Inverse Distance Weighting (IDW) for Estimating Spatial Variation of Monthly and Annually Rainfall in Azraq Basin during the monitor Period (1980-2016).

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Abstract

This paper applied spatial interpolation techniques to produce spatial maps for the monthly and annually rainfall data form 22 meteorological stations, -within, and around the Azraq basin - during the period of (1980-2016). Data was automated analyzed to monitor the spatial variability and fluctuations of the rainfall. The inverse distance weighting (IDW) method practically was used to model the spatial variability of rainfall for the selected months, and years from the study period; which represents the Semi –arid, and hyper arid years. The rainfall data was tested by adopting cross validation method. The results indicates that both the monthly and the annually of the rainfall displayed a strong spatial variability trend, and highly fluctuated for both the semi-arid, and the hyper arid years during the monitor period.

Keywords: IDW, spatial variation, Azraq basin, Validation.

استخدام عامل المسافة العكسي لتقدير التباين المكاني لكمية الأمطار الشهرية، والسنوية في حوض الأزرق خلال فترة الدراسة 1980-2016

يسرى الحسبان*

الملخص

لإنتاج الخرائط المطرية اعتمد هذا البحث على أدوات التحليل المكاني Geostatistical Analyst وتحديداً عامل المسافة العكسي (IDW) المساحية من 22 محطة مطرية تتوزع جغرافياً داخل وحول حدود منطقة الدراسة خلال فترة الدراسة الممتدة بين (1980-2016). وقد عولجت البيانات آلياً بغرض تحديد الاختلاف المكاني، والتذبذب في كمية الأمطار السنوية، والشهرية، واختيرت سنوات لتمثل الفترات شبه الرطبة، وجاءت أبرز نتائج الدراسة لتؤكد الاختلاف والتباين الكبير لكلا نتائج التحليل دقة وأخرى لتمثل السنوات الأكثر جفافاً. وقد جرى التأكد من على المستويين الشهري والسنوي، وعلى مستوى السنوات الأكثر رطوبة، والأقل رطوبة. البيانات المستخدمة في البحث

الكلمات المفتاحية: عامل المسافة العكسي، التباين المكاني، حوض الأزرق، الدقة.

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1. Introduction

The average monthly or annually, rainfall is very important especially in the countries experiencing drought, where the spatial patterns of the rainfall distribution, and intensity are the most important, therfor spatial interpolation technique was applied using monthly, and annually rainfall in Azraq basin; where vegetation dependent completely either on rain fed which is very sensitive to the fluctuation of rainfall (Burrough, 1986), or depends on ground water. The study area suffers from insufficient of meteorological stations covering such a large area (12400km²). There is variety number of interpolation techniques (points): trend surface, IDW, spline, Kriging, etc. (Meijering, 2002; Ball, and Luk, 1998; ESRIArcGis10.2, help; ESRI, 2008; 2003; Earls, and Dixon, 2007). In this study, Spatial interpolation methods with geostatistical analysis were applied to estimate the monthly and annually rainfall in Azraq Basin; which is classified as semi-arid and hyper arid area. inverse distance weighted (IDW) was applied as the one of the simplest, and widely used in climatology (daly,et al,2002;Zhang,X., et al, 2016;Dobesch, et al, 2007).(IDW) which is uses a sample of known points to estimate an unknown value (Mund, ,2013;Khajeh F, 2007;Matthrew,et al,2008; Matador, 2007; Childs., 2004;Xihua, et al,2015). (IDW) was used to interpolate rainfall data in many articles; (Dryas, and Ustrnul 2007; Lam, et al, 2015; Ball, and Luk, 1998).

2. Study Area

Azraq basin (AB) or Azraq depression (AD) is extented between 36º ´20 to 37º ´40 longitudes and 31º ´00 to 32º ´20 latitudes, fig.1 and covers an area of about 12400 km², is extending from the lava peaks of Jebel Al-Druze in southern Syria to the Wadi Sirhan in northern Saudi Arabia. The study area is characterized by complex and heterogenic in landforms; due to the topographic and climatic conditions (Al-Hadidi, and Subuh, 2001; Al-Zubi., 2000),and it is a circulated area of mud flats, salt pans and wetlands (Azraq Qa'a) The highest elevation is 1175 m, above mean Sea level (a.m.s.l) which is located in the northern of the basin, while the lowest elevation is 511 m, (a.m.s.l) in the Qa'a which is dried up in the early nineties,as a result of the excessive pumping of groundwater for drinking purposes in the capital, Amman (Al-Hadidi and Subuh , 2001). Slopes in the basin are gentle with an average slope of (0º-1.5º);while about % 70% of the study area is hilly flat area except in the northern part where gradient increase to 30%. Runoff generated by high intensity rainstorm events drains in to Azraq Qa'a, and other playas in the central part of the study area. As The study, area suffers from a lack of meteorological stations covering such a large area; only 8 of meteorological station located within the study area; with a completed records used in this study. The total amounts of rainfall during the study periods about 21672.3 mm from all stations, the rainfall data for this research was collected for a total of 36years from 1980 to 2016, from Jordan Meteorological Department.

