International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org ||Volume 6 Issue 7|| July 2017 || PP. 06-10

Temporal Distribution of 24-hour Maximum Rainfall

*Omer Levend Asikoglu
(Ege University, Department of Civil Engineering, 35100, Bornova, Izmir, TURKEY)

Abstract: *Rainfall measurements are an important input to hydrological modeling or design of water structures. For example, while average flows and hence average rainfalls are effective in planning a hydroelectric power plant, minimum rainfall for drought analysis studies and maximum precipitation for flood analysis studies are important. Rainfall measurements can be conventionally measured with devices called pluviometers and pluviographs. The main difference between the two devices is that the pluviometer measures rainfall at certain intervals (generally every 24 hours) while the pluviograph continuously records the amount of the rainfall. With this feature pluviographs are of great advantage in achieving the temporal distribution of rainfall and thus determining the rainfall amount in certain standard durations (5min, 10min, …, 1h, …, 18h, 24h). In this study, an empirical approach was investigated in order to determine the temporal distribution of 24-hour rainfall. By determination of the temporal distribution of rainfall, the rainfall depth of a standard duration can be calculated using the data of a pluviometric station (with a 24-hour rainfall record).*
Keywords: *Temporal distribution of rainfall, pluviograph records*

I. INTRODUCTION

In cases where the project flow of water structures such as flood control, erosion and drainage systems are estimated using synthetic methods, maximum rainfall of certain durations are used as a basic hydrological input. In United States, the Natural Resources Conservation Service has continued working on the development of empirical formulas to improve the Soil Conservation Service (SCS) method for predicting storm runoff from design storm events. The SCS method (1973) presents the 24-hr Type I, IA, II, and IIA rainfall time distributions for runoff predictions. Technical Release 55 (TR-55) presents rainfall distribution maps for the United States. [1, 2, 3]. Guo and Hargadin [3] analyzed a 57-year hourly rainfall data recorded in Denver, Colorado and compared the results with the SCS 24-hr rainfall curves. It is concluded that these SCS 24-hr Type I and II curves are not the statistically averaged, rather, they represent the worst time distribution to form a sever storm. The measurement network of pluviometric stations is much bigger than that of pluviographic stations. The main reason for this is that pluviometer is a more economical tool. Genovez [4] and Mello et al. [5] stated that the time distribution of a design storm should be obtained from data observed in the area of study or from regional data. Back [6] determined the time distribution pattern of heavy rain events in Urussanga, Santa Catarina State, Brazil. Rain events were classified into four types according to the duration quartile in which the greatest amount of precipitation occurred. It is found that type I rain events are more frequent, followed by type II, and these occur predominantly during the summer, while type III and IV rain events are distributed throughout the year. Ghassabi et al. [7] fitted a three-parametric logistic function to the rainfall data in order to compute the temporal rainfall distribution. They examined the spatial variation of the parameters of this distribution. Asikoglu [8] developed two functional approaches for the time distribution of annual extreme rainfall of standard durations. The three-point method and polynomial approach found to represent the time distribution of rainfall successfully.

In this study, the temporal distribution curves of maximum rainfall are successfully represented with a logarithmic relationship. Annual maximum rainfall observations of 14 standard durations (5min, 10min, …, 1h, …, 18h, 24h) of 31 stations in the Aegean region of Turkey are used in obtaining these curves. A generalized relationship is constructed to represent the study area. By determining the temporal distribution of rainfall, it may be possible to shift from maximum 24-hour (or daily) rainfall to the maximum rainfall of another duration. It also allows the calculation of rainfall depths of standard durations at stations without any pluviograph equipment.

