WIND ENERGY AS SOURCE FOR RURAL ELECTRICITY TO ENHANCE AGRICULTURAL PRODUCTION AT DJELFA STATE (CENTER OF ALGERIA)

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ABSTRACT

In this paper we have estimated the mean wind power density at Djelfa station. This wild source could be used to electrify the rural regions in the state since most of the fertile farmlands are located in it. We found that the electricity powered by wind reaches 534.93 W/m² (February) in the monthly study, 546.23 W/m² (winter) in the seasonal study and 384.91 W/m² as annual average at 50m height. The two-parameter Weibull distribution used to represent the diurnal mean wind speed data and Bayesian Estimation method is adopted statistical method used to estimate the shape and scale parameters.

KEYWORDS:

Wind Power; Bayesian Estimation; Weibull Distribution; Rural Electrification.

JEL CLASSIFICATION : K32. N70. Q20. Q34. Q47.

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L'ENERGIE EOLIENNE COMME SOURCE D'ELECTRICITE RURALE POUR AMELIORER LA PRODUCTION AGRICOLE DANS LA WILAYA DE DJELFA (CENTRE D'ALGERIE)

RÉSUMÉ

Dans cet article, nous avons estimé la densité moyenne de l'énergie éolienne à la station Djelfa. Cette source mondiale pourrait être utilisée pour électrifier les régions rurales de la wilaya (puisque la plupart des terres agricoles fertiles y sont situées) Nous avons constaté que l'électricité produite par le vent atteint 534,93 W/m2 dans l'étude mensuelle, 546,23 W/m2 (hiver) dans l'étude saisonnière et 384.91 W/m2 en moyenne annuelle à 50m de hauteur La distribution Weibull à deux paramètres est la méthode statistique utilisée pour calculer les formes et les échelles et la méthode estimation Bayesian est adoptée pour calculer les données quotidiennes moyennes des vents et les données de vitesse.

MOTS CLÉS

Énergie éolienne; Estimation bayésienne; Distribution de Weibull; Electrification Rural .

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طاقة الرياح كمصدر للكهرباء الريفية من أجل تعزيز الإنتاج الزراعي في محطة الجلفة (مركز الجزائر)

ملخص

في هذه المقالة قمنا بتقدير متوسط كثافة طاقة الرياح في محطة الجلفة. يمكن استخدام هذا المصدر العالمي لإمداد المناطق الريفية في الولاية بالكهرباء، حيث توجد معظم الأراضي الزراعية الخصبة).

لاحظنا أنّ الكهرباء المولّدة من الرياح تصل إلى 534.93 واط/م^2 مربع في الدراسة الشهرية (فبراير)، وتصل إلى 546.23 واط/ م^2 في الدراسة الموسمية (الشتاء) و إلى 384.91 واط/م^2 كمتوسط سنوي على ارتفاع 50 متر.

يعتبر توزيع وايبل **Weibull** ذو المعلمة الثنائية المستخدم لتمثيل بيانات سرعة الرياح المتوسطة اليومية وطريقة تقدير بايزيان **Bayesian** هي طريقة احصائية معتمدة لحساب متوسط معلمات الشكل والحجم للرياح اليومية.

كلمات مفتاحية:

قوّة الرياح؛ تقدير بايزي، توزيع وايبول كهرباء الريف.

تصنيف جال: .K32. N70. Q20. Q34. Q47.

INTRODUCTION

The drop of Algerian revenues from oil and natural gas in mid 2014 let the government to look for alternatives to provide hard currency. Enhancing agriculture sector seemed one of the obvious options. by improving this sector Algeria could guarantee its food security, increase its agricultural exports, make this sector produce his own needs from energy and reduce its food' imports bill which is very high the bill reached 9.31$ billion in 2015, it mainly composed of 3.54$ billion for cereals and semolina flour, 1.17$ billion for milk and dairy products, 751.12$ million for sugar and its derivatives and 386.23$ million for pulses [1].

One of the important Algerian states in agricultural production is the state of Djelfa. It situated in middle of Algeria, 300km south of Algiers. The area of Djelfa is 32256 km² which is very 1.36% of the total area of Algeria. It is home for over 1475000 inhabitants, which makes it the fourth populated state in Algeria. Djelfa is generally a steppe pasture zone [2].

