Energy Cartography of the Wind Resource in the City of Faya and Application to Water Pumping

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Abstract: The objective of this work is to map the wind energy resource of the city of Faya, as well as the evaluation of the annual energy produced at an altitude of 80 m by the simulation of the wind data using the wind speed data collected by the Faya Airport weather station and available for five years. In this perspective, we begin with the description of the site, the determination of the various wind parameters, such as the mathematical modeling of the wind frequency distribution: Weibull distribution and the numerical simulation of the real wind data collected during five years to provide predictions on a site in the city of Faya. Then, we estimate its wind potential, its prediction of the electric energy produced and we proceed to an analysis of the turbulence of the wind while relying on the taking into account of the obstacles surrounding near the mast of measurement of the airport of Faya, the topography, the roughness of the site, the density and a judicious choice of wind turbines. The installation of a wind farm of 4 wind turbines Vestas V80 / 1.8 MW at a height of 80 m would produce 4,647 GWh of energy and the monthly amount of water has 1322 m^3 and 2069 m^3 for the rotor -pump-dynamic.

Key-Words: - Wind Turbine - Energy Conversion - Numerical Simulation – Data SRTM-Water Pumping-Faya

1 Introduction

The production of fossil fuels contribute to the degradation of the environment, and its fossil fuels have an indefinite lifespan and this leads to what is called the climate change that the world is experiencing today constitute a very large challenge that all countries face. In this regard, scientists have drawn attention to renewable energy sources (solar, wind, geothermal and biomass) that represent a real opportunity for a clean and environmentally friendly future (Dahmouni, 2011).

Of all renewable energy sources, wind energy is the oldest. It has been exploited by man since antiquity. On the Nile River, wind energy has been used to advance sailing boats, in China as in the Middle East for pumping water and irrigation, in Iran and Afghanistan in grinding cereals (Ilkılıç, 2011)

The negative effects of fossil fuels on the environment have led scientists to consider the possibility of using renewable energies for electricity production. Among these many own resources, there is wind energy, which has grown very rapidly over the past two decades. In fact, great technological progress has been made, which has reduced the cost of producing electricity from wind. Today, the share of renewable energy accounts for only about 20.2% of global electricity production (EDF, 2012).

Due to pollution and greenhouse gases, wind energy, which is a reliable and promising renewable energy, has attracted increasing attention due to their almost inexhaustible and non-polluting characteristics (Omer, 2008, Li and Li, 2005). The conversion of wind power to power generation or pumping has thus helped to reabsorb a number of problems of African populations.
The main objective of this paper is to evaluate the available wind resource in the city of Faya and apply to pumping to contribute to the development of the exploitation of national energy resources.

2 Description of the Study Area

2.1 Geographical Data

Originally called Faya, the city was renamed Largeau during colonization, after the name of Colonel Étienne Largeau. When Chad regained independence, the city took the name of Faya-Largeau.
Faya-Largeau enjoys a warm desert climate (Köppen BWh classification) markedly accentuated typical of Borkou, Chadian region located in the hyper-arid Saharan zone in the heart of the largest hot desert in the world. The warmest months are December and January with average maximum temperatures between 28 ° C and 29 ° C. The sky is perfectly clear in this extremely dry region. It is one of the hottest, driest, driest and sunniest regions in the world. Potential evaporation attains a global maximum: it is recorded between 6.000 mm and 7.000 mm per year at Faya-Largeau, a power evaporating air nearly four hundred times higher than the average annual rainfall received.

The meteorological station is located at the airport of Faya whose geographical coordinates of the measuring mast of the wind data are: longitude 19 ° 06 '.39"E and latitude 17 ° 55'01"N.

Fig. 1: Location of the study area

3 Materials and Methods

3.1 Materials

3.1.1. Golden Software

According to Golden Software is a powerful tool for contouring, grid and surface mapping for scientists, engineers, educators or anyone who needs to generate maps quickly and easily. Virtually every aspect of your cards can be customized to produce exactly the presentation you want.
Golden software specializes in the development of topographic maps. The latter has a grid-based mapping program that interpolates irregularly spaced XYZ data into a regularly spaced grid.
in the topographic map in 2D and 3D we observe the difference between the lowest point and the highest point of the relief does not exceed 150 m. One can think that relief of the site is relatively flat.

3.1.2 WAsP

WAsP (Wind Atlas Analysis and Application Program) is a computer program developed by the Department of Wind Energy of the Technical University of Denmark. For vertical and horizontal extrapolation of wind climate statistics. It is commercial software for wind data analysis, wind atlas generation, wind climate estimation, wind energy production calculations and wind turbine location. Predictions are based on wind data measured at stations in the same area. The program includes a complex land-flow model, a roughness change model and an obstacle shelter model.
Using a wind atlas dataset, the program can estimate the wind climate at any point and at any height by performing the inverse calculation as it is used to generate an atlas. The wind. By introducing field descriptions around the predicted site, the models can predict the expected real wind at this site, the average annual energy output of a wind turbine by providing its power curve, estimate wake losses for each turbine on a farm, the annual net energy production of each wind turbine and the entire farm

3.1.3 Data SRTM

The SRTM data is the result of a collaborative effort between NASA (National Administration of Space and Aeronautics) and NGA (National Geospatial Intelligence Agency - previously known as the National Agency for Imaging and Cartography, or NIMA). Together, they produced a digital terrain model of the global surface of the planet. This digital terrain model (NASA SRTM) has a resolution of 90 meters, and is available for free access since 2013. It is this SRTM file that will be used later to model and simulate the influence of obstacles and roughness on the speed and movement of the wind.

