al*., 2015), the state of Paraíba (CAMPOS *et al*., 2017) and the state of Rio Grande do Norte (SILVA *et al*., 2018).

On the other hand, for the state of Alagoas, only the capital city of Maceió has provided the parameters of the IDF equation, estimated by Denardin and Freitas (1982). Therefore, it is important to estimate the parameters of the IDF equation for other locations in the state due to the spatial variability of rainfall. It is important to update the equation, expanding the study to the entire state, since the existing equation has been used for over 30 years.

Thus, the objective of this study was to estimate the parameters (K, a, b, c) of the equation of intensity, duration and frequency (IDF) for municipalities in the state of Alagoas, through 164 rainfall stations available at the National Water Agency (ANA), as well as spatialize the maximum likely intensities of rainfall for the entire State of Alagoas for different durations and frequencies.

MATERIAL AND METHODS

The state of Alagoas has a total area of approximately 2,7843.295 km², totaling 102 municipalities and considered as the third smallest state in Brazil (IBGE, 2017). The state is inserted in the hydrographic basins of the North Atlantic - North / Northeast Section and the São Francisco river basin and sub-basins of the Eastern Northeast Atlantic and São Francisco (MARCUZZO, 2017). According to the Köppen classification, the climate of the region is predominantly characterized in a tropical zone with dry summer - As (71%), followed by a semi-arid dry zone - BSh (14.9%) and tropical monsoon zone - Am (11.7%) (ALVARES *et al*., 2013). The state stands out particularly for the spatial and temporal irregularities of the rainfall, with greater prominence in the regions of Agreste and Sertão (MARCUZZO, 2017).

The average annual rainfall for the state of Alagoas is 1032.5 mm (CPRM, 2011). Because of its location in the tropical zone, there is an occurrence of low rainfall totals in the region, which is explained by phenomena such as El Niño - Southern Oscillation (ENSO), general circulation of the atmosphere (NOBRE, 1986; MOLION and BERNARDO 2002), and, yet, directly related to the atmospheric and oceanic circulation configurations on a large scale over the tropics, in which the Intertropical Convergence Zone (ITCZ); the frontal systems (FS); the South Atlantic Convergence Zone (SACZ); the Eastern waves; and the North and Southeast Trade Winds (BARROS *et al*., 2012) are mentioned.

This study used the data on rainfall available in the database of the National Water Agency (ANA, 2016) with a guarantee of more than 20 years of daily observations and with data after the year 1980. The data were analyzed based on corrections of inconsistencies in the historical time series, as well as the need for historical series over 20 years of daily observations, for 164 rainfall stations, distributed in different municipalities in the state of Alagoas. Because of the large number of adjusted equations, many municipalities presented more than one equation, thus, it was decided to present only one equation per municipality, with the exclusion following the criteria in the order: i) the largest historical data series; ii) presence of more recent data; iii) greater R^2; iv) slope of the line closest to 1,000 (Figure 1).

