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INTENSITY DURATION FREQUENCY CURVES FOR SINAI PENINSULA, EGYPT

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ABSTRACT

Climate change is one of the most important parameters affecting the water resources. It can be considered as a long-term change. It obviously affects the whole hydrologic cycle, therefore it causes a variation in rainfall intensity, duration and frequency of precipitation. Many regions in Egypt need to create or update their rainfall characteristics as a result to the climate changes (e.g. **I**ntensity **D**uration **F**requency **IDF**). This study aims to create a new IDF curve of Sinai Peninsula using the available methods of recurrence period (California, Hazen, Kimball and Gumbel) with Sherman formula. Field data is used to build the statistical equations of IDF curve. Data was collected by Water Resources Research Institute (WRRI), National Water Research Center (NWRC), Egypt. It was found that both California and Kimball methods are more accurate than the other methods compared to the local field data. In addition, both methods have the same outputs. Finally the contour maps of Sherman coefficients of Sinai Peninsula have been developed and calibrated.

KEYWORDS: Climatic Changes, Intensity Duration Frequency Curves, Return Periods, Wadi Sudr, Sinai Peninsula

INTRODUCTION

The disastrous events in the arid and semi arid regions increased in the last century due to climate change. Actually, the climate changes lead to change precipitation and temperature characteristics which automatically change IDF curves, (Prodanovic and simonovic 2007) [1]. Many researchers focused on IDF curves in engineering hydrology over the past decades [1-14].

Bell (1969) [2] and Chen (1983) [3] derived the IDF formulae for the United States. Koutsoyiannis et al., (1998) [3] proposed a new generalizing approach to the formulation of IDF curves using efficient parameterization. Nhat et al. (2006) [4] established IDF curves for the Monsoon area of Vietnam. Raiford et al. (2007) [5] updated the existing intensity-duration-frequency curves in the South Carolina, North Carolina, and Georgia and obtained these curves at un-gauged sites throughout the region using the newly developed rainfall frequency analysis techniques. Van et al, 2010 [6], proposed a technique to overcome the lack of long-term extreme precipitation data by combining limited high-frequency information on rainfall extremes with long-term daily rainfall information. Awadallah et al, (2011) [7] developed Intensity Duration Frequency (IDF) of a region in the North-West of Angola used limited data from ground rainfall stations and TRMM data. El-Sayed (2011) [8] created IDF curve of Sinai Peninsula depended on samples of records at proper meteorological stations. El-Fiky, et al. (2013) [9] updated the IDF curves for Riyadh city, KSA through the last ten years after 2000G depended on four recorded stations. The results illustrated the effect of climate change on the intensity of the rainfall. Liew et al, (2014) [10] developed IDF curve for un-gauged area (Java, Indonesia) depended on data from regions of climatologically similar characteristics, his approach extended to other un-gauged sites particularly in Peninsular Malaysia.

The objective of the present research is to create a new IDF curve of Sinai Peninsula using the available recurrence period methods depending on Sherman equation. In addition, the methods that get the maximum and minimum values of rainfall should be determined. Finally, the research developed contour maps of Sherman coefficients to calculate intensity of rainfall in the Sinai Peninsula.

METHODOLOGY

Different approaches can be used to develop the IDF curves. Actually, the present study adopted Sherman formula [11]. The main reason is due to its noticeable accuracy and simplicity. It states:

$$I = \frac{k \quad T^{x}}{t^{e}} \tag{1}$$

The parameters clarify the IDF graph are rainfall Intensity (I), storm duration or Time (t) and storm recurrence interval or Frequency (T). Four different methods are adopted to define the storm recurrence interval, see equations (2, 3, 4 and 5). The recurrence intervals are generally specified as: 2, 5, 10, 25, 50 and 100 years. K, x and e are constants.

