Wind Speed Distribution in Ninava Governorate

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الملخص

تم دراسة سرع الريا ح في أربعة مواقع في محافظة نينوى وه ي الموصل، ربيعة، سنجار وتلعفر للفترة (١٩٨٠ – ٢٠٠٢)، وكذلك دراسة المعدلات الشهرية لقيم سرع الرياح، الانحراف القياسي، معامل التباين والسلاسل الزمنية لجميع المواقع المذكورة.

كما تم إيجاد كثافة قدرة الرياح وتوزيع ويبل في مختل ف المناطق ووضحت النتائج على شكل جداول ورسوم بيانية.

أظهرت النتائج أن هناك ميل سالب طفيف في السلسلة الزمنية لسرع الرياح في محطات الموصل، ربيعة وسنجار، في حين تلعفر لم تظهر أي ميل واضح.

كما لوحظ هنالك توافق بين القيم المقاسة لسرعة الرياح والقيم المحسوبة بواسطة توزيع ويبل.

Abstract

Wind speed was studied in four locations in Ninava Governorate which are Mosul, Rabea, Sinjar and Talafar for the period (1980–2002).

The mean monthly values, the standard deviation, the coefficient of variation and the time series for the wind speeds was studied during this period in all locations.

Wind power density and Weibull distribution were found in the different locations. The results were shown in tabulated and graphical form. The results indicate in Mosul, Rabea and Sinjar slightly downward trend in the time series of wind speed while in Talafar no trend was observed also a reasonable agreement was obtain between actual data of wind speed and that calculated by Weibull distribution.

Introduction

The wind of the earth are caused primarily by un equal heating of the earth's surface by the sun. This create temperature–density–pressure difference, which in turn create forces that move air from one place to another (1).

Wind is a free, clean and inexhaustible source. It has been used for hundreds of years for: sailing, grinding grain and for irrigation (2,3).

Now wind energy is one of the most important source of renewable energy. It is perhaps most suitable, effective and inexpensive sources for electricity production. As a result, it is vigorously pursued in many countries.

In 2004 wind energy supplied 18.8% of Denmark's electricity consumptions, which equal to consumption of 1.4 million Danish house holds. (4).

In Taiz-Republic of Yemen, the wind speed was more frequent between 3-6.5 m/s, which indicate that the area can be explored for wind energy applications. (5)

In most of the meteorological stations, generally wind speed is recorded at 10 meters height above the ground. Since wind turbine hub height are typically between 20 and 50 meters, extrapolation of wind speed to the planned hub height is usually required to estimate wind potential (6). Many techniques and models have been established for height extrapolation of wind speed, among these power law models, logarithmic model, 1/7 power law model. The most important and widely used models are the power law model (7).

For wind speed the Weibull distribution is a practical tool in representing the data available and an alternative method to the simple one parameter distribution of the Rayleigh distribution. Many researcher have fitted the Weibull distribution for their applications of wind speed data and they found that Weibull method is a useful tool for wind power analysis (8,9).

The aim of the present study is to analyze and predict the wind speed and wind power at the four locations (Mosul, Rabea, Sinjar and Talafar) in Ninava Governorate during the period (1980 – 2002).

Fig(1) and table(1) shows the map and the geographical locations of the four meteorological stations in Ninava Governorate.

Data Analyzed

1) Mean monthly wind speed at 10m height for the four stations (Mosul, Rabea, Sinjar, and Talafar) were presented in the appendix (1,2,3,4).

2) The Standard Deviation Coefficient of Variation and the Time Series for the wind seed is performed during the period (1980 – 2002) in all stations.

3) Mean monthly wind speed at 50 m height is calculated using the following power model:

$$V_2 / V_1 = (Z_2 / Z_1)^{\alpha p}$$

Where:

V_1 and V_2 are wind speed at height Z_1 and Z_2.

α p is dimensionless exponent = **0.34**.

The results of wind speed at 50 m height were presented in the appendix (5).

4) The wind power density (P) in (w/m^2) is determined using the following mathematical model:

$$P(w/m^2) = 1/2\ \rho\ V^3$$

Where:

ρ = density of air (**1.225** kg / m^3).

V = wind speed (m/ s).

5) Weibull distribution is used to determine the distribution of wind speed in all stations. The two parameters of weibull distribution is describe by**:**

$$f(v) = (K / C)\,(V / C)^{K-1} \exp[-(V / C)^{K}]$$

Where:

f (v) = Frequency distribution of wind speed.

K = Shape parameter.

C = Scale parameter.

V = Wind speed (m /s).

The values of **K** and **C** can obtained from a straight line equation

$$Y = ax + b$$

Where:

a = slope and **b** = intercept

$x = \ln V$

$y = \ln [-\ln (1-F(V))]$

from the straight line equation :

$a = k$

$b = -k \ln C$

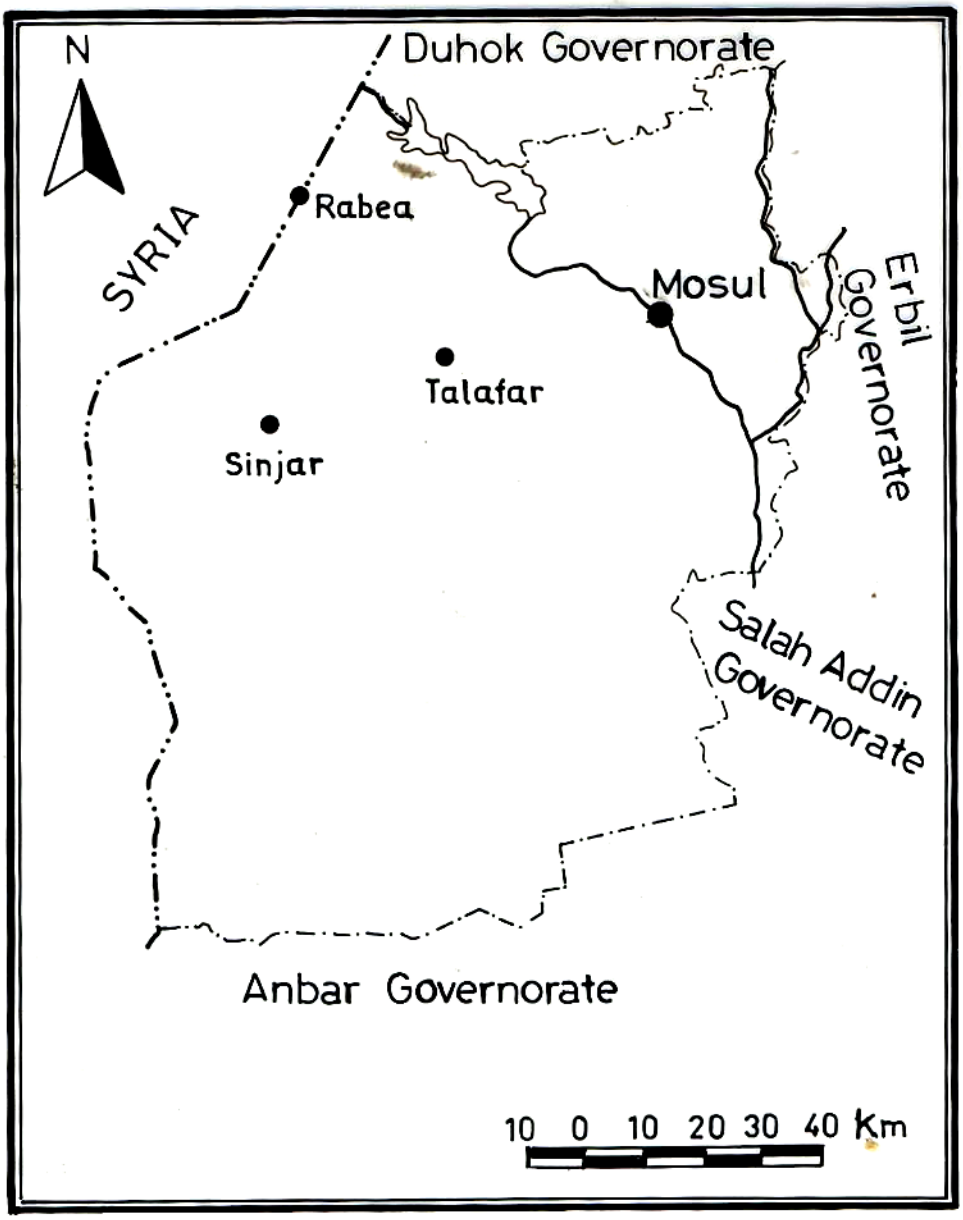


Fig. (1): Ninava Governorate Map.

