Assessment of Wind Energy Potential for achieving Sustainable Development Goal 7 in the Rural Region of Jeje, Nigeria

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ABSTRACT

The implementation of a decentralized energy system has the potential to improve the life quality of the people who live in remote rural areas with limited or nonexistent power sources. Renewable energy technologies can be very important in the production of power. The main purpose of this study is to assess Jeje, Nigeria's wind energy potential, using a reanalysis and analysis dataset. To this aim, data on wind speed at a height of 10 m were gathered from a variety of sources, including EAR5, EAR5 Ag, EAR5 Land, CFSR, and MERRA-2. The Weibull distribution function, commonly employed to evaluate wind energy potential, was utilized. A maximum wind power density value of 15.75 W/m^2 was obtained when the MERRA-2 dataset was implemented. The results indicate that large-scale wind turbines are not a viable alternative in this area. Thus, the performance of six wind turbines, expressed by output power with a cut in speed ranging between 1 and 1.5 m/s, was investigated. The results demonstrated that the AWI-E1000T is the most efficient wind turbine under consideration. In addition, it has been shown that each considered turbine can be installed in this area based on the data acquired from the MERRA-2 and CFSR.

Keywords-wind energy potential; Jeje, Nigeria; Nigeria; small scale wind turbine; wind speed characterization

I. INTRODUCTION

Energy has a crucial part as a catalyst in industrialization and economic growth [1]. The world's energy needs are met in a large part by the global energy supply system, which is mostly dependent on fossil fuels [2]. Due to the depletion of fossil fuel supplies and their negative effects on the environment, renewable energy can be viewed as an alternate response to the current energy problem [3]. Renewable energy sources, like wind power, are growing more competitive economically and expanding quickly [4]. One of the most promising alternative energy sources is wind energy, which has an enormous global potential. The first benefit of wind energy is that it is widely available. Certain countries have higher wind potential due to their advantageous geographic location [7]. The second benefit is the enormous energy production that commercial wind turbines can produce [8].

For economic development and the construction of a wind power farm in a specific location, certain wind characteristics are needed [9]. Generally, the two-parameter Weibull distribution function is a widely recognized and effective method for representing the distribution of wind speed [10]. The average Wind Power Density (WPD) can be used to evaluate the wind energy potential of a region once the parameters of the Weibull distribution have been determined deploying wind speed data. Numerous scholars have investigated the potential wind energy and wind speed characteristics in different locations. For instance, authors in [11] utilized actual data collected at a height of 80 m to determine the Weibull parameters in Osmaniye, Turkey. Authors in [12] evaluated the wind energy potential at Imphal, Manipur India applying the Weibull distribution function. Authors in [13] utilized the Weibull distribution function to analyze the wind characteristics and wind energy potential at Ardal and Faridan in Iran. Authors in [14] assessed wind energy potential in Northern Morocco putting into service the Weibull distribution function. The aforementioned studies manifest that the first phase of assessing wind power potential involves measuring wind speed data at the specific location of the planned wind power establishment using an anemometer [15, 16]. On the other hand, in certain cases, actual measurement of wind speed may be difficult due to logistical concerns, financial constraints, or lack of monitoring infrastructure. In such instances, a source that can provide the required data to estimate wind speed is gridded datasets [17]. Over a grid of geographic locations, gridded datasets offer data on a range of weather-related variables [18]. Observational data, satellite imaging, and numerical models are combined to generate these datasets [17, 18]. Several researchers have employed satellite databases [19–39]. For instance, authors in [19] assessed the wind energy potential in Libya's coastal agricultural regions using TerraClimate (gridded climate dataset offering historical climate information on a global scale), ERA5 (Fifth Generation of the European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis), ERA5-Land (ERA5-Land has been produced by replaying the land component of the ECMWF ERA5 climate reanalysis), MERRA-2 (Second-generation Modern-ERA Retrospective Analysis for Research and Applications), and CFSR (NCEP (NOAA NWS National Centers for Environmental Prediction) Climate Forecast System Reanalysis dataset). Authors in [20] engaged measured data from 2009 to 2018 to examine the reliability of the ERA5 dataset at three windy locations in the southwest of the Algerian Sahara. Authors in [21] assessed the accuracy of ERA-Interim (the third-generation reanalysis dataset produced by the European Center for Medium-Range Weather Forecasts (ECMWF)), JRA-55 (the second Japanese global atmospheric reanalysis project provided by the Japan Meteorological Agency), CFS, and MERRA-2 in the Northern Hemisphere region using measured wind speed. Authors in [22] implemented a NASA dataset to assess the wind energy potential of three coastal cities in Cameroon.

The lack of reliable electricity supply is one of the main issues Nigeria is facing today [40-43], limiting both the country's economic development and technological improvement. This explains why stakeholders seem to be placing more emphasis on power generation and a consistent supply of power. Most urban residents are keeping up with advancement, globalization, and a good standard of living, but, in many rural areas, the lack of electricity has resulted in poverty, increasing economic gaps, and more challenges in living standards. Approximately 22.6% of Nigerians living in rural areas have access to electricity.

The contribution of this work is the evaluation of the wind energy potential in the rural area of Jeje community, Nigeria, for the first time, employing five satellite-based wind energy products. The Weibull distribution function is deployed to assess the wind speed characteristics to estimate the wind power-producing potential. Besides, the WPD value for the selected location was estimated for each month and season (rainy and dry seasons). Moreover, the performance of small-scale wind turbines with different characteristics is assessed considering the WPD value. The results disclose that employing large-scale wind turbines in the area is not feasible.

