Wind Energy Resources Potential Maps of Borno State - Nigeria

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Abstract

The technical evaluation of wind resource potential available in all the twenty seven (27) local government area head quarter of Borno state have been investigated and identified. The annual average wind speeds for ten (10) years at the heigths of 10meters, 50 meters and 100meters and their corresponding power densities were used for the analysis. From the analysis, the annual average wind speed at 10meter, 50 meters and 100 meters heights are 4.14m/s, 5.24m/s and 5.82m/s and the approximate power densities are 43.46W/m^2, 88.13W/m^2 and 120.75W/m^2 respectively. The wind resource maps were produced using the annual average wind speeds and the corresponding power densities. From the maps all areas of interest in wind development can be explored, and can also serve as a reference document for further research work. The analysis shows that the potential of wind varies from one local government area to another. The state falls within the wind class regimes of I to II and can benefit from grid wind energy projects through the installation of wind farms in addition to non grid-connected electrical and mechanical applications.

Keywords: Wind resources, wind speed, power densities, and wind farms.

Introduction

The power sector can be referred to as the livewire of Nigerian economy; similarly, power supply can also be considered as one of the main instrument for technological and economical development of any nation. The erratic electric power supply today in Nigeria has become a perrenial problem, hence, nothing new could be written about the sorry state of the Nigerian power sector. At present, the electricity generation in Nigeria is mainly hydroelectric and gas(daily trust, 2011).

NERC (2008), reported that, Nigeria has good potential from wind, with the average wind speed that varies from 5.5m/s to 2m/s onshore. Much higher values are available offshore. Velocity and quality of wind to support onshore wind farms are better in the northern latitudes of the country. The country's wind power potentials may be classified into moderate-high (>4m/s), Moderate (3-4m/s), low-moderate (2-3m/s) and low (<2m/s).

Electric power was introduced to Nigeria in 1896, about 115 years ago (Daily trust, 2011). Yet, the nation currently generates about 3000 megawatts of electricity. Table 2, gives the generating capacity in megawatts of some countries (including Nigeria) with their corresponding populations (daily trust, 2011).

Tabe1; below shows the total generating capacity of Nigeria.

Table1: Power output per station as at February 8, 2011

S/n	Power state	Type of turbine	Generation capacity (mw)
1	Kainji	Hydro	350
2	Jebba	Hydro	334
3	Shiroro	Hydro	284
4	Egbin	Steam	961
5	Trans-Amadi	Gas	21.8
6	A.E.S	Gas	162.6
7	Sapele	Steam	84
8	Ibom	Gas	32.3
9	Okpai	Gas	224
10	Afam 1-5	Gas	60
11	Afam vi	Gas	334
12	Delta	Gas	50
13	Gegeru	Gas	250
14	Omoku	Gas	32.9
15	Omotosho	Gas	31.7
16	Olorunsogo phase I	Gas	
17	Olorunsogo phase II	Gas	101.5
	Total		**3313.8**

Source: Daily Trust, 9/02/2011

Table 2: Electric power generating capacity of some countries including Nigeria with their population

S/NO	Country	Population (millions)	Available capacity (mw)
1	Germany	82	120,000
2	United kingdom	62	80,000
3	Brazil	201	100,000
4	South Africa	49	40,000
5	Egypt	77	24,000
6	Algeria	35	11,000
7	Nigeria	150	3,000

Source: Daily Trust, 12/01/2011

In every economy including Nigeria, electricity is seen as an essential infrastructure, the most basic need of all people and with the increasing population it is needed more than ever before. In fact, it is in the same category as water, telecommunication and road. Hence, with the advancement of technology the potential of wind energy should be tested. Therefore, the need to use wind energy source is nowhere accurate than in Nigeria. This research work is aimed at evaluating wind energy resource of Borno State with a view to serve as the basis for wind development and utilization.