II. METHODS

The definition of temporal distribution of precipitation is of great importance in terms of the establishment of synthetic unit hydrograph models. Besides, by using the temporal distribution of rainfall, it is possible to calculate project rainfall of different duration from certain period of precipitation [9, 10, 11] In order to obtain the temporal distribution of the 24-hour rainfall, the largest rainfall amounts of every duration (d= 5min, 10min, …, 1h, …, 18h, 24h) for each year is considered. Then the averages of these maximum values are calculated for each duration and these values are divided by the average of the 24-hour maximums.

$$w_d = X_d / X_{24} \quad (1)$$

When the variation of these values obtained for each station (i=1, 2, …, k) over time is analyzed graphically, it is observed that this change is perfectly defined by the logarithmic equation.

$$w_{d,i} = a_i + b_i . \ln(d) \quad (2)$$

From here, the $w_{d,i}$ ratios were determined for all the stations and the averages (or the regional values, $w_{d,r}$) of the ratios are calculated as in Eq. (3).

$$\overline{w}_d = w_{d,r} = \frac{\sum_{i=1}^{k} w_{d,i}}{k} \quad (3)$$

In the equation, k is the number of stations in the region. Finally, a logarithmic equation is adopted to the series of the averages and a regional logarithmic curve ($w_d = a_r + b_r . \ln(d)$) was determined. The performance of this generalized logarithmic relationship, which defines the rainfall rates (or the temporal distribution) of the whole region, is measured by the correlation coefficients.

III. DATA and STUDY AREA

The study area covers nearly one-eighth of Turkey. The region has a Mediterranean climate with annual mean rainfall ranging from 450 to 1200mm yr^{-1}. This work examines annual maximum rainfalls of 14 standard durations of 34 rain gauge stations from the Aegean region of Turkey. The data were obtained from the State Meteorological Works (DMI). Figure 1 displays the locations of the stations and Table 1 shows geographical characteristics and annual maximum 24-hour rainfall of the stations.

Figure 1. The locations of rain gauging stations

IV. RESULTS

The temporal distribution of 24-hour rainfall was obtained for all pluviographic rainfall stations, with the rates (w_d=X_d/X_{24}) on the vertical axis, and standard rainfall durations (d) on the horizontal axis. It has been found that logarithmic equations are the most appropriate representations of temporal distribution curves in each station. A regional logarithmic temporal distribution curve was obtained at this stage to represent the entire region. For this, the average of the wd ratios of all stations was calculated for 14 different rainfall durations. Then a generalized logarithmic equation was fitted to these averages.

$$w_d = -0,1366 + 0,1437 . \ln(d) \quad (4)$$

Figure 2 displays the generalized temporal distribution curve of maximum 24-hour rainfall. The w_d ratios of 34 rain gauging stations; the averages $w_{d,r}$ of the ratios, and the estimations $\hat{w}_{d,r}$ obtained according to the Eq. 4 are given in Table 2.

Table 1: The geographical characteristics and annual maximum 24-hour rainfall of the stations

№	Station	N	X_{24} (mm)	Latitude (N)	Longitude (E)	Altitude (m)
1	Acıpayam	18	37,6	37,42	29,34	1000
2	Afyonkarahisar	45	29,7	38,75	30,54	1050
3	Akhisar	38	45,4	38,92	27,83	100
4	Aydın	43	47,2	37,85	27,84	70
5	Ayvalık	39	69,1	39,31	26,69	10
6	Bergama	42	56,7	39,12	27,17	50
7	Bodrum	46	65,2	37,04	27,43	10
8	Bolvadin	36	31,4	38,71	31,05	995
9	Bornova	39	57,3	38,46	27,21	50
10	Çeşme	40	63,7	38,32	26,30	10
11	Demirci	11	42,6	39,04	28,65	900
12	Denizli	42	43,4	37,78	29,08	400
13	Dikili	45	57,6	39,07	26,88	10
14	Dinar	38	33,0	38,07	30,16	900
15	Edremit	43	67,7	39,59	27,01	25
16	Fethiye	47	79,3	36,62	29,10	10
17	Gediz	31	39,9	38,99	29,39	800
18	Güney	32	42,9	38,15	29,05	750
19	İzmir	64	64,3	38,43	27,13	8
20	Köyceğiz	36	97,5	36,95	28,68	24
21	Kuşadası	42	62,3	37,85	27,25	21
22	Kütahya	48	35,6	39,41	29,97	970
23	Manisa	43	59,7	38,61	27,43	75
24	Marmaris	43	138,2	36,85	28,27	10
25	Milas	39	60,7	37,30	27,78	50
26	Muğla	48	87,2	37,21	28,35	660
27	Nazilli	22	45,5	37,90	28,32	90
28	Ödemiş	33	42,9	38,22	27,97	120
29	Salihli	36	42,2	38,47	28,12	110
30	Selçuk	37	65,4	37,95	27,36	20
31	Sultanhisar	29	45,0	37,89	28,15	90
32	Tavşanlı	36	37,5	39,54	29,49	840
33	Uşak	53	36,6	38,67	29,40	900
34	Yatağan	37	54,2	37,34	28,13	400