II. MATERIALS AND METHODS

A. Study Area

Nigeria is regarded as one of the world's eight most populous countries. It has long struggled with water constraints in several of its states and now explores both short- and long-term solutions to growth, infrastructure, and environmental difficulties. Given that the country is home to over 152 million people, just 30% of them have access to enough clean drinking water, making water scarcity one of the most pervasive issues in existence. The rate of access to facilities for appropriate sanitation fell from 39% in 1990 to 35% in 2010, with a discernible fall, particularly in metropolitan areas. In this paper, Jeje Community has been chosen as a case study. Jeje Community is located in the Karu Local Government Area of Nasarawa State, a state in the Northern Central area of Nigeria.

B. Data on Agricultural Farms through the Survey

To assess data on agricultural farms and gather perspectives from farm owners, a straightforward survey was carried out at the location selected for the current study. To collect data, a mixed-method survey that combined qualitative and quantitative techniques was implemented. There were direct questions in the survey, with both multiple-choice and open-ended questions. It is noteworthy that the majority of farms in the selected area have similar requirements.

A typical farm occupies an area of 2000 m^2. It consists of different parts, including the house, the crops, and several barns for fish, pigs, poultry (chicken), rabbits, and grass cutters. Moreover, the farm has a water well exploited for domestic use, irrigation, and other purposes. Additionally, the farm uses a variety of agricultural equipment such as:

- Tiller & Cultivator (120 V, 12 A, and 1440 W), which is used to cultivate maize, beans, and groundnuts.
- Water Pump (115 V, 9.5 A, and 1100 W) utilized for facilitating domestic use, irrigation, and water management on the farm.
- Pound Aerator (360 W) employed for fish farming, ensuring proper aeration in the ponds.
- Electrical fencing system (25 W) deployed to secure poultry, rabbits, and grass cutters.
- An automatic Poultry Feeder (50 W) is put into service for feeding chickens and an electric heat lamp (150W) for providing warmth to chickens and piglets.
- An Electric Fertilizer Spreader (420W) is used for the efficient spreading of manure across the farm.

Generally, 50% of the electricity is provided by diesel generators and the remaining 50% is supplied by the grid for the majority of the farms in the Jeje area. Furthermore, the monthly expenses for fuel and electricity amount to 30,000 and 10,000 Nigerian Naira (₦), respectively. Accordingly, the family farm's daily electricity consumption is projected to be 8 kWh for the household and 10 kWh for farm uses when all of these factors are taken into account.

C. Wind Speed Dataset

Reanalysis and analysis of datasets include large-scale meteorological data produced by sophisticated data assimilation methods [19]. These datasets are the product of combining many observational sources deploying advanced mathematical models, including observations from weather stations, satellite data, and other relevant inputs [17]. In this study, five datasets, were chosen based on their high spatial resolution, coverage domain, and periods of availability as depicted in Table I.

TABLE I. MAIN CHARACTERISTICS OF THE CONSIDERED SATELLITE DATABASES

Database	Main characteristics	
ERA5	Description	5th-generation reanalysis product of the European Centre for Medium-Range Weather Forecasts
	Resolution	0.05°/1 d
	Period	1979-01-02–present
	Spatial extent	Global
ERA5-Ag	Description	This dataset is based on the hourly ECMWF ERA5 data at the surface level.
	Resolution	0.1° × 0.1°
	Period	1979-01-01–present
	Spatial extent	Global
ERA5-Land	Description	ERA5-Land has been produced by replaying the land component of the ECMWF ERA5 climate reanalysis
	Resolution	0.125°×0.125°
	Period	1963-07-11-present
	Spatial extent	Global
MERRA-2	Description	2nd-generation modern-era retrospective analysis for research and applications
	Resolution	0.5° × 0.625°
	Period	1981-present
	Spatial extent	Global
CFSR	Description	NCEP (NOAA NWS National Centers for Environmental Prediction) climate forecast system reanalysis dataset
	Resolution	1/5°
	Period	1979-present
	Spatial extent	Global

D. Probability Distribution Models

Wind speed analysis is essential for the optimal design and operation of wind energy facilities. Wind speed characteristics in a given area are described using probability distribution models. Therefore, determining the best distribution model is the first step in evaluating the wind energy potential at a particular location. Wind speed data at a given location are often evaluated utilizing two-parameter Weibull (2p-W). This statistical model accurately represents the pattern of wind speed data and is both flexible and robust. The Weibull distribution is essentially characterized by the probability density function ($f(v)$) and cumulative distribution function ($F(v)$), which can be seen in (1) and (2) [31]. Two parameters affect the shape of the curve: the scale parameter (c) changes the mean wind speed, which represents the standard deviation of the wind speed at the location, and the parameter (k) that defines the peak or spread of the curve.

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

$$F(v) = 1 - \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (2)$$

with $v > 0, k > 0, c > 0$.

This study followed the Maximum Likelihood Method (MLM) due to its proven effectiveness. Using MLM, the parameters k and c of the Weibull distribution are estimated as [32]:

$$k = \left[\frac{\sum_{i=1}^{n} v_i^k \ln(v_i)}{\sum_{i=1}^{n} v_i^k} - \frac{1}{n}\sum_{i=1}^{n} \ln v_i\right] \quad (3)$$

$$c = \left(\frac{1}{n}\sum_{i=1}^{n} v_i^k\right) \quad (4)$$

Equation (3) requires a numerical solution for the parameter k, and a bisection approach was deployed in this inquiry to solve (4).