Borno state is located in the North Eastern part of Nigeria, lying on latitude 11^{0}50'N and longitude 13^{0} 00' E. The state has 27 local government areas and occupies 70,898 square kilometers with a population of 4098391 (2006 estimate), it share borders with the Republic of Niger, to the North

Chad to the North-East and Cameroun to the East. Within Nigeria, it shares boundaries with Adamawa State to the South, Gombe State to the West, and Yobe State to the North West.

Data Collection and Analysis

Data for 10 years (2000-2009) was used for the study. The annual average wind speed at heights of 10 meters, 50 meters and 100 meters above the surface of the earth were considered for the study. The data was obtained from NASA, surface meteorology and solar energy table, (NASA, 2010). Twenty seven locations, which are the local government area headquarters were selected for the study. The annual average wind speeds for the selected sites were used to calculate the annual power densities and annual energy densities. However automated interpolation methods computer software called surge (mapping and grinding software) was used to produce the annual average power densities and mean wind speed maps for the state.

Table 3: Geographical data of the locations

S/NO	Locations	Latitude (n)	Longitude (e)	Land Area (km^2)	Population (2006 estimate)
1	Malum-Fatori	13^{0}39’	13^{0}21’	3973	100,180
2	Askira	10^{0}38’	12^{0}54’	2362	138,091
3	Bama	11^{0}31’	13^{0}41’	4997	269986
4	Biriyel	10^{0}20’	11^{0}39’	956	78978
5	Biu	10^{0}36’	12^{0}11’	3764	176072
6	Chibok	10^{0}52’	12^{0}50’	1350	66105
7	Damboa	11^{0}09’	12^{0}45’	6219	231573
8	Dikwa	12^{0}02’	13^{0}55’	1774	105905
9	Gubia	12^{0}29’	12^{0}47’	2464	152778
10	Gudumbali	12^{0}56’	13^{0}10’	2517	95648
11	Gwaza	11^{0}05’	13^{0}42’	2883	276312
12	Azara	10^{0}26’	12^{0}07’	2098	120314
13	Khaddamari	11^{0}57’	13^{0}14’	868	211204
14	Benisheikh	11^{0}48’	12^{0}29’	2700	90015
15	Rann	12^{0}16’	14^{0}27’	1896	60797
16	Konduga	11^{0}39’	13^{0}25’		13400
17	Kukawa	12^{0}55’	13^{0}34’		
18	Kwaya-kusar	10^{0}32’	12^{0}07’	732	56500
19	Mafa	11^{0}55’	13^{0}36’	2869	103518
20	Magumeri	12^{0}06’	12^{0}49’	4856	140231
21	Maiduguri	11^{0}50’	13^{0}09’		1197497
22	Marte	12^{0}21’	13^{0}49’	3154	129370
23	Damasak	13^{0}06’	12^{0}00’	2790	116654
24	Monguno	12^{0}40’	13^{0}36’	1913	109851
25	Gambasi-Ngala	12^{0}21’	14^{0}11’	1465	237071
26	Gajiram	12^{0}29’	13^{0}12’	2467	99799
27	Shani	10^{0}13’	12^{0}03’	1262	102317

Source: Office of the surveyor general, Borno state ministry of lands and survey, Maiduguri (2011)

Analysis

The probability distributions function i.e., the scale factor (C) and shape factor (k), are given below as expressed by Ali (2003).

$K=0.83(v_m)^{½}$……………(1)

$C=V_m/\sqrt{(\Pi/4)}$……………(2)

Energy and power densities distributions were calculated using equations (3) and (4) below as expressed by (Aramu, 2009 and Zekai 2003).

$P(v) = ½ \rho v^3_m$……………………(3)

$E(v) = ½ \rho v^3_m T$…………………..(4)

Where

V_m = Annual Average Velocity (m/s)

ρ = density of the air (kg/m^3)

T = Time per day (s)

For this study, density of air (ρ) is taken to be 1.225kg/m^3.

