DOI: 10.5965/223811712332024454

Revista de Ciências Agroveterinárias 23 (3): 2024
Universidade do Estado de Santa Catarina

Intensity-Duration-Frequency Relationships of intense rainfall in Lages, SC

Relações Intensidade-Duração-Frequência de chuvas intensas de Lages, SC

Romeu Souza Werner[1(0000-0003-4396-5382)], Ildegardis Bertol*[2(0000-0003-4396-5382)], Fabrício Tondello Barbosa[3(0000-0002-1724-2327)]

[1]Santa Catarina State University, Lages, SC, Brazil.
[2]Santa Catarina State University, Lages, SC, Brazil. *Author for correspondence: ildegardis.bertol@udesc.br.
[3]Ponta Grossa State University, Ponta Grossa, Brazil.

Submission: 16/11/2023 | Acceptance: 10/05/2024

ABSTRACT

Knowledge of rainfall intensity is essential for planning hydraulic works. With the aim of filling the lack of this information for conservation planning in rural areas, this work aimed to determine the empirical constants of the heavy rainfall equations using precipitation data, and the adjustments of these equations to the observed precipitation. The rainfall data were obtained in equipment (pluviograph and pluviometer) located to the meteorological at the station of the Center for Agro-Veterinary Sciences, in Lages city, Santa Catarina state, Brazil, from 1989 to 2016 (28 years). To obtain the height and intensity of the rainfall in the return periods of 2, 5, 10, 15, 20, 25, 30, 40 and 50 years, the statistical distribution of Gumbel was applied. Parameters were obtained for rainfall periods of up to 240 minutes (Equation I) and from 360 to 1,440 minutes (Equation II). The frequency of intense rain estimated by the Gumbel method, with adherence tested using the Anderson-Darling test, adjusts to the frequency of rain observed in the Lages city. This provides reliability of the probabilistic distribution of the observed data for certain return times and duration of rainfall. The intensity-duration-frequency (IDF) equation fits rainfall data observed over a 28-year and can be used to predict the maximum average rainfall intensity. The IDF I equation is $i=1,285.65Tr^{0.133}(t+14.2)^{-0.87}$, applied to rainfall lasting up to 240 minutes, and the IDF II equation is $i=1,923.06Tr^{0.188}(t+34.85)^{-0.86}$, applied to rainfall lasting between 360 and 1,440 minutes.

KEYWORDS: Gumbel distribution; daily rainfall; return time.

RESUMO

O conhecimento da intensidade das chuvas é essencial para o planejamento de obras hidráulicas. Com o objetivo de suprir a falta destas informações para o planejamento conservacionista em áreas rurais, este trabalho teve como objetivo determinar as constantes empíricas de equações de chuvas intensas utilizando dados de precipitação, e ajustar essas equações às chuvas observadas. Os dados de precipitação foram obtidos em equipamentos (pluviógrafo e pluviômetro) localizados na estação meteorológica do Centro de Ciências Agroveterinárias, na cidade de Lages, Santa Catarina, Brasil, no período de 1989 a 2016 (28 anos). Para obter a altura e intensidade das chuvas nos períodos de retorno de 2, 5, 10, 15, 20, 25, 30, 40 e 50 anos, foi aplicada a distribuição estatística de Gumbel. Foram obtidos parâmetros para períodos de precipitação de até 240 minutos (Equação I) e de 360 a 1.440 minutos (Equação II). A frequência de chuvas intensas estimada pelo método Gumbel, com aderência testada pelo teste de Anderson-Darling, ajusta-se à frequência de chuvas observadas na cidade de Lages. Isto proporciona confiabilidade da distribuição probabilística dos dados observados para determinados tempos de retorno e duração das chuvas. A equação intensidade-duração-frequência (IDF) ajusta-se aos dados de precipitação observados ao longo de 28 anos e pode ser usada para prever a intensidade média máxima de chuva. A equação IDF I é $i=1.285,65Tr^{0,133}(t+14,2)^{-0,87}$, aplicada a chuvas com duração de até 240 minutos, e a equação IDF II é $i=1,923.06Tr^{0.188}(t+34.85)^{-0.86}$, aplicada à chuvas com duração entre 360 e 1.440 minutos.
PALAVRAS-CHAVE: distribuição Gumbel; chuvas diárias; tempo retorno.

INTRODUCTION

The planning of hydraulic works aims to control surface runoff in rural or urban areas. To do this, it is necessary to use intense rainfall in the region. The forecast of intense rainfall is necessary, taking account the spatial and temporal variability of rainfall, using the principle of probability (MELLO & SILVA 2013). With information regarding the average maximum rainfall intensities, it is possible to adequately predict the effect of these rainfalls on runoff. Thus, the hydraulic works necessary for flood control can be appropriately dimensioned, based on the magnitude of the maximum predicted rainfall.

