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Wind Statistical Analysis and the Number of Generation Hours for Different Wind Turbines at Three Lakes in Iraq

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Abstract
The use of wind as an energy source is becoming popular because it is non-polluting and renewable. There is a pressing need in Iraq to develop site-based technology on wind energy, which can be used for optimal design of wind turbines and wind farming. The main objective of this research is to analyze the wind data statistics for one year period of January to December 2012 at three lakes in Iraq; Tharthar, Habbaniyah, and Razzazah. In the other hand, data recorded at 10m are estimated at 30m and 50m above ground level. Statistical analysis of these data is achieved using Weibull distribution function; the analysis included different wind turbine machines (500 kW, 950 kW, and 1500 kW) in order to assess the number of hours electricity generation from those turbines. The results show that Tharthar Lake gives more generation hours than the other lakes depending on the site characteristics and on the turbine type.
Keywords: Wind speed, Weibull parameters estimation, Generation hours, lakes, Iraq.

1. Introduction

Renewable energy refers to energy resources that occur naturally and repeatedly in the environmental where it can be harnessed for human benefit. The renewable energy resources include solar, wind, hydro, geothermal and biomass. Steps taken to establish these types of resources are a new solution for the present energy shortage. Because of the limited fossil fuel reserves, and also the adverse effects associated with their use, the alternatives energy becomes conventional energy sources, especially the renewable ones become increasingly attractive.

Moreover, utilization of solar and wind power has become increasingly significant, attractive and cost-effective, since the oil crises of early 1970s.Both of these and other renewable energy resources are abundant in Iraq. Wind energy is one of leading ones among the new, renewable, clean and cheap resource. This is an important resource of energy which has been popular in recent years and which has exhibited rapid technological development,[1].Therefore, there were many studies aimed to assess the energy in the wind to generate electrical energy and find the best statistical distribution. Iraq is an oil country, but this does not prevent the possession of other inexhaustible resources such as solar, hydro and wind energy. This research made a comparison between five methods in calculating Weibull distribution parameters, then using the best one to find wind characteristics and assesses the number of generation hours of electricity at three lakes in Iraq (Tharthar, Habbaniyah, and Razzazah) using different wind turbines.

2. Theoretical Analysis and Formulation

2.1 Weibull Distribution

The Weibull distribution gives a good match with the experimental wind data, as mentioned in many references. This distribution is characterized by two parameters: the shape parameter k(dimensionless) and scale parameter c (m/s), [2].In Weibull distribution, the variations in wind velocity are characterized by the two functions; The probability density function $f(v)$ and the cumulative distribution function $F(v)$.The probability density function $f(v)$indicates the fraction of time (or probability) for which the wind is at a given velocity v. It is given by,[3];

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} e^{-\left(\frac{v}{c}\right)^k} \quad (1)$$

The cumulative distribution function of the velocity v gives us the fraction of time (or probability) that the wind velocity is equal or lower than v. Thus the cumulative distribution function F(v) is the integral of the probability density function. Thus,[2]:

$$F(v) = \int_0^{\alpha} f(v)\, dv = 1 - e^{-\left(\frac{v}{c}\right)^k} \quad (2)$$

2.2 Methods for Estimating Weibull Parameters

Parameters defining Weibull distribution function can be classified into two categories, graphical and analytical methods as in below;

2.2.1 Graphical Methods

Usually, the graphical methods are used because of their simplicity and speed. However, they involve a great probability of error. Next we discuss two main graphical methods.

i. Weibull Probability Plotting (PPM)

To come up with the relation between the cumulative distribution function and the two parameters (c, k), we take the double logarithmic transformation of Eq. (2) finally we get, [4]:

$$ln\, ln\left[\frac{1}{1-F(v)}\right] = k\ln(c) - k\ln(v) \quad (3)$$

ii. Hazard Plotting Technique (HPM)

The hazard plotting technique is an estimation procedure for the Weibull parameters. This is done by plotting cumulative hazard function H(v) against failure times on a hazard paper or a simple log-log paper. The hazard function is given below, [5]:

$$\mathrm{H(v)} = (\tfrac{\mathrm{v}}{\mathrm{c}})^{\mathrm{k}} \quad (4)$$

We can transform (4) by taking the logarithm as follows

$$ln\, H(v) = k(ln\, v - ln\, c) \quad (5)$$

$$ln\, v = \frac{1}{k} ln\, H(v) + ln\, c \quad (6)$$

From (6), we can then plot ln H(v) versus ln v, where k=1/slope at H=1, c=v.