California Method [11]

$$T = \frac{N}{m} \tag{2}$$

Hazen Method [11]

$$T = \frac{N}{m - 0.5} \tag{3}$$

Kimball Method [12]

$$T = \frac{N + 1}{m} \tag{4}$$

Gumbel Method [13]

$$T = \frac{N}{m + c - 1} \tag{5}$$

Where: N = Number of recorded years, m = Rank of the recorded years, c = Gumbel correction factor which depends on (m/N) values,

Table 1: Gumbel Correction Factor [13]

m/N	.0	.90	.80	.70	.60	.50	.40	.30	.20	.10	.08	.04
C	.0	.95	.88	.85	.78	.73	.66	.59	.52	.40	.38	.28

THE PROCEDURE TO GENERATE THE IDF CURVE

The next five steps were followed to develop the IDF curve for Sinai peninsula, chow (1988) [11].

- The available rainfall data of rainfall stations have been collected over the certain period (1990-2010);
- The rainfall measurements are arranged in a descending order at the different storm durations;
- The recurrence interval (T) is calculated using the considered 4-methods (California, Hazen, Kimball or Gumbel);
- The rainfall intensity at any time along the storm duration has been calculated using the following equation:

$$I_t = \left(\frac{60 \quad P_t}{t} \right) \tag{6}$$

Where; I_t= rainfall intensity at time (t) from the storm start (mm/hr), P_t= Precipitation depth recorded at time (t) from the storm start (mm); and t = Time passed from the storm start (min).

- Finally, the equations of IDF curve can be simply created

DATA COLLECTION AND PREPARATION

Sinai Peninsula is an important region at the North East part of Egypt. It has a network of daily rainfall recording rain stations since 1988. The available data are collected from 5-stations by WRRI, NWRC, MWRI. The metadata of the collected are shown figure 1. The rainfall measurements are checked with the General Metrological Authority (GMA) measurements, so the errors in the data are removed through quality control and verification analysis. Table 2 gives summary for the information of the recording stations. It is noticed that the maximum and minimum values of rainfall were measured at Ras Sudr and El Godirat, respectively. It is observed that rainfall intensity decreases in west direction.

Table 2: Number of Recorded Years and Events [8]

Station Name	Elevation	Observation Period	No. of Years	No. of Event	Max. Event (mm)	Ave. Duration (hr)
Ras Sudr	290	1990-2010	20	51	27.4	4.6
El Godirat	390	1990-2010	18	53	20	5.6
Nekhel	402	1990-2010	6	22	23.6	1.7
Ber Albd	18	1990-2010	16	53	26.8	6.1
Saint Kathrine	1652	1990-2010	17	38	25.02	4.7

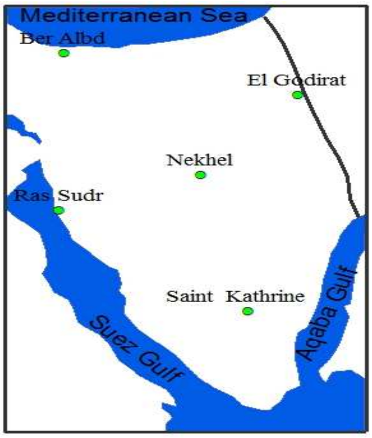
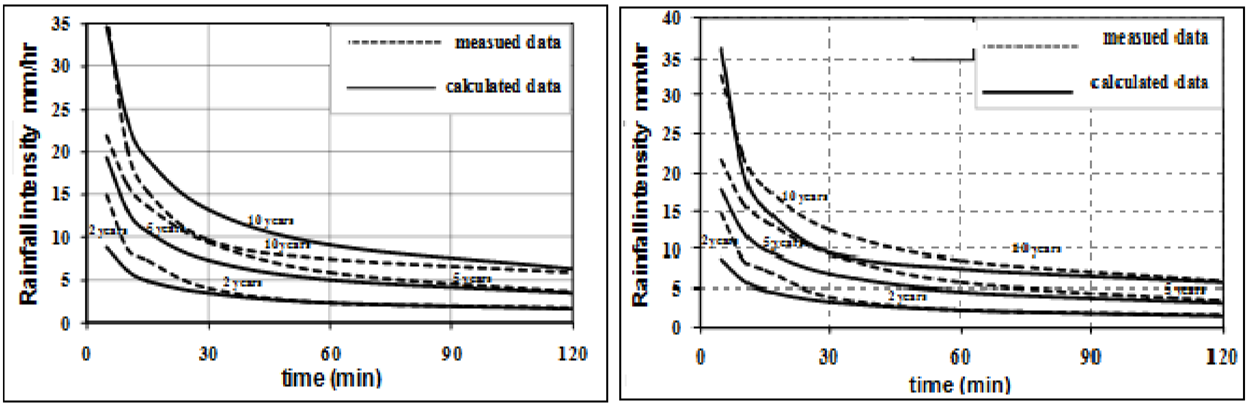