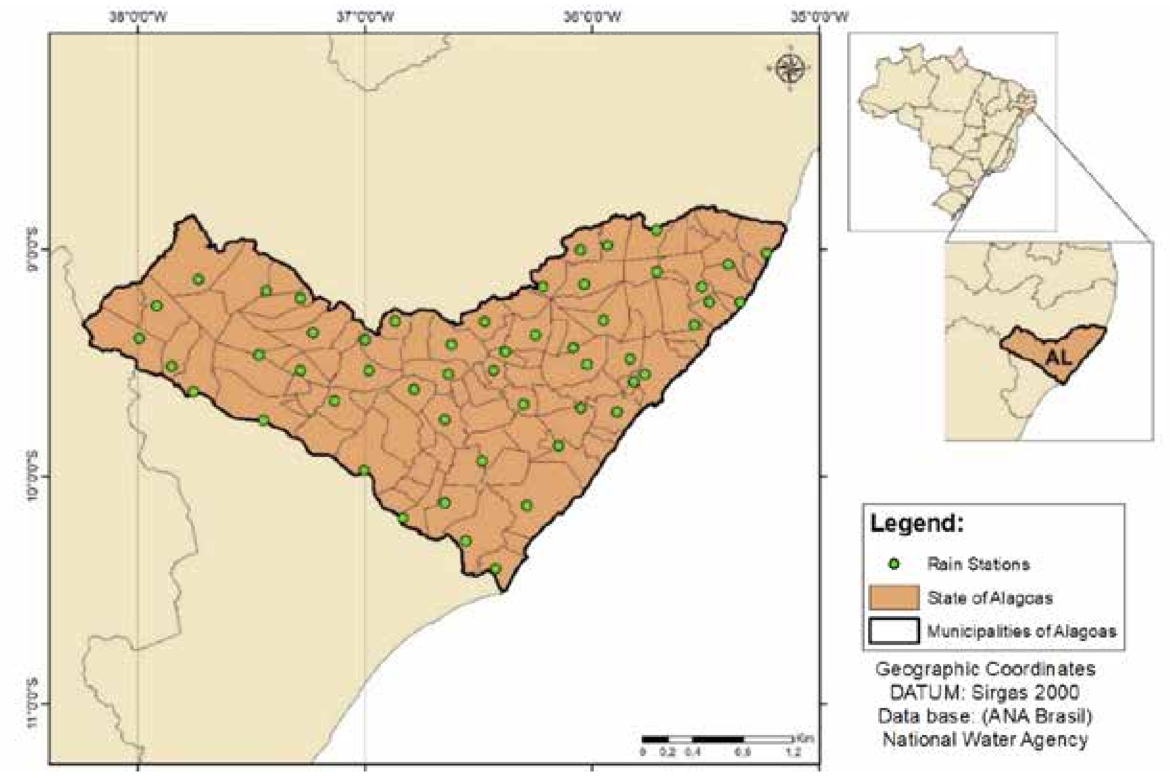

Figure 1. Study area location

The maximum 1-day rainfall series, which was sequentially based on the study stations, for the return periods (TR) of 5, 10, 15, 20, 50 and 100 years was sequentially obtained using the study station based on the application of different probability distributions of the Gumbel type; Log-Normal II; Log-Normal III; Pearson III; Log-Pearson III (NAGHETTINI and PINTO, 2007). The station was selected based on the greater adherence to the probabilistic model through the lowest average standard error observed. It is guaranteed that the probability of the occurrence of the rainfall event is obtained using a probability distribution function, allowing extrapolation of information in the form of years in addition to the number of years used as actual observed data, since the variation in intensity frequency is closely related to the study event (OLIVEIRA *et al*., 2005). All of these steps were performed with the aid of the SisCAH software (SOUSA *et al*., 2009).

The rainfall disaggregation method used in the study follows recommendations from Cetesb (1979), in which the disaggregation of one-day rainfall is reduced in intervals of 5, 10, 15, 20, 25, 30, 60, 360, 480, 600, 720 and 1440 minutes. After the disaggregation of rainfall, the parameters K, a, b, and c of the IDF equation (intensity-duration-frequency equation) were determined (Equation 1).

$$IDF = \frac{K.TR^{a}}{(t+b)^{c}} \quad (1)$$

where,
IDF= intensity, duration and average maximum frequency of rainfall, mm h^{-1};
TR= return period, years;
t= rainfall duration, min; and
K, a, b, and c= parameters adjusted based on the rainfall data of the location.

The parameters of the IDF equations were adjusted based on the non-linear multiple regression model using the Generalized Reduced Gradation (GRG) iteration method, using the coefficient of determination (R^2). The adjustment was also evaluated by means of the angular coefficient of the line, with a relationship between the data observed and estimated by the linear regression equation. These steps were performed with the aid of the Solver in Excel (SOLVER, 2010).

