

Wind Potential Modeling at Kanfarandé Site in the Republic of Guinea

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Abstract

The purpose of this work is to assess wind potential on the Kanfarandé site (Guinea). The data used for this research covers a period of 6 years (2018 to 2023) and consists of *in situ* data (Boké meteorological station) and satellite products via NASA Power Larc. The study is based on sorted hourly data (speed and direction). The treatments focus on the monthly, annual and seasonal average of speeds, by sector and their frequencies as well as the annual available powers. The obtained results made it possible, on the one hand, to assess wind potential and, on the other hand, to highlight the most favorable periods for wind energy exploitation. The analyzes show the months of July and August have the best average wind speeds with 5.01 m/s and 5.34 m/s respectively. Average wind speeds are higher during the day than at night with a peak observed at 6 p.m. The study also shows that the prevailing winds are oriented towards the South-West. The Weibull parameters determined for the site give an average of 4.5 m/s for the scale parameter and for the shape parameter 2.40 corresponding to an average power density of 65 w/m² with an annual available power of 194.80 W/m² and an annual available energy of 1706.45 kWh/m².

Keywords

Wind Potential, Modeling, Weibull Distribution, Wind Rose, Power Density, Available Power, Guinea

1. Introduction

Access to energy is a major challenge for the well-being of people and the nation's development. Due to the progressive exhaustion of traditional energy resources, on the one hand, and the increase in the prices of petroleum products on the other, particular interest is now being given to the development of other energy sources.

Perspectives are then open up for renewable energies, notably in the fight against desertification, limiting the impacts of climate change and rural electrification [1]. One of the current concerns of Guinea and even of the sub-region, is the exploration of renewable energy sources in order to valorize them as solutions to the energy problems which is shaking the country [2].

The wind is a promising sustainable energy source that can help reduce dependence on fossil fuels [3]. Wind potential assessment is addressed by several researchers in several countries including among others: India by [4]; Saudi Arabia [5]; in Eastern-Jerusalem [6] and Nigeria [7]. Wind Energy modeling is also investigated in [8], [9]. Some studies have been carried out to assess wind potential across Senegal [10], Mauritania [11], Algeria [12] and Guinea [13]. The results from Guinea showed the presence of excellent potential in several localities. Among all these localities, the study area is the only one without access to clean energy although it has high wind energy potential. This is the reason why we proposed to address the wind characteristics on the site in order to assess the potential available to cover the energy needs of the rural commune.

2. Materials and Methods

2.1. Study Area

Kanfarandé is a rural commune of the urban commune of Boké in the administrative region of Boké in Guinea. It is located between longitude $10^{\circ}49'60''$ North and attitude $14^{\circ}33'00''$ West at an altitude of 25 m. It is located at 79 km from the Urban commune of Boké and limited to the east by the rural commune of Kola-boui, to the west by the island of Kanoff, to the north by the rural commune of Sansalé and to the south by the Atlantic Ocean. The climate is characterized by the alternation of two seasons; a rainy season which extends from May to October and a dry season which extends from November to April. The dominant winds are: The harmattan which blows of the North-East from December to February and the monsoon which blows of the South-West in the other months. According to the general population census in 2016, Kanfarandé has a population of 31,428 inhabitants. The city is characterized by a multi-ethnic population and agriculture is the dominant activity [14]. **Figure 1** shows the map of the rural commune Kanfarandé.

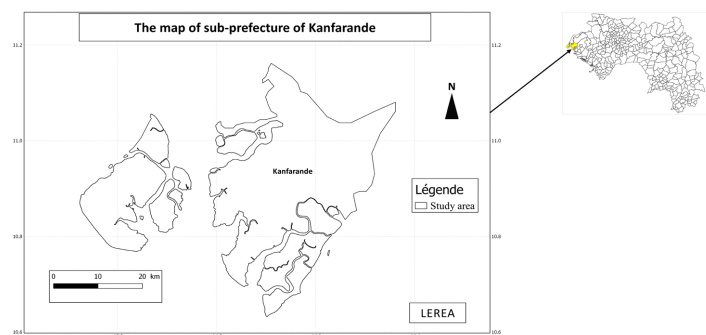


Figure 1. Map of the rural commune of kanfarandé.

