Estimating Electricity Generation from Wind Power by V82 at ThiQar – Iraq

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Abstract

One of the most demanded studies is wind turbine site assessment. It is difficult to build a simulation program because of the many variables that affect the wind speed and direction. The procedure of this research depend on two approaches, the Wind Atlas Analysis model and the Inverse Distance Wait interpolation. These procedures give the estimated annual energy production for each turbine (V82) with 82m blades diameter at 70m hub heights. The output at this location for each turbine is about (4.3 GWh). The studied area is about 20x20km^2 and could be plant at least 600 turbine and have about 2500 GWh of annual energy production.

Keywords:wind power, WAsP, GIS

Introduction

Electricity is the kind of power that has been demanded rapidly from the entire world for the last decades. These demands depend on the easily converted electric power to other kind of energy. The other issues are the sustainability and clean sources for generating electricity, also the coast of the primary fuel. Renewable energies are the goal for the researchers to be studied, see figure (1)

Wind energy is one of the most common and typical sources to be evaluated for the studied region. Wind power that is produced by turbines is often used as a supplement to other power sources, because the turbines cannot produce power on demand; their output depends on the wind speed and sustainability, and not feasible for all geographical locations.

The main advantage of using wind source, it does not produce harmful greenhouse gases or waste products. Wind farms create little disruption to local environment. The land which will be located for establishing wind farms will be occupied with 5% by wind farm equipments and the rest of the land could be used for other purposes like farming and ranching.

The disadvantage of using wind power is the high initial cost; building the turbines, towers and foundations is expensive. [1]

Wind Atlas Analysis and Application Program Model (WAsP) and arcGIS software are the tools for estimating the power gained from the studied region. WAsP is a theoretical estimation model depends on a measured climate data for a series of time. The other software arcGIS is a package that deals with GIS form of presentation and analysis.

Wind Atlas Analysis and Application Program WAsP

This model is depends on several parameters which had to be calculated previously in order to be used. These parameters could be summarized

1- Wind Speed and Direction

The wind speed data usually measured at 10m height from the ground. The period of data measured depend on the station Specifications, it varies between 1min. to 15min. for each measure.

2- Wind Profile

The WAsP uses the logarithmic wind profile to calculate the wind speed variance with height. It therefore utilizes three variables; i.e. the height above ground, the roughness length, and the frictional velocity. [2].

Equation (1) is for high wind speeds and (2) for lower wind speeds which are used in WAsP in order to describe the surface layer wind profile.

$$u(z) = \frac{u_*}{k} ln \frac{z}{z_0} \quad ....(1)$$

$$u(z) = \frac{u_*}{k} (\ln \frac{z}{z_0} - \Psi\left(\frac{z}{L}\right)) \quad ......(2)$$

$$\Psi\left(\frac{z}{L}\right) = \begin{cases} -4.7\frac{z}{L} & if\ conditions\ are\ stable \\ \left(1-16\frac{z}{L}\right)^{\frac{1}{4}} - 1 & if\ conditions\ are\ unstable \end{cases} \quad ....(3)$$

Where $u(z)$ is the air velocity at a height of z, u_* is the air friction velocity, κ is von Karmans constant which in this case is set equal to 0,40 and z_0 is the roughness length of the surface. L is the Monin-Obukhov length which is defined according to equation (4)

$$L = \frac{T_0}{kg} \frac{C_p u_*^3}{H_0} \quad ....(4)$$

Where T_0 and H_0 are the absolute temperature and heat flux, respectively. cp is the heat capacity of air at constant pressure and g is the gravitation constant.

3- Roughness length

Roughness length z_0 is a corrective measure for wind flow which account for the effect of the roughness of a surface. It is ranged between 1/10 and 1/30 of the average height of the roughness elements on the ground [3].

4- Obstacles

The wind is strongly influenced by the presence of the obstacle such as a building or shelter belt, which may change the wind profile (speed and direction) considerably.

5- Weibull Distribution and Parameters

The Weibull distribution is characterized by:

a) Shape parameter (*k)* (dimensionless)
b) Scale parameter (A) (m/s), [4].

"The variations in wind velocity are characterized by the two functions": [5]

i) Probability density function f(V)
ii) Cumulative distribution function F(V).