Fig. 2: SRTM image of a digital terrain model [The Shuttle Radar Topography Mission (SRTM) User Guide Collection, 2015]

3.2 Mathematical Modeling

3.2.1 Modeling of the Distribution of Frequencies of the Wind

3.2.2 The Weibull Distribution

The Weibull distribution is a special case of the Pearson distribution (Sathyajith, 2012). In this distribution, variations in wind speed are characterized by two features: the probability density function and the cumulative distribution function.

The probability density function f(v) indicates the fraction of time (or probability) for which the wind has given velocity *v*.

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

With K the form factor (without unit) and C the scale factor (m/s). The cumulative distribution function of the velocity v or Weibull cumulative distribution function F (v) gives the fraction of time (or the probability) for which the wind speed is less than or equal to *v*.

$$F(V) = \int_0^{\infty} f\,(v)\;dv = 1 - \;exp\left[-\left(\frac{v}{c}\right)^{k}\right] \qquad (2)$$

The average wind speed according to the Weibull distribution is calculated by the following formula:

$$V_m = \int_0^{\infty} v\, \times f\,(v)\; dv \qquad (3)$$

The distribution of Weibull proves to be suitable for the description of the statistical properties of the wind (Faida, 2010 ; Seguro, 2000).

3.2.3 Estimates of Weibull Parameters

There are several methods for determining the parameters K and C from the wind data of a site. The most common are: the graphic method, method of moment, maximum likelihood method, the modified maximum likelihood method and the standard deviation method (Sathyajith, 2011; Sathyajith, 2006; Seguro, 2000). Since wind data are available in the format of frequency distribution, the recommended method is the modified maximum likelihood method (Seguro, 2000). Weibull parameters are determined using equations (4) and (5):

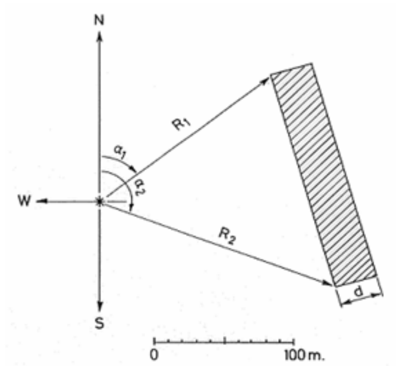
$$K = \left(\frac{\sum_{i=1}^{n} V_i^k \times Ln(v_i) \times f(v_i)}{\sum_{i=1}^{n} V_i^k \times f(v_i)} - \frac{\sum_{i=1}^{n} Ln(v_i) \times f(v_i)}{F(v \geq 0)}\right)^{-1} \qquad (4)$$

$$C = \left(\frac{1}{F(v \geq 0)} \times \sum_{i=1}^{n} V_i^k \times f(v_i)\right)^{1/k} \qquad (5)$$

Where Vi is the midpoint of the interval of speeds i, n the number of intervals, f (Vi) the frequency for which the wind speed falls in the interval i, F (v = 0) the probability that the wind speed is greater than or equal to zero. Equation (4) is solved numerically by successive iterations until the convergence of the value of K using a code written in FORTRAN 90. The computations are initialized with K = 2. After convergence, equation (5) is then explicitly resolved using the value of K to find that of C.

3.3 Modeling of an Obstacle

Near an obstacle, such as a building, the wind is strongly influenced. The mast of the anemometer to the airport is surrounded by buildings and trees, which influences thedata-gathering.The exploitation of those requires taking into account the various obstacles of the site. We model the obstacle as follows:



For an observer located at the position of the anemometer and watching a given obstacle, we have:

- ❖ α_1, angle en (°) between the geographical north and the first corner;
- ❖ R1, radial distance (m) to the first corner;
- ❖ α2, angle en (°) between the geographical north and the second corner;

- R2: radiale distance (m) to the second corner;
- h, height of the obstacle in (m);
- d, depth of the obstacle in (m);
- P, estimates of the porosity of the obstacle...

Number located between (0 -0.1 -0.2 - -0.9 -1).

Roughness intuitively defines obstacles seen from a distance, or a set of very small obstacles considered at wind scale. Data covering this concept of roughness are empirical and there is no sufficiently precise formula to represent all the moving and lively variety of grass, trees growing and cities built (Dubois, 2009 ; Tieleman, 2003).

The roughness of land is often parameterized by a length scale called Zo roughness length. A simple empirical relation between the elements of roughness and roughness length was formulated by Lettau (1969).

$$Z_0 = 0.5\,(h \times S) / A_H \qquad (6)$$

Where h is the height of the roughness element (m), S, its cross-section facing he wind (m^2) and A_H ,the average horizontal surface (m^2) defining the distribution of roughness elements.