E. Wind Power Density

When assessing the potential of wind resources and determining, the amount of wind energy available at a given location, WPD is a crucial metric [17, 19]. This feature is essential for identifying the best kind of wind turbine for a particular location and evaluating wind turbine production [56]. Equation (5) is employed to calculate the WPD in W/m^2 using wind speed data.

$$\frac{P}{A} = \frac{1}{2}\rho c^3 \Gamma\left(\frac{k+3}{k}\right) \quad (5)$$

where ρ denotes the air density (kg/m^3). The standard air density is taken to be ρ = 1.225 kg/m^3.

Furthermore, the wind energy potential is categorized according to the average WPD as displayed in Table II.

TABLE II. MAIN CHARACTERISTICS OF THE SATELLITE DATABASE USED IN THE STUDY

Class number	Power class	P (W/m^2) at 10 m	P (W/m^2) at 30 m
1	Poor	≤100	≤160
2	Marginal	≤150	≤240
3	Moderate	≤200	≤320
4	Good	≤250	≤400
5	Excellent	≤300	≤480
6	Excellent	≤400	≤640
7	Excellent	≤1000	≤1600

F. Power Law

In general, a standard height of 10 m above the ground is typically employed to gather wind speed data. Utilizing the power law model, wind speeds can be estimated at various hub heights:

$$\frac{v}{v_{10}} = \left(\frac{z}{z_{10}}\right)^{\alpha} \quad (6)$$

where v is the wind speed at the wind turbine hub height z, v_{10} is the wind speed at the original height z_{10}, and α is the surface roughness coefficient, which depends on the characteristics of the region. The value of α can be determined by:

$$\alpha = \frac{0.37 - 0.088 ln(v_{10})}{1 - 0.088 ln(z_{10}/10)} \quad (7)$$

G. Output Power of Wind Turbines

In general, a wind turbine's capability to produce electricity varies with wind speed, as seen in Figure 1. Before generating any significant power, a wind turbine needs the wind to achieve its required speed (v_{ci}). From this point on, power generation rises to the wind turbine's rated speed (v_R). When the wind speed is higher than the rated wind speed value, the wind turbine produces stable (rated) power (P_R) up to the rated wind speed. When the wind speed exceeds the cut-off wind speed (v_{co}), the energy generation is halted to prevent damage to the wind turbines.

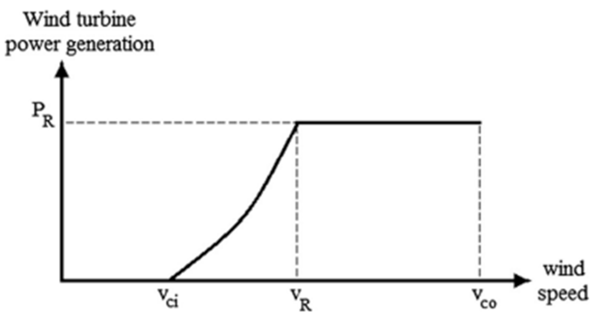


Fig. 1. A wind turbine's power generation curve.

Thus, a wind turbine's power production can be described as [9]:

$$P_{out} = P_R \left[\frac{exp\left[-\left(\frac{v_{ci}}{c}\right)^k\right] - exp\left[-\left(\frac{v_R}{c}\right)^k\right]}{\left(\frac{v_R}{c}\right)^k - \left(\frac{v_{ci}}{c}\right)^k} - exp\left[-\left(\frac{v_{co}}{c}\right)^k\right] \right] \quad (8)$$

It is necessary to compute the shape (k) and scale (c) parameters at the hub heights of the chosen turbine. The following equations are used for this purpose [9]:

$$k_z = k_a \left[\frac{1 - 0.088 \times ln\left(\frac{z_a}{10}\right)}{1 - 0.088 \times ln\left(\frac{z}{10}\right)} \right] \quad (9)$$

$$c_z = c_a \left(\frac{z}{z_a}\right)^n \quad (10)$$

$$n = \frac{0.37 - 0.088 \times ln c_a}{1 - 0.088 \times ln\left(\frac{z_a}{10}\right)} \quad (11)$$

where k_a and c_a are the shape and the scale parameters at height z_a = 10 m and k_z and c_z are the shape and the scale parameters at height z (hub-height of the turbine).

Equation (12) is engaged to estimate the wind turbine's Capacity Factor (CF) [2]:

$$CF = \frac{E_{out}}{8760 P_R} \quad (12)$$

III. RESULTS AND DISCUSSION

A. Descriptive Statistics of Various Dataset Sources

The descriptive statistical representation of the wind speed data, including mean, standard deviation, minimum, and maximum for the chosen sites based on multiple data sources, is illustrated in Figure 2. The mean wind speed varied from 0.52 to 2.03 m/s according to the EAR5 data. October and April recorded the highest and lowest wind speed values, respectively. According to EAR5 Ag data, the average wind speed varied between 1.08 m/s (September) and 1.93 m/s (April). By the EAR5 Land data, the mean wind speed fluctuated between 0.49 m/s in October and 1.87 m/s in April, whereas the average wind speed varied from 1.57 m/s (September) to 3.55 m/s (January) based on MERRA-2 data. EAR5 Ag data indicate that the average wind speed ranges between 1.10 m/s in November and 2.33 m/s in May. Moreover, the wind behavior appears to be quite consistent, as seen by the mean speed and standard deviation values. In general, spatial resolution greatly affects the resolution and detail in both reanalysis and satellite data. The accuracy may be affected by processing methods, which may compromise inconsistency. Therefore, analysis of comparisons with real measurements provides insight into limitations and dependencies that are essential to determining how useful these data are for estimating wind potential at a given location.

