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SYNTHESIS OF RAINFALL INTENSITY-FREQUENCY REGIME OF IRAN[1]

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ABSTRACT

The recording raingauge data for two yr at the Bajgah valley (29°, 32′ N, 52°, 35′ E, altitude 1810 m) at Fars province of Iran were analyzed and the intensity-duration-frequency relationships were constructed. The ratios of D-duration to one-hr rainfall depths over a range of 2 to 100 yr of return periods were found to be fairly constant. These constants were similar to those of the other regions of the world. A constant value of 3.76 was found for the ratio of the max. 24-hr rainfall depth to one-hr rainfall at different frequencies up to 100 yr. This ratio could be used in synthesizing the high rainfall intensity-duration-frequency relationships for the areas where no rainfall data from recording raingauge are available.

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تخمین منحنی های شدت ـ مدت وتناوب بارندگی در ایران

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خلاصه

اندازه‌گیری های دوساله شدت بارندگی درباجگاه (عرض جغرافیائی ۲۹ درجه و ۳۲ دقیقه وطول جغرافیائی ۵۲ درجه و ۳۵ دقیقه وارتفاع ۱۸۱۰ متر) دراستان فارس ـ ایران تجزیه وتحلیل شده ومنحنی های شدت ـ مدت وتناوب بارندگی درآن تهیه گردیده است. نسبتهای مقدار باران درمدتهای مختلف به مقدار باران یکساعته دردوره‌های تناوب ۲ تا ۱۰۰ ساله بطورمحسوسی ثابت بوده واعداد حاصله دراین منطقه با سایرمناطق دنیا تشابه داشته است .همچنین نسبت ثابتی (۳/۷۶) بین حداکثرمقدار باران ۲۴ ساعته ومقدار باران یکساعته درتناوبهای ۲ تا ۱۰۰ ساله در ۳ ایستگاه درایران حاصل شده است . این عددثابت را میتوان برای تخمین منحنی های حداکثرشدت ـ مدت وتناوب بارندگی برای مناطقی ازایران که دارای اطلاعات اندازه‌گیری شده نیستند بکاربرد .

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INTRODUCTION

Flood estimation is essential in many agricultural and engineering waterworks such as soil conservation, drainage and reservoir spillways. Rainfall intensity as a function of duration and return period is important when the design flood must be estimated. Considerable attention has been paid to this subject throughout the world and many empirical rainfall intensity formulae have been derived from recording raingauge data. These formulae usually show ralations between intensity-duration-frequency of rainfall. The universal results of such investigations showed that the ratios of the T-yr to 10-yr rainfall depths for a range of durations up to 2 hr are fairly constant for all return periods T up to 100 yr (3, 4). These results also indicated that the ratios of D-duration to 1-hr rainfall depths are similarly constant over a range of T-yr of return periods. Therefore the derived mean ratios might be used to estimate the rainfall intensities corresponding with any duration up to 2 hr for return periods up to 100 yr for design in regions where no data of intensity-duration-frequency are available (3).

At present time, scarce data of intensity-duration-frequency are available in Iran. The aim of this paper was to examine ways of utilizing such limited data, particularly to estimate intensity-duration-frequency relationships for points without recording raingauges. Therefore, the recording raingauge data for 2 yr at the Bajgah valley at Fars province of Iran were analyzed and the intensity-duration-frequency relationships were constructed. Furthermore, the possible use of max. 24-hr rainfall for synthesizing rainfall intensity-duration-frequency relationships was examined.

MATERIALS AND METHODS

The data of a recording raingauge (TB-175 tilting raingauge, and QAC-1275 rain recorder, Stevens Instruments Co.) for 2 yr (1980-81, 1981-82) were analyzed. This recording raingauge

was situated in an agro-meteorological field station at the Bajgah valley (29°, 32′ N, 52°, 35′ E, altitude 1810 m), Fars province of Iran. The characteristics of the field station and other climatic information of the area were reported elsewhere (5). The analysis of data for rainfall intensity-duration-frequency was carried out according to the depth-duration procedure described by Jones *et al.* (4) with the exception that instead of max. intensity of rainfall all data of intensities were used in the analysis. Other data for Mehrabad and Saadabad have also been analyzed.