Table 4. Annual average measured wind speeds and Weibull parameter at 10 meters height.

S/no	Locations	Annual average wind speed (m/s)	Average scale factor (c) (m/s)	Average shape factor (k)	Power density (w/m^2)	Energy density Kwh/m^2
1	Malum-Fatori	4.14	4.67	1.69	43.49	38.07
2	Askira	3.59	4.05	1.57	28.34	24.83
3	Bama	3.79	4.28	1.62	33.34	29.21
4	Biriyel	3.50	3.95	1.55	26.26	23.00
5	Biu	3.59	4.05	1.57	28.34	24.83
6	Chibok	3.59	4.05	1.57	28.34	24.83
7	Damboa	3.68	4.15	1.59	30.52	26.74
8	Dikwa	3.94	4.45	1.65	37.46	32.82
9	Gubio	3.86	4.36	1.63	35.23	30.86
10	Gudumbali	3.94	4.45	1.65	37.46	32.82
11	Gwoza	3.79	4.28	1.62	33.34	29.21
12	Azare	3.59	4.05	1.57	28.34	24.83
13	Khaddamari	3.79	4.28	1.62	33.34	29.21
14	Benisheikh	3.68	4.15	1.67	30.52	26.74
15	Rann	4.03	4.55	1.67	40.09	35.12
16	Konduga	3.79	4.28	1.62	33.34	29.21
17	Kukawa	3.94	4.45	1.65	37.46	32.82
18	Kwaya-kusar	3.59	4.05	1.57	28.34	24.83
19	Mafa	3.79	4.28	1.62	33.34	29.21
20	Magumeri	3.86	4.36	1.63	35.23	30.86
21	Maiduguri	3.79	4.28	1.62	33.34	29.21
22	Marte	3.94	4.45	1.65	37.46	32.82
23	Damasak	4.14	4.67	1.69	43.46	38.07
24	Monguno	3.94	4.45	1.65	37.46	32.82
25	Gambari-Ngala	4.03	4.55	1.67	40.09	35.12
26	Gajiram	3.97	4.45	1.65	37.46	32.82
27	Shani	3.59	4.05	1.57	28.34	24.83

Table 5: Annual average measured wind speeds and Weibull parameters at 50 meters height.

S/no	Locations	Annual average wind speed (m/s)	Average scale factor (c) (m/s)	Average shape factor (k)	Power density (w/m^2)	Energy density (kwh/m^2)
1	Malum-Fatori	5.24	5.91	1.90	88.13	77.20
2	Askira	4.54	5.12	1.77	57.32	50.21
3	Bama	4.80	5.42	1.82	67.74	59.34
4	Biriyel	4.43	5.00	1.75	53.25	46.65
5	Biu	4.54	5.12	1.77	57.32	50.21
6	Chibok	4.54	5.12	1.77	57.32	50.21
7	Damboa	4.65	5.25	1.79	61.58	53.95
8	Dikwa	4.99	5.63	1.85	76.10	66.67
9	Gubio	4.89	5.52	1.84	71.62	62.74
10	Gudumbali	4.99	5.63	1.85	76.10	66.67
11	Gwoza	4.80	5.42	1.82	67.74	59.34
12	Azare	4.54	5.12	1.77	57.32	50.21
13	Khaddamari	4.80	5.42	1.82	67.74	59.34
14	Benisheikh	4.65	5.25	1.79	61.58	53.95
15	Rann	5.10	5.75	1.87	81.25	71.17
16	Konduga	4.80	5.42	1.82	67.74	59.34
17	Kukawa	4.99	5.63	1.85	76.10	66.67
18	Kwaya-kusar	4.54	5.12	1.77	57.32	50.21
19	Mafa	4.80	5.42	1.82	67.74	59.34
20	Magumeri	4.89	5.52	1.84	71.62	62.74
21	Maiduguri	4.80	5.42	1.82	67.74	59.34
22	Marte	4.99	5.63	1.85	76.10	66.67
23	Damasak	5.24	5.91	1.90	88.13	77.20
24	Monguno	4.99	5.63	1.85	76.10	66.67
25	Gambari-Ngala	5.10	5.75	1.87	81.25	71.17
26	Gajiram	4.99	5.63	1.85	76.10	66.67
27	Shani	4.54	5.12	1.77	57.32	50.21

Table 6: Annual average measured wind speeds and Weibull parameters at 100 meters height.