B. Weibull Parameters and Wind Power Density

According to various data sources, Figure 3 depicts the parameters k and c of the Weibull distribution function. It should be noted that these parameters were estimated using the MLM based on mean daily wind speed data gathered from different datasets. It is found that the k values are within the range of 6.52-20.43, 14.72-35.00, 6.62-20.39, 8.92-26.24, and 9.91-31.06 considering data from EAR5, EAR5 Ag, EAR5 Land, MERRA-2, and CFSR, respectively. The lowest value of 6.52 m/s occurred in September, and the highest value of 35.00 m/s was observed during the rainy season. Besides, it has been found that when the EAR5, EAR5 Ag, EAR5 Land, MERRA-2, and CFSR data were considered, the ranges of the k value are: 0.84-1.81 m/s, 1.20-1.87 m/s, 0.72-1.65 m/s, 1.86-3.06 m/s, and 1.35-2.20 m/s, respectively. The maximum c value of 3.06 m/s was obtained in January, while the minimum value was recorded in November. Figure 4 displays the Weibull distribution plots at a height of 10 m for each month and season according to the considered datasets. WPD is calculated utilizing (5) to evaluate the wind potential in the selected location. The value of WPD for each location is tabulated in Figure 5. The value of WPD lied within the range of 0.33-3.23 W/m^2 for EAR5, 0.95-3.06 W/m^2 for EAR5 Ag, 0.21-2.45 W/m^2 for EAR5 Land, 3.50-15.75 W/m^2 for MERRA-2, and 1.34-5.79 W/m^2 for CFSR. Furthermore, it is noted that the WPD value for both the rainy and dry seasons falls between 0.42 and 8.52 W/m^2. The chosen location can be categorized as poor (WPD < 100 W/m^2) based on wind power classification at 10 m height (see Table II). Consequently, high-capacity (MW) commercial wind turbines are not appropriate for usage in this region. However, small-scale wind turbines can be deployed to take advantage of the region's potential for wind energy.

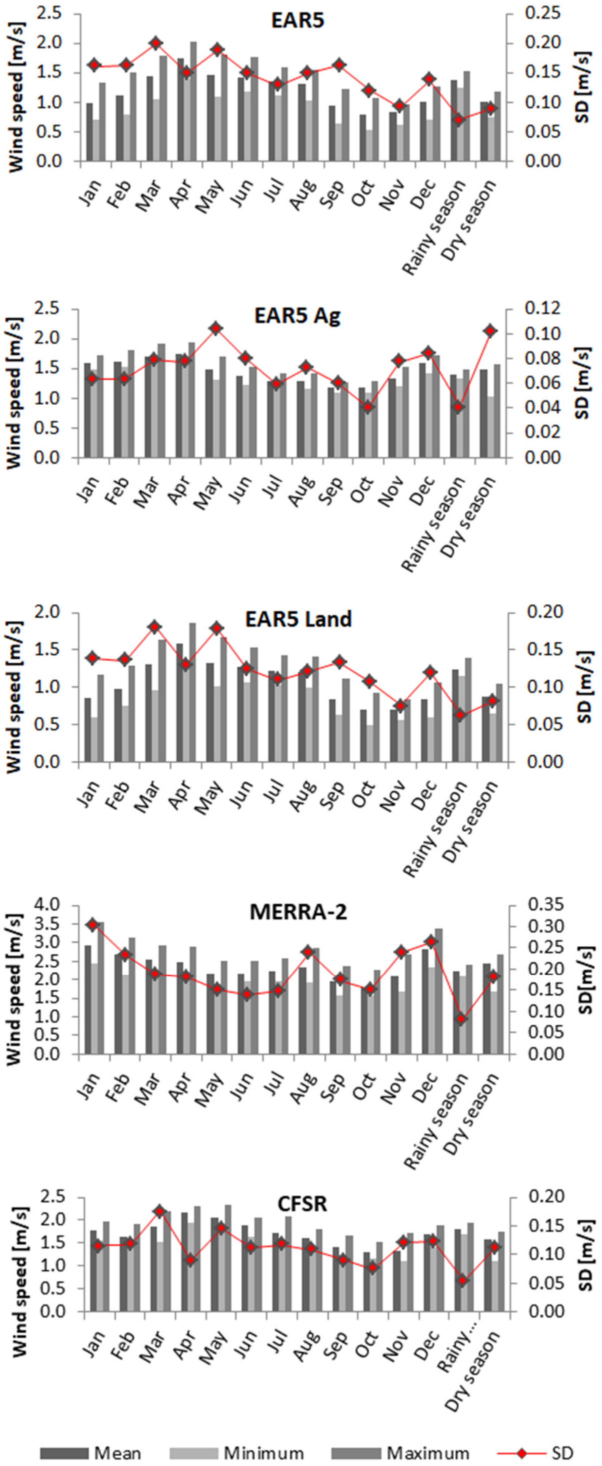


Fig. 2. Descriptive statistics of wind speed data.

