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Characterization of Wind Speed in Some Tropical Stations in Nigeria

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Abstract

In this study, a statistical analysis of wind speed was carried in 20 stations covering all the regions in Nigeria, using weibull distribution for 30 years wind data. The shape and scale parameters of the weibull distribution including the speed frequently distribution and their cumulative distribution on annual timescale were determined for all the stations. It was found that 10% of the stations in the arid region of Nigeria belong to class 1.5%to class 2.5% to class 4 and 5% to class 5 of the International System of Wind Classification and having power density ranging between 62.3 w/m^2 and 318W/m^2 while 30% of the midland region belongs to class 1 and 5% class 7 of the International System of Wind Classification and having power density ranging between 11.8 W/m^2 and 423 w/m^2. Finally, 30% of the coastal region exhibits class 1 of the International System of Wind Classification and having power density ranging between 23.W/m^2 and 89.3 W/m^2. The analysis demonstrates the economic feasibility of using wind energy as a means of electricity supply in areas like Sokoto, Kastina, Zaria and Kano in the arid region of Nigeria and Jos in the Midland region of Nigeria This could be used to compliment the present source of power supply and hence ameliorate the degenerated power distribution in the country.

1.0 Introduction

Wind and solar are the most natural sources of energy which are freely available for both domestic and industrial use. Though they are not continuously obtainable but energy storage system is provided to make energy available when needed. The usefulness of wind cannot be over-emphasized (Iloeje, [1]). Wind power has long been found relevant as an aid for grain grinding, water pumping, electricity generation, e.t.c. According to Alnaser [2]), it had been estimated that, on a global scale, the wind would account for a total available power of 2 x 10^{13}W, which was three time the world energy consumption in 1972. In view of the present cost of generating electrical energy and the associated hazards coupled with fact that supply cannot get to the rural areas, the world is seeking for additional alternative sources of renewable energy of low cost and hazards free (Asrag et. Al., [3]) and hence, wind is presently receiving a good consideration in this regards. In this connection, several countries have developed wind machines capable of hundreds of kilowatts up to several megawatts. Various studies (Adekoya and Adewale[4];Iloeje [1]; Matthew, et. al.[5]; Weisser[6]; Fadare[7]) have been carried out to assess the wind potential in different part of the world so as to determine the possibilities of generating electrical power from wind power. Study had also been carried out and it was established that the wind strength in the tropical environment are characteristically low. Hence, the main objective of this study is to assess the areas where generation of wind power is possible.

In Nigeria, wind power has so far received only limited attention even though there are some Wind Energy Conversion Systems (WECS) installed for various purposes. Subjectively, without proper knowledge of the wind distribution in respective areas in which they are operating, consequently, such systems where ignored and most of them were destroyed. Hence, detailed knowledge of the wind characteristics is essential to allow for optimization of the design and the usage of WECS (Chang et. al.[8]).

In statistical modeling of the wind speed variation, much consideration has been given to the weibull two parameter (shape parameter, K and scale parameter, C) functions because it has been found to fit a wide collection of wind data (Weilbull[9], Isaac[10]; Aknipar and Aknipar, [11], Fadare[7]; Fyrippis et al.[12]).

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2.0 Site Description and Data Acquisition

2.1 Site Description

Twenty tropical stations were involved in this study fairly distributed into different climatic conditions in Nigeria. The geographical locations are described in Table 1 and displayed in fig.1. It spanned from (lat. 4.58^o N, long.3.20oE) to (lat. 14^{o}N, long. 13.05^{o}E) covering stations in the coastal environment through savannah and the midland to sahel region. Seven stations were selected from both Midland and Arid regions while seven stations from Coastal region. The stations involved include Minna, Abuja, Jos, Yola, Kaduna, Bida, Lokoja, Maiduguri, Sokoto, Zaria, Kano, Kastina, Bauchi, Gusau, Ikeja, Benin, Port Harcourt, Enugu and Calabar.

Table 1: The geographical position of the tropical stations.

Station	**Latitude (^{o}N)**	**Longitude (^{o}E)**	**Altitude(m)**	**Expected Height of Turbine (m)**	**Height of Anemometer (m)**
Sokoto	13.01^{1}N	05.15^{1}E	350.75	20	5.57
Gusau	12.10^{1}N	06.42^{1}E		20	5.69
Kaduna	10.36^{1}N	07.27^{1}E	645.38	100	6.68
Kastina	13.01^{1}N	07.41^{1}E		20	4.48
Zaria	11.06^{1}N	07.41^{1}E	653.90	40	5.55
Kano	12.03^{1}N	08.12^{1}E	472.14	20	3.72
Bauchi	10.17^{1}N	09.49^{1}E		__	2.46
Maiduguri	11.51^{1}N	13.05^{1}E	353.80	100	3.43
Bida	09.06^{1}N	06.01^{1}E		__	4.32
Minna	09.37^{1}N	06.32^{1}E	258.64	__	2.2
Abuja	09.15^{1}N	07.00^{1}E		__	5.38
Jos	09.52^{1}N	08.45^{1}E	1285.85	20	3.39
Yola	09.14^{1}N	12.28^{1}E		40	1.59
Ikeja	06.35^{1}N	03.20^{1}E		__	3.57
Benin	06.19^{1}N	05.06^{1}E	77.52	__	4.89
Lokoja	07.47^{1}N	06.44^{1}E	61.4	__	7.09
Warri	05.31^{1}N	05.44^{1}E	6.10	__	4.59
Port Harcourt	04.51^{1}N	07.01^{1}E	195.51	__	3.91
Enugu	06.28^{1}N	07.33^{1}E	141.50	40	2.68
Calabar	04.58^{1}N	08.21^{1}E	63.14	__	6.68

Fig 1.0: The map of Nigeria showing the position of the Tropical Stations.

2.2. Acquisition and Treatment of Data

Wind data were extracted from the archive of the Nigeria Meteorological Agency (NIMET) for a period of three decades (30 years) covering the twenty (20) tropical stations were involved in this study. The windspeed was measured by sonic anemometer positioned at different heights above the ground for each station as shown in Table1. The observed disparity in the height positions of the anemometer above the ground is due to the presence of obstruction to wind by tall buildings or trees. The acquired data were properly screened for cases of missing event and unnecessary spikes due to breakdown of equipment

3.0 Methodology and Materials

3.1 Theoretical Background

3.1.1 Probability Density Function

Wind speed for a given location can be characterized by several probability density functions. For wind data analysis, the Weibull and Rayleigh probability density functions are commonly used and widely adopted. Here, the Weibull density function is used to describe the wind speed frequency distribution. The Rayleigh distribution is a special case of the weibull distribution. The general form of the parameter Weibull probability density function is mathematically expressed according to Celik[13] as:

$$F(v) = (k/c)(v/c)^{K-1} \exp(-(v/c)^{k}) \qquad (1)$$

(k.>0,V>0,C>1)

Where F (v) is the probability of having a wind speed of V (m/s), K is dimensionless shape factor and C is the weibull scale factor with units of speed (m/s), which is related to the average wind speed through the shape factor, and which describes the distribution of the wind speeds. The relationship between the weibull scale factor, C; weibull shape factor and average wind speed, Vm is given (Weibull [9], Akpinar and Akpinar,[11]; Youm et. al.[14]) by the following formula:

Fig. 23: Probability Density Function for Enugu

$$Vm = C\,\Gamma(1 + 1/K) \qquad (2)$$

Where Γ is the usual gamma function; the parameters K and C may be estimated by the linear regression of the cumulative weibull distribution given expressed (Seguro and Lambert [15]; Isaac [10]) by

$$F(v) = 1 - \exp(-(v/c)^{K}) \qquad (3)$$

3.2 Variation of Windspeed with Height

According to Ojosu and Salawu[16], wind speed fluctuates in a random manner and varies with height according to terrain roughness which is an effect of surface features coupled with decrease in turbulence event as height increases; thus, under normal conditions, wind speed is greater at higher distance above ground. In view of the profile variation of wind speed, reference height wind speed is generally related to a height of 10 m above the ground for a well-defined flat and open terrain. Hence, wind speeds are often adjusted to a height of 10 m so as to relate it to the intentions of those working in the renewable sector. The correction for this profile variability of wind speed can be accomplished by power law (Mursgrave,[17]) expressed as:

$$V/V_O = (H/H_O)^{\alpha} \qquad (4)$$

Where V is the wind speed at the required height, V_O is the wind speed at the original height, H_O and α is the surface roughness coefficient. The value of the exponent α varies from less than 0.10 over the tops of steep hills to over the 0.25 in sheltered locations. The typical value for flat coastal regions is 0.143, which is termed the one-seventh power law from which measurements at different height the exponent can be determined (Youm et. al.[14]; Ojosu and Salawu.[16]).