2.2.2 Analytical Methods

Due to the high probability of error in using graphical methods, we prefer to use the analytical methods. In the following, we discuss some of the analytical methods used in estimating Weibull parameters.

i. Maximum Likelihood Estimation Method (MLE)

The maximum likelihood method is used for the wind speed data in time series format. The maximum likelihood method was used by Stevens and Smulders, [6] in their study for estimation of parameters of the Weibull wind speed distribution for wind energy utilization purposes. The shape factor *k* and the scale factor *c* can be estimated by the following equations, [7]:

$$k = \left(\frac{\sum_{i=1}^{n} v_i^k \ln(v_i)}{\sum_{i=1}^{n} v_i^k} - \frac{\sum_{i=1}^{n}\ln(v_i)}{n}\right)^{-1} \quad (7)$$

Where v_i is the wind speed in time step *i*, and *n* the number of nonzero wind speed data points. Eq. (7) must be solved using iterative procedure, after which Eq. (8) can be solved explicitly. Care must be taken to apply Eq. (9) only to the nonzero wind speed data points.

$$c = \left(\frac{\sum_{i=1}^{n} v_i^k}{n}\right)^{1/k} \quad (8)$$

ii. Energy Pattern Factor Method (EPF)

Energy pattern factor (EPF) or Cube Factor is the ratio between the total power available in the wind and the power corresponding to the cube of the mean wind speed, [4]:

$$EPF = \frac{Total\ amount\ of\ power\ available\ in\ the\ wind}{Power\ calclated\ by\ mean\ cube\ speed} \quad (9)$$

In terms of wind speed we have:

$$EPF = \frac{1}{n}\sum_{i=1}^{n} v_i^3 / \left(\frac{1}{n}\sum_{i=1}^{n} v_i\right)^3 \quad (10)$$

Once the energy pattern factor for a regime is found from the wind data, an approximate solution fork is:

$$k = 3.957\, EPF^{-0.898} \quad (11)$$

iii. Modified Maximum Likelihood Estimation Method (MME)

The Modified maximum likelihood estimation method (MME) is used only for wind speed data available in the Weibull distribution format. The MME method is solved through numerical iterations to determine the parameters of the Weibull distribution. The shape factor and the scale factor are estimated by Eqs.12 and 13, [8]:

$$k = \frac{ln\left(\frac{1}{n}\right)}{ln\left(\frac{Y_1}{\bar{v}}\right)} \quad (12)$$

$$c = \left(\frac{\left(1 - \frac{1}{n^{\frac{1}{k}}}\right)\Gamma\left(1 + \frac{1}{k}\right)}{\bar{v} - Y_1}\right)^k \quad (13)$$

where Y_1 is first order.

3. Vertical Estimation of Wind Speed Using the Power Law Model

Winds are slowed by friction at the earth's surface, so that wind speeds tend to be greater at higher elevations. For regions with relatively level terrain and little vegetation, the method most commonly used to obtain this extrapolation is the 1/7 power-law model. The equation of the 1/7 power-law model is, [7]:

$$\frac{v(z)}{v(z_\circ)} = \left(\frac{z}{z_\circ}\right)^{\frac{1}{7}} \tag{14}$$

where z is the height at which the wind speed is to be estimated, v(z)is the wind speed to be estimated, and $z_\circ$and $v(z_\circ)$ are the reference height and wind speed, respectively [9].

4. Correlation Coefficient (R)

The correlation coefficient is a statistical technique that is used to determine the linear relationship between two datasets. The mathematical equation for R is defined as, [4]:

$$R = \frac{ń \sum_{i=1}^{ń}(y_i \cdot x_i) - \sum_{i=1}^{ń} y_i \cdot \sum_{i=1}^{ń} x_i}{\sqrt{ń \sum_{i=1}^{ń} y_i^2 - \left(\sum_{i=1}^{ń} y_i\right)^2} \cdot \sqrt{ń \sum_{i=1}^{ń} x_i^2 - \left(\sum_{i=1}^{ń} x_i\right)^2}} \tag{15}$$

where, yi = is the ith actual wind distribution (measured data).
xi = is the predicted wind distribution from the Weibull.
ń = is the number of wind speed dataset (bins).
The values of R always lie between -1 and 1.

5. Turbine Generation Power Time

The cumulative distribution function can be used for estimating the time for which wind is within a certain velocity interval. Probability of wind velocity being between v_1 and v_2 is given by the difference of cumulative probabilities corresponding to v_2 and v_1, thus, [2]:

$$P\ (v_1 < v < v_2) = F\ (v_2) - F\ (v_1) \tag{16}$$

That is,

$$P(v_1 < v < v_2) = e^{-(\frac{v_1}{c})^k} - e^{-(\frac{v_2}{c})^k} \tag{17}$$

Now, for how many hours in a day (consequently in a year) will the turbine generate power, its most convenient to know the wind turbine cut-in velocity v1 and cut-out velocity v2 in addition to the site Weibull shape factor and scale factor, then by applying all these variables in Eq.17, and multiplied the result by 24 hours we can get the turbine generated power in a day or year.

