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Discovery

Harmattan wind and its potential for electricity generation in Northeastern Nigeria

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The paper seeks to examine the spatial and the temporal variations of surface winds over Northeastern Nigeria and their potential for energy generation. Wind data for six (6) synoptic stations located in northeastern Nigeria were obtained from the Nigerian Meteorological Agency (NIMET). The stations; Nguru, Maiduguri, Potiskum, Gombe, Bauchi and Yola are well distributed across the region. Descriptive statistics - mean, standard deviation and coefficient of variation - were used in analyzing the data. In addition, inferential statistics - time series analysis and regression were also used to provide further insight into the temporal and spatial characteristics of surface wind over the study area. The study found surface wind to vary over time and space. It was also observed that the North-east trade wind plays a key role in influencing the variations of Harmattan season climatic elements especially surface wind flow; because it is the driver of the season and is controlled by the movements of the Inter Tropical Discontinuity (ITD). Latitude has also demonstrated a great deal of influence on the variations of climatic parameters in the region. Accurate documentation of surface wind characteristics over the study area help in the determining the specification of suitable wind turbines for various locations.

INTRODUCTION

Fundamentally two wind systems affect the weather and climate of the region northeastern Nigeria. These are the northeast trade wind and the southwest monsoon (Ojo, 1977; Iloeje, 1981 and Buba, 1995). The influence of these wind systems are determined by the North to South and South to North movements of the Inter-tropical Discontinuity (ITD); the boundary between the Southwesterly (maritime) wind and the Northeasterly (continental) wind. The ITD advances inland as far as latitude 22^0 to 25^0N in August at the margin of the Sahara beyond Nigeria's northern border, while it does not retreat equator-ward beyond latitude 4^0N during the Harmattan season (Adedokun, 1978).

The changing direction of the South west monsoonal wind in the month of November which is influenced by the migration of the IT southward paves the way for the dust characteristic of the Harmattan to engulf the clear atmosphere experienced during the rainy season that mostly end in October in the region. Hazy weather accompanied by poor visibility is experienced during this season, basically caused by the presence of the crustal materials usually made up of fine particles blown from the Sahara desert by the Northeast trades over West Africa. The Northeast trade wind is the driver of this weather event because it conveys huge amount of dust into the air across the West African sub region thereby blocking out solar radiation that lowers the temperature and the parching wind that rids the atmosphere of its moisture thus resulting in low relative humidity. The study focused on wind speed as climatic element that plays a key role in defining the Harmattan season.

The wind, as a source of energy is gradually gaining prominence around the world, although backed by long history, the technology is still new unlike the sun; its availability undoubted, many countries are yet to embrace it. Today, wind power is not used in Nigeria, what is available are relics pointing to its previous usage. However, the desire to seek for a lasting solution to the energy situation of Nigeria has prompted the government as well as independent researchers to assess the nation's potentials for wind energy. The use of wind power, by wind mills is not basically different northeastern Nigeria. The steadiness of the trade winds is an important advantage. Wind was observed to be strongest in the hilly regions of the North, while the mountainous terrains of the middle belt and northern fringes demonstrated high potential for great wind energy harvest. It was equally observed that, due to varying topography and roughness of the country, large differences may exist within the same locality. It is common to have values for the wind speeds range from 4.0 to 5.12 m/s over the study area, at about 10 m height. Peak wind speed occurs between April and August (Ajayi, 2010).

DATA AND METHODS

Archival data for wind speed for thirty years (1884-2014) were obtained from the Nigerian Meteorological Agency (NIMET).The thirty-year period is what the World Meteorological Organisation (WMO) recognizes as a climatological normal period. Six synoptic stations used for the study are: Nguru, Maiduguri, Potiskum, Gombe, Bauchi and Yola (Fig. 1). The stations are well distributed spatially over Northeastern Nigeria, which makes them adequate representatives of the region.