3.3 Wind Energy Potential

At a wind speed V, the available energy per unit area perpendicular to the wind stream over a given period of time t is expressed by kinetic energy (Youm et al[14]).

$$E_a = 0.5\,\rho\, v^3 \qquad (5)$$

Where p is the air density (kg /m^3) and E_O is the theoretical total energy available for doing work on the turbine. However, only a fraction of the total energy would be extracted .The maximum extractable energy from a system working at its optimum efficiency is limited by a coefficient of performance called Beltz limit (16/27 = 0.593).This capacity factor makes the extractable energy approximately 59.3% of the theoretical energy and is given by

$$E_M = 0.2965\,\rho\, v^3 \qquad (6)$$

3.4 Energy in the Wind

Wind is merely air in motion. It is produced by an uneven heating of the earths surface by energy from the sun. Since the earth's surface is made at different types of land and water, it absorbs radiant energy at different rates. Much of this energy is converted into heat as it is absorbed by land areas, bodies of water and the air over these formations. The air has mass, though its density is low and when this mass has velocity, the resulting wind has kinetic energy which is proportional to ½ (mass X (velocity)^2). The mass of air passing in unit time is ρAV and the kinetic energy passing through the area in unit time (power available in the wind) (Oriaku et. al.[18]).

$$P_W = \tfrac{1}{2}\,\rho\, AV^3 \qquad (7)$$

After establishing this, the analysis of the recordings was performed and the corresponding weibull distribution was determined. Additionally, the yearly wind speed variation was obtained in order to check the validity of the data and to extract any useful information regarding the wind potential of the location under consideration. Hence, data were used to evaluate frequency of a certain wind speed as well as the monthly and annual mean wind speed.

Two different statistical softwares were used Excel spreadsheet and Matlab. Excel spreadsheet was used to calculate the mean wind speed, shape factor, scale factor, probability density function and cumulative distribution function while Matlab was used for the plottings of the probability density function and cumulative distribution function graphs.

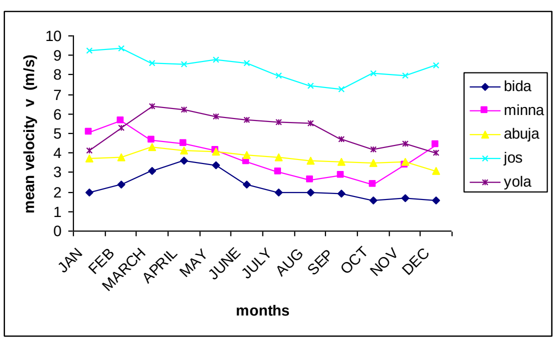
SITE DESCRIPTION

Nigeria is a country in West Africa, Nigeria shares land borders with the Republic of Benin in the west Chad and Cameron in the east, and Nigeria in the north. Its coast lies on the Gulf of Guinea in the south and it borders Lake Chad to the northeast. Noted geographical features in Nigeria include the Adamawa highlands, Mambulla Plateau, Jos Plateau, Obudu Plateau, the Niger River, River Benue and Niger Delta. Nigeria lies in the tropical area where there is lot of sunshine characterized with spatial and temporal variations in the sky condition; however, the climate varies from the coastal area to the Northern part. The coastal region is the most humid while the Midland region is more humid and damper than the arid region of Nigeria. The midland region experiences dry season from the month of November and lasts till March. The arid region is much drier in nature compared to the coastal and midland regions. The dry season begins in the arid region from the month of October and lasts till the month of April while in the coastal region the dry season ranges between the month of December and February. The north east trade winds from the northern part of the country originating from the Sahara desert is responsible for the Harmattan, dry dusty wind that blows across the country from November to March.

In addition, the average annual rainfall in midland region is almost 1,000mm, 600mm in the arid region and 2,500mm in the coastal region which is characterized by heavy rainfall. Temperatures in the midland region rarely exceed 32^{O}C, while 36^{o}C observed for the arid region and 28 ^{O}C in the coastal region. The coastal region comprises the south western, south-south of the country and considering the sea breezes enjoyed in some stations, namely Warri, Port Harcourt, Calabar, Ikeja, Enugu and Benin while the Northern region of the country are Maiduguri, Sokoto, Zaria, Kano, Kastina, Bauchi and Gusau which lies between (7^{0}N – 11.5^{0}N). The midland is (9^{0}N – 11.5^{0}N) which comprises Minna, Abuja, Jos, Yola, Kaduna, Bida and Lokoja. The region were selected simply on the basis that they constitute the major agriculture belt of the country as the water pumping for irrigation is identified as one of the viable application of wind energy and also contribute to the country's electricity target.

4.0 Result and Discussion

4.1 MEAN MONTHLY WIND SPEED DISTRIBUTION PATTERN FOR THE STATIONS



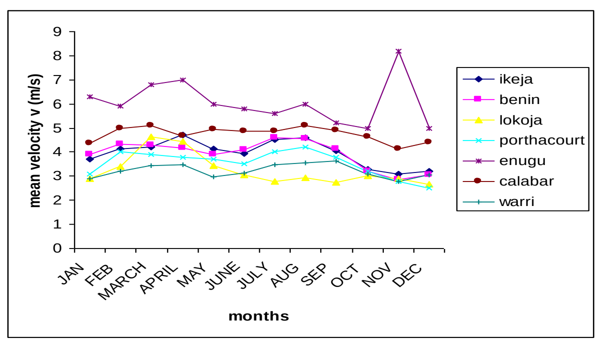


Fig.2: Mean Monthly windspeed Distribution for Latitude 4oN – 7^{O}N Fig. 3: Mean Monthly windspeed Distribution for Latitude Latitude 8 ^{o}N – 9 ^{o}N

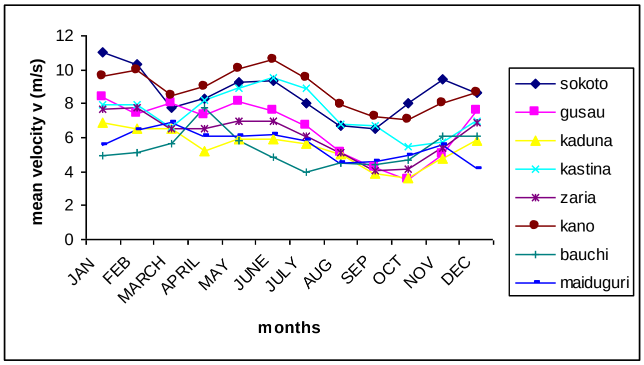


Fig. 4: Mean Monthly windspeed Distribution for Latitude 10^0N – 13^ON

Figures 1-4 above is the distribution latitudinal distribution of wind speed in Nigeria. The distribution is divided into three classes defined as follow: 4^oN -7^oN, 8^oN-9^oN and 10^oN -13^oN. The three classifications are according to three climatic conditions, namely the coastal/Rainforest, Gunnies savannah and the semi and arid condition respectively. In the first classifications, the windspeed are all consistently exhibit peak values in March and between August and September. A minimum point was observed between May and June. The windspeed in this classification ranges from 2.5m/s to 7.5 m/s with Enugu in the Rainforest having the highest windspeed compared with the rest stations throughout the year. The coastal effect on the evolution of wind speed is also observed as Calabar, a typical coastal city perpetually experienced higher windspeed next to Enugu. In the next classification, a fairly constant windspeed variation is observed. Here, Jos, a city situated on a highland with altitude of 1285.85m has a perpetual higher windspeed above others throughout the year. Windspeed ranges from less than 2m/s and above 9m/s. The third category lies in the arid region has the highest recorded windspeed compared with other regions. It ranges between 4.0m/s and about 12m/s. The highest windspeed stagers between Sokoto and kano. The pattern of variation is seasonally oriented. The strength of the wind speed is low in March and September and maximum in July in the latitude 10^0N – 13^ON while the maximum is observed in April and minimum in May in the rest latitude classifications. The strength of windspeed in this region is higher latitudes than the lower latitude.