S/no	Locations	Annual average wind speed (m/s)	Average scale factor (c) (m/s)	Average shape factor (k)	Power density (w/m^2)	Energy density (kwh/m^2)
1	Malum-Fatori	5.82	6.57	2.00	120.75	105.77
2	Askira	5.04	5.69	1.86	78.41	68.69
3	Bama	5.32	6.00	1.91	92.22	80.79
4	Biriyel	4.91	5.54	1.84	72.50	63.51
5	Biu	5.04	5.69	1.86	78.41	68.69
6	Chibok	5.04	5.69	1.86	78.41	68.69
7	Damboa	5.17	5.83	1.89	84.64	74.15
8	Dikwa	5.54	6.25	1.95	104.14	91.23
9	Gubio	5.42	6.12	193	97.52	85.43
10	Gudumbali	5.54	6.25	1.95	104.14	91.23
11	Gwoza	5.32	6.00	1.91	92.22	80.79
12	Azara	5.04	5.69	1.86	78.41	68.69

13	Khaddamari	5.32	6.00	1.91	92.22	80.79
14	Benisheikh	5.17	5.83	1.89	84.64	74.15
15	Rann	5.66	6.39	1.97	111.06	97.29
16	Konduga	5.32	6.00	1.91	92.22	80.79
17	Kukawa	5.54	6.25	1.95	104.14	91.23
18	Kwaya-kusar	5.04	5.69	1.86	78.41	68.69
19	Mafa	5.32	6.00	1.91	92.22	80.79
20	Magumeri	5.42	6.12	1.93	97.52	85.43
21	Maiduguri	5.32	6.00	1.91	92.22	80.79
22	Marte	5.54	6.25	1.95	104.14	91.23
23	Damasak	5.82	6.57	2.00	120.75	105.77
24	Monguno	5.54	6.25	1.95	104.14	91.23
25	Gambari-Ngala	5.66	6.39	1.97	111.06	97.29
26	Gajiram	5.54	6.25	1.95	104.14	91.23
27	Shani	5.04	5.69	1.86	78.41	68.69

Table 7: Maximum and minimum values of wind speed`

S/no	Locations	Maximum speed (m/s)	Height (m)	Minimum speed (m/s)	Location
1.	Malum – Fatori and Damasak	4.14	10	3.50	Biriyel
2	Mallum - Fatori and Damasak	5.24	50	4.43	Biriyel
3	Malum - Fatori and Damasak	5.82	100	4.91	Biriyel

Discussion

Table 3 shows the geographical locations of all the twenty seven (27) local government area headquarters, i.e. their latitudes and longitudes, total land areas and population as estimated in 2006.

Table 4 presents the wind data analysis at the length of 10meters. It was observed that the maximum annual average wind speed is 414m/s while 3.50m/s is the minimum. The corresponding power density is 43.46wm^{-2} and 24.26wm^{-2} respectively. This corresponds to wind power class I to II of the National Renewable Energy Laboratory (NREL) standards (Mukund, 2006).

It is seen from Table 5, that the highest annual average wind speed at 50 meters height is 5.24m/s with the lowest value being 4.43m/s.

Wind power density varies between 88.13W/m^2 and 53.25W/m^2. The wind speeds and the computed power densities corresponds to wind power class I to II of the National Renewable Energy laboratory (NREL) standards (Pantaleo et al, 2005).

