Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 9 (10): 1922-1928, 2009
ISSN 1812-5654

A Study on the Temporal and Local Distribution of Showers Generating Flood in Zolachai River Basin by Using Intensity-Duration-Frequency-Area Curves Relationships

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Abstract: The present research sets out to study the temporal and local distribution of showers generating flood in Zolachai river basin. To carry out this research the rainfall data of 13 non-recording and recording rain gauges over a 15-year statistical period (1986-2000) were employed. The main aim of this study is to prepare intensity-duration-frequency and duration-area-depth 2 curves and combine them in intensity-duration-frequency-area curve forms in order to recognize and study rainfall parameters. To do so, after selecting stormy days isohyet's maps and Duration-Area-Depth curves were drawn using Excel, Arcview and ArcGIS software. Also, to draw Intensity-Duration-Frequency curves, hydrological software called Hyfa was utilized. Finally, the above-mentioned curves were combined and Intensity-Duration-Frequency-Area curves were drawn using Excel software for different return periods. In this research four parameters including intensity-duration-frequency-area were presented collectively, which had never been performed in the previous researches on Zolachai river basin. Thus, this research was carried out to raise the confidence of coefficient in water projects like construction of dams and prediction of flood for Zolachai river basin.

Key words: Rainfall parameters, duration, frequency, area, ArcGIS software, Zolachai

INTRODUCTION

Water resources are one of Iran's considerable potentials and a main proportion of environmental planning particularly sub structural plans including water projects are based on them.

The distribution of water resources is influenced by the scattering of climatic elements such as pressure and rainfall patterns. Due to the climatic variety, different regions in the country have different potentials to supply water demands (Javelle *et al*., 2002).

The planning and water projects which are carried out suiting the needs of each region, are a huge step towards removing the limitation of water resources and making better use of environmental potentials. Some important planning to further this aim include constructing dams on rivers in order to make good use of rainfall and predicting flood in order to prevent financial and life losses and also prevent water wastage. These measures and projects require conducting studies on the region in question and examining and realizing rainfall parameters considering intensity-duration-frequency-area.

The recognition of rainfall parameters indicates the rainfall pattern and its temporal-local distribution: that is to say the amount of rain that has fallen within a certain amount of time in a certain area with certain intensity over the time (Dai, 2006).

Determining the relationships in intensity-duration-frequency-area is one of the first and fundamental studies in the rainfall and run-off models which presents all the features and parameters of rainfall at the same time (Stow and Drinks, 1999). Since the amount of rainfall within a certain period of time and in a certain area determines the amount of run-off and the river's debit play an important role in the likelihood of the occurrence of flood and water reservation in dams, determining intensity-duration curves in order to estimate the run-off made by showers is of great importance, especially if in a river basin there aren't any hydrometric stations. Also, when presenting these curves in order to take climatic changes into consideration, it is necessary to conduct new studies and formulate new equations for intensity-duration-frequency-area curves of the showers incorporating also data from non-recording rain gauges (Koutsyoyiannis *et al*., 1998). Since river basins in the country are areas within which hydrological projects are carried out, all of them must be studied to fulfill the water potential in each and every river basin in order to supply

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water demand in the country, especially demands for agriculture (irrigation), the production of electricity and drinking water.

Among the river basins in the country, the one which belongs to the Oroumyie lake is a region with heavy rainfalls and it has an almost intense drainage network and also various rivers. Zolachai river basin, which is an important sub-river basin with a considerable area compared to the other 8 sub-river basins, has experienced the occurrence of flood that the frequency of flood occurrence in Zolachai basin is shown in Table 1 (www.iran news.com). Financial and life losses resulting from these floods in Salmas and the surrounding villages have been considerable.

The occurrence of such disaster and the importance of making good use of river water in order to provide irrigation water in plains in Salmas by constructing Zolachai Dam on the river necessitates hydrological and climatic studies such as determining intensity-duration-area-frequency.

Table 1: Frequency of flood occurrence in Zolachai river basin

Frequency of flood occurrence in Zolachai river basin	50	95	125	230	550	1080
Return period	2	10	20	100	1000	10000

Huff (1967) has determined temporal and local distribution patterns probable maximum precipitation in East Illinois. Also, Huff (1994) in his study estimated the frequency of extreme rainfall events for 1993 storm in east-central Illinois. Dairaku *et al*. (2004) studied the rainfall amount, intensity, duration and frequency relationships in Mae Chaen watershed. Wilks (1988) for studying short duration precipitation rates used Weibull distribution.

MATERIALS AND METHODS

To carry out this research the rainfall data of non-recording and recording rain gauges over a 15-year statistical period (1986-2000) were employed. The situation of the region in this study is located in Zolachai river basin in western Azarbaijan province in Iran. Zolachai river basin which is located in the North-west of the Oroumyie lake is one of the eight sub-river basins and considering vastness, it is the fifth in rank. This river basin is located in Eastern 44°/45° and Northern 37°/38° (Fig. 1). This river basin is limited by Darickchai from north, by Nazloochai from South, by Salmas and Oroumyie lake from East and by Iran-Turkey border from West. It is mainly located in Salmas.