Figure 1: Location of Rainfall Stations [8]

CALIBRATION OF DEVELOPED EQUATIONS

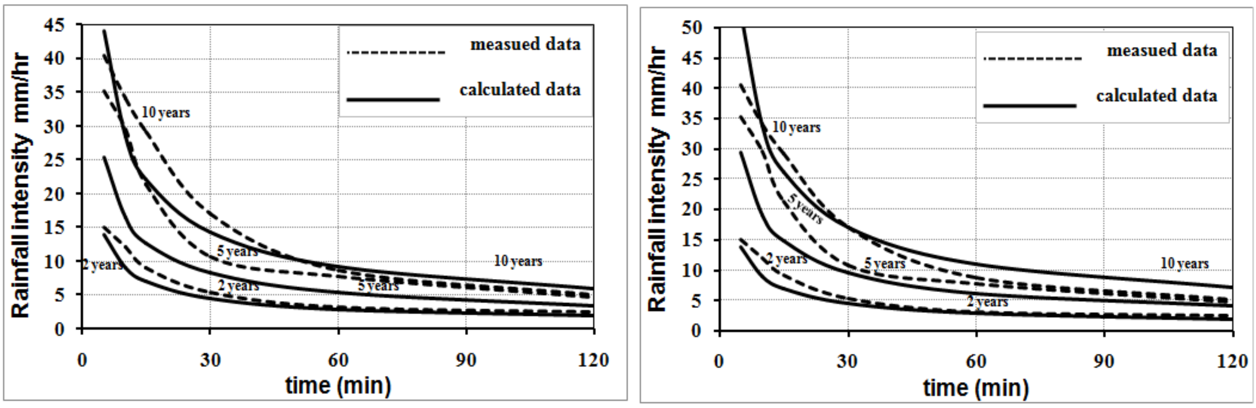
Filed data and statistical analysis are used to build equations of IDF curves of Sinai Peninsula depend on Sherman equation. Four equations of IDF curve are built to each region. The outputs for Sudr region and El Godirat region are compared to filled data as shown in figure 2 and 3. It is observed that the calculated values are very close to the field data.

The statistical measurement (i.e. the degree of confidence R^2) is calculated and tabulated in table 3. It clears that California and Kimball methods give the maximum values of R^2. As a result, both of California and Kimball methods are adopted to develop IDF curve for Sinai peninsula. Sherman coefficients of all studied regions are calculated as shown in table 4. As the result IDF curves are created for these regions, seen figure 4.



(a) (b)

Figure 2: Comparison between Measured and Calculated Rainfall Intensity of (Sudr Region)
(a) California Method (b) Hazen Method



(a) (b)

Figure 3: Comparison between Measured and Calculated Rainfall Intensity of (El Godirat Region)
(a) Gumbel Method (b) Kimball Method

Table 3: Degree of Confidence of Established Equations of IDF Curve

Station Name	California	Hazen	Gumbel	Kimball
Ras Sudr	0.83	0.80	0.77	0.83
El Godirat	0.905	0.88	0.86	0.905
Nekhel	0.92	0.89	0.87	0.92
Ber Albd	0.89	0.88	0.86	0.89
Saint Kathrine	0.87	0.84	0.81	0.87