4.1 Probability Density Function For all the Stations (1980-2009

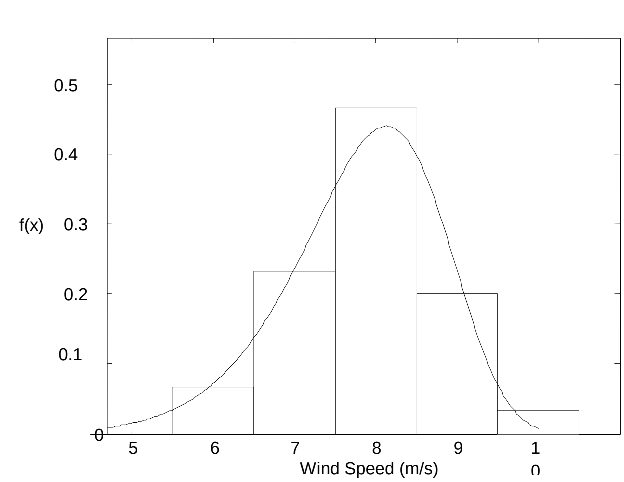


Fig . 5: Probability Density Function for Sokoto

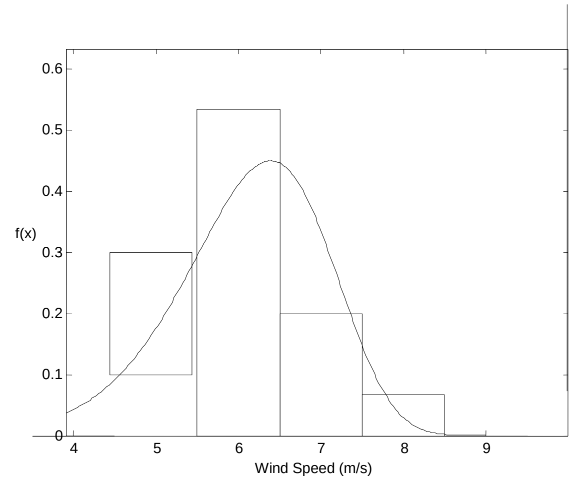


Fig .6: Probability Density Function for Gusau

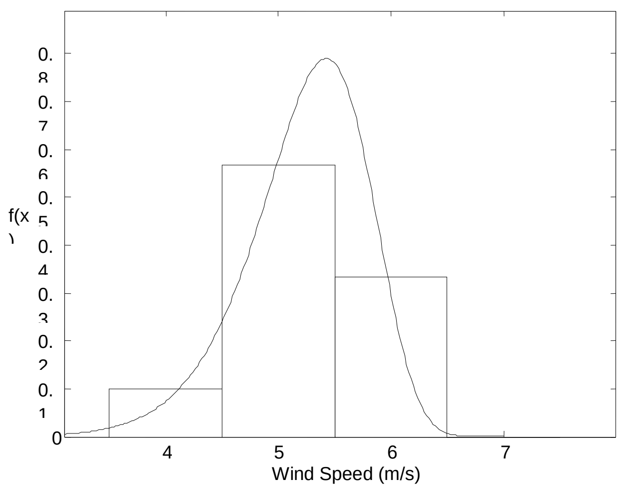


Fig. 7: Probability Density Function for Kaduna

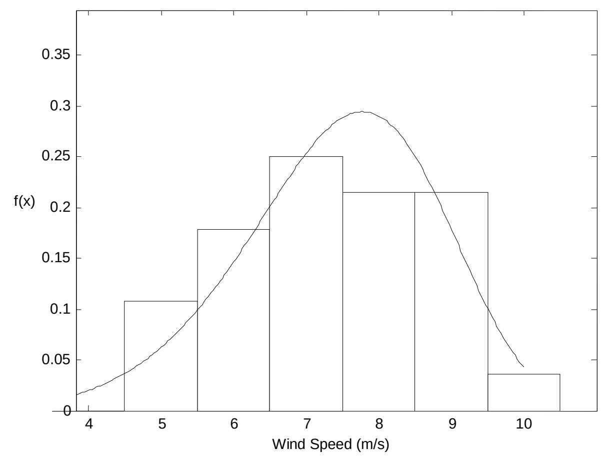


Fig. 8: Probability Density Function for Katsina

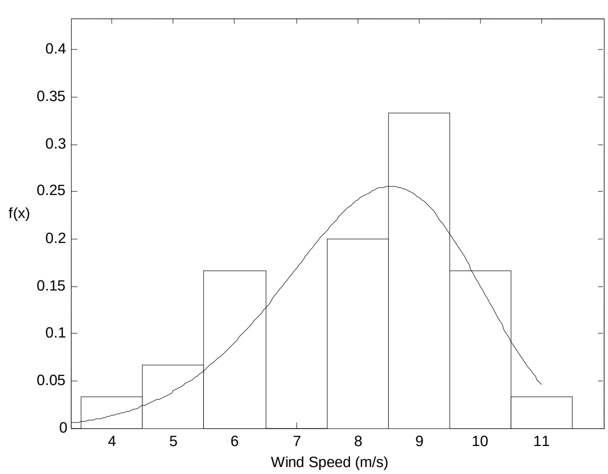


Fig.9. Probability Density Function for Kano

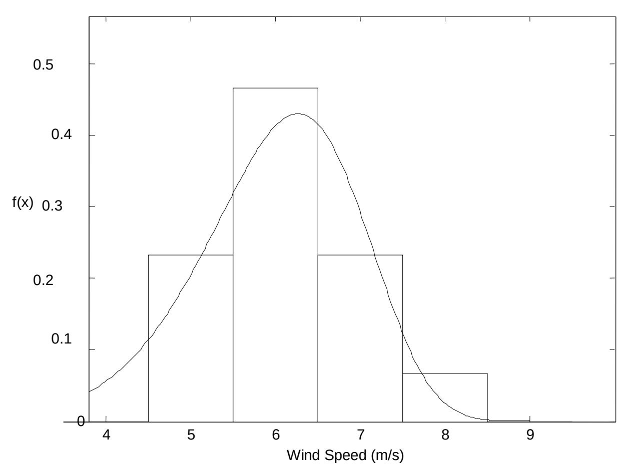


Fig.10: Probability Density Function for Zaria

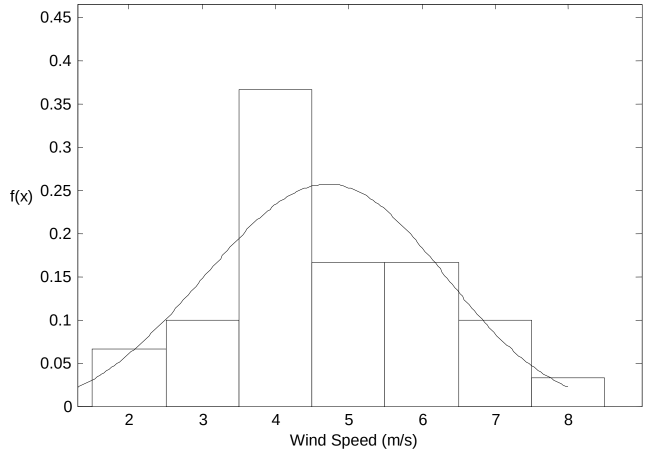


Fig.11: Probability Density Function for Bauchi

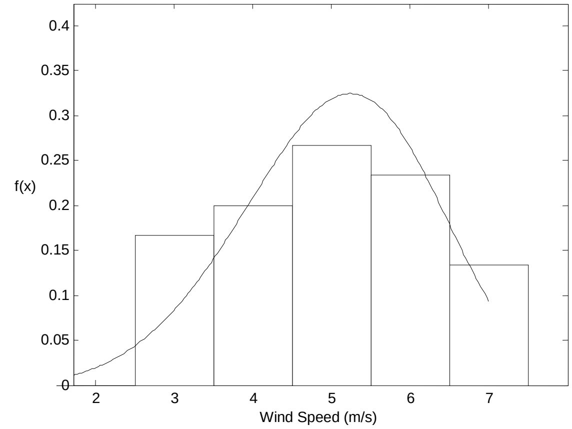


Fig12: Probability Density Function for Maiduguri

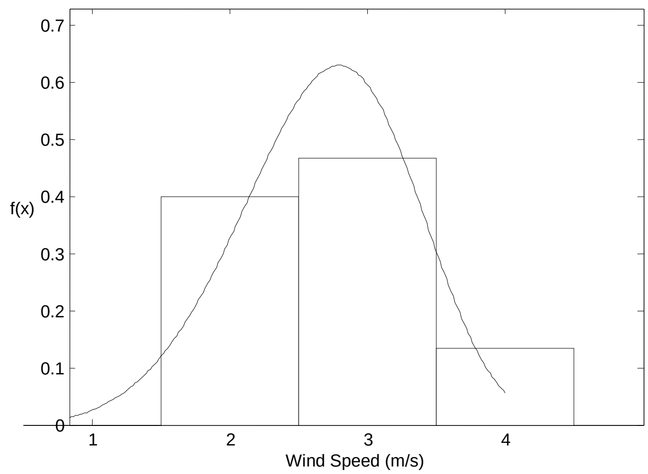


Fig.13: Probability Density Function for Bida

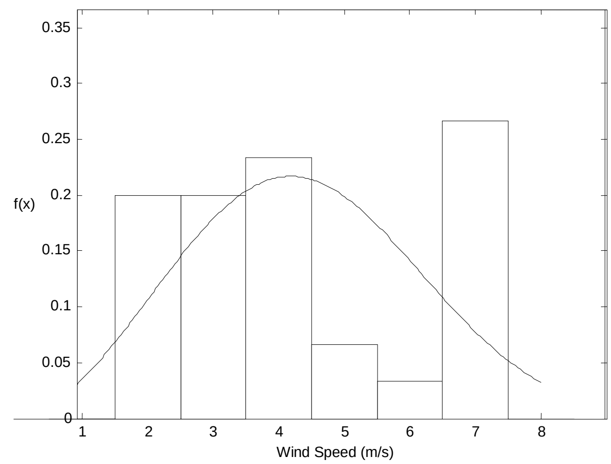


Fig.14. Probability Density Function for Minna

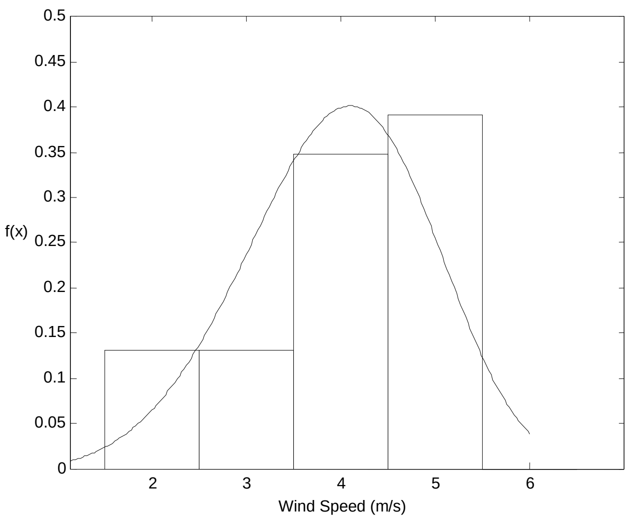


Fig.15: Probability Density Function for Abuja

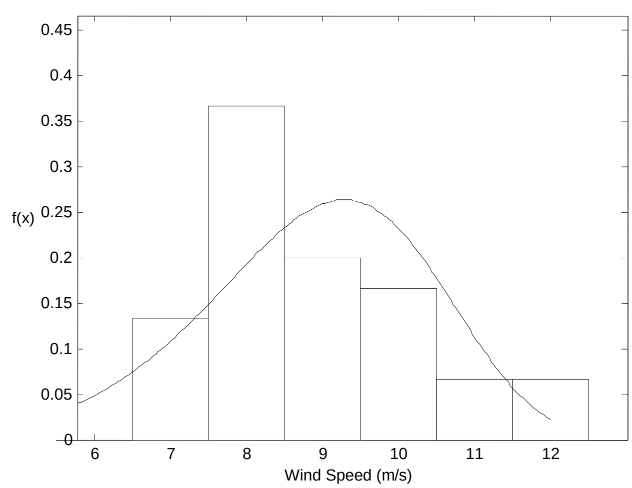


Fig.16. Probability Density Function For

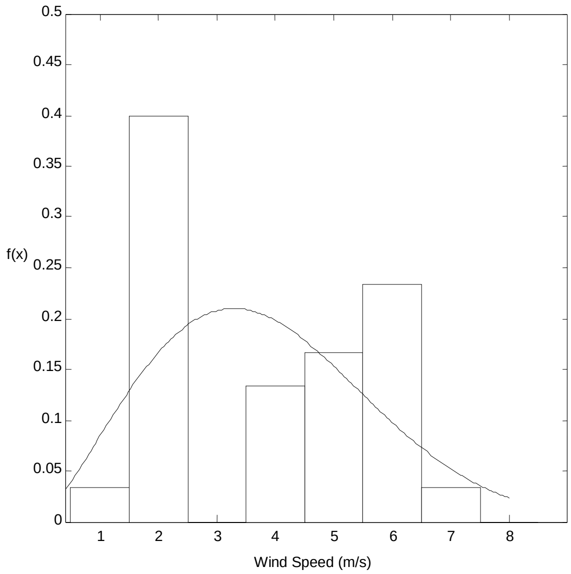


Fig.17: Probability Density Function for Yola

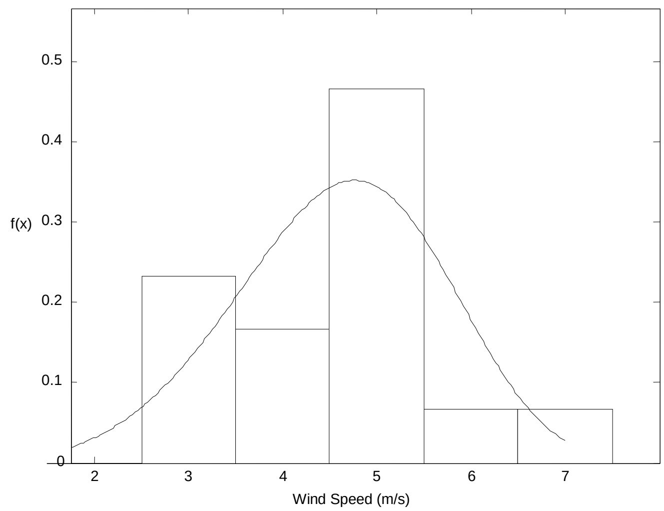


Fig.18: Probability Density Function For Ikeja

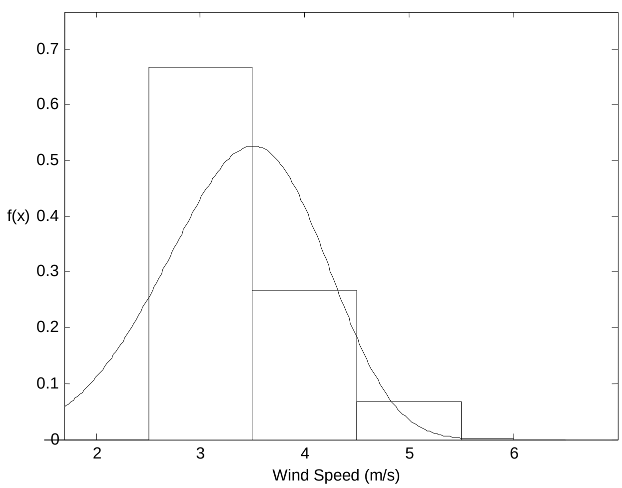


Fig.19: Probability Density Function for Benin

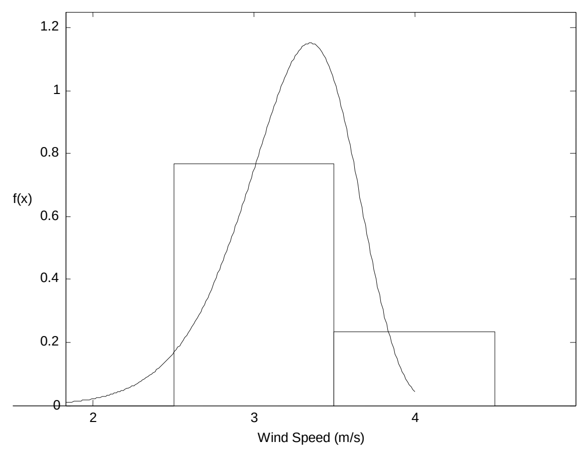


Fig. 20: Probability Density Function for Warri

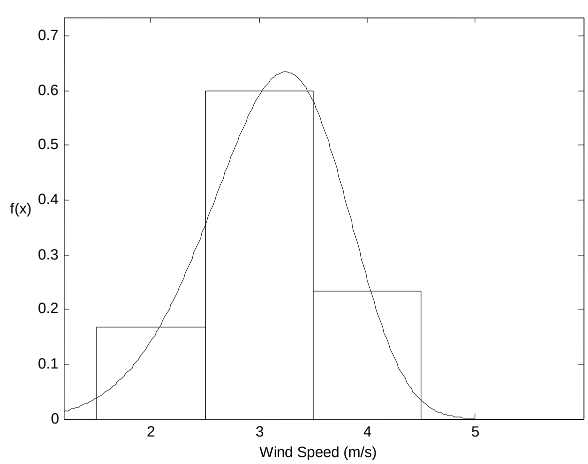


Fig. 21: Probability Density Function for Lokoja

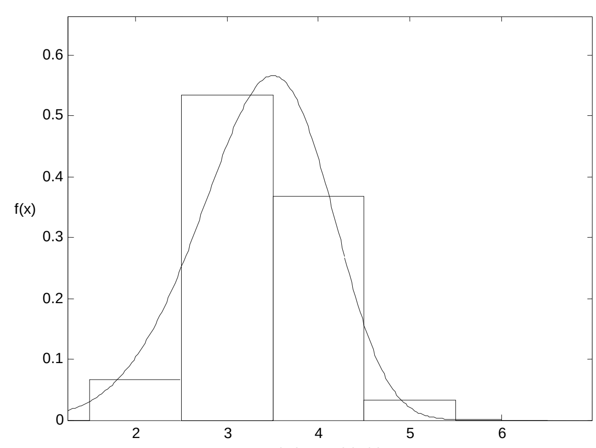


Fig. 22: Probability Density Function for Port Harcourt

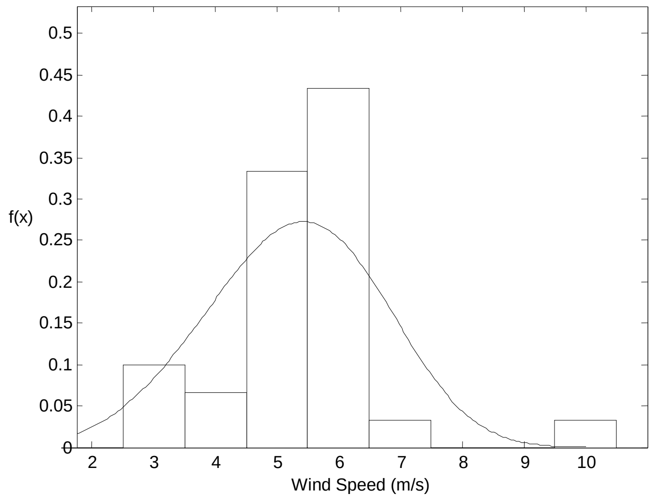


Fig. 23: Probability Density Function for Enugu

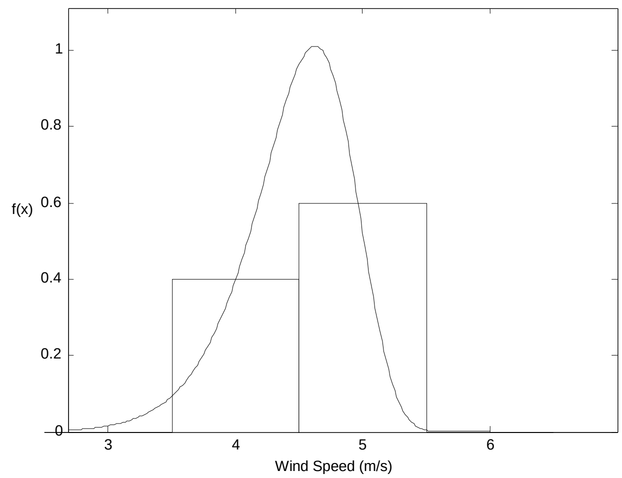


Fig. 24: Probability Density Function for Calabar