The GRG parameter optimization method is considered to be very efficient for the general solution of nonlinear optimization problems (SACOMAN, 2012). In studies described by Silva *et al*. (2018) and Campos *et al*. (2014), the GRG method was also used and it is highlighted that the non-linear regression method performed better when compared to the linear regression method, thus evidencing the choice of such applications in this study.

Based on the adjusted IDF parameters, estimates of maximum intensities of rainfall were carried out, considering the duration of 10 and 30 minutes. These values were chosen based on characteristics of the rainfall that promotes large platforms normally with a short duration and a return period of 10 and 50 years, which are the most used values for estimating hydraulic projects and works.

The spatialization of data for maximum intensity estimates for the entire state of Alagoas was developed in the R software (R DEVELOPMENT CORE TEAM VIENA, 2005) with the aid of the geoR package (RIBEIRO JUNIOR and DIGGLE, 2001) through the adjustment of semivariograms and trend analyses of the study data, using the Ordinary Kriging as the interpolation method used in the study. The subdivision into areas was done with the aid of maximum rainfall intensity data with manual ordering. The maps were elaborated in the SIG environment using the ArcGIS 10.6 software (ESRI, 2012).

RESULTS AND DISCUSSIONS

For the state of Alagoas, 61 stations from the 164 rainfall stations were initially discarded with data provided by the National Water Agency (ANA). This disposal proceeded because of the lack of data or the non-fulfillment of minimum criteria for data registration. Therefore, the IDF parameters were adjusted based on the 103 rainfall stations owned by the State. Due to a large number of adjusted stations, it was decided to present only one station per municipality, resulting in 52 municipalities with adjusted equations out of the 102 municipalities in the state of Alagoas (Table 1).

Table 1. Adjusted values for the parameters of the intensity-duration-frequency equation (IDF) and the respective coefficient of determination (R^2) for 52 municipalities in the state of Alagoas, Brazil

