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Electric Water Pumping Powered by a Wind Turbine in North East Chad

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Abstract: In Chad, the lack of drinking water is a real problem in the desert area. This paper focuses on the statistical assessment of water production using a wind source in North-Eastern Chad to serve the population. The statistical analysis method used for estimating wind power density is the Weibull distribution. Two sites were chosen for the study, namely Fada and Amdjarass. The data used is collected over eight years and two statistical tests were used to assess the convergence of the different distributions. Average wind speeds were calculated to assess the energy potential of the sites. At 10m from the ground, the average wind speeds obtained over eight (08) years are 6.11 m/s at Amdjarass with predominant winds from the North East and 5.43 m/s at Fada with predominant winds from the East. This makes the two localities with high wind potential in Chad. An electric water pumping technique was used for water quantity estimation by testing four (04) wind turbines. The GEVMP aerogenerator meets the needs of both sites. Installed on a 55m high mast, this two-blade aerogenerator can provide on average between 3778.3 m^3 of water/day to 1511.3 m^3 of water/day for a system ranging from 60m to 150m in head at Fada. This corresponds on average to 139.36l/d/pers (60m HMT) to 55.74l/d/pers (150m HMT). As in Amdjarass, the GEVMP aerogenerator can provide between 3986.3 m^3 of water/day to 1594.5 m^3 of water/day for a system ranging from 60m to 150m in head. This corresponds on average to 129.57l/d/pers (60m HMT) to 51.82l/d/pers (150m HMT).

Keywords: Wind, Energy, Pumping, Water

1. Introduction

Chad, a livestock country (93.8 million head of cattle) with a surface area of 1,284,000 km² and 17,414,717 inhabitants, is a landlocked Sahelian country in the heart of Africa [1, 2]. Consisting of three (03) climatic zones (Saharan, Sahelian and Sudanian) and an average temperature of 35°C, 60% of Chad's surface is desert [3]. It has significant water resources, 540 billion m³ of exploitable underground reserves, including 20 billion m³ renewable per year, unequally distributed [4]. Only 45.9% of people living in rural areas, which represent 78.1% of the population, have access to safe water [5]. According to the study on the rate of access to drinking water in Chad in 2017, Ennedi province is the least served by water points, with 8% and 4.2% of the population having access to drinking water in West Ennedi and East Ennedi respectively [4, 6].

In the context of environmental preservation and sustainable development, the exploitation of available renewable energies will make water available in quality and quantity, particularly in isolated sites.

In this study, whose objective is to produce water using a wind source, we first present the evaluation of the wind potential of the North-East zone of Chad using real data, then we apply to these data the types of wind generators available on the market to evaluate the quantity of water that can be produced per day in this zone.

2. Materials and Method

2.1. Data Collection and Location

Data provided by meteorological stations at Fada (17°11'N, 21°30'E) and Amdjarass (15°58'N, 22°46'E) airports. the measurements are made at 10m from the ground over a period of eight years, from January 2013 to December 2020. Figure 1 shows the map of the study area.

Excel allowed us to draw the curves and Wind Rose Excel V. 1.7 to plot wind roses.

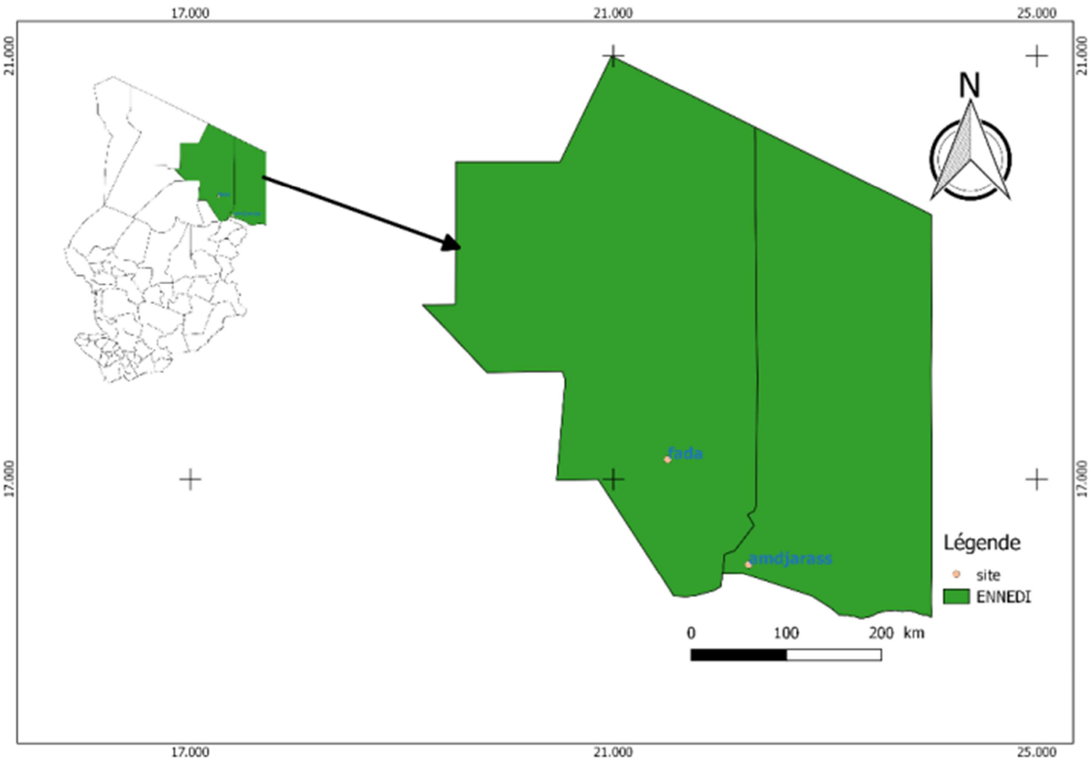


Figure 1. *Study area.*

2.2. Methods

2.2.1. Mean Wind Speed and Standard Deviation

The mean speed v_m and standard deviation σ of the Weibull distribution are given by [7, 8]:

$$\overline{v} = \frac{1}{N}\left(\sum_{i=1}^{N} v_i\right) \tag{1}$$

$$\sigma = \sqrt{\left[\frac{1}{N-1}\sum_{i=1}^{N}(v_i - \overline{v})^2\right]} \tag{2}$$

Where, v_m, mean wind speed, m/s; σ, standard deviation of the observed data, m/s; v_i, hourly wind speed, m/s; N, number of measured hourly wind speed data.

2.2.2. Wind Distribution Model

The model used is the Weibull distribution, which is still the correct method for statistical analysis of wind [9-11]. This model uses the probability density function as a useful tool to characterise the wind speed and power at a given location [12]. The same model can be used to evaluate monthly, annual and seasonal net energy production and performance of wind power systems [13]. The probability density function is given by [14, 15]:

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1}.exp\left(-\left(\frac{k}{c}\right)^{k}\right), (k \succ 0, v \succ 0\ c \succ 1) \tag{3}$$

The Weibull cumulative density function corresponding is given by the expression:

$$\mathrm{F(V)} = 1 - \exp\left[-\left(\frac{\mathrm{v}}{\mathrm{c}}\right)^{k}\right] \tag{4}$$

Where:

1. k and c are the Weibull parameters;
2. f(v) is the probability of observing wind speed v;
3. v is the wind speed (m/s);

The determination of the parameters k et and c allows the knowledge of the wind distribution for a given site.

The values of k vary according to the wind conditions. In the case where k=2, the Weibull distribution is called the Rayleigh distribution and is given by the simplified expression [16, 17]:

$$f(v) = \left(\frac{2v}{c^2}\right) exp\left(\left(-\frac{v}{c}\right)^2\right) \tag{5}$$

The determination of the parameters k and c gives the wind distribution for a given site.

2.2.3. Weibull Parameter Estimation Methods

(i). Wind Variability Method

This method estimates k, from the variability of the wind and the average wind speed [18, 19]:

$$k = \begin{cases} 1.05v^{0.5}\ if\ v < 3 \\ 0.94v^{0.5}\ if\ 3 < v < 4 \\ 1.05v^{0.5}\ if\ > 4 \end{cases} \quad (6)$$

C is always given by equation (7):

$$c = \frac{\bar{v}}{\Gamma\left(1+\frac{1}{k}\right)} \quad (7)$$

(ii). Moroccan Method

This method is proposed by Mabchour in 1999 [20-22]. k and c are given by:

$$k = 1 + \left(0.483(\bar{v} - 2)\right)^{0.51} \quad (8)$$

C is always given by equation (7)

2.2.4. Performance Metrics of Weibull Parameters

In this paper, we use two statistical tests to assess the convergence of the different distributions to the measured data: root means square error (RMSE) and determination coefficient (R^2) given by equations (15) and (16) [23, 24].

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{n}(X_i - x_i)^2} \quad (9)$$

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(X_i - x_i)^2}{\sum_{i=1}^{n}(X_i - \bar{X})^2} \quad (10)$$

With X_i, x_i and $\bar{X}$ are the observed, estimated and mean of the data respectively.

2.2.5. Wind Speed Extrapolation

Wind speed measurements are generally made at 10 m altitude above the earth's surface. In order to have adequate speeds for the operation of wind turbines, the extrapolation of wind speed for different altitudes is obtained by the following relationship [25]:

$$V(z_1) = V(z_0) \times \left(\frac{z_1}{z_0}\right)^{\alpha} \quad (11)$$

With $V(z_0)$, the wind speed at 10 m altitude; $V(z_1)$, the speed to be calculated at altitude z_1; α, the exponent of the power law, a function of the surface roughness given by the expression [26]:

$$\propto = \frac{0.37 - 0.088\ln(V_{Z0})}{1 - 0.00881\ln\left(\frac{Z_0}{10}\right)} \quad (12)$$

The extrapolation of the parameters k and c is given by the expressions 8 and 9 [27].

$$K_z = \frac{K_{Z0}}{1 - 0.00881 ln\left(\frac{Z}{10}\right)} \quad (13)$$

$$C_z = C_{Z0} \times \left(\frac{Z}{Z0}\right)^n \quad (14)$$

$$\text{With } n = [0.37 - 0.088\ln(c_0)] \quad (15)$$

2.2.6. Wind Power Density and Energy Density

The expected monthly or annual wind power density per unit area, of a site based on a Weibull probability density function given by [28, 29]:

$$\frac{P(V)}{A} = \frac{1}{2}\rho\int_0^{+\infty} V^3 f(V)dv = \frac{1}{2}\rho c^3 \Gamma(x) \quad (16)$$