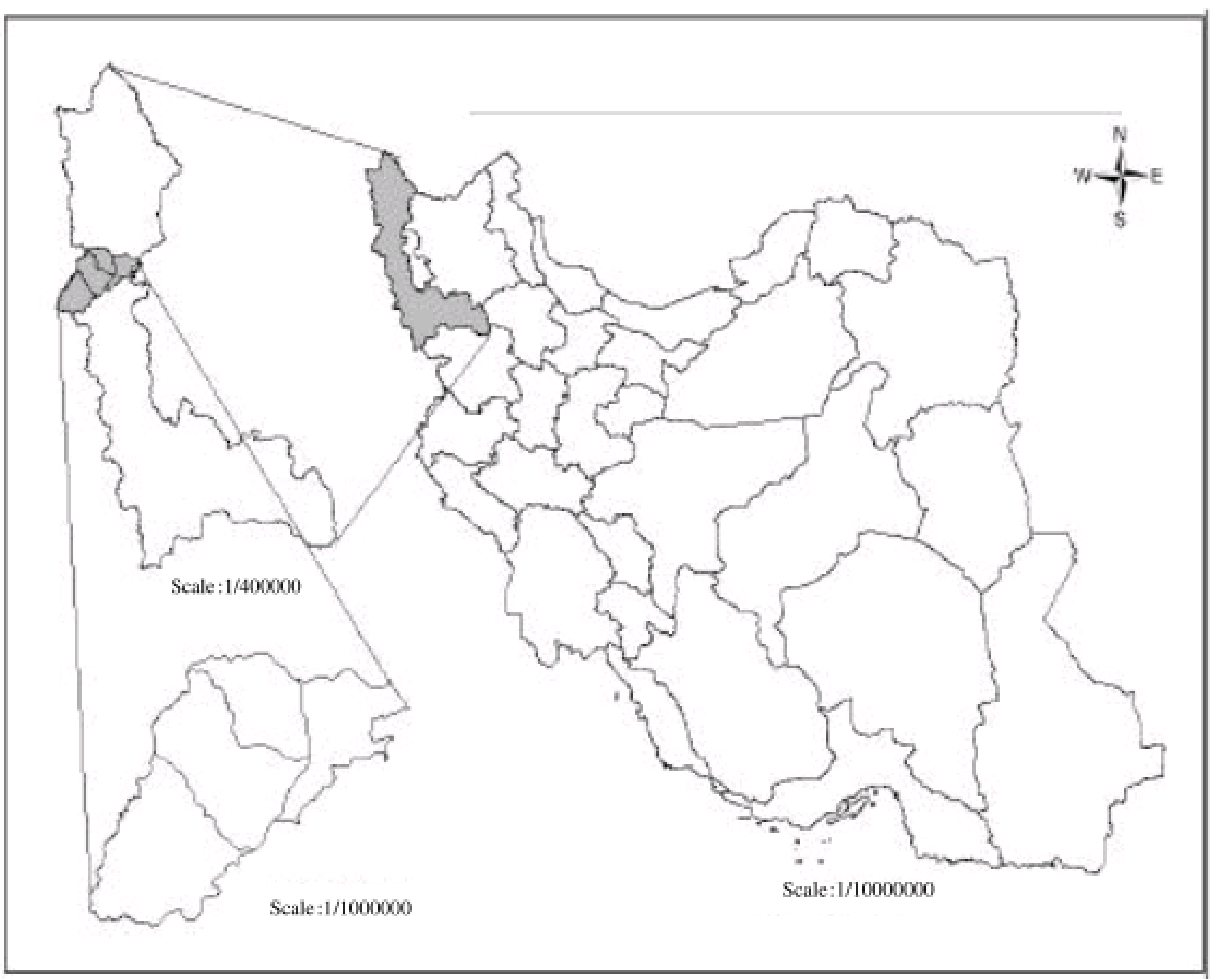

Fig. 1: The situation of Zolachai river basin in the province and country

Table 2: The geographical situation of studied stations (1986-2000)

Name of station	Model of station	Geographical altitude	Geographical longitude	Elevation
Diralichai	Non-rec.rain gauge	38°20'	44°44'	1440
Salmas	Non-rec.rain gauge	38°11'	44°46'	1350
Darickchai	Non-rec.rain gauge	38°11'	44°46'	1620
Yalghouze aghaj	Non-rec.rain gauge	38°14'	44°56'	1300
Tamor	Non-rec.rain gauge	38°07'	44°52'	1410
Chehrigh olya	Non-rec.rain gauge	38°05'	44°36'	1600
Ghareh bagh	Non-rec.rain gauge	38°04'	45°04'	1480
Gachi	Non-rec.rain gauge	37°49'	44°43'	1950
Ghatour	Non-rec.rain gauge	38°24'	44°47'	1540
Tars abad	Non-rec.rain gauge	38°24'	44°20'	2100
Oroumyieh camp	Non-rec.rain gauge	37°32'	45°02'	1381
Salmas	Non-rec.rain gauge	38°11'	44°46'	1350
Pol navaee	Non-rec.rain gauge	38°35'	45°03'	1050