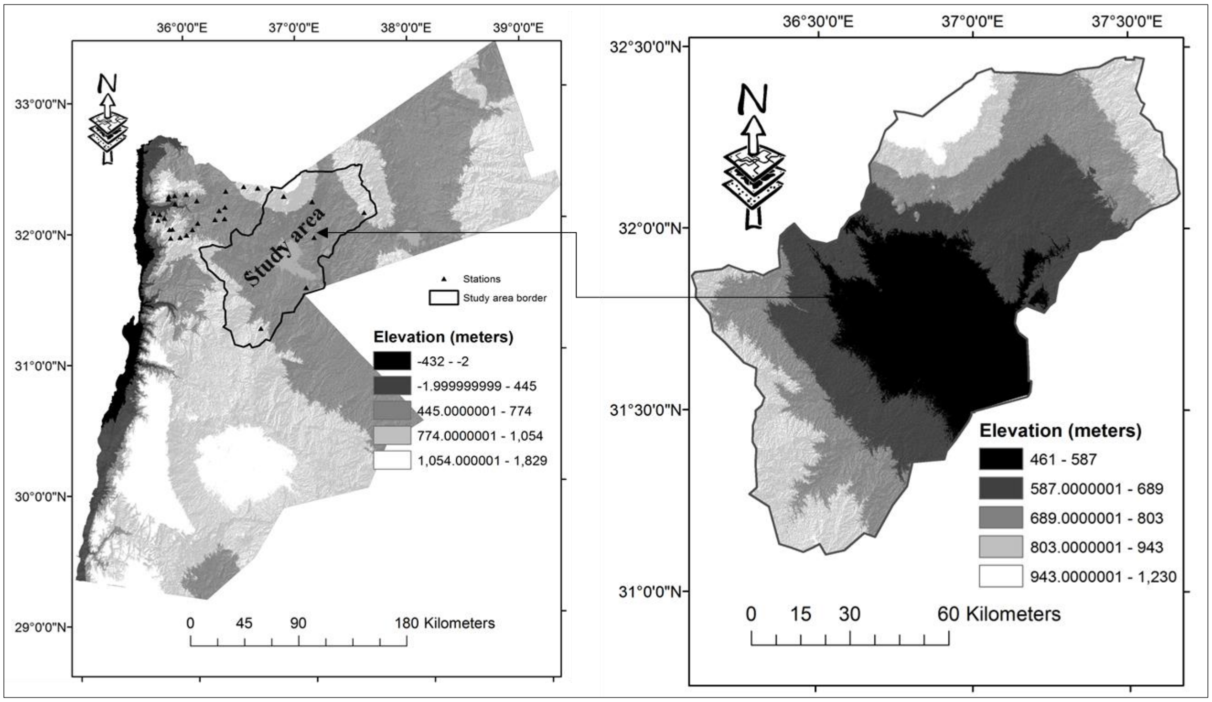

Fig.1. Jordan map, location of the study area and position of the meteorological stations.

3. Data and Methodology

3.1Data

Monthly rainfall data from only 8 meteorological stations distributed within the study area, and14 meteorological station around the study area Fig. 1 was summarized into hydrological years. The hydrological year used in this study starts from October to May. Four set of rainfall data representing a Semi-arid (the highest mean rainfall) and hyper arid (the least mean rainfall) years were selected, and tested in order to evaluate the effectiveness of the IDW technique in interpolating and capturing the vast difference in spatial heterogeneity of rainfall that fell during the selected years. The hydrological year rainfall of each station was calculated for the hyper arid years (1984-1985), (1992-1993),(1999-2000), and (2005-2006), while the Semi-arid years are (1982-1983),(1987-1988),(1990-1991), and (2015-2016). The normality of the dataset was checked totally for all stations (inner and outer), and checked indivually for each station using normal QQ plots to compare the distribution of rainfall data to a standard normal distribution by plotting data values versus the value of a standard Normal distribution and all data showed normality distributions, as shown in Fig.2.and its example the year 1982-1983.