Fig 4-24 show the probability density functions which indicates the fraction of time for which wind speed possibly prevails at the area under investigation. The distribution of wind speed is high in the arid compared to the coastal and midland regions. Wind speed of the stations from the histogram exhibits maximum frequency between 2.0m/s and 9.0m/s. The result shows that the mean wind speed ranges 5.0 m/s and 7.8 m/s in the northern region with an overall mean wind speed of 6.4m/s. The coastal region has an overall mean wind speed of 4.2m/s and ranges between 3.4m/s and 5.3m/s. The midland area ranges between 3.1m/s and 8.9m/s and gives an overall mean wind speed of 4.6m/s. Furthermore, there is higher mean wind speed over areas like Sokoto, Kastina and Kano ranges between 7.4m/s and 8.8m/s where others ranges between 4.7m/s and 6.1 m/s over the northern area. Mean wind speed ranges between 4.4 m/s and 4.6 m/s are higher in the coastal regions except Enugu with highest wind speed of 5.3 m/s. mean wind speed range between 4.4 m/s and 5.2 m/s are higher in the midland area except Jos with mean wind speed of 8.9 m/s.

In addition, weibull is a statistical tool which is often used to characterized winds of different speed for location with a certain mean wind speed as determined by the shape factor and scale factor. Where the shape factor is indicative of a normal wind distribution of wind power obtained, the knowledge of which enables us to choose a wind turbine with the optimal cut in speed (the wind speed at which the turbine start to generate usable power) and the cut out speed (the speed at which the turbine hits the limits of its alternator and no longer put out increase power output with further increase in wind speed). The standard cut in speed of most machines is 4.5 m/s and the cut-out speed is 25 m/s).The scale factor is a parameter of the weibull