2.2. Study Environment

The Teaching and Research Laboratories in Applied Energy and Renewable Energy of the Gamal Abdel Nasser University of Conakry and the Higher Institute of Technology of Mamou served as study environment for this present work.

2.3. Materials Used

The software used for data processing and analysis includes:

- Anemo-weathervane (INOVALLEY SM56PRO);

It is a new generation professional weather station (**Figure 2**) manufactured with advanced components and technology. This device provides precise and reliable measurement of wind speed and direction.

- Matlab software 2022;
- Wasp software 8.2;
- QGIS software 2.18;
- Instat plus software.



Figure 2. Anemo-weathervane.

2.4. Wind Potential Assessment Method

To assess the energy potential of a wind site, it is important to express the wind speed frequency distribution. The Wind speed distribution modeling have been oriented towards models combining power and exponential. Among the usual models used, we chose the Weibull distribution. This distribution was used for the statistical study of data measured on the ground. The probability density and cumulative frequency of this distribution are given by [15]:

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

where v is the wind speed, c (m/s) is the scale parameter that determinates the position of the curve, k (unit less) is a shape parameter that indicates the shape of the curve. There are several methods for determining the Weibull parameters, among which we used the standard deviation method (SD). With the average

speed and the standard deviation available, the estimation of the Weibull parameters is done using the following two formulas [16]:

$$k = \left(\frac{\sigma}{v}\right)^{-1.086} \tag{2}$$

$$c = \frac{\bar{v}}{\Gamma\left(1 + \frac{1}{K}\right)} \tag{3}$$

where \bar{v} the average speed, σ the standard deviation and Γ is the usual gamma function defined by the following relation

$$\Gamma(x) = \int_0^{+\infty} e^{-t} t^{x-1} dt \tag{4}$$

When the frequency of calm winds recorded on a given site is greater than or equal to 15% then the hybrid Weibull distribution can be used [17]. It is written

$$\text{For } v > 0 \quad f(v) = (1 - FF_o) \left(\frac{k}{c}\right) \left(\frac{v}{c}\right)^{k-1} e^{-\left(\frac{v}{c}\right)^k} \tag{5}$$

$$\text{For } v = 0 \quad f(v) = FF_o \tag{6}$$

where F and F_o .

The cubic average speed is given by [18]

$$\bar{V}^3 = c^3 \Gamma\left(1 + \frac{1}{k}\right) \tag{7}$$

And the cubic speed is given

$$V^3 = c^3 \Gamma\left(1 + \frac{3}{k}\right) \tag{8}$$

Wind power available

The available energy power of a wind of speed V crossing a surface unit S is given by the Relation [19]:

$$\bar{P} = \frac{1}{2} \rho \bar{V}^3 \tag{9}$$

By replacing \bar{V}^3 from (Equation (7)) into (Equation (9)) we obtain

$$\bar{P} = \frac{1}{2} \rho c^3 \Gamma\left(1 + \frac{3}{k}\right) \tag{10}$$

where, ρ (kg/m³) is the wind density.

Wind energy available

The wind energy available per day with the Weibull distribution is [20]:

$$E_j = 0,0147 c^3 \Gamma\left(1 + \frac{3}{k}\right) \tag{11}$$

3. Results and Discussions

3.1. Presentation of Data and Site

This research focused on the analysis of two data which are among others: *in situ*

data (Boké meteorological station) and data obtained by NASA aerial satellite. The data used to assess wind potential of the Kanfarandé site are collected over six years and cover the period from 2018 to 2023. They correspond to acquisitions of wind velocity and direction at 20 m height every 3 hours (8 measurements per day).

3.2. Wind Average Characteristics at the Kanfarandé Site

- Monthly, annual and interannual variation of wind average speed.

Data processing allowed us firstly to calculate the monthly, annual and interannual average speed and then to present their evolution curve. The results of the comparison between the interannual monthly averages speed over the six-year period and the annual monthly average speed are presented in **Figure 3**.