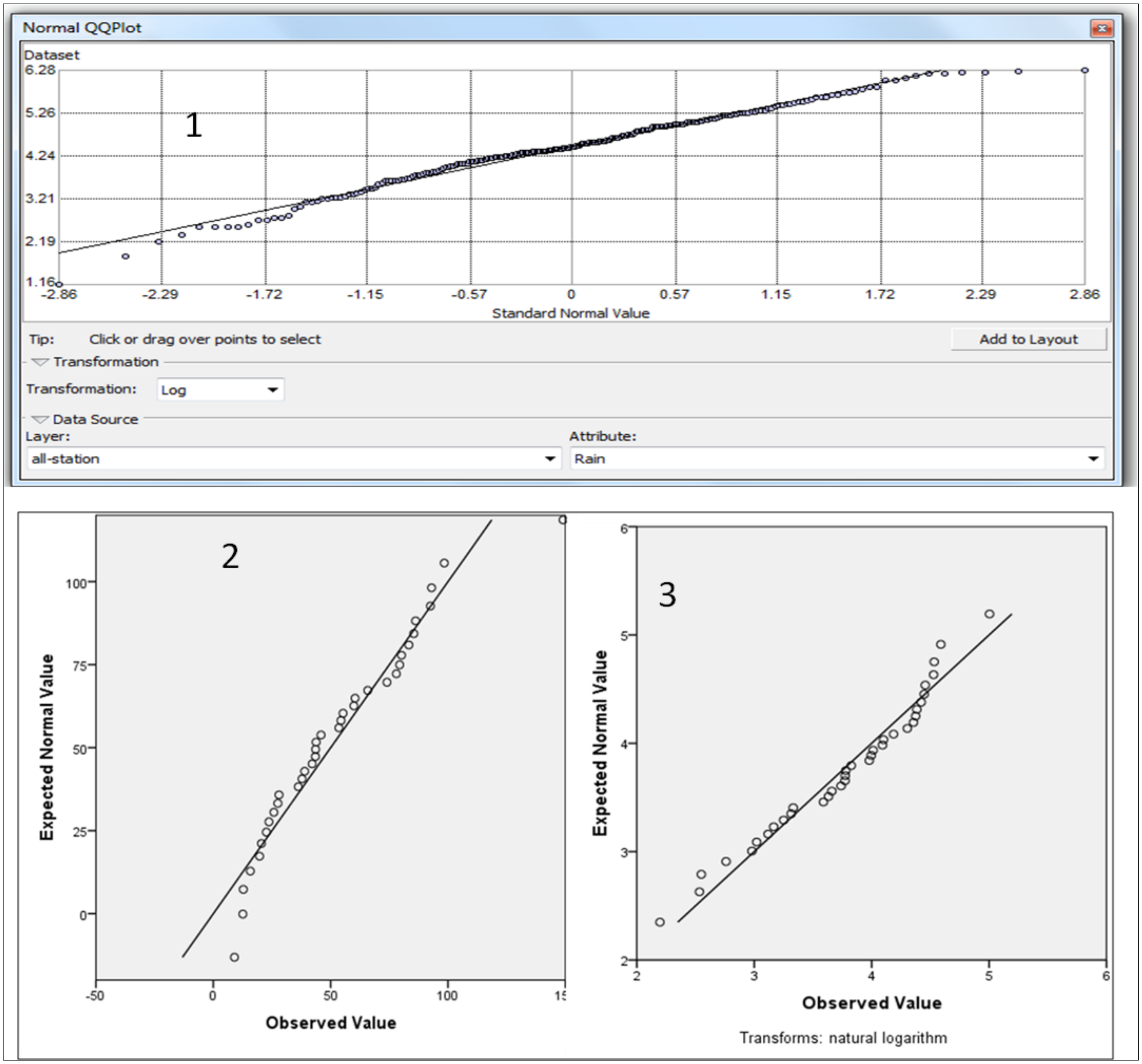

Fig.2 (1)-Normal QQ plot for all station (2)-Normal QQ plot with Log transformation for the year of 1982-1983.

.1. Validation

Interpolation results checked by statistics, that indicated the degree of matching between the models and reality (Zhang, et al, 2016). Through various statistical calculations, the differences between the predictions obtained by means of the different interpolation methods and the measured data recorded at the rain stations can be observed. Cross validation (Geostatisical Analyst) uses all the data to estimate the trend and autocorrelation models; by removing each data location once at a time and predicts the associated data value.IN this study, an interpolation method was used to estimating the yearly time series from 1980 to 2016 using all 8 rainfall stations, (by excluded all stations outer the boundary of the study area), the results in Fig.3

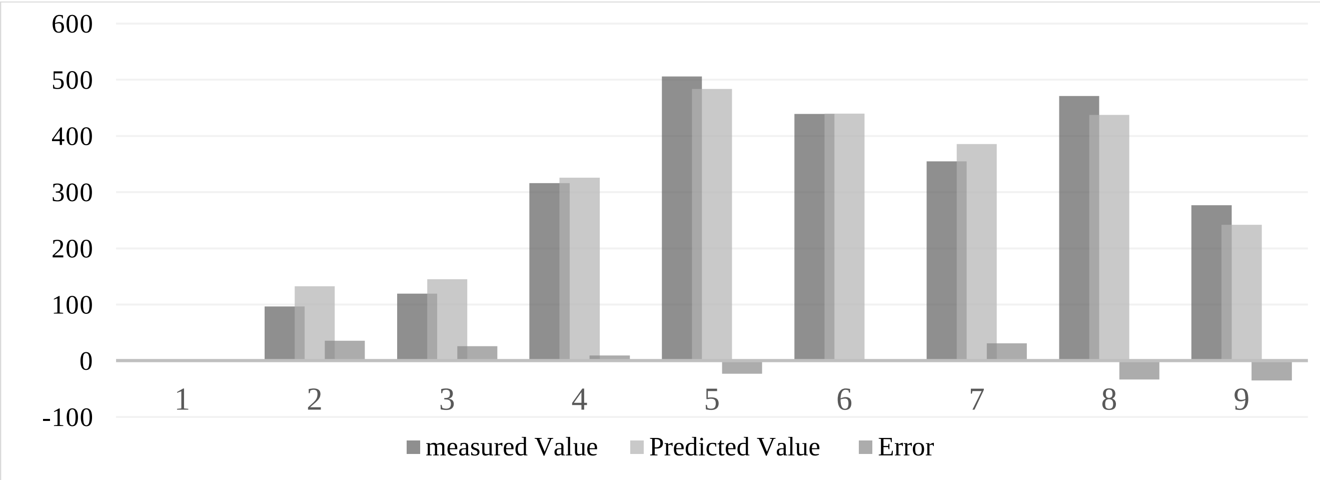

Fig.3 cross validation results of measured values in comparison with predicted values from IDW rainfall interpolation for all stations within the study area.

Fig.3 summarized the prediction accuracy based on the data points Which represents only the eight stations located within the boundaries of the study area (With excluding the rest of fourteen other stations);with Root Mean Square (RMSE) is ranges between -23.2_-34.9 mm and 0.88_35mm.