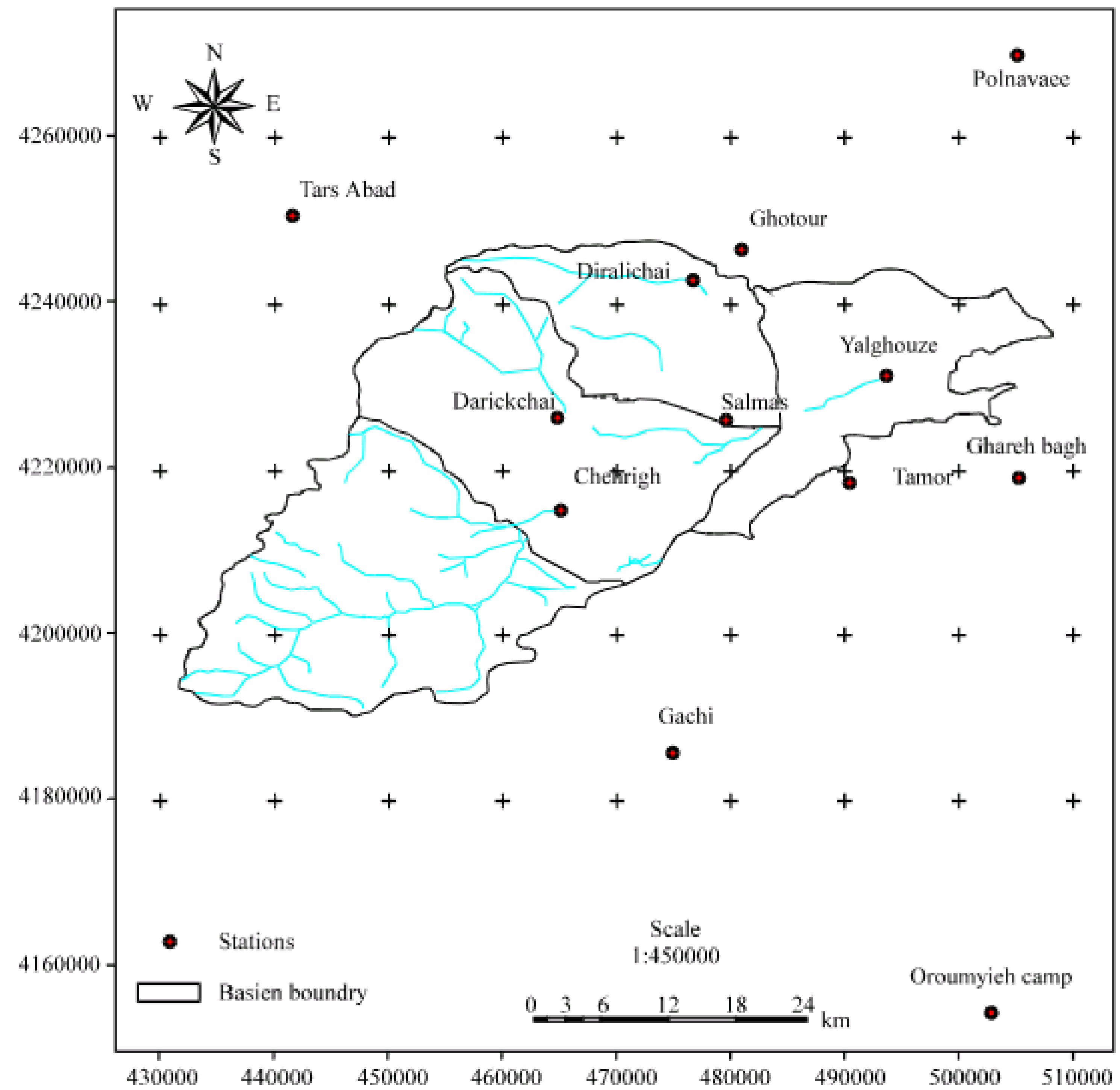

Fig. 2: Distribution of studied stations in Zolachai river basin

This river basin covers an area of 2225 km^2 of which an area of 1025 km^2 is located in an altitude of 1300 to 2200 m and an area of 1100 km^2 is located in an altitude of over 3100 m and the altitude of the region varies between 1300 and 3300 m.

Zolachai is one of the individual rivers in Oroumyieh lake basin and various branches join it.

In this study, it is necessary to select stormy days in order to draw IDFA curves for the river basin (Ghiasi-Agyei, 2005). So, some days namely 1991-5-13, 1993-5-3, 4, which had the highest amount of daily rainfall and also had high debits were selected among 15-year statistics of all regular rain gauges inside and outside the region.

The statistics employed in this study include 13 non-recording and recording rain gauge stations. The features and the situation of these stations have been presented, respectively in Table 2 and Fig. 2.

