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Assessment of wind energy potential of two sites in North-East, Nigeria

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ABSTRACT

The study is used to assess the wind energy potential of Maiduguri and Potiskum, two sites in North-East, Nigeria. 21 years (1987–2007) monthly mean wind data at 10 m height were assessed from the Nigeria Meteorological department and subjected to 2-parameter Weibull and other statistical analyzes. The result showed that average monthly mean wind speed variation for Potiskum ranged from 3.90 to 5.85 m/s, while for Maiduguri, it ranged from 4.35 to 6.33 m/s. Seasonally, data variation between the dry and wet seasons revealed that, the mean wind speed variation for Potiskum ranged from 4.46 (for dry) to 5.16 m/s (for wet), while for Maiduguri it ranged from 5.10 (dry) to 5.59 m/s (wet). The wind power density variation based on the Weibull analysis ranged from 102.54 to 300.15 W/m^2 for Potiskum and it ranged from 114.77 to 360.04 W/m^2 for Maiduguri respectively. Moreover, Maiduguri was found to be the better of the sites in terms of monthly and seasonal variation of mean wind speed, but they both can be suitable for stand alone and medium scale wind power generation.

1. Introduction

The challenge of providing adequate and sufficient amount of energy for the populace is a global issue. The depth of concern may vary from developed to underdeveloped nations but the exercise of providing required energy is a major challenge throughout the world. Therefore, there is a need for concerted efforts to be deployed to seeking ways of adequately meeting the growing energy demand of the global population. The finite nature of the conventional sources of energy has made the sources unsustainable. Moreover, lack of energy in an economy or its inadequacy had been reported to be a source of social and economic poverty [1].

Nigeria is a country whose energy demand exceeds supply from the national utility. Current electricity production within the country is reported to be less than 4000 MW due to fluctuations in the availability and maintenance of production sources. This has culminated into high losses in electricity distribution leading to a shortfall in supply. However, considering the fact that some of the rural areas are not connected to the national grid, suggests a need to develop adequate and sustainable energy system which will be suitable, sustainable, and able to be deployed as stand alone power source [2,3]. One way through this is to develop the available renewable energy resources of which wind energy technology is a major. To begin harvesting wind resources for power production involves therefore, the initial effort of resource assessment to ascertain its potential for power generation. Based on this, the northern part of Nigeria has been identified as a region possessing great potential for wind energy utilization for power generation because of the prevailing wind situation of the place [2]. Therefore, a careful wind resource assessment of this region will be a major leap in the move towards developing sustainable energy and power for the nation. This is the focus of this study. It evaluated and compared the prevailing wind resource potential of two sites, Maiduguri and Potiskum, in North-East Nigeria, as captured by a cup-generator anemometer at 10 m height. The sites, about 142 miles apart, were formerly in old Borno State, but now separated into two different states in August 1991 as a result of the state creation exercise of the federal government. Presently, Maiduguri is the capital city of Borno state while Potiskum is in Yobe state.

2. Materials and methods

Twenty one years (1987–2007) monthly mean wind data for the two sites were assessed from the Nigeria Meteorological department, Oshodi, Lagos State, South-West, Nigeria. Continuous 3 h daily readings over the period considered were used and subjected to various statistical analyses. The data were recorded continuously using cup-generator anemometer at a height of 10 m and presented

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graphically in Figs. 1 and 2. However, Fig. 1 gives the monthly mean wind distribution of the sites across the years considered while Fig. 2 gives the annual contribution of each site's mean wind distribution for each month. The sites' details for the stations considered are as displayed in Table 1 below.

2.1. Mathematical analysis

Various statistical distributions exist for describing and analyzing wind resource data. Some of these include normal and lognormal, Rayleigh and Weibull probability distributions to mention a few [4,5]. However, of the statistical methods, the Weibull distribution has been found to be accurate and adequate in analyzing and interpreting the situation of measured wind speed and in predicting the characteristics of prevailing wind profile over a place [6–8]. Thus, in this study, the Weibull two parameter Probability Density Function (PDF) was employed in carrying out the analyses of wind speed potentials over the sites considered. This is given as [9–13]:

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

Where k is the Weibull shape parameter, c is the scale parameter and $f(v)$ is the probability of observing wind speed v (m/s).

The Weibull Cumulative Density Function (CDF) corresponding to the PDF is given as

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

Where $F(v)$ is the cumulative distribution function of observing wind speed v.

