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IDF Relationships for Short Duration Rainfall

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Abstract. The intensity-duration-frequency (IDF) relationships bound rainfall intensity to duration and return period. These relationships are commonly used as an input in design of many hydraulic structures and drainage systems. Empirical IDF are estimated on the basis of recorded maximum annual precipitation of given durations, often ranging from 1 h to 24 h. For shorter durations, extrapolations are applied. In this paper, maximum annual precipitation for durations shorter than 1 h (namely, 30 min and 10 min) are evaluated using a rainfall disaggregation model and then used for the evaluation of the IDF relationship. A comparison of values obtained with the extrapolated values is then performed, and the results are discussed. Keywords: intensity–duration–frequency curves, rainfall disaggregation, entropy
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INTRODUCTION

In practical applications, IDF relationships are widely used in planning, designing and operating water resource projects or for protection against floods. Since 1932 [1], many relationships between the intensity (more precisely, the mean intensity) of precipitation (measured in mm/h), the duration or the aggregation time of the rainfall (in hours or minutes) and the return period of the event have been developed [2, 3, 4]. Denoting by i the rainfall intensity (mm/h), δ the duration of the rainfall (min) and T the return period (years), the IDF relationship is then expressed mathematically as follows:

$$i = f(T, \delta) \tag{1}$$

In recent years, several authors have developed approaches for evaluating IDF for short durations of rainfall or in the absence of adequate datasets [5, 6, 7,.8], given that heavy short duration rainfall can affect the reliability of drainage systems and cause flooding in urban areas [9,10]. To assess a methodology for evaluating the IDF relationships for short duration rainfall and scarce data in this study, first the IDF relationship will be evaluated for the Bracciano rain gauge, which is located in Central Italy (42 years of observations), given the maximum annual precipitation for 1, 3, 6 and 24 h. Then, the coefficients obtained will be used for evaluating intensity for shorter durations (1 min, 5 min, 10 min and 30 min). Second, the maximum annual precipitation for durations of 10 min, 30 min, 1 h, 3 h, 6 h and 12 h will be obtained using a rainfall disaggregation model [11] based on the informative entropy concept [12, 13], given the maximum annual daily data. With the disaggregated dataset the IDF will be evaluated again. Finally, the IDF relationships obtained for all durations ranging from 1 min to 24 h will be discussed.

IDF RELATIONSHIPS

In this work, the following form of the IDF relationship is adopted:

$$i_{\delta,k} = \frac{a_k}{(b+\delta)^m} \tag{2}$$

where *k* indicates the order of the relationship, and *a* , *b* and *m* are parameters estimated from data.
The parameters of Eq. (2) depend on the return period T and are estimated as follows:

1. For each standard duration δ, a common type of frequency distribution function is fitted separately for the individual rainfall data.
2. Storm intensities of δ-duration rainfalls for a number of fixed return periods, such as T = 1, 2, 5, 10, 25, 50 and 100 years, are estimated as the T-year quantiles of the fitted distribution functions.

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3. The intensities of the second step for all selected return periods are treated simultaneously, and a relationship of *i* as a function of both δ and T (i.e., $i = i(T, \delta)$) is established by least squares.

IDF Evaluated using Observed Data

The distribution function adopted for fitting data is the Gumbel distribution [14], widely used for IDF estimation :

$$F(i_\delta) = e^{-e(\alpha_\delta(i_\delta - \varepsilon_\delta))} \tag{3}$$

where α_δ and ε_δ are the scale and location parameters, respectively, of the distribution function.
In Table 1 the parameters for each standard duration δ are reported, while in figure 1 the adaptations are shown.

TABLE 1. Gumbel distribution parameters for each standard duration δ

δ	α_δ	ε_δ
1	0.093	27.86
3	0.162	12.78
6	0.320	8.08
12	0.529	4.89
24	0.879	2.95

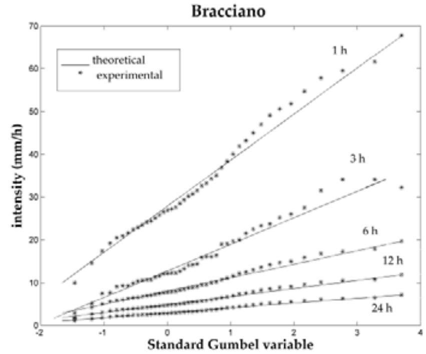

FIGURE 1. Adaptation of intensities to Gumbel distribution

The intensities obtained for each of the previous duration and return times are shown in Table 2.The relationship (2) evaluated from observed data leads to the parameters *b*= 0.144 and *m*=0.745.