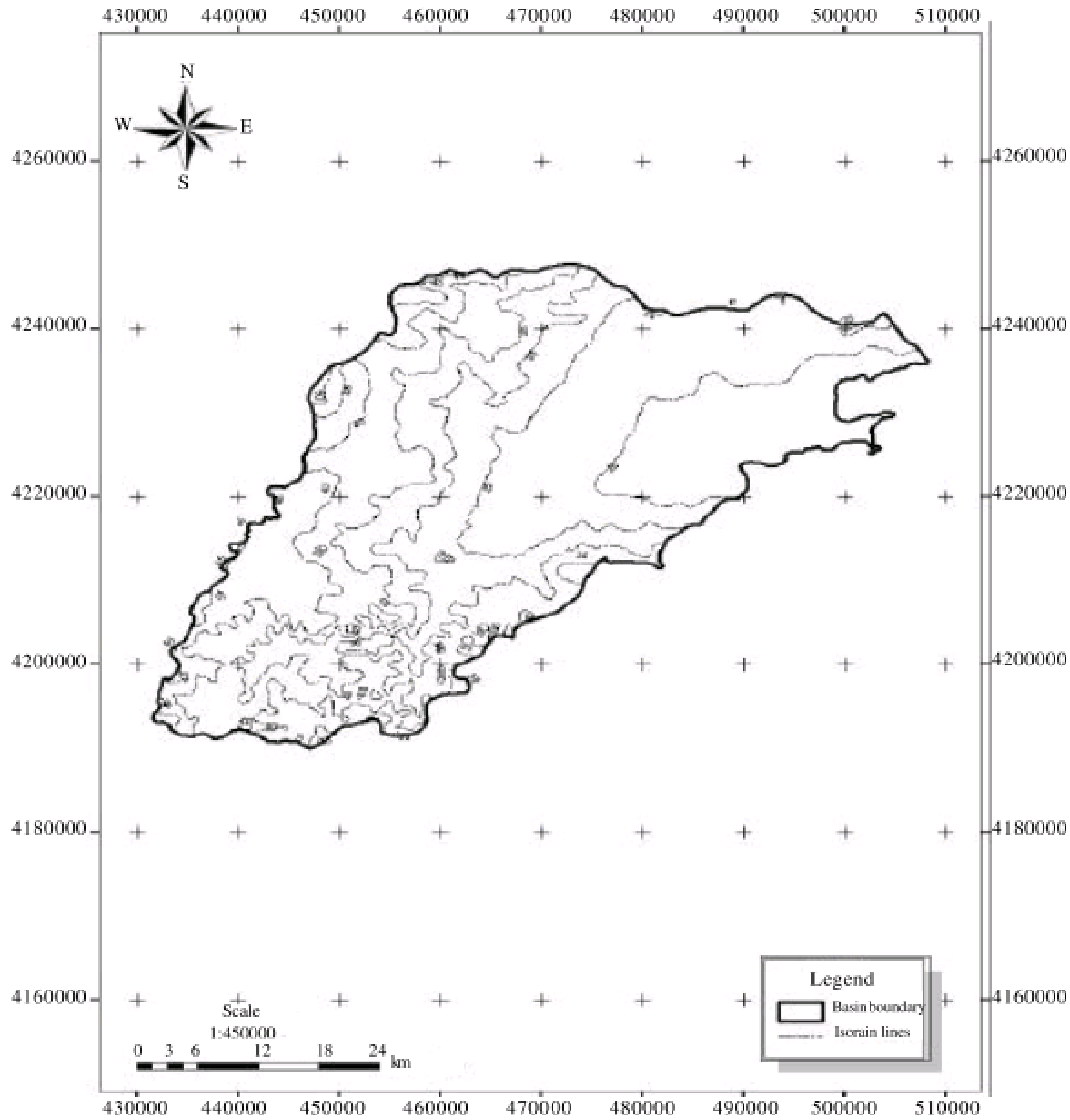

Fig. 3: Isohyet map, 1991-5-13

DRAWING DAD CURVES

The first step for drawing DAD curves is drawing isohyets maps for sample days (Fig. 3). So isohyets maps were drawn using precipitation gradient equation here, only the isohyets map of one of the selected days is given as an example:

$$Y = ah + b \text{ precipitation gradient equation}$$

Having drawn isohyet maps and prepared DAD tables, DAD curves were drawn for sample days and since DAD curves of the river basin were needed, shower curves of the sample days in the same temporal basis were combined and DAD curve of the river basin for a 24 h unit was drawn (Hallak-Alegria and Watkins, 2007) (Fig. 4).