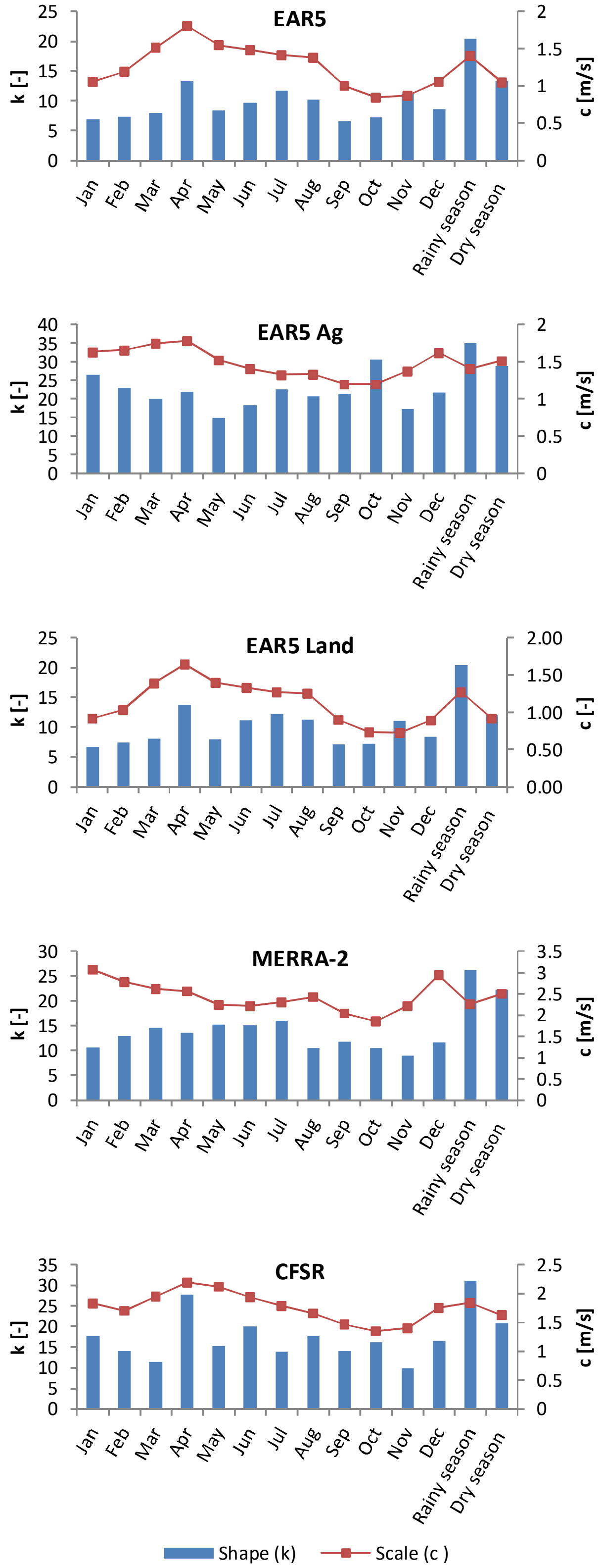


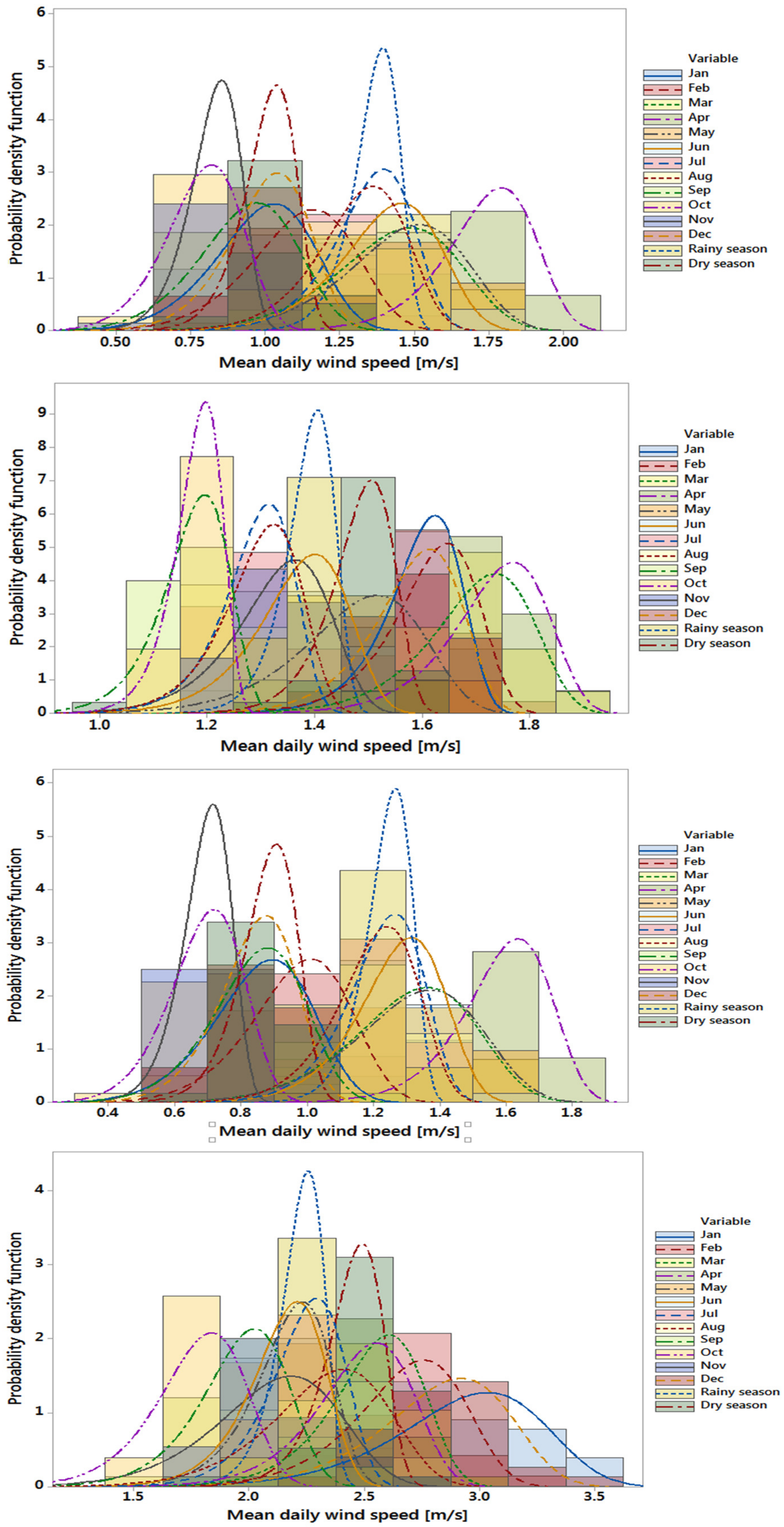
Fig. 3. Weibull parameters.