Table 6 shows that the highest annual average wind speed at the height of 100 meters is 5.82m/s, with a minimum value of 4.91m/s. The calculated power densities corresponding to these wind speeds are 120.75W/m^2 and 72.50W/m^2 respectively. The computed data corresponds to wind power class I to II of the American wing Energy Association (AWEA) standards (AWEA, 2007).

Table 7 gives the maximum and minimum values of the annual average wind speed (m/s) with their corresponding locations and heights at which they occur.

Map Description

Figure 4 shows the wind resources, expressed in terms of wind power classes, ranging from the lowest to the highest class. Each class represents a range of annual average wind speeds and approximate mean power density at the height of 10 meters above the ground. Areas designated with wind speed of 4m/s or greater are suitable for most wind energy applications, whereas areas with wind speed of 3m/s and above are Marginal; areas with wind speed below 3m/s are generally not suitable for wind development.

The wind map in figure 5 shows the calculated mean annual wind speed and the corresponding mean power density at 50 meters height.

Locations with annual average wind speed greater than 5.0m.s at 50meters height are generally considered to be suitable wind resource for wind development, whereas towns with annual average wind speed of 4m/s and above are marginal; while those below 4m/s are considered not suitable for wind projects.

The 100 meters wind resource map showing the wind resource potential for Borno state is presented in figure 6. The areas with AVERAGE Wind speeds of around 7.0m/s with height above 100 meters are generally considered good for most wind energy conversion systems; those with wind speeds of 5m/s and above are marginal; while areas with wind speeds below 4m/s are considered not suitable for wind energy systems.

Conclusion

The wind resources potential of Borno State were evaluated at the heights of 10 meters, 50 meters and 100 meters in maps, in order to determine the areas suitable for different types of wind power development. From the analysis, the most important outermost of the study are summarized below.

1. The study shows that the maximum annual average wind speeds for Borno state are, 4.14m/s, 5.24m/s

and 5.82m/s at 10meters, 50meters and 100meters heights respectively.

2. The maximum annual average power densities are 43.46w/m2, 88.13w/m2 and 120.75w/m2 at 10meters, 50meter, and 100 meters heights respectively.

The map will also serve as a reference document for further research work and development of wind energy studies in Borno state.

