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Evaluation of wind power potential in three selected Northwestern State, Nigeria

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Abstract:
Because of the increasing demand for clean energy to solve the environmental problems brought on by the use of fossil fuels, Nigeria must create an alternative energy source from the untapped wind that is abundant in the area. This study aims to assess the wind power potential of Jigawa, Katsina, and Kano, three (3) states in Nigeria's northwest. Wind speed data spanning 25 years (1996-2020) was acquired from the Nigerian Meteorological Agency (NiMet). Wind power density was calculated in the analysis using the statistical model Weibull two-parameter; the scale parameter (c) and shape parameter (k) were also determined using the moment model. Microsoft Excel was used to analyze the collected wind speed data. Nigeria's wind speed distribution shows that certain northern regions are capable of producing wind. Furthermore, an assessment of the wind energy resources in the area reveals that Kano has the most potential, with an annual WED of 4.921kWhm^{-2}day^{-1} and a WPD of 443.03 Wm^{-2} at 10m AGL. The lowest potential is 7.69 Wm-2 for Dutse. 492 kWhm^{-2}day^{-1}. Due to their WED of 0.712 kWhm^{-2}day^{-1}, Dutse have the lowest potential (7.69 Wm-2). This means that whereas Kano and Katina are excellent for large-scale wind power generation, Kaduna is best suited for small-scale wind power development. Dutse, however, might not be feasible because of their poor wind potential. Since wind is a very significant energy source with a lot of potential to help Nigeria overcome its energy crisis, it is advised that it be properly utilized. Additionally, much research should be done to better understand how climate change is affecting Nigeria's weather patterns, which are exhibiting a chaotic tendency.

Keywords: *Renewable energy, Fossil fuel, Power, Weibull distribution, Wind*

1. Introduction

The global energy landscape is rapidly transitioning towards sustainable alternatives due to mounting environmental concerns and the depletion of fossil fuel reserves. According to the International Energy Agency (2016), global energy consumption increased from 4,244 megaton of energy (Mtoe) in 1971 to 9,426 (Mtoe) in 2014, highlighting the urgent need for renewable energy sources. Wind energy has emerged as one of the most promising renewable technologies, with Europe generating 300 tera watt hour (TWh) in 2016, supplying 10.4% of the EU's electricity needs (WindEurope, 2017).

Nigeria faces a persistent energy crisis that significantly hampers its economic development potential. With 60-70% of the population lacking access to electricity and only 30-40% of the overall population having access to power, the country's energy deficit poses a major challenge to poverty alleviation and achievement of sustainable development goals (Sambo, 2006). The nation's heavy reliance on fossil fuels and government subsidies has created an unsustainable energy system that requires diversification into renewable alternatives.

Nigeria possesses substantial renewable energy potential, particularly in wind resources across its northern regions. The northwestern geopolitical zone, characterized by higher wind speeds during the dry season, presents significant opportunities for wind energy development. However, limited research has been conducted on the wind resource assessment and energy potential in this region, particularly in the states of Kano, Katsina, and Jigawa (represented by Dutse).

Wind energy assessment requires comprehensive analysis of temporal and spatial variations in wind speed, as the output power generation of any wind energy conversion system (WECS) is directly related to the wind characteristics of the location (Ucar and Balo, 2009). The Weibull probability distribution function has proven to be an effective tool for modeling wind speed distributions and estimating wind power potential across different geographical locations.

This study aims to evaluate the wind power potential in three northwestern Nigerian states: Kano, Katsina, and Jigawa, using 25 years of meteorological data (1996-2020). The research objectives are to: (i) assess the wind speed patterns in the selected states, (ii) determine wind power density using Weibull analysis, and (iii) evaluate the wind characteristics and energy potential for each region.

2. Methodology

2.1 Material

The materials employed on this research are; 25years (1996-2020) secondary data of monthly average wind speed for seven locations obtained from Nigeria meteorological agency (NiMet), laptop computer window 10 with 500GB harddisk, 2GB RAM, installed with Microsoft excel 2013 and Origin 6.0.