The return time (Tr) of a rainfall is the inverse of the probability that this rainfall will be equaled or exceeded at least once within the period. The Tr of a rainfall is estimated using the probability of occurrence of that rainfall, after the frequency distribution has been adjusted to the extreme data of the historical series. At the same time, in general, the frequency of extreme values in a historical rainfall series is in accordance with the “Fisher-Tippet” type I distribution (VILLELA & MATTOS 1975), known as the “Gumbel” distribution.

Intense rains are distinguished in terms of intensity (I), duration (D) and frequency (F) of occurrence and can be represented by intensity-duration-frequency curves (IDF equations). For these curves to be reliable, they must be obtained by analyzing a long series of extreme rainfall data. The lack of long series of rainfall data, due to the scarcity of collection points at climatological stations and the short period of records, makes it difficult to adjust forecasting models. The lack of this data hinders the proper design of hydraulic works (SILVA et al. 1999 and OLIVEIRA et al. 2005). In addition to the need for relatively long historical series, the data set has regional characteristics, which makes planning hydraulic works even more difficult.

IDF curves based on historical rainfall records can be obtained using two main methodologies: The first consists of disaggregating one day rainfall into shorter durations using specific coefficients (CETESB 1979). By adapting a distribution of extreme values (Gumbel, GEV, log-Gumbel), the height and maximum intensity of rainfall are estimated for time periods of less than 24 hours. In the second methodology, rainfall records are used, identifying the highest intensities in each duration period. For this, maximum intensities are used to adjust the equations, taking in account the duration and time of recurrence.

The equation adjustment method, prepared from rainfall records, offers greater reliability in terms of results, since they are rain sheets and their real durations for the study site. However, this type of equation adjustment sometimes presents limitations when tracing IDF curves. This limitation is due to the low availability of meteorological stations with rain gauges and the difficulty in processing the data contained in rainfall records due to the large volume of information (MELLO & SILVA 2013).

The average maximum rainfall intensity behaves inversely to the duration of the event (TUCCI 1993). Therefore, when correlating only the intensity values with the duration values, for a given return period, it is verified that the greater the intensity, the shorter the duration of the rains, configuring a curve with a hyperbolic shape.

Based on this, it was hypothesized that an intensity-duration-frequency equation would fit the intense rainfall data observed at the meteorological at the station of the Center for Agro-Veterinary Sciences, in Lages, Santa Catarina state, Brazil. In this way, the empirical constants would be obtained, and the adjusted model would be available to support the planning and sizing of hydraulic works in this location.

MATERIAL AND METHODS

To adjust the parameters of the general heavy rainfall equation, the rainfall heights recorded over 28 years (1989-2016) were used. Rainfall height, duration and intensity data were obtained from a rainfall diagram at the station of the Center for Agro-Veterinary Sciences, in the municipality of Lages, Santa Catarina state, Brazil. The nonparametric tests of randomness, stationarity and double mass analysis were applied in order, to identify the adequacy and viability of the data regarding the probability distribution.

The first non-parametric test applied was that of the randomness of the data to identify whether the hydrological magnitude was due to natural causes, verified using the methodology proposed by MELLO & SILVA (2013). The test has as a premise the hypothesis H0, by means of which it is inferred that a historical series of the rainfall is constituted by random data. Second non-parametric test applied to the rainfall data series was that of stationarity, aiming to identify temporal trends, and or, clear cycles within the study period. The third test was the double masses analysis, used to verify the homogeneity of the data. With this test, it was possible to identify whether the variations were the result of anomalies in the rainfall station. The methodology used for this test was developed by the US Geological Survey, based on the construction of a double cumulative curve. This double curve relating the annual totals of the accumulated rainfall of the historical series of 28 years with the data of the Experimental Station of Lages, which is part of the Information Environmental Resources and Hydrometeorology Center of Santa Catarina, Brazil. The results of the non-parametric tests express the requirements that the historical series must meet to obtain reliable fits with the forecasting models applied. The tests allowed to verify the adequacy and feasibility of the data for the study, thus allowing to obtain the parameters for two IDF equations.

The "Equation I" was adjusted to predict mean maximum rainfall intensity values for duration times of up to 240 minutes (4 h). The second, called "Equation II", was adjusted to predict mean maximum rainfall intensity values for duration times between 360 and 1,440 minutes (6 to 24 h). With the values of maximum daily rainfall, the annual series of extreme values were constructed, using data from the computer program (not published) of the Soils Department of the Federal University of Rio Grande do Sul (UFRGS). This program provided the maximum rainfall heights for the durations of 5, 10, 15, 20, 25, 30, 40, 50, 60, 90, 120, 150, 180 and 240 min, assuming limit values established by WILKEN (1978). Data of the rainfall annual were evaluated as to the adherence to the Gumbel distribution, using the Anderson-Darling test ($p<0.05$). The maximum rainfall intensity values possible to be equaled and/or exceeded were calculated for return times of 2, 5, 10, 15, 20, 25, 30, 40 and 50 years.