Table (1): Geographical locations of Meteorological stations in Nineveh Governorate

Stations	Latitude, N°	Longitude, N°	Altitude, m	Period of records, yr
Mosul	36° 19'	43° 09'	232	1980 – 2002
Rabiaa	36° 48'	42° 06'	382	1980 – 2002
Talafar	36° 22'	42° 06'	273	1980 – 2002
Sinjar	36° 19'	41° 50'	465	1980 – 2002

Results & Discussion

1) Study of the mean monthly values of wind speed at 10 height for all stations

The mean monthly values of wind speed for all stations were presented in the appendix (1,2,3,4) and in the Fig (2). It can seen that the mean monthly values of wind speed was ranged between (3.8 -5.4) m/s in Talafar, (1.9-4.5) m/s in Sinjar, (1.5-2.2) m/s in Rabea and (1.0 -1.8) m/s in Mosul.

The lowest values of the monthly mean wind speed were observed in Winter months in all stations and the highest values were observed in the Summer months.

The values of wind speed in Talafar is much higher than in Mosul and Rabea in all months. Sinjar indicate also higher values than in Mosul and Rabea but less than in Talafar.

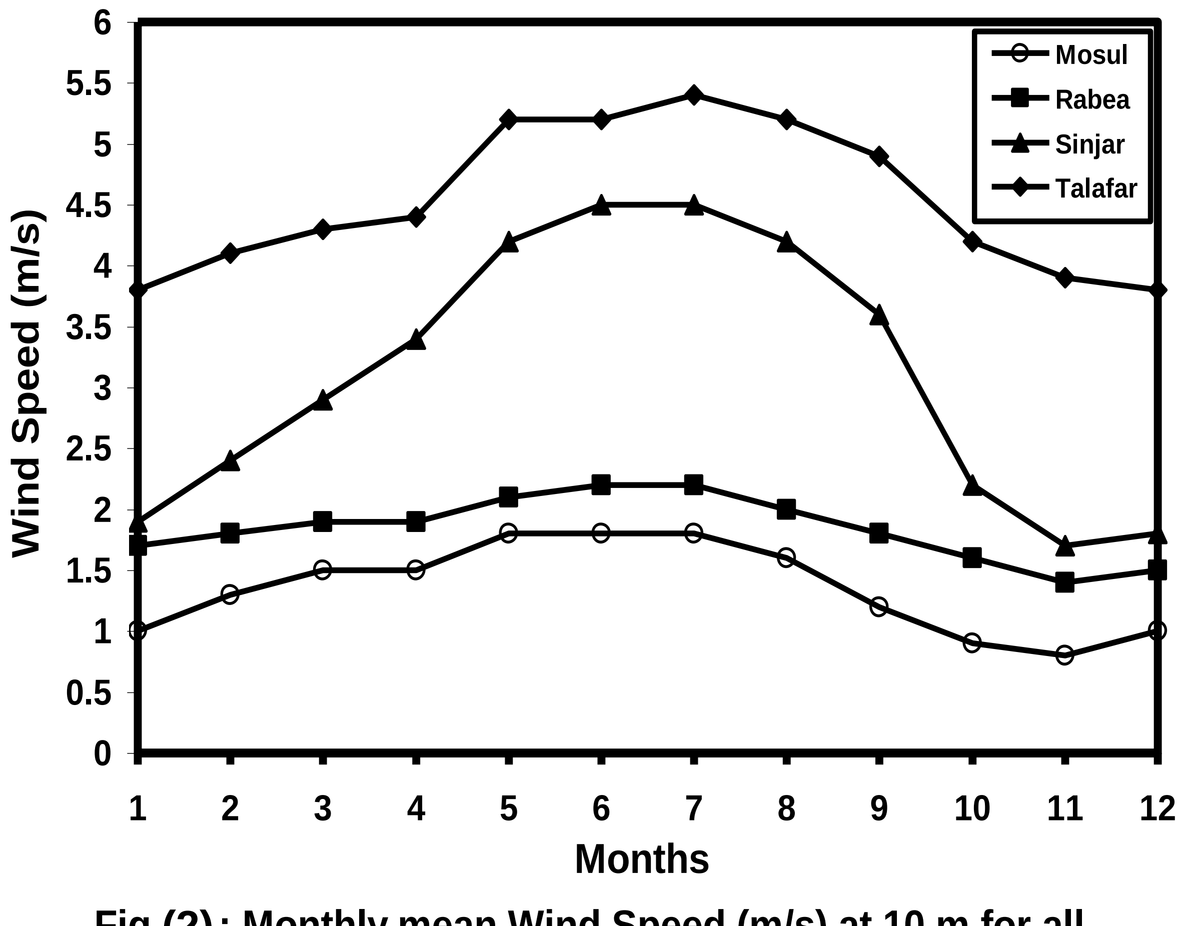


Fig (2): Monthly mean Wind Speed (m/s) at 10 m for all Stations

Fig (3) shows the standard deviation of the monthly values of wind speed in all stations. Sinjar station gives higher values of (SD) especially during the months March to September which is ranged between (0.72 - 1.15)m/s. The other stations gave values ranged between (0.36– 0.86)m/s.

The lower value of (CV) was observed in Talafar station which is ranged between (9.8 -22.6)%, then in Sinjar (20-38.8)%, after that in Rabea (25.9– 48)%, and finally Mosul station present the higher values of (CV) among the other stations which reach to 60% in December.

The trend of time series of wind speed at all stations during the period (1980-2002) were presented in Fig (5). Mosul, Rabea and Sinjar indicate slightly downward trend while Talafar shows nearly neutral slope and no trend can be observed.

Fig (6) shows the monthly mean wind speed at all stations calculated at 50m height. It can be observed that the wind speed at 50m height is nearly 70% higher than that of 10m height.