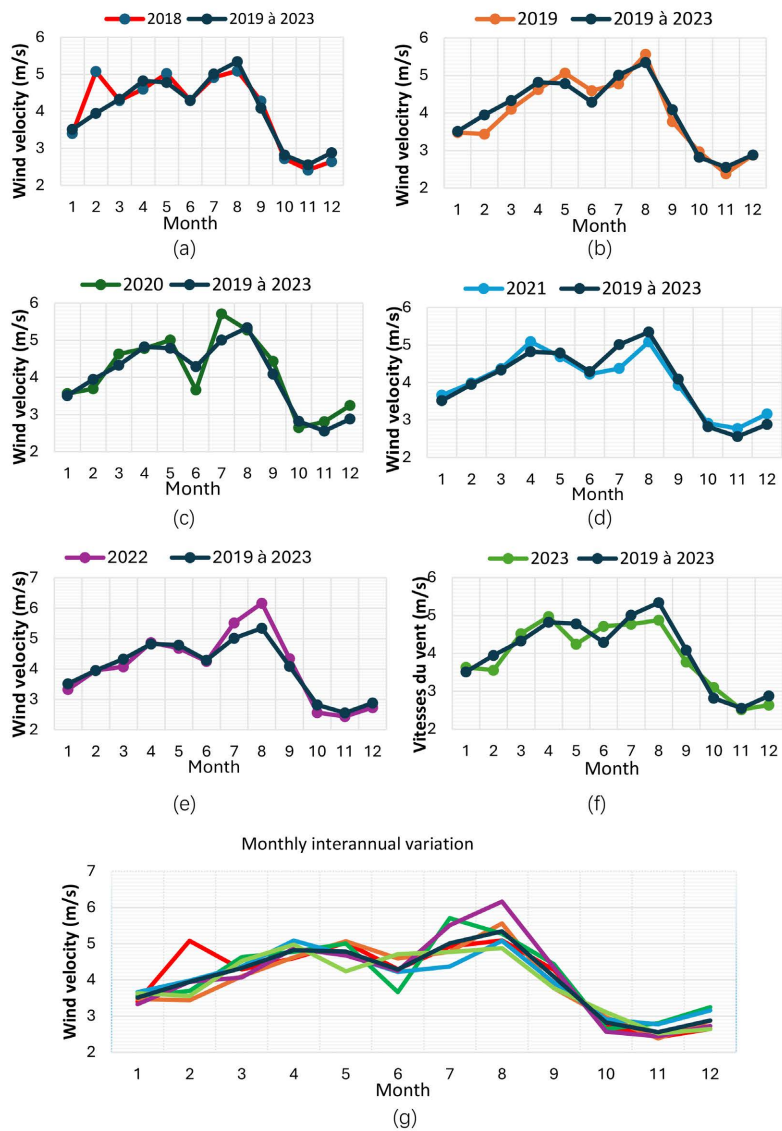


Figure 3. Evolution curves of the annual monthly average (a - f) and interannual (g) speed.

Figure 3 shows the curves follow the same trend and the maximum annual and

interannual monthly average speeds are observed in July and August. This means, wind potential is greater for these two months. We also noticed the most favorable year is 2020 where the average speed is 4.08 m/s while the most unfavorable year is 2023 in which the average speed is 3.95 m/s as shown in **Figure 4**.