6. The Study Area

6.1 Tharthar Lake

Tharthar Lake is the biggest artificial lake in Iraq within (33°57'33.1"N 43°14'42.0"E) and located (65 km) to the north west of the city of Baghdad, as shown in Fig. (1-a),It is the one of the most important flood control and storage project in Iraq, which it is protects the city of Baghdad and other cities from flood hazard. The maximum capacity of the reservoir (lake) is (85 Km3) at height (65m) the lowest water level of the lake is (4m), the length of it is about (250 Km) with (40 Km) wide, [9].

6.2 Habbaniyah Lake

Habbaniyah Lake which is located in the middle of Iraq, in the south west of Baghdad city (capital of Iraq), as shown in Fig. (1-b),within (33°17'26.5"N 43°27'35.5"E) , this artificial lake is deeded with water from Euphrates River through Al-Warar control water spill way which have a maximum discharge of(2,800 m^3/sec) and channel total length of 8,000m, the water is drown off through Al-Thaban water control channel length(9,300m) that have normal water discharge of (200m^3/sec), the south of Habbaniyah lake was connected with water channel to Razzazah Lake, and Hoor Abo-Deb is the east side of the lake is a low level ground which can be flood when water level's rises in this lake, The surface water area rises from (426 Km2) water in high level, down to (184Km2) water in low level water level rise from (51m), to(42m) over sea level, and the water storage volume is 3,2 billions m3 to 0,67 billion m3, [10].

6.3 Al Razzazah Lake

Al Razzazah Lake is the second biggest lake in Iraq with a surface area about (1700 km2) located within the administrative boundaries of Karbala and Anbar provinces as shown in Fig.(1-c), within (32°42'04.3"N 43°35'28.6"E),and is fed with water from Habbaniyah Lake. Its northern part lies within Anbar province and its southern part is in Karbala province .The surface area of Al Razzazah Lake varies with the variation in its water level. Whenever the water level rises, its surface area increases and vice versa. It is noted that the lake bottom (the lowest point) of Al Razzazah Lake is at level (17m) from the sea level. On the other hand, the highest water level of the lake is (40m) at which the quantity of water is 25.75 billion m3,[11].

7. Results and Discussion

In this study, three sites in Iraq have been selected, as shown in Fig.1, all three sites are taken as bodies of water Habbaniyah

