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MATHEMATICAL MODELLING OF HYDROLOGICAL PARAMETERS EFFECT ON PROBABLE MAXIMUM PRECIPITATION FOR AL-NAJAF AL-ASHRAF CITY

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ABSTRACT

In this research, the main aim is to formulate a mathematical model describe the relationship between annual probable maximum precipitation (PMP) for the city of Najaf and other hydrological variables such as temperature, relative humidity and evaporation rates depending on hydrologic data for the period between 1980 to 2005.

All the calculations of the values of annual probable maximum precipitation were made depending on Hershfield's method, which is depended on the general equation of hydrologic frequency analysis and calculating the frequency factor for a group of data. The model was derived by the help of the program (SPSS 21).

The study demonstrated a relative correlation between the previous independent variables, as a group, and the dependent variable (PMP) in one hand and the correlation between each independent variable with the value of PMP in the other hand. The coefficient of determination (R2) obtained from the statistical analysis for four equations were derived for each case with very suitable values.

KEYWORDS: Probable maximum precipitation, hydrologic parameters, Mathematical model, Coefficient of determination, Al-Najaf City

1. INTRODUCTION

The rainfall is one of the hydrological factors that affected by other weather factors and the variation in its values occurred according to the change in season and geographical location of the area. The maximum expected rainfall depth at a specific period can be defined as the maximum possible precipitation.

The magnitude of maximum possible precipitation affect by several hydrological factors and its variation is depending on the rainy season period, the concomitant change in temperatures, evaporation rates and relative humidity. Al-Najaf city is located between longitudes 44o 18' 34" and 44o 19' 14" seconds, and between (31o 59' 27") and (31o 59' 56") latitudes as shown in Fig. 1, as shown in Fig. 1. The meteorological stations scattered in Al-Najaf governorate are shown in Fig. 2.

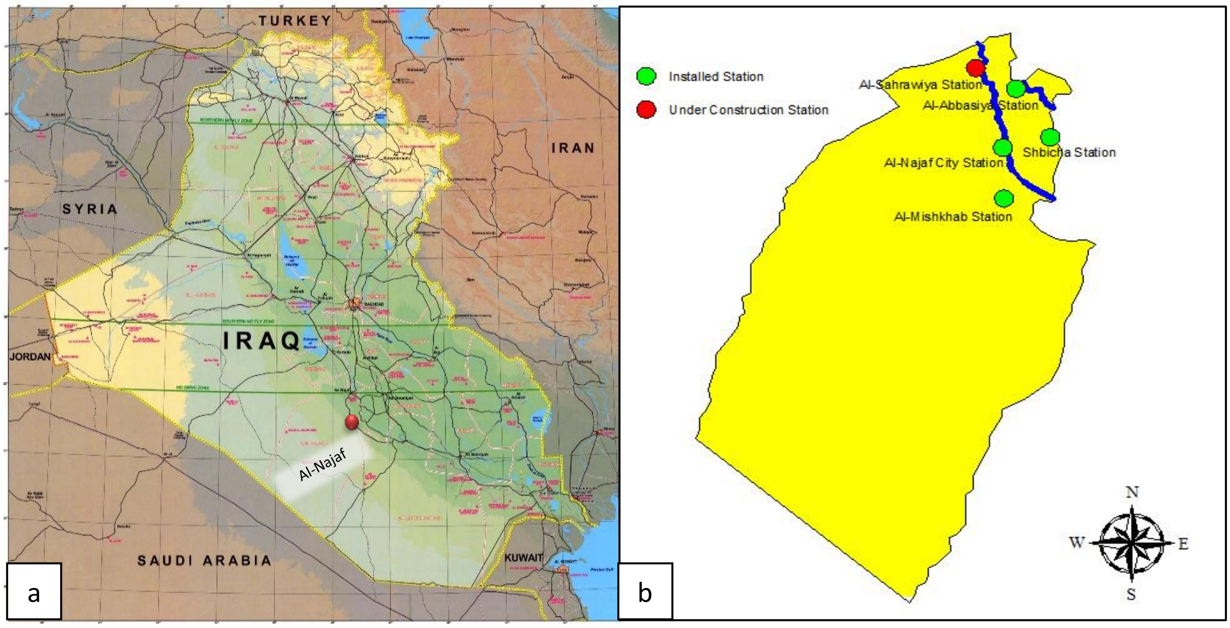

Fig. 1. (a) Al-Najaf Al-Ashraf Province Location (b) The Location of Meteorological Stations in Al-Najaf City

The value of probable maximum precipitation (PMP) is an indicator for the value of probable maximum flood (PMF) which could be calculated by the known probability distribution such as Gumbel's extreme values, log normal distribution and log – Pearson type III.

Depending on the value of PMF, which is a main factor for design of hydraulic structures such as dams and reservoirs, the geometry of the components for each structure will be designed to reduce the risk of floods as much as possible.