3.4 Density of Wind Energy

The available power in a wind flow of velocity v is obtained from the relation:

$$P = \frac{1}{2}\rho \times A \times V^3 \qquad (7)$$

Where ρ is the air density (kg/m^3), and A, the scanned surface (m2) of the blade of the wind turbine. Expressing this power per area unit, we have:

$$P_v = \frac{1}{2}\rho \times V^3 \qquad (8)$$

The time fraction for which this velocity v prevailing in the system is given by the probability distribution function f (v). Thus, the energy contributed by v, per time unit and per area unit,

$\boldsymbol{P_v \times f(v)}$. So the total energy contributed by all possible speeds in the wind regime, available by area unit and time unit (Energy Density ED) can be expressed as follows (Sathyajith, 2011 ; Meishen, 2005 Jamil, 1995).

$$E_D = \int_0^{\infty} P_v \times f(v) \times d_v \qquad (9)$$

3.4 Statistical Data Processing

a- Calculating the arithmetic velocity mean

$$\overline{V} = \frac{1}{n} \times \sum_{i=1}^{n} v_i \qquad (10)$$

b- Calculating arithmetic weighted velocity mean

$$\langle P \rangle = \sum_{i=1}^{n} v_i \times (v_i) \qquad (11)$$

c- Calculating of the average power per area unit (energy density)

$$\langle P \rangle = \frac{\sum_{i=1}^{n} P(v_i) \times f(v_i)}{\sum_{i=1}^{n} f(v_i)}; \quad P(v_i) = \frac{1}{2} \times \rho \times v_i^3 \quad \text{alors}$$

$$\langle P \rangle = \frac{1}{2} \times \frac{\sum_{i=1}^{n} v_i^3 \times f(v_i)}{\sum_{i=1}^{n} f(v_i)} \qquad (12)$$

3.5 Extrapolation of Weibull Parameters

Most modern wind turbines have hub heights considerably higher than measurement heights of meteorological towers. Hence, the measured wind characteristics at the lower measurement height must be extrapolated to the hub height of the turbine. For this task we choose the use of the Justus and Mikhail law (Boudia, 2013; Ohunakin, 2012; Justus, 1976). The values of Weibull's parameters (k_h and C_h) are then evaluated at any desired height (Zh) by the following equations (13) and (14):

$$k_h = k_a \left[1 - 0.0881 Ln\left(\frac{Z_h}{10}\right)\right]^{-1} \qquad (13)$$

$$C_h = C_a \left(\frac{Z_h}{Z_a}\right)^n \qquad (14)$$

$$n = 0.37 - 0.0881 Ln C_a \qquad (15)$$

3.6 Estimated pumped flow

According to the paper (Mathew and Pandey, 2003), the discharge of an ideal roto-dynamic pump at any speed V can be estimated by using the equation (16) below:

$$Q_R = T \int_{vi}^{vo} Q(v)\, f(v)\, dv \qquad (16)$$

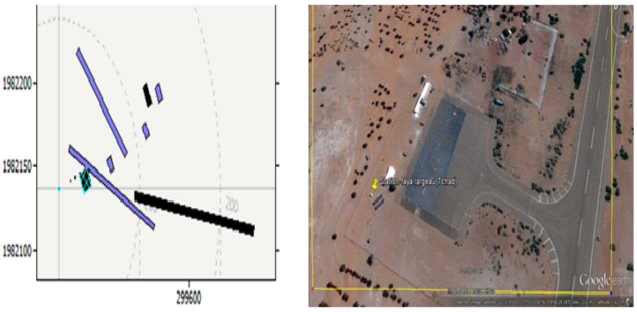
$$Q_R = \frac{1}{8} K C_{pd}\, \eta_{pd}\, D_T \frac{\rho_a}{\rho_w} \frac{V_d^2}{gH} \frac{G\lambda_d}{N_{pd}}\, T \int_{vi}^{vo} \left(\frac{V}{C}\right)^k \exp\left[-\left(\frac{V}{C}\right)^k\right] dV \qquad (17)$$

The integrated output of the roto-dynamic pump is then estimated by the computation of equation

4 Results and Discussion

4.1 Modeling Obstacles of the Site of Collection

Some of the major obstacles on Faya airport site were modeled using the software WAsP (Wind Atlas Analysis and Application Program) in order to take into account their influences on data collection. Buildings are in black and trees in blue.



1- Modeled obstacles **2- Aerial view of the site**

Fig. 3: Obstacles surrounding the data collection site

4.2 Wind Potential of the Airport Site at the Height of Measurement

The wind speed measurements were grouped in intervals and associated with their frequencies on the site. This mode of representation gives us information on the number of hours for which the speed is within a specific range. Those of the Faya Airport site are presented in Table 1.

Table 1: Frequency distribution of wind speed (m/s)

vitesses	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
frequencies	6,4	2,2	9,7	15,6	14,6	13	10,8	8,2	5,4	4,1
Vitesses	10-11	11-12	12-13	13-14	14-15	15-16	16-17	-	-	-
frequencies	3,1	1,4	1,5	1,3	1,1	1	0,4	-	-	-

The Weibull parameters for this distribution are: C = 6.2 m / s and k = 1.69. The wind rose shows the distribution of wind attendance according to the direction on the site. It allows us to know the direction of the prevailing wind. Atmospheric circulation at ground level is primarily driven by north-northeast wind.

Since these parameters are known, it is possible to represent on the same graph the probability density function and the frequency histogram of the speed.