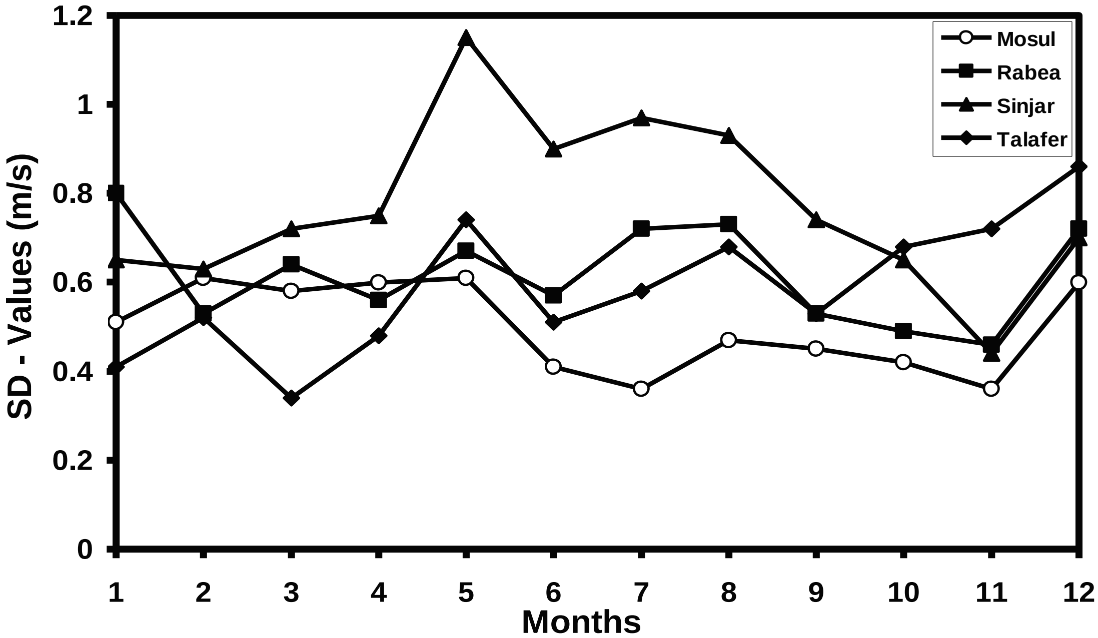


Fig (3): Standerd Deviation of the Monthly Values of Wind Speeds at all Stations

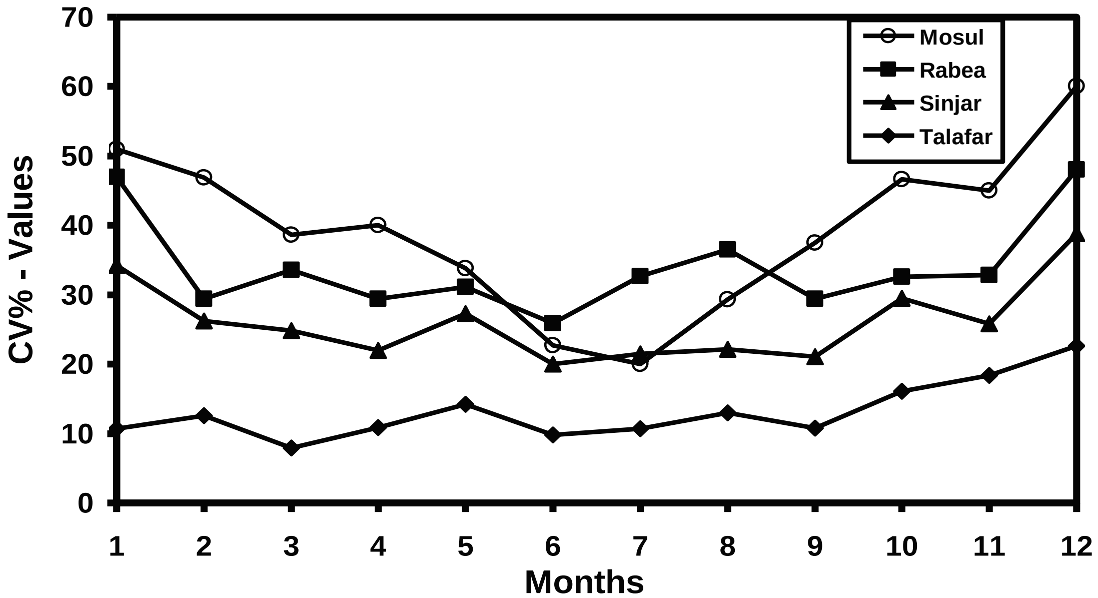
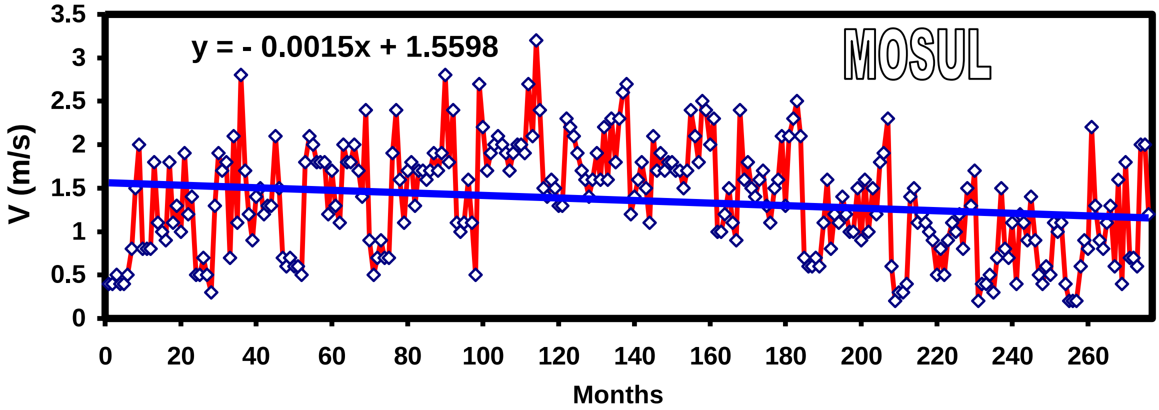
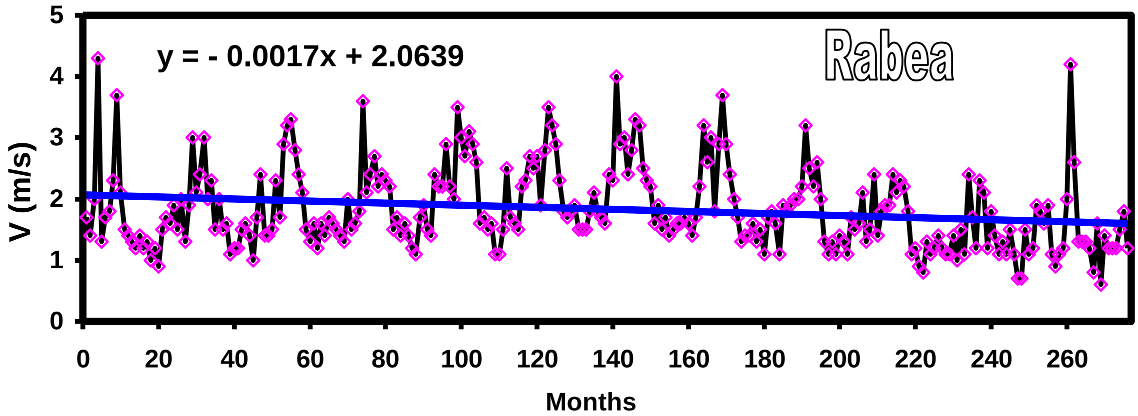
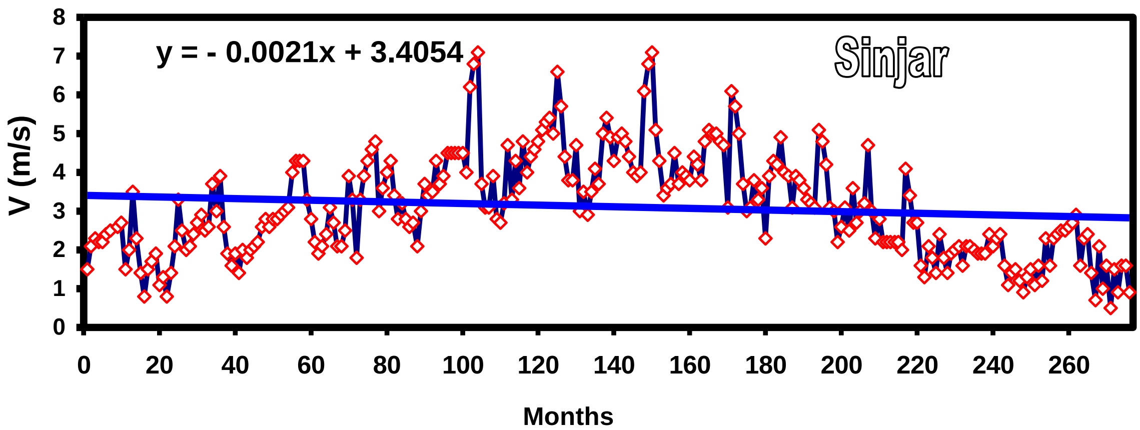


Fig (4) :Coefficient of Variation of the Monthly Values of Wind Speed at the Four Stations