Casas et al (2008) introduced a summarized review of multi techniques to estimate the probable maximum precipitation (PMP). The value of PMP for a duration of one day and for the province of Catalonia in Spain as an appointed case has been calculated with high value of spatial resolution. The analysis of data has been conducted depending on a rainfall series data obtained from 145 meteorological stations. When using the method of Cressman (1959), the data of monthly precipitation obtained from Geographic Information System (GIS) have been analyzed to apply the primary section of the analysis. For 1 km2 spatial resolution, the PMP for duration of one day has been calculated and it was ranged between 200 mm to 550 mm.

Vivekanandan 2015 used the statistical method to predict the values of PMP. The distribution of extreme values type 1 (EV1) of rainfall and then all the results are compared with the values of PMP with duration of one day which are calculated from the method of Hershfield (1961). The test of adequacy between the two series of results are made by the test of Anderson – Darling, while the randomness and homogeneity of the data series are checked by Wald – Wolfowitz run test and Mann – Whitney Wilcoxon U – test. Finally, the outlier values in the series are checked by Grubbs test. The values of estimated one day PMP of 25.7 cm for Devarapalle and 46.3 cm for Visakhapatnam could be adopted for the purposes of design.

The model suggested by Bethlahmy (1984) was modified by Ghahraman and Sepaskhah (1994). The new development offered a new criterion for extreme rainfall values estimation for the southern parts of Iran. They show the difference between the method of Bethlahmy and Hershfield in one hand and the method of synoptical in the other.

Koutsoyiannis (1999) presented a new method and by the help of frequency factor method, to assign the return period for a series of PMP values.

Paimozd (2002) suggested a new method for estimation PMP by combining the synoptical and statistical methods at eastern basins of Hormozgan province in Iran. He concluded the values of PMP resulted from Hershfield method are larger than that resulted from synoptical method while closer to the values resulted from statistical method.

In this research, a mathematical model are derived to describe the relationship between the value of PMP and other hydrological factors for Al-Najaf Al-Ashraf province in Iraq for the period between 1980 to 2005.

2. CALCULATING THE PROBABLE MAXIMUM PRECIPITATION (PMP)

The Calculation of the probable maximum precipitation were made depending on the Hershfield (1965), which is one of the statistical method, used to estimate the value of PMP. Hershfield method depends on the general frequency equation derived by Chow (1951) and Table 1 shows the results:

$$\mathrm{PMP} = \overline{\mathrm{X}}_n + k_m\,\sigma_n \quad (1)$$

$\overline{\mathrm{X}}_n$: The mean value for series of annual maximum rainfall of a certain period

σ_n : The standard deviation for series of annual maximum rainfall of a certain period

k_m: the frequency factor, which can be calculated by:

$$k_m = \frac{X_m - \overline{X}_{n-1}}{\sigma_{n-1}} \quad (2)$$

X_m: highest value for series of (n) annual maximum rainfall values of a given period

$\overline{X}_{n-1}$: The mean value for series excluding the highest value from the series

σ_{n-1} : The standard deviation for series excluding the highest value from the series

3. REPRESENTATION AND DISCUSSION OF DATA

3.1. General Data

3.1.1. Data of Rainfall

The data of rainfall used in this research are given in Table 2.

Table 1. Calculations of the Annual Values of Probable Maximum Values for Al-Najaf Al-Ashraf City from 1980 to 2005.

Year	Sum of Annual Rainfall (mm)	X_{n-1}	σ_{n-1}	X_m	σ_n	K_m	PMP (mm)
1980	116.4	3.8	6.4	9.7	21.28	10.94	242.61
1981	56.0	3.0	5.0	4.7	7.45	4.00	34.46
1982	169.7	11.0	11.8	14.1	15.63	3.21	64.24
1983	119.9	6.8	12.1	10.0	16.05	3.19	61.19
1984	109.5	4.9	6.4	9.1	15.8	7.87	133.55
1985	58.8	3.5	6.5	4.9	7.83	2.5	24.47
1986	117.7	6.6	10.5	9.8	15.01	3.71	65.49
1987	159.3	7.5	14.2	13.3	24.24	4.9	132.07
1988	173.8	11.7	13.8	14.5	16.24	2.39	53.28
1989	140.4	6.9	10.5	11.7	19.41	5.49	118.21
1990	82.7	3.1	4.3	6.9	13.62	10.39	148.41
1991	84.3	4.4	4.9	7.0	10.15	6.33	71.25
1992	111.9	6.4	9.2	9.3	13.49	3.86	61.48
1993	170.0	7.3	11.6	14.2	26.25	7.13	201.27
1994	147.6	7.8	10.3	12.3	18.51	5.31	110.52
1995	64.1	3.7	5.4	5.3	7.77	3.72	34.28
1996	91.3	4.7	8.0	7.6	12.73	4.42	63.92
1997	142.9	8.1	11.8	11.9	17.36	3.88	79.31
1998	95.6	5.7	10.7	8.0	12.84	2.55	40.75
1999	49.9	2.8	4.2	4.2	6.17	3.95	28.56
2000	54.6	2.6	4.0	4.6	7.69	5.82	49.34
2001	75.0	5.1	8.0	6.3	8.7	1.77	21.66
2002	64.2	3.7	4.2	5.4	6.94	4.65	37.58
2003	68.7	3.9	6.5	5.7	8.74	3.28	34.44
2004	52.0	2.5	3.6	4.3	7.32	6.13	49.19
2005	71.9	4.0	5.3	6.0	8.51	4.46	43.94