The annual balance of this frequency distribution of the wind speed gives the following information:

From the statistics of the measures of the site
– Maximum wind speed on the site = 22m/s
– Annual speed = 6.2 m/s

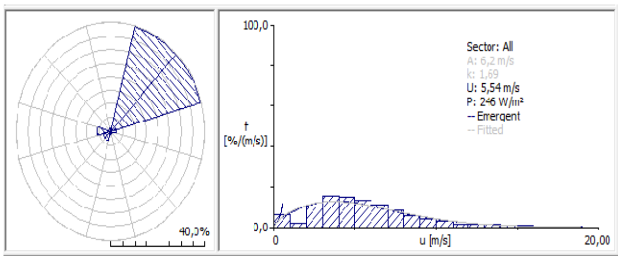


Fig.4: Frequency histogram and wind rose of wind speeds modeled with Weibull distribution

From Weibull distribution.
- Mean velocity = 5.54 m/s
- Density of energy = 246 W/m²

4.3 Probability Density Function

Equation (1) describes the parameters of the Weibull probability density function of wind speed; they follow the shape of a 1/2 Gaussian and are the same as those of the CDF. The red curve represents the PDF and the blue histogram represents the data.

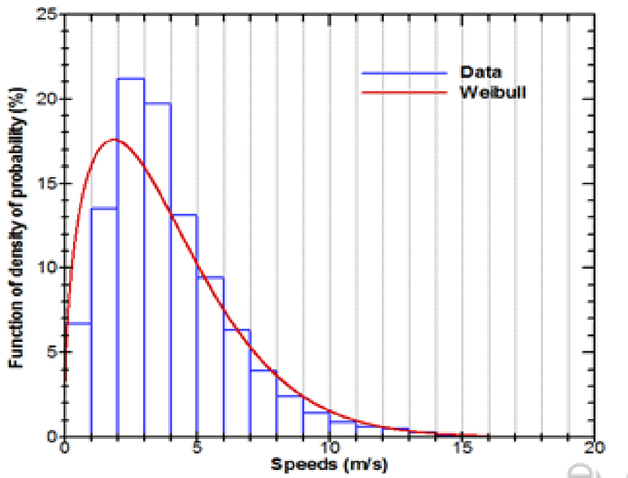


Fig. 5: Histogram of wind speed frequencies modelled by the distribution of Weibull.

4.4 Cumulative Distribution Function

Parameters of the cumulative distribution function (CDF) of wind speed are the same as those used for the PDF. The curve represents the CDF while the histogram represents the data. Another observation shows a similarity between the evolution of the histogram and the shape of the CDF curve.

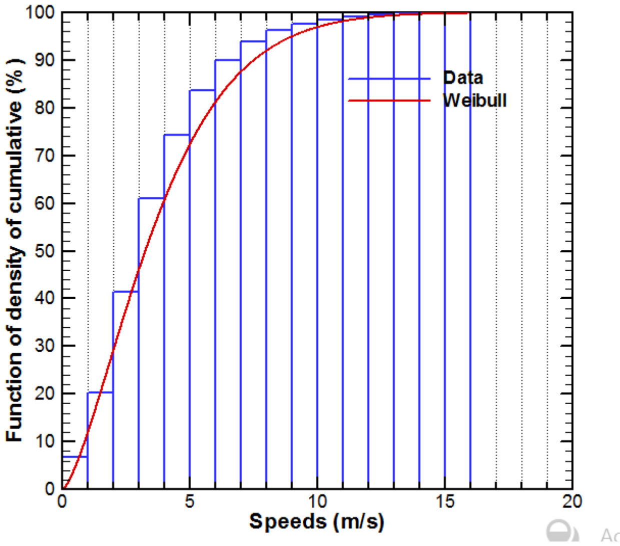


Fig. 6**:** Histogram of cumulative frequencies of wind speed modeled by the distribution of Weibull.

4.5. Wind Atlas of the City of Faya

Wind characteristics are specified for a number of roughness classes chosen as reference, and heights taken with respect to ground level. These characteristics are independent of the location and therefore describe the wind behavior all over the site.

The wind atlas contains data for 5 reference roughness lengths (0.000 m, 0.030 m, 0.100 m, 0.400 m, 1.500 m) and 5 reference heights (10 m, 25 m, 50 m, 100 m, 200 m) above ground level.

Table 2: Atlas éolien.

Height	Parameter	R-Class 0 0,000 m	R-Class 1 0,030 m	R-Class 2 0,100 m	R-Class 3 0,400 m	R-Class 4 1,500 m
Hauteur 1 Z = 10 m	A (m/s)	15,85	11,64	10,14	7,96	5,29
	K	1,59	1,56	1,58	1,59	1,60
	U (m/s)	14,22	10,46	9,11	7,14	4,74
	P (W/m²)	4415	1793	1167	558	161
Hauteur 2 Z = 25 m	A (m/s)	17,21	13,54	12,21	10,27	7,86
	K	1,59	1,58	1,59	1,60	1,62
	U (m/s)	15,44	12,15	10,95	9,20	7,04
	P (W/m²)	5632	2772	2009	1180	524
Hauteur 3 Z = 50 m	A (m/s)	18,26	15,02	13,81	12,04	9,84
	K	1,60	1,60	1,61	1,62	1,63
	U (m/s)	16,38	13,47	12,38	10,78	8,81
	P (W/m²)	6674	3727	2864	1882	1015
Hauteur 4 Z = 100 m	A (m/s)	19,34	16,60	15,50	13,88	11,86
	K	1,61	1,63	1,63	1,64	1,65
	U (m/s)	17,34	14,86	13,87	12,41	10,61
	P (W/m²)	7865	4862	3936	2806	1740
Hauteur 5 Z = 200 m	A (m/s)	20,46	18,34	17,31	15,82	7,17
	K	1,61	1,67	1,68	1,68	5,42
	U (m/s)	18,34	16,38	15,46	14,13	13,54
	P (W/m²)	9311	6315	5275	4011	6439