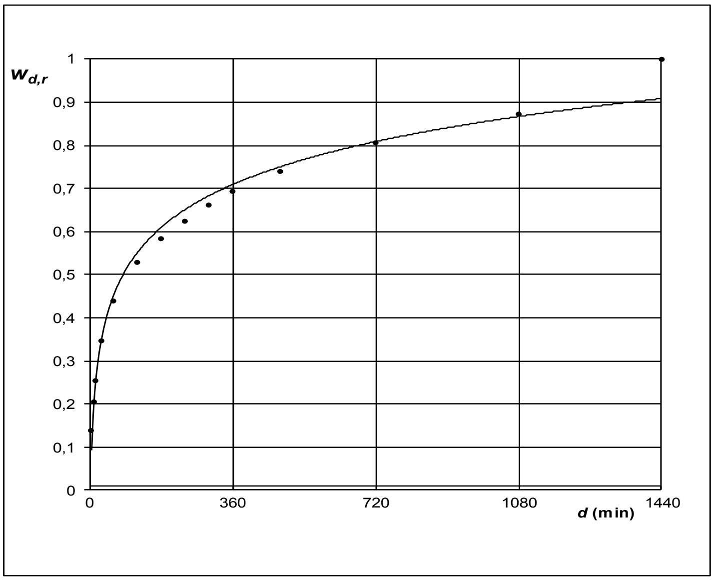

Figure 2: Average $w_{d,r}$ ratios and temporal distribution curve of 24-hour maximum

Table 2. The w_d ratios of rain gauging stations, the averages $w_{d,r}$, and the estimations $\hat{w}_{d,r}$ of the ratios