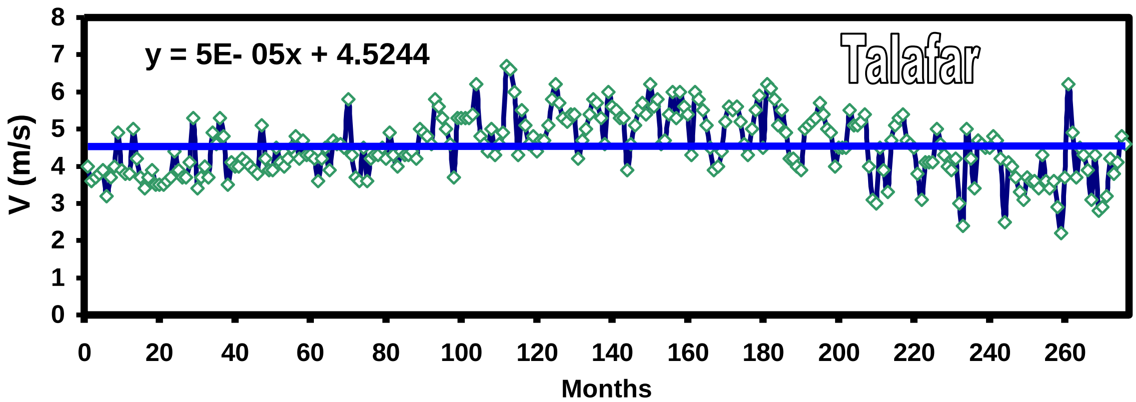


Fig (5) :The Trends of Time Series for the Wind Speed at all Stations for the period (1980 -2002)

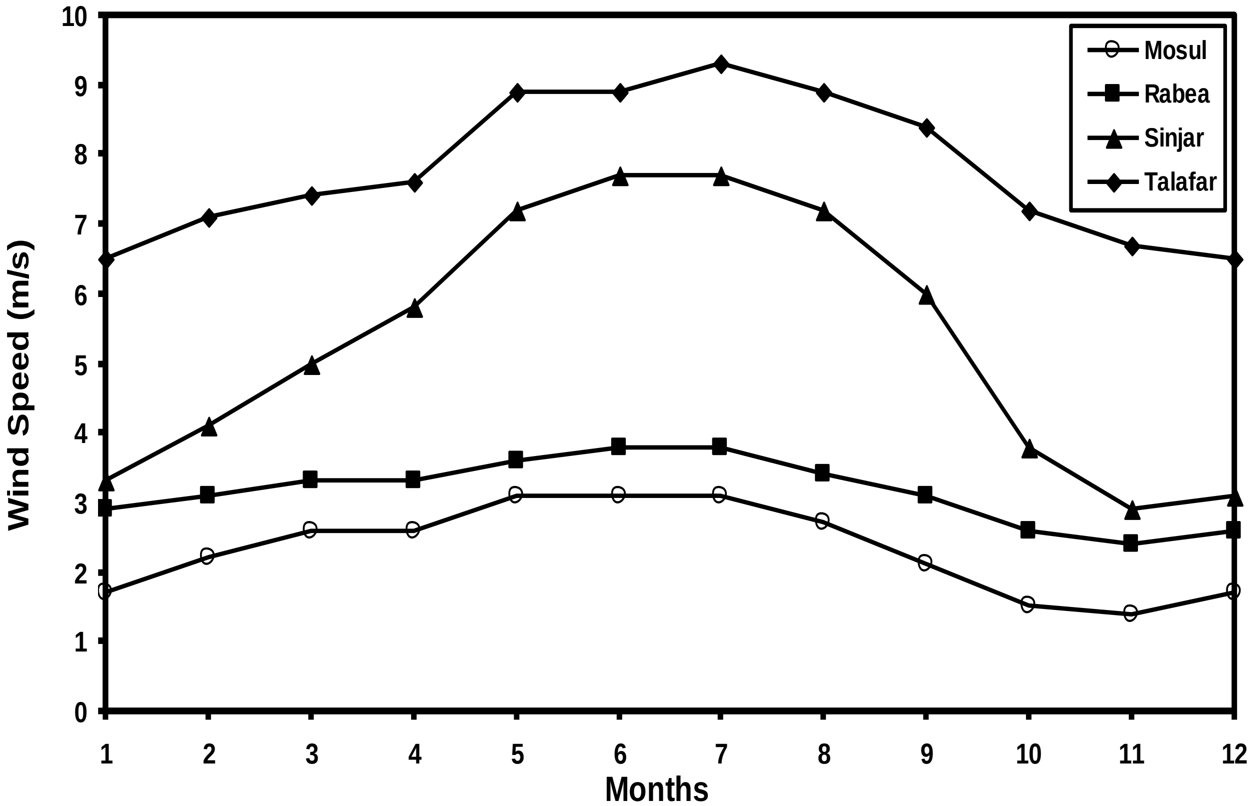


Fig (6) : Monthly Mean Wind Speed (m/s) at 50 m for all Stations

2) Study of Wind Power Density at all station

The results of the estimation of the mean monthly values of wind power densities (w/m^2) for all stations at (10–50)m height were presented in appendix (6,7). The stations can be classified according to their wind power densities from the higher to the lower values as: Talafar station, Sinjar station, Rabea station and finally Mosul station.

The wind power density in all stations shows a large variations in their values during the months of the year. The maximum wind power density was observed in Summer months while the minimum wind power density was seen in Winter months.

The maximum values of wind power density was observed in July for all stations, and their values at 50m height are (492.7, 279.6, 33.6, 18.2) w/m^2 for Talafar, Sinjar, Rabea and Mosul station respectively.

3) Study of Weibull Distribution in different stations

A) Mosul station

Table (2) represent the different parameters of wind speed used in the calculation of weibull distribution in Mosul station, from this table the frequency histogram and the cumulative distribution curve of wind speed at 10m height were presented in Fig (7,8) respectively. Linear correlation between ln [-ln{1-F(v)}] and ln (v) was obtained and presented in Fig (9) This correlation was:

Y = 2.488x – 1.004 and **R^2 = 0.995**

Determining the annual value of **K = 2.488** and **C = 1.4979**, the annual weibull distribution was drawn and presented in Fig (10). The figure compares annual values of the measured and the theoretical frequency distribution of wind calculated from weibull distribution model. In Mosul station we have a variation between the actual data and the weibull distribution data.

B) Rabea station

Table (3) shows the different parameters of wind speed in Rabea station. The frequency histogram and the cumulative curve of wind speed at 10m height were presenting in Fig (11,12) respectively. Fig (13) shows the linear correlation obtained between ln [-ln{1-ln(v)}] and ln (v) which is:

Y= 3.227x – 2.506 and **R^2 = 0.924**

The annual value obtained for **K = 3.227** and for **C = 2.174** m/s. Fig (14) show reasonable result for weibull distribution in Rabea station.

C) Sinjar station

The different parameters of wind speed in Sinjar station was presented in table (14). Fig (15-16) represent the frequency histogram and the cumulative distribution curve of wind speed at 10 m height respectively. The liner correlation between ln[-ln{1-F(v)}] and ln (v) was presented in Fig (17),This correlation was:

Y =2.766 – 3.521 and **R^2 = 0.991**

The annual value of K obtained was (2.766) and for C = 3.571m/s. Fig(18) shows excellent fit and agreement between measured and calculated values.

D) Talafar station

Table (5) shows the different parameters of wind speed in Talafar station The frequency histogram and the cumulative distribution curve of wind speed at 10m height were presented in Fig (19,20) respectively. Fig(21) shows the linear correlation between ln[-ln{1-F(v)}] and ln (v). Which is:

Y = 6.706 – 10.62 and **R^2 = 0.993**

The annual value obtained for K and C were (6.706,4.873) respectively. Fig(22) shows also a very good fit and agreement between measured and calculated values.

Conclusion

1) The mean monthly values of wind speed was ranged between (3.8-5.4) m/s in Talafar, (1.9 – 4.5)m/s in Sinjar, (1.5 – 2.2)m/s in Rabea and (1.0 -1.8) in Mosul.

2) Sinjar station gave the higher value of (SD) which ranged between (0.72–1.15), and Mosul station gave the higher value of CV% which reach to 60% in December.

3) Mosul, Rabea, and Sinjar stations indicate slightly downward trend of the wind speed time series, while Talafar no trend was observed.

4) The maximum wind power densities (w/m^2) was observed in July in all stations

5) Good fit was obtained between the measured value of wind speed and the calculated value by weibull distribution.

6) Talafar and Sinjar can be explored for wind energy applications.