The agricultural sector in this state has seen a remarkable development in the last years. For the agricultural season 2014/2015, Djelfa ranked the first nationally in production of wool, red meat, sheepskins and goatskins. The state occupied the 5^{th} place in production of onion, the 18^{th} place in production of fodder. Djelfa is one of the top states in producing olive, olive oil and fruits especially the apricot, pomegranate and watermelon besides the dry dates. The state has also its share from the Algerian grain production especially barely and oat (tables 1, 2 and 3).

Table 1: **Land distribution in the state of Djelfa.**

Land distribution	Area	Percentage from the total area of the state
Total agricultural area	2 501 093 ha	77.54 %
Allocated agricultural area	378 665 ha	11.73 %
Irrigated area	34 000 ha	1.05 %
Pastureland	212 2428 ha	65.79 %
Barren land	164 804 ha	5.10 %
Forest	208 940 ha	6.47 %
Alfa steppe	350 798 ha	10.87 %

Table 2: **Livestock in the state of Djelfa.**

Type	Number by heads
Sheep	3 364 460
Goats	35 250
Cattle	405 400
Camels	6240

Table 3: **Plant and Animal production Table in the state of Djelfa.**

Product	Quantity	Product	Quantity
Wool	62 430 q	Red meat	504 990 q
White meat	61 430 q	Milk	28 591 hl
Honey	152 q	Olive oil	18 600 hl
Barely	94 960 q	Soft wheat	2590 q
Durum wheat	80 190 q	Oat	5110 q
Fodder	64 400 q	Onion	604 920 q
Potato	535 800 q	Olive	159 860 q
Apricot	147 960 q		

The state counted 3563 fertile farmlands, 71 storage and cooling facilities, 10808 wells. There are some manufacturing facilities like mills, processing and drying units, the regional slaughterhouse for red meat with daily capacity of 200 head of sheep and 80 head of cattle and the largest slaughterhouse in Africa for white meat with an hourly capacity of 6000 chicken and 2000 turkey [3].

The main issue that encounters the Algerian farmers in general and Djelfa's farmers in particular is bringing the electrical power to their farms which is usually located in remote areas. This power will be used not only for lightning and household purposes but also to pump water from wells, spray crops, milking, hoisting grain…etc. that will facilitate the peasants life and make their crops grow.

Even though the authorities has launched many programs concern rural electrification in the state – with capacities of 996 km and 840 km in 2015 – the number of covered farms small, many farmers still waiting for electricity to increase their irrigated areas which will lead necessarily to enlarge their production [4].

Wind energy considered a strategic option to provide electricity in agriculture sector because it considered the cheapest among conventional and non-conventional power sources according to table 4. Wind farms themselves can be used to produce electricity and simultaneously to raise crops, as long there is breeze wind turbines can operate during the day or the night – which is very useful for off-grid locations – unlike solar energy. The tract of land required by solar power is relatively large in comparison with wind power. Even though the wind speed isn't very high, the wind turbine still can be used to pump water or grind grain.

Table 4: **Cost of some different sources of energy by C€/kWh [5].**

Source	Coal	Oil	Gas	Nuclear
Cost	20-15	3-11	1-3	0.2-0.7

Table 4: **(Following the table)**

Source	PV	Biomass	Hydroelectric	Wind
Cost	0.6	0.08-0.3	0.3-1	0.05-0.25

In this paper we will try to assess the wind energy that can be produced in Djelfa using Bayesian estimation method to estimate the two-parameter Weibull distribution.

In wind energy field, it is better to use the two-parameter Weibull distribution to model wind velocity data, since the wind speed is the key player who determines the wind energy output [6] – [7].

The Weibull probability distribution function (pdf) is

$$\begin{cases} f(V) = \frac{\beta}{\alpha}\left(\frac{V}{\alpha}\right)^{\beta-1} e^{-\left(\frac{V}{\alpha}\right)^{\beta}} & (1) \\ f(V) = \frac{\beta}{\lambda} V^{\beta-1} e^{-\frac{V^{\beta}}{\lambda}} & (2) \end{cases}$$

Where α is the scale parameter expressed in m/s, β is the dimensionless shape parameter , V is the wind speed in m/s and λ is parameter combines both scale and shape features as $\lambda = \alpha^{\beta}$ [8].