function that increases with height and this helps to determine how valuable a wind speed could be of importance to wind energy community. As shown in the histograms the wind speed with high shape and scale factor has high mean wind speed and gives high wind potential of good quality.

The Weibull distribution is well suited for this study since it is a convenient technique for the calculation of parameters relevant to wind power generating systems (Weibull [9], Chang [8]). This study is based on the estimation of the wind energy potential at different locations and getting areas where wind energy conversion systems could be best installed (Torress et. al. [20]). Weibull distribution was applied to the wind speed data in order to surpass the non-predictability of the wind speed characteristics.

Figures 24-39 shows cumulative distribution function which indicates the fraction of time the wind speed is below a particular speed by taking the difference of its values and the corresponding time for which the turbine would be fractional and which can be determined (i.e the cut in and cut out speed). For a typical machine, with cut- in speed 4.5 m/s and rated speed 8.0m/s on the basis of the cumulative distribution and frequency. At Kano and Jos, the wind turbine with the above specifications would be a stand still for about 3% and operate for about 97% of the time at partial load. While for Enugu, Maiduguri, Zaria, Kastina, Kaduna, Gusau, Calabar, Bauchi, Ikeja and Sokoto, the wind turbine with the above specification would be a stand still for about 13% and operate form about 87% of the time at partial load. Further at Bida, Abuja, Warri, Yola, Benin, Lokoja, Port Harcourt and Minna 76% of the wind speed was less than 4.5m/s and 24% of the wind speeds recorded between the cut in and rated speed. The observation agrees perfectly well with the result of Youm et al.[14].