Table 2. Rainfall Data for Al-Najaf Al-Ashraf City from 1980 to 2005.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	4.1	74.4	3.7	2.4	1.0	0.0	0.0	0.0	0.0	0.4	21.4	9.0
1981	14.5	7.5	22.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	8.6
1982	48.7	14.4	9.5	35.1	22.1	0.0	0.0	0.0	0.0	23.8	8.3	7.8
1983	1.0	2.1	4.3	31.0	31.0	0.0	0.0	0.0	0.0	0.0	5.1	45.4
1984	9.3	0.7	12.6	0.5	15.5	0.0	0.0	0.0	0.0	1.8	55.4	13.7
1985	19.5	1.7	13.2	0.4	2.3	0.0	0.0	0.0	0.0	0.0	1.8	19.9
1986	6.0	45.4	15.4	9.2	7.5	0.0	0.0	0.0	0.0	0.0	34.0	0.2
1987	0.0	7.8	46.6	0.0	0.0	0.0	0.0	0.0	0.0	11.3	16.5	77.1
1988	34.6	13.5	30.7	44.7	0.0	0.0	0.0	0.0	0.0	8.1	12.7	29.5
1989	3.2	64.5	31.6	22.2	3.8	0.0	0.0	0.0	0.0	5.9	8.6	0.6
1990	8.9	48.1	3.1	12.1	0.0	0.0	0.0	0.0	0.0	3.2	0.2	7.1
1991	5.3	35.6	13.6	6.0	1.0	0.0	0.0	0.0	0.0	6.6	4.0	12.2
1992	3.5	6.2	19.5	13.7	1.2	0.0	0.0	0.0	0.0	0.0	41.9	25.9
1993	34.7	23.5	0.5	89.8	7.1	0.0	0.0	0.0	0.0	1.8	10.5	2.1
1994	27.0	3.5	8.1	4.2	0.6	0.0	0.0	0.0	0.0	18.9	62.2	23.1
1995	2.6	17.0	8.7	23.8	0.3	0.0	0.0	0.0	0.0	0.0	6.2	5.5
1996	40.0	14.3	25.1	4.7	3.2	0.0	0.0	0.0	0.0	0.0	0.8	3.2
1997	12.8	0.7	10.9	4.1	0.6	0.0	0.0	0.0	0.0	33.0	53.9	26.9
1998	32.5	18.4	32.9	9.7	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0
1999	19.2	7.8	3.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	6.0	12.1
2000	10.0	1.6	0.3	1.5	0.0	0.0	0.0	0.0	0.0	5.4	25.8	10.0
2001	12.1	9.9	4.0	25.7	1.4	0.0	0.0	0.0	0.0	0.4	2.2	19.3
2002	5.0	4.5	9.3	23.3	4.0	0.0	0.0	0.0	0.0	0.4	5.3	12.4
2003	8.9	0.0	0.4	8.4	5.3	0.0	0.0	0.0	0.0	0.0	25.3	20.4
2004	24.8	1.2	1.0	4.4	7.2	0.0	0.0	0.0	0.0	0.6	11.1	1.7
2005	27.7	9.7	12.8	12.4	0.2	0.0	0.0	0.0	0.0	0.5	6.6	2.0

3.1.2. Data of Evaporation

The data of evaporation used in this research are given in Table 3.