The analysis of the frequency distribution of the rainfall data and the observed frequencies were obtained using the Kimball method, and the theoretical frequencies through the distribution of probabilities of Gumbel. To obtain the value of the reduced variable of the Gumbel distribution, the frequency distribution function of CHOW (1959) was applied. To evaluate the performance of the adjustment of the theoretical frequencies, estimated by the distribution of Gumbel to the observed frequencies, the coefficient of performance (C) proposed by CAMARGO & SENTELHAS (1997) was utilized. The coefficient of performance (C) is obtained by the reason between the Willmott index product (d) and the Pearson correlation coefficient (R), i.e., $C = d\ R^{-1}$. The values of the parameters **C**, **m**, **t0** and **n** of the IDF equation, obtained through the linearization of the IDF curves, when applying the anamorphosis process, and were adjusted using the Excel software, by application of the "Solver" tool. The software carried out the minimization of the mean square error, iteratively adjusting all the parameters of the definitive IDF equation.

The Equation II was obtained for the rainfall duration times (td) greater than 360 and up to 1,440 minutes, by method of daily rainfall disaggregation, proposed by DAEE-CETESB (1986). Using the maximum values of daily rainfall, values were calculated for shorter durations in the times of 360, 480, 600, 720 and 1,440 minutes, by use of the corresponding coefficient for each rainfall duration time. The maximum rainfall intensity for each time was obtained dividing the rainfall height calculated by the corresponding duration, expressed in mm h^{-1}. With the values obtained by the disaggregation of the rainfall of one day, enough points were obtained for the construction of the IDF curves. Through the same methodology used in Equation I, were obtained the parameters of Equation II.

For the evaluation of the performance and quality of adjustment of the two equations (I and II), the following statistical measures were used: Root Mean Square Error for the standard deviation of the measured data which standardizes the root mean square error using the standard deviation of the observations to evaluate the performance of the adjusted model. The Nash-Sutcliffe Coefficient, which is a normalized statistic that determines the relative magnitude of the residual variance compared to the variance of the observed data, was used to evaluate the efficiency of the model. Percent Trend Index was used for identification and precision, regarding the tendency of sub or overestimation of the model. Finally, the coefficient of determination (R^2), obtained from the relationship between estimated and observed rainfall, was used to assess the degree of adherence between these variables.

RESULTS

The results of the randomness and temporality tests indicate the absence of interference from human action and the effect of time on the behavior of the rainfall data set (Table 1). The values for the number of inflections observed in the series, number of sample data, variance, significance level, equation coefficient and coefficient variance were suitable for this type of adjustment. Using the Double Mass test, the homogeneity of the rainfall data set was confirmed (Figure 1). The relationship between the data showed that there was no change in the slope of the model's adjustment line to the points. The degree of adherence of the data resulted in a very high correlation coefficient ($R^2 = 0.999$) between the data.

The absolute values obtained with the Anderson-Darling adherence test, by means of which the adjustment of the statistical distribution of Gumbel to the observed data was verified, allowed to conclude that the distribution was adjusted to the data (Table 1). The accuracy of the probabilistic distribution adjustment, through the concordance index (d), shoved a perfect agreement between the predicted values and observed values, since the results close to one (1.0) signify agreement and close to zero (0) total disagreement. The accuracy was measured by the correlation coefficient (R = 0.997), which indicated a minimum degree of dispersion of the data obtained in relation to the mean, that is, high precision according to the classification proposed by HOPKINS (2000).

Table 1. Results of the non-parametric tests applied to the dataset of the historical series of rainfall intensities, of the Willmott's accuracy or concordance index (d), of the correlation coefficient (R), and of the performance index (C), obtained in the calculation of the Gumbel distribution, for Lages City of 28 years (1989 - 2016)

Test	Ni	N	E (Ni)	Var (Ni)	α	Critical Value	|t|
Value randomness	16	28	17.33	4.656	0.05	1.96	0.618
Conclusion: H0 hypothesis accepted (random series)							
Stationary	Cs 0.038	-	-	Var (cs) 0.037	0.05	1.96	|t| 0.196
Conclusion: H0 hypothesis accepted (stationary series)							

Parameter	Value	Performance
d	0.998	-
R	0.997	Almost perfect
C (d R^{-1})	0.995	Grat

Ni: number of inflections observed in the series; N: number of sample data; E (Ni): hope for Ni; Var (Ni): variance of Ni; α: level of significance; | t |: test statistic; Cs: coefficient of the equation; Var (cs): coefficient variance "cs".