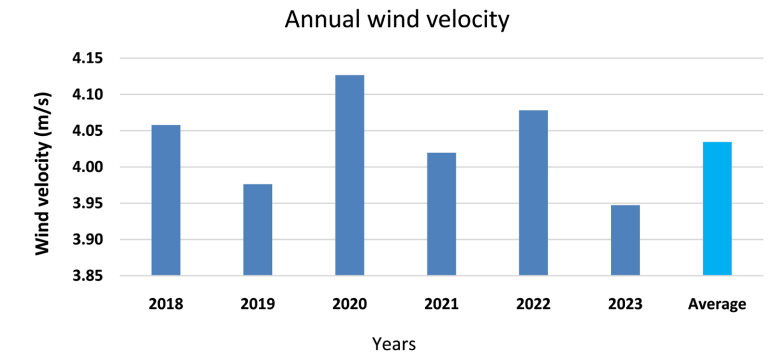
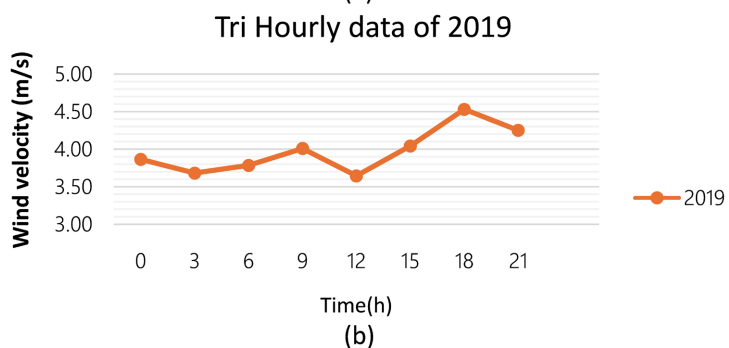
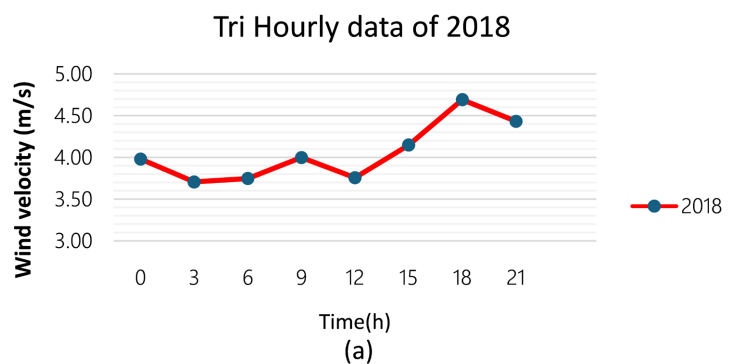


Figure 4. Histogram of the annual average speed.

- Diurnal variation of average wind speed

The study of the average characteristics of wind potential on the Kanfarandé site is associated with the study of the diurnal variation of the wind average speed on the site.

The following **Figure 5** shows the average speed is higher during the day than during the night. Therefore, wind potential is higher during the day than at night. This remark is observed, both for the data of each year and for the data of six years.