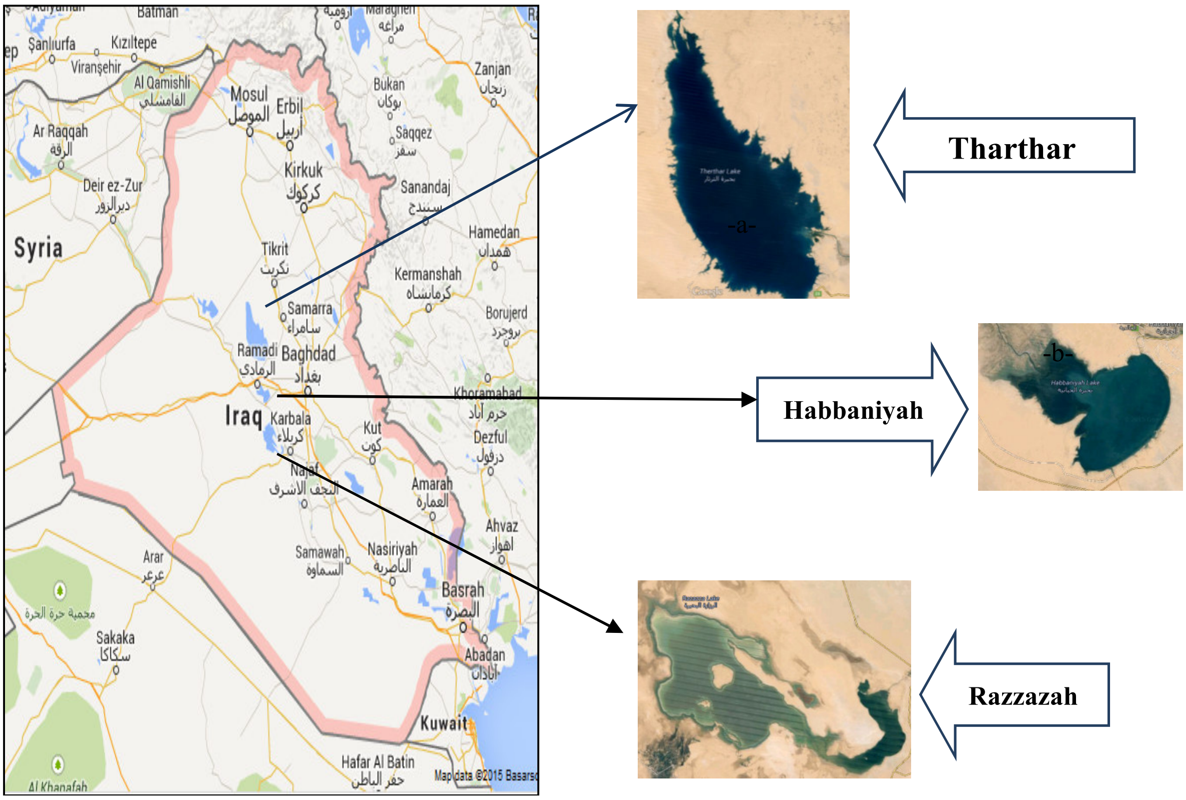

Figure 1. Three Selected Study Area

The wind speeds of these sites are collected as six records per day during one year from the European Centre for Medium-Range Weather Forecasts (ECMWF) (an independent intergovernmental organization supported by 34 states). The wind site characteristics are estimated graphically and numerically using COWFD (A Computer Code for Optimum Wind Farm Design) program.

Since most wind turbine shave hub height more than 10meterespecially for high output energy types, thus the data collected at 10mheight from ground surface must extrapolate to another height, and this can be done using power law model (Eq. 14). The characteristics of the sites were studied using Weibull parameters (c, k), the parameters were calculated via five estimation methods Maximum Likelihood Estimation method MLE, Modified Moment Estimation method MME, Hazard Plot Method HPM, Probability Plot Method PPM, and Energy Pattern Factor method EPF (results are shown in Table 1) at 10, 30, and 50 meters from the ground surface.

Table 1. Weibull parameters values for three areas estimated byfive methods (annual based)

10m		**MLE**		**MME**		**HPM**		**PPM**		**EPF**	
No.	Areas	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*
1	Thrthar	1.33	2.91	1.43	2.97	1.19	2.99	1.37	2.97	1.55	2.99
2	Habbaniyah	1.40	2.62	1.51	2.68	1.28	2.71	1.46	2.69	1.67	2.70
3	Razzazah	1.34	2.63	1.44	2.68	1.24	2.70	1.37	2.67	1.57	2.70
30m		**MLE**		**MME**		**HPM**		**PPM**		**EPF**	
No.	Areas	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*
1	Thrthar	1.33	3.38	1.43	3.45	1.19	3.47	1.18	3.28	1.55	3.47
2	Habbaniyah	1.40	3.06	1.51	3.13	1.27	3.16	1.43	3.13	1.67	3.15
3	Razzazah	1.34	3.05	1.44	3.11	1.24	3.13	1.36	3.10	1.57	3.141
50m		**MLE**		**MME**		**HPM**		**PPM**		**EPF**	
No.	Areas	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*
1	Thrthar	1.33	3.65	1.43	3.72	1.19	3.74	1.34	3.71	1.55	3.80
2	Habbaniyah	1.40	3.29	1.51	3.36	1.27	3.39	1.42	3.35	1.67	3.38
3	Razzazah	1.34	3.29	1.44	3.36	1.24	3.38	1.36	3.35	1.57	3.39

Tables 2, 3, and 4 show the monthly mean wind speed and Weibull parameters (shape and scale parameters) calculated by five preceding methods. Since the scale factor directly relates with the average wind speed, it may be concluded from this table that scale factor is higher in June than the other months at Tharthar and Razzazah Lake, while May month is the month which has more mean wind speed than the others at Habbaniyah Lake.

Table 2. Monthly average wind speed and Weibull parameters using five estimation methods at 50m high for the year 2012 at Tharthar Lake (monthly based)