With

$$x = 1 + \frac{3}{k} \quad (17)$$

where:

ρ = air density equal on average to 1.25 kg/m^3;

A = swept area of the rotor blades (m^2)

The mean energy density over a period of time T is expressed as equation [29, 30]:

$$E_D = \frac{P(V)}{A}T = \frac{1}{2}\rho c^3 \Gamma(x) T \quad (18)$$

2.2.7. Useful Wind Power

The useful wind power is given by [11, 31]:

$$P_u = \begin{cases} 0\ (v < v_{start}) \\ \frac{1}{2}\rho c^3 \Gamma(x)\ (v_{start} \le v \le v_{rat} \\ P_n\ (v_{rat} \le v \le v_{stop} \\ 0\ (v_{stop} < v) \end{cases} \quad (19)$$

$$P_u = \int_0^{\infty}\frac{1}{2}\rho c^3 \Gamma(x)\, f(v,k,c)dv + \int_{Vstart}^{V\,rate} P_n f(v,k,c)dv \quad (20)$$

$$P_u = P_n . FC \quad (21)$$

Which

$$FC = \frac{exp\left(-\left(\frac{V_{start}}{C}\right)^K\right) - exp\left(-\left(\frac{V_{rat}}{C}\right)^K\right)}{\left(-\left(\frac{V_{start}}{C}\right)^K\right) - \left(-\left(\frac{V_{rat}}{C}\right)^K\right)} - exp\left(-\left(\frac{V_{stop}}{C}\right)^K\right) \quad (22)$$

2.2.8. Usable Wind Power

The average of usable (produced) wind power is [11]:

$$P_p = \eta P_u \quad (23)$$

Where η is the machine efficiency, it is given by:

$$\eta = 2\frac{P_n}{\rho A {V_n}^3} \quad (24)$$

P_n: rated power, given by the manufacturer.

2.2.9. Water Pumping Capacity [11, 8]

For an electrical pump with efficiency η and height H, the daily flow is given by:

$$Q_{de} = 3600 * 24 * \frac{\eta P_{el}}{\rho_{water}\, g\, H_{mt}} \quad (25)$$

With:

H_{mt} is total manometric height; η pumping system overall efficiency; g gravity acceleration; ρ_{water} water density and P_{el} is electrical power provided by wind.

3. Results and Discussions

3.1. Observation of Wind Speed

Figure 2 shows the annual change in wind speed over an eight-year period at Fada and Amdjarass. The analysis shows that over eight years, the average annual speed varies between 3.88m/s and 8.44m/s at Fada, 5.23m/s and 7.07m/s at Amdjarass. The shape of the curves shows that the wind speeds are more stable at Amdjarass than at Fada. These results are similar to the results obtained in 2020 by Abakar Mahamat Tahir et *al*. who has Estimate of the Wind Resource of Two Cities in the Sahara and Sahel in Chad [32].

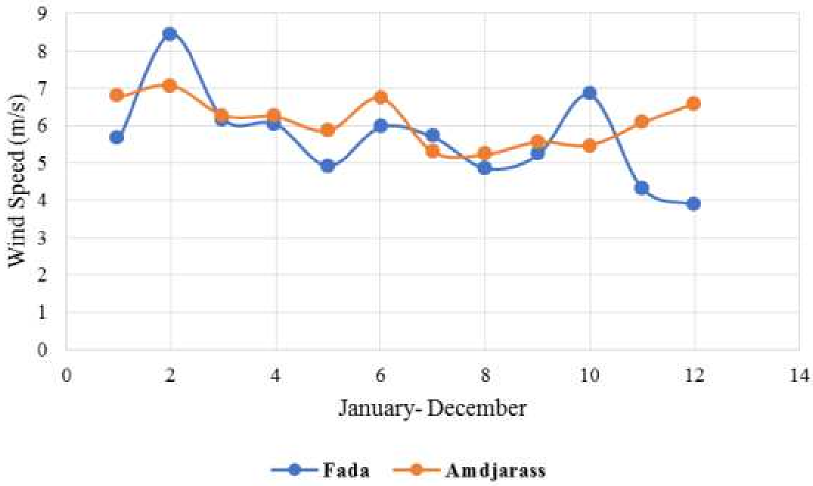


Figure 2. *Average annual variation of wind speed at 10m height over height (08) years.*

3.2. Wind Roses

Wind roses at Fada and Amdjarass sites are shown in figures 3 and 4. The statistical analysis of the wind observations shows that the wind is predominant from the East to the North-East in Fada. In Amdjarass, it is predominant in the North-East with three predominance in the North-West (July, September and August).

Figure 3. *Wind rose at Fada.*

Figure 4. *Wind rose at Amdjarass.*

3.3. Evaluation of Weibull Parameters and Statistical Performance

Higher values of k and c are revealed at both sites in February, since the wind speed values are also important in this month. In order to evaluate the statistical performance of the Weibull parameters, it is important to note that the value of R^2 varies between 0 to 1. The higher values R^2 and the smaller values of RMSE indicates that the calculated results describe better the observed results [20].

Using the two methods of evaluating the Weibull parameters, we find that the values are very close to each other. The values of R^2 are around 1 and those of RMSE are mostly very close to 0. This verifies the efficiency of the model used. Tables 1 and 2 below give the values of the Weibull parameters and the statistical analysis.