Long-term wind speed characteristics for the region were described using mean, standard deviation and coefficient of variation. The data

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were subjected to the prescribed Statistical tools for analysis so as to gain an insight into the spatio-temporal variations of this key element over the study area. Graphs were also generated for the monthly and seasonal distribution to show the long-term monthly and seasonal variations of the wind speed. Five-year moving averages and trend lines were superimposed on the time series so as to capture variations in the seasonal patterns of wind speed of all the synoptic stations. Wind speed maps of the region were also generated over different time scales within the study period using ArcGIS software.

RESULTS AND DICUSSION

This section presents and discusses results obtained from the data. The first section deals with the monthly distribution of wind speed over the study; the second section concerns itself with the seasonal; and the third section with spatial variations in the distribution of isovents; assesses the potential of wind speed over the region for electric power generation.

Monthly wind speed distribution

Figure 2 presents the monthly mean wind speed situation for northeastern Nigeria. Wind speed variations are clearly seen across the six synoptic stations of the study area. Yola has the lowest wind speed value ranging from 1.2 to 3.0 Knots. Maiduguri and Potiskum stations exhibited highest values of 5.00 to 6.00 Knots. Gombe, Bauchi and Nguruhave values are in the range from 3.00 to 5.00 Knots. It can further be observed that wind speed values for all the stations fluctuate with the seasons of the year in line with the apparent movements of the overhead sun. Higher wind speeds coincided with the Harmattan seasons (December, January, February) in the study area. The pattern described above supports the assertion that is higher at the source region and decrease with distance southward (De Longueville et al., 2010).

Seasonal mean distribution of wind speed

Table 1 shows the influence of latitude and some other local geographical factors that affect the seasonal means distribution of wind speed and coefficient of variations.

The Northeast trade wind is the driver of the Harmattan season across West Africa, by conveying huge amount of dust into the atmosphere across the region. The Northeast trade wind that advances into the savannah belts of Nigeria due to the migration of the Inter-tropical Discontinuity (ITD) southwards in October and November remains the dominant wind system during this season over the study area. This is because the subtropical high pressure system is usually strong during the Harmattan season and intensifies the movement of the wind which is responsible for mobilizing and transporting the dust for the source regions (Bodele Depression) in the Sahara desert to West Africa and beyond. The speed of the wind therefore, determines the amount of dust it carries into the atmosphere.

Table 1 presents the seasonal characteristics of wind speed over Northeastern Nigeria. While the mean ranges from 1.68 at Yola to 7.08 knots at Potiskum, standard deviation from 0.22 to 2.16 and coefficient of variation from 9.40 to 56.08, it is clear that wind speed over the study area varies in time and space. The values above seem to be lower than those of NIMET (2014) who gave a range of 5 to 20knots for Northern Nigeria. However, from the description above, it can be observed that wind speed over the study area increase with latitude. This agrees with the findings of (Adaramola and Oyewole 2011).

Figure 3 shows the variable temporal nature of wind speed from one station to another in Northeastern Nigeria. The pattern is characterized by fluctuation on different time scales. The system is in all the locations remain stable as no sign of upward or downward trend was detected. This is a good position from the view point of the wind's potential for power generation. Seasonal surface wind speed range from 1knot to 12knots across the six synoptic stations (Fig. 3 and Table 1) of the study area. The seasonal means distribution of wind speed in Bauchi recorded its lowest in 2003/2004 and the highest in two seasons (2009/2010 and 2010/2011). Gombe recorded its lowest wind speed in 1994/1995 and the highest in 2003/2004; Maiduguri recorded the lowest wind speed in 1998/1999 and the highest in 2010/2011; Nguru recorded the lowest wind speed in 1986/1987 and the highest in 1992/1993; Potiskum recorded the lowest wind speed in 1984/1985 and the highest in 1993/1994 and Yola recorded the lowest wind speed in 1995/1996 and the highest in 2005/2006.