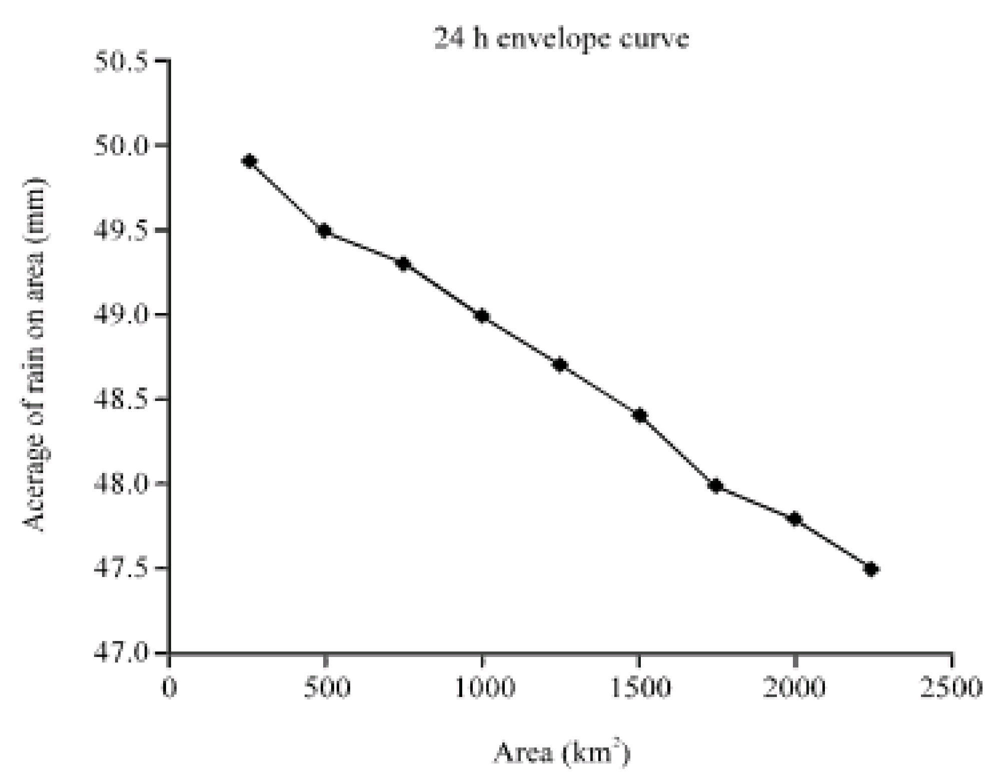

Fig. 4: DAD curve of the Zolachai river basin

DRAWING IDF CURVES

In order, to study the temporal distribution of the rainfall, recording rain gauge graphs existing in the region are needed. For this purpose, the data related to 3 recording stations inside and outside the river basin were collected. In order to draw IDF curves, long term statistics are needed, so, all the recorded statistics existing in the stations were employed. In the analysis of intensity-duration relationships in the present study, the maximum precipitation in the AMS (annual maximum series) data in different temporal frequencies for each year and each situation were chosen (Willems, 2000) and statistical distribution was determined based on the above-mentioned data in Hyfa software (hydrologic software for determining statistical distribution). Statistical distribution appropriate to the data in the three stations was Gumbel statistical distribution with the maximum accuracy method, which presents the least standard fault with the data related to Zolachai river basin's rainfall intensity.

Then, by putting the obtained results in different return periods in the equation of rainfall intensity, the amount of rainfall intensity-duration for each station in different return periods were obtained. Lastly, using the average of all IDF points of the three stations, IDF curves for the river basin were drawn (Fig. 5-8).

$$I = \frac{a}{(t+b)^c} \qquad \text{Rainfall intensity equation}$$

DRAWING IDFA CURVES

In the present study, in order to combine IDF and DAD curves and draw IDFA curves, dimensionless amounts of intensity-duration of all IDF curves in average rainfall amounts in desired areas (DAD curve of the river basin) were employed and IDFA curves for different return periods were drawn (Fig. 9-14).