1- DATA DESCRIPTION

The National Meteorological Office has provided us with windspeed data of Djelfa station from January 2006 to December 2010 at 10m height. The longitude, latitude, altitude and topographic situation for the sites are given in table (5).

Table 5: **Geographical coordinates of the meteorological station of Djelfa.**

longitude	**latitude**	**altitude**	**Topographic station**
3.15E	34.40N	1144m	Highlands

2- BAYESIAN ESTIMATION METHOD

A true alternative to the classical methods of estimation, this method based on consideration that the parameters of the random variable are also random variables, and then we combine the prior distribution of the parameters with the observation's distribution to get an updated posterior distribution by using Bayes theorem.

We found that The Bayes estimators of the shape and scale parameters are:

$$E(\beta/\underline{V}) = \frac{1}{\phi(\beta)}\int_{0}^{\infty} \beta^{n} \left(\prod_{i=1}^{n} V_i\right)^{\beta-1} \left(\sum_{i=1}^{n} V_i^{\beta}\right)^{-n} d\beta \quad (3)$$

$$E(\lambda/\underline{V}) = \frac{\Gamma(n-1)}{\phi(\lambda)}\int_{0}^{\infty} \beta^{n-1}\left(\prod_{i=1}^{n} V_i\right)^{\beta-1} e^{-\frac{1}{\lambda}\sum_{i=1}^{n} V_i^{\beta}} d\beta \quad (4)$$

Where

$$\phi(\beta) = \int_0^\infty \beta^{n-1} (\prod_{i=1}^{n} v_i)^{\beta-1} (\sum_{i=1}^{n} v_i^\beta)^{-n} d\beta$$

$$\phi(\lambda) = \Gamma(n) \int_0^\infty \beta^{n-1} (\prod_{i=1}^{n} v_i)^{\beta-1} (\sum_{i=1}^{n} v_i^\beta)^{-n} d\beta$$

We cannot compute (3) and (4) analytically. Therefore, we suggested the Marcov Chain Monte Carlo (MCMC) approach to approximate them, we propose using Gibbs sampler [9] – [12] .

3- USEFUL EQUATIONS

$$\begin{cases} P_{avail} = \frac{1}{2}\rho A V^3 & (5) \\ \bar{V} = \alpha\Gamma\left(1+\frac{1}{\beta}\right) & (6) \\ \bar{P} = \frac{1}{2}\rho\alpha^3\Gamma\left(1+\frac{3}{\beta}\right) & (7) \\ \bar{E} = \frac{1}{2}\rho\alpha^3\Gamma\left(1+\frac{3}{\beta}\right) * T & (8) \\ \alpha_2 = \alpha_1\left(\frac{Z_2}{Z_1}\right)^m & (9) \\ m = \frac{0.37 - 0.0881 * \ln\alpha_1}{1 - 0.0881 * \ln\left(\frac{Z_1}{10}\right)} & (10) \\ \beta_2 = \beta_1 \frac{1}{1 - 0.0881 * \ln\frac{Z_2}{Z_1}} & (11) \end{cases}$$

Equation (5) shows us that the power available from P_{avail} from the wind increases cubically with wind velocity V ,Whereϱ is the air density (kg/m3) and Γ(.) is the gamma function.

Equations (6), (7) and (8) represents the mean wind speed $\bar{V}$, the mean wind power density $\bar{P}$ and the mean wind energy respectively.

The wind energy must be calculated at the hub height of wind turbine Z_2 which is usually higher than the anemometer level Z_1. Equations (9), (10) and (11) serve this purpose, where$m$ is power-law coefficient. [13] – [15].

4- RESULTS

4.1. Goodness of fit

Despite the widely acceptance of presenting the wind speed data by the two-parameter Weibull distribution, it is still important to check its suitability. Kolmogorov - smirnov and Anderson - darling goodness of fit tests were applied at 5% level of significance to the measured data of Djelfa[16].