Municipalities	Code	K	a	b	c	R^2
Água Branca	00937009	949.226	0.157	13.414	0.782	0.998
Anadia	00936070	779.941	0.149	11.067	0.758	0.999
Arapiraca	00936066	598.533	0.254	14.102	0.788	0.997
Atalaia	00936010	795.141	0.141	11.519	0.763	1.000
Batalha	00937010	597.361	0.285	9.461	0.741	0.991
Cacimbinhas	00937011	826.880	0.170	12.777	0.776	0.998
Capela	00936014	868.789	0.178	13.598	0.784	0.998
Colônia Leopoldina	00835072	639.253	0.221	11.995	0.768	0.997
Coruripe	01036012	811.600	0.251	9.307	0.740	0.998
Craiba	00936015	563.358	0.260	14.523	0.792	0.996
Delmiro Gouvéia	00937013	868.240	0.214	14.600	0.793	0.997
Ibatequara	00835073	699.468	0.107	12.753	0.775	0.999
Igaci	00936019	672.673	0.298	8.694	0.733	0.997
Igreja Nova	01036003	779.721	0.176	10.985	0.758	0.999
Jequiá da Praia	00936056	628.558	0.175	9.132	0.738	0.998
Joaquim Gomes	00935055	1073.707	0.146	14.075	0.788	0.997
Junqueiro	00936020	707.223	0.213	12.247	0.770	0.998
Maceió	00935004	1370.474	0.132	13.362	0.781	0.998
Major Isidoro	00936028	639.190	0.171	11.433	0.762	0.999
Mar Vermelho	00936031	765.850	0.231	10.006	0.747	0.998
Maragogi	00935010	735.564	0.157	7.021	0.713	0.996
Maravilha	00937004	781.849	0.164	11.677	0.765	0.999
Marechal Deodoro	00935057	1142.655	0.080	9.826	0.745	0.999
Mata Grande	00937014	669.343	0.222	8.443	0.730	0.998
Matriz de Camaragibe	00935011	467.039	0.272	12.265	0.771	0.996
Santa Luzia do Norte	00936032	1132.251	0.152	9.519	0.742	0.999
Minador do Negrão	00935012	809.408	0.165	13.897	0.786	0.998
Murici	00937016	825.268	0.162	10.183	0.749	1.000
Olho d'água das Flores	00937017	531.418	0.222	11.330	0.761	0.999
Olho d'água do Casado	00937012	593.788	0.268	9.955	0.747	0.998
Ouro Branco	00936035	560.832	0.184	13.090	0.779	0.999
Palmeira dos Índios	00937018	783.341	0.167	10.949	0.757	0.998
Pão de Açúcar	00935013	689.233	0.162	13.861	0.786	0.998
Passo de Camaragibe	01036005	1333.680	0.141	12.215	0.770	0.998
Penedo	01036007	835.491	0.174	9.968	0.747	0.999
Piaçabuçú	00937023	992.811	0.139	12.690	0.775	0.998
Piranhas	00935016	604.207	0.220	11.126	0.759	0.999
Porto de Pedras	01036009	963.570	0.296	12.827	0.776	0.992
Porto Real do Colégio	00936115	612.421	0.217	9.409	0.741	0.998
Quebrangulo	00935021	770.141	0.118	11.299	0.761	0.999
Rio Largo	00935023	465.118	0.341	11.418	0.762	0.984
Santana do Ipanema	00937006	723.795	0.178	11.441	0.762	0.999
Santana do Mundaú	00936045	797.748	0.147	10.450	0.752	0.999
São José da Laje	00936112	682.010	0.103	8.337	0.729	0.998
São Luís do Quitunde	00935025	1695.470	0.290	19.843	0.838	0.987
São Miguel dos Campos	00936016	15785.423	0.116	65.950	1.118	0.949
São Miguel dos Milagres	00935028	729.995	0.146	7.162	0.715	0.997
Senador Rui Palmeira	00937005	528.095	0.188	14.586	0.793	0.997
Tanque d'Arca	00936052	839.207	0.098	10.273	0.750	0.999
Traipu	00936076	840.353	0.086	12.995	0.778	0.999
União dos Palmares	00936113	680.450	0.112	8.344	0.729	0.998
Viçosa	00936111	642.094	0.140	8.979	0.736	0.999

Source: Prepared by the authors.

In this analysis of the maximum rainfall associated with a return period, the data showed adherence to the Kolmogorov-Smirnov test, in which the probabilistic distribution of Log-Normal 3 showed the highest data prevalence. It was found that the lowest value of the average standard error was observed for the station of the municipality of Palmeira dos Índios of 1.69, with maximum rainfall associated with the return period of 5 years of 66.94 and Pearson-3 Probabilistic Distribution. The highest average standard error value was observed for the station in the municipality of Igaci of 47.82, with maximum rainfall associated with the return period of 100 years of 270.09 and Gumbel Probabilistic Distribution.

Rainfall was disaggregated and the parameters of the IDF equation were adjusted by means of non-linear multiple regression, according to the Generalized Reduced Gradation (GRG) iteration method (Solver, 2010). The adjusted parameters for the municipalities of Alagoas are shown in Table 1. All adjustments to the equations showed a determination coefficient (R^2) greater than 0.949 and with a mean value (R^2) of 0.989. The R^2 of 0.659 for the Jacuípe station resulted in the exclusion of this station from the study since it was not classified as a "very strong correlation" as presented by the other stations. The same was found when observing the angular coefficient of the line, which was closer to 1.0 for the other analyzed stations.

All IDF parameters varied from one station to the other (Table 1), which is explained by the great variability of the spatial and quantitative distribution of rainfall in the state of Alagoas. Regarding the adjusted parameters, parameter "a" has an amplitude ranging from 0.080 to 0.341 for the municipalities of Marechal and Rio Largo, respectively. The parameter "b" had values ranging from 7.021 to 65.950, with a lower value for the municipality of Maragogi and a higher value for the municipality of São Miguel dos Campos. The "c" parameter ranged from 0.713 to 1.118 for the same municipalities and stations as the "b" parameter. The amplitude of the "K" parameter was 465,118 for the municipality of Rio Largo and 15785,423 for the municipality of São Miguel dos Campos. No negative values were found for the evaluated parameter.