The mean value of the wind speed v_m and standard deviation σ for the Weibull distribution as defined in terms of the Weibull parameter k and c are given as [9,10]:

$$v_m = c\Gamma\left(1+\frac{1}{k}\right) \quad (3)$$

and

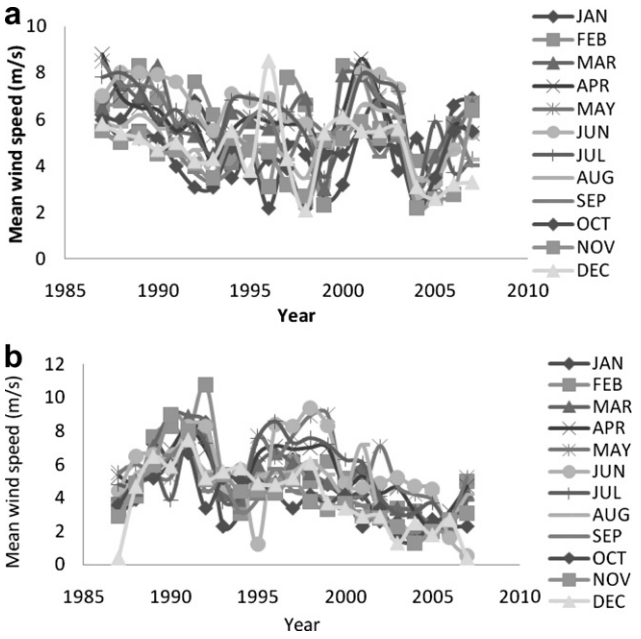

Fig. 1. a) Plot of whole monthly wind speeds for Maiduguri; b) Plot of whole monthly wind speeds for Portiskum.

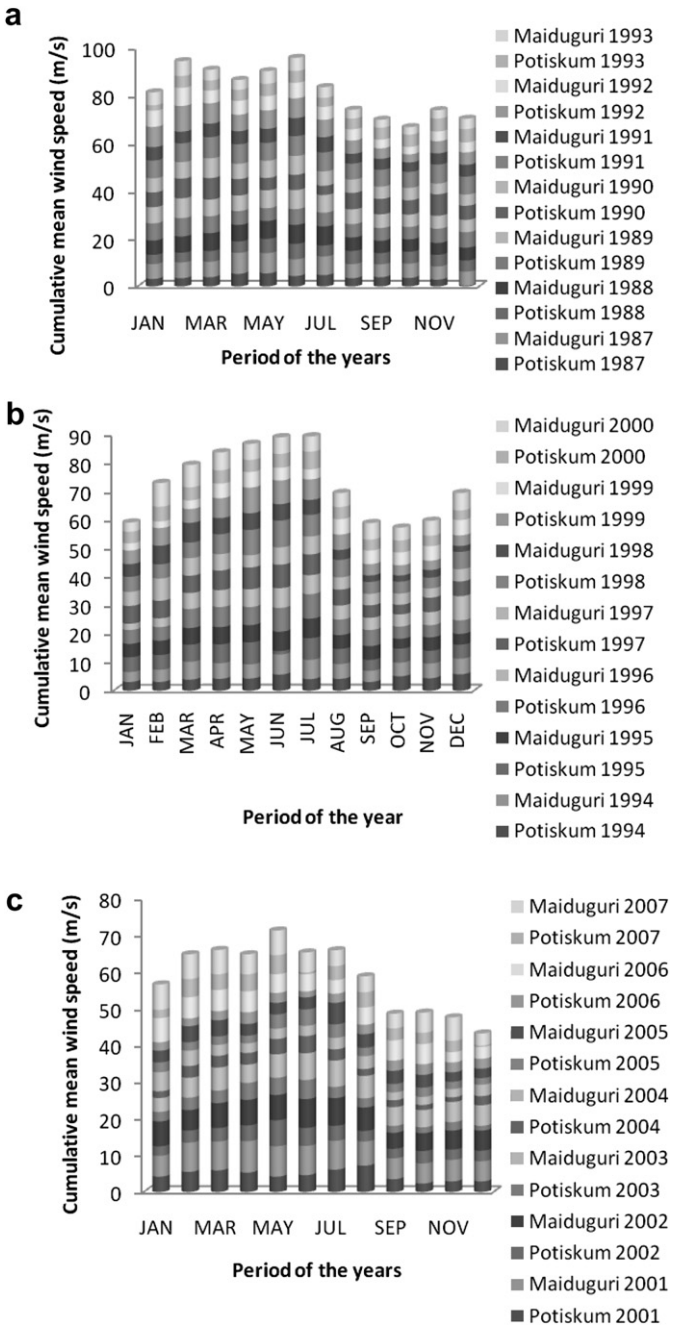

Fig. 2. Plot displaying annual mean wind speed distribution for the two sites combined together.

$$\sigma = \sqrt{c^2\left\{\Gamma\left(1+\frac{2}{k}\right) - \left[\Gamma\left(1+\frac{1}{k}\right)\right]^2\right\}} \quad (4)$$

Where $\Gamma()$ is the gamma function of ().

Table 1
Details of the two stations for which wind data were assessed and analyzed.

Sites	Location	Latitude	Longitude	Air density (kg/m^3)	Elevation (m)
Maiduguri	Borno State	11.51′	13.05′	1.1842	353.8
Potiskum	Yobe State	11.42′	11.02′	1.1771	414.8