TABLE 2. IDF relationships for given T and δ, evaluated from scaling relationship (δ from 0.02 h to 0.5 h) and observed data (δ from 1 h to 24 h)

	d (hours)								
T (years)	**0.02**	**0.08**	**0.17**	**0.5**	**1**	**3**	**6**	**12**	**24**
1	54.2	41.8	33.1	19.2	12.5	8.8	6.1	3.7	2.2
2	142.3	109.8	87.0	50.5	32.9	15.0	9.2	5.6	3.4
5	196.8	151.9	120.4	69.9	45.5	22.1	12.8	7.7	4.7
10	233.0	179.8	142.4	82.7	53.9	26.7	15.1	9.1	5.5
25	278.6	215.1	170.4	98.9	64.5	32.6	18.1	10.9	6.6
50	312.5	241.2	191.1	111.0	72.3	36.9	20.3	12.3	7.4
100	346.1	267.1	211.6	122.9	80.1	41.3	22.4	13.6	8.2

For evaluating the intensities for duration shorter than 1 hour, a scaling factor is adopted:

$$s(\delta) = \frac{i_\delta}{i_1} = \left(\frac{b+1}{b+\delta}\right)^m \tag{4}$$

where b and m are the previously estimated parameters, i_δ is the intensity for the considered duration, and i_1 is the intensity corresponding to δ=1 h. Consequently, the parameters of the distribution are scaled by $s(\delta)$ and the IDF relationships for durations ranging from 1 min to 1 h are also reported in Table 2..

IDF Evaluated using Disaggregated Data

In sites with short rainfall records or only daily data available, resorting to the rainfall disaggregation model can provide useful information. In this study, the disaggregated rainfall for the durations 10 min, 30 min, 1 h, 3 h, 6 h and 12 h is obtained, given the 24-h annual maxima. The disaggregation model [11] is based on the concept of informative entropy, which is widely used in hydrological applications [15, 16, 17].

In Table 3 the parameters for each duration δ are reported, and in Figure 3, the adaptations to the Gumbel distribution for all the durations are shown. The intensities obtained for each of the duration and return times are shown in Table 4.

TABLE 3. Gumbel distribution parameters for each duration δ

δ	α_δ	ε_δ
0.17	0.042	80.02
0.50	0.072	46.46
1	0.105	31.87
3	0.196	17.12
6	0.292	11.49
12	0.463	7.69
24	0.879	2.95

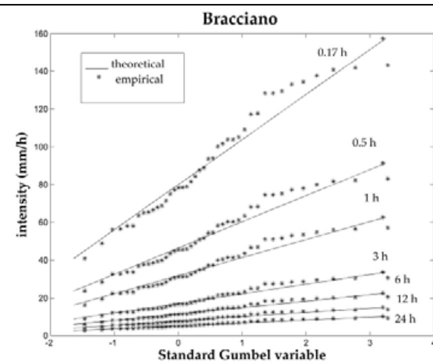

FIGURE 2. Adaptation of intensities to Gumbel distribution

TABLE 4. IDF relationships for given T and δ, evaluated from disaggregated data

	d (hours)								
T (years)	**0.02**	**0.08**	**0.17**	**0.5**	**1**	**3**	**6**	**12**	**24**
1	89.9	59.9	45.1	26.2	17.9	9.6	6.5	4.3	2.9
2	177.2	117.9	88.8	51.5	35.4	19.0	12.7	8.5	5.7
5	231.2	153.9	115.9	67.3	46.1	24.8	16.6	11.1	7.4
10	267.0	177.7	133.8	77.7	53.3	28.6	19.2	12.9	8.6
25	312.2	207.8	156.4	90.8	62.3	33.5	22.5	15.0	10.1
50	345.7	230.1	173.2	100.6	69.0	37.1	24.9	16.6	11.1
100	379.0	252.3	189.9	110.3	75.6	40.6	27.3	18.3	12.2

The relationship (2) evaluated from disaggregated data leads to the parameters b= 0.049 and m=0.582.

DISCUSSIONS OF RESULTS

The comparison of values in Table 2 and 4 and Figure 3 shows interesting results related to the reliability of disaggregated rainfall data for evaluation of IDF relationships..

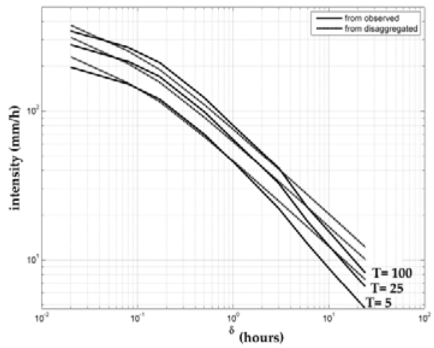

FIGURE 3. Comparison of IDF obtained from observed and disaggregated data, for T=5, T=25 and T= 100 years

For the range of durations between 5 min and 3 h that is particularly relevant for urban flood management, the results are quite similar. These results are promising for evaluating IDF relationship given only daily annual maxima and so useful in contexts of scarce availability of recorded data. For the other durations, the IDF obtained from the disaggregated model offers values significantly higher than from observed data. This factor can lead to overestimation of design variables.

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