Month	Mean (m/s)	MLE		MME		HPM		PPM		EPF	
		k	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*
Jan.	3.27	1.48	3.57	1.61	3.75	1.55	3.75	1.54	3.73	1.70	3.66
Feb.	3.43	1.13	3.58	1.23	3.72	1.13	3.67	1.12	3.68	1.22	3.68
Mar.	4.25	1.07	4.35	1.28	4.66	1.02	4.62	1.03	4.63	1.33	4.64
Apr.	3.09	1.20	3.26	1.33	3.42	1.20	3.41	1.23	3.41	1.37	3.38
May	4.20	1.30	4.49	1.58	4.83	1.24	4.83	1.23	4.83	1.75	4.72
Jun.	4.49	1.69	4.87	2.03	5.34	1.74	5.43	1.68	5.35	2.23	5.06
Jul.	3.81	1.32	4.07	1.57	4.36	1.31	4.37	1.32	4.37	1.75	4.28
Aug.	4.31	1.59	4.57	1.95	5	1.63	5.17	1.56	5.08	2.22	4.87
Sep.	3.45	1.55	3.66	1.89	3.99	1.69	4.14	1.62	4.07	2.14	3.89
Oct.	2.41	1.19	2.53	1.41	2.70	1.17	2.71	1.15	2.70	1.51	2.67
Nov.	2.27	1.19	2.39	1.40	2.54	1.14	2.53	1.11	2.53	1.52	2.52
Dec.	2.90	1.34	3.12	1.50	3.28	1.37	3.31	1.34	3.29	1.59	3.23
Mean	3.94	1.33	3.70	1.56	3.96	1.34	3.99	1.32	3.73	1.69	3.88

Table 3. monthly average wind speed and Weibull parameters using five estimation methods at 50m high for the year 2012 at Habbaniyah Lake (monthly based)

Month	Mean $\overline{v}$(m/s)	MLE		MME		HPM		PPM		EPF	
		k	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*
Jan.	2.83	1.36	3.01	1.54	3.19	1.47	3.28	1.44	3.26	1.67	3.17
Feb.	3.14	1.26	3.35	1.41	3.52	1.21	3.49	1.21	3.50	1.47	3.47
Mar.	3.56	1.17	3.74	1.38	3.97	1.07	3.93	1.06	3.94	1.47	3.81
Apr.	2.97	1.39	3.14	1.59	3.34	1.49	3.41	1.59	3.34	1.78	3.33
May	3.92	1.46	4.26	1.73	4.59	1.47	4.62	1.48	4.63	1.88	4.43
Jun.	3.83	1.50	4.15	1.78	4.47	1.45	4.46	1.43	4.44	2.01	4.32
Jul.	3.39	1.43	3.69	1.65	3.92	1.36	3.86	1.36	3.86	1.85	3.82
Aug.	3.76	1.53	4.07	1.84	4.41	1.52	4.44	1.47	4.39	2.07	4.25
Sep.	3.14	1.45	3.30	1.74	3.57	1.48	3.62	1.43	3.58	2.01	3.54
Oct.	2.37	1.32	2.53	1.58	2.71	1.36	2.77	1.33	2.75	1.74	2.66
Nov.	2.08	1.24	2.20	1.47	2.35	1.25	3.37	1.23	2.36	1.61	2.33
Dec.	2.73	1.39	2.94	1.59	3.13	1.53	3.25	1.48	3.21	1.71	3.06
Mean	3.14	1.37	3.36	1.60	3.59	1.38	3.70	1.37	3.60	1.77	3.51

Table 4. monthly average wind speed and Weibull parameters using five estimation methods at 50m high for the year 2012 at Razzazah Lake (monthly based)

Month	Mean $\overline{v}$(m/s)	MLE		MME		HPM		PPM		EPF	
		k	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*	*k*	*c(m/s)*
Jan.	3.35	1.46	3.61	1.63	3.81	1.55	3.86	1.53	3.83	1.79	3.77
Feb.	3.68	1.42	4	1.60	4.25	1.36	4.19	1.36	4.20	1.71	4.12
Mar.	3.82	1.14	3.99	1.25	4.14	1.09	4.08	1.08	4.08	1.30	4.14
Apr.	2.78	1.39	2.99	1.49	3.15	1.32	3.11	1.31	3.11	1.63	3.11
May	3.79	1.37	4.10	1.59	4.36	1.38	4.41	1.39	4.41	1.70	4.26
Jun.	3.92	1.62	4.28	1.92	4.65	1.62	4.66	1.58	4.61	2.12	4.43
Jul.	3.20	1.33	3.41	1.49	3.58	1.36	3.59	1.33	3.58	1.63	3.58
Aug.	3.74	1.72	4.12	2.08	4.53	1.70	4.51	1.72	4.51	2.22	4.22
Sep.	3.19	1.45	3.44	1.74	3.71	1.31	3.64	1.30	3.63	1.98	3.59
Oct.	2.40	1.32	2.57	1.51	2.73	1.38	2.78	1.37	2.77	1.63	2.68
Nov.	2.35	1.29	2.49	1.46	2.63	1.47	2.76	1.45	2.74	1.54	2.61
Dec.	3.19	1.44	3.47	1.68	3.72	1.51	3.79	1.49	3.78	1.82	3.60
Mean	3.28	1.41	3.53	1.61	3.77	1.55	3.78	1.40	3.77	1.75	3.67