The suitability of the two-parameter Weibull distribution for the 17 samples was checked using Kolmogorov - smirnov and Anderson - darling tests. As we can see from table (6) and figure (1) (in the appendix), the proposed distribution fit well the gathered data in exception of the summer data sample. But, we can re-use the two-parameter Weibull distribution too represent the summer sample through the relationship between Rayleigh and Weibull distributions, knowing that Rayleigh distribution is a special case of Weibull distribution with $\alpha = \sqrt{2}$ and $\beta = 2$ [17].

4.2- Analysis of Wiebull parameters, mean wind speed and mean power density

The results presented in table 7 are summarized as follows:

The maximum monthly wind speed equal to 5.02 is observed in May while the minimum value of 3.08m/s occurs in July. Furthermore, the shape parameter β varies between 1.39 and 2.34, while the scale parameterα lies between 3.48m/s and 5.67m/s. based on last column of table 7 the wind power has the lowest value of 31.44 W/m² in July whereas the highest value is 174.20 W/m² in February.

For the seasonal distribution, we can notice that the mean wind speed is higher during spring season with a value of 4.93 m/s and lower during summer season with value of 3.76 m/s. the dimensionless parameter of Weibull distribution varies between 1.41 and 2.09 while the scale parameter ranges between 4.25 m/s and 5.57m/s. the minimum wind power density is 62.50 W/m² observed in summer season while the maximum value is 182.31 W/m² in winter season.

The annual wind characteristics for the site are mean wind speed of 4.40 m/s and mean wind power density is 118.19 W/m².

Table 7-**Weibull parameters, mean wind speed and mean power density at 10m height.**

	$\alpha\ (m/s)$	β	$V(m/s)$	$P\ (W/m^2)$
Monthly study				
January	4.69	**1.39**	4.27	146.95
February	5.40	1.59	4.84	**174.20**
March	5.35	1.57	4.80	173.04
April	5.60	2.06	4.96	138.73
May	**5.67**	2.12	**5.02**	140.06
June	5.12	**2.34**	4.53	94.89
July	**3.48**	2.19	**3.08**	**31.44**
August	4.14	1.94	3.67	59.72
September	4.33	1.90	3.84	69.97
October	4.23	1.66	3.78	78.19
November	4.66	1.48	4.21	127.11
December	4.77	1.58	4.28	121.33
Seasonal study				
Winter	5.09	**1.41**	4.63	**182.31**
Spring	**5.57**	**2.09**	**4.93**	134.59
Summer	**4.25**	2.00	**3.76**	**62.50**
Autumn	4.57	1.64	4.08	100.46
Yearly study				
Year	4.90	1.72	4.40	118.19

4.3- Wind data analysis at higher elevation

As we can see from table 8 (in the appendix), the maximum monthly wind power is 534.93 W/m² reached in February while the minimum is 135.69 W/m² in July. For seasonally mean wind power density it ranges between 236.55 W/m² (summer) and 546.23 W/m² (winter). The annual mean wind power output for Djelfa at 50m height is 384.91 W/m².

According to Pacific Northwest Laboratory (PNL) classification scheme, if a large-scale wind farm installed at Djelfa it will operate well during the whole year in exception for the period between July and October [18]-[19].

CONCLUSIONS

The dependency of Algerian agriculture on rainfall is its biggest disadvantage. That's what farmers in state like Djelfa irrigate only 340000 hectares from an available 2.5 million hectares of useful agricultural land. To increase the irrigated area, the authorities should provide the peasants with energy so they can pump water from wells since Algeria is one of the top countries in the world with huge reserves of groundwater [20].

Providing electricity to farmers is essential for upgrading agriculture, especially if we knew that more than 40% of agricultural increase in food production of the past decades due to the increase in irrigated areas [21]. Installing a large-scale wind farm in Djelfa is proposed solution to overcome the dependency on rainfall. According to the above results, the wind can produce 384.91 MW as mean annual available power. We have seen that wind turbines will not operate well during July-October period, but that isn't an issue because even though the wind velocity is week or moderate it can still be used to pump water or grind grain.