Table 1. *Weibull parameters and statistical performance at Fada.*

Months	Wind variability Method					Moroccan Method				
	Vweibull	C(m/s)	K	RMSE	R^2	Vweibull	C(m/s)	K	RMSE	R^2
Jan	5,63	6,35	2,49	2.E-05	9.E-01	5,63	6,35	2,33	1.E+00	7.E-01
Feb	8,52	9,53	3,05	6.E-03	1.E+00	8,48	9,53	2,78	2.E-03	1.E+00
Mar	5,84	6,57	2,6	1.E-01	1.E+00	5,83	6,57	2,43	1.E-01	1.E+00
Apr	6,04	6,8	2,58	2.E-05	1.E+00	6,03	6,8	2,4	8.E-04	1.E+00
May	4,88	5,5	2,33	2.E-03	1.E+00	4,88	5,5	2,19	2.E-03	1.E+00
Jun	5,19	5,85	2,56	6.E-01	1.E+00	5,19	5,85	2,39	6.E-01	1.E+00
Jul	5,69	6,4	2,51	2.E-04	1.E+00	5,68	6,4	2,34	5.E-04	1.E+00
Aug	4,84	5,46	2,31	3.E-04	1.E+00	4,84	5,46	2,18	4.E-04	1.E+00
Sep	5,16	5,82	2,4	3.E-03	1.E+00	5,15	5,82	2,25	4.E-03	1.E+00
Oct	6,85	7,69	2,74	7.E-04	1.E+00	6,83	7,69	2,54	1.E-04	1.E+00
Nov	4,32	4,88	2,18	1.E-06	1.E+00	4,32	4,88	2,06	6.E-06	1.E+00
Dec	3,88	4,36	1,85	2.E-04	1.E+00	3,87	4,36	1,95	4.E-05	1.E+00

Table 2. *Weibull parameters and statistical performance at Amdjarass.*

Months	Wind variability Method					Moroccan Method				
	Vweibull	c(m/s)	K	RMSE	R 2	Vweibull	C(m/s)	K	RMSE	R 2
Jan	6,42	7,22	2,73	0,118	0,9975	6,4	7,22	2,52	0,12	0,9972
Feb	6,92	7,78	2,79	0,022	0,99957	6,91	7,78	2,57	0,028	0,99945
Mar	6,12	6,89	2,63	0,023	0,9994	6,1	6,89	2,45	0,027	0,99931
Apr	5,87	6,6	2,62	0,14	0,9965	5,85	6,6	2,44	0,145	0,9963
May	5,63	6,33	2,54	0,057	0,9983	5,62	6,33	2,38	0,061	0,9982
Jun	6,68	7,5	2,72	0,0033	0,999926	6,66	7,5	2,53	0,0054	0,99988
Jul	5,05	5,67	2,41	0,069	0,9975	5,03	5,67	2,27	0,071	0,9974

Months	Wind variability Method					Moroccan Method				
	Vweibull	c(m/s)	K	RMSE	R 2	Vweibull	C(m/s)	K	RMSE	R 2
Aug	5,09	5,75	2,4	0,017	0,99938	5,09	5,75	2,25	0,018	0,99933
Sep	5,37	6,06	2,48	0,035	0,9989	5,37	6,06	2,32	0,038	0,9988
Oct	5,19	5,85	2,45	0,085	0,9972	5,18	5,85	2,3	0,088	0,997
Nov	5,76	6,49	2,59	0,108	0,9972	5,75	6,49	2,41	0,0108	0,9971
Dec	6,36	7,15	2,7	0,055	0,9987	6,35	7,15	2,5	0,062	0,9986

3.4. Wind Speed Extrapolation and Weibull Parameters

Wind speed is proportional to height. Figures 5 and 6 show that from 30m above the ground, there are good exploitable wind speed values varying between 6.26 m/s and 10.31 m/s from January to September at Fada. The values 5.63 m/s and 5.10 m/s are observed in November and December.

At Amdjarass, the wind speed data is almost stable. At 30m from the ground, for example, stable speed values are obtained, which vary very little between 6.69 m/s and 8.79 m/s during the year.

At 55m and 67m from the ground, the wind speed values are close in Fada as in Amdjarass.