Legends:

R-class 0: represents the surface of the water

R-class 1: the surface of the field quite little building or tree

R-class 2: territory of the land with a close appearance

R-class 3: represents a small void or territory with several broken winds

R-class 4: a big void with tall buildings

4.6 Extrapolation of Wind Speed at 80 m Height

The mast of the selected wind mill has a height of 80 m who is the height of implantation of aero-generator. This height is greater than that of the mast used for data collection (10 m). The vertical extrapolation of wind speed measurement of 10 m to the axis of rotation of the wind turbine becomes imperative, and consequently causes a variation of the wind distribution mode. The characteristics of the wind climate are summarized in the figure below. For all sectors of this site, the average wind speed Vm = 16.36 m /s with an energy density E_D = 6564W / m².

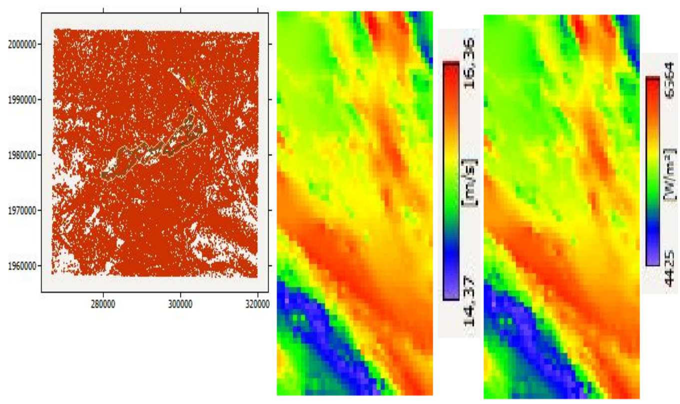


Fig. 7: Extrapolation of wind Speed and energy density

Table 3: Energy density

Maximum Value:	**6564 W/m² at (303863, 1995208)**
Minimum Value:	4425 W/m² at (301763, 1990408)
Mean Value:	5645 W/m²

4.9 Turbulence Analysis

The average variations over the year are sometimes used to define the wind or the winds (sometimes quite different) that visit the site regularly. This measure also allows to see, according to what one wishes to make of the production of electricity, and with other forms of electric production of the wind turbines, if this production is, on average, in phase or not with the consumers of electricity, and with other forms of electricity generation. These variations could be partly explained by the change in roughness due to the alternation of seasons.
The study of the monthly variations makes it possible to know if there will be a continuity of service (permanent electricity production) at the level of the station. This variation in wind speed shows two (2) peaks in February and March. These months are expected to be the most productive in terms of energy.

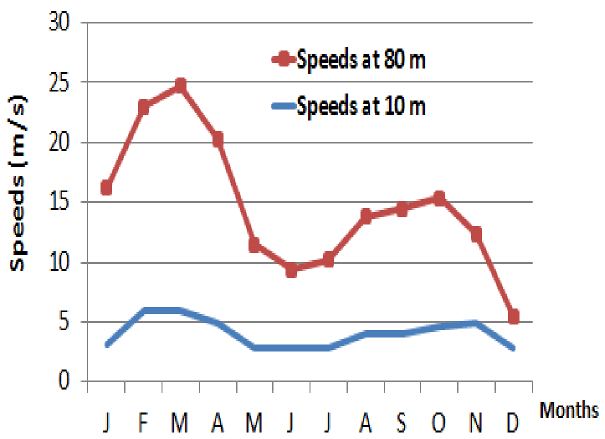


Fig. 8: Average speed variations over the year

4.10 Topographic Map in 2D and 3D of Faya city

According to the topographic map in 2D and 3D we observe that the gap between the lowest point and the highest relief does not exceed 150 m; this may indicate that the site is a relatively flat terrain.