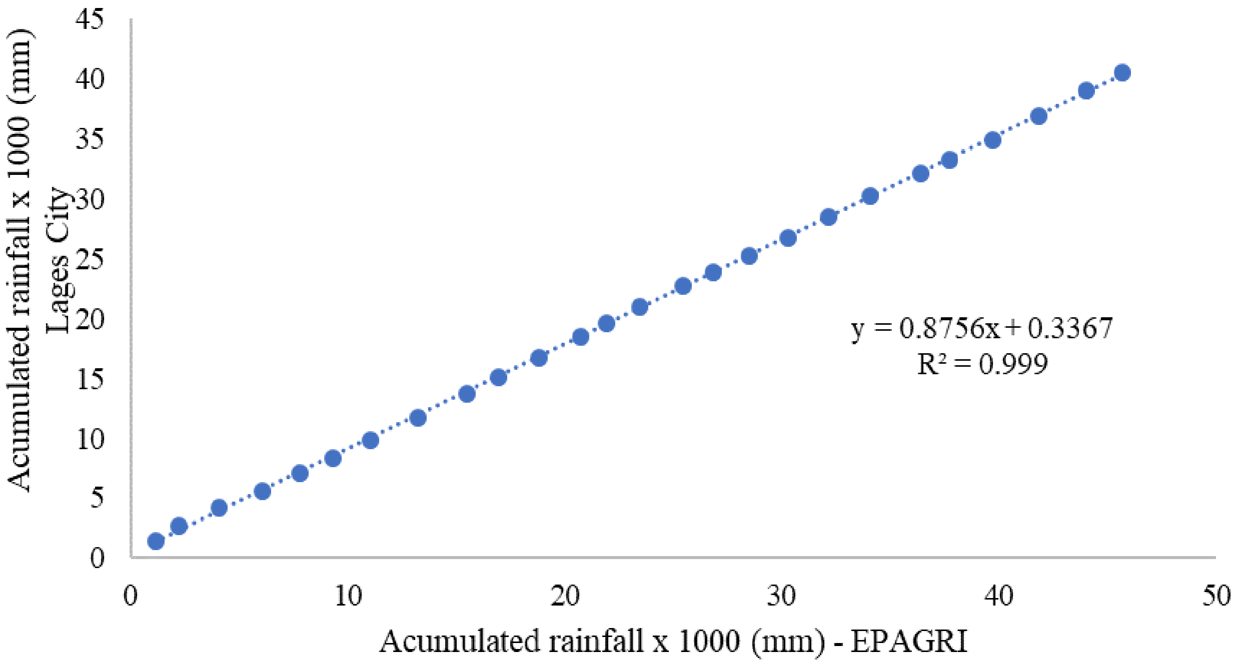

Figure 1. Curve adjusting the precipitation values for the Lages city to the rainfall values from the EPAGRI Meteorological Station, using the Double Mass Analysis method.

Using the Gumbel distribution parameters, it was possible to calculate the maximum rainfall intensity values and compare them to the observed maximum rainfall intensity data (Figure 2). The almost perfect fit was evident in the IDF relationship, which resulted in a straight relationship between the values (R^2 = 0.999), that is, with a slope of the straight line close to one. This indicates how well the probability distribution used was adjusted to the data.