2.2 Study Area

The study focuses on three states in Nigeria's northwestern region: Kano, Katsina, and Jigawa (represented by Dutse). The northwestern zone occupies approximately 214,395 km², located within longitude 3°45'00"E to 10°20'00"E and latitude 9°00'00"N to 13°49'30"N. This region is the most populated geopolitical zone in Nigeria with over 35 million inhabitants (Salihu, *et al.*, 2018).

The geographical coordinates and elevations of the study locations are:

a. Kano: 12°03'N, 08°12'E, elevation 472.5m
b. Katsina: 13°01'N, 07°41'E, elevation 517.6m
c. Dutse (Jigawa): 11°70'N, 09°33'E, elevation 431.36m

Table 1 lists the geographic locations and heights of the sites and lists the sites' physical coordinates and heights While Figure 1 depicts the precise positions of the researched area.

Table 1: Geographical Locations of North-Western 3 States of Nigeria

S/N	Station Name	Station no.	Latitude (°N)	Longitude (°E	Elevation (m)	Duration
1	Kano	1208.03	12^0 03’	08^0 12’	472.5	1996-2020
2	Katsina	1307.04	13^0 01’	07^0 41’	517.6	1996-2020
3	Jigawa	1007.04	11^0 70’	09^0 33’	431.36	2014-2020