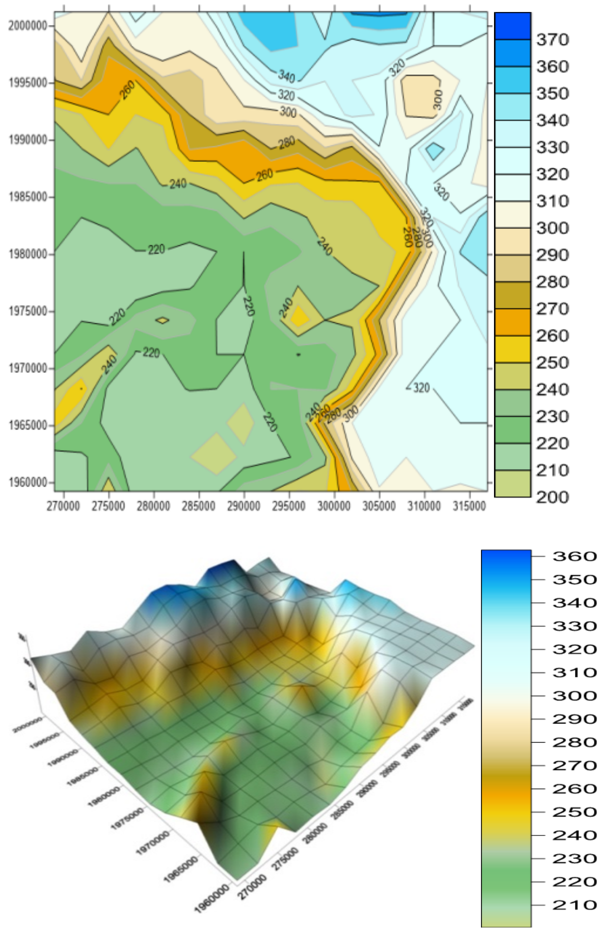


Fig. 9: Topographic in 2D and 3D of Faya city

4.11 Annual Wind Map in Faya

One notices in this topographic chart three dominant colors:

- The red zone, which represents the zone having the strongest potential wind mill with a speed of 15,8 m/for latitude de 199100 m and a longitude of 304000m;
- The green zone represents the average zone speed;
- The red zone, which represents the zone having the strongest potential wind mill with a speed of 17,4 m/s for latitude of 1993000 m and a longitude of 305000m.

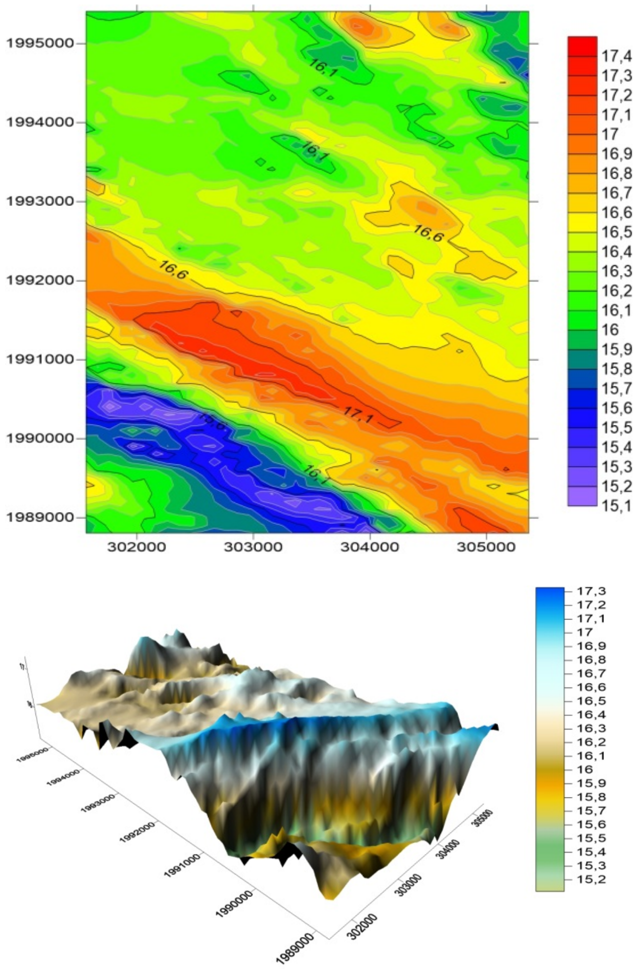
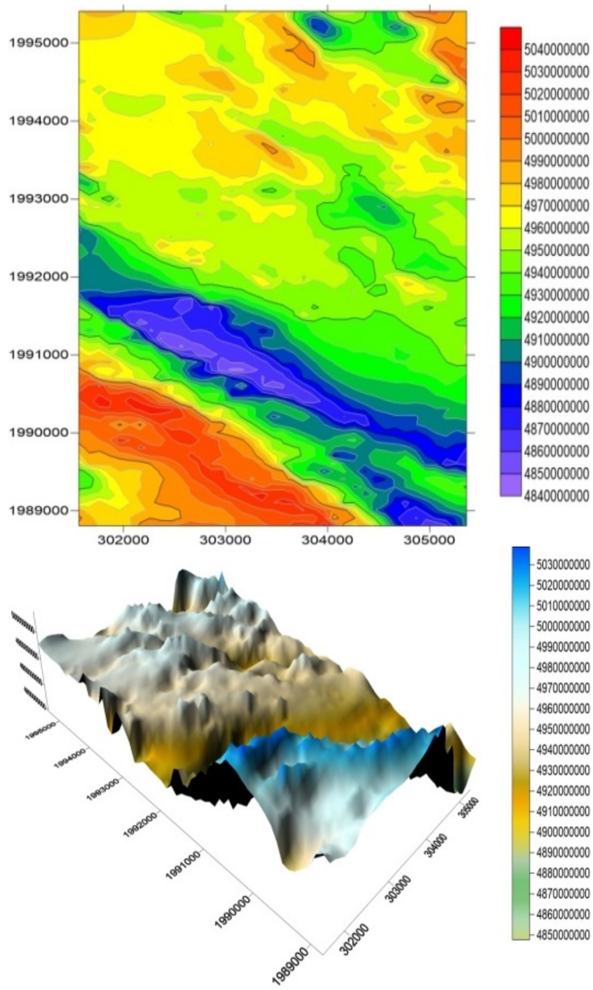