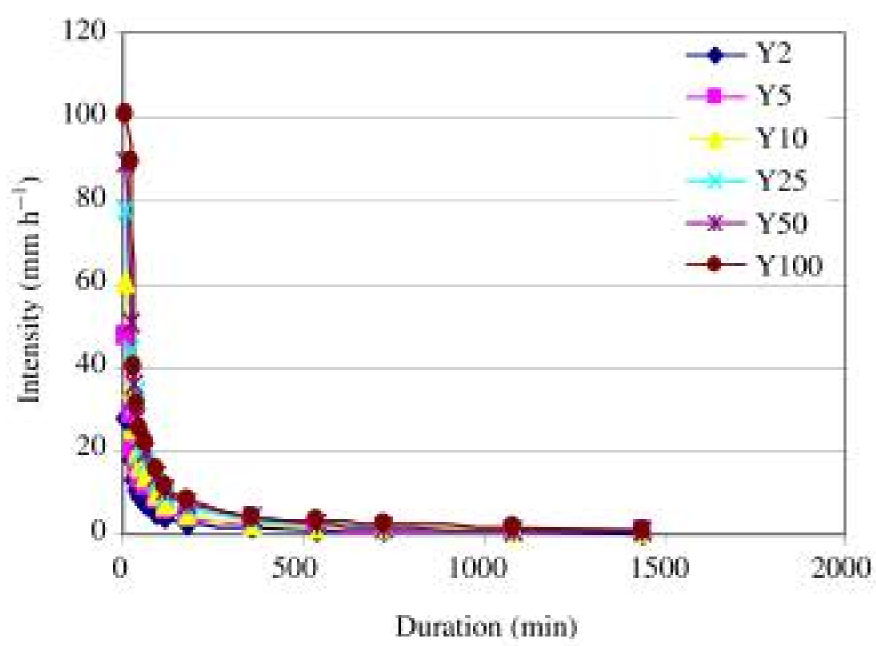

Fig. 5: IDF curves of different return periods Pol navaee

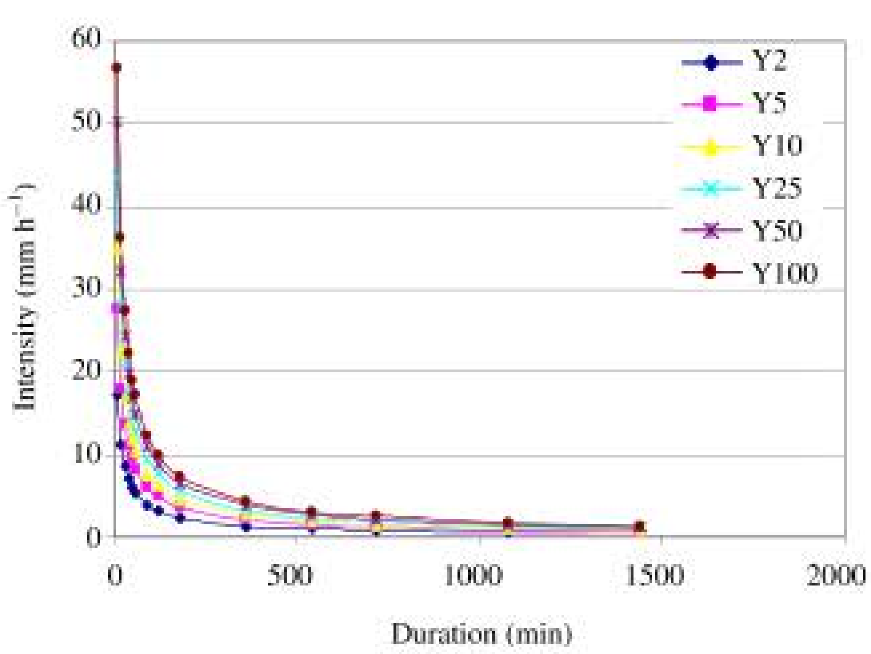

Fig. 6: IDF curves of different return periods Salmas

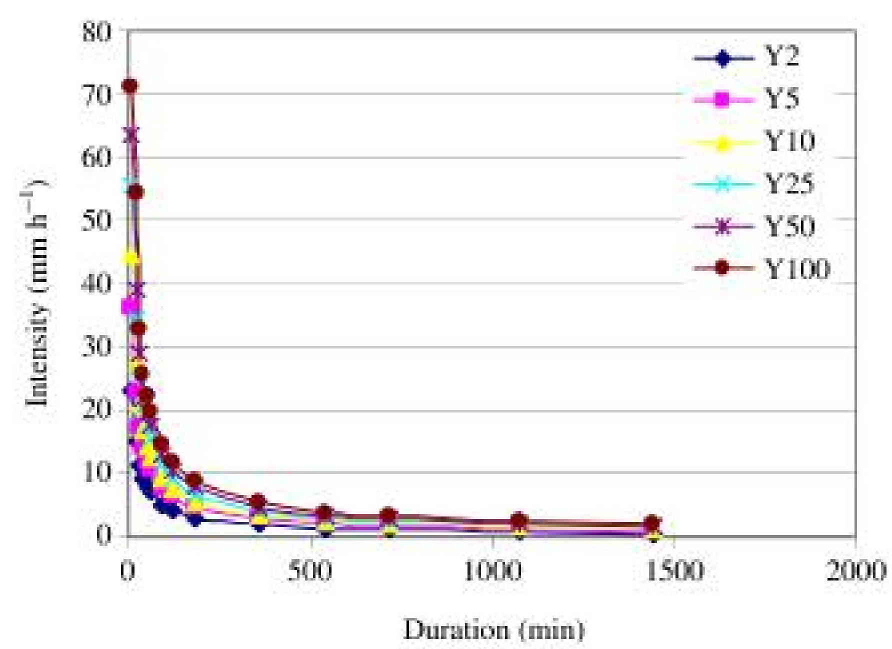

Fig. 7: IDF curves of different return periods Zolachai

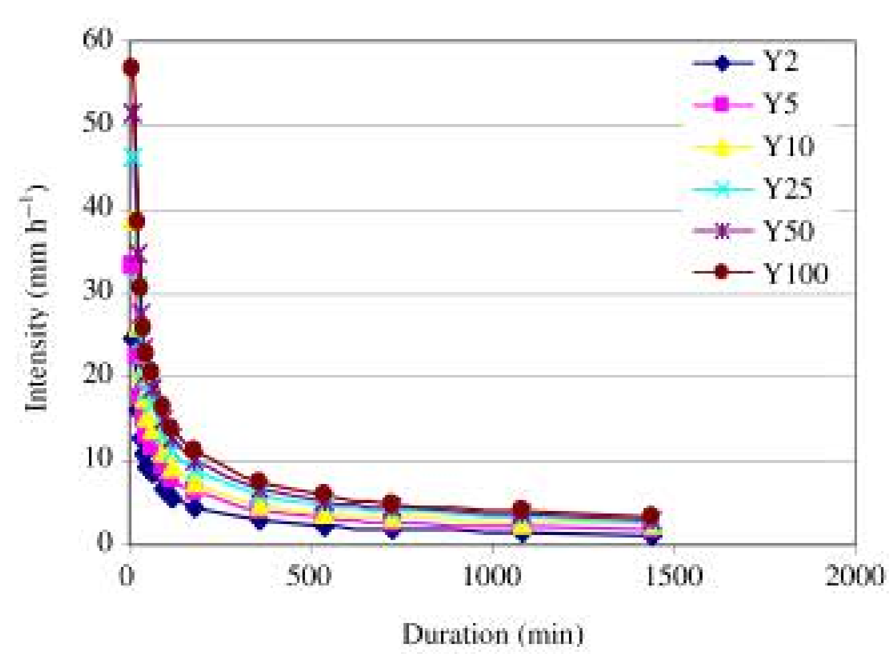

Fig. 8: IDF curves of different return periods Kamp Oromieh

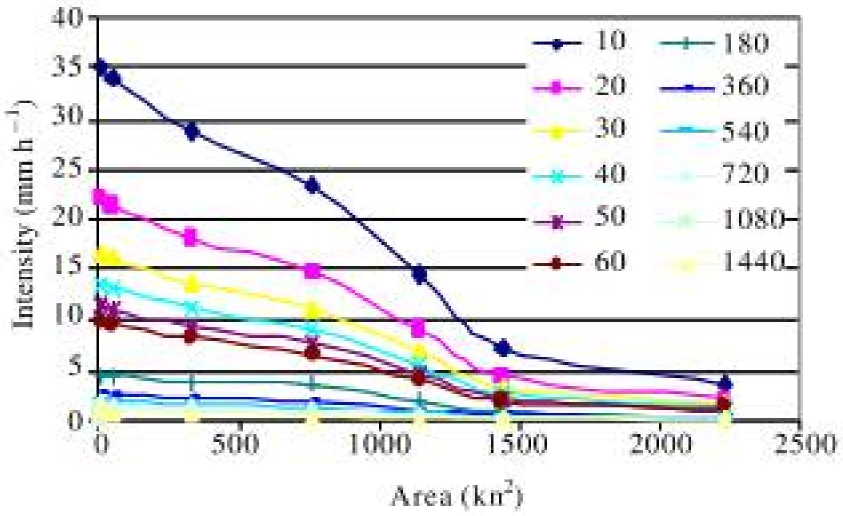