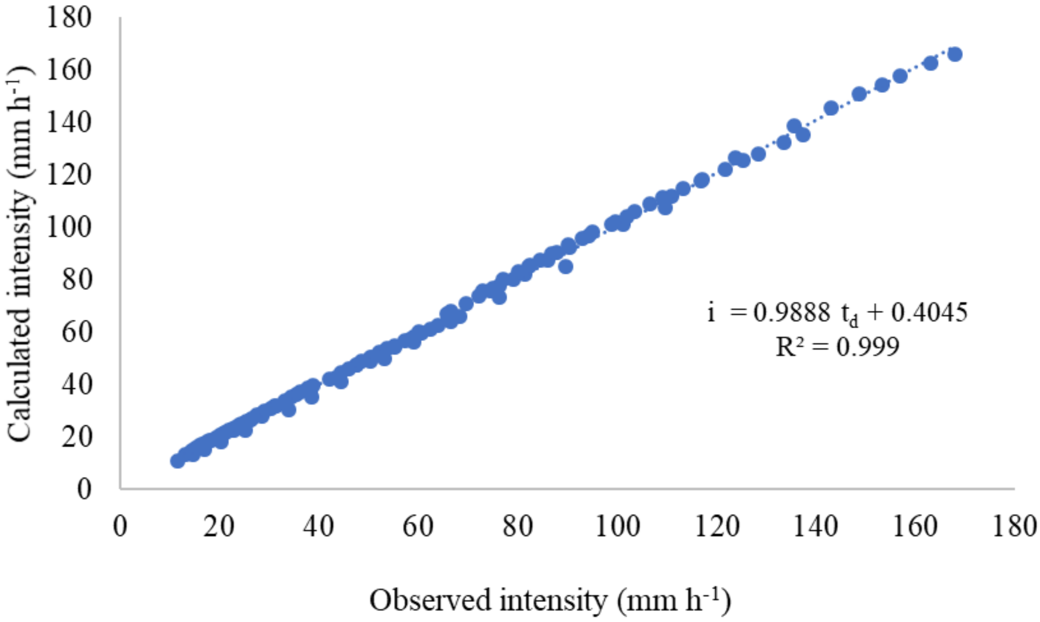

Figure 2. Relationship between observed rainfall intensity values and calculated rainfall intensity values for durations of up to 240 minutes, in Lages city.

The average intensity of rainfall decreased exponentially with increasing duration (Figure 3), regardless of the period and return (Tr) of rainfall, in accordance with the behavior classic normally observed in this relationship. Naturally, the average rainfall intensity value increased with the increase in the rainfall Tr value.

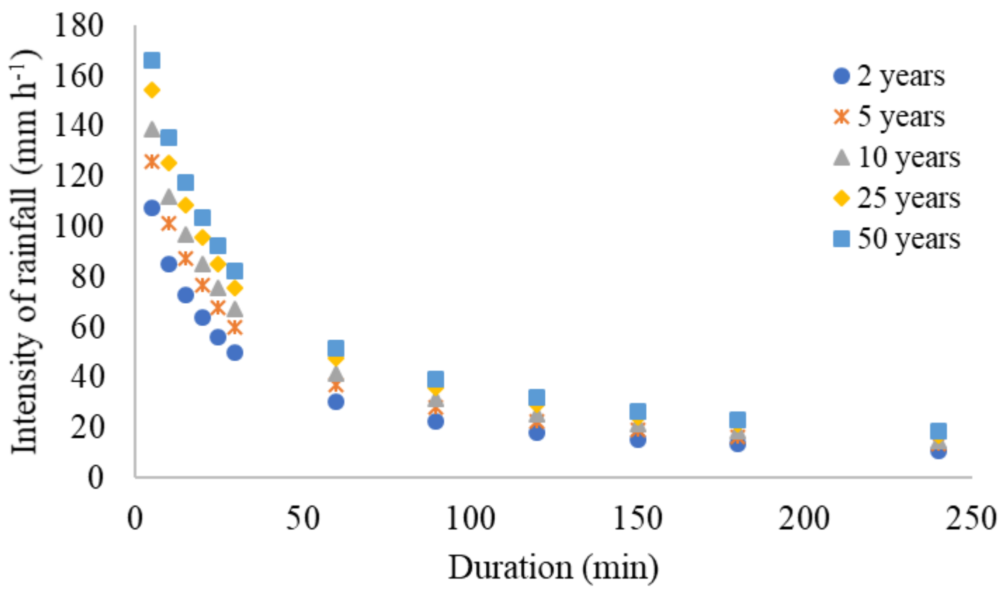

Figure 3. Intensity-duration-frequency curves (IED) resulting from the relationship between the average maximum rainfall and the duration of these rainfall up to 240 minutes (Equation I), obtained with rainfall between 1989 and 2016, for the return periods of 2, 5, 10, 25, and 50 years, in Lages city.

The relationship between the calculated rainfall intensity and the observed rainfall intensity resulted in an excellent fit of the model to the data, with a coefficient of determination (R^2) equal to 0.990 (Figure 4). Furthermore, the slope of the straight line was 44.06º for the angular coefficient of the straight line (0.968). This means that the relationship resulted in excellent adherence of Gumbel's theoretical data series to the data and observed rainfall values.