Table 3. Evaporation Data for Al-Najaf Al-Ashraf City from 1980 to 2005

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	8.35	9.56	20.2	31.89	45.01	68.35	67.92	56.86	44.65	32.9	15.85	10.61
1981	10.22	13.88	21.13	32.44	41.65	56.01	67.12	62.59	50.88	29.18	16.43	8.51
1982	6.42	9.32	17.91	25.47	38.52	55.93	63.98	64.21	42.8	24.71	10.78	7.95
1983	8.09	10.98	19.22	27.88	38.26	57.8	68.72	66.72	42.51	29.75	18.75	7.56
1984	9.61	16.5	21.47	31.4	39.2	60.18	61.47	54.81	40.5	29.65	11.6	8.26
1985	9.21	14.25	20.89	31.29	41.6	56.35	59.77	55.12	41.06	26.73	14.86	8.56
1986	9.23	10.81	21.18	28.79	38.4	49.6	61.3	49.32	37.17	26.58	15.49	8.1
1987	9.51	14.76	17.29	31.12	41.58	55.62	58.34	50.06	30.28	24.78	12.45	17.61
1988	6.85	12.08	19.18	21.62	36.58	45.02	50.83	46.6	43.14	27.37	20.16	11.99
1989	8.23	9.76	21	28.6	41.12	51.53	58.39	50.22	38.15	27.78	12.42	8.5
1990	8.09	12.97	26.56	28.07	48.62	60.33	63.09	54.89	42.01	25.56	14.93	10.27
1991	7.82	13.46	21.44	25.69	39.42	52.5	59.76	52.22	39.3	24.61	15.14	9.09
1992	8.46	11.18	16.41	25.21	32.79	46.51	56.86	56.43	36.82	21.47	11.22	6.23
1993	6.48	19.93	20.58	20.89	35.16	51.61	60.69	47.34	40.21	23.64	14.88	8.36
1994	9.27	13.49	22.24	34.61	44.48	54.26	61.89	58.65	44.93	34.15	12.13	8.11
1995	7.71	10.68	19.54	27.42	46.07	54.66	58.62	54.83	37.04	27.93	18.48	10.1
1996	8.87	12.75	19.26	30.82	56.24	55.47	65.79	66.11	43.58	34	16.92	13.01
1997	18.83	11.17	19.28	31.05	40.95	54.79	62.24	55.37	37.08	25.38	10.38	6.42
1998	7.18	11.32	19.83	43.81	48.78	56.33	59.33	56	42.22	31.27	17.85	15.43
1999	11.47	13.74	25.12	34.83	67.84	53.1	59.92	62.84	40.71	29.27	17.58	9.69
2000	10.39	15.44	26.67	35.08	46.27	61.97	72.99	59.02	41.37	27.51	10.88	9.96
2001	9.66	12.8	23.78	33.69	47.23	63.85	62.47	60.36	38.95	31	20.95	9.94
2002	9.48	14.32	25.67	30.41	40.69	59.62	58.12	59.33	39.08	29.91	20.72	9.85
2003	9.84	15.32	25.71	29.8	40.33	52.56	65.93	64.9	39.03	30.1	25.94	9.74
2004	9.52	11.17	21.83	24.04	37.89	46.08	55.22	49.43	44.37	37.75	10.64	7.46
2005	9.25	10.97	21.73	34.07	41.15	51.03	57.9	48.07	38.71	27.74	14.45	11.71

3.1.3. Data of Temperature

The data of evaporation used in this research are given in Table 4.

Table 4. Temperature Data for Al-Najaf Al-Ashraf City from 1980 to 2005

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	15.6	17.4	24.3	30.4	36.8	42.1	44.5	42.1	38.6	32.2	24.6	18.2
1981	17.2	19.7	25.1	29.7	34.9	40.5	43.9	43.3	41.0	34.2	32.0	19.7
1982	17.9	17.8	25.7	30.1	35.7	40.7	42.7	43.6	40.5	34.3	28.2	19.8
1983	17.1	17.3	25.8	32.0	37.9	41.6	43.5	43.8	40.6	33.8	27.0	19.6
1984	16.8	20.5	24.9	31.2	35.2	40.4	43.3	42.7	39.6	32.6	26.3	17.3
1985	18.7	21.1	25.1	32.7	37.8	40.7	44.1	45.2	41.6	34.6	27.7	18.1
1986	17.3	20.4	23.4	30.9	35.8	39.7	44.7	45.3	42.6	34.0	21.7	16.4
1987	18.8	22.9	21.5	30.3	37.5	40.8	44.8	43.6	40.9	31.1	23.5	18.9
1988	16.0	20.0	24.2	31.0	38.4	41.2	44.9	44.3	41.6	33.9	24.9	18.2
1989	14.0	16.7	23.4	33.4	38.1	40.9	44.8	44.1	39.2	34.0	24.7	18.6
1990	14.6	17.8	24.6	30.4	37.7	41.9	44.6	41.2	40.1	33.5	27.1	20.3
1991	14.2	17.0	24.8	32.5	37.4	43.3	45.9	44.4	40.5	33.9	26.1	19.5
1992	15.1	18.6	22.8	31.3	35.1	42.8	45.0	45.0	40.6	34.7	25.7	19.5
1993	14.5	17.5	23.5	28.8	34.8	41.1	44.0	43.8	40.2	34.1	22.2	20.2
1994	18.3	20.2	25.4	33.0	38.2	41.6	43.1	42.6	40.3	33.8	22.9	14.5
1995	18.3	20.6	24.9	33.3	38.6	42.5	44.6	43.7	40.5	34.6	23.6	17.2
1996	16.9	19.8	22.8	30.2	40.1	42.2	46.6	44.8	39.7	33.3	24.5	21.4
1997	17.4	17.7	21.5	30.1	39.0	43.6	43.5	44.5	39.6	32.8	25.2	20.7
1998	14.6	18.5	22.1	32.5	38.3	44.5	45.8	46.2	40.9	34.7	28.3	21.6
1999	18.3	21.6	25.8	32.3	39.4	43.1	44.4	45.1	40.0	35.0	24.6	18.4
2000	16.1	18.7	24.6	33.3	38.4	42.5	47.3	46.0	40.4	31.5	23.0	17.8
2001	16.9	20.2	27.3	31.3	37.2	42.1	45.2	46.3	41.9	34.6	24.1	19.2
2002	16.6	20.1	26.0	32.6	38.5	42.9	45.9	45.9	41.4	34.5	23.9	17.5
2003	17.1	21.0	25.4	33.0	39.0	43.3	45.6	46.2	42.7	36.2	25.1	18.2
2004	17.6	19.8	24.8	31.2	38.0	43.0	45.0	45.0	41.8	33.8	21.9	16.9
2005	17.2	19.3	25.9	33.2	38.5	43.3	46.6	45.6	41.2	34.3	24.2	22.6