Fig. 9: IDFA curves of Zolachai river basin in 10-1440 min frequencies for 5 year return period

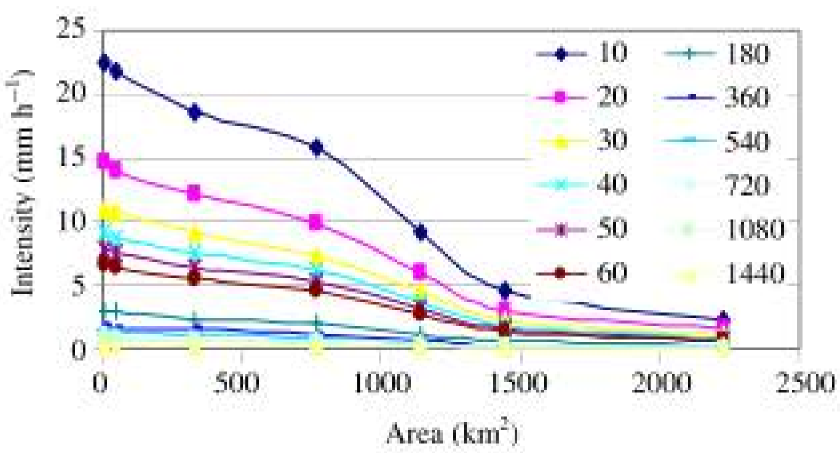

Fig. 10: IDFA curves of Zolachai river basin in 10-1440 min frequencies for 2 year return period

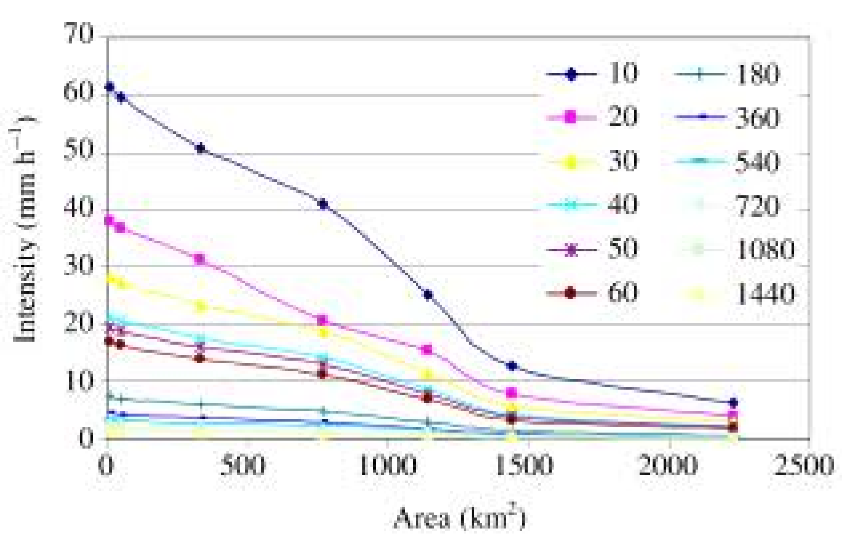

Fig. 11: IDFA curves of Zolachai river basin in 10-1440 min frequencies for 50 year return period

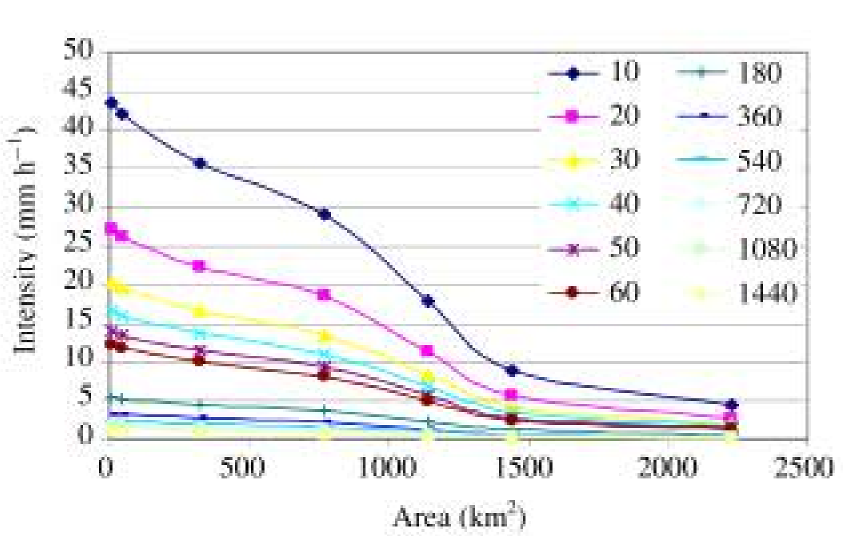

Fig. 12: IDFA curves of Zolachai river basin in 10-1440 min frequencies for 10 year return period