(a)

(b)

(c)

(d)


Probability density function
Mean daily wind speed [m/s]
Variable
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Rainy season
Dry season

(e)

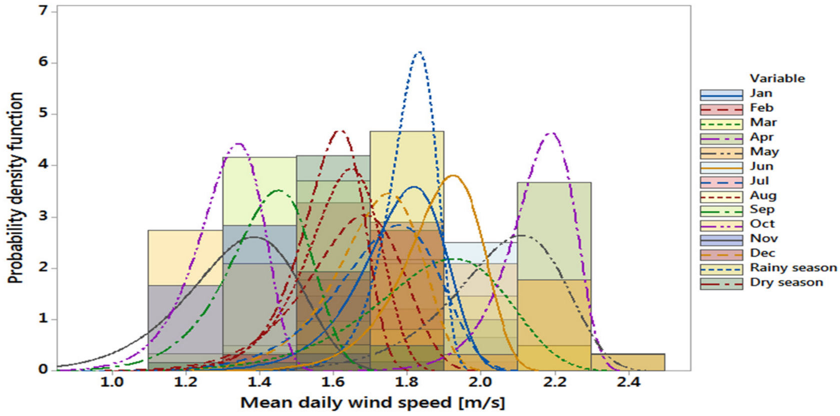
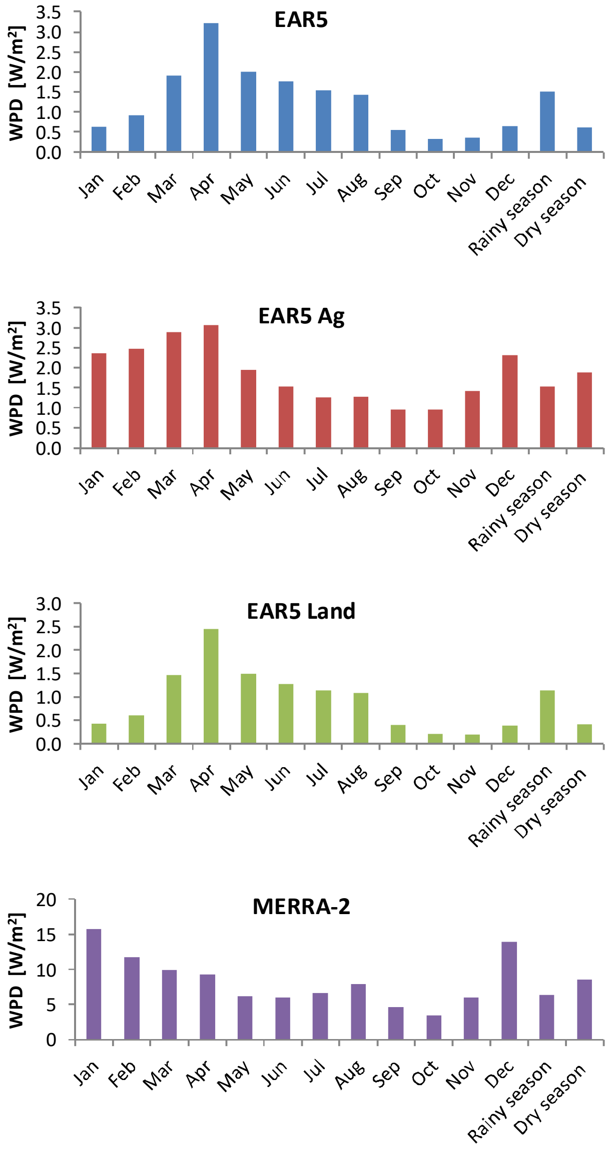


Fig. 4. Histograms of the collected wind data at 10 m height and the Weibull distribution of wind speed for each month and season. (a) EAR5, (b) EAR5 Ag. (c) EAR5 Land, (d) MERRA-2, and (e) CFSR.



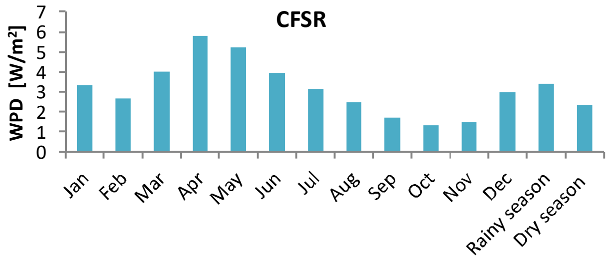


Fig. 5. WPD value for each month and season.

C. Selection of Wind Turbines

Cut-in wind speed, CF, cost, and space requirements are the most essential factors that must be carefully contemplated during the selection of a wind turbine for an area with low wind speeds [44, 45]. The cut-in speed of wind turbines, at which they can start producing power, ranges between 2.0 and 4.0 m/s [46] or 2.5-3.5 m/s [47]. The majority of wind turbines with a cut-off speed greater than 1.9 m/s, and a center height of less than 65 m, were determined to be unsuitable for the area due to the relatively low wind speeds. Consequently, the cut-in speed represents the most crucial aspect to be taken into account considering selecting a wind turbine in the present investigation. It is more important to ensure that the turbine can begin producing power efficiently under the given wind conditions than it is to consider the CF, cost, and space needs. The specifications of the considered wind turbines for this purpose are listed in Table III. These turbines were selected due to their low cut-in speed values.