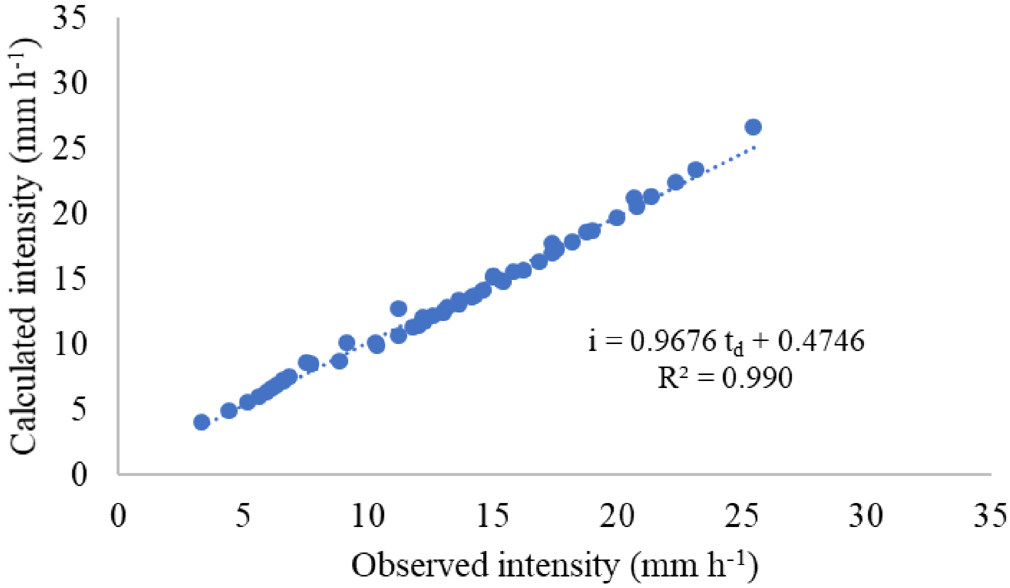

Figure 4. Relation between the observed values of rainfall intensity and calculated rainfall intensity for the duration times of 360 to 1,440 minutes, in Lages city.

The adjusted parameters and the intensity-duration-frequency (IDF) equation II for the data recorded in the meteorological station under study are presented in Table 2. Equation II, adjusted from the disaggregation of the maximum rainfall of 1 (one) day, represents the IDF equation for the study location, which will allow the calculation of the maximum rainfall intensity for duration times of 360 to 1,440 minutes and the return of up to 50 years.

The average intensity of rainfall decreased exponentially with increasing duration (Figure 5), regardless of the period of return (Tr) of rainfall, in accordance with the behaviour classic normally observed in this relationship. Naturally, the average rainfall intensity value increased with the increase in the rainfall Tr value.

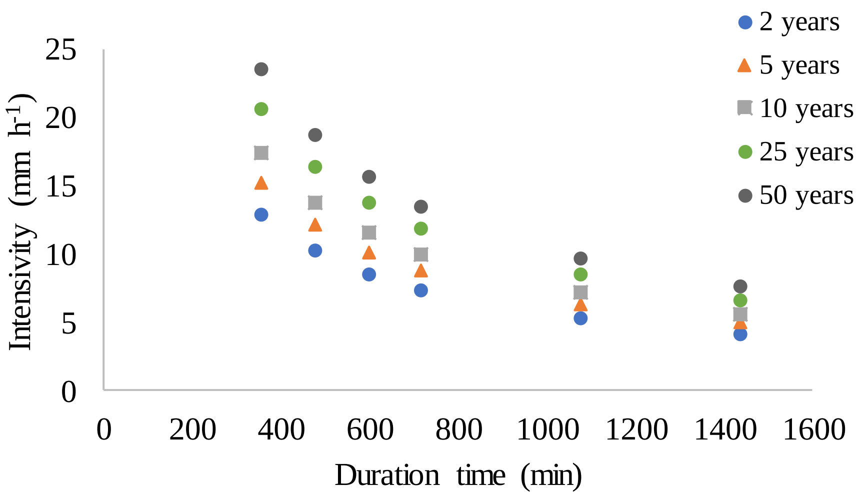

Figure 5. Intensity-duration-frequency (IDF) curves resulting from the relationship between the average maximum rainfall and the duration of these rainfalls between 360 minutes and 1440 minutes (Equation II), obtained with rainfall between 1989 and 2016, for return periods of 2, 5, 10, 25 and 50 years old, in Lages city.

The adjusted equation II shown in Table 2 can be used to predict intense rainfall lasting up to 360 minutes 1,440 minutes for the city of Lages. The intense rainfall predicted by this equation is valid for return periods of less than 50 years. The return period must be expressed in the unit year and the duration of the rains in the unit minute.

The final phase of obtaining the adjusted equation I consisted of adjusting the equation to the index and to the parameters that resulted in the rainfall values in Table 2. For reasons of practicality and aiming to minimize errors, two truncated decimals were adopted in the value of the performance index "C" and in the data adjustment parameter "t_0", and three truncated decimals in the value of the performance index "m" and in the adjustment parameter "n". The adjusted equation I shown in Table 2 can be used to predict intense rainfall lasting up to 240 minutes for the city of Lages. The adjusted equation II shown in Table 2 can be used to predict intense rainfall lasting up to 360 minutes 1,440 minutes for the Lages city. In equation I and equation II, the intense rainfall predicted is valid for return periods of less than 50 years, and the return period must be expressed in the unit year and the duration of the rains in the unit minute.