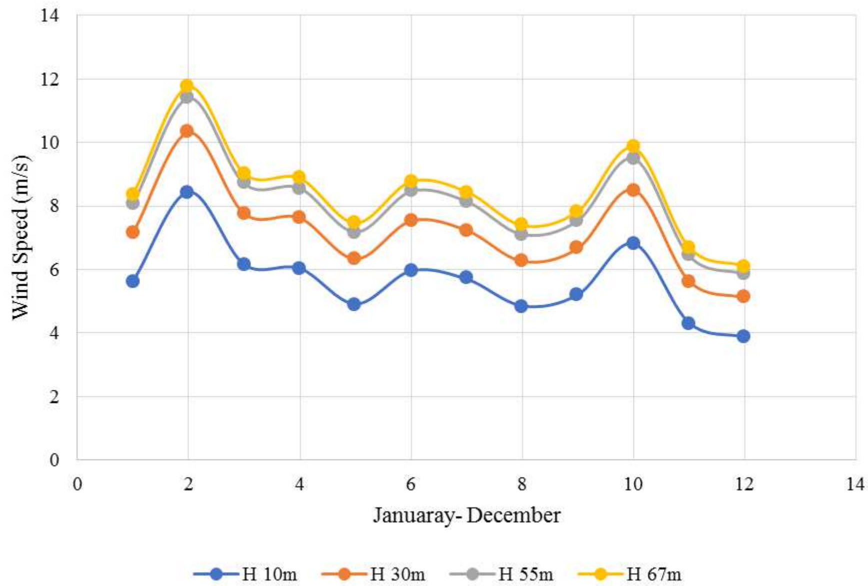


Figure 5. *Wind rose at Fada.*

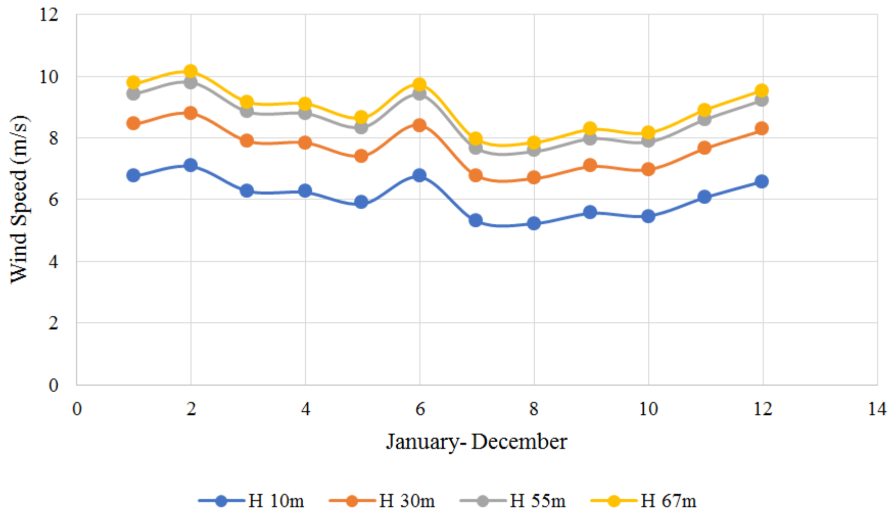


Figure 6. *Wind rose at Amdjarass.*

The extrapolation of the Weibull parameters is presented in Tables 3 and 4. It can be seen that the values of k vary very little in the two sites.

In Fada, k goes from 1.85 in December at 10m, to 3.10 in February at 67m while c goes from 4.37 m/s at 10m in December, to 13.01 m/s at 67 m in February.

In Amdjarass, the value of k goes from 2.40 in August at 10m, to 2.84 in February at 67m while c goes from 5.67 m/s at 10m in July, to 10.97 m/s at 67 m in February.

Table 3. *Extrapolation of K as a function of height.*

K (-)	FADA											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
H 10m	2,49	3,05	2,61	2,58	2,33	2,56	2,51	2,31	2,40	2,74	2,18	1,85
H 30m	2,52	3,08	2,63	2,61	2,35	2,59	2,53	2,34	2,42	2,77	2,20	1,87
H 55m	2,53	3,10	2,65	2,62	2,36	2,60	2,54	2,35	2,43	2,78	2,22	1,88
H 67m	2,54	3,10	2,65	2,62	2,37	2,61	2,55	2,35	2,44	2,79	2,22	1,88
K	AMDJARASS											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
H 10m	2,73	2,79	2,63	2,62	2,54	2,73	2,42	2,40	2,48	2,46	2,59	2,70
H 30m	2,76	2,82	2,66	2,65	2,57	2,75	2,44	2,42	2,50	2,48	2,61	2,72
H 55m	2,77	2,84	2,67	2,66	2,58	2,77	2,45	2,44	2,51	2,49	2,63	2,74
H 67m	2,78	2,84	2,67	2,67	2,59	2,77	2,46	2,44	2,52	2,50	2,63	2,74

Table 4. *Extrapolation of C as a function of height.*

C(m/s)	FADA											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
H 10m	6,35	9,53	6,57	6,80	5,51	5,85	6,41	5,46	5,82	7,70	4,88	4,37
H 30m	7,98	11,51	8,22	8,49	7,01	7,41	8,04	6,96	7,37	9,49	6,29	5,69
H 55m	8,93	12,64	9,20	9,48	7,91	8,33	9,00	7,85	8,29	10,53	7,13	6,49
H 67m	9,25	13,01	9,52	9,80	8,21	8,64	9,32	8,15	8,59	10,87	7,41	6,76
C(m/s)	AMDJARASS											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
H 10m	7,22	7,78	6,89	6,60	6,34	7,51	5,67	5,75	6,06	5,85	6,49	7,15
H 30m	8,95	9,58	8,58	8,26	7,96	9,28	7,20	7,29	7,64	7,40	8,13	8,88
H 55m	9,97	10,63	9,58	9,24	8,92	10,31	8,11	8,21	8,58	8,32	9,10	9,89
H 67m	10,30	10,97	9,91	9,56	9,24	10,65	8,42	8,51	8,89	8,63	9,42	10,22

3.5. Estimation of Electric Power Generation by Wind Turbines

Table 5 shows the characteristic properties of selected wind turbines.