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Appendices

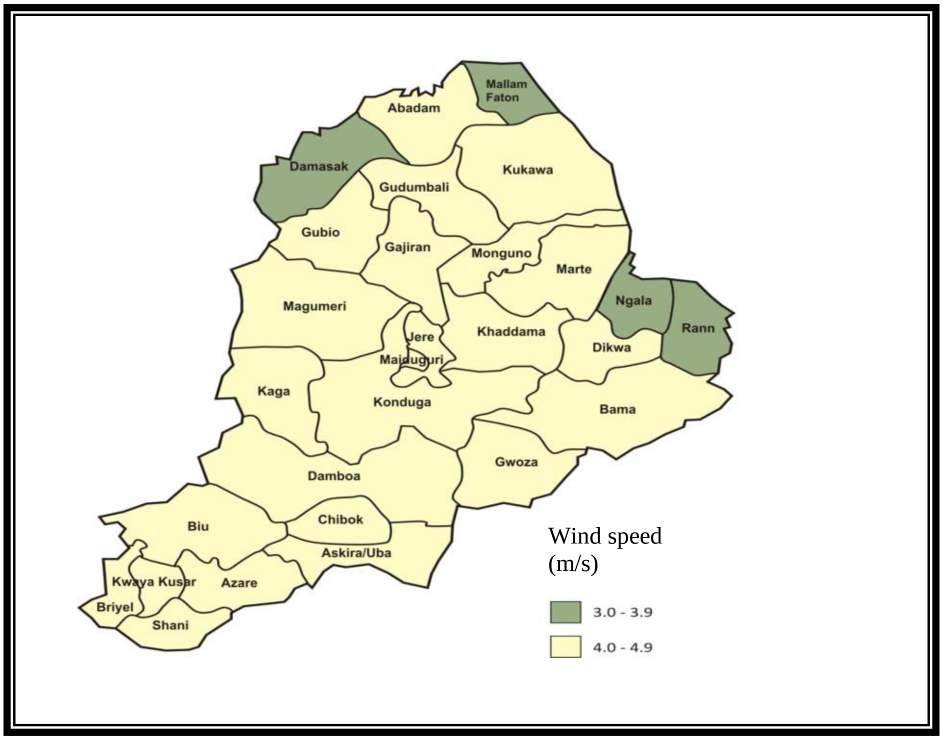

Figure 1. 10 Meter wind resource potential map showing Annual average measured wind speeds and Weibul parameter at 10 meters height.

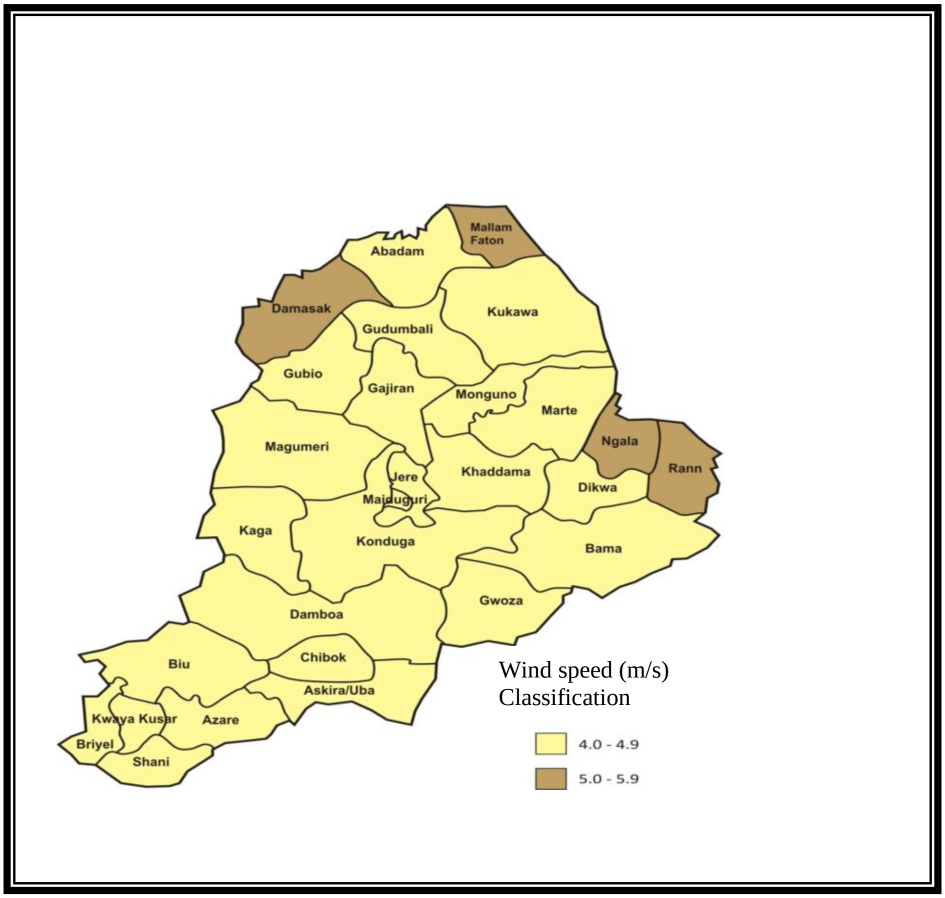

Figure 2. 50m wind resource potential map showing Annual average measured wind speeds and Weibul parameter at 50 meters height.