Great variability is found between the values of the estimated parameters, considering a wide range between the same parameter, and among the various parameters, with the largest variation found for parameter "K" of 15320,304 and the smallest variation for "a" parameter of 0.262. In studies proposed by Campos *et al*. (2014) and Silva *et al*. (2018), a wide range of variation was found for the parameters adjusted for the IDF equations, as verified in this study, in particular. This variability reinforces the importance of obtaining the intensity, duration, and frequency relationships for each location, revealing specific characteristics linked to the distribution of rainfall in the state.

The comparison between the outcome of the equation obtained in this study with the equation obtained by Denardin and Freitas (1982) for the municipality of Maceió (the only municipality in the state with an adjusted equation in the literature) showed that the value of determination coefficient (R^2) of 0.998 was higher than that of 0.983 of the referred authors, therefore, it could have been observed the update of the equation effectively, with a rise in the coefficient of determination (R^2), expansion of the study to greater representativeness of the state of Alagoas and greater coverage of the studied cities (Table 2).

The comparative analysis between the two equations allowed to conclude that, by varying the values of RP and t, it is possible to infer for the equation proposed in this study, that for lower values of t and higher values of RP, higher values of the average intensity of rainfall are observed, thus evidencing, as the equation was updated, the rise in the frequency of more intense short-term rains for the capital Maceió, a fact that is not observed in the average intensity of rainfall in the equation proposed by Denardin and Freitas (1982).

Table 2. Comparison between the adjusted maximum rainfall equations and the literature

Code	Municipalities	Adjusted Equation	R^2	Literature Equation	R^2
00935005	Maceió	$IDF = \frac{1370.474 * TR^{0.132}}{(t + 13.362)^{0.781}}$	0.998	$IDF = \frac{274.09 * TR^{0.28}}{(t + 6)^{0.56}}$	0.983*

Source: Prepared by the authors.

*R^2 (determination coefficients) obtained by Denardin e Freitas (1982).

The maximum likely intensities were spatialized with return periods (RP) of 10 years and 50 years and duration of 10 and 30 minutes as shown in Figure 2.

After the spatialization of the rainfall data, it was identified that the rainfall station in the municipality of Flexeiras showed very high values in relation to the other stations, so, this station was disregarded, even with a value of R^2 of 0.970, highlighting the need for spatialization of the data.

The highest and lowest values of maximum likely rainfall intensities in mm h^{-1} obtained through the IDF parameters were the municipalities of São Luís do Quitunde and the municipality of Senador Rui Palmeira, respectively, for all the return periods and durations considered in this study as described in Table 3. It is observed that the increment in this quantity occurs as the return period is increased and it is reduced as the duration of the rain is increased, so it observed that the difference between the municipalities of different regions is as much as twice or three times higher, which justifies the importance of this study in the estimation and use of IDF equations.