Table 5. *Characteristic properties of selected wind turbines.*

Trade Name	**Rated power (KW)**	**Cut-in Wind speed (m/s)**	**Rated Wind speed (m/s)**	**Cut-off Wind speed**	**Rotor diameter (m)**	**Hub height H (m)**	**Number of blades**
GEVMP 275KW/32	275	4	12	30	32	55	Two-bladed
BONUS 300KW/33	300	3	14	25	33,4	30	Tree-bladed
VESTAS 2MW/V80	2000	4	16	25	80	67	Tree-bladed

In this paragraph, we first evaluate the power and the energy density available on the two sites at different altitudes (30m, 55m and 67m) depending on the wind turbines chosen. Then, we estimate the useful and usable power of each wind turbine.

Table 6 presents the power density and the annual energy per unit area. The record values of power density are observed in February in Fada, 1221.51 KW/m^2, 923.31 KW/m^2 and 1331.35 KW/m^2 respectively for GEVMP, BONUS and VESTAS. Low values are observed in December.

At Amdjarass, high values are also observed in February, 754.66 KW/m^2, 552.85 KW/m^2 and 829.93 KW/m^2 respectively for GEVMP, BONUS and VESTAS. Low values are observed in July.

Figures 7 and 8 give the estimate of the useful and usable powers through the three wind turbines chosen. It appears that the VESTAS aerogenerator gives very good results reaching up to 879.76 KW in February and 617.26 KW in November of useful power in Fada. The other two wind turbines give very similar values during the year. The maximum values are reached in February (148.48 KW for GEVMP and 175.11 KW for BONUS) and the minimum values are observed in December (53.27 KW for GEVMP and 49.29 KW for BONUS). In all cases, the powers actually usable are six (06) times lower than the useful powers available.

In Amdjarass, the VESTAS aerogenerator gives very good results reaching up to 622.56 KW in February and 588.91 KW in June of useful power in Fada. The other two wind turbines give similar values during the year. The maximum values are reached in February (66.05 KW for GEVMP and 69.89 KW for BONUS) and the minimum values are observed in December (53.27 KW for GEVMP and 49.29 KW for BONUS). We still see here, the powers actually usable are six (06) times lower than the useful powers available.

When only GEVMP and BONUS are considered, it can be seen through Figures 7 and 8 that GEVMP gives the best values in terms of usable power, although BONUS gives the best values in terms of useful power.

Table 6. *Energy potential of the two sites according to the wind turbines.*

Aerogenerator		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
FADA													
GEV MP 275KW/32	CF	0,29	0,54	0,30	0,33	0,24	0,24	0,30	0,23	0,25	0,39	0,20	0,19
	P (W/m^2)	477,40	1221,39	507,21	557,73	347,18	380,64	486,85	341,57	391,23	740,45	267,85	238,51
	E(KW/m^2/an)	4182,06	10699,35	4443,13	4885,76	3041,34	3334,38	4264,78	2992,14	3427,19	6486,31	2346,37	2089,33
BONUS 300KW/33	CF	0,30	0,58	0,31	0,34	0,23	0,24	0,30	0,22	0,25	0,42	0,18	0,16
	P (W/m^2)	340,78	923,31	363,72	401,99	242,91	268,46	347,95	238,71	275,83	543,06	184,26	161,77
	E(KW/m^2/an)	2985,23	8088,16	3186,14	3521,47	2127,92	2351,71	3048,08	2091,13	2416,31	4757,23	1614,13	1417,13
VESTAS 2MW/V80	CF	0,22	0,44	0,23	0,25	0,18	0,18	0,23	0,17	0,19	0,31	0,15	0,15
	P (W/m^2)	529,66	1331,35	561,93	616,94	387,57	423,87	539,93	381,43	435,71	814,66	300,57	268,80
	E(KW/m^2/an)	4639,80	11662,67	4922,51	5404,38	3395,08	3713,07	4729,75	3341,32	3816,81	7136,46	2632,95	2354,70
AMDJARASS													
GEV MP 275KW/32	CF	0,35	0,40	0,33	0,30	0,29	0,38	0,24	0,25	0,27	0,25	0,30	0,35
	P (W/m^2)	629,50	754,66	569,58	511,71	469,27	697,07	365,17	379,33	424,74	389,73	492,77	618,64
	E(KW/m^2/an)	5514,44	6610,80	4989,51	4482,55	4110,81	6106,30	3198,86	3322,90	3720,76	3414,02	4316,67	5419,26
BONUS 300KW/33	CF	0,37	0,43	0,34	0,31	0,29	0,40	0,23	0,24	0,27	0,25	0,30	0,36
	P (W/m^2)	456,19	552,85	409,97	366,06	333,74	508,03	255,58	265,99	300,10	273,95	351,63	447,70
	E(KW/m^2/an)	3996,19	4842,95	3591,35	3206,72	2923,53	4450,31	2238,87	2330,10	2628,84	2399,76	3080,25	3921,87
VESTAS 2MW/V80	CF	0,27	0,31	0,25	0,23	0,22	0,29	0,18	0,19	0,20	0,19	0,22	0,27
	P (W/m^2)	694,57	829,93	629,72	566,80	520,70	767,77	407,14	422,67	472,22	433,97	546,24	682,85
	E(KW/m^2/an)	6084,47	7270,16	5516,33	4965,19	4561,36	6725,69	3566,54	3702,61	4136,65	3801,55	4785,04	5981,79