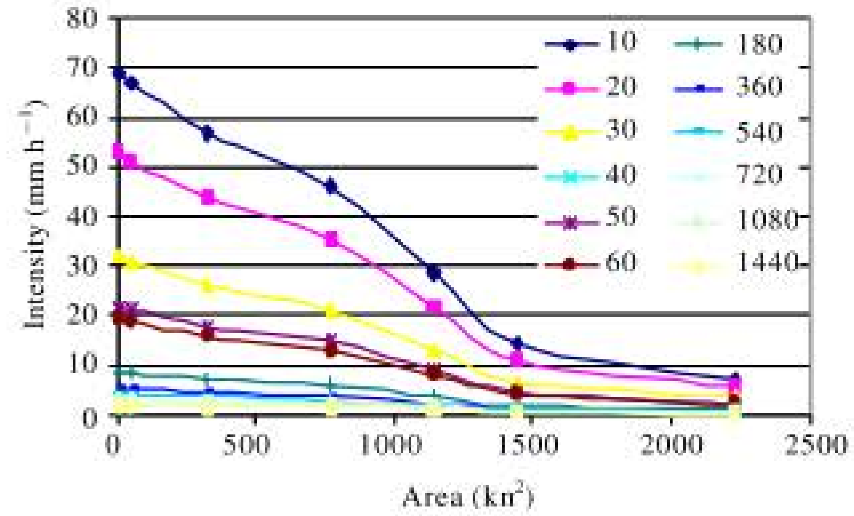

Fig. 13: IDFA curves of Zolachai river basin in 10-1440 min frequencies for 100 year return period

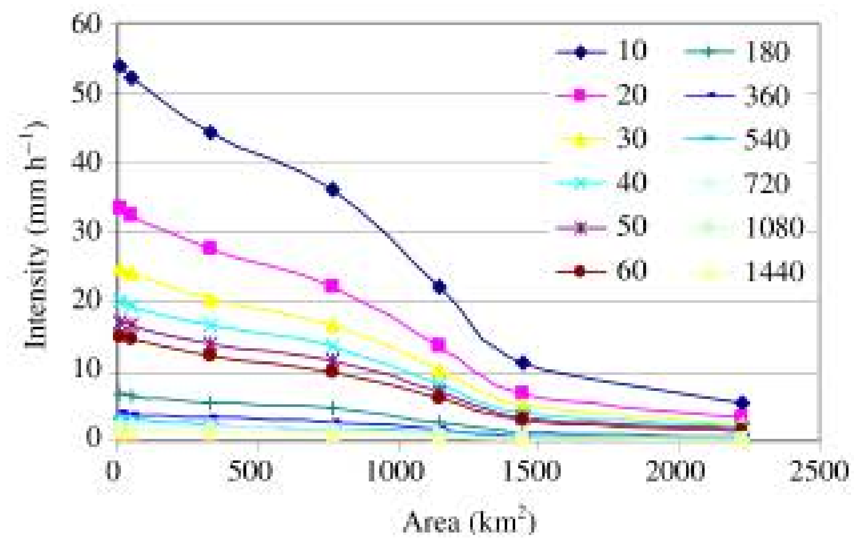

Fig. 14: IDFA curves of Zolachai river basin in 10-1440 min frequencies for 25 year return period

CONCLUSION

IDFA curves drawn for the mentioned river basin in 2-to-100-year return periods, is obtained by combining intensity-duration-frequency-depth curves and duration-area curves, presenting 4 rainfall parameters (Madsen *et al*., 1998). In all these curves the changes of intensity in relationship with area clearly indicate the relationship between these two features and by increasing the area, the intensity decreases. On the other hand, in higher return periods, high intensity measures are noticed, it means that the highest intensity measures have been in the 100-year return period. In the smallest area and the least frequency, the highest intensity has occurred. On the contrary, the least intensity measures in the largest area and the most frequency has occurred. Rainfall intensity changes in different frequencies, from short 10 min to longer 1440 min ones (for sample days) is from high to low. Because, as the frequency of rainfall increases, the rainfall intensity decreases.

As is indicated by the IDFA curves with the increase in the area from the least to the most (the area of the whole river basin) the intensity measures change. So, that with the increase in area, the intensity in different return periods decreases and gets closer to zero. This trend confirms the relationship between the rainfall features.

The equation of rainfall intensity-duration of the river basin changes according to the alternation or return period. The longer the return period; the heavier rain should be expected. Within a certain period of time, an increase in return period causes an increase in the intensity of the rain. This trend is observed both in IDF and IDFA curves in which the rainfall intensity measures in higher return periods increases. So, the recognition of the rainfall features of a river basin enables water construction engineers to plan for water projects more confidently (Yu *et al*., 2004).

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