Table (2) : Different parameters of wind speed distribution for Mosul station during the period (1980-2002)

V(m/s)	f	F(V)	ln (v)	ln[-ln{1-F(v)}]
1	0.327	0.327	0	-0.926
2	0.540	0.867	0.693	0.702
3	0.130	0.997	1.099	1.760
4	0.003	1	1.386	

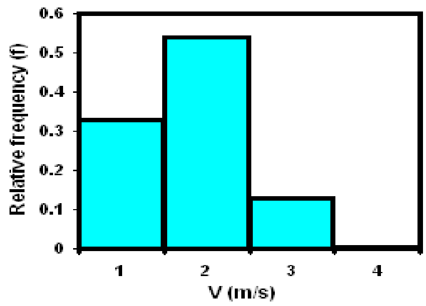


Fig (7) : Monthly Wind speed frequency data (10 m height) at Mosul Station for the period (1980-2002)

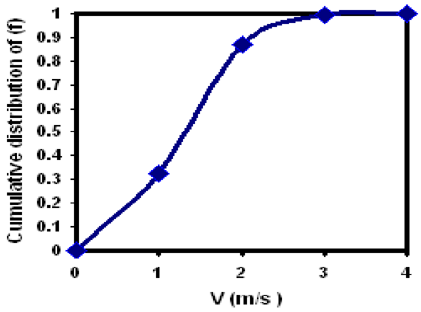


Fig (8) : Cumulative distribution of the relative frequency data of Wind Speed at Mosul Station

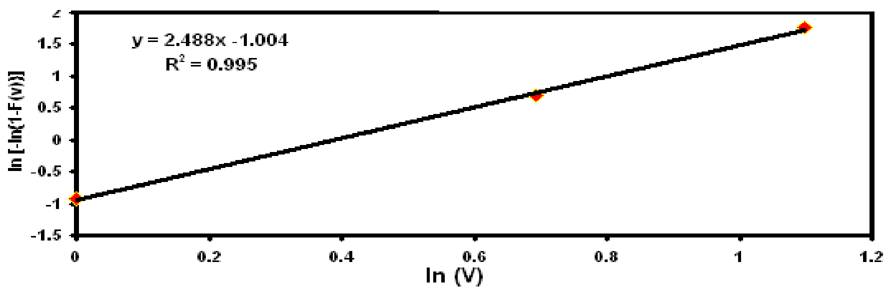


Fig (9) :The correlation parameters between ln [-ln{1-F(V)}] Versus ln (V) for Mosul Station

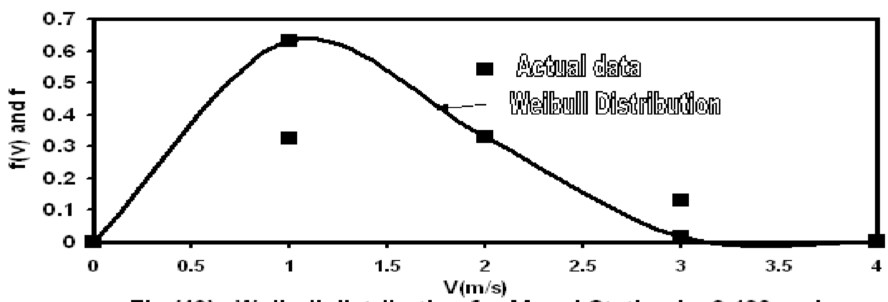


Fig (10) : Weibull distribution for Mosul Station,k =2.488 and c = 1.497

Table (3) :Different parameters of wind speed distribution for Rabea station during the period (1980-2002).

V(m/s)	f	F(V)	ln(V)	ln[-ln{1-F(V)}]
1	0.04	0.04	0	-3.199
2	0.656	0.696	0.693	0.175
3	0.246	0.942	1.099	1.046
4	0.051	0.993	1.386	1.602
5	0.007	1	1.609	

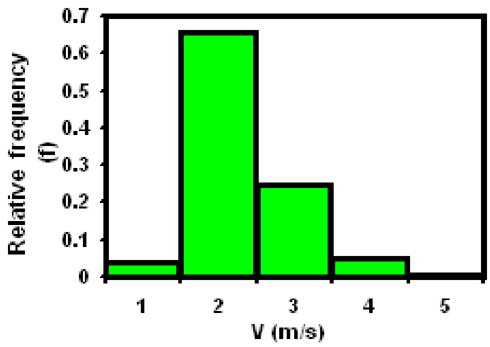


Fig (11) :Monthly Wind Speed frequancy data (at 10m height) at Rabea Station for the period (1980-2002)

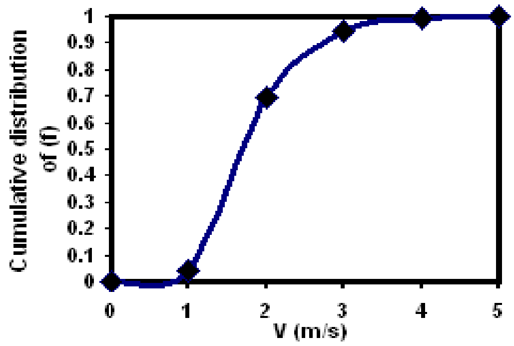


Fig (12) : Cumulative distribution of the relative frequancy data of Wind Speed

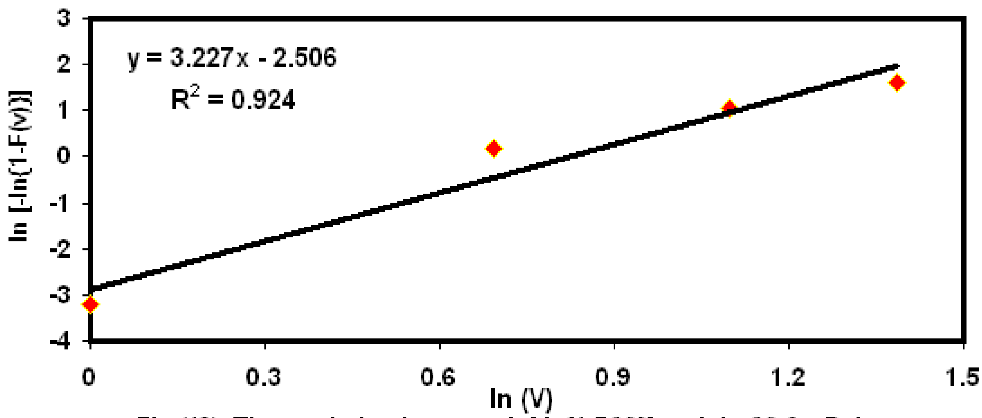


Fig (13) :The corrlation between ln[-ln{1-F(V)}] and ln (V) for Rabea Station

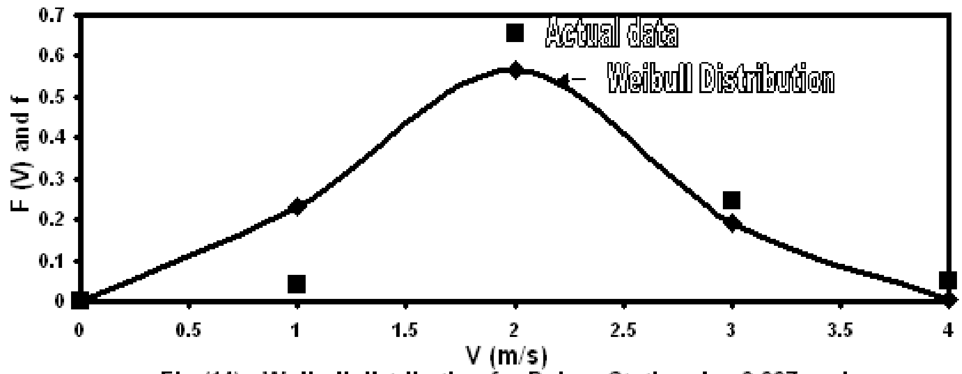
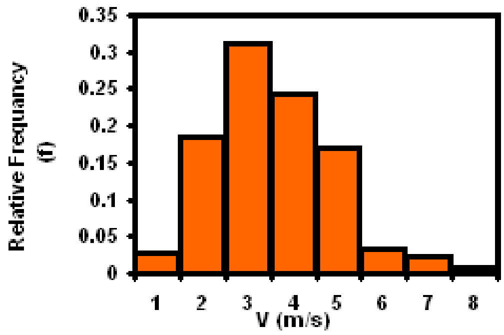