Spatial distribution of seasonal wind speed

The spatial distributions of seasonal wind speed over northeastern Nigeria are presented for six (6) five-year periods (see Fig. 4a to 4f). Wind speed distribution for 1984/1985 – 1988/1989 Harmattan season (Fig. 4a) showed variations between 2.27knots in south to 5.79knots in the north of the study area. Maiduguri shows the highest wind speed followed by areas around Nguru and Potiskum. Areas around Bauchi, Gombe and Yola in the south showed relatively low wind speed in this sub period. 1989/1990 – 1993/1994 and 1994/1995 – 1998/1999 periods (Fig. 4b and 4c) show similar variations and distribution patterns. Variation for the period ranges are from 1.98knots to 8.78knots and form 1.79knots to 7.40knots respectively. Potiskum area in both periods show the highest wind speed followed by Nguru and Maiduguri in the north. Areas around Bauchi, Gombe and Yola witnessed relatively lower wind speed.

The period 1990/2000 – 2003/2004 (Fig. 4d) showed variation in seasonal wind speed between 1.71knots in the south and 7.05knots in the north. Areas around Potiskum, Nguru and Gombe witnessed high wind speed while Bauchi and Yola in the south had lower wind speed. 2004/2005 – 2008/2009 periods (Fig. 4e) showed variations between 2.71knots in south and 7.11knots in the north. Potiskum area had high wind speed followed by Nguru, Maiduguri, while Gombe. Bauchi and Yola had low wind speeds. The period for 2009/2010 – 2013/2014 (Fig. 4f) showed relatively high wind speed across the study area. It varied from 3.56knots in the south to 6.62knots in the north. Maiduguri area witnessed high wind speed followed by Nguru, Potiskum and Gombe while Bauchi and Yolahad low wind speed.

The spatial distribution of wind speed over northeastern Nigeria is primarily controlled by latitude and other local factors. This is clearly shown by the fact that wind speed increase with latitude. Moreover, the plains of Maiduguri and Potiskum are contributory factor to high speed of wind experienced in the region. It is important to state here that wind speed tends to be higher in areas where there are no barriers like shelter belts and highlands. From the foregoing, it is clear that wind speed in the study area regular in its flow pattern for the entire period of study. The speed of the wind increases northwards in agreement with the work of Adaramola and Oyewole (2011). It should be noted that Maiduguri and Potiskum have featured prominently as areas with high wind speed at one point or the other throughout the study period and this may not be unconnected with the influence of the easterlies wind in shifting the flow pattern of the northeast trade wind. Variation observed in the distribution of wind speed in the study area is important with respect to the impacts of climate variability and change (Karaburun et al., 2012) and (Amadi et al., 2014). The movement of the wind in the first place is determined by pressure gradient in the Sahara desert during the period of