RESULTS AND DISCUSSION

The results of depth-duration analysis for rainfall intensity-duration-frequency are shown in Fig. 1. The analysis was carried out for the durations of 5-120 min and the frequencies of 2-100 yr. The slope of the rainfall intensity-duration relationship at any given frequency was somewhat different (-0.44 to -0.50). The average value of the slope over different frequencies was -0.48 for Bajgah. The average values of this slope for Mehrabad (Tehran, 35°, 41′ N, 51°, 19′ E, altitude 1191 m) and Saadabad (Tehran, 35°, 50′ N, 51°, 25′ E; altitude 1700 m) stations were reported to be -0.83 and -0.75, respectively (6). Similar results to those of Bajgah have been reported for other regions of the world (1).

The ratio of the rainfall depths at duration of 5, 15, 30 and 120 min (P_D) to that of 60 min (P_{60}) over the frequencies of 2 to 100 yr was calculated and resulted means and standard deviations, are shown in Table 1. These ratios were found to be fairly constant and are similar to those reported for the Australia (3), U.S.A. and Saudi Arabia (4) (Table 1).

The max. 24-hr rainfall for the periods of 1957-70 and 1965-76 at stations of Mehrabad and Saadabad (2), respectively,

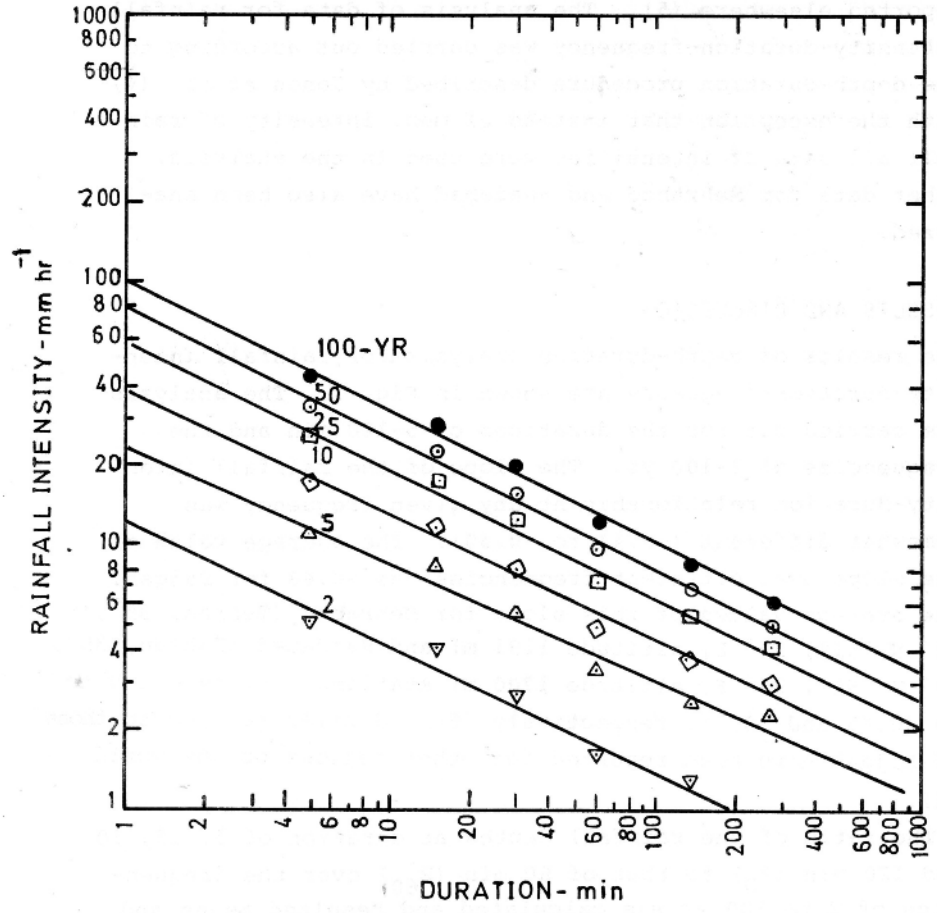

Fig. 1. Rainfall intensity duration-frequency relationships of Bajgah valley.

Table 1. Comparison of P_D/P_{60} of Bajgah with other regions of the world.