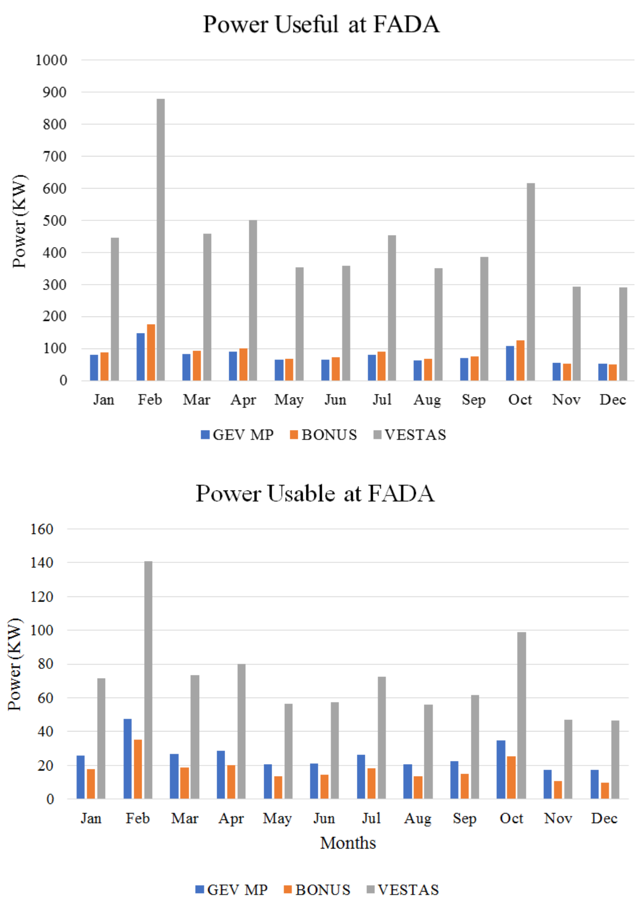


Figure 7. *Useful and usable power of wind turbine at Fada.*

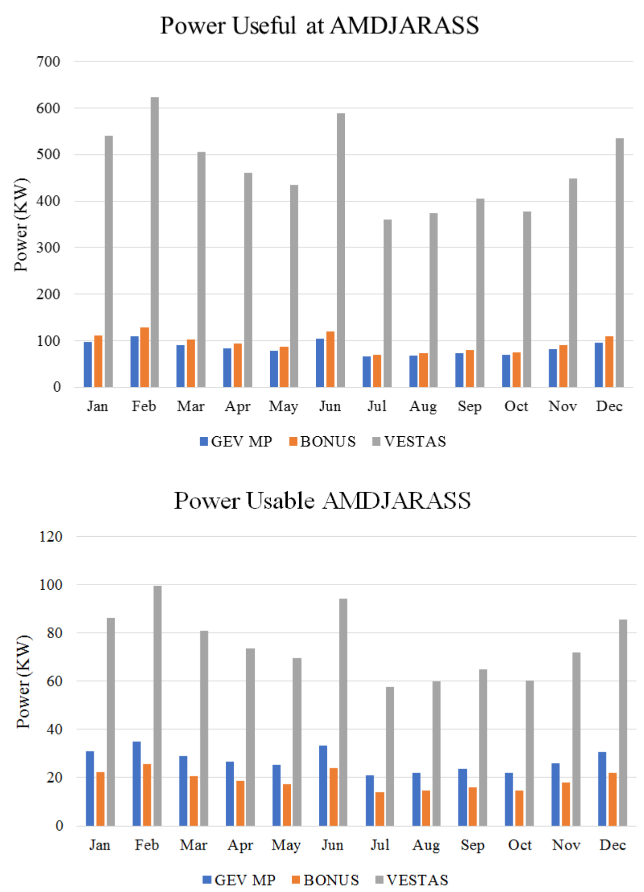


Figure 8. *Useful and usable power of wind turbine at Amdjarass.*

3.6. Water Volume Assessment

Here, we evaluate the quantity of water produced per day by each aerogenerator able to serve the populations of the chosen sites. We consider that the amount of water needed for a one-person household is 50l/d. Recall that according to data from the town halls of Amdjarass and Fada, the respective populations are around 30,765 and 27,112 inhabitants respectively.