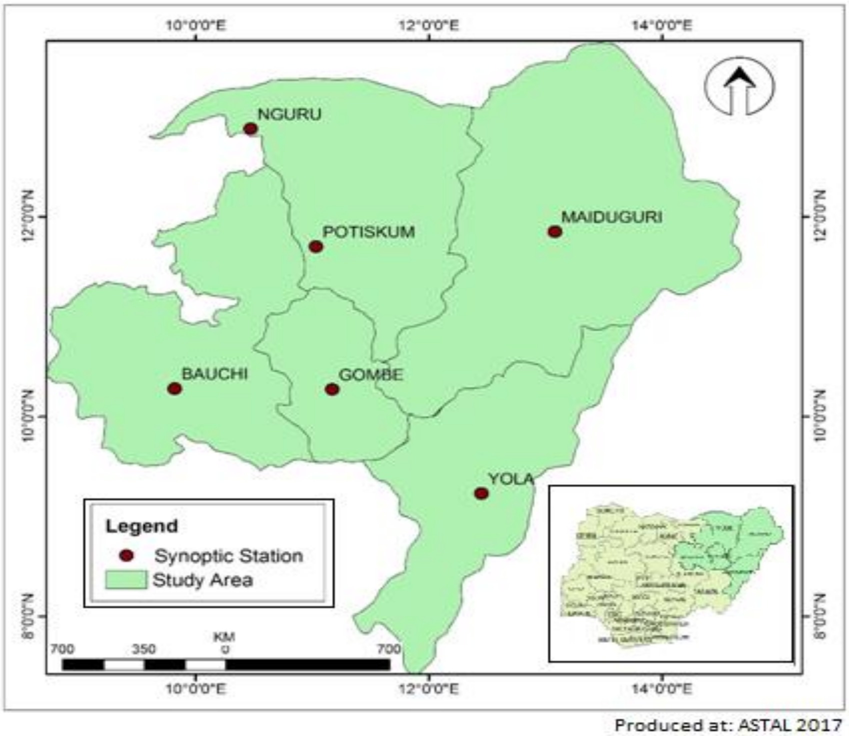

Figure 1 The Study Area

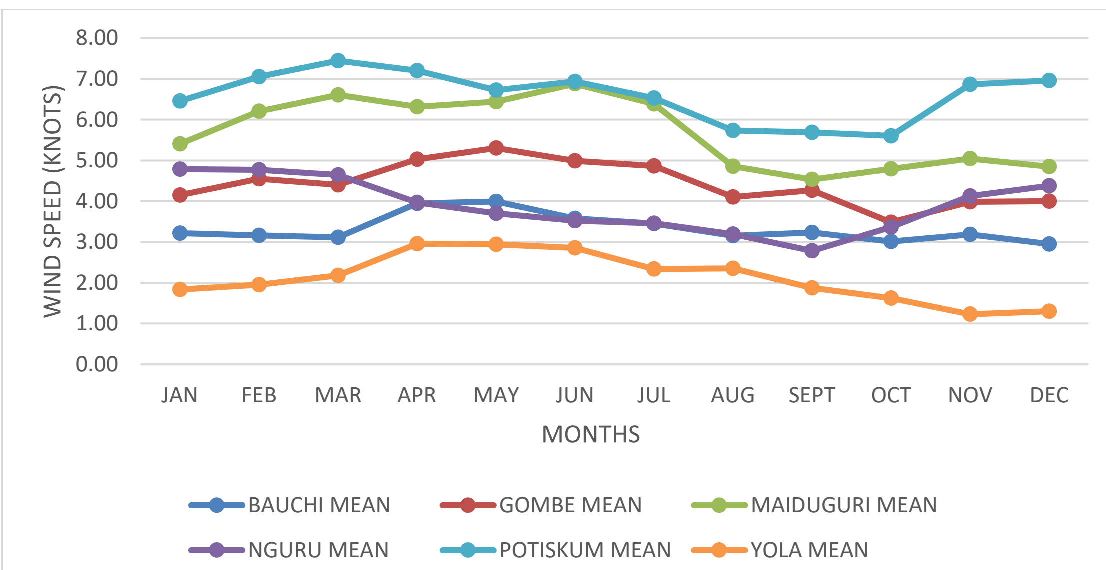

Figure 2 Mean Monthly Distribution of Wind Speed (1984-2014)

Table 1 Descriptive Statistics of Seasonal Wind Speed and Coefficient of Variation

Station	Latitude	Wind Speed (knots)	Standard Deviation	Coefficient of Variaton (%)
Nguru	12.88	4.56	0.43	9.40
Maiduguri	11.85	5.67	0.69	12.24
Potiskum	11.70	7.08	2.11	29.86
Bauchi	10.28	3.07	1.72	56.08
Gombe	10.27	4.21	2.16	51.21
Yola	9.23	1.68	0.22	12.84