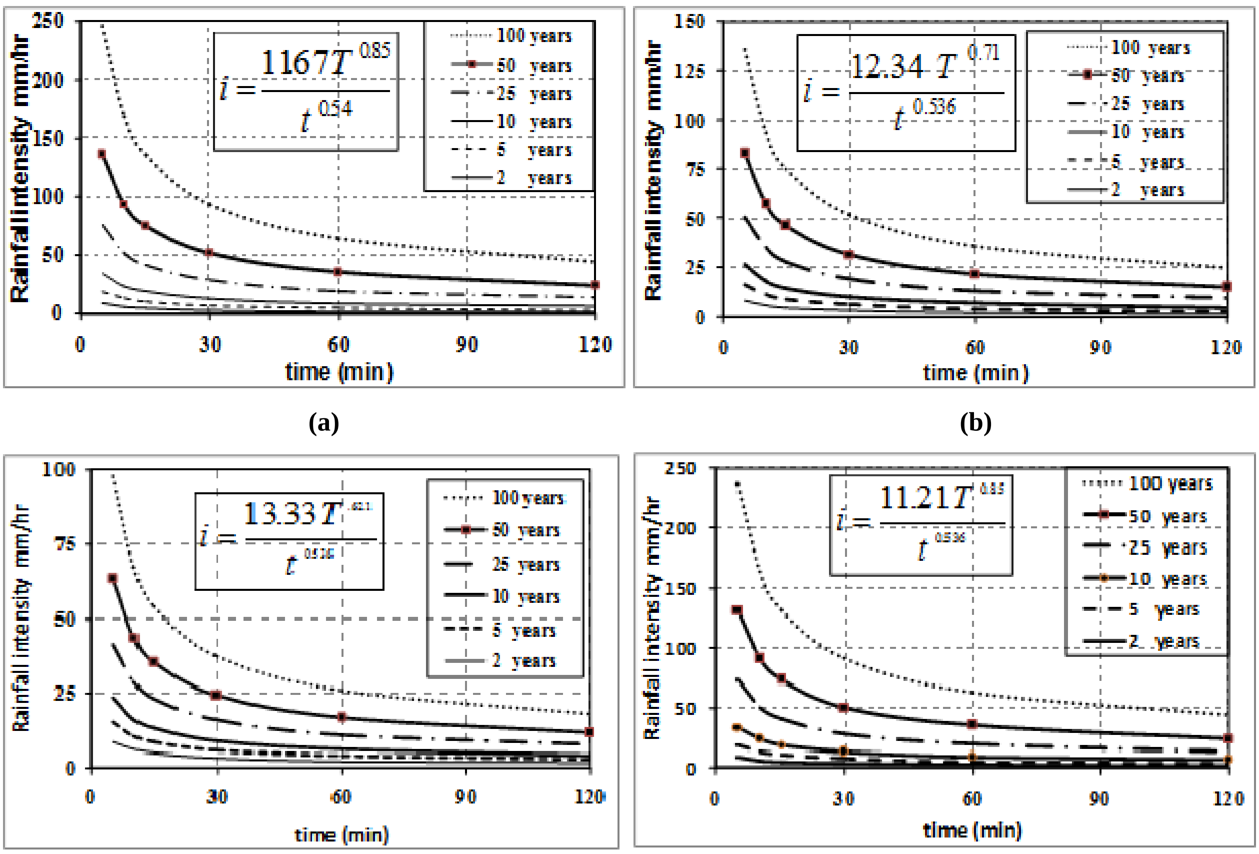
Table 4: Sherman Coefficients of IDF Curve

Station Name	California Method			Hazen Method			Gumbel Method			Kimball Method		
	K	e	X	K	e	x	K	e	X	k	e	x
Ras Sudr	11.67	0.54	0.85	12.35	0.54	0.71	13.33	0.54	0.62	11.21	0.54	0.85
El Godirat	23.30	0.63	0.83	24.47	0.63	0.68	26.4	0.63	0.6	22.28	0.63	0.83
Nekhel	17.65	0.67	1.50	17.78	0.67	1.10	20.5	0.67	1.00	14.00	0.67	1.50
Ber Albd	23.77	0.52	0.66	24.54	0.52	0.54	25.7	0.52	0.50	22.84	0.52	0.66
Saint Kathrine	14.29	0.47	0.78	14.93	0.47	0.64	16.08	0.47	0.56	13.66	0.47	0.78

GENERATION OF DESIGNED CONTOUR MAPS

One of the main objectives of the present study is generation of contour maps of Sherman coefficients depending on the calculated values for Sherman coefficients (i.e. K, e and X). Using GIS tools, three contour maps are developed for the different study parameters see figures 5, 6, and 7. These contours maps will facilitate the design process for hydraulic structures to be constructed in Sinai Peninsula by determine the intensity of rainfall.