3.1.4. Data of Relative Humidity

The data of relative humidity used in this research are given in Table 5.

Table 5. Relative Humidity Data for Al-Najaf Al-Ashraf City from 1980 to 2005

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	60.0	62.0	48.0	36.0	24.0	16.0	20.0	22.0	27.0	35.0	63.0	71.0
1981	70.0	59.0	56.0	40.0	34.0	28.0	23.0	24.0	27.0	38.0	58.0	72.0
1982	81.0	70.0	53.0	54.0	43.0	23.0	20.0	20.0	27.0	47.0	65.0	71.0
1983	61.0	52.0	45.0	40.0	34.0	23.0	19.0	24.0	27.0	37.0	56.0	81.0
1984	73.0	49.0	53.0	40.0	37.0	24.0	20.0	24.0	28.0	36.0	72.0	73.0
1985	72.0	55.0	51.0	41.0	32.0	26.0	23.0	22.0	25.0	39.0	62.0	70.0
1986	64.0	65.0	56.0	47.0	28.0	28.0	25.0	26.0	28.0	40.0	62.0	66.0
1987	57.0	50.0	57.0	47.0	31.0	27.0	30.0	29.0	31.0	46.0	53.0	67.0
1988	74.0	58.0	52.0	51.0	31.0	28.0	28.0	27.0	29.0	40.0	51.0	70.0
1989	65.0	56.0	57.0	39.0	31.0	25.0	20.0	22.0	29.0	39.0	61.0	63.0
1990	63.0	59.0	39.0	35.0	24.0	20.0	19.0	20.0	29.0	38.0	46.0	58.0
1991	69.0	61.0	52.0	44.0	33.0	25.0	21.0	30.0	30.0	54.0	55.0	66.0
1992	73.0	63.0	61.0	46.0	35.0	29.0	24.0	27.0	31.0	39.0	66.0	75.0
1993	75.0	67.0	49.0	56.0	40.0	24.0	20.0	25.0	28.0	38.0	49.0	66.0
1994	72.0	51.0	48.0	36.0	27.0	20.0	20.0	21.0	27.0	43.0	68.0	71.0
1995	77.0	70.0	54.0	43.0	27.0	25.0	23.0	21.0	28.0	42.0	51.0	67.0
1996	71.0	59.0	53.0	46.0	34.0	30.0	24.0	22.0	26.0	33.0	51.0	57.0
1997	63.0	46.0	44.0	35.0	26.0	23.0	23.0	26.0	29.0	43.0	68.0	79.0
1998	73.0	65.0	60.0	38.0	30.0	24.0	24.0	24.0	31.0	40.0	50.0	57.0
1999	71.0	58.0	42.0	35.0	29.0	27.0	26.0	24.0	33.0	38.0	51.0	71.0
2000	71.0	64.0	50.0	42.0	34.0	24.0	20.0	21.0	26.0	38.0	58.0	73.0
2001	71.0	57.0	51.0	43.0	34.0	17.0	17.0	16.0	23.0	33.0	42.0	63.0
2002	66.0	60.0	47.0	40.0	32.0	24.0	21.0	21.0	25.0	34.0	53.0	65.0
2003	66.0	56.0	48.0	40.0	33.0	22.0	21.0	20.0	23.0	31.0	51.0	58.0
2004	76.0	58.0	52.0	42.0	37.0	25.0	23.0	24.0	30.0	32.0	67.0	68.0
2005	59.0	53.0	50.0	38.0	33.0	23.0	24.0	23.0	30.0	41.0	66.0	70.0

3.2. PMP vs. Temperature (T)

As shown in Fig. 3 that represents the relation between PMP and annual temperature (for 26 years). The maximum value of PMP was recorded at 1980 and it was 242.61 mm, while the annual average temperature (T) was 30.6^o C, which represents the minimum value during the period of records. The minimum value of PMP was recorded at 2001 and it was 21.66 mm with annual average of temperature of 32.2^o C, which is one of the years that experienced a hot dry climate and high temperatures at the summer especially and over the year in general, and this proves the negative relationship between the temperature and PMP.