The probability density function *f(V)* indicates the probability for which the wind is at a given velocity *V*.;

$$f(V) = \frac{k}{A}\left(\frac{V}{A}\right)^{k-1} e^{-\left(\frac{V}{A}\right)^k} \qquad (5)$$

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 F(V) is the integral of the probability density function. Thus,

$$F(V) = \int_0^V f(V)dV = 1 - e^{-\left(\frac{V}{A}\right)^k} \qquad (6)$$

The cumulative distribution function can be used for estimating the time for which wind is within a certain velocity interval.

Studied Area

The studied area lies at ThiQar province at south of Iraq. The metrological station located at 599868E & 3423436N. The wind power evaluation area will be (20km x 20km) around the station, as seen in figure (2).

Procedure and Results

The procedure is summarized as:

1- input data
  a) Metrological wind speed and directions for the years 2011 to 2013 which are presented in this research with 10 minute intervals and at 10m heights.
  b) Digital Elevation Model (DEM) for the studied area, and its presented from ASTER GDEM with 30m Horizontal resolution and 15m Vertical resolution.
  c) Photomap for Iraq LANDSAT-7 Satellite with 28.5m resolution. Photomap for the studied area (ThiQar) QuickBird Satellite with 0.6m resolution.
  d) Previous study [6], which located the best places to establish wind farms.
2- Preparing the input data to match the requirement of the WAsP and arcGIS softwares.
3- Preprocessing for the photomaps and DEM.
4- Create a contour map from DEM photomap for the studied area.
5- Calculate the Weibull shape and scale parameters.
6- Estimating the wind speed for each sector of the studied area by using WAsP model.
7- Calculating the Annual Energy Production (AEP).

(OWC) observed wind climate files produced by WAsP Climate Analyst is the first step after preparing the input data. This step allows the WAsP program to initialize the wind atlas table. Figure (3) represents the contour map for the area to observe the roughness (red lines) and elevations (gray lines) of the land.

The area around the metrological station was divided into 12 sectors radially. Each sector has its characteristic of nature which depends on the obstacles and the type of land (soil, water, grass, …..etc.).

The power density at ThiQar is (107) W/m^2 and average wind speed is (4.13 m/s). The Weibull parameters scale and shape are (4.6 m/s), and (1.60) respectively. Sectors (10 with mean speed 3.53 m/s & power densities 57 W/m^2), (11 with mean speed 4.46 m/s & power densities 118 W/m^2) and (12 with mean speed 5.31 m/s & power densities 176 W/m^2) are the dominant direction. These data are illustrated in table (1), figure (4), for observed wind climate and figure-5, for the frequency of the wind and its amount in each direction (wind rose).

The wind maps for ThiQar metrological station is shown in figure (6). This feature is an important to have the wind resource grid for the selected area. This figure represents the location of each sector that has a specific amount of wind speed. The map shown in this figure illustrated the value of mean wind speed at 70m height.

By providing WAsP a power curve of V82 (1.65 MW) turbine, it will be an accurate result to calculate annual energy production (AEP). For more information about V82, see [7]. The mean wind speed can be calculated with respect to the frequency of counting exact value of wind speed. Table (2) represents the mean wind speed and power density and AEP that were calculated at 70 m (hub height), for a ten proposed sites, the selected sites chosen to cover as much as they can.

Figure (7) illustrated the turbine site that has been selected to evaluate the AEP at these sites. Figure (8) represents the wind speed map calculated through applying IDW interpolation technique on the ten (10) turbine sites points. The figure shows the average amount of wind speed for the entire area. This result gives us a very close view to the variance of wind power from site to site in this region.

The calculated area for the classes in figure (8) can be summarize in table (3).

Conclusions

The wind farm that has been proposed at ThiQar province – Iraq, could be very promised area to establish it. The total area that has been studied 20x20km^2 and divided into a regions that have certain value of power. The design of wind farm depends on the proposed distance between on turbine and another which varies between 3 to 10 times of rotor diameter. If we take the least number of turbines to be planted in this farm will be 800m spacing between turbines horizontally and vertically. This area could have about 600 turbines and will generate roughly about 2500 GWh.