*one nautical mile is 1.852km

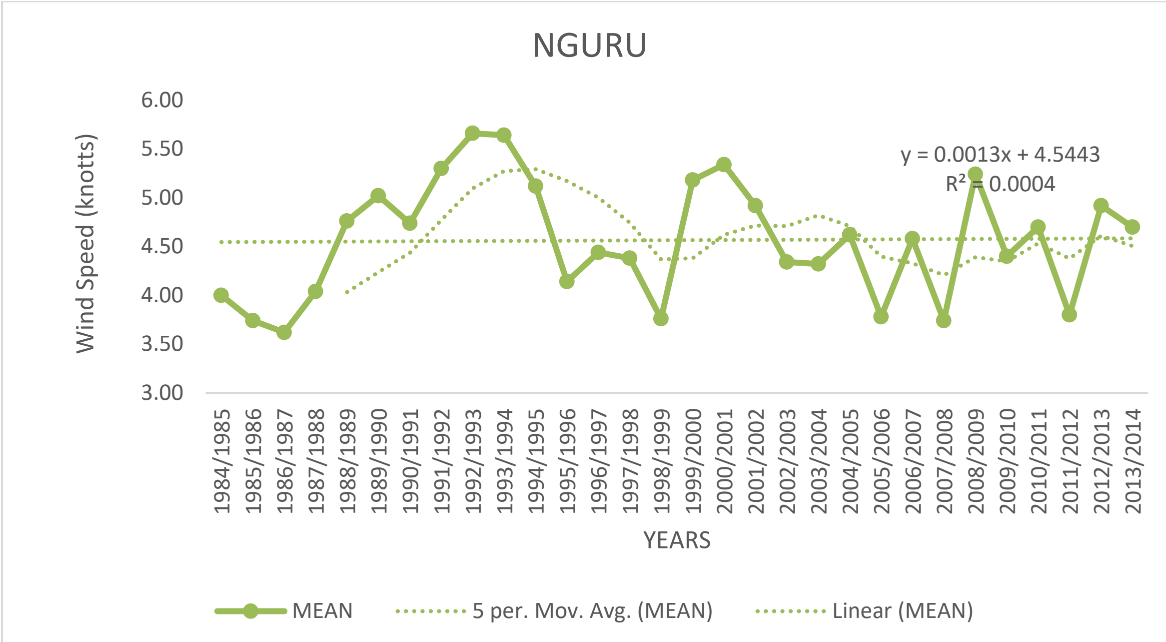

Figure 3a Seasonal Wind Speed Distribution at Nguru (1984-2014)

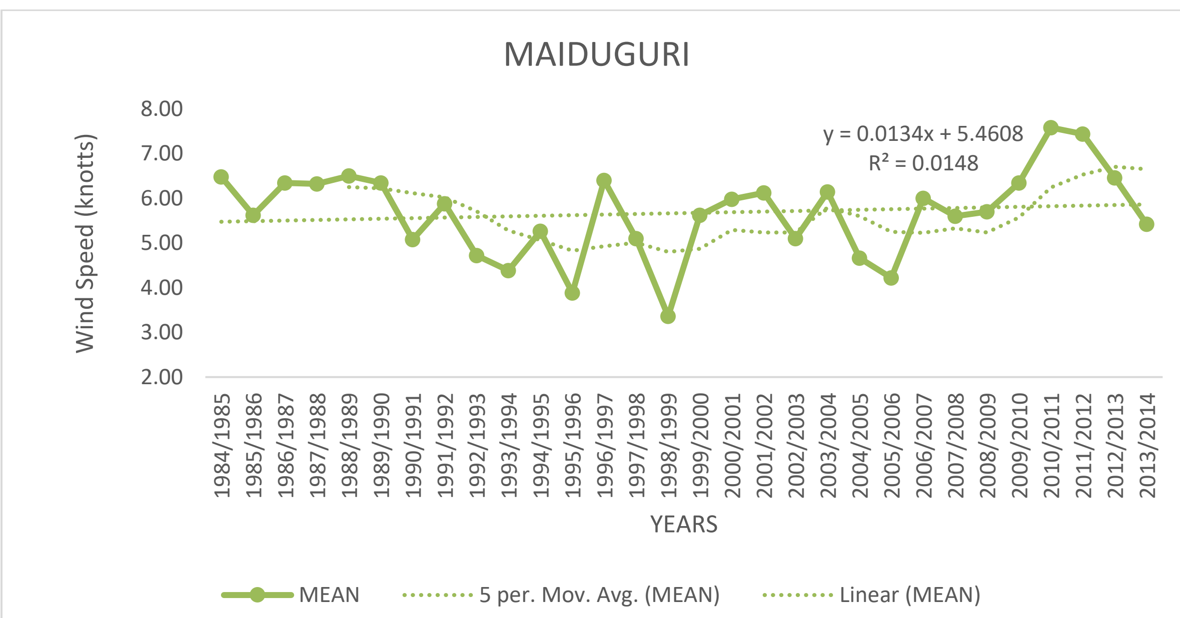

Figure 3b Seasonal Wind Speed Distribution at Maiduguri (1984-2014)