The representative equation, which describe the relation as shown in figure above and by using SPSS 21 program for 90% of data, is:

$$PMP - 20.12\sqrt{\mathbf{PMP}} = 7.3\,T - 92.8 * \ln(T) \quad 3$$

The equation above gives high coefficient of determination R^2 of 0.976.

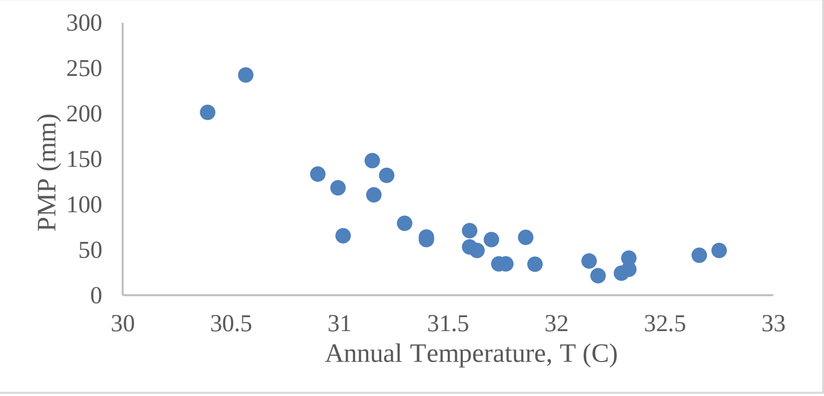

Fig. 3. Relation between Probable Maximum Precipitation (PMP) and Annual Temperature (T) for Al-Najaf City from 1980 to 2005.

3.3. PMP vs. Evaporation (E)

As shown in Fig. 4 that represents the relation between PMP and annual evaporation (for 26 years). The maximum value of PMP was recorded at 1980 and it was 242.61 mm, while the annual average evaporation (E) was 27.05 cm, which represents the minimum value during the period of records. The minimum value of PMP was recorded at 2001 and it was 21.66 mm with annual average of evaporation of 34.56 cm, and this proves that there is a negative relationship between the evaporation and PMP.

The representative equation, which describe the relation as shown in figure above and by using SPSS 21 program for 90% of data, is:

$$PMP - 19.4\sqrt{PMP} = 2.65 * E - 48.73 * \ln(E) \quad 4$$

The equation above gives high coefficient of determination R^2 of 0.977.

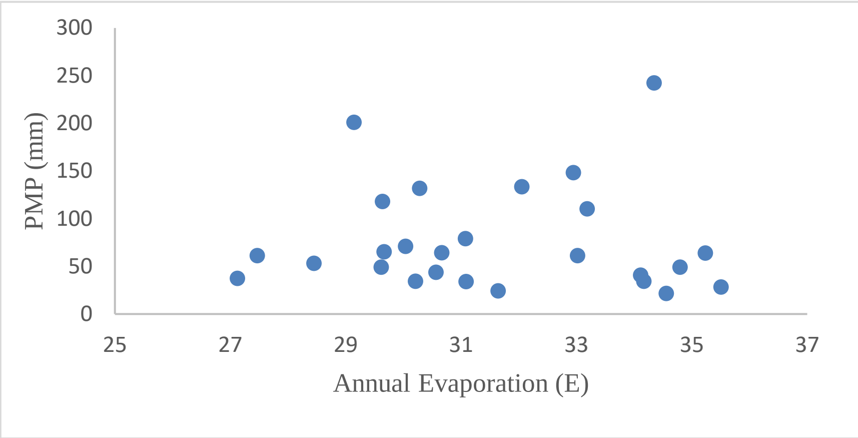

Fig. 4. Relation between Probable Maximum Precipitation (PMP) and Annual Evaporation (E) for Al-Najaf City from 1980 to 2005.

3.4. PMP vs. Relative Humidity (RH)

Fig. 5 shows the relation between PMP and annual relative humidity. The maximum value of PMP was recorded at 1980 and it was 242.61 mm, while the annual average of Relative humidity (RH) was 40.4 %, while the minimum value of PMP was recorded at 2001 and it was 21.66 mm with annual average of relative humidity of 39%. The data recorded between 1980 to 2005 showed that the values of annual average of relative humidity varies randomly and decrease or increase by the effect of the other meteorological parameters and the intensity of temperature at the summer season particularly.