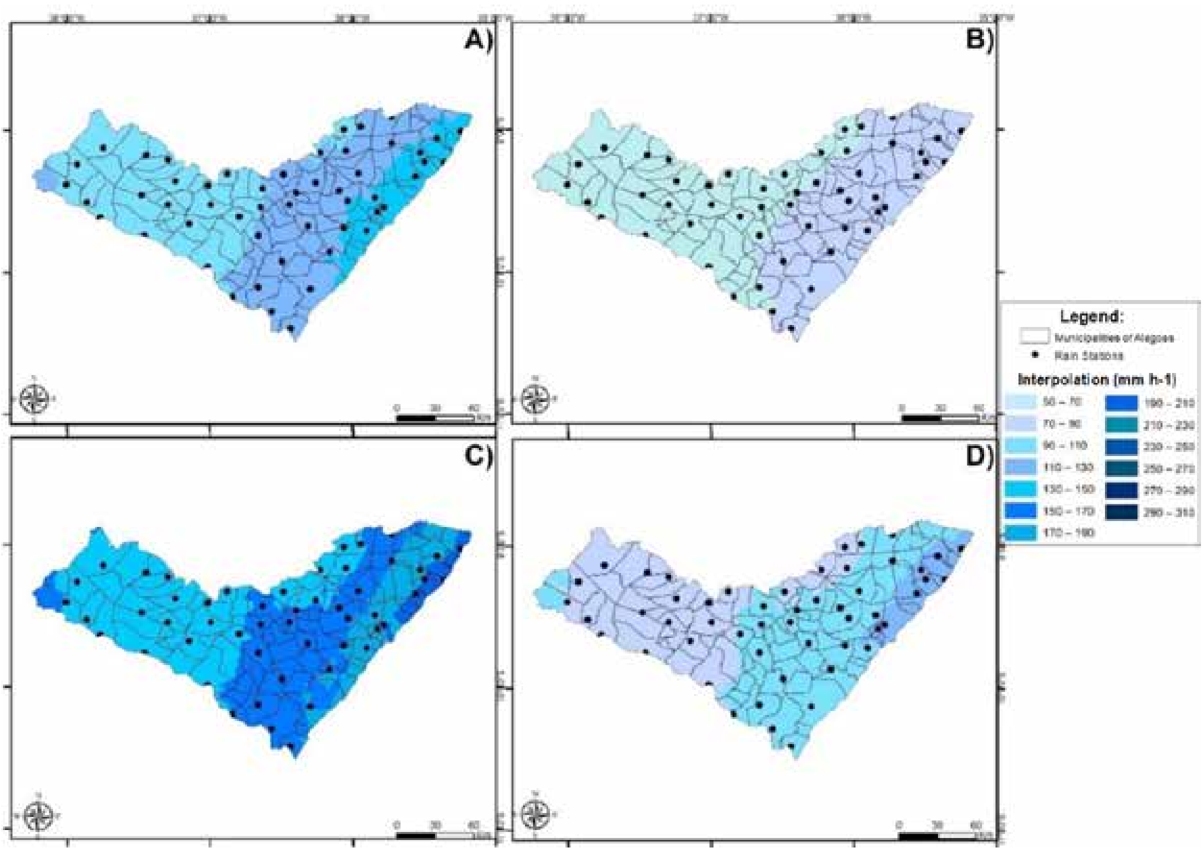

Figure 2. Spatialization of the maximum likely intensities estimated for the state of Alagoas: 10-year return period and 10-min (A), 30-min (B) duration, and 50-year return period and 10-min (C) and 30-min duration (D)

Table 3. Maximum and minimum values of maximum likely rainfall intensities (mm h^{-1}) with their respective municipalities for the return periods (RP- years) and durations (t- minute)

Municipalities	TR 10 t 10	TR 10 t 30	TR 50 t 10	TR 50 t 30
Senador Rui Palmeira (minimum)	64.274	40.093	86.986	54.260
São Luís do Quitunde (maximum)	191.759	124.731	305.858	198.948

Source: Prepared by the authors.

The spatialized results of the maximum probable intensities estimated for the state of Alagoas demonstrate similar spatial distribution behavior in the categories of classes when considering the same duration of rainfall, 10 minutes (Figure 2 - A and C) and 30 minutes (Figure 2 - B and D) for each return period in the study. Thus, this spatialization allowed to identify that the highest intensities, regardless of the period of return in the study, occur in the mesoregion of Eastern Alagoano and the lowest intensities occur mainly in the mesoregion of the Sertão Alagoano.