Duration min	U.S.A.†	Australia‡	Saudi Arabia†	Bajgah	World average
	Mean	Mean	Mean	Mean	
5	0.29 ± 0.03§	0.30 ± 0.04	0.29 ± 0.03	0.29 ± 0.02	0.29
15	0.57 ± 0.04	0.57 ± 0.04	0.56 ± 0.04	0.60 ± 0.02	0.57
30	0.79 ± 0.04	0.78 ± 0.03	0.78 ± 0.07	0.83 ± 0.01	0.78
120	1.25 ± 0.08	1.24 ± 0.06	1.20 ± 0.17	1.48 ± 0.07	1.23

†Reference (4)
‡Reference (3)
§Standard deviation

were analyzed for the frequencies of 10 to 100 yr by using the annual max. series on data. Furthermore, the 24-hr rainfall data for the periods of 1980-81 and 1981-82 at the Bajgah station were analyzed for the frequencies of 2 to 100 yr by using the partial duration series on data. Because of the great uncertainty associated with a 100-yr return period value derived from 2-yr data, the ratio of the 24-hr rainfall (max. 24 hr for Mehrabad and Saadabad) to the 60-min rainfall at different frequencies was calculated (Table 2). The 60-min rainfalls for different frequencies at Mehrabad and Saadabad stations were reported by Mohsseneian (6). These ratios were fairly constant (3.63 to 3.88, average of 3.76). Therefore, in regions of Iran where no data of rainfall intensity-duration-frequency are available a constant value of the ratio may be used to estimate a reasonable intensity-duration-frequency relationships. The procedure of estimation is shown in the following example.

Example: The max. 24-hr rainfall data of 1967-83 for Bajgah station were analyzed and found to be 40, 56, 62, 72, 80 and

Table 2. The ratio of max. 24-hr rainfall of Mehrabad and Saadabad and 24-hr rainfall of Bajgah to 60-min rainfall at the different frequencies.

Return period yr	Max. 24-hr to 60-min rainfall		24-hr to 60-min rainfall
	Mehrabad	Saadabad	Bajgah
2	-	-	3.64
5	-	-	3.68
10	3.82	4.19	3.58
25	3.82	3.85	3.73
50	3.67	3.87	3.59
100	3.76	3.60	3.54
Mean	3.77 ± 0.07†	3.88 ± 0.24	3.63 ± 0.07

†Standard deviation

87 mm at frequencies of 2, 5, 10, 25, 50 and 100 yr, respectively. By dividing the above mentioned max. 24-hr rainfall by the average ratio of the max. 24-hr rainfall to 60-min rainfall (3.76), the max. 60-min rainfall at different frequencies will be found (Table 3). Multiplying the max. 60-min rainfall at different frequencies by the world averages of the ratio of P_D/P_{60} at different durations (Table 1) will result in the max. depths of rainfall at the different durations and frequencies. The results could be converted to the max. intensity of rainfall, mm hr^{-1}, which are shown in Table 3.

A generalized equation for synthesis of high intensity-duration-frequency has been proposed by Bell (3) as follows:

$$P_T^t = (0.21 \ln T + 0.52)\ (0.54t^{0.25} - 0.5)\ P_{10}^{60}$$

where P_T^t is the rainfall depth at t duration, min, T is the frequency, yr, and P_{10}^{60} is the rainfall depth at 60-min duration and

Table 3. Estimated max. rainfall intensity-duration-frequency data for Bajgah.

Duration min	Return period, yr					
	2	5	10	25	50	100
	mm hr^{-1}					
5	37.03	51.82	57.39	66.64	74.05	80.53
15	24.26	33.95	37.60	43.66	48.52	52.76
30	16.60	23.23	25.72	30.87	33.20	36.10
60	10.64	14.89	16.49	19.15	21.28	23.14
120	6.54	9.16	10.14	11.78	13.09	14.23