3.2. Methodology

Surface Interpolation Methods: (S.I.M) using ArcGISV.10.3, which provides a number of different tools for interpolated point data, such as; (Spline, Kriging, IDW, Etc.), for creating spatial surface from sample data points (ESRI, 2008), the interpolation formula can be written as (Childs, 2004):

$$Z * = \frac{\sum_{i=1}^{N} \left(\frac{1}{dP} Zi\right)}{\sum_{i=1}^{N} \left(\frac{1}{dP}\right)}$$

Where: Z* = estimated value.

Zi = a neighboring data point value

N = the number of neighboring point.

d = the distance between the data point and the point being interpolated.

P = a positive-power parameter

4. Results and discussion

In general, rainfall characterized by variations spatially and temporally, and also within the same station from year to year in the study area. The average annual precipitation is below 204 mm in most areas about 92% from the study area, and gradually increases from the center to the north and northwest. The precipitation is mostly concentrated in November, December, January, February, and march which accounts of 94% of the annual precipitation.

Rainfall analysis Fig.4 showed the spatial and temporal variability and fluctuations between 1980-2016. The highest rainfall received at Tell_Rmah and Um_Elquttein stations about 55.9% from the total rainfall in the study area, during the monitor period, This is due to their locations in the mountain area in the northern part of the study area at height about 11750m, (a.m.s.l), (DEM of the study area) Fig.1 besides the effects of Jebel Al-Druze in the southern Syria Which reaches its peak height to 1850m; and caused orographic precipitation.

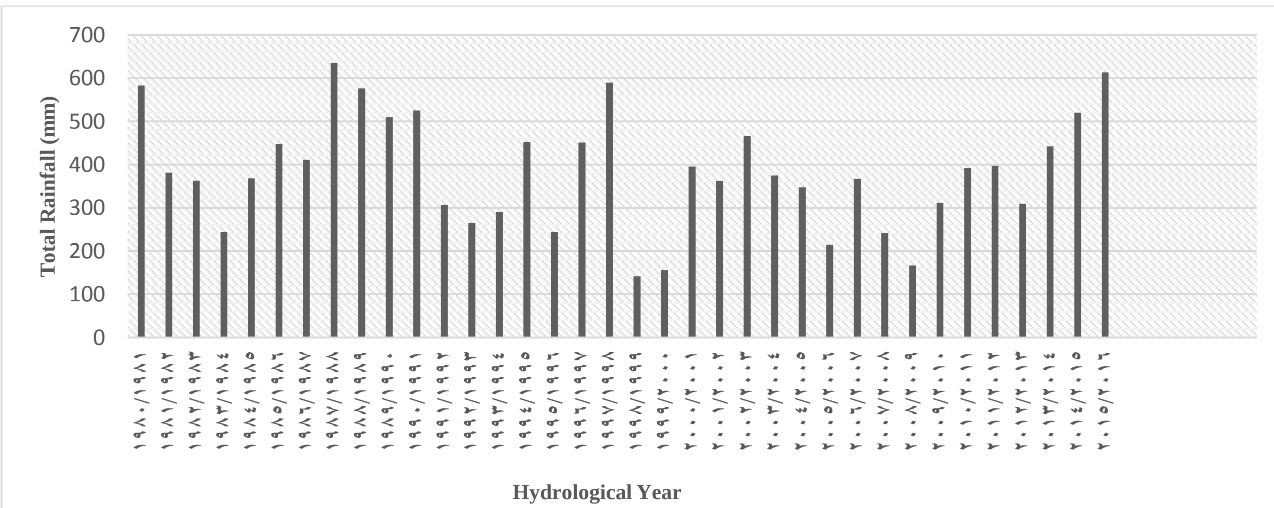

Fig.4 Spatial and temporal differences in Hydrological year's rainfall during the monitor period.

4.1.Inverse Distance Weighted (IDW) results;

4.1.1 IDW interpolator for the time series 1980-2016 for all twenty-two stations

As shown in Fig .5 the study area extracted by mask tools in GIS. The main results showed that 86.1% from the study area received about annually mean rainfall <204m, and only 13.9% received mean rainfall between >204-267m.On monthly 70.9% from the study area received < 115m and 29.1% from the study area received >115-161m Fig.5 and table 1.

Table 1. Spatial distribution of rainfall during the monitor period.