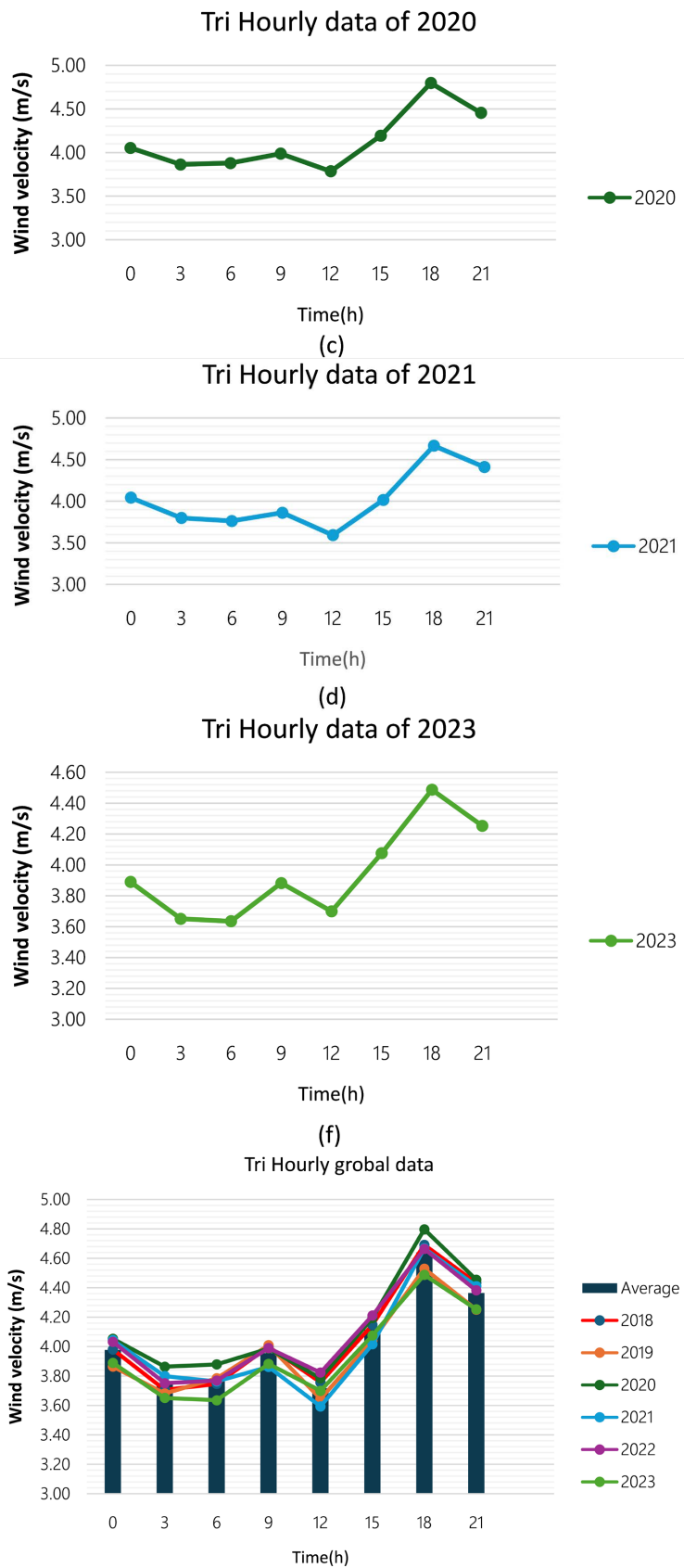


Figure 5. Variations of the annual and interannual wind speed.

- Seasonal wind speed

The seasonal wind speeds given in **Figure 6** indicate us the rainy season is the windiest. We can see the most favorable year in rainy season is 2022 with an average speed of 4.59 m/s, while the most unfavorable year is 2021 where the average is 4.20 m/s. For the dry season, the most favorable year is 2021 with an average of 3.84 m/s while the most unfavorable year is 2019 with an average of 3.48 m/s.

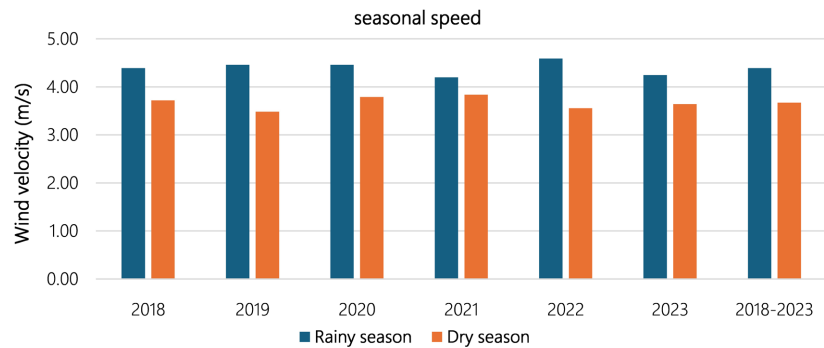


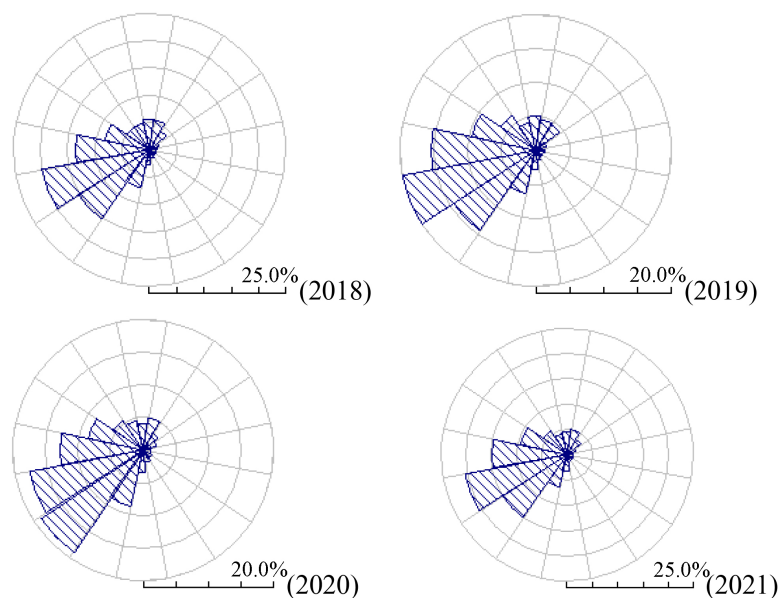
Figure 6. Seasonal wind speed.