However, for stations like Bida, Warri, Abuja, Yola, Benin, Lokoja, Porthacourt and Minna, vesta V42 – 600kw with 4.5m/s of cut in speed (Vesta Turbine [20]) could be found suitable with low output result, but stations like kano, Jos and other arid stations characterized with high speed will exploit the machine more perfectly.

The frequency distribution of wind speed is indispensable in evaluating the availability of wind power at a station. It also permits the selection of appropriate wind turbine for exploiting the wind, this evaluation also agrees with the work of Asrag et. al.[3]

TABLE 2: Weibull Distribution Parameters, Mean, Windspeed and Wind Power Density

STATION	SCALE PARAMETER C (m/s)	SHAPE PARAMETER K	V (m/s)	POWER DENSITY (W/M^2)
SOKOTO	8.2	9.8	7.8	284.7
GUSAU	6.5	7.9	6.1	136.2
KADUNA	5.5	11.7	5.2	84.4
KASTINA	8.0	6.3	7.4	243.1
ZARIA	6.4	7.4	6.0	136.2
KANO	8.8	6.0	8.1	318.9
BAUCHI	5.2	3.5	4.7	62.3
MAIDUGURI	5.5	4.7	5.0	75.0
BIDA	2.9	4.9	2.7	11.8
MINNA	5.0	2.7	4.4	51.1
ABUJA	4.3	4.6	3.9	35.6
JOS	9.5	6.7	8.9	423.0
YOLA	4.3	2.2	3.8	32.9
IKEJA	5.0	4.7	4.6	58.4
BENIN	3.7	5.1	3.4	23.6
WARRI	3.3	10.5	3.2	19.7
LOKOJA	3.4	5.7	3.1	17.9
PORTHACOURT	3.6	5.5	3.4	23.6
ENUGU	5.8	4.2	5.3	89.3
CALABAR	4.7	12.8	4.5	54.7

TABLE 3 TYPICAL MONTH OF HIGH WINDSPEED FOR EACH STATION

station	**Month of high wind**
Sokoto	January
Gusau	January
Kaduna	January
Kastina	June
Zaria	January
Kano	June
Bauchi	April
Maiduguri	March
Bida	April
Minna	February
Abuja	March
Jos	February
Yola	March
Ikeja	April
Benin	July
Warri	September
Lokoja	March
Porthacourt	August
Enugu	November
Calabar	August

Finally, Table 3 shows the months in which high wind is experienced at various stations. Stations like Sokoto, Gusau, Kaduna, Abuja, Zaria, Minna, Jos, Maiduguri, Yola, Lokoja and Enugu experiences high wind speed during the dry season while the wet season is the period of high wind speed in stations like Kastina, Kano, Bauchi, Bida, Ikeja, Benin, Warri, Port Harcourt and Calabar.