Rainfall classes	1980-2016/Percentage (%)
1	21.1
2	43.4
3	11.6
4	10
5	8.6
6	5.3

	100

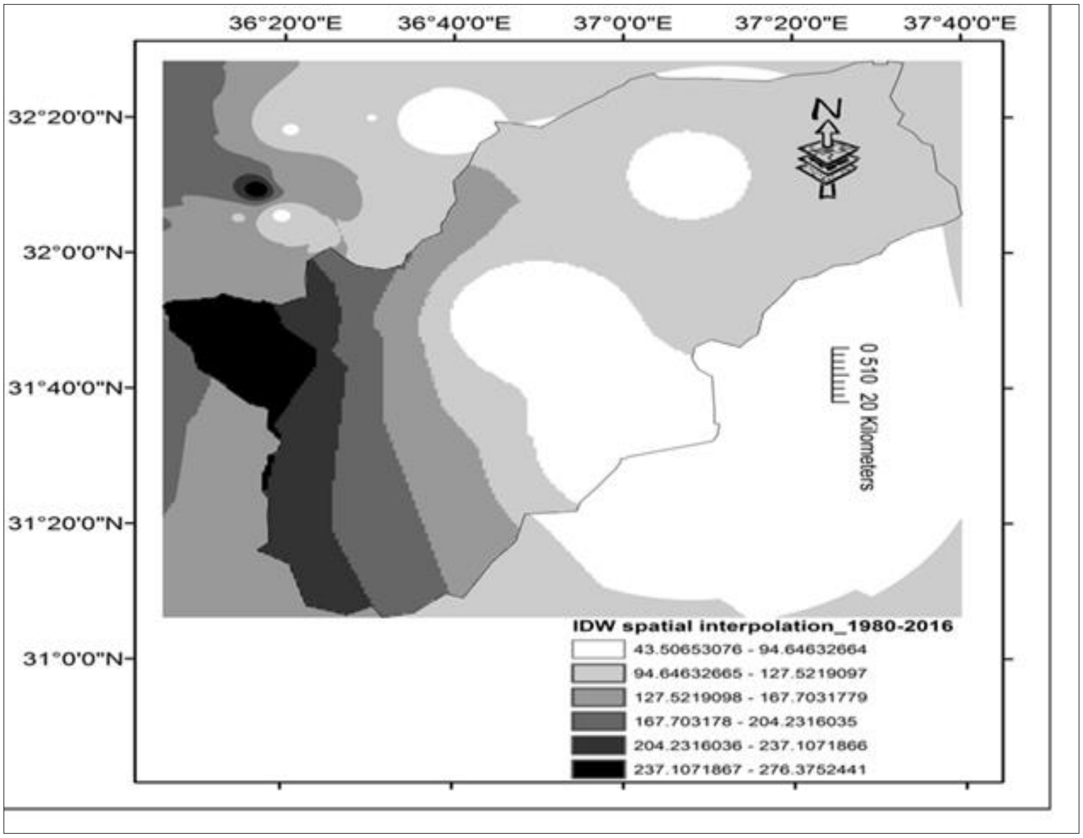

Fig.5 IDW for the monitor period (1980-2016).

4.1.2. IDW spatial interpolation for the rainy months for the stations within the study area boundary:

Fig. (6-7), and table 2. Summarized the main results of the spatial variations of monthly rainfall interpolated from all months excluded (December and January) which showed the highest monthly rainfall in the northern part of the study area, and lower values appeared in the center, southern and eastern; With significant differences, with respect to the mean value of the spatial rainfall; January is the 25.1mm, in February about 22.1mm and 19.9mm for December; while the mean values declined to 2.4mm in May. In December, the higher spatial rainfall occurred in the eastern center of the basin influenced by random nature of desert rain. While in January the spatial high rainfall equals 11% from the study area received, 13-17mm/month concentrated in the north and center of the (Qa’a).