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Table (1) ThiQar regional wind climate

Sector		Wind climate				Power	Quality	
Number	**angle**	**frequency**	**Weibull -A[m/s]**	**Weibull -k**	**Mean speed [m/s]**	**Power density[w/m²]**	**Speed discrepancy**	**quality**
1	0	22.0	3.1	1.47	2.77	37	-5.537%	4.004 %
2	30	3.1	4.1	2.04	3.59	53	-0.647%	1.240 %
3	60	2.3	4.2	1.91	3.69	62	-0.744%	1.562 %
4	90	4.2	5.1	2.41	4.48	89	-0.087%	1.482 %
5	120	5.5	6.3	2.03	5.61	204	0.427%	1.373 %
6	150	3.1	5.9	1.63	5.27	216	-1.194%	1.563 %
7	180	1.2	4.6	1.44	4.20	131	-4.648%	3.606 %
8	210	1.3	3.8	1.24	3.51	100	-4.677%	3.007 %
9	240	2.3	2.9	1.34	2.68	39	-3.672%	3.451 %
10	270	9.0	4.0	1.81	3.53	57	-0.207%	1.530 %
11	300	26.2	5.0	1.77	4.46	118	-2.164%	1.872 %
12	330	19.7	6.0	2.0	5.31	176	-1.205%	1.015 %
All fitied			4.6	1.60	4.13	107	-2.687%	1.649 %
Source data					4.12	104		

Table (2) Mean speed, Power density and AEP for the wind farm

Turbine Site	Easting (m)	Northen (m)	Mean speed (m/s)	P. D. (W/m2)	AEP (GWh)
site 1	602231.9	3424747	6.220	290	4.300
site 2	5933322.9	3431994	6.230	290	4.304
site 3	607292.4	3414870	6.230	290	4.306
site 4	593831.5	3416113	6.230	291	4.306
site5	602951.1	3432407	6.230	290	4.300
site 6	594212.8	3425359	6.220	290	4.300
site 7	607877.7	3428190	6.220	290	4.300
site 8	602303.8	3419137	6.230	291	4.306
site 9	602303.8	3416080	6.230	291	4.306
site 10	608093.4	3432659	6.230	290	4.300

Table (3) Geostatistical analysis

Classes	Area m^2	Percentage of the total area
0	37075852.10	8.65
1	62710883.55	14.64
2	47751904.22	11.15
3	36607434.79	8.55
4	33914872.83	7.92
5	35386168.28	8.26
6	41365580.64	9.66
7	49055020.22	11.45
8	44279210.84	10.34
9	40229548.44	9.39