Finally, food, paper and pulp, textile and footwear are promising industries in the state because the availability of raw materials they need like wool, sheepskins, goatskins, red meat, Alfa, olive, plum, apricot…etc. beside the huge market of 1.4 million inhabitants that the state represents.

Abbreviation

ha hectare q quintal
hlhectoliter PV
photovoltaic
Γ(.) the gamma function. ϱ the air
density.
*T*time *m* power-law
coefficient.

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APPENDIX

Figure 1: **Probability density distribution obtained from the measured data and the Weibull distribution.**

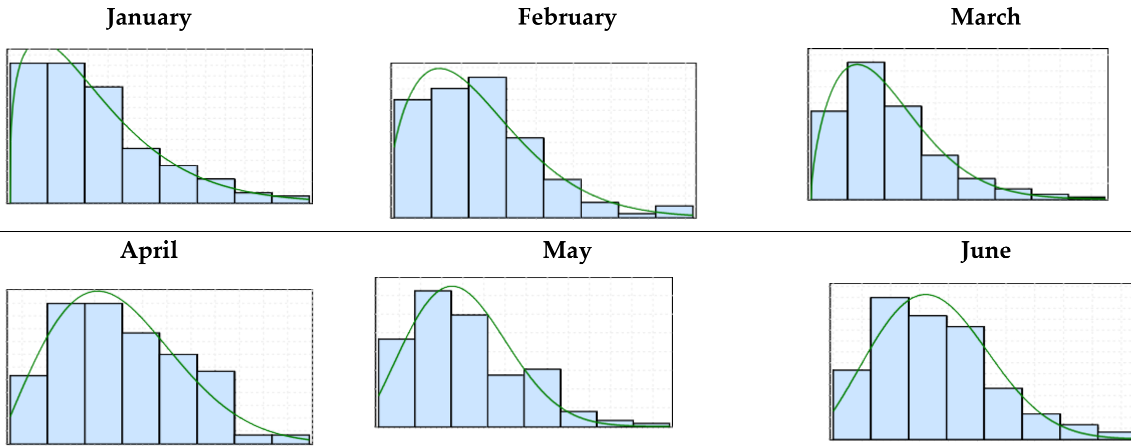
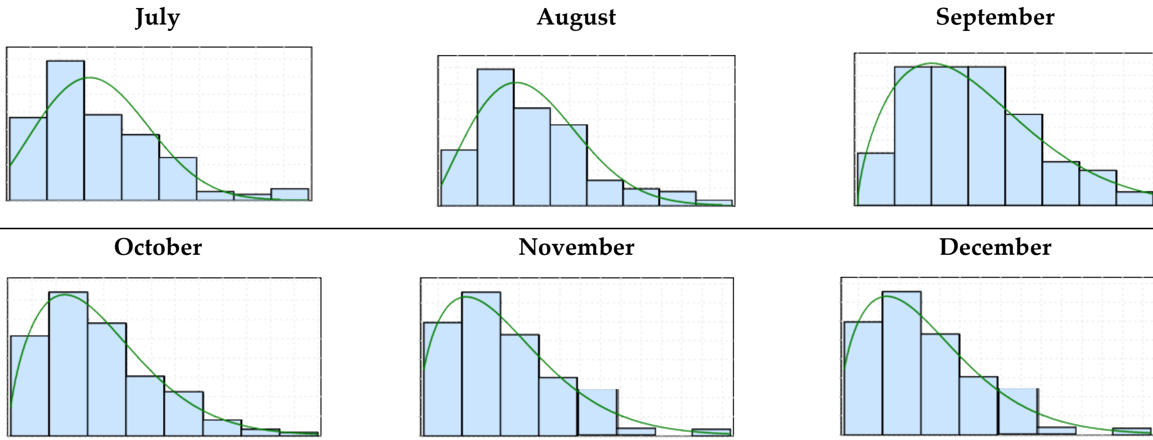


Figure 1: **Probability density distribution obtained from the measured data and the Weibull distribution.**