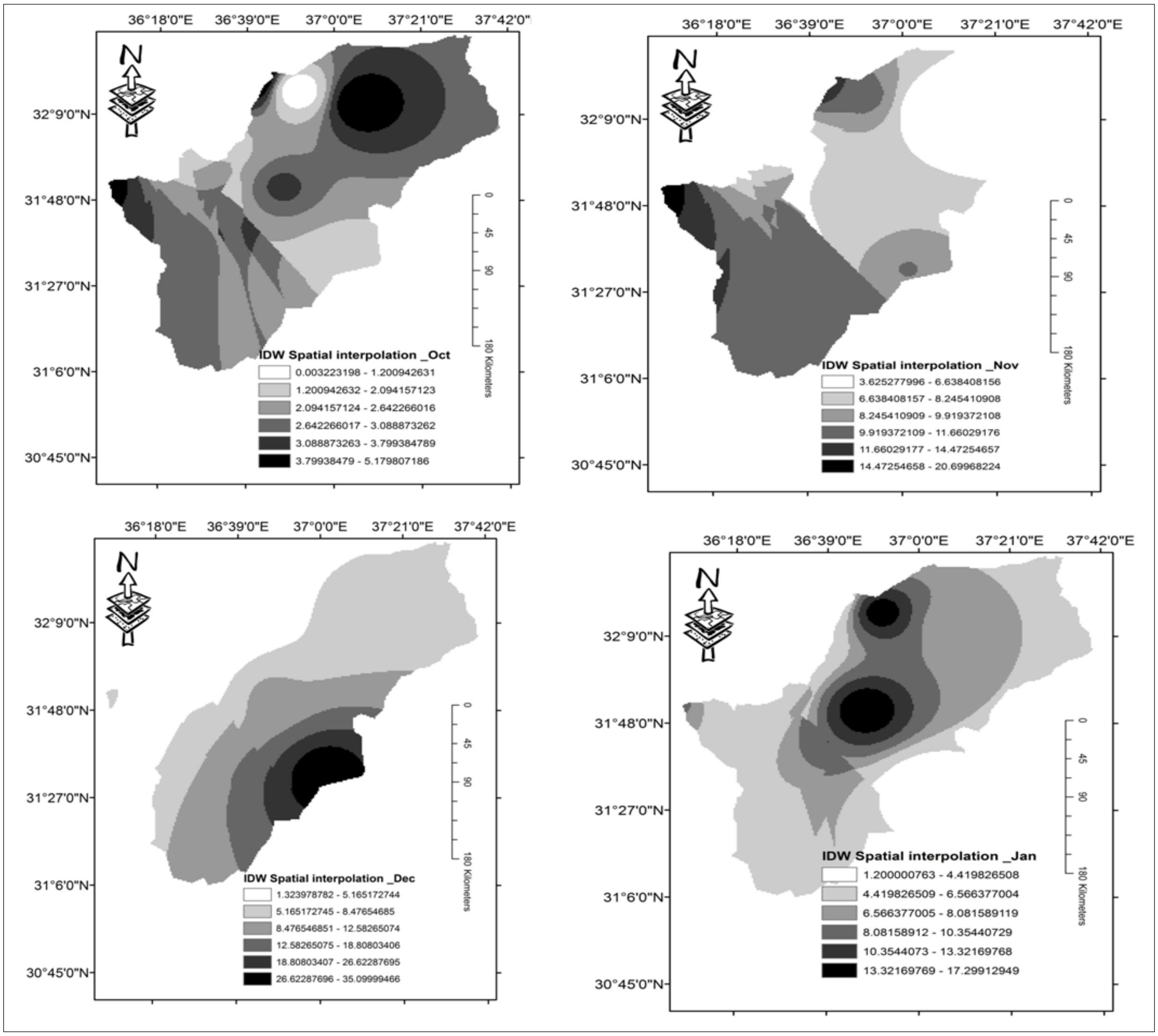

Fig.6 IDW spatial interpolation for the Months; October, November, December and January.

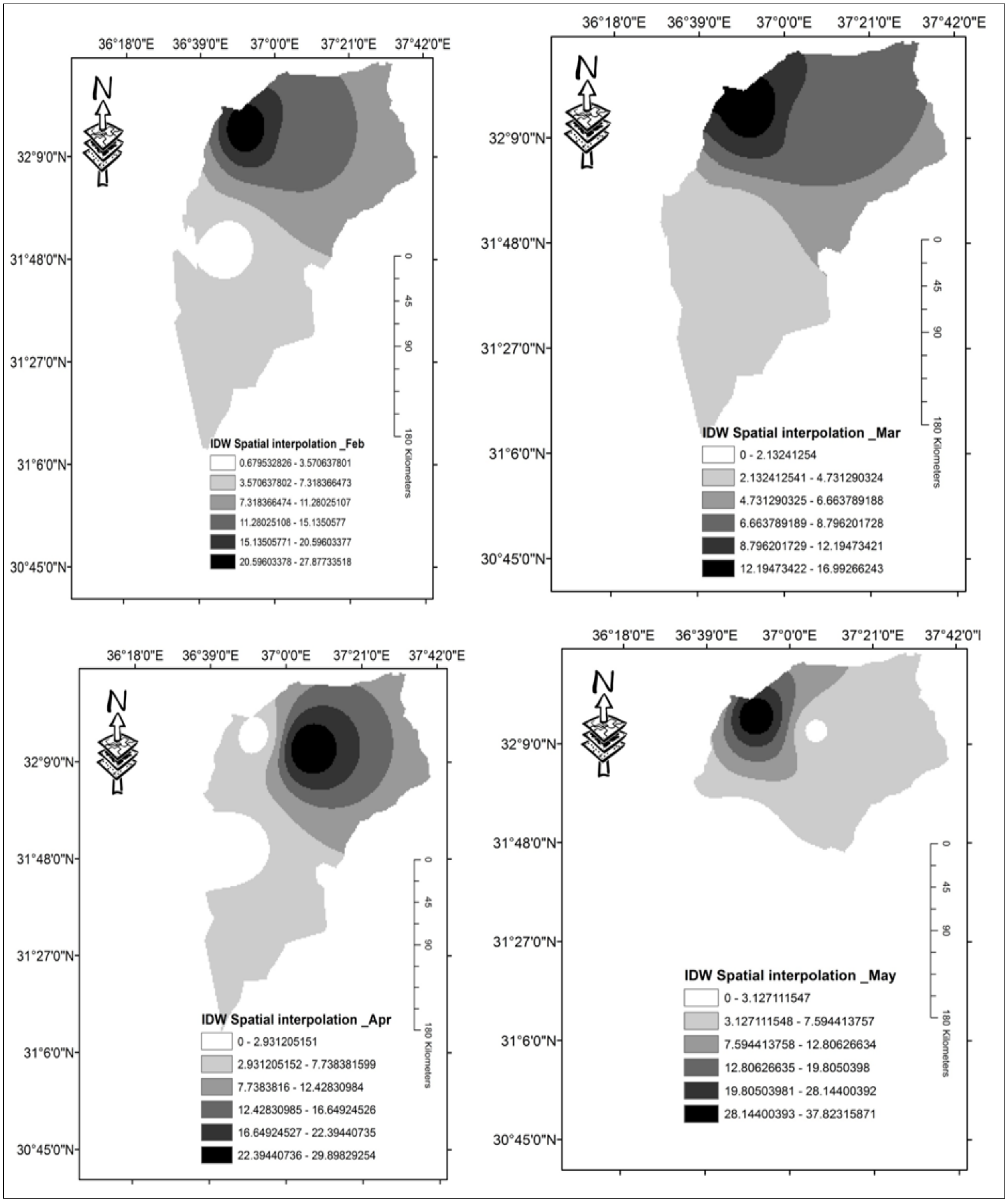

Fig.7IDW spatial interpolation of Months; February, March, April, and May.