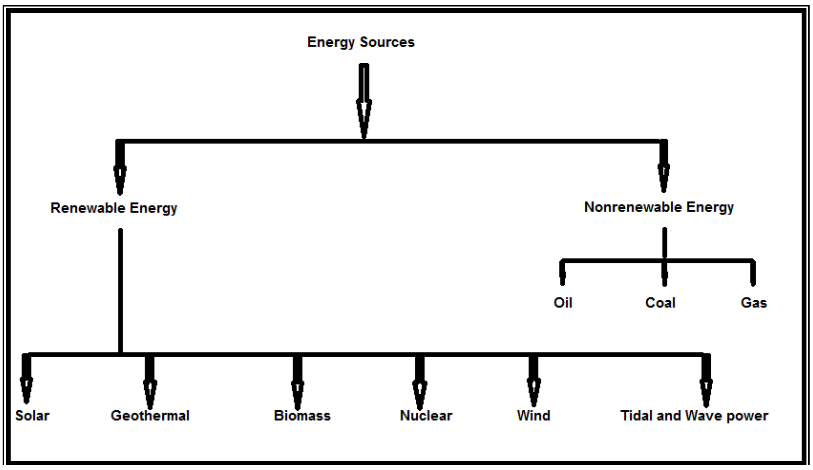

Figure (1) Types of Energy Sources

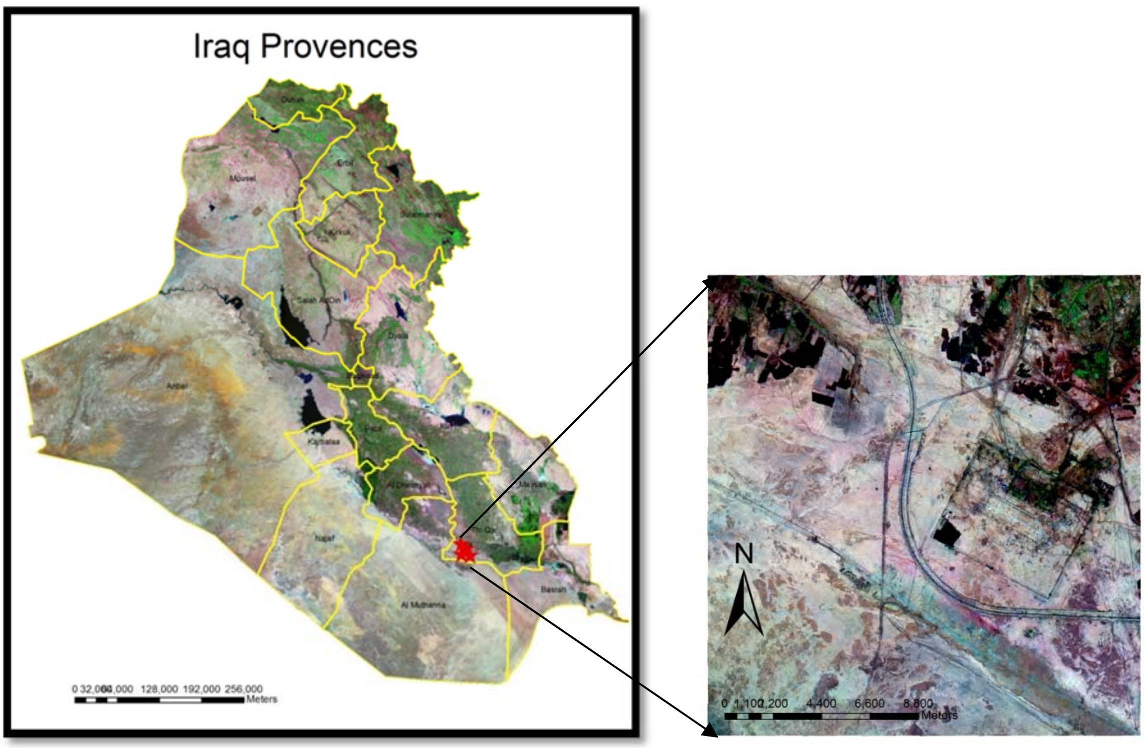

Figure (2) Studied area – ThiQar province

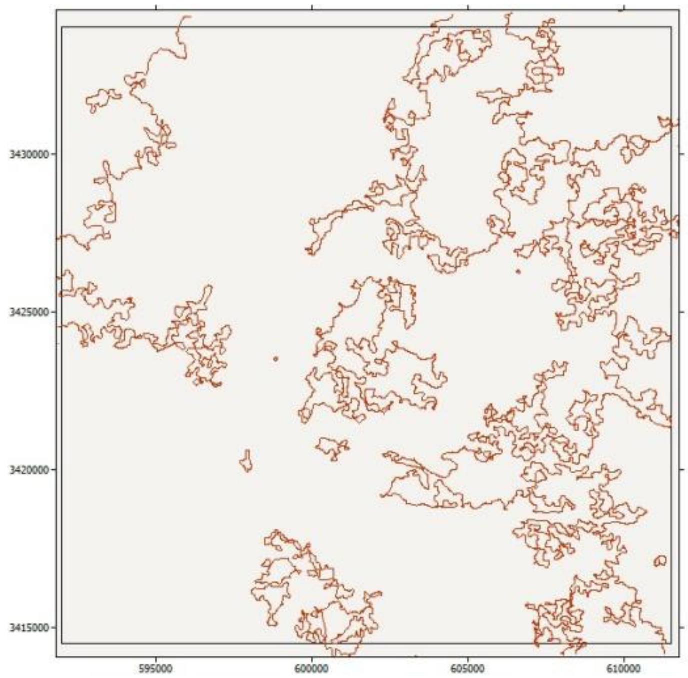

Figure (3) Contour maps for the studied area

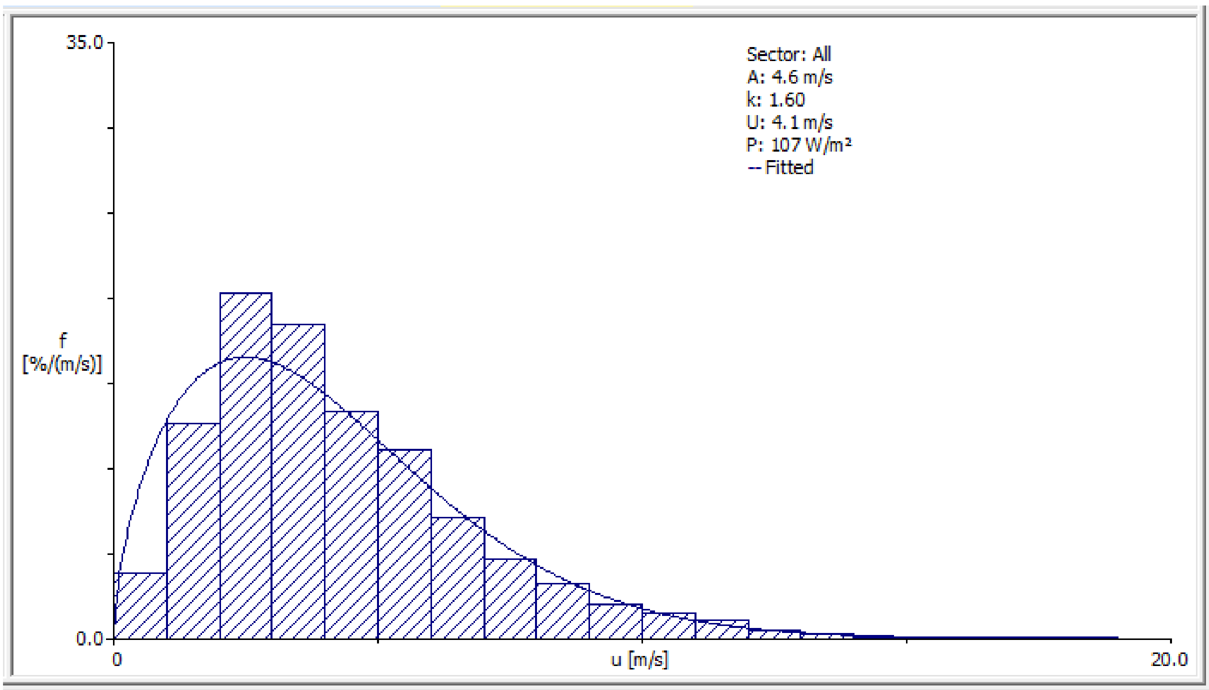

Figure (4) Observed wind climate at ThiQar