3.3. Statistical Characteristics of the Wind on the Kanfarandé Site

- The wind rose

The statistical analysis data allowed to determine the wind rose which is the graphic representation of the frequency of the wind average speed as a function of the direction in a polar reference. The wind rose is determined for each year and for all data over the 6 years. The results obtained show the dominant wind direction is the South-West as shown in **Figure 7**.

- The Weibull distribution



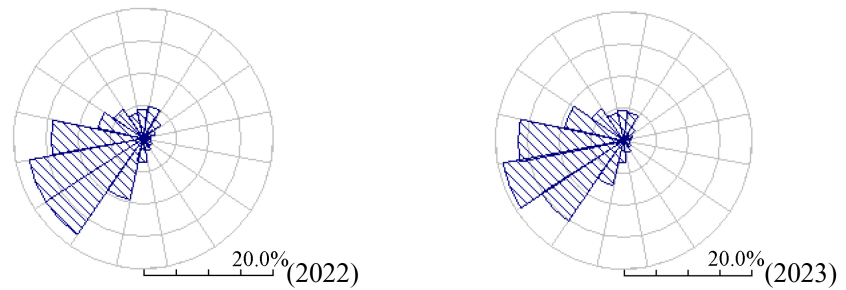


Figure 7. The wind roses for 2018, 2019, 2020, 2021, 2022 and 2023.

The data are also fitted to the Weibull law. The theoretical average speed, Weibull parameters and theoretical power density are calculated. **Figure 8** shows the evolution of monthly power density over the six-year period.

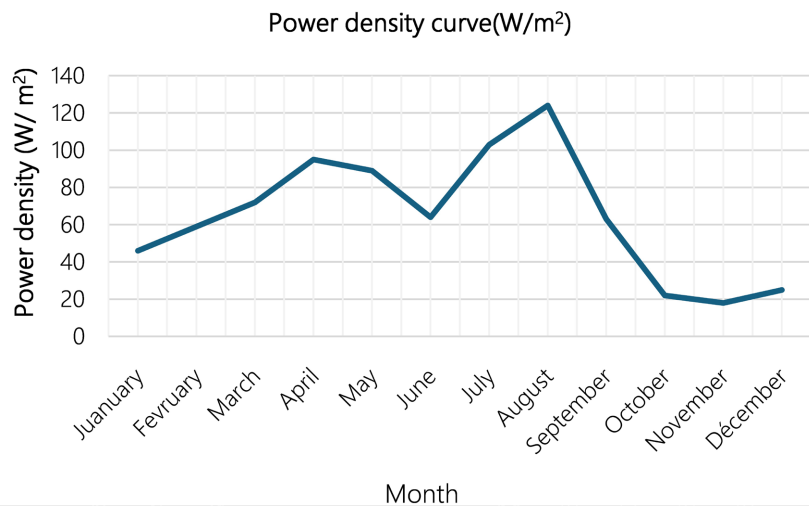


Figure 8. Evolution of interannual power density.

The results obtained show the calculated average speed is higher during the months of July and August, for which the power density reaches 103 W/m² and 124 W/m² respectively. This result agrees with the results presented previously on the average wind characteristics.

- Summary of Weibull parameters and power density

The weibull parameters and power density are summarized in **Table 1**.

Table 1. Weibull parameters and monthly power density.