4.2 CUMMULATIVE DISTRIBUTION FROM 1980 TO 2009 FOR ALL THE STATIONS

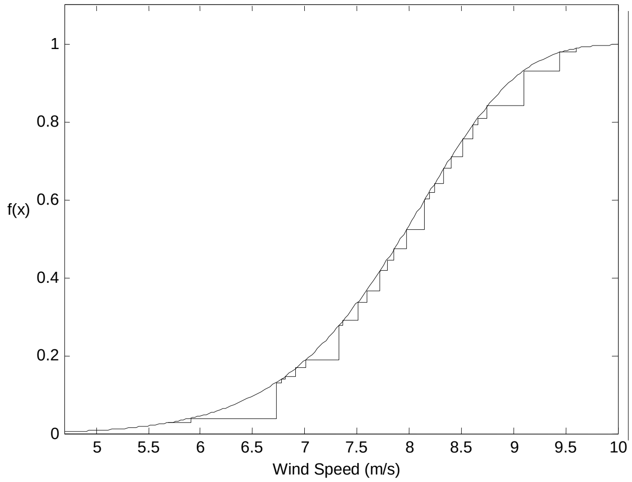


Fig. 24: CUMULATIVE DISTRIBUTION FREQUENCY FOR SOKOTO

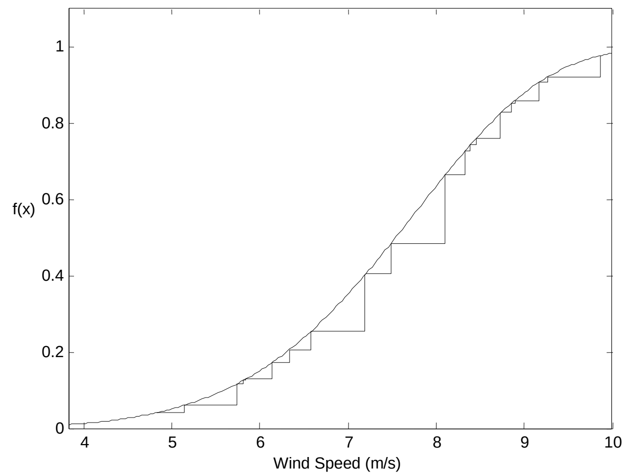


Fig.27: CUMULATIVE DISTRIBUTION FREQUENCY FOR KATSINA

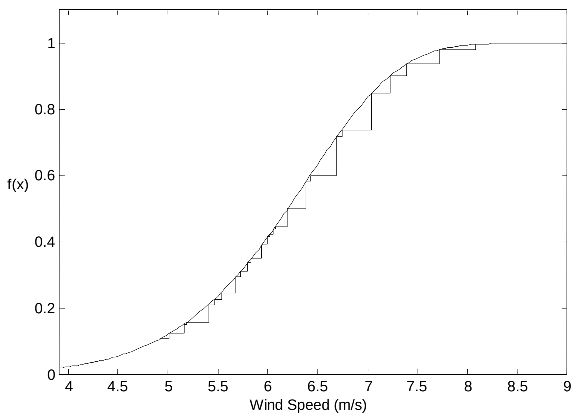


Fig25: CUMULATIVE DISTRIBUTION FREQUENCY FOR GUSAU

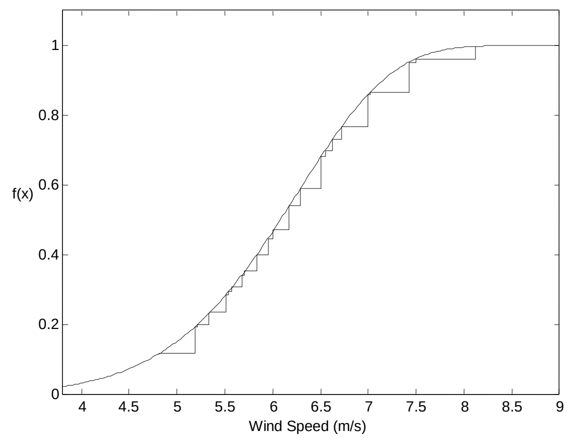


Fig.28: CUMULATIVE DISTRIBUTION FREQUENCY FOR ZARIA

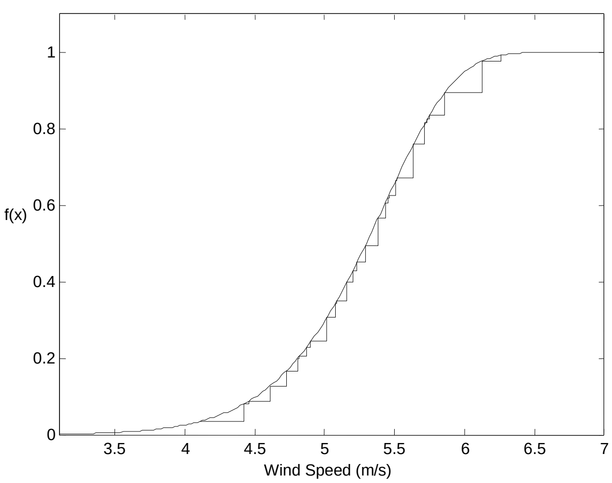


Fig. 26. CUMULATIVE DISTRIBUTION FREQUENCY FOR KADUNA

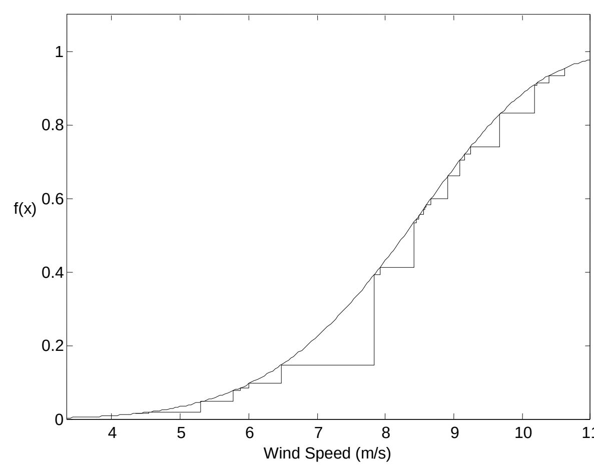


Fig.29: CUMULATIVE DISTRIBUTION FREQUENCY FOR KANO

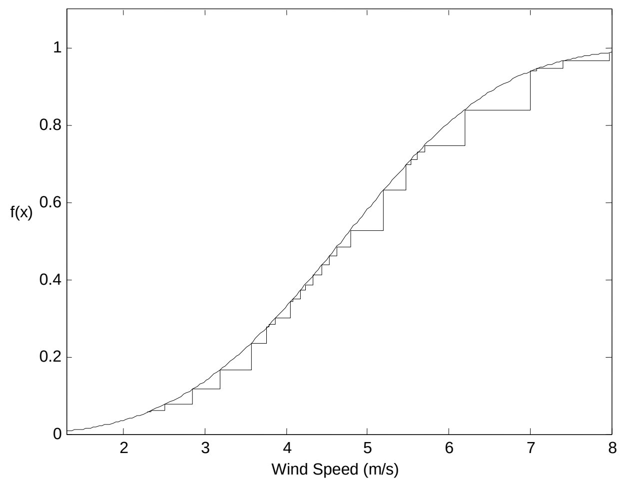


Fig.30: CUMULATIVE DISTRIBUTION FREQUENCY FOR BAUCHI

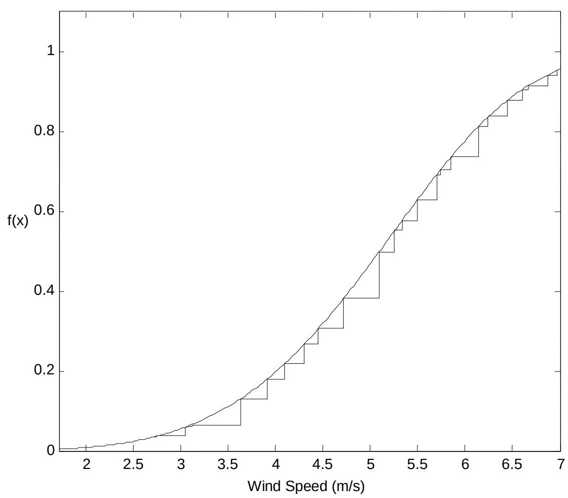


Fig.31: CUMULATIVE DISTRIBUTION FREQUENCY FOR MAIDUGURI

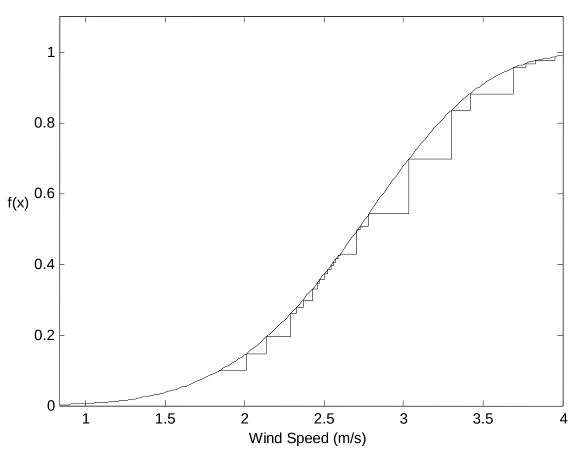


Fig.32: CUMULATIVE DISTRIBUTION FREQUENCY FOR BIDA

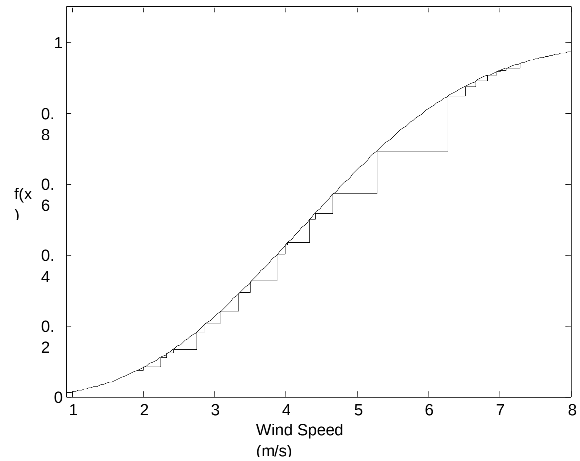


Fig.33: CUMULATIVE DISTRIBUTION FREQUENCY FOR MINNA

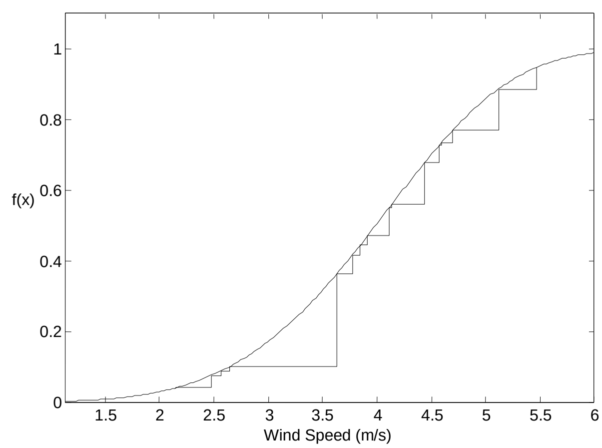


Fig.34: CUMULATIVE DISTRIBUTION FREQUENCY FOR ABUJA

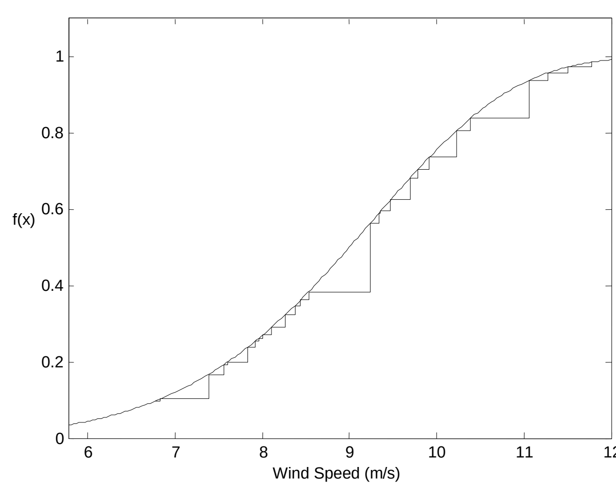


Fig. 35: CUMULATIVE DISTRIBUTION FREQUENCY FOR JOS

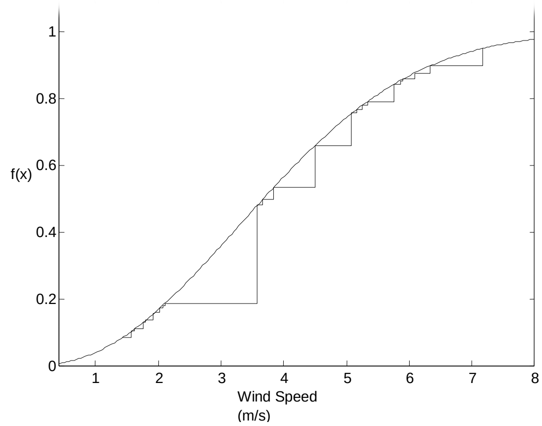


Fig.36: CUMULATIVE DISTRIBUTION FREQUENCY FOR YOLA

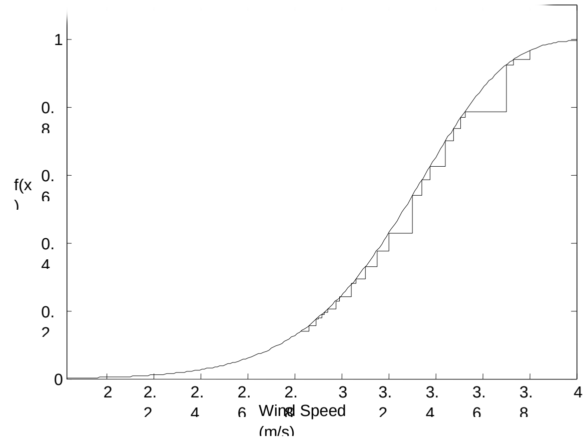


Fig. 39: CUMULATIVE DISTRIBUTION FREQUENCY FOR WARRI

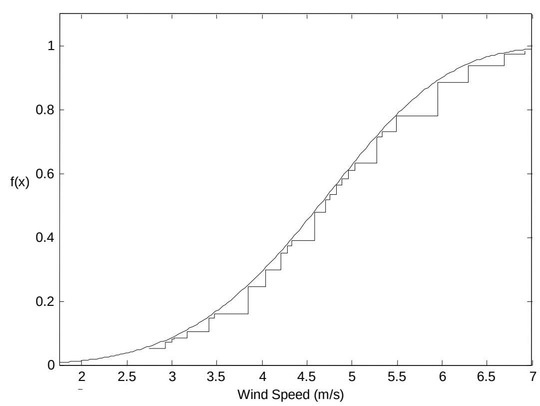


Fig.37: CUMULATIVE DISTRIBUTION FREQUENCY FOR IKEJA

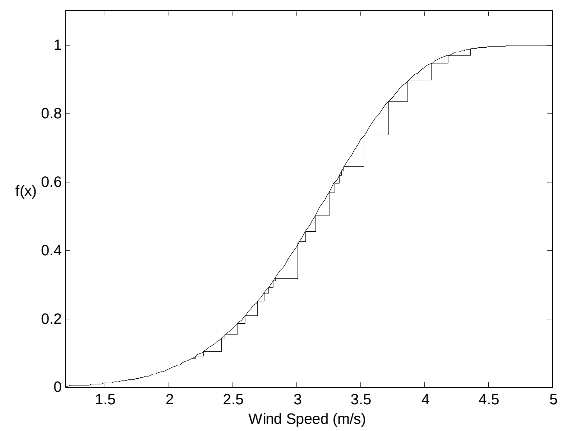


Fig. 40: CUMULATIVE DISTRIBUTION FREQUENCY FOR LOKOJA

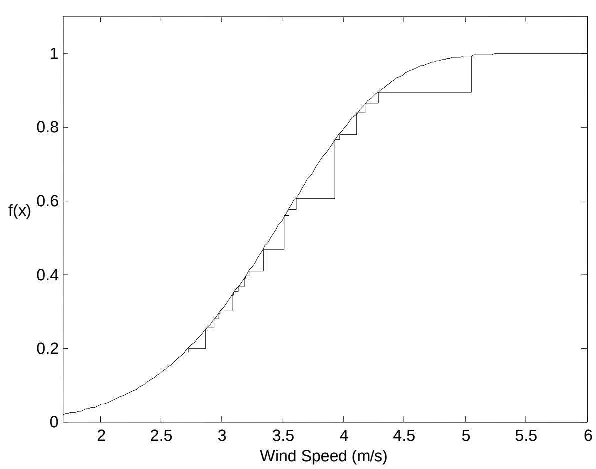


Fig. 38: CUMULATIVE DISTRIBUTION FREQUENCY FOR BENIN

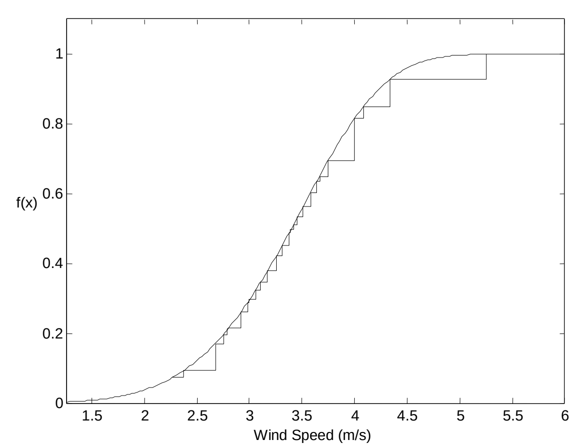


Fig.41: CUMULATIVE DISTRIBUTION FREQUENCY FOR PORTHACOURT

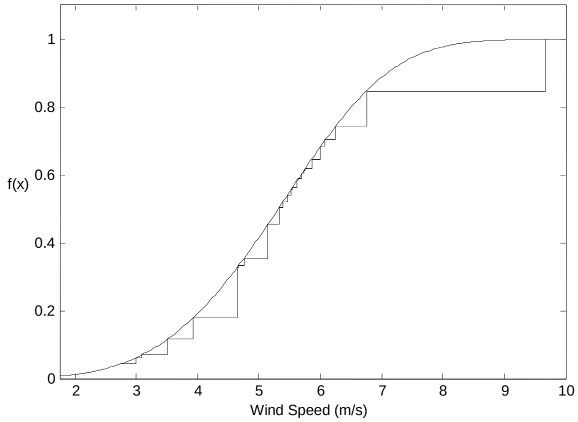


Fig. 42: CUMULATIVE DISTRIBUTION FREQUENCY FOR ENUGU

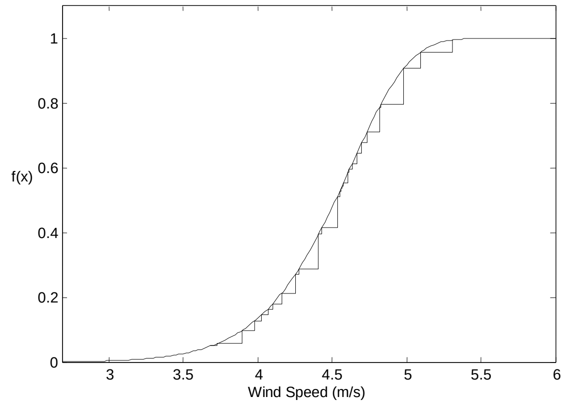


Fig .43: CUMULATIVE DISTRIBUTION FREQUENCY FOR CALABAR

CONCLUSION