The typical farming system in the Alagoas state has been associated with the production of sugar cane since its historical formation, especially in Eastern Alagoas, as despite several crises faced by the sugar and alcohol sector, sugar cane remains the balance for the agricultural economy of the state, in particular, its production for export. This is the region with the highest productivity and profitability in the state since it concentrates the best lands for the production and potential development of tropical agriculture (SEPLAG, 2016), however, it reveals characteristics of the highest rainfall intensities, regardless of the return period of the study, which must be carefully evaluated and monitored, since these consequences may influence the productive and economic capacity of the region.

According to a study of the rainfall stationarity in the city of Maceió (SALGUEIRO *et al*., 2017), the results of the statistical tests show that there are growing trends in the rainfall in the city of Alagoas, therefore, water resource planning should prioritize a greater action with water excesses rather than with scarcity, and the relevant agencies should evaluate drainage projects, with a view to the predominance of greater surface runoff in the future, as it was also evidenced in this study.

The municipality of Senador Rui Palmeira is located in the western region of the state inserted in the mesoregion of the Sertão Alagoano and is currently included in the list of municipalities from which the government of Alagoas renewed the emergency decree due to drought (DOU, 2019). The municipality in question falls within the Drought Polygon, an area established by the state that recognizes the effects of nature on the socio-spatial organization of the territory as well as its population, therefore defining specific and effective actions that address the demands of the region with special criteria (SUDENE, 1997).

On the other hand, the municipality of São Luís do Quitunde is located in the eastern region of the state inserted in the microregion of Mata Alagoana, which integrates the mesoregion of Eastern Alagoano. The municipality stands out in the Brazilian news, showing issues with floods. Through the state's Technical Cooperation Agreement, the alert system was organized in the main hydrographic basins with a history of floods in the state of Alagoas for surveillance and control of risk situations. Currently, it has equipment installed in several municipalities, including São Luís do Quitunde, which are responsible for monitoring and transmitting information about rainfall and the level of the rivers in real time (SEMARH-AL, 2019).

Considering the possibility of carrying out studies within the limits of two or more municipalities in the state, which would comprise several equations described by this study, it was proposed to subdivide the state into three regions for the applicability of three equations based on data of maximum likely rainfall intensity obtained by the spatialization previously described (Figure 2). For each region of the subdivision, the application of the most restrictive parameters was proposed, so for regions A, B, and C, the parameters referring to the municipalities Joaquim Gomes, Olhos D'água do Casado and São Luís do Quitunde are used respectively (Figure 3). It is noteworthy, however, that for the case of study applicability between bordering regions, it is recommended to use the parameters referring to the most restrictive region, which guarantees greater reliability for the study to be carried out.

Based on the Agroecological Zoning of the state of Alagoas (ZAAL-EMBRAPA, 2014), which aims to generate useful information for planning and improving the use of land and water in the state, it was considered in its development a different approach from the traditionally climatic zoning that is carried out, which was based on historical averages of monthly rainfall totals with an indication of climatically most suitable areas for the cultivation of each species of agricultural interest, with a focus on pedoclimatic aptitude for the crop based on maps of climatic aptitude and pedological aptitude with emphasis on eight crops of agricultural interest: herbaceous cotton, sugar cane, Phaseolus beans, Macassar beans, castor beans, cassava, corn, and sorghum.