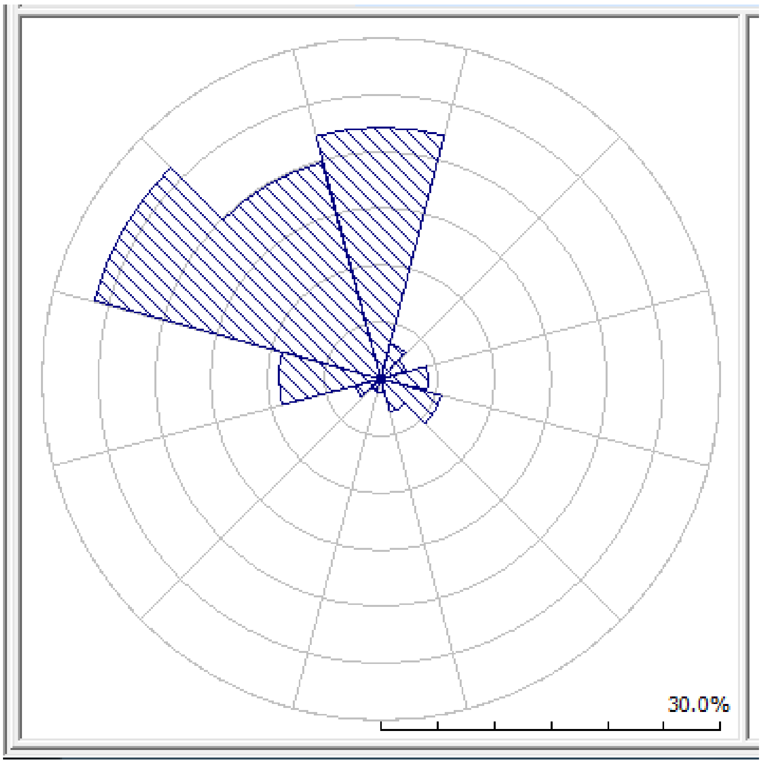

Figure (5) Wind rose

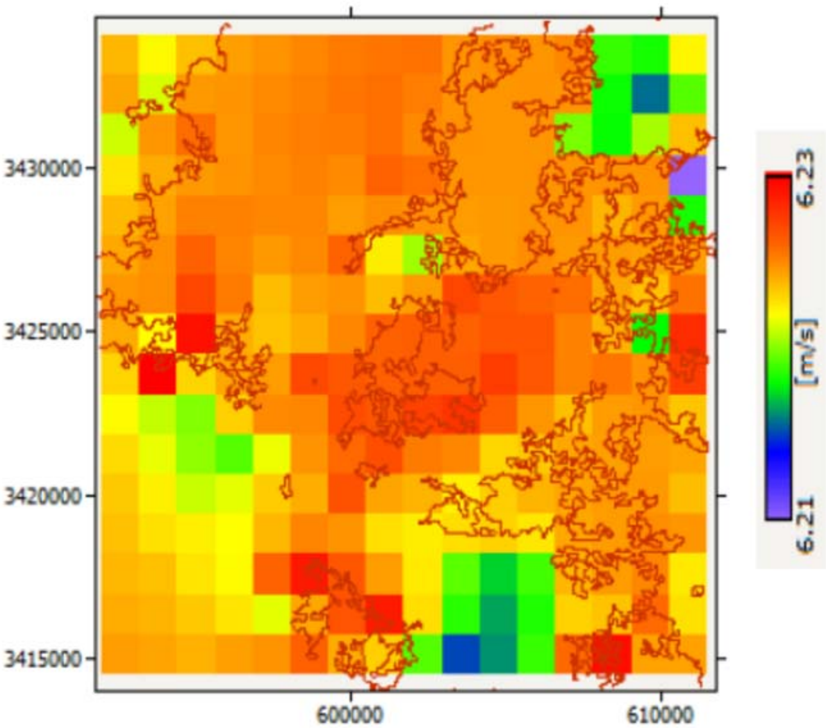

Figure (6) Mean wind speed map at ThiQar Site

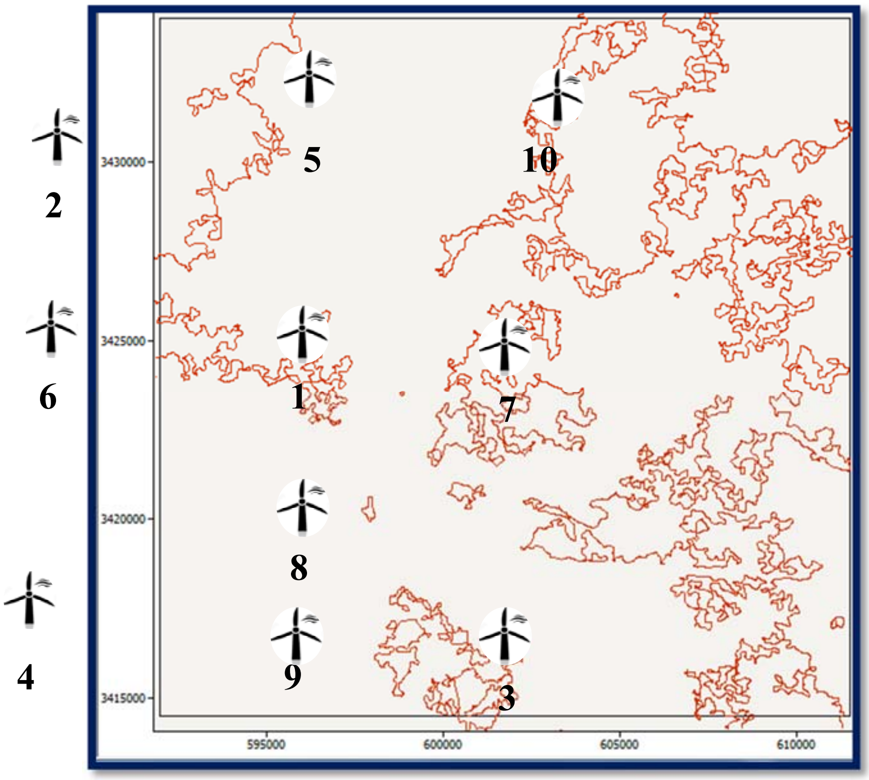

Figure (7) The selected turbines sites

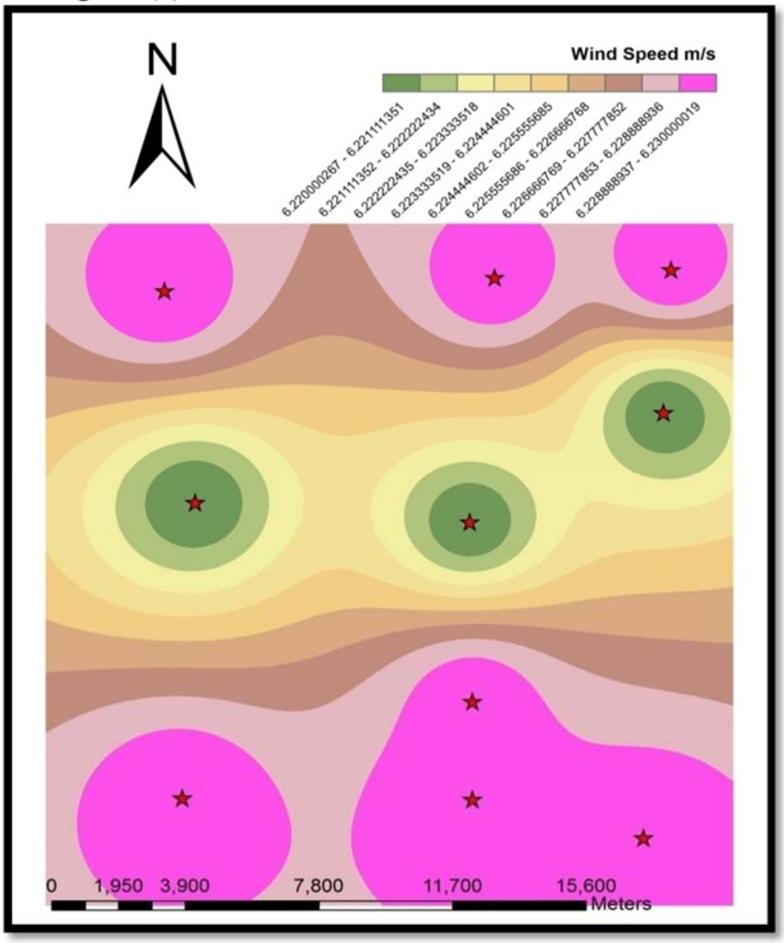

Figure (8) Interpolated wind speed map

تقدير الطاقة الكهربائية المنتجة من طاقة الرياح بواسطة V82 في ذي قار-العراق

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الخلاصة

واحدة من اكثر الدراسات المطلوبة هي انشاء محطات توربينات الرياح . ان بناء برنامج المحاكاة يعد من البرامج الصعبة نظرا لكثرة المتغيرات التي تؤثر في سرعة واتجاه الرياح. ان خطوات هذا البحث تعتمد على طريقتين هي تحليل نموذج اطلس الرياح وطريقة استيفاء IDW. هذه الخطوات سوف تحسب الانتاج السنوي للطاقة الكهربائية لتوربين (V82) وبقطر رئيسي (82m) وبارتفاع (70m). ان الانتاج السنوي لكل توربين في هذه المنطقة بحدود (4.3GWh). ان المنطقة المدروسة بحدود $20*20\ Km^2$ ويمكن وضع 600 توربين على الاقل التي تنتج (2500GWh) كانتاج سنوي.

الكلمات المفتاحية: طاقة الرياح, WAsP, GIS