Figs. 2,3, and 4 are graphical representations demonstrate monthly mean wind speed values and Weibull scale parameter throughout the year 2012 obtained from Weibull probability model at a height of 50m for the three selected areas. The behavior exist in the three above tables is clear in these figures, the similarity can be seen among the methods with the true data almost for all the months for parameter *c*(m/s),which almost close to the mean of wind speed, the divergence of the methods with the actual data obtained due to the difference in the estimated values. The correlation between the monthly mean values of Weibull scale parameter and the measured wind speed values was found to be linear for all the sites and they have the same trend, [12].

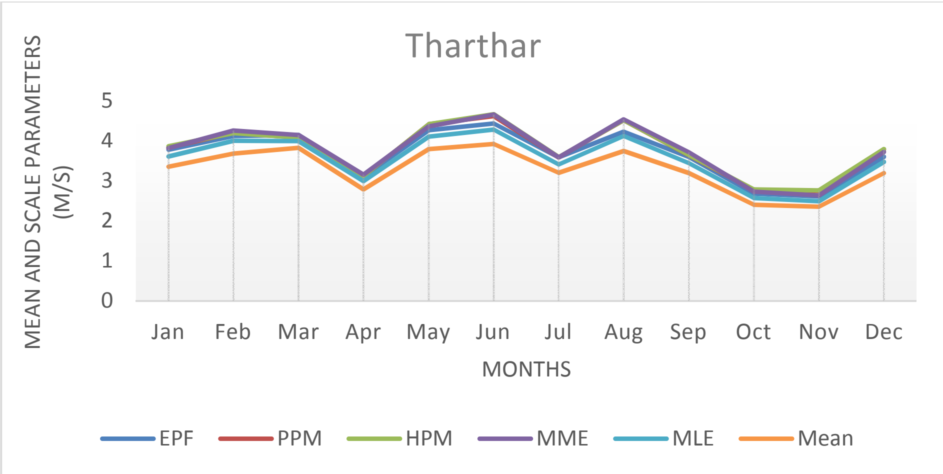

Figure 2. Monthly variation of scale factor and mean wind speed at Tharthar Lake

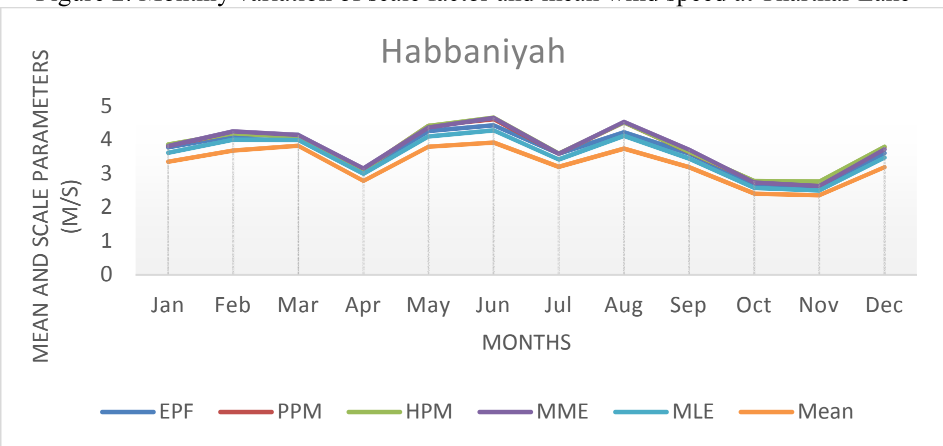

Figure 3. Monthly variation of scale factor and mean wind speed at Habbaniyah Lake