Fig. 10: Annual wind map of the city of Faya

4.12 The Predicted Annual Wind Energy Production in Faya

We note in this topographic map three dominant colors:

- The blue zone, which represents the area where the wind energy potential is the lowest of energy with a power of 491GWh for a latitude of 1992000 m and a longitude of 305000 m
- The blue zone, which represents the area where the wind energy potential is the highest of a power of 491GWh for a latitude of 1992000 and a longitude of 305000 m
- The red zone represents the zone with the highest wind power potential with a power of 504GWh for a latitude of 504000 m and a longitude of 1344000m



AEP (GWh)

Fig. 11: Annual wind power production in Faya

4.13 Choice of the Aerogenerator

The production power of a wind turbine varies with the wind on the rotor. Indeed, the power output curve increases with wind speed. The choice of a wind turbine relies on criteria such as: boot speed, mast height, the maximum power output and the air density. The wind turbine, which we chose for our site, is the Vestas V80 model builder.

Table 4: Vestas V80 wind turbine features

Charateristics	Specifications
Boot speed	4m/S
Mast height	80 m
Diameter of rotor	30 m
Maximum power	1,8 M
Density	1,139 kg/m3
Manufacturer	Vestas.Wind.system

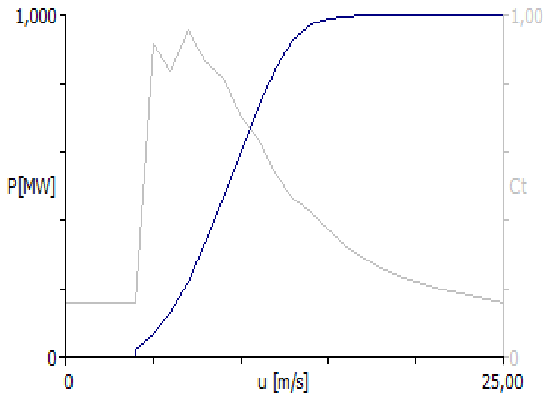


Fig. 12: Power curve of the Vestas V80 wind turbine

4.14 An Estimate of Wind Power Production of a Wind Park at 80 m

Some wind turbines in the site of the city of Faya.

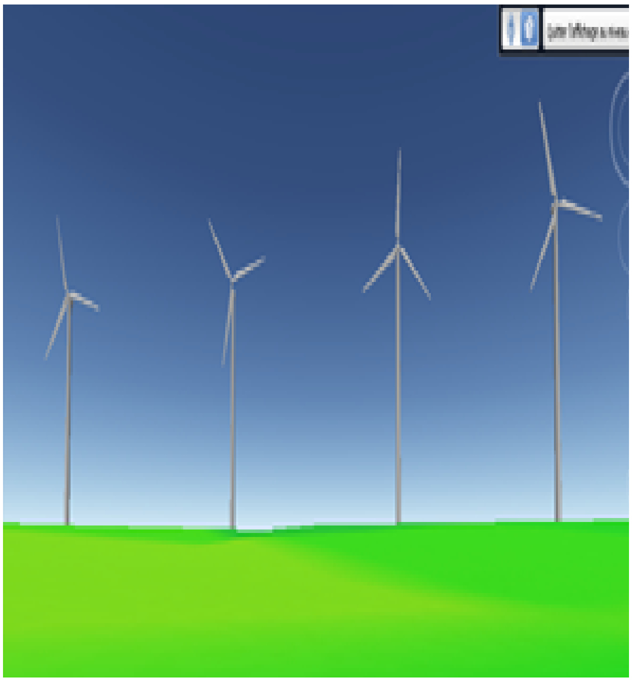


Fig. 13: Wind turbines on a site of the city of Faya

4.14.1 Coordinates for the Different Turbines for the Town of Faya

The table below gives the Coordinates of the different turbines for the city of Faya.

Table 5: Coordinates for the different turbines

These different turbines are in the north-northeast of the city of Faya

Site	Location [m]	Turbine	Elevation [m] a.s.l.	Height [m] a.g.l.	Net AEP [GWh]	Wake loss [%]
Turbine site 001	(303073,7, 1991164,0)	WTG 1 MW Faya	334,3797	80	4,647	0,57
Turbine site 002	(303170,8, 1991075,0)	WTG 1 MW Faya	334,5321	80	4,648	0,52
Turbine site 003	(303289,8, 1991000,0)	WTG 1 MW Faya	333,9218	80	4,653	0,39
Turbine site 004	(303005,0, 1991237,0)	WTG 1 MW Faya	334,1949	80	4,654	0,48

4.14.2 Annual Production of the Site

Table 6 shows the statistics of the overall characteristics of the park /year in the city of Faya and the different parameters of the annual energy production of the Faya site are given in Table 6 below.