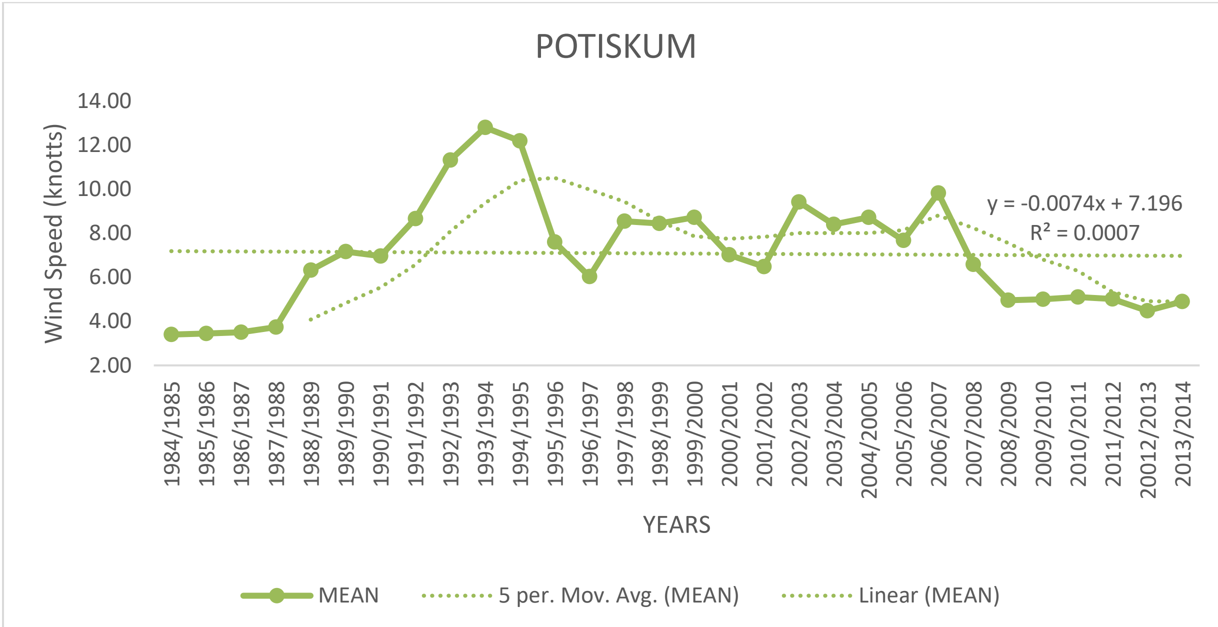

Figure 3c Seasonal Wind Speed Distribution at Potiskum (1984-2014)