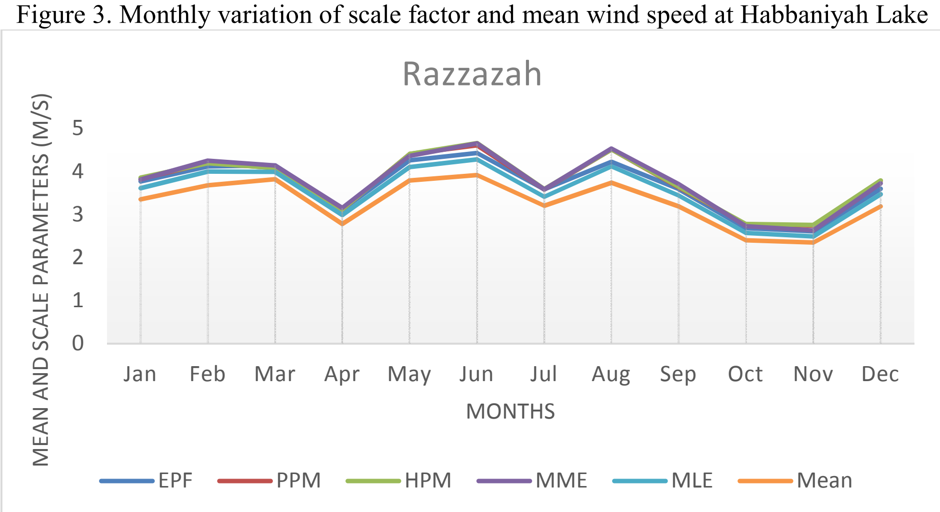

Figure 4. Monthly variation of scale factor and mean wind speed at Razzazah Lake

Now, in order to examine which method is suitable to describe the wind speed data, the correlation coefficient test (Eq.15) is used for validating the accuracy of the predicted wind speed distribution obtained from

Weibull parameters. This achieved by comparing the monthly average wind speed (listed in Tables 2,3, and 4)with Weibull scale factor(listed in the same tables) using the five preceding methods at the study area for one year (2012) at 50m height. Table 5 illustrates the results of these criteria and they clarify that the best fit is observed with EPF method.

Table 5. The correlation coefficient using five methods at height 50m for the year 2012 at the selected areas

No.	Areas	MLE	MME	HPM	PPM	EPF
1	Tharthar	0.996	0.993	0.985	0.989	0.997
2	Habbaniyah	0.998	0.996	0.901	0.993	0.996
3	Razzazah	0.996	0.984	0.977	0.979	0.997

Different turbines are used for pairing between sites and wind turbines. Three wind turbines Suzlon, Nordex, and Power Wind were selected to have much more suited one to our site. Table 6, 7, and 8; show the main parameters for the each wind turbine (Power rated P_r, cut-in v_c, rated v_r and furling v_f wind speeds) at 10, 30, 50 hub height. Furthermore, the number of generation hours per a day and per a year for all three wind turbine types are also listed in Table 7.

Table 6. No. of generation hours for Suzlon wind turbine type per a day and per a year at three water bodies

SuzlonS64 950 64m P_r=950kW, v_c=3m/s, v_r=11m/s, v_f=25m/s					
10m		**Energy pattern factor method**		**No. of Generation hrs**	
No.	Areas	*K*	*c(m/s)*	Per day	Per year
1	Tharthar	1.55	2.99	8.7	3205
2	Habbaniyah	1.67	2.70	7.2	2658
3	Razzazah	1.57	2.70	7.3	2692
30m		**Energy pattern factor method**		**No. of Generation hrs**	
No.	Areas	*K*	*c(m/s)*	Per day	Per year
1	Tharthar	1.55	3.47	10.8	3943
2	Habbaniyah	1.67	3.15	9.5	3484
3	Razzazah	1.57	3.14	9.4	3454
50m		**Energy pattern factor method**		**No. of Generation hrs**	
No.	Areas	*K*	*c(m/s)*	Per day	Per year
1	Tharthar	1.55	3.80	11.9	**4379**
2	Habbaniyah	1.67	3.38	10.5	3860
3	Razzazah	1.57	3.39	10.5	3837

Table 7. No. of generation hours for Nordex turbine type per a day and per a year at three water bodies

Nordex N70 P_r=1.5MW, v_c=4m/s, v_r=13m/s,v_f=25m/s					
10m		**Energy pattern factor method**		**No. of Generation hrs.**	
NO.	Areas	*K*	*c(m/s)*	Per day	Per year
1	Tharthar	1.55	2.99	4.9	1822
2	Habbaniyah	1.67	2.70	3.4	1274
3	Razzazah	1.57	2.70	3.7	1372
30m		**Energy pattern factor method**		**No. of Generation hrs.**	
NO.	Areas	*K*	c(m/s)	Per day	Per year
1	Tharthar	1.55	3.47	6.9	2518
2	Habbaniyah	1.67	3.15	5.4	1973
3	Razzazah	1.57	3.141	5.5	2029
50 m		**Energy pattern factor method**		**No. of Generation hrs.**	
NO.	Areas	*K*	c(m/s)	Per day	Per year
1	Tharthar	1.55	3.80	8.1	**2966**
2	Habbaniyah	1.67	3.38	6.3	2328
3	Razzazah	1.57	3.39	6.5	2395

Table 8. No. of generation hours from PowerWind turbine type per a day and per a year at three water bodies