Month	Scale factor (m/s)	Form factor	Average speed (m/s)	Power density (W/ m ²)
January	4.00	2.19	3.50	46
February	4.30	2.31	3.81	59
March	4.90	2.87	4.34	72
April	5.40	3.08	4.82	95
May	5.30	3.47	4.81	89

Continued

June	4.80	3.45	4.31	64
July	5.50	3.06	4.95	103
August	5.80	2.70	5.14	124
September	4.50	2.48	4.01	63
October	3.20	2.55	2.84	22
November	2.90	2.27	2.59	18
December	3.30	2.49	2.95	25

- Annual available power

The power and energy available for the 6 years are presented in **Table 2**.

Table 2. Power and energy available for each year of study.

Years	Pd (W/m ²)	Ed (kWh/m ²)
2018	205.07	1796.38
2019	187.08	1638.82
2020	205.87	1803.46
2021	185.00	1620.57
2022	207.61	1818.69
2023	178.17	1560.79

We observe in **Table 2**, the year 2022 presents the best potential with 207.61 W/m² while the low potential was observed in 2023 with 178.17 W/m².

- Histogramme de la fréquence du vent Wind frequency histogram

The frequency histograms associated with the Weibull distribution curve for each year and for all the data are also determined. The results in **Figure 9** show, the observed distribution follows the Weibull distribution well.

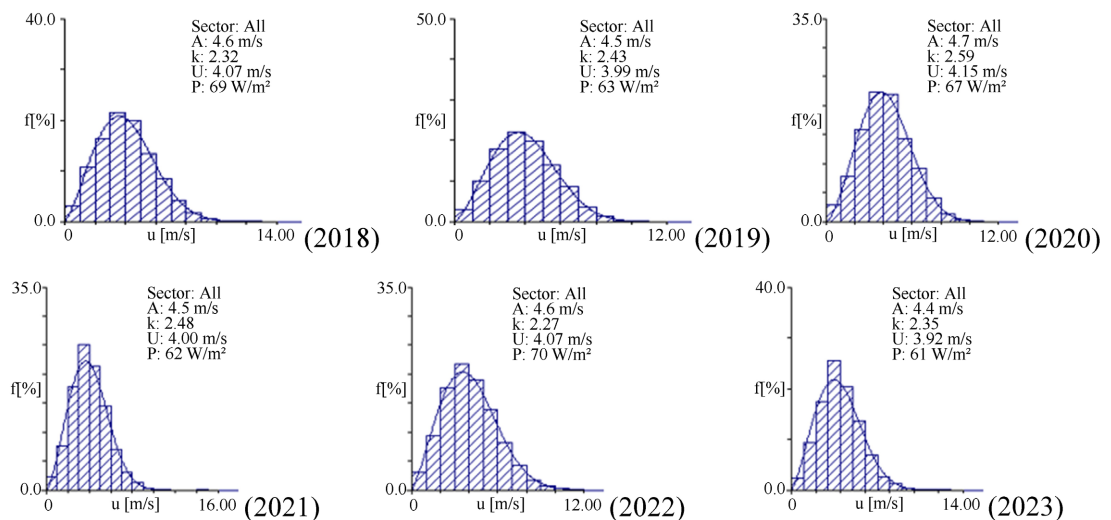


Figure 9. Frequency distribution of average wind speed.

- Wind power available

Figure 10 represents the histogram and weibull distribution of wind speed for Kanfarandé site. While **Figure 11** gives the available wind powers available at kanfarandé site. According to **Figure 11**, we notice the available powers are very important throughout the locality, especially near the ocean, with a slight variation from 194.43 to 195.29 W/m².