Table 2. Adjusted parameters and intensity-duration-frequency equation (IDF) for Equation I and II, to be used in the prediction of rainfall intensity for duration times (td) of less than 240 minutes and (td) from 360 to 1,440 minutes, respectively, for Lages city

Parameter				IDF equation I
C	*m*	t_0	*n*	
1,285.65	0.133	14.15	0.865	$i = \frac{1{,}285.65\ Tr^{0.133}}{(t_d + 14.15)^{0.865}}$
Parameter				IDF equation II
C	*m*	t_0	*n*	
1,923.06	0.188	34.85	0.86	$i\ (mm\ h^{-1}) = \frac{1{,}923.06\ Tr^{0.188}}{(t_d + 34.85)^{0.86}}$

C: performance index; m, t0 and n: adjustment parameters.

The first test applied was the Root Mean Square Error (RMS). In this test the result can vary between zero indicating a perfect simulation model, and a high positive value indicating an imperfect simulation model. The value obtained with the RMS test was 0.041 for Equation I and 0.040 for Equation II (Table 3). These values indicate a residual variation close to zero. The lower the residual value, the lower the root mean square error and the better the model performance, according to MORIASI et al. (2007).

Table 3. Results of the statistical tests, applied in the performance evaluation of the adjusted IDF equations, for Lages City.

Test applied	Value obtained	
	Equation I	Equation II
Root Mean Square Error (RMS)	0.041	0.040
Nash-Sutcliffe Coefficient (NS)	0.998	0.998
Percentage Trend Index (PBIAS)	- 0.476	- 0.338
Coefficient of determination (R^2)	0.979	0.970

Next, the test known as the Nash-Sutcliffe (NS) coefficient was applied to verify the efficiency of the IDF equation model (NASH & SUTCLIFFE 1970). The results for both equations were 0.998, which indicated excellent performance (Table 3). The range of acceptable values for a given test varies from 0 to 1. In the case of a negative value, it means that the average of the observed data can provide a better prediction than the values predicted by the model.

The third test applied, called Percentage Trend Index (PBIAS), which recommends almost null results for adequate simulation of the model, resulted in values with similar magnitude and signals. For Equation I the value was -0.476 and for Equation II was -0.338 (Table 3). Both equations presented excellent results, as low values indicate good accuracy in the model simulation. Furthermore, according to MORIASI et al. (2007), negative values indicate a tendency to overestimate the model. Still, in the last test similar results were obtained for the two equations, with values of 0.979 and 0.970 for Equations I and II, respectively. The coefficient of determination (R^2) values can range from 0 (zero) to 1. Zero means no correlation and 1 means perfect correlation. The result of the two equations approached the unit value, indicating how much the variance of the observed values was replicated by the prediction of the adjusted model.

DISCUSSION

The response of the randomness test indicated that the oscillations in the rainfall series were due to natural causes, without anthropic interference. Regarding the stationarity hypothesis, the assumption was confirmed that the data set did not present temporal trends, i.e., there were no clear cycles along the time of observation. In general, the historical of the rainfall data presented the necessary requirements for the application of probability distributions (Table 1). The adherence test applied to the data confirmed the high reliability of the probabilistic distribution and could be adopted for the data of heavy rainfall of the study site. Similar results were found by BACK (2006), COLOMBELLI & MENDES (2013), and CARDOSO et al. (2014). Theses authors obtained satisfactory values of adherence of Gumbel probabilistic distribution to the data, using a significance level of 0.1, in the cities of Videira, Chapecó, and Lages, respectively, in Santa Catarina state.

The criterion proposed by CAMARGO & SENTELHAS (1997) was adopted to interpret the degree of adjustment of the Gumbel distribution, using the **C** index (Figure 1). Based on the results presented in Table 1, and on the classification of the resulting values according to WILLMOTT (1981), CAMARGO & SENTELHAS (1997) and HOPKINS (2000), we conclude that the use of the Gumbel distribution was perfectly acceptable. This acceptance is possible since the combination of the test results revealed the high degree of approximation between the estimated and observed values.

According to BERTONI & TUCCI (2001), when the mean rainfall intensity was related to duration, the values varied inversely for the same return time. This behavior typical, was identified in all curves of Equation I when relating intensity to rainfall duration (Figure 2). Analyzing the IDF curves, estimated by the Gumbel distribution from the disaggregation method (Equation II), it is observed that as the duration of the rainfall increased when its intensity decreased as identified and previously described, typical of the IDF relations.

Using data from the annual series of maximum rainfall of the Meteorological Station in Lages city, between 2000 and 2009 years, CARDOSO et al. (2014) obtained the IDF equation from the analysis of daily diagrams, presented by the following notation: $i=2{,}050Tr0.32(t+42.3)^{-1.21}$. In this equation, **i** is the maximum average intensity, **Tr** is the return time, and **t** is the duration of the rainfall. CARDOSO et al. (2014), established a single equation to be used for times of duration from 1 h to 24 h. In this study, distinctly, to obtain a higher precision two equations were adjusted for different rainfall duration times (Equation I and II).