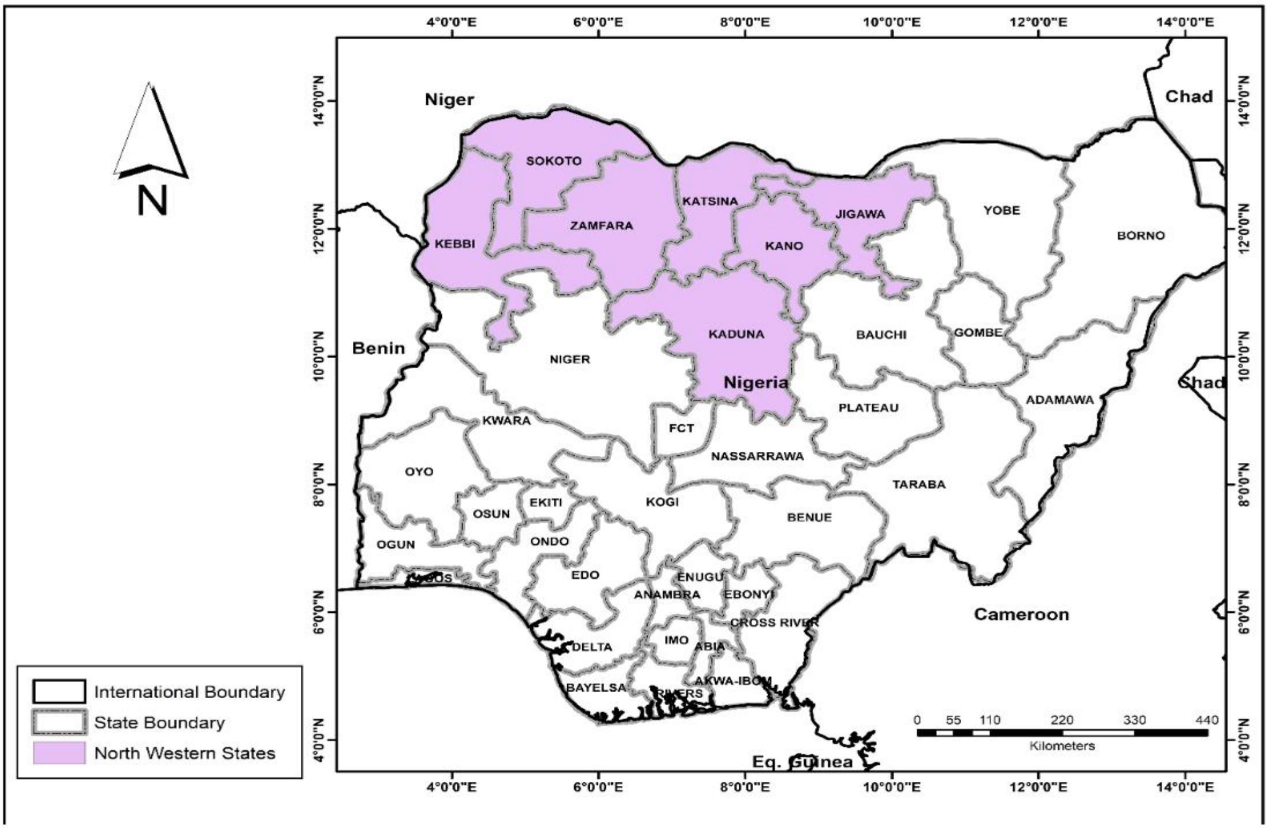

Figure 1: Map of Nigeria showing the study locations in the Northwestern Geopolitical Zone

2.3 Data Collection

Secondary wind speed data spanning 25 years (1996-2020) was obtained from the Nigerian Meteorological Agency (NiMet). For Dutse, data was available for a shorter period (2014-2020) due to station establishment. The wind speed measurements were recorded at 10 meters above ground level using NiMet cup-generator anemometers.

2.4 Data Analysis

2.4.1 Weibull Probability Distribution

Due to its significant impact on wind potential, wind power will be utilized to measure actual wind resources and to ascertain the distribution of wind speed for the site. A mathematical idealization of the wind speed distribution over time is the Weibull probability density function. Over the period covered by the statistics, the function accounts for both seasonal and annual variations and provides the likelihood that the wind speed will be within a 1 m/s interval centered on a specific speed (v). Walker and Jenkins (1997) provide equation 1 as the Weibull distribution function:

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

Where f(v) is the probability density defined as the frequency of occurrence of wind speed (v), c (in unit of m/s) is the scale parameter which is closely related to the modal wind speed for the location, and k is the dimensionless shape parameter which describes the form and width of the distribution. The Weibull distribution is therefore characterized by the two parameters c and k.

2.4.2 Wind power density calculation (WPD)

The Weibull two parameter methods were utilized to calculate the mean wind power density as expressed by Kamau, *et al.,* (2010) in equation 2:

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

Where, P (v) is the wind power density (Wm^{-2}), v is the Wind speed (ms^{-1}), c is weibull scale parameter (ms^{-2}), k is Weibull shape parameter (dimensionless) and Γ(x) is the gamma function, which is defined as in equations 3 and 4:

$$\Gamma(x) = \int_0^\infty t^{x-1}e^{-t}dt \quad (3)$$

$$\rho = \rho_o - 1.194 \times 10^{-4} \times H_m \quad (4)$$

Where the air density ρ_0 is value at sea level usually taken as 1.225Kgm^{-3} and H_m is the site elevation in meters.

2.4.3 Wind Energy Density

The product of the mean power density and the time (T) in hours yields the wind energy density (WED). The daily wind energy density was estimated by multiplying WPD by 24 and the annual wind energy density was estimated by multiplying WPD by 8760 hours. WED is usually expressed in $kWhm^{-2}$ and can be given as in equation 5:

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

The c and k Weibull parameters were calculated using the standard deviation method given as in equations 6, 7 and 8 reported in Justus, *et al.* (1978):

$$k = \left(\frac{\sigma}{v_m}\right)^{-1.086} \quad (6)$$

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

$$\sigma = \left[\left[\frac{1}{N-1}\sum_{i=1}^{N}(v_i - v_m)^2\right]\right]^{\frac{1}{2}} \quad (8)$$

Where σ is standard deviation, v_m mean wind speed (m/s), $v_i$is observed wind speed (m/s) and N is the number of months in the period of time considered.

3. Results and discussion

3.1 Wind speed characteristics

The analysis revealed significant seasonal variations in wind speed across all three states. Higher wind speeds were consistently observed during the dry season (November-March) compared to the wet season (April-October).