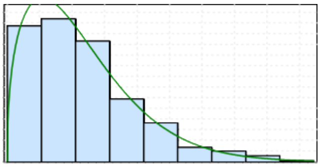
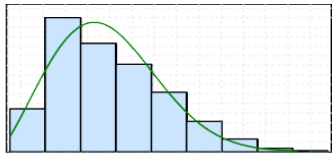
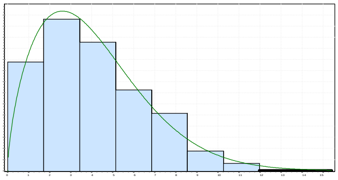
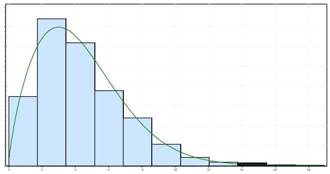
Winter	Spring
	
Summer	**Autumn**
Autumn	**Year**
	

Table 6: **Kolmogrov-Smirnov and Anderson –Darling calculated and tabulated statistics.**

	n	D_n	P-value	D_α	A_n^2	A_α^2	Distribution	Decision
Monthly study								
January	155	0.03	0.96	0.10	2.18	2.50	Weibull	Accept H_0
February	141	0.06	0.65	0.11	0.35	2.50	Weibull	Accept H_0
March	155	0.05	0.79	0.10	2.28	2.50	Weibull	Accept H_0
April	150	0.05	0.80	0.11	0.39	2.50	Weibull	Accept H_0
May	155	0.09	0.12	0.10	2.11	2.50	Weibull	Accept H_0
June	150	0.05	0.80	0.11	0.63	2.50	Weibull	Accept H_0
July	155	0.09	0.14	0.10	2.01	2.50	Weibull	Accept H_0
August	155	0.07	0.81	0.10	1.07	2.50	Weibull	Accept H_0
September	150	0.05	0.71	0.11	2.73	2.50	Weibull	Accept H_0
October	155	0.04	0.90	0.10	0.27	2.50	Weibull	Accept H_0
November	150	0.06	0.56	0.11	2.52	2.50	Weibull	Accept H_0
December	155	0.05	0.67	0.10	0.53	2.50	Weibull	Accept H_0
Seasonal study								
Winter	451	0.03	0.60	0.06	4.29	2.50	Weibull	Accept H_0
Spring	460	0.06	0.03	0.06	2.29	2.50	Weibull	Accept H_0
Summer	460	0.06	0.03	0.06	2.79	2.50	Weibull	Reject H_0
Summer	460	0.05	0.12	0.06	2.09	2.50	Rayleigh	Accept H_0
Autumn	455	0.03	0.55	0.06	4.51	2.50	Weibull	Accept H_0
Annual study								
Year	1826	0.02	0.08	0.06	9.26	2.50	Weibull	Accept H_0

Table 8: **Weibull parameters, mean wind speed and mean power density at 50m height.**

	$\alpha\ (m/s)$	β	$V(m/s)$	$P\ (W/m^2)$	m	class	potential
Monthly study							
January	7.52	1.62	6.73	456.55	0.293	4	Good
February	8.44	1.85	7.50	534.93	0.278	5	Excellent
March	8.38	1.82	7.44	531.11	0.279	5	Excellent
April	8.70	2.40	7.71	456.98	0.274	4	Good
May	8.79	2.47	7.79	461.92	0.272	4	Good
June	8.08	2.72	7.19	338.47	0.284	3	Moderate
July	5.88	2.55	5.22	135.69	0.326	1	Poor
August	6.78	2.26	6.01	227.13	0.307	2	Marginal
September	7.04	2.21	6.23	258.16	0.302	2	Marginal
October	6.90	1.93	6.12	278.40	0.305	2	Marginal
November	7.48	1.72	6.66	408.87	0.294	4	Good
December	7.62	1.84	6.77	397.02	0.291	3	Moderate
Seasonal study							
Winter	8.04	1.64	7.19	546.23	0.284	5	Excellent
Spring	8.66	2.43	7.68	446.40	0.274	4	Good
Summer	6.93	2.33	6.14	236.55	0.304	2	Marginal
Autumn	7.36	1.91	6.53	341.58	0.296	3	Moderate
Annual study							
Year	7.79	2.00	6.90	384.91	0.289	3	Moderate