After adjusting the parameters of the two equations (I and II), some tests were applied to verify the quality of the adjustments (Table 3). From the results, it was then considered, based on the four tests used, that the two models of equation (I and II) were satisfactorily calibrated, because the calculated values of the objective function presented higher values than the minimum quality requirements, for both equations. Thus, these equations can be used to predict rainfall for Lages city.

CONCLUSION

The frequency distribution of the rainfall intensity in Lages city, estimated by the Gumbel method using the Kolmogorov-Smirnov test ($p < 0.05$), is adjusted to the frequency of observed rainfall. This confirm the reliability of probabilistic distribution of the data and can be used in the estimation of intensity for certain return times and duration of rainfall. The intensity-duration-frequency (IDF) equation model adjusts to the rainfall data observed in a 28-year series in Lages city and can be applied to predict the mean maximum rainfall intensity. The IDF equations I is written as: $i=1{,}285.65Tr^{0.133}(t+14.2)^{-0.87}$ and is applied for times of rain duration of up to 240 minutes. The IDF equations II is written as: $i=1{,}500.42Tr^{0.189}(t+42.1)^{-0.82}$ and is applied for times of rain duration between 360 and 1,440 minutes.

ACKNOWLEDGMENT

To the National Council for Scientific and Technological Development (CNPq) for the second author's PQ Grant and for the financial resources to develop the research, and to FAPESC for part of the financial resources spent on the research.

REFERENCES

BACK AJ. 2006. Relação intensidade-duração-frequência de chuvas intensas de Chapecó, Estado de Santa Catarina. Acta Scientiarum Agronomy 28: 575-581.

BERTONI JC & TUCCI CEM. 2001. Precipitação. In: TUCCI CEM. (Org.). Hidrologia: ciência e aplicação. 2.ed. Porto Alegre: ABRH. p.177-235.

CAMARGO AP & SENTELHAS PC. 1997. Avaliação do desempenho de diferentes métodos de estimativa da evapotranspiração potencial no Estado de São Paulo. Revista Brasileira de Agrometeorologia 5: 89-97.

CARDOSO CO et al. 2014. Generation of intensity duration frequency curves and intensity temporal variability pattern of intense rainfall for Lages/SC. Brazilian archives of biology and technology 57: 274-283.

CETESB. 1979. Drenagem urbana: Manual de projeto. São Paulo: Publisher. 479p.

CHOW VT. 1959. Open-Chanel hydraulics. New York: Musgraw-Hill.

COLOMBELLI C & MENDES R. 2013. Determinação dos parâmetros da equação de chuvas intensas para o município de Videira, SC. UNOESC & Ciência 4: 169-180.

DAEE-CETESB. 1986. Departamento de Águas e Energia Elétrica do Estado de São Paulo - Companhia de Tecnologia de Saneamento Ambiental. Drenagem urbana – Manual de projeto. 3.ed. São Paulo: CETESB. 464p.

HOPKINS W G. 2000. Correlation coefficient: a new view of statistics. Available in: <http://www.sportsci.org/resource/stats/correl.html>. Accessed on: 10 Jan 2017.

MELLO CR & SILVA A M. 2013. Hidrologia: princípios e aplicações em sistemas agrícolas. Lavras: UFLA. 455p.

MORIASI DN et al. 2007. Model Evaluation Guidelines for Systematic Quantification of Accuracy in Watershed Simulations. Transactions of the ASABE 50: 885-900.

NASH JE & SUTCLIFFE JE. 1970. River flow forecasting through conceptual models: Part I. A discussion of principles. Journal of Hydrology 10: 282-290.

OLIVEIRA LFC et al. 2005. Intensidade-duração-frequência de chuvas intensas para localidades no Estado de Goiás e Distrito Federal. Pesquisa Agropecuaria Tropical 35: 13-18.

SILVA DD et al. 1999. Estimativa e espacialização dos parâmetros da equação de intensidade-duração-frequência da precipitação para o Estado de São Paulo. Revista Engenharia na Agricultura 7: 70-87.

TUCCI CEM (Org). 1993. Hidrologia: ciência e aplicação. Porto Alegre: UFRGS. 943p.

VILLELA SM & MATTOS A. 1975. Hidrologia Aplicada. São Paulo: Mcgraw-Hill do Brasil. 245p.

WILKEN PS. 1978. Engenharia de Drenagem Superficial. São Paulo: CETESB. 477p.

WILLMOTT CJ. 1981. On the validation of models. Physical Geography 2: 184-194.