By representing the data for each annual PMP and relative humidity and then selecting the best relation between them as follows:

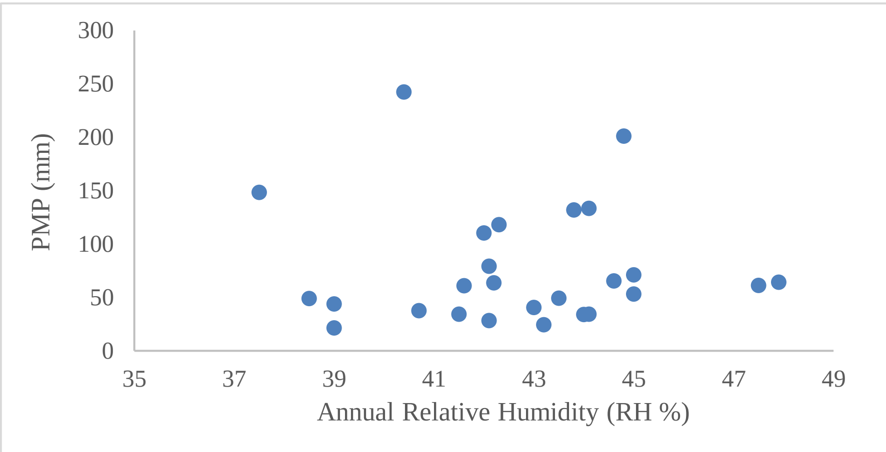

Fig. 5. Relation between Probable Maximum Precipitation (PMP) and Annual Relatve Humidity (RH) for Al-Najaf City from 1980 to 2005.

The representative equation, which describe the relation as shown in figure above and by using SPSS 21 program for 90% of data, is:

$$PMP - 19.33\,\sqrt{\mathbf{PMP}} = -0.64 * RH - 15.06 * \ln(RH) \qquad 5$$

The equation above gives high coefficient of determination R^2 of 0.977.

4. GENERAL MATHEMATICAL MODEL

Using SPSS 21 program (Fig. 6) and depending on 90% of the data given from 1980 to 2005, the mathematical model derived that relates between PMP and other hydrological factors is:

$$PMP - 83.751 * \ln(PMP) = 3.861 * \sqrt{\boldsymbol{E}} * \ln(T) - 91.738 * \ln(RH) \qquad 6$$