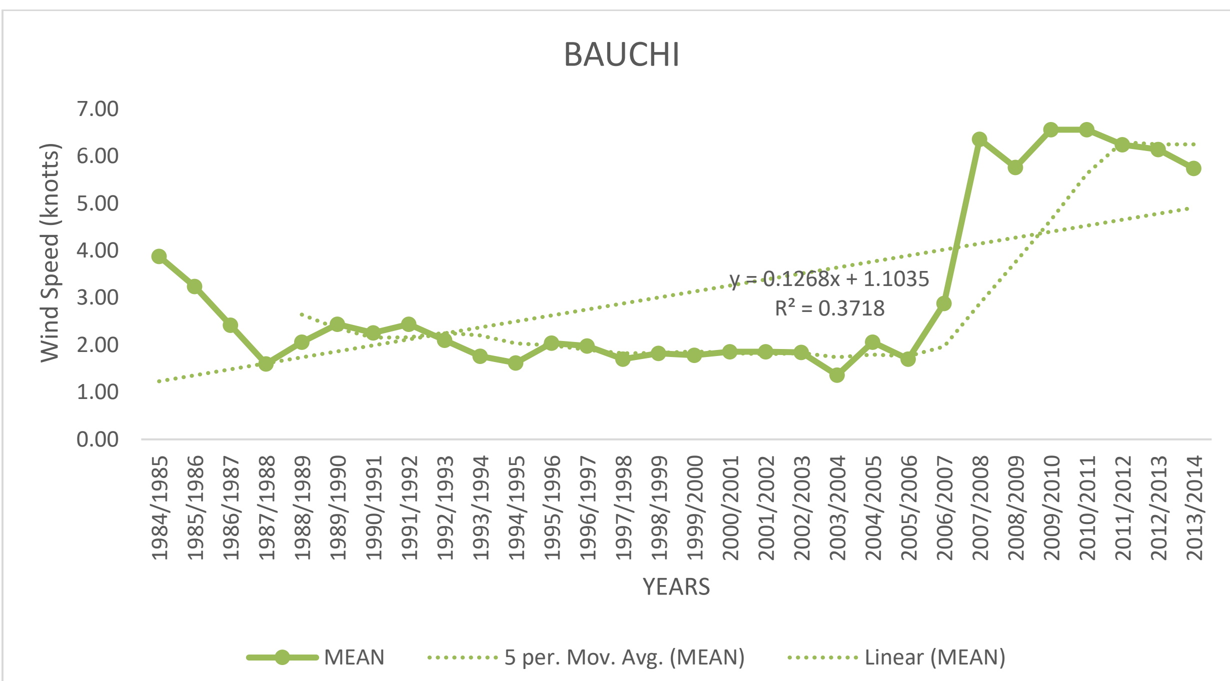

Figure 3d Seasonal Wind Speed Distribution at Bauchi (1984-2014)

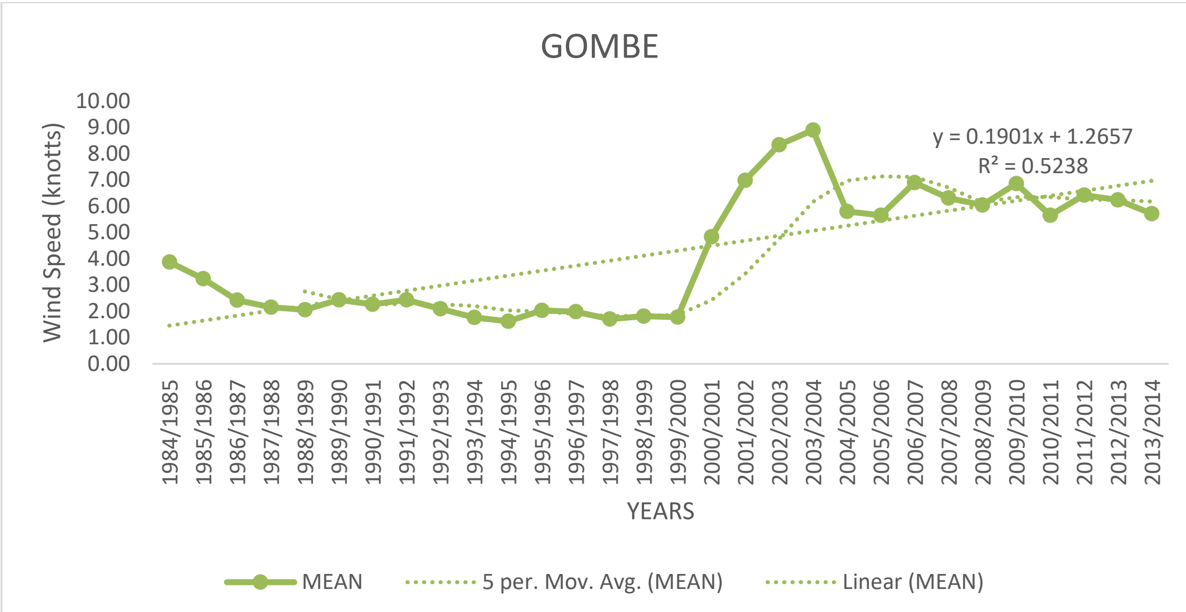

Figure 3e Seasonal Wind Speed Distribution at Gombe (1984-2014)