Fig (14) : Weibull distribution for Rabea Station, k = 3.227 and c = 2.174

Table (4): Different parameters of wind speed distribution for Sinjar station the period (1980-2002)

V(m/s)	f	F(V)	ln (v)	ln[-ln{1-F(v)}]
1	0.028	0.028	0	-3.561
2	0.186	0.214	0.693	-1.423
3	0.312	0.526	1.099	-0.292
4	0.243	0.769	1.386	0.382
5	0.170	0.939	1.609	1.028
6	0.032	0.971	1.791	1.264
7	0.022	0.993	1.945	1.601
8	0.007	1	2.079	



Fiq (15) : Monthly Wind speed frequancy data (at 10m height)at Sinjar Station for the period (1980-2002)

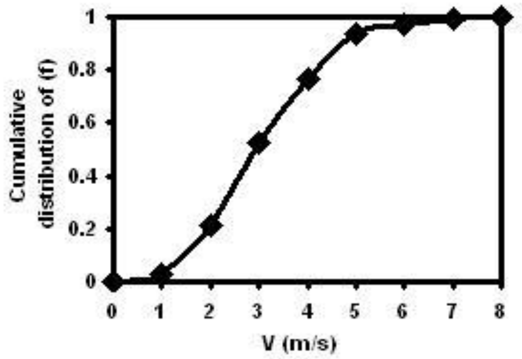


Fig (16) : Cumulative distribution of the relative frequancy data of Wind speed at Sinjar Station

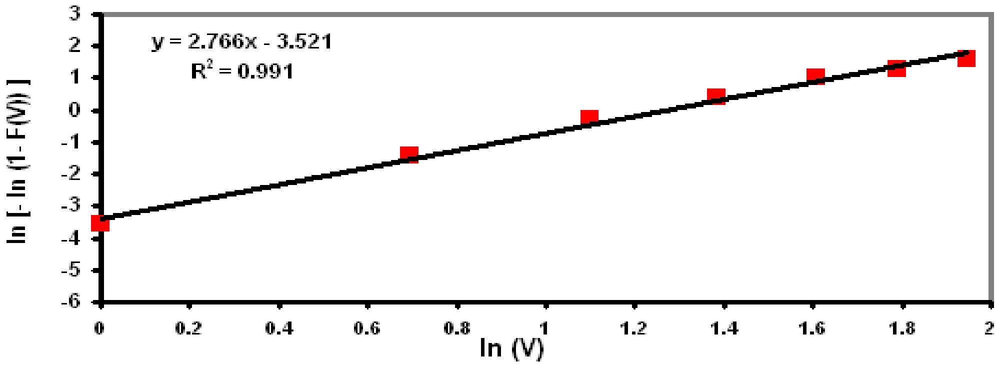


Fig (17) :The correlation between ln[-ln{1-F(v)}] and ln (v) at Sinjar station

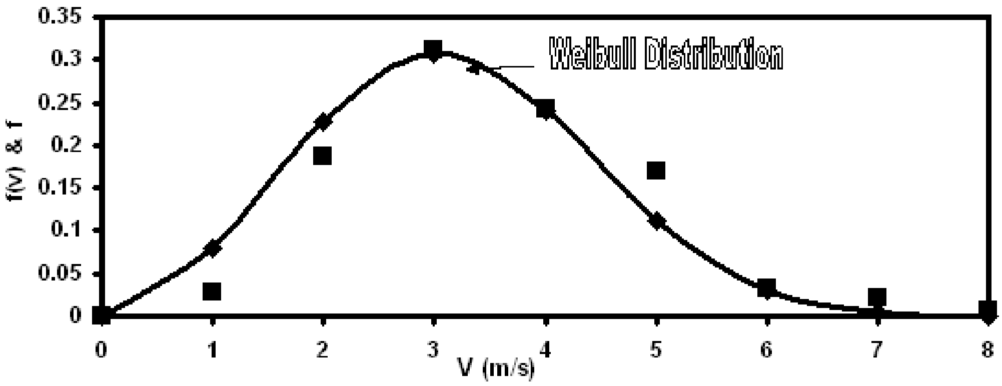


Fig (18):Weibull distribution for Sinjar station,k = 2.766 and c = 3.571

Fig (5): Different parameters of wind speed distribution for Talafar station the period (1980-2002)

V(m/s)	f	F(V)	ln (V)	ln[-ln{1-F(v)}]
1	0	0	0	0
2	0	0	0.693	0
3	0.029	0.029	1.099	-3.458
4	0.272	0.301	1.386	-1.022
5	0.417	0.718	1.609	0.238
6	0.253	0.971	1.791	1.274
7	0.029	1	1.945	

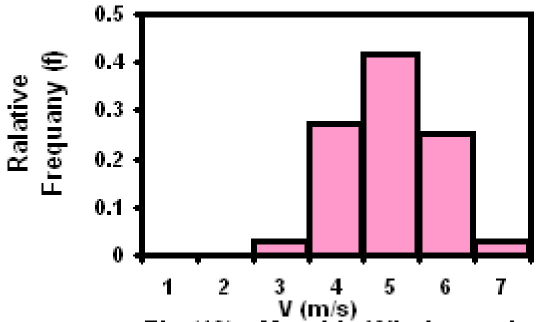


Fig (19) : Monthly Wind speed frequancy data (10m height)at Talafar Station for the period (1980-2002)

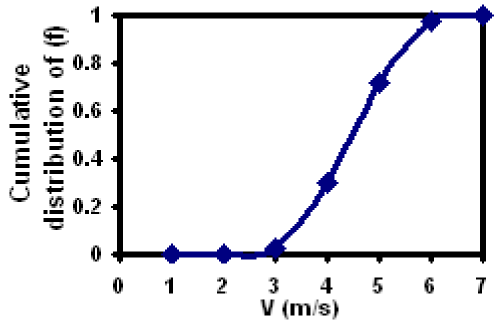


Fig (20) : Cumulative distribution ofthe relation frequancy data of Wind speed

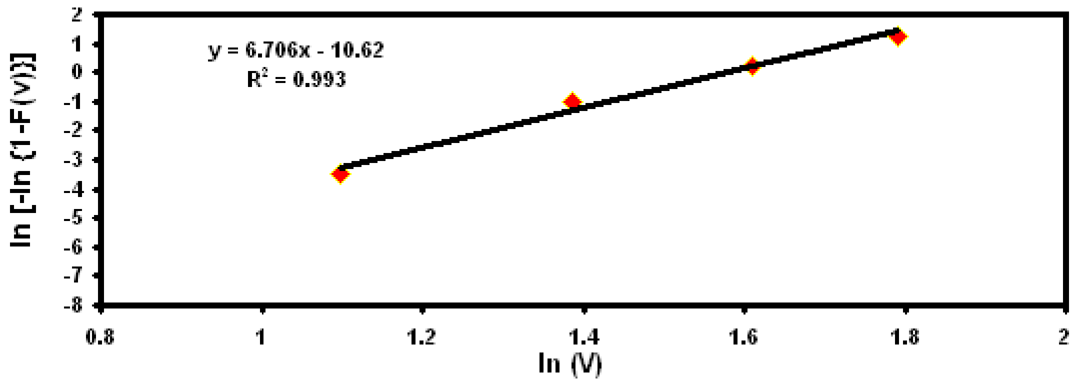


Fig (21) : The correlation between ln [-ln{1-F(V)}]and ln (V) for Talafar Station

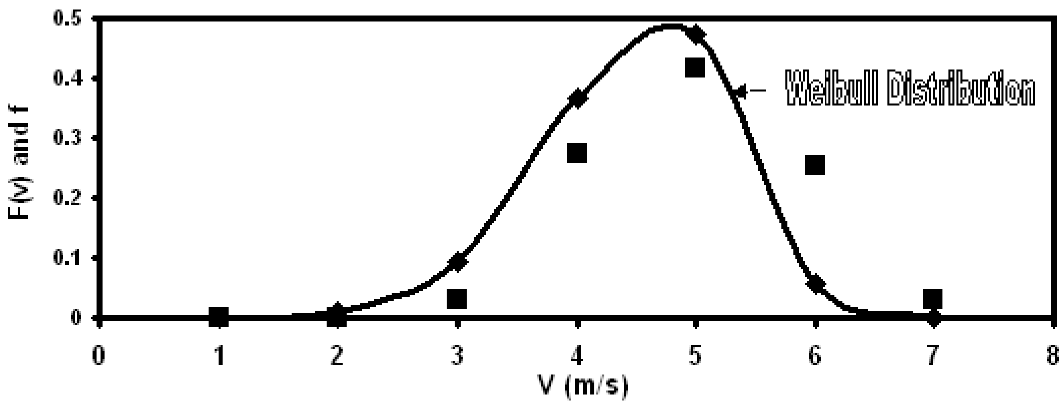


Fig (22) : Weibull distribution for Talafar Station , k = 6.7062 and c = 4.8739

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Appendix (1): Monthly Values of Wind Speed (m/s) at Mosul station for the period (1980 - 2002) at 10m height