This equation above gives a good coefficient of determination R^2 of 0.908

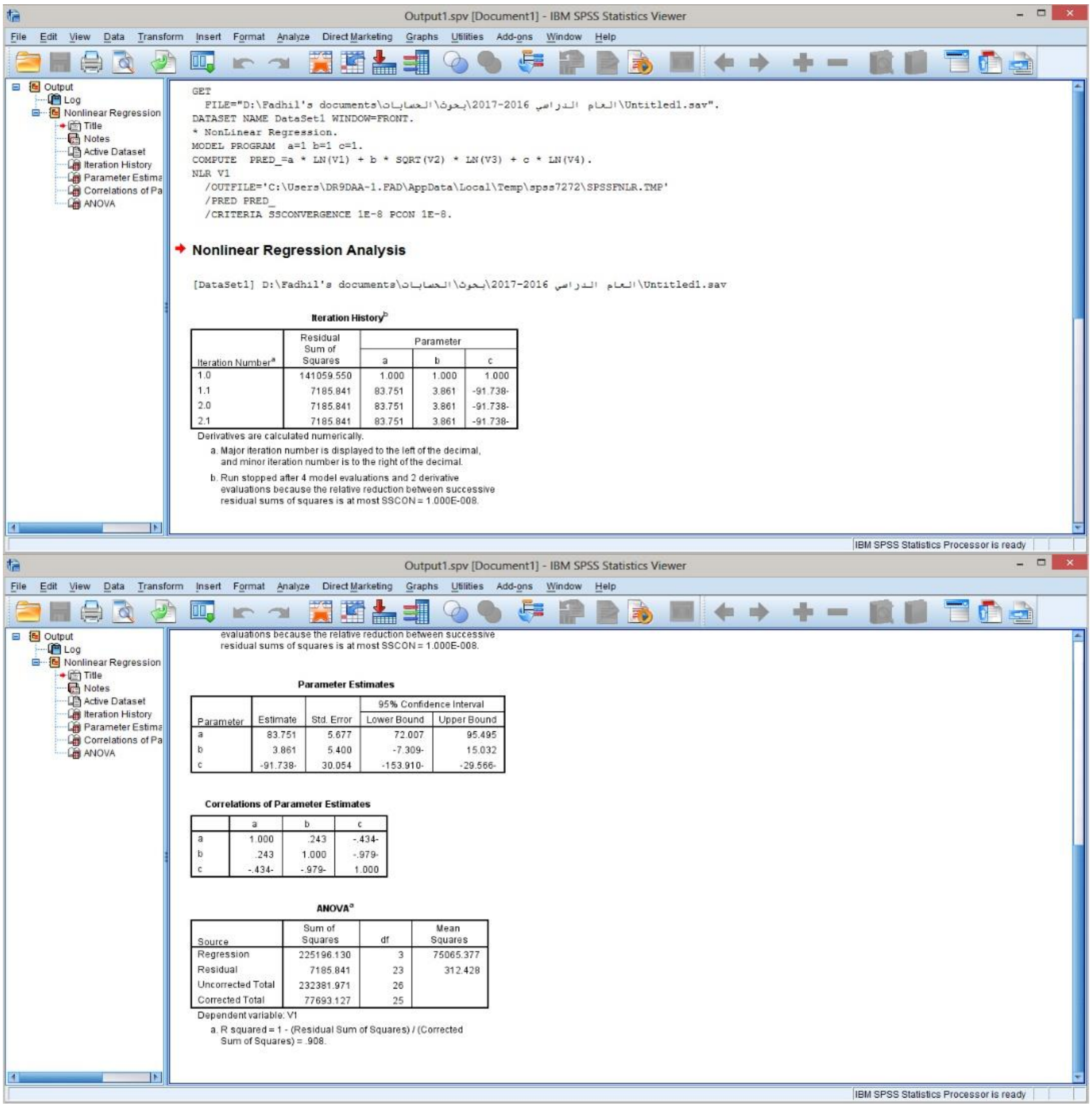

Fig. 6. Output File of SPSS Program of Non-Linear Regression for PMP and other Hydrological Data (Derivation of Equation 6).

5. A COMPARISON BETWEEN CALCULATED VALUES FROM DATA AND CALCULATED VALUES FROM DERIVED EQUATIONS

In the previous sections, 90% of data were used to derive the formulas from (3) to (6), while the other 10% has been used as input data in the formulas. The results from these formulas are called "the calculated values of PMP".

In order to test the accuracy for each formula derived in this section, these results will be compared with registered values and then the difference percentage is calculated. A brief calculation for difference percentage are listed in Table 6.

Table 6. A comparison between the Registered and Calculated Values of PMP.

Equation Number	Calculated PMP from Hydrological Data (mm)	Calculated PMP from Equations (mm)	*Difference Percentage %
3	37.58	40.2	6.5
	34.44	36.1	4.6
	49.19	45	9.3
	43.94	40.2	9.3
4	37.58	40.5	7.2
	34.44	37.9	9.1
	49.19	48.5	1.4
	43.94	45.9	4.3
5	37.58	39.2	4.1
	34.44	36.6	5.9
	49.19	47.1	4.4
	43.94	40.9	7.4
6	37.58	35.15	6.9
	34.44	31.65	8.8
	49.19	47.3	4
	43.94	40.6	8.2

* Difference Percentage % = $\left|\frac{\textbf{Calculated PMP from eqs.} - \textbf{Calculated PMP from Hydro.Data}}{\textbf{Calculated PMP from eqs.}}\right| * 100$

6. CONCLUSIONS

The study examined the correlation between the amount of annual rainfall as the dependent variable and some weather variables and other climate independent variables, study also showed the importance of the variables studied and their impact on the amount of rainfall in

Al-Najaf city. The study showed that the area of cases of persistent drought for the last seven years for a period of data recording rates have fallen much annual rainfall rates for the public, which is due to the phenomenon of global warming being witnessed by the world in general and the region in particular . The study highlighted the mutual relationship between the impact of weather variables and annual rainfall on the one hand and between those same variables, on the other hand where you cannot rely on one variable to influence and interact with other variables.

1. From the analysis of data, the relation between probable maximum precipitation and annual temperature is inverse relation, i.e. when PMP values increase, the value of T decrease.
2. The analysis also shows that the relation between probable maximum precipitation and annual temperature is inverse relation within the same season, i.e. when PMP values increase, the value of E decrease.
3. The hydrological information available for Al-Najaf city during this period indicates that the relationship between PMP and RH is positive. It is clear that in the summer, when the temperature rises, the relative humidity and rainfall are reduced due to the semi-dry climate of the region. This relationship is shown separately for each year due to the adoption of annual rates. The reason for the random distribution of the points is that the difference between the value of PMP and RH differs between one year and another due to the difference of other hydrological conditions that have a direct effect on the values of PMP and RH.
4. Ninety percent of available data for each annual PMP, annual temperature, annual evaporation and annual relative humidity were used to develop new formulas to describe the relations between PMP and other hydrologic factors. While the rest of data were applied to satisfy the accuracy of these equations. The different percentage between the values calculated from equations and the values recorded from registered data did not exceed 9.3%.

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