Table .2 Inverse Distance Weighted (IDW) interpolation results monthly.

Classes Percentage area (%)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	6	37	45	13	21	33	52	62
2	35.3	22	29	31	34	36	23	22
3	43	32	15	25	19	14.3	11	7
4	8	4	7	12	16	7	9	5
5	5.3	4	3	8	7	4.7	3	3
6	2.4	1	1	11	3	5	2	1
Total	100	100	100	100	100	100	100	100
Monthly mean value (1980-2016)	4.7	11.7	19.9	25.1	22.1	9.1	4.6	2.4

4.1.3 IDW spatial interpolation annually results for the selected years;

The mean value of the rainfall of the hyper arid ranges between 115mm for the year of (1992-1993) covering an area about 98% of the study area to 60m for the (1999-2000) covering an area about 98.4% of the study area. With respect to the patterns distribution of the rainfall we found that the center, southern and eastern parts from the study area were the most in the lowest of rainfall amounts, due to the height which ranges from (511-771) m. While a very small percentage from the study area (1.3%-2%) received mean values between (186-221) m.In the semi-arid years the mean values ranges 116mm for the year of (1990-1991) covering an area about 92% of the study area to 241mm for the (2015-2016) covering an area about 97% of the study area. With respect to the patterns distribution of the rainfall we found that the center, southern and eastern parts were the most lowest of rainfall, due to the low height ranges from 511-771m. While a very small portion from the study area, about (3%-16%) received mean values between (148-371) m.Fig.8 – 9 and table 3. Overall results showed that, in all years (hyper arid and semi-arid) the rainfall concentrated in the northwest of the basin show high spatial variation of rainfall.

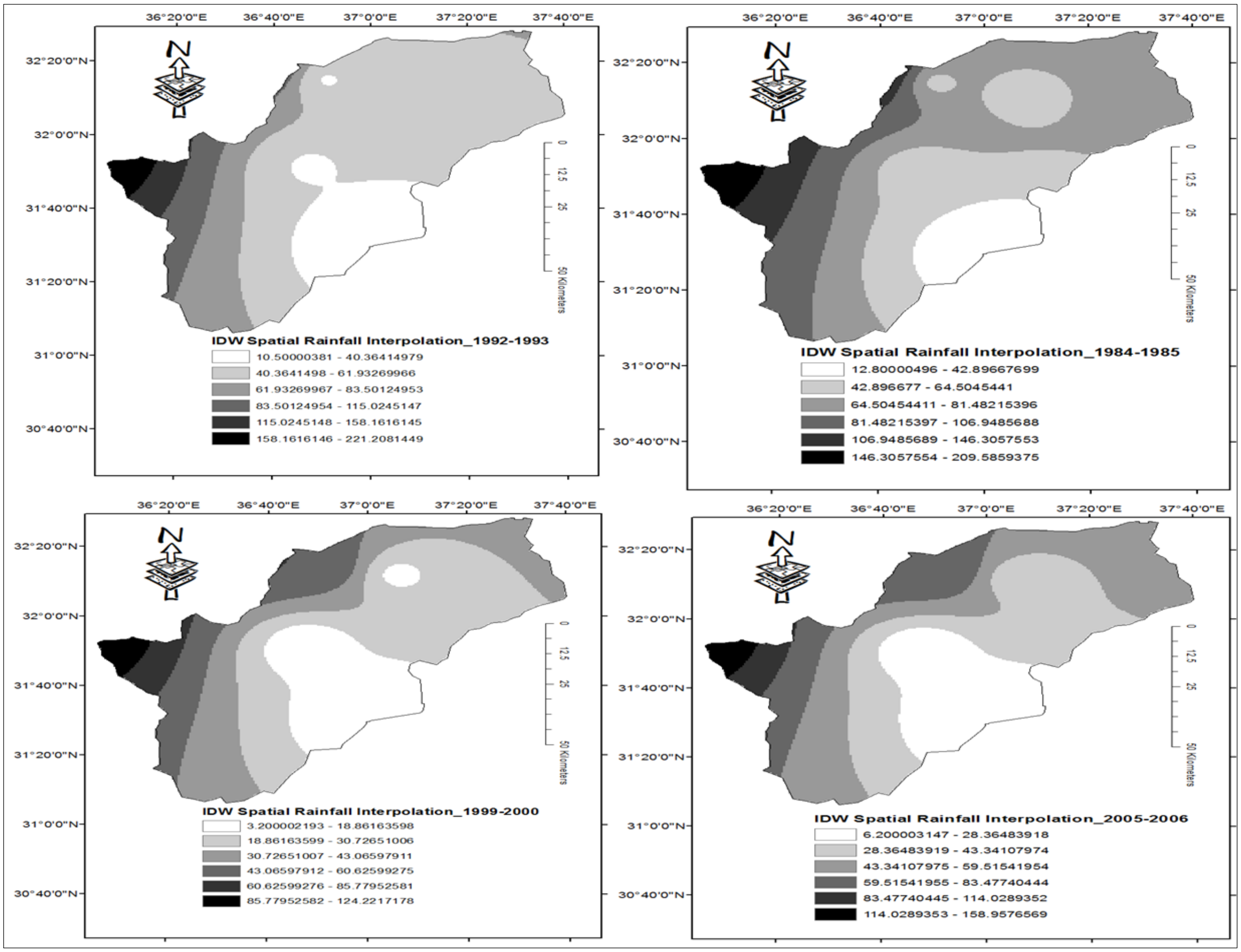

Fig.8 IDW spatial interpolation for the hyper arid years.