Table 6: the overall statistical characteristics of the wind farm

Parameter	Total	Average	Minimum	Maximum
Net AEP [GWh]	18,603	4,651	4,647	4,654
Gross AEP [GWh]	18,695	4,674	4,671	4,677
Wake loss [%]	0,49	-	-	-

4.14 Application

In wind turbine water pumping systems, the latter is directly connected to the pump. The pump used is a rotor pump. These operating conditions cause the efficiency of the overall system to vary with the wind speed.

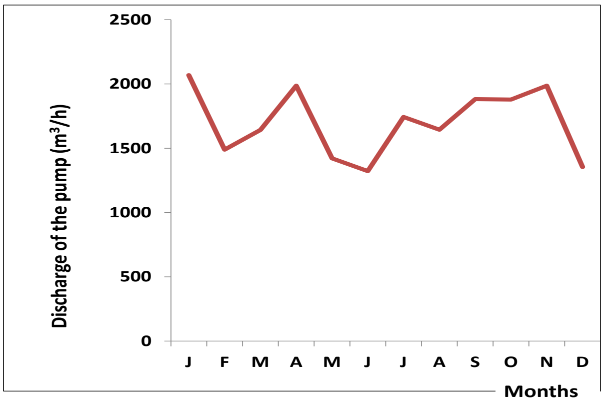


Fig. 14: Monthly water discharge of pump

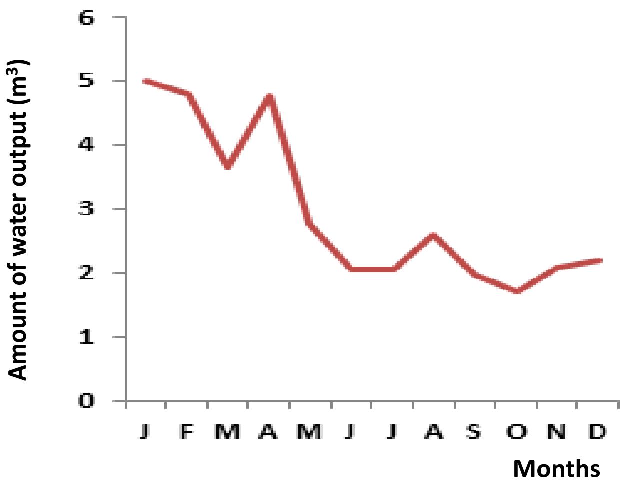


Fig. 15: Monthly water amount provided of pump

Results obtained from the computation (Eq.16 and Eq 17). It presents the monthly and annual volume flow rate and amount of water for the pump considered at the same height.

the maximum value of the volume flow rate is computed as 5.2 m^3/h in January and the minimum value is computed as 1.4 m^3/h in October. However, the monthly amount of water has maximum average value of 2069 m^3 in January while the minimum value is obtained as 1322 m^3 in December.

5 Conclusion and Perspectives

The work consisted of the modeling and numerical simulation of the wind data in order to map the evaluation of the wind potential and application to pumping in the city of Faya (Chad). The evaluation of the wind potential of the city of Faya, delimited by the latitudes 12 ° 07 '36 .24"N and the longitudes 15 ° 01'48.49 E, is carried out using the software WAsP and Golden Surfer.

The Weibull parameters characterizing the site are of the order of 6.2 m / s for the scale factor and 1.69 for the form factor, which means that the wind speed is variable at the site of the site. Faya Airport, the winds have predominance around the North-North-East direction according to the wind rose.

The wind resource of this site, 80 m high, has an average speed of 17.16 m / s and an energy density of 6564 W / m2. The monthly amount of water has 1322 m3 and 2069 m3 for the rotor -pump-dynamic. Underground water can be pumped using this power and it could be an initial solution for people living in remote areas. Although the data are collected 10 m above ground level, the installation of a wind farm of 4 Vestas V80 / 1.8 MW wind turbines at a height of 80 m, would produce 4.671GWh of energy.

In perspective, it will be question for us to take into account the estimate of the cost of a wind turbine.

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APPENDIX

Abbreviations:

V : Speed of the wind, m/s

C : Scale factor, m/s

Z_0 : Roughness length, m

Z : Measuring height, m

V_{max} : Maximum speed of the site, m/s

K : Curve form factor

n : Number of speed intervals, m/s

ρ : *Density of air*, Kg/m^3

h : Height of the roughness element, m

$f(V)$: Probability density function

$\bar{V}$: Average speed of wind speed, m/s

P_v : Puissance par unité de surface, W/m^2

λd : Design tip ratio;

Npd: *Pump speed at design point*

V : Speed of wind, m/s

VI: *Cut – in wind* , m/s

Vd: *Design wind velocity*, m/s

G: Gear ratio;

T: Time, h

$V0$: *Cut – out wind speed* , m/s

λd: : *Design wind velocity*, m/s

ρw : Water density, Kg/m^3

Q: Water flow rate, m3/h

$F(V)$: Cumulative distribution function of speed

$\langle V \rangle$: Average speed of the wind arithmetic, m/s

$\langle P \rangle$ = Density of wind energy obtained from measurements , W/m^2

S : Area of the cross section of the obstacle facing the wind, m^2

E_D : Density of wind energy calculated using distribution, W/m^2

A : Area of the swept surface of the wind turbine blade, m^2

V_m : Average wind speed using the weibull distribution, W/m^2

$R - classe$: *Roughness class, m*