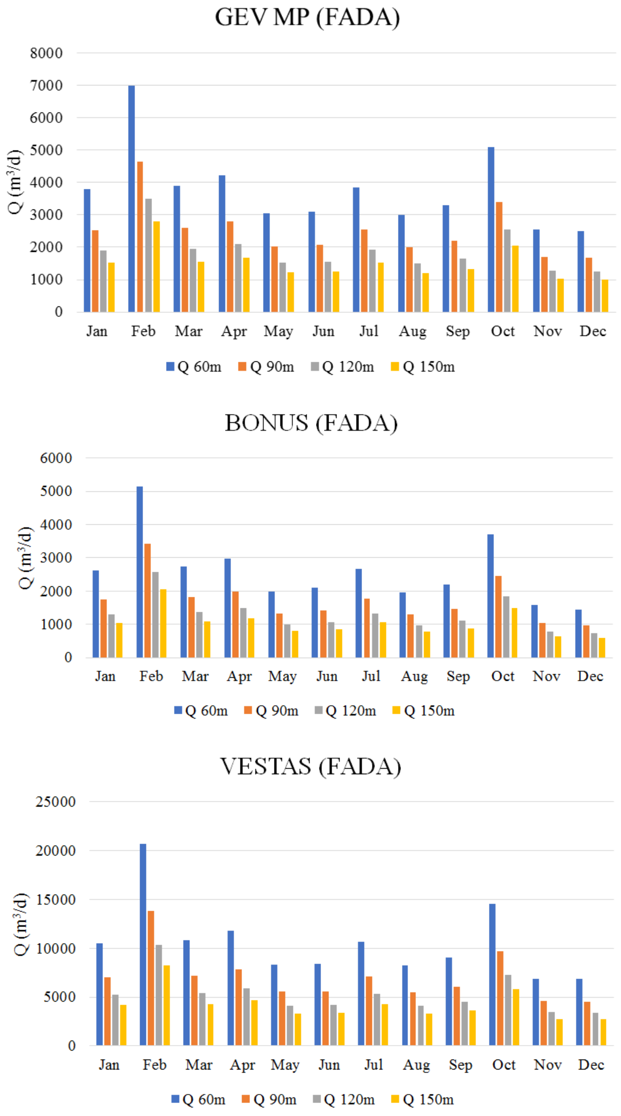
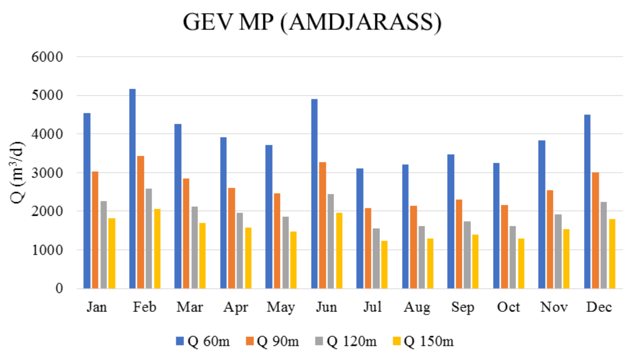


Figure 9. *Volumetric Flow Rate of Water in Fada use electrical system.*



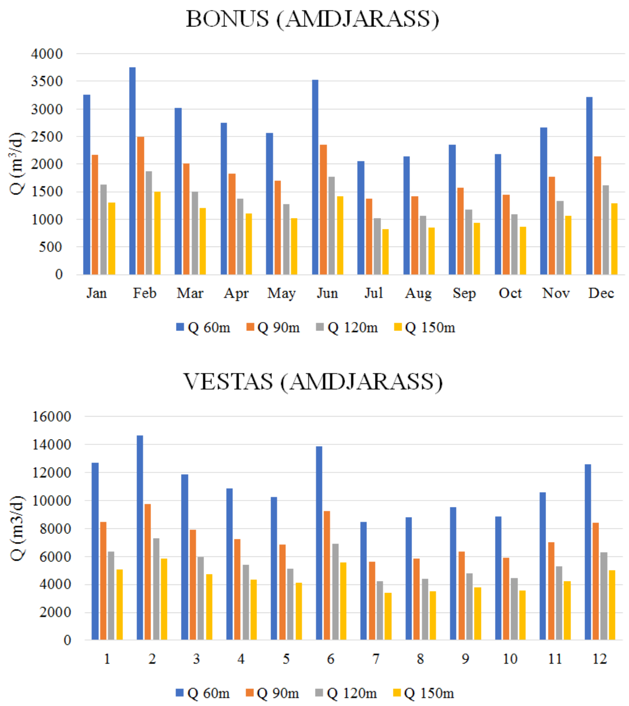


Figure 10. *Volumetric Flow Rate of Water in Amdjarass use electrical system.*

Figures 9 and 10 show that the GEVMP aerogenerator meets the needs of both sites. Installed on a 55m high mast, this two-blade aerogenerator can provide on average between 3778.3 m^3 of water/day to 1511.3 m^3 of water/day for a system ranging from 60m to 150m in head at Fada. This corresponds on average to 139.36l/d/pers (60m HMT) to 55.74l/d/pers (150m HMT).

As in Amdjarass, the GEVMP aerogenerator can provide between 3986.3 m^3 of water/day to 1594.5 m^3 of water/day for a system ranging from 60m to 150m in head. This corresponds on average to 129.57l/d/pers (60m HMT) to 51.82l/d/pers (150m HMT).

To meet the water requirement for 2040 sets by the authorities, which is 6,000 m^3/d at both sites, the VESTAS wind turbine is the best option for supplying water to the population. Installed on a 67 m high mast, this aerogenerator can supply on average between 10,552.7 m^3 of water/day to 4,221.1 m^3 of water/day for a system ranging from 60m to 150m in manometric height in Fada, and in Amdjarass, it can provide on average between 11076.3 m^3 of water/day to 4430.5 m^3 of water/day for a system ranging from 60m to 150m in head.

4. Conclusion

The purpose of this article is to evaluate the use of a wind source for pumping water in the North East of Chad. An assessment of the wind speed and direction of two sites has revealed the wind potential of the North East of Chad. Two statistical methods namely the wind variability method and the Moroccan method have evaluation Weibull parameters. It follows that the two methods are convergent, efficient and give satisfactory results. An electric pumping system was used to estimate the amount of water pumped per day at both sites. The electric pumping system used gives satisfactory results, given the development prospects set for these two sites.

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