Tables 2 to 4 show the annual mean wind speed values and monthly range over Kano, Katsina and Jigawa. Kano State exhibited the highest wind potential among the three locations were the Annual mean wind speed recorded as 6.95 m/s, Monthly range is 5.532-8.216 m/s. The highest speeds recorded in May-June (8.2+ m/s) while the lowest speeds in October (5.532 m/s).
Katsina State demonstrated moderate to high wind potential were the Annual mean wind speed recorded as 6.23 m/s, Monthly range: 4.25-7.66 m/s. Peak speeds in June (7.66 m/s) while the minimum speeds in October (4.25 m/s). Lastly Dutse (Jigawa State) showed the lowest wind potential, were the Annual mean wind speed recorded as 3.53 m/s, Monthly range is 2.20-4.97 m/s. The highest speeds recorded in January are 4.97 m/s while the lowest speeds recorded in September is 2.20 m/s.

Table 2: Wind speed and other parameters in Kano

Period	V_m (ms^{-1})	k	c (ms^{-1})	WPD (Wm^{-2})	WED ($kWh/m^2/d$)
JAN	6.704	7.39	7.12	176.05	4.225
FEB	6.78	7.48	7.19	182.10	4.370
MAR	7.224	8.01	7.63	220.27	5.287
APR	7.812	8.72	8.20	278.56	6.685
MAY	8.216	9.21	8.59	324.05	7.777
JUN	8.2	9.19	8.58	322.16	7.732
JUL	7.596	8.46	7.99	256.09	6.146
AUG	6.42	7.05	6.84	154.61	3.711
SEP	6.124	6.70	6.55	134.19	3.221
OCT	5.532	6.00	5.96	98.92	2.374
NOV	5.808	6.32	6.23	114.47	2.747
DEC	6.984	7.72	7.39	199.04	4.777
Average	**6.950**	**7.69**	**7.36**	**205.04**	**4.921**

Table 3: Wind speed and other parameters in Katsina

Period	V_m (ms^{-1})	k	c (ms^{-1})	WPD (Wm^{-2})	WED ($kWh/m^2/d$)
JAN	7.39	5.00	8.06	234.91	5.638
FEB	6.68	4.99	7.29	173.67	4.168
MAR	5.95	6.02	6.41	122.63	2.943
APR	6.57	6.77	7.02	164.79	3.955
MAY	6.84	5.95	7.37	186.12	4.467
JUN	7.66	5.41	8.30	260.99	6.264
JUL	7.07	4.12	7.80	205.71	4.937
AUG	5.62	4.25	6.19	103.46	2.483
SEP	4.94	4.51	5.42	70.11	1.683
OCT	4.25	4.79	4.64	44.58	1.070
NOV	5.18	5.41	5.62	81.02	1.945
DEC	6.55	4.21	7.21	163.29	3.919
Average	**6.23**	**5.12**	**6.78**	**150.94**	**3.623**

Table 4: Wind speed and other parameters in Dutse

Period	V_m (ms^{-1})	k	c (ms^{-1})	WPD (Wm^{-2})	WED ($kWh/m^2/d$)
JAN	4.97	7.00	5.29	71.89	1.725
FEB	4.53	6.34	4.86	54.66	1.312
MAR	4.38	6.11	4.71	49.42	1.186
APR	3.42	4.66	3.74	23.40	0.562
MAY	3.02	4.66	3.74	16.11	0.387
JUN	3.26	11.97	3.30	20.28	0.487
JUL	3.21	8.69	3.38	19.49	0.468
AUG	2.79	6.06	3.00	12.68	0.304
SEP	2.20	9.46	2.30	6.25	0.150
OCT	2.83	10.68	2.93	13.28	0.319
NOV	3.53	4.89	3.85	25.78	0.619
DEC	4.17	4.62	4.57	42.59	1.022
Average	**3.53**	**7.10**	**3.81**	**29.65**	**0.712**

3.2 Wind power density (WPD)

Figure 2 display the wind power density for the investigation period for the northwest states. Wind power density calculations revealed substantial differences in wind energy potential, Figure 2 shows that the highest wind power density for Kano the highest wind power density is $443.04\ \mathrm{Wm^{-2}}$ in June and the lowest wind power density is $112.55\ \mathrm{Wm^{-2}}$ October, respectively, In Katsina, the highest was found to be 297.65 Wm^{-2} in June while the lowest was $53.35\ \mathrm{Wm^{-2}}$ in October. As for Dutse, the highest wind power density is 77.69 Wm^{-2} in January and the lowest wind power density was found to be 6.54 Wm^{-2} October. By implication, Kano measured highest and lowest wind power densities in the months of June and October, respectively.