The accuracy of the developed contour maps has to be checked before actual using. The validation process for contour map has been done for Ghrandal and El Timid which are located at east and west of Sinai peninsula. The comparison indicated a good convergence between values. This explained that the contour maps is an effective tools to calculate rainfall intensity of Sinai Peninsula. Table 5 illustrates the comparison between measured rainfall and calculated values.



(a) (b)

(c) (d)

Figure 4: IDF Curve of (Sudr Region) Depend on (a) California, (b) Hazen (c) Gumbel (d) Kimball Methods

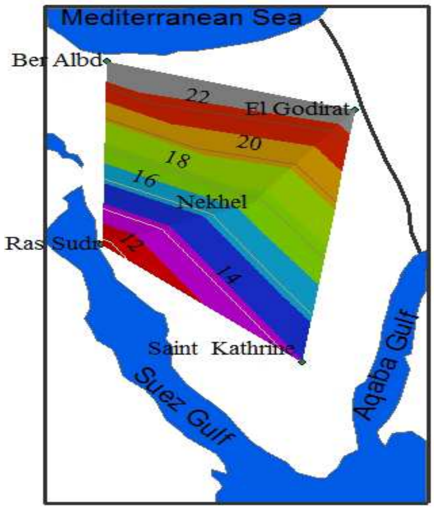


Figure 5: Contour Map of K Coefficient of California

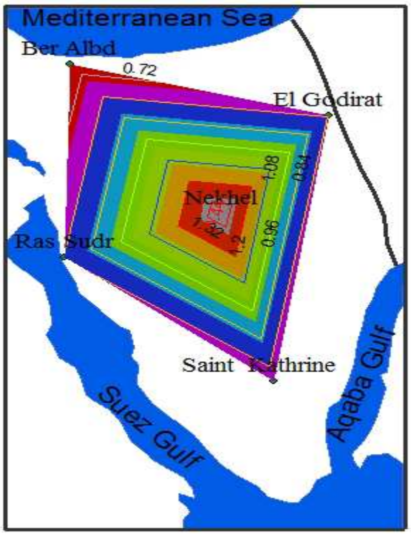


Figure 6: Contour Map of X Coefficient of California

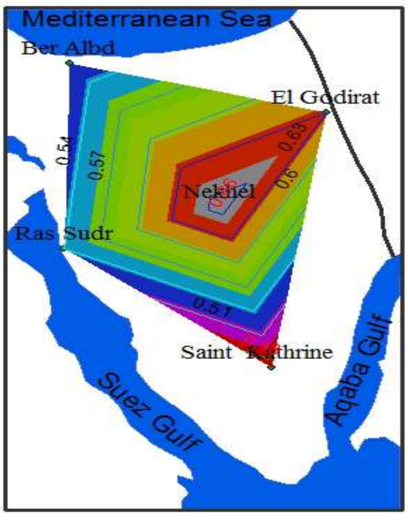


Figure 7: Contour Map of e Coefficient of California

Table 5: Comparison between the Measured and Calculated Data of Rainfall

Station Name	Measured (I) mm/hr for 100 min Duration			(K) Coeff. from Chart	(x) Coeff. from Chart	(e) Coeff. from Chart	Calculated (I) mm/hr for 100 min Duration			R Square
	(2) Years	(5) Years	(10) Years				(2) Years	(5) Years	(10) Years	
Ghrandal	1.8	5	8	13	0.86	.54	1.976239	4.385784	8.015735	0.95
El Timid	2	4	7	18	0.84	0.57	2.213744	4.736065	8.419233	0.95

CONCLUSIONS

Within the available data for Sinai Peninsula which was collected by WRRI, NWRC, MWRI, an updating of IDF curve of Sinai Peninsula was created. The analysis and discussions of the results indicated that California and Kimball methods give the maximum values of R^2. As a result, both California and Kimball methods are be adopted to develop IDF curve for Sinai Peninsula. Consequently, an update of IDF curve of Sinai Peninsula was created using these methods. Moreover, validated contour maps of Sherman coefficient was generated and hence can be used to calculate intensity of rainfall in higher accuracy. It is recommended to update the IDF for Sinai Peninsula the impact of climate change if the wrong the IDF curves were used in the design.

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