D. Wind Energy Production Assessment of Small-Scale Wind Turbines

Table IV provides the estimated seasonal and monthly average production of a wind turbine based on (6). With an annual energy production ranging from 28.13 kWh to 4.07 kWh, it is evident that the AWI-E1000T is the most efficient wind turbine among those under consideration. Furthermore, all the selected turbines were determined as appropriate for installation in this region based on data collected from the MERRA-2 and CFSR datasets as observed in Table IV.

TABLE III. MAIN CHARACTERISTICS OF THE CONSIDERED WIND TURBINES

Model	Specification	Value
WKV-600	Rotor height [m]	25
	Rated power [kW]	0.6
	Cut-in wind speed [m/s]	1.3
	Rated wind speed [m/s]	12
	Cut-off wind speed [m/s]	-
YWS-500 Wind Luce	Rotor height [m]	25
	Rated power [kW]	0.5
	Cut-in wind speed [m/s]	1
	Rated wind speed [m/s]	12.5
	Cut-off wind speed [m/s]	60
AWI-E1000T	Rotor height [m]	25
	Rated power [kW]	1
	Cut-in wind speed [m/s]	1
	Rated wind speed [m/s]	15
	Cut-off wind speed [m/s]	60
BT-5KH	Rotor height [m]	25
	Rated power [kW]	5
	Cut-in wind speed [m/s]	1.5
	Rated wind speed [m/s]	9
	Cut-off wind speed [m/s]	65
BT-5KP	Rotor height [m]	25
	Rated power [kW]	3
	Cut-in wind speed [m/s]	1.5
	Rated wind speed [m/s]	9
	Cut-off wind speed [m/s]	65
BT-3KR	Rotor height [m]	25
	Rated power [kW]	1000
	Cut-in wind speed [m/s]	1.5
	Rated wind speed [m/s]	9
	Cut-off wind speed [m/s]	65

The AWI-E1000T turbine is the most efficient wind turbine under examination, generating 72.75 kWh of electricity annually. Since the AWI-E1000T turbine produced more energy than earlier turbines, its low cut-in and rated speeds were essential to its operation. Two factors need to be reviewed to determine the maximum number of wind turbines that could be installed at a given location: (1) In case the wind direction is perpendicular to the turbine's diameter, the distance between wind turbines should be 3–5 times the turbine's diameter (2), otherwise, it should be 6–9 times the turbine's diameter.

It should be noted that the expected power of wind turbines is specific to a single turbine. Equation (13) can be utilized to identify the number of wind turbines required to meet the energy needs of family farms.

$$TN = \frac{TEC}{EO \times \eta \times CF} \quad (13)$$

where *TN* is the number of turbines, *TEC* is the total energy consumption, *EO* is the energy output per turbine, and η is the efficiency, which refers to how much of the wind energy is converted into electricity:

$$\eta = \frac{Electric\ output\ power}{available\ wind\ power} \times 100 \quad (14)$$

IV. LIMITATIONS AND FUTURE WORK

It is essential to acknowledge several limitations to this research requiring additional analysis and clarity in future investigations.

- One of the main limitations of the current study is the lack of measured data. Consequently, wind direction and speed measurements at the selected place are substantial to provide accurate results for estimating the wind energy potential.
- The impact of economic data on wind turbine performance, which is crucial to the techno-economic model, was not investigated in this study. Future studies should examine the impact of economic issues on wind farm performance. This can be performed through the employment of mathematical models, which provide a more complete evaluation of the financial effects of wind energy projects.
- Moreover, for future developments, it is necessary to develop wind turbines, especially vertical axis wind turbines, taking the special requirements of the chosen region into account. A high CF and a minimum cutting speed of less than 1 m/s are the goals this turbine is supposed to aim for. Using computational fluid dynamics simulations or experimental studies, the turbine design may need to be modified to obtain maximum power to achieve this goal.

V. CONCLUSIONS

The current study investigated the potential of wind energy in the Jeje community in Nigeria. To achieve this, two Weibull distribution parameters were calculated utilizing wind speed data gathered from several sources (EAR5, EAR5 Ag, EAR5 Land, CFSR, and MERRA-2). Besides, the Wind Speed Density (WPD) values at a height of 10 m above the ground were calculated after the estimation of the parameters of the Weibull distribution function. It was observed that the highest WPD value of 15.75 W/m^2 was recorded when utilizing the MERRA-2 dataset. This result indicates that large-scale wind turbines are not a suitable source of electricity generation from the wind in this area. To generate wind power, six different small-scale wind turbines were selected due to their low cut-in speed values and their output power was estimated. It was seen that from the considered wind turbines, the AWI-E1000T was the most efficient. Furthermore, using the data gathered from the MERRA-2 and CFSR, it has been determined that all the considered turbines are suitable for installation in this region.

In summary, the current study assessed the wind energy potential in Jeje, Nigeria and it was found that the area is appropriate for producing wind energy with small-scale wind turbines. A hybrid system that combines solar cells and a small wind turbine may be taken into consideration if there is an increased demand for electricity.