10-yr frequency. A reasonable estimate of P_{10}^{60} value for an area is required in this synthesis. A simple relationship between mean annual rainfall and 10-yr 1- hr rainfall for Saudi Arabia has been presented by Jones *et al.* (4) in Fig. 2. This figure shows an increase in 10-yr 1-hr values with increase in the mean annual rainfall. Such relationships are relatively easy to obtain but much less easy to verify since the depth-intensity relationships are virtually independent of mean annual rainfall. Similar relationship for three stations of Iran (Mehrabad, Saadabad and Bajgah) is presented in Fig. 2. Since the frequency of storms is greater in high rainfall areas, it follows that the average max. D-duration rainfall depth in any yr with higher rainfall would also be higher. The relationship between 10-yr 1-hr rainfall and mean annual rainfall in Iran has been resulted from a few data points and should not be generalized at present. However, when comparing locations in Iran with those with similar rainfall in Saudi Arabia, it is found that the 10-yr 1-hr rainfall in Iran is smaller than in Saudi Arabia (Fig. 2). This might be due to the difference in the

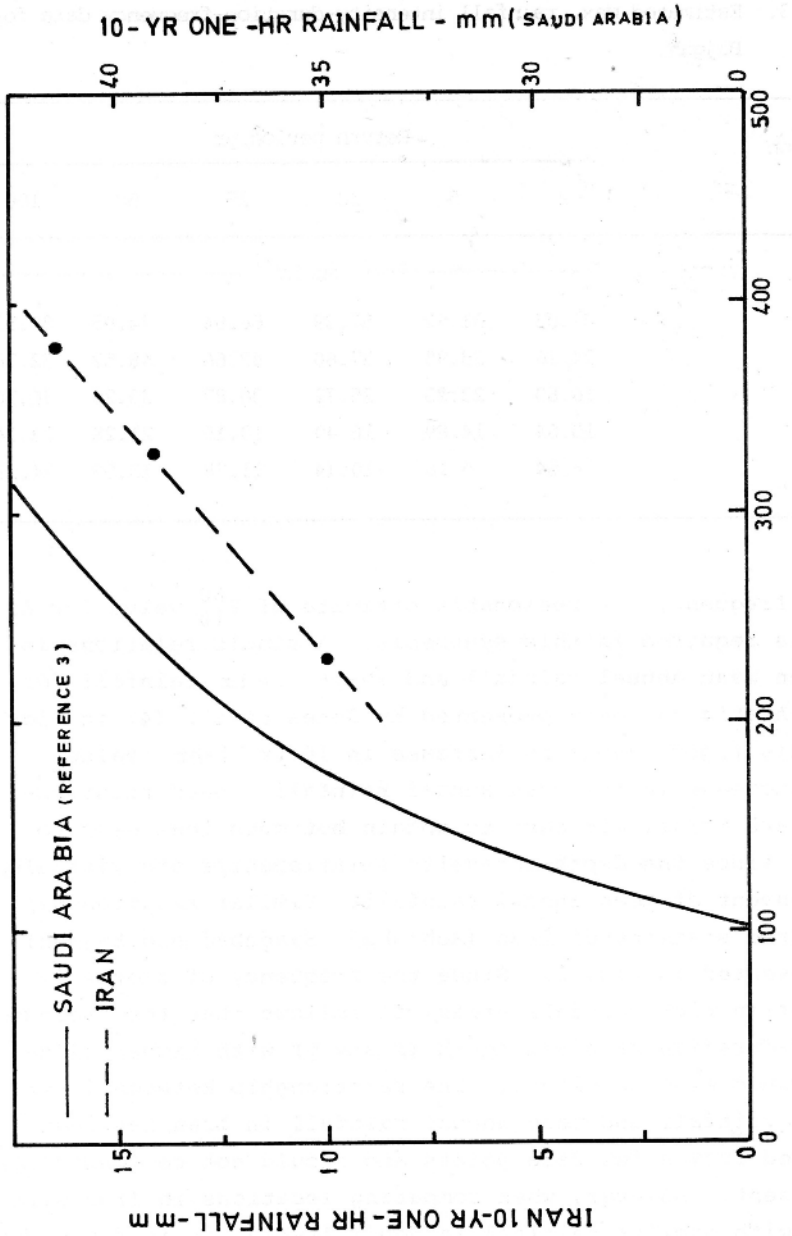

Fig. 2. Relationship between 10-yr 1-hr rainfall and annual rainfall for Saudi-Arabia and Iran.

type of rain producing storm fronts affecting the two countries.

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