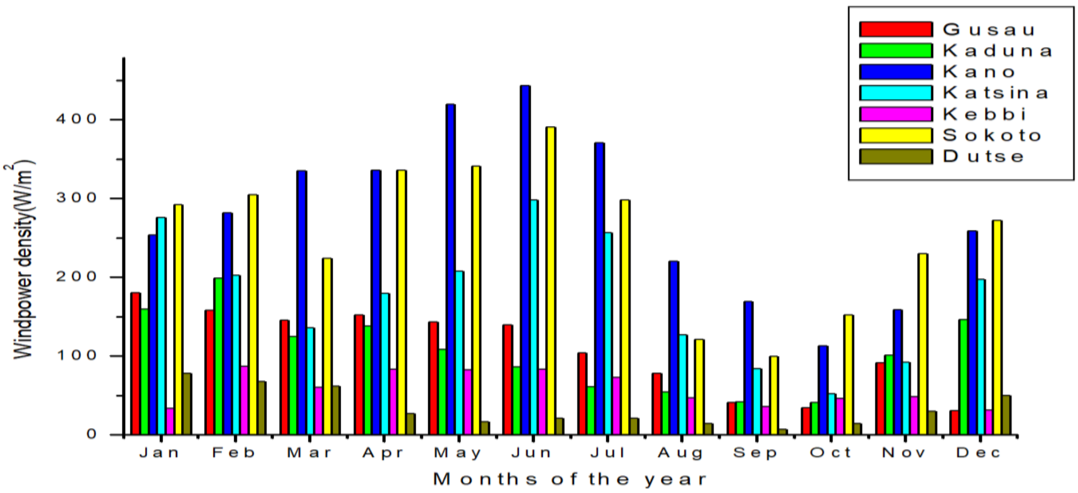

Figure 2: Monthly wind Power for locations under study

3.3 Wind Energy Density (WED)

Figure 3 display monthly Kano's wind power density during the investigation period. The result shows that the highest annual wind power potential was found in February 2014 as $1781.29\ \mathrm{Wm^{-2}}$, an annual WED is obtained as $4.921\ \mathrm{kWhm^{-2}}day^{-1}$. Figure 4 displays the annual wind power density for Katsina during the investigation period. The result shows that the highest annual wind power potential was found in January 1998 as 1248.513 Wm⁻², an annual WED is estimated as 3.623 kWhm⁻²day⁻¹. Lastly, Dutse in Jigawa State display the annual wind power density during the investigation period was shown in Figure 5. The result shows that the highest annual wind power potential was found in February 2017 and March 2018 as 161.136 Wm⁻², an annual WED of 0.712 kWhm⁻²day⁻¹ are shown in Figure 5.