YEARS	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1980	0.4	0.5	0.7	0.9	1.1	1.5	1.2	1.0	0.7	0.6	0.2	0.4
1981	0.4	0.5	0.6	0.5	1.0	1.4	1.4	1.0	0.6	0.2	0.4	0.2
1982	0.5	0.7	0.7	0.7	1.1	1.6	1.6	1.2	0.6	0.3	0.4	0.2
1983	0.4	0.5	0.6	0.9	1.6	1.5	1.8	1.5	0.7	0.3	0.5	0.2
1984	0.4	0.3	0.6	0.7	1.1	1.3	1.5	1.1	0.6	0.4	0.3	0.6
1985	0.5	1.3	0.5	0.7	0.5	1.3	1.1	0.9	1.1	1.4	0.7	0.9
1986	0.8	1.9	1.8	1.9	2.7	2.3	2.1	2.4	1.6	1.5	1.5	0.8
1987	1.5	1.7	2.1	2.4	2.2	2.2	1.7	1.6	0.8	1.1	0.8	2.2
1988	2.0	1.8	2.0	1.6	1.7	2.1	1.9	1.8	1.2	1.2	0.7	1.3
1989	0.8	0.7	1.8	1.1	1.9	1.9	1.7	1.5	1.1	1.1	1.1	0.9
1990	0.8	2.1	1.8	1.7	2	1.7	1.8	1.4	1.4	1.0	0.4	0.8
1991	0.8	1.1	1.8	1.8	2.1	1.6	1.8	1.6	1.2	0.9	1.2	1.1
1992	1.8	2.8	1.2	1.3	2.0	1.4	1.7	1.7	1.0	0.5	1.1	1.3
1993	1.1	1.7	1.7	1.7	1.9	1.6	1.7	1.3	1.0	0.8	0.9	0.6
1994	1.0	1.2	1.3	1.7	1.7	1.9	1.5	1.1	1.5	0.5	1.4	1.6
1995	0.9	0.9	1.1	1.6	1.9	1.6	1.7	1.5	0.9	0.9	0.9	0.4
1996	1.8	1.4	2.0	1.7	2.0	2.2	2.4	1.6	1.6	1.1	0.5	1.8
1997	1.1	1.5	1.8	1.9	2.0	1.6	2.1	2.1	1.0	1.0	0.4	0.7
1998	1.3	1.2	1.8	1.7	1.9	2.3	1.8	1.3	1.5	1.2	0.6	0.7
1999	1.0	1.3	2.0	1.9	2.7	1.8	2.5	2.1	1.2	0.8	0.5	0.6
2000	1.9	1.3	1.7	2.8	2.1	2.3	2.4	2.3	1.8	1.5	1.1	2.0
2001	1.2	2.1	1.4	1.8	3.2	2.6	2.0	2.5	1.9	1.3	1.0	2.0
2002	1.4	1.5	2.4	2.4	2.4	2.7	2.3	2.1	2.3	1.7	1.1	1.2

Mean	1.0	1.3	1.5	1.5	1.8	1.8	1.8	1.6	1.2	0.9	0.8	1.0
SD	0.51	0.61	0.58	0.60	0.61	0.41	0.36	0.47	0.45	0.42	0.36	0.60
CV%	51.0	46.9	38.6	40.0	33.8	22.7	20.0	29.3	37.5	64.6	45.0	60.0

Appendix (2): Monthly Values of Wind Speed (m/s) at Rabea Station for

YEARS	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1980	1.7	1.9	2.4	2.0	2.4	2.2	2.4	1.7	1.9	1.5	1.0	1.6
1981	1.4	1.5	1.4	1.5	2.2	2.3	2.3	2.2	1.8	2.4	1.5	1.9
1982	2.0	2.0	1.4	1.6	2.2	2.7	4.0	3.2	1.9	1.4	1.1	1.1
1983	4.3	1.3	1.5	1.8	2.9	2.5	2.9	2.6	2.0	1.8	2.4	0.9
1984	1.3	1.9	2.3	3.6	2.2	2.7	3.0	3.0	2.0	1.9	1.7	1.1
1985	1.7	3.0	1.7	2.1	2.0	1.9	2.4	1.8	2.2	1.9	1.2	1.2
1986	1.8	2.1	2.9	2.4	3.5	2.8	2.8	2.9	3.2	2.4	2.3	2.0
1987	2.3	2.4	3.2	2.7	3.0	3.5	3.3	3.7	2.5	2.1	2.1	4.2
1988	3.7	3.0	3.3	2.2	2.7	3.2	3.2	2.9	2.2	2.3	1.2	2.6
1989	2.1	2.0	2.8	2.4	3.1	2.9	2.5	2.4	2.6	2.2	1.8	1.3
1990	1.5	2.3	2.4	2.3	2.9	2.3	2.3	2.0	2.0	1.8	1.4	1.3
1991	1.4	1.5	2.1	2.2	2.6	1.8	2.2	1.7	1.3	1.1	1.1	1.3
1992	1.3	2.0	1.5	1.5	1.6	1.7	1.6	1.3	1.1	1.2	1.3	1.2
1993	1.2	1.5	1.3	1.7	1.7	1.8	1.9	1.4	1.3	0.9	1.1	0.8
1994	1.4	1.6	1.6	1.4	1.5	1.9	1.5	1.4	1.1	0.8	1.5	1.6
1995	1.2	1.1	1.2	1.6	1.6	1.5	1.7	1.6	1.4	1.3	1.1	0.6
1996	1.3	1.2	1.6	1.4	1.1	1.5	1.4	1.3	1.3	1.1	0.7	1.4
1997	1.0	1.2	1.4	1.2	1.1	1.5	1.5	1.5	1.1	1.2	0.7	1.2
1998	1.2	1.5	1.7	1.1	1.5	1.8	1.6	1.1	1.7	1.4	1.5	1.2
1999	0.9	1.6	1.6	1.7	2.5	2.1	1.6	1.7	1.5	1.2	1.1	1.2
2000	1.5	1.4	1.5	1.9	1.7	1.8	1.7	1.8	1.6	1.1	1.2	1.5
2001	1.7	1.0	1.4	1.5	1.6	1.7	1.6	1.6	2.1	1.1	1.9	1.8
2002	1.6	1.7	1.3	1.4	1.5	1.6	1.4	1.1	1.3	1.4	1.8	1.2
Mean	1.7	1.8	1.9	1.9	2.1	2.2	2.2	2.0	1.8	1.5	1.4	1.5
SD	0.80	0.53	0.64	0.56	0.67	0.57	0.72	0.73	0.53	0.49	0.46	0.72
CV%	47.0	29.4	33.6	29.4	31.1	25.9	32.7	36.5	29.4	32.6	32.8	48.0

the period (1980 - 2002) at 10m height

Appendix (3): Monthly Values of Wind Speed (m/s) at Sinjar Station for the period (1980 - 2002) at 10m height