The yearly measured time series wind speed data for some stations in Nigeria (across different climatic conditions) have been analyzed statistically based on weibull probability distribution function. The yearly weibull probability distribution parameters, mean wind speeds and wind energy density availability for the location have been determined. Based on the analysis the following conclusions can be made:

(a) Stations in the Arid region of Nigeria like Gusau, Zaria, Kastina, Sokoto and Kano belongs to wind power class 2, 4, and 5 with power density ranging between 136.2 w/m^2 and 318.9w/m^2 except Bauchi and Maiduguri which belongs to wind power class 1 with power density of 62.3w/m^2 and 75 w/m^2.

(b) Stations in the midland region like Bida, Minna, Lokoja, Yola, Abuja and Kaduna all belongs to wind power class one with power density ranging between 11.8w/m^2 and 84.4w/m^2 except Jos which belongs to wind power class 7 and has power density of 423w/m^2.

(c) All stations in the coastal region: Benin, Port Harcourt, Calabar, Ikeja, Warri and Enugu belong to wind power class 1 with power density ranging between 23.6$w/m^2$and 89.3w/m^2.

(d). This study shows that wind energy is available in Nigeria mostly in the Arid area than the Coastal and the Midland regions which could be used to generate electrical energy and helps to enhance irrigation system (for water pumping) for farmers in the Northern part of Nigeria.

(e)The turbine could be best installed at height 20 meters in stations like Sokoto, Gusau, Kastina, Kano and Jos; while at 40 meters in Zaria, Yola and Enugu and 100 meters in Kaduna and Maiduguri. However, stations like, Bauchi, Bida, Minna, Abuja, Ikeja, Benin, Warri, Lokoja, Port Harcourt and Calabar at height 200 meters exhibits very minute wind speed potentials and which implies that such stations are not prospective areas for wind power generation.

(f) In conclusion, this study reveals many promising areas (Sokoto, Gusau, Kastina, Zaria, Kano and Jos) in Nigeria in which wind farms can be erected and installed.

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