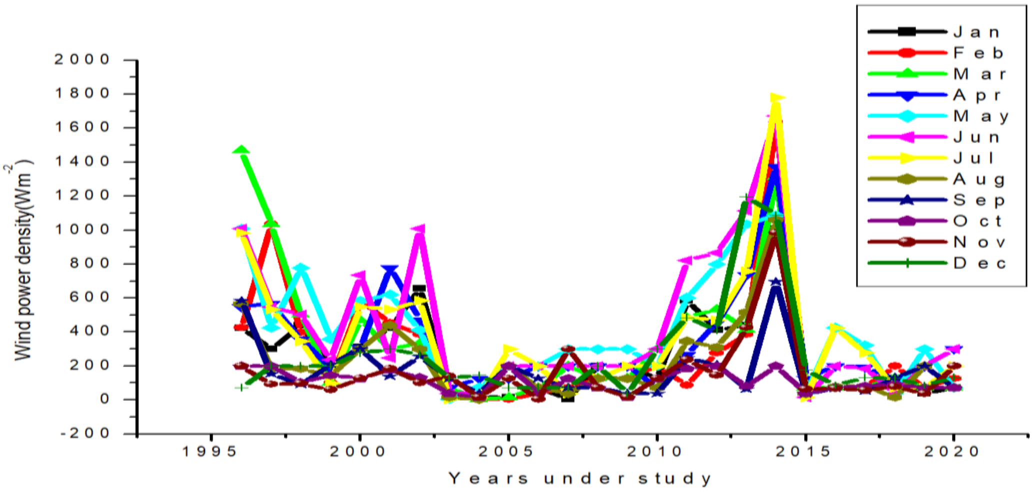

Figure 3: Annual wind Power density for Kano

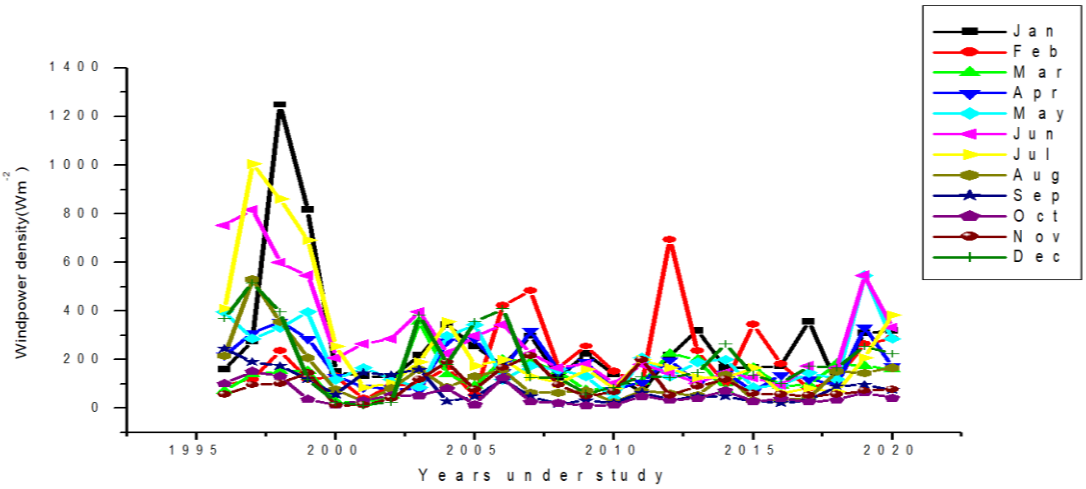

Figure 4: Annual wind Power density for Katsina

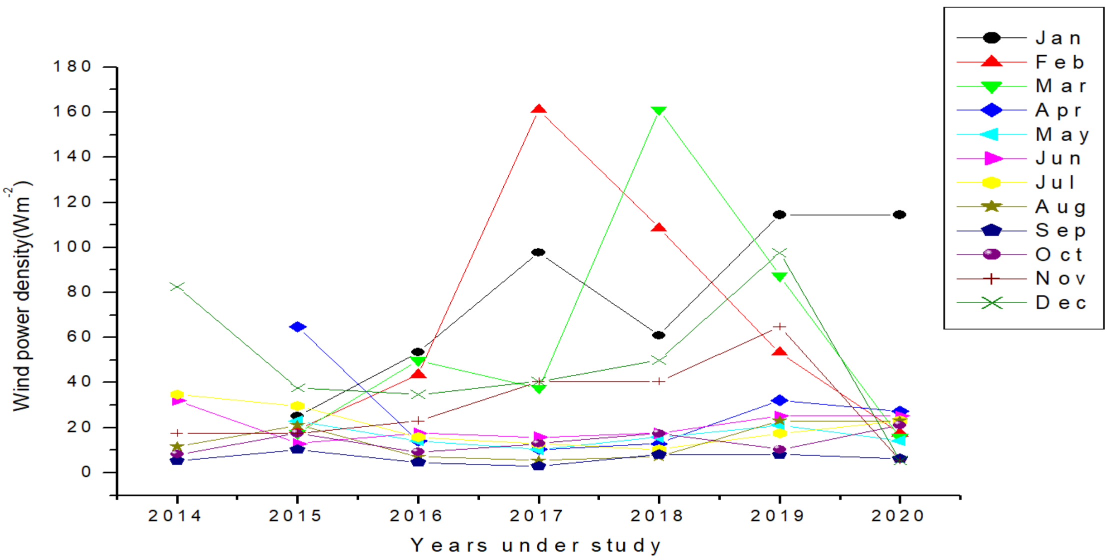

Figure 5: Annual wind Power density for Dutse

3.4 Weibull Parameters

The Weibull shape parameter (k) and scale parameter (c) varied significantly across locations:

Kano:

a. Shape parameter (k): 5.996-9.194
b. Scale parameter (c): 5.958-8.592 m/s
c. Average k = 7.69, c = 7.36 m/s

Katsina:

a. Shape parameter (k): 4.116-6.77
b. Scale parameter (c): 4.642-8.301 m/s
c. Average k = 5.12, c = 6.78 m/s

Dutse:

a. Shape parameter (k): 4.619-11.97
b. Scale parameter (c): 2.296-5.294 m/s
c. Average k = 7.10, c = 3.81 m/s

The high values of k (≥2) and c (≥2) for Kano and Katsina indicate good wind consistency and normal distribution characteristics, while Dutse showed lower scale parameters indicating reduced wind intensity.

4. Conclusion

The results obtained and presented This research has applied statistical tool of weibull distribution function to analyze wind speed (m/s) collected across three locations in northwestern geopolitical zone of Nigeria to investigate the wind power (W/m^2) and wind energy potential ($KW/m^2/h$) by analyzing shape parameter (k) and scale parameter (c).

The research has shown the wind power strength across all the locations and the energy potential of each region which has shown that Kano and Katsina has highest potential while Jigawa has the lowest. Therefore, the locations that show high potential i.e. Kano and Katsina can be utilized for large scale wind power generation, while Dutse on the other hand has shown a poor potential thereby not viable for wind energy generation.

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References

International Energy Agency (2016). Key World Energy Trends — Excerpt from World Energy Balances (2016 Edition). International Energy Agency, at four monitored locations in Liguria region (Italy).

Kamau, J. N., Kinyua, R. and Gathua, J. K., (2010). Six years of wind data for Marsabit, Kenya average over 14 m/s at 100 m Hub height; an analysis of the wind energy potential, *Renewable Energy*, 35(6), 1298–

Olayinka S. O., (2011). Assessment of wind energy resources for electricity generation using WECS in North-Central region Nigeria, *Renewable and Sustainable Energy Reviews*, 15(2011) 1968–1976

Olomiyesan B., Oyedum, O., Ugwuoke, P. and Abolarin, M. S., (2017). Assessment of wind energy resources in Nigeria-a case study of north-western region of Nigeria, *International journal of physical research*, 5(2), 83-90; doi: 10.14419/ijpr.v5i2.8327

Salihu, T., Olukunle, J. O., Adenubi, O. T., Mbaoji, C. and Zarma, M. H., (2018). Ethnomedicinal plant species commonly used to manage arthritis in North-West Nigeria, *South African Journal of Botany*, 118, 33-43.

Sambo, A. S., (2006). Paper Presented at the Renewable Electricity Policy Conference ''Renewable Energy Electricity in Nigeria; the Way Forward'' 11th December 2006, North-West Nigeria

Sambo, A. S., (2006). Renewable Energy Electricity in Nigeria; the Way Forward, Paper presented at the Renewable Electricity Policy Conference, December 11, 2006, North-West Nigeria

Ucar, A. and Balo, F., (2009). Evaluation of wind energy potential and electricity generation at six locations in Turkey, *Applied Energy*, 86(10), 1864-1872.

Walker, J. F. and Jenkins, S., (1997), Wind Energy Technology, John Wiley and Sons, Chinchester.

WindEurope. (2017). Wind in Power: 2016 European Statistics. WindEurope Annual Statistics Report.

Udo, N. A., Oluleye A. I. and Ishola, K. A., (2017). Investigation of Wind Power Potential over Some Selected Coastal Cities in Nigeria, *Innovative Energy and Research*, 6(1), 1000162.