YEARS	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1980	1.5	2.1	2.6	3.9	4.3	4.8	4.9	4.2	4.0	3.0	2.1	2.3
1981	2.1	3.3	2.8	3.3	3.7	4.0	4.3	3.8	3.9	2.3	1.6	1.6
1982	2.3	2.5	2.6	1.8	3.9	4.4	4.9	4.8	3.1	2.8	2.1	2.3
1983	2.2	2.0	2.8	3.3	4.5	4.6	5.0	5.1	3.9	2.2	2.1	2.4
1984	2.2	2.1	2.8	3.9	4.5	4.8	4.8	5.0	3.8	2.2	2.0	2.5
1985	2.3	2.4	2.9	4.3	4.5	5.1	4.4	5.0	3.6	2.2	1.9	2.5
1986	2.4	2.7	3.0	4.6	4.5	5.3	4.0	4.8	3.3	2.2	1.9	2.6
1987	2.5	2.9	3.1	4.8	4.5	5.4	3.9	4.7	3.2	2.2	1.9	2.7
1988	2.6	2.5	4.0	3.0	4.0	5.0	4.0	3.1	3.1	2.0	2.4	2.9
1989	2.7	2.6	4.3	3.6	6.2	6.6	6.1	6.1	5.1	4.1	2.1	1.6
1990	1.5	3.7	4.3	4.0	6.8	5.7	6.8	5.7	4.8	3.4	2.3	2.3
1991	2.0	3.0	4.3	4.3	7.1	4.4	7.1	5.0	4.2	2.7	2.4	2.4
1992	3.5	3.9	3.3	3.4	3.7	3.8	5.1	3.7	3.1	2.7	1.6	1.4
1993	2.3	2.6	2.8	2.8	3.1	3.8	4.3	3.0	3.0	1.6	1.1	0.7
1994	1.4	1.9	2.2	3.2	3.1	4.7	3.4	3.1	2.2	1.3	1.4	2.1
1995	0.8	1.6	1.9	2.8	3.9	3.0	3.6	3.8	2.6	2.1	1.5	1.0
1996	1.5	1.9	2.1	2.6	2.8	3.5	3.7	3.3	3.1	1.8	1.2	1.6
1997	1.7	1.4	2.4	2.7	2.7	2.9	4.5	3.6	2.5	1.4	0.9	0.5
1998	1.9	2.0	3.1	2.1	3.2	3.5	3.7	2.3	3.6	2.4	1.3	1.5
1999	1.1	1.8	2.7	3	4.7	4.1	4.0	3.9	2.7	1.8	1.5	0.9
2000	1.3	2.0	2.1	3.7	3.3	3.7	3.9	4.3	3.0	1.4	1.1	1.6
2001	0.8	2.1	2.1	3.4	4.3	5.0	3.8	4.2	3.2	1.9	1.6	1.6
2002	1.4	2.2	2.5	3.5	3.6	5.4	4.4	4.9	4.7	2.0	1.2	0.9
Mean	1.9	2.4	2.9	3.4	4.2	4.5	4.5	4.2	3.5	2.2	1.7	1.8
SD	0.65	0.63	0.72	0.75	1.15	0.9	0.97	0.93	0.74	0.65	0.44	0.7
CV%	34.2	26.2	24.8	22.0	27.3	20.0	21.5	22.1	21.1	29.5	25.8	38.8

Appendix (4): Monthly Values of Wind Speed (m/s) at Talafar Station for the period (1980 - 2002) at 10m height

YEARS	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Auq.	Sep.	Oct.	Nov.	Dec.
1980	4.0	4.4	5.1	5.8	5.8	5.5	6.0	6.0	5.5	4.0	4.2	4.3
1981	3.6	3.9	4.2	4.3	5.6	5.1	5.6	5.8	4.9	3.1	3.0	3.6
1982	3.7	3.7	3.9	3.7	5.3	4.6	5.5	5.5	4.2	3.0	2.4	3.4
1983	3.8	3.7	3.9	3.6	5.0	4.8	5.3	5.1	4.2	4.5	5.0	3.6
1984	3.9	4.1	4.5	4.5	4.6	4.4	5.3	4.5	4.0	3.9	4.2	2.9
1985	3.2	5.3	4.1	3.6	3.7	4.7	3.9	3.9	3.9	3.3	3.4	2.2
1986	3.7	3.4	4.0	4.2	5.3	4.7	4.6	4.0	5.0	4.7	4.7	3.7
1987	4.0	3.7	4.2	4.3	5.3	5.1	5.1	4.4	5.1	5.1	4.6	6.2
1988	4.9	4.0	4.5	4.3	5.3	5.8	5.5	5.2	5.2	5.3	4.5	4.9
1989	3.9	3.7	4.8	4.5	5.3	6.2	5.7	5.6	5.3	5.4	4.5	3.7
1990	3.8	4.9	4.2	4.2	5.4	5.7	5.4	5.5	5.7	4.7	4.8	4.5
1991	3.8	4.6	4.7	4.9	6.2	5.3	6.2	5.6	5.4	4.6	4.7	4.3
1992	5.0	5.3	4.3	4.3	4.8	5.2	5.6	5.2	5.0	4.5	4.2	3.9
1993	4.2	4.8	4.3	4.0	4.6	5.4	5.8	4.6	4.9	3.8	2.5	3.1
1994	3.7	3.5	4.2	4.4	4.4	5.4	4.6	4.3	4.0	3.1	4.1	4.3
1995	3.4	4.1	3.6	4.3	5.0	4.2	4.7	5.0	4.5	4.1	4.0	2.8
1996	3.7	4.0	4.2	4.3	4.3	4.7	5.4	5.5	4.5	4.1	3.7	2.9
1997	3.9	4.0	4.5	4.4	4.6	5.0	6.0	5.9	4.5	4.1	3.3	3.2
1998	3.5	4.2	3.9	4.2	4.9	5.4	5.3	4.5	5.5	5.0	3.1	4.2
1999	3.5	4.1	4.7	5.0	6.7	5.8	6	6.2	5.1	4.6	3.7	3.8
2000	3.5	4.0	4.6	4.9	6.6	5.7	5.9	6.1	5.1	4.3	3.6	4.1
2001	3.6	3.9	4.6	4.8	6.0	5.3	5.4	5.8	5.2	4.0	3.6	4.8
2002	3.7	3.8	4.5	4.6	4.3	4.6	4.3	5.1	5.4	3.9	3.4	4.6
Mean	3.8	4.1	4.3	4.4	5.2	5.2	5.4	5.2	4.9	4.2	3.9	3.8
SD	0.41	0.52	0.34	0.48	0.74	0.51	0.58	0.68	0.53	0.68	0.72	0.86
CV%	10.7	12.6	7.9	10.9	14.2	9.8	18.9	13.0	10.8	16.1	18.4	22.6

Appendix (5): Mean Monthly Values of Wind Speed (m/s) for all stations at 50 m height

STATIONS	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
MOSUL	1.7	2.2	2.6	2.6	3.1	3.1	3.1	2.7	2.1	1.5	1.4	1.7
RABEA	2.9	3.1	3.3	3.3	3.6	3.8	3.8	3.4	3.1	2.6	2.4	2.6
SINJAR	3.3	4.1	5.0	5.8	7.2	7.7	7.7	7.2	6.0	3.8	2.9	3.1
TALAFAR	6.5	7.1	7.4	7.6	8.9	8.9	9.3	8.9	8.4	7.2	6.7	6.5

Appendix (6): Monthly Mean Values of Wind Power density (w/m2) for all Stations at 10 m height

STATIONS	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
MOSUL	0.6	1.3	2.1	2.1	3.6	3.6	3.6	2.5	1.1	0.4	0.3	0.6
RABEA	3.0	3.6	4.2	4.2	5.7	6.5	6.5	4.9	3.4	2.5	1.7	2.1
SINJAR	4.2	4.5	14.9	24.1	45.4	55.8	55.8	45.4	28.6	6.5	3.0	3.6
TALAFAR	33.6	42.2	48.7	52.2	86.1	86.1	96.4	86.1	72.0	45.4	36.3	33.6

Appendix (7) : Monthly Mean Values of Wind Power density (w/m2) for all Stations at 50 m height

STATIONS	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
MOSUL	3.0	6.5	10.8	10.8	18.2	18.2	18.2	12.1	5.7	2.1	1.7	3.0
RABEA	14.9	18.2	22.0	22.0	28.6	33.6	33.6	24.1	18.2	10.8	8.5	10.5
SINJAR	32.8	42.2	76.6	120	229	280	280	229	132.3	28.6	14.9	18.2
TALAFAR	168	219	248	269	432	432	493	432	363	229	184	168.2