TABLE IV. OUTPUT POWER PRODUCED BY THE SELECTED WIND TURBINE IN KWH

Model	Month	EAR5	EAR5 Ag	EAR Land	MERRA-2	CFSR	Model	Month	EAR5	EAR5 Ag	EAR Land	MERRA-2	CFSR
WKV-600	Jan	0.75	9.32	*	39.26	12.43	BT-5KH	Jan	*	113.97	*	564.83	160.72
	Feb	2.07	8.77	0.52	29.27	9.09		Feb	7.28	108.11	*	416.85	112.95
	Mar	6.62	11.15	4.84	28.88	14.10		Mar	73.23	141.44	46.41	408.41	185.93
	Apr	11.42	11.38	8.89	26.70	19.38		Apr	146.38	145.83	108.21	376.41	266.29
	May	7.09	7.35	4.99	20.43	17.91		May	80.33	84.27	48.69	281.18	243.19
	Jun	6.11	5.52	4.17	19.39	13.99		Jun	66.36	57.60	37.19	266.36	185.07
	Jul	5.47	4.58	3.69	21.85	11.71		Jul	55.85	42.50	29.09	302.56	149.93
	Aug	4.89	4.63	3.35	23.91	9.51		Aug	47.20	43.29	23.97	333.55	116.79
	Sep	0.13	2.86	*	15.51	6.21		Sep	*	17.51	*	207.98	67.93
	Oct	*	3.08	*	12.60	4.90		Oct	*	19.98	*	163.32	47.28
	Nov	*	5.03	*	18.33	5.18		Nov	*	50.11	*	250.46	52.43
	Dec	0.92	9.03	*	36.43	11.17		Dec	*	109.60	*	522.16	141.80
	Annual	3.30	6.88	1.68	24.40	11.23		Annual	23.21	77.12	*	341.01	142.59
	Rainy season+	5.69	6.02	3.91	21.53	13.06		Rainy season+	59.25	64.19	32.36	297.78	170.24
	Dry season +	1.17	7.76	*	27.40	9.48		Dry season +		90.48	*	386.23	116.28
YWS-500 Wind Luce	Jan	2.23	8.78	1.18	31.65	11.15	BT-5KP	Jan	*	68.38	*	338.90	96.43
	Feb	3.07	8.19	1.89	23.85	8.43		Feb	4.37	64.87	*	250.11	67.77
	Mar	6.71	10.17	5.35	23.71	12.43		Mar	43.94	84.86	27.84	245.05	111.56
	Apr	10.32	10.30	8.39	21.99	16.41		Apr	87.83	87.50	64.92	225.85	159.77
	May	7.07	7.27	5.47	17.26	15.33		May	48.20	50.56	29.22	168.71	145.91
	Jun	6.26	5.82	4.79	16.41	12.29		Jun	39.82	34.56	22.32	159.81	111.04
	Jul	5.83	5.15	4.47	18.34	10.60		Jul	33.51	25.50	17.46	181.53	89.96
	Aug	5.39	5.19	4.21	19.91	8.92		Aug	28.32	25.97	14.38	200.13	70.07
	Sep	1.70	3.79	1.04	13.45	6.34		Sep	*	10.51	*	124.79	40.76
	Oct	0.66	4.01	*	11.28	5.39		Oct	*	11.99	*	97.99	28.37
	Nov	0.89	5.44	*	15.60	5.56		Nov	*	30.07	*	150.28	31.46
	Dec	2.35	8.55	1.04	29.48	10.19		Dec	*	65.76	*	313.29	85.08
	Annual	4.17	6.91	2.93	20.29	10.23		Annual	13.92	46.27	*	204.60	85.56
	Rainy season+	6.00	6.25	4.64	18.10	11.63		Rainy season+	35.55	38.51	19.42	178.67	102.14
	Dry season +	2.55	7.58	1.45	22.59	8.89		Dry season +	*	54.29	*	231.74	69.77
AWI-E1000T	Jan	3.09	12.17	1.64	43.87	15.45	BT-3KR	Jan	*	22.79	*	112.97	32.14
	Feb	4.26	11.35	2.62	33.06	11.69		Feb	1.46	21.62	*	83.37	22.59
	Mar	9.30	14.10	7.41	32.87	17.23		Mar	14.65	28.29	9.28	81.68	37.19
	Apr	14.31	14.27	11.63	30.48	22.74		Apr	29.28	29.17	21.64	75.28	53.26
	May	9.80	10.08	7.58	23.92	21.25		May	16.07	16.85	9.74	56.24	48.64
	Jun	8.68	8.07	6.63	22.75	17.03		Jun	13.27	11.52	7.44	53.27	37.01
	Jul	8.08	7.14	6.20	25.43	14.69		Jul	11.17	8.50	5.82	60.51	29.99
	Aug	7.47	7.20	5.84	27.60	12.36		Aug	9.44	8.66	4.79	66.71	23.36
	Sep	2.36	5.25	1.44	18.64	8.79		Sep	*	3.50	*	41.60	13.59
	Oct	0.91	5.56	*	15.63	7.48		Oct	*	4.00	*	32.66	9.46
	Nov	1.23	7.54	*	21.63	7.70		Nov	*	10.02	*	50.09	10.49
	Dec	3.26	11.86	1.44	40.87	14.12		Dec	*	21.92	*	104.43	28.36
	Annual	5.78	9.57	4.07	28.13	14.18		Annual	4.64	15.42	*	68.20	28.52
	Rainy season +	8.32	8.66	6.43	25.09	16.12		Rainy season+	11.85	12.84	6.47	59.56	34.05
	Dry season+	3.54	10.51	2.01	31.31	12.33		Dry season +	*	18.10	*	77.25	23.26

* The wind speed of the location is less than the cut-in speed

+ Value of average energy production in the rainy season (April to September) and dry season (December to March)

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