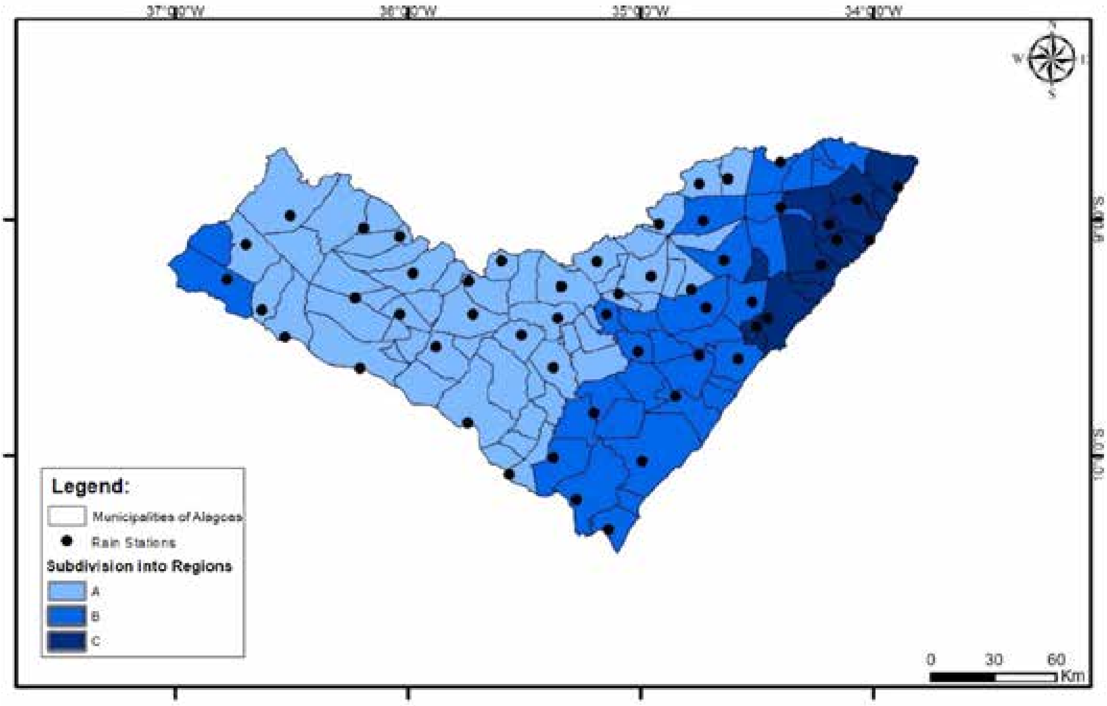

Figure 3. Subdivision regions of the state of Alagoas based on the maximum likely rainfall intensities

As a result, it is reported that drier regions restrict the cultivation of almost all crops in the semi-arid region of the state (VIRÃES, 2018). Nevertheless, in regions that present moderate water excess and a likely action of extreme events, as part of the region of the Forest and Coat Zone, has potential risks of harming the harvest and drying of grains, given the fact that prolonged and intense rains in the period of crop growth cause a reduction in productivity, delay in harvest, lodging of the plants consequently reflecting in low yield and quality of the implemented cultures (HEINEMANN *et al*., 2009; SILVA *et al*., 2009). However, the importance of studies focusing on rainfall events is highlighted to understand the dynamics of behavior, especially in tropical agriculture in the state of Alagoas, to synthesize the difficulties in maintaining the standard of quality and efficiency of productivity and profitability in predominantly hot and humid climates.

The application of this analysis to the municipalities of the state of Alagoas, according to the equations proposed by the parameters described in the study, is mainly associated with the dimensioning of hydraulic works for urban and soil drainage, flood control, erosion modeling and control in agricultural areas, soil management, and conservation, mapping of potential areas for the occurrence of floods and erosion, among other applications. In such situations, according to the specific characteristics of the proposed work associated with different periods of return and periods of duration of intense rains, it becomes possible to estimate the intense rain associated with a certain frequency of occurrence, carrying out prevention projects and thus ensuring that costs of the investments are sufficient to meet the risk control and optimization project for extreme events.

CONCLUSIONS

- The number of municipalities served with the intensity-duration-frequency equations was expanded to the state of Alagoas, which previously included only the capital Maceió and now serves 52 municipalities, totaling 51% of the municipalities in the State of Alagoas;
- According to the spatialization for the different durations and return periods, the highest expected intensities of rainfall were observed in the eastern mesoregion in the State of Alagoas and the lowest intensities in the Sertão Alagoano mesoregion.

- The characteristic of the state of Alagoas, as it presents a wide range in the spatial distribution of rainfall, shows the importance of studies of this nature, which aids in making intelligent decisions, since they support the correct conception of control projects and agricultural works.

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