PowerWind 56-500 56m P_r=500kW,v_c=3m/s, v_r=10m/s,v_f=25m/s					
10m		**Energy pattern factor method**		**No. of Generation hrs.**	
No.	Areas	*K*	*c(m/s)*	Per day	Per year
1	Tharthar	1.55	2.99	8.7	3205
2	Habbaniyah	1.67	2.70	7.2	2658
3	Razzazah	1.57	2.70	7.3	2692
30m		**Energy pattern factor method**		**No. of Generation hrs.**	
No.	Areas	*K*	c (m/s)	Per day	Per year
1	Tharthar	1.55	3.47	10.8	3943
2	Habbaniyah	1.67	3.15	9.5	3484
3	Razzazah	1.57	3.141	9.4	3453
50 m		**Energy pattern factor method**		**No. of Generation hrs.**	
No.	Areas	*K*	c(m/s)	Per day	Per year
1	Tharthar	1.55	3.80	12	**4394**
2	Habbaniyah	1.67	3.38	10.5	3860
3	Razzazah	1.57	3.39	10.5	3837

From three above tables it could be concluded that the mid and less turbines types is more suitable than the large one at the studied areas, and the more generation hours at 50m above the surface of earth are available at Tharthar Lake than Habbaniyah and Razzazah Lakes.

Finally, Tables 9 shows the results of applying different statistics related to wind speed data for the highest potential wind speed area (Tharthar) throughout the year 2012. The characteristics of the wind speed at 50m height above the surface are described based on Weibull parameters. The parameters are concluded from measured data after applying the EPF method, then the probability density function (Weibull plot) which depends on these parameters can be shown drown in Fig.(5). Following points are observed:

- The annual mean wind speed recorded shows the suitability of the wind resources at this site for mid and less wind energy systems.
- The mean and the median are unequal, then distribution appears to be asymmetric
- Since the mean wind speed is less than the median, the distribution is skewed to the left, Fig. (5).
- The skewness of the wind speed data is positive, indicating that the distribution is asymmetric with tail extending toward positive values, Fig.(5)..
- Kurtosis has positive value which indicates that we have peaked distribution.

Table 9: Descriptive statistics for wind data measured at Tharthar Lake (2012)

Characteristic	**Value**
c (m/sec)	3.80
K	1.55
Mean speed (m/sec), conventional method	3.41
Median speed (m/sec)	3.00
Modal speed (m/sec)	1.94
Max frequency	0.198
Variance (m/sec)2	5.00
The Std. of wind velocity (m/sec)	2.20
Coefficient of variation	66.0
1st raw moment (Mean speed, Weibull based) (m/sec)	3.41
2nd raw moment $(m/sec)^2$ - measure of Spread	16.7
3rd raw moment $(m/sec)^3$- measure of Skewness	103.5
4th raw moment $(m/sec)^4$- measure of Kurtosis	758.2
Total Power density (W/m^2)	63.30

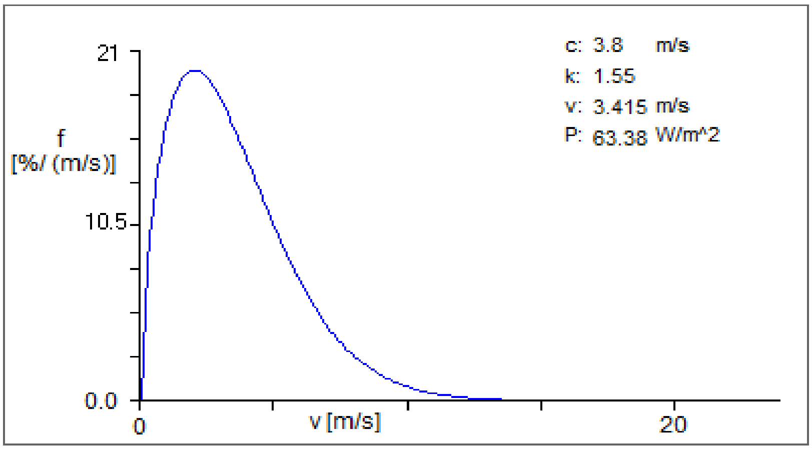

Figure 5. The probability density function at Tharthar (2012)

8. Conclusions

1- The results indicated that water bodies in Iraq considered as poor sources of wind, such that the highest average wind speed exist is 3.4 m/sec at Tharthar Lake site.
2- The highest wind speed at the selected sites is available within the period May to June.
3- Mid wind turbines types and less are suitable choice for the three sites.
4- The most generation hours can be noted in Tharthar Lake which reaches to 4394 hr/year if we use PowerWind turbine at 50m height.

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