№	Station	5	10	15	30	60	120	180	240	300	360	480	720	1080	1440	R
1	Acıpayam	0,17	0,26	0,30	0,41	0,51	0,61	0,64	0,66	0,69	0,70	0,74	0,79	0,84	1,00	0,999
2	Afyonkarahisar	0,18	0,26	0,32	0,43	0,53	0,63	0,68	0,72	0,74	0,76	0,81	0,86	0,91	1,00	0,991
3	Akhisar	0,16	0,22	0,27	0,36	0,43	0,51	0,57	0,62	0,66	0,69	0,74	0,80	0,87	1,00	0,988
4	Aydın	0,14	0,21	0,27	0,37	0,47	0,55	0,60	0,63	0,67	0,70	0,73	0,78	0,85	1,00	0,992
5	Ayvalık	0,11	0,18	0,22	0,32	0,42	0,53	0,59	0,62	0,67	0,73	0,76	0,82	0,89	1,00	0,994
6	Bergama	0,13	0,19	0,23	0,31	0,39	0,48	0,54	0,60	0,65	0,69	0,74	0,82	0,89	1,00	0,986
7	Bodrum	0,14	0,21	0,27	0,37	0,46	0,56	0,64	0,69	0,73	0,75	0,79	0,84	0,93	1,00	0,998
8	Bolvadin	0,18	0,26	0,33	0,46	0,55	0,63	0,69	0,73	0,77	0,81	0,84	0,89	0,93	1,00	0,999
9	Bornova	0,13	0,18	0,23	0,31	0,42	0,52	0,60	0,63	0,67	0,70	0,75	0,83	0,93	1,00	0,993
10	Çeşme	0,13	0,20	0,25	0,33	0,45	0,56	0,60	0,63	0,66	0,69	0,74	0,83	0,88	1,00	0,994
11	Demirci	0,14	0,19	0,25	0,33	0,44	0,53	0,60	0,65	0,69	0,72	0,74	0,78	0,85	1,00	0,992
12	Denizli	0,16	0,22	0,28	0,39	0,48	0,55	0,62	0,66	0,69	0,71	0,74	0,79	0,84	1,00	0,992
13	Dikili	0,12	0,18	0,22	0,31	0,39	0,50	0,56	0,61	0,66	0,69	0,75	0,82	0,89	1,00	0,990
14	Dinar	0,16	0,24	0,30	0,41	0,51	0,61	0,66	0,69	0,71	0,73	0,77	0,81	0,86	1,00	0,995
15	Edremit	0,10	0,16	0,21	0,29	0,39	0,51	0,58	0,63	0,66	0,71	0,75	0,81	0,86	1,00	0,993
16	Fethiye	0,11	0,17	0,22	0,32	0,43	0,51	0,56	0,60	0,64	0,66	0,72	0,79	0,88	1,00	0,990
17	Gediz	0,16	0,22	0,28	0,37	0,46	0,54	0,58	0,61	0,64	0,68	0,73	0,80	0,86	1,00	0,989
18	Güney	0,13	0,20	0,25	0,36	0,44	0,50	0,55	0,60	0,64	0,66	0,72	0,79	0,85	1,00	0,987
19	İzmir	0,12	0,17	0,21	0,28	0,37	0,46	0,54	0,60	0,65	0,69	0,74	0,83	0,90	1,00	0,986
20	Köyceğiz	0,10	0,15	0,19	0,27	0,38	0,49	0,55	0,59	0,64	0,67	0,72	0,81	0,89	1,00	0,989
21	Kuşadası	0,14	0,20	0,25	0,36	0,47	0,55	0,61	0,66	0,69	0,72	0,78	0,85	0,91	1,00	0,997
22	Kütahya	0,18	0,27	0,34	0,43	0,49	0,56	0,60	0,63	0,66	0,68	0,71	0,76	0,82	1,00	0,982
23	Manisa	0,11	0,17	0,21	0,29	0,37	0,44	0,50	0,54	0,58	0,62	0,69	0,76	0,82	1,00	0,977
24	Marmaris	0,08	0,13	0,16	0,24	0,33	0,45	0,51	0,55	0,59	0,63	0,70	0,81	0,91	1,00	0,980
25	Milas	0,15	0,23	0,28	0,39	0,48	0,57	0,61	0,64	0,68	0,71	0,76	0,81	0,88	1,00	0,995
26	Muğla	0,10	0,14	0,17	0,23	0,32	0,42	0,47	0,52	0,57	0,60	0,66	0,77	0,87	1,00	0,971
27	Nazilli	0,12	0,19	0,24	0,33	0,40	0,48	0,53	0,58	0,61	0,66	0,70	0,78	0,85	1,00	0,984
28	Ödemiş	0,13	0,18	0,23	0,30	0,38	0,48	0,54	0,58	0,61	0,63	0,67	0,73	0,81	1,00	0,980
29	Salihli	0,16	0,23	0,29	0,39	0,48	0,56	0,63	0,67	0,69	0,73	0,77	0,85	0,91	1,00	0,996
30	Selçuk	0,14	0,20	0,25	0,31	0,39	0,48	0,56	0,61	0,66	0,69	0,75	0,83	0,89	1,00	0,987
31	Sultanhisar	0,14	0,20	0,25	0,32	0,39	0,48	0,53	0,58	0,63	0,67	0,73	0,80	0,86	1,00	0,983
32	Tavşanlı	0,20	0,29	0,34	0,46	0,56	0,63	0,66	0,68	0,71	0,74	0,77	0,82	0,89	1,00	0,994
33	Uşak	0,17	0,24	0,30	0,39	0,48	0,54	0,58	0,63	0,66	0,69	0,72	0,78	0,83	1,00	0,988
34	Yatağan	0,12	0,19	0,24	0,34	0,44	0,51	0,57	0,61	0,63	0,65	0,69	0,75	0,84	1,00	0,987
	$w_{d,r}$	0,14	0,20	0,25	0,35	0,44	0,53	0,58	0,62	0,66	0,69	0,74	0,80	0,87	1,00	
	$\hat{w}_{d,r}$	0,09	0,19	0,25	0,35	0,45	0,55	0,61	0,65	0,68	0,71	0,75	0,81	0,87	0,91	0,992