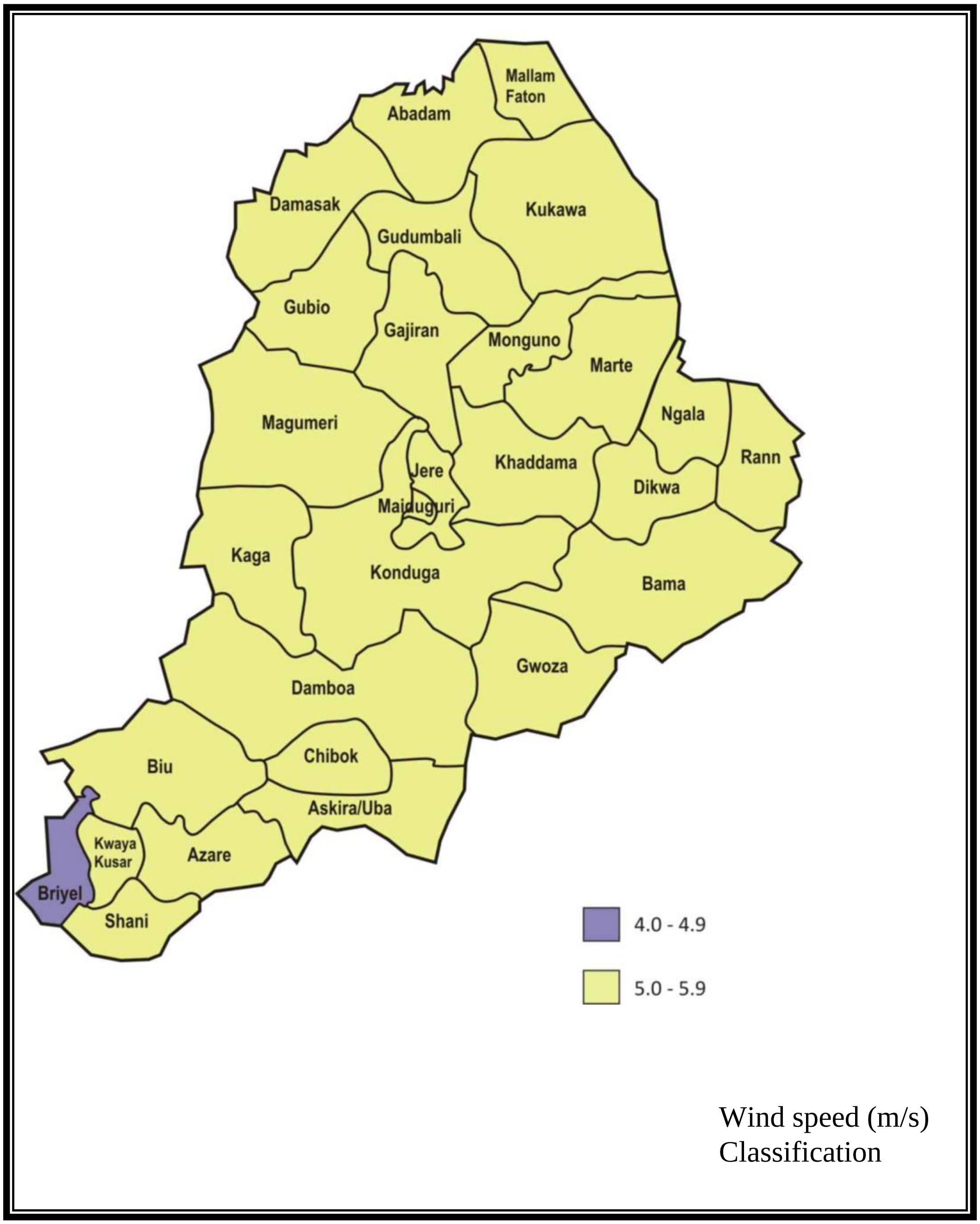

Figure. 3: 100 – meter wind resource potential maps