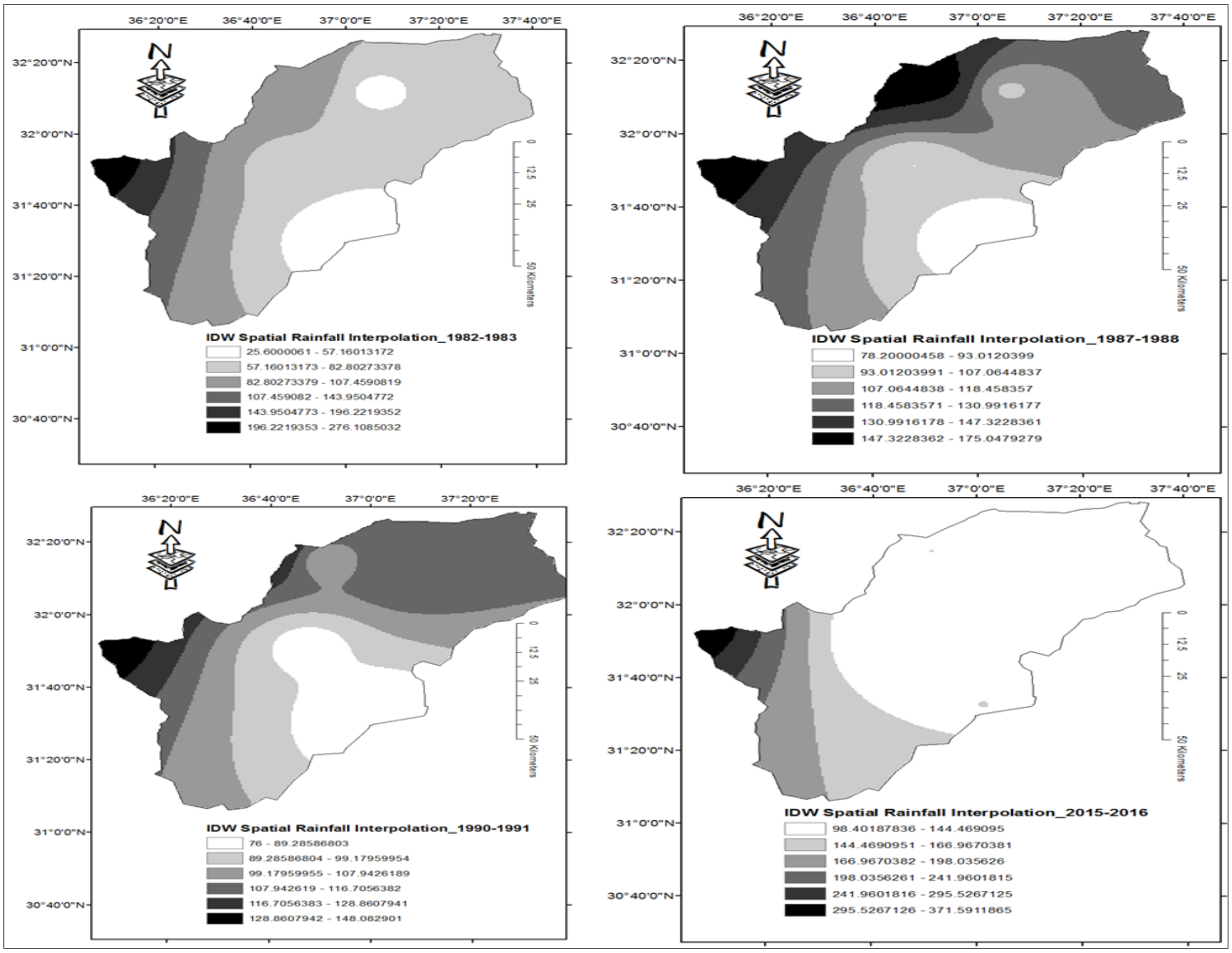

Fig.9 IDW spatial interpolation for the Semi- arid years.

Table .3summarizes the distribution of spatial rainfall, according to the percentage of area.

Years	Mean Values mm/yr	Area (Percentage %)
1984-1985	106 and below	98.7
	>161-209	1.3
1992-1993	115 and below	98
	116-221	2
1999-2000	60 and below	98.4
	61-124	1.6
2005-2006	83 and below	98.7
	84-168	1.3
1982-1983	143 and below	95
	144-276	5
1987-1988	130 and below	84
	131-175	16
1990-1991	116 and below	92
	117-148	8
2015-2016	241 and below	97
	242-371	3

5. Conclusions

In this study, IDW interpolator methods was applied to predict the spatial distribution of precipitation in (AB) which facing desertification since the beginning of the nineties of the 20th century, the study area rainfall data for 36 years were used to generates the spatial rainfall-interpolation method in ArcGIS, an annual and monthly precipitation spatial distribution from 1998 to 2016 was produced. Cross validation was done using the geostatistical analyst to compare the predicted and measured values from data points within the study area boundary. Azraq basin represents the optimal region for rainfall harvesting according to the its topographic, and the analysis of spatial rainfall the areas which can be harvested ranges from 1.3-16% from the study area; because Jordan is classified the fourth water scarce country in the world.

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