The last column (R) in Table 2 shows the correlation coefficients calculated between the w_d ratios of each station and the generalized temporal distribution curve. The correlation coefficient (R=0,992) at the bottom of the table is calculated between the average (or regional) $w_{d,r}$ ratios and the generalized temporal distribution curve.

V. DISCUSSION

Almost all meteorological stations, with or without pluvyograph equipments, have 24-hour or daily total rainfall records. There is no possibility to directly calculate the rainfall depth for any standard rainfall duration, especially at stations without pluviograph equipment. In this study, it is aimed to find an approximate solution to this problem. In this study, the data of 34 rain gauging stations with measurements of standard rainfall durations (5min, 10min, …, 1h, …, 18h, 24h) are evaluated. The $w_d = X_d / X_{24}$ ratios for each station were calculated, and the average $w_{d,r}$ values of these ratios are obtained for the region. Then a logarithmic curve is fitted to these $w_{d,r}$ averages to obtain a generalized temporal distribution curve for all stations.

When Figure 2 is examined, it is seen that the generalized temporal distribution curve successfully represents the regional average $w_{d,r}$ ratios. The correlation coefficient at the bottom of Table 2 (R=0,992) also confirms this suitability mathematically. When the generalized temporal distribution curve is evaluated on the station-by-station basis, the R correlation coefficients for each station in Table 2 show that this generalized curve successfully represents the w_d ratios of each station. In summary, the generalized curve obtained for the studied area is sufficiently safe to represent the temporal distribution of maximum 24-hour precipitation.

REFERENCES

[1] U. S. Soil Conservation Service, A Method for Estimating Volume and Rate of Runoff in Small Watersheds, SC-TP-149, (Department of Agriculture, 1973).

[2] U. S. Soil Conservation Service, A Method for Estimating Volume and Rate of Runoff for Urban Watersheds, SC-TP-55, (Department of Agriculture, 1986).

[3] J.C. Guo, K. Hargadin, Conservative Design Rainfall Distribution. Journal of Hydrologic Engineering, 14(5), 2009.

[4] A.M. Genovez, Vazões máximas. In: Paiva, J. B. D.; Paiva, E. M. C. D. (Ed.). Hidrologia aplicada á gestão de pequenas bacias hidrográficas. (Porto Alegre: ABRH, 2003), 33-112.

[5] C.R. Mello, A.M. Silva, J.M. Lima, D.F. Ferreira, M.S. Oliveira, Modelos matemáticos para predição da chuva de projetos para regiões do Estado de Minas Gerais. Revista Brasileira de Engenharia Agrícola e Ambiental, 7(1), 2003, 121-128.

[6] A.J. Back, Time distribution of heavy rainfall events in Urussanga, Santa Catarina State, Brazil, Acta Scientiarum, 33 (4), 2011.

[7] Z. Ghassabi, G. Alikamali, A-H. Meshkatee, S. Hajam,, N. Javaheri, Time distribution of heavy rainfall events in southwest of Iran, Journal of Atmospheric and Solar-Terrestrial Physics, 145. 2016, 53–60

[8] O. L. Asikoglu, Regional Frequency Analysis of Maximum Rainfall in the Aegean Region of Turkey, MSc Thesis, Ege University, Graduate School of Natural and Applied Sciences, (1997)

Omer Levend Asikoglu “Temporal Distribution of 24-hour Maximum Rainfall**” International Journal of Engineering and Science Invention (IJESI)** 6.7 (2017): 06-10