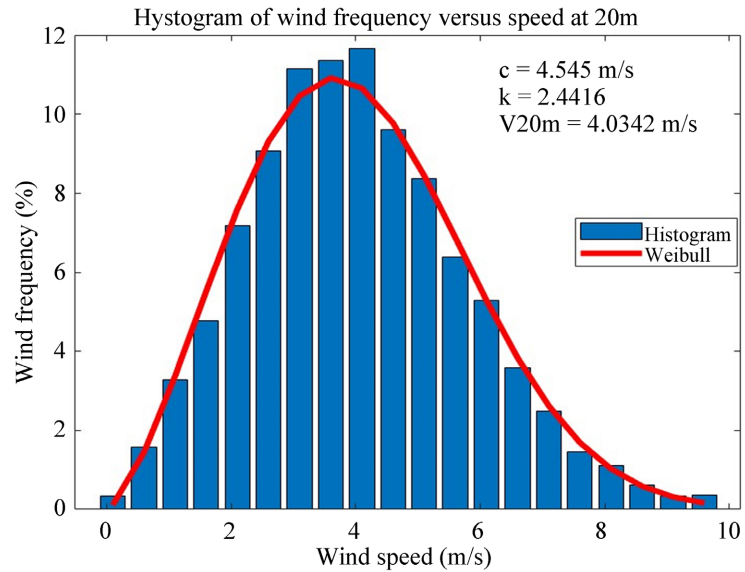


Figure 10. Histogram and Weibull distribution of wind speeds.

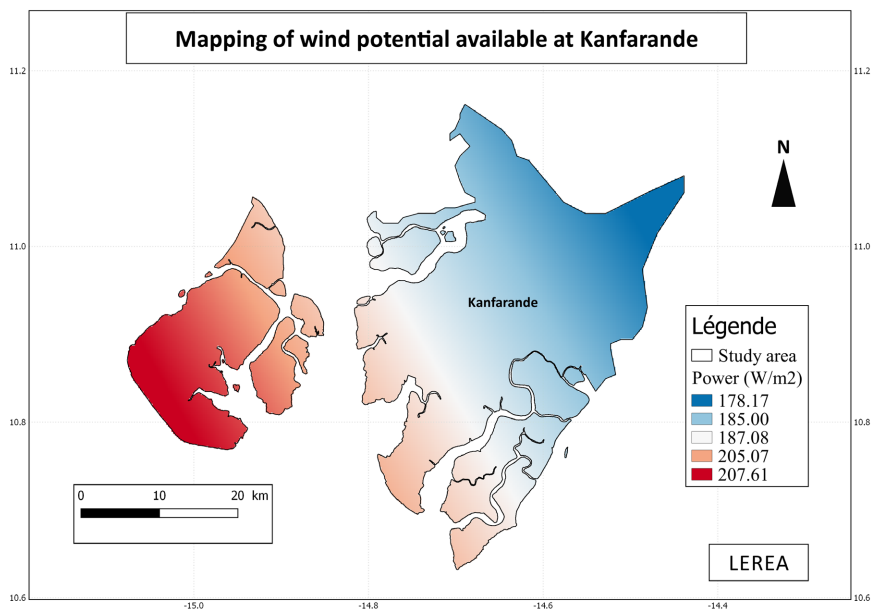


Figure 11. Available wind power.

3.4. Discussion

In this study, we examined wind potential of the Kanfarandé site at an altitude of

20m which allowed us to get a form factor of 2.40, a scale factor of 4.5 m/s, an annual power density of 65 W/m² and a monthly potential of 103 to 124 W/m². These values are close to that found by [10] [(B. Ould Bilal, 2008)] namely 65 and 85 W/m² respectively, with a slight difference in altitude elevation of 10 and 20 m. In his study he obtained: a form factor of 2.58; a scale factor of 5m/s; an available power of 85 W/m² and a monthly potential varying from 113 to 116 W/m². However, we note the power density obtained by [10] is slightly higher than that found in this study with a difference of 10 W/m².

4. Conclusions

The assessment of wind potential was carried out on 6 years data collected by NASA satellite and Boké meteorological station. Wind data acquisition (speed and direction) was done every 3 hours. The results obtained show: An overall coverage rate of 100% for all the data, which shows, they are enough representative to assess wind potential during the study period. The average wind characteristics analysis shows wind potential is greater for the months of July and August and it is greater during the day than at night. The statistical study allowed us to determine the wind rose which shows that the dominant wind direction is the South-West. The results obtained show the wind data fits well with the Weibull law. We thus found greater wind potential for the months of July and August (103 W/m² and 124 W/m² respectively). Thus we found an available power of 194.80 W/m² and an annual available energy of 1706.45 kWh/m² at 20 m above the ground.

It would be interesting to perform the study on a larger database (over 20 years) and to assess wind potential on other potential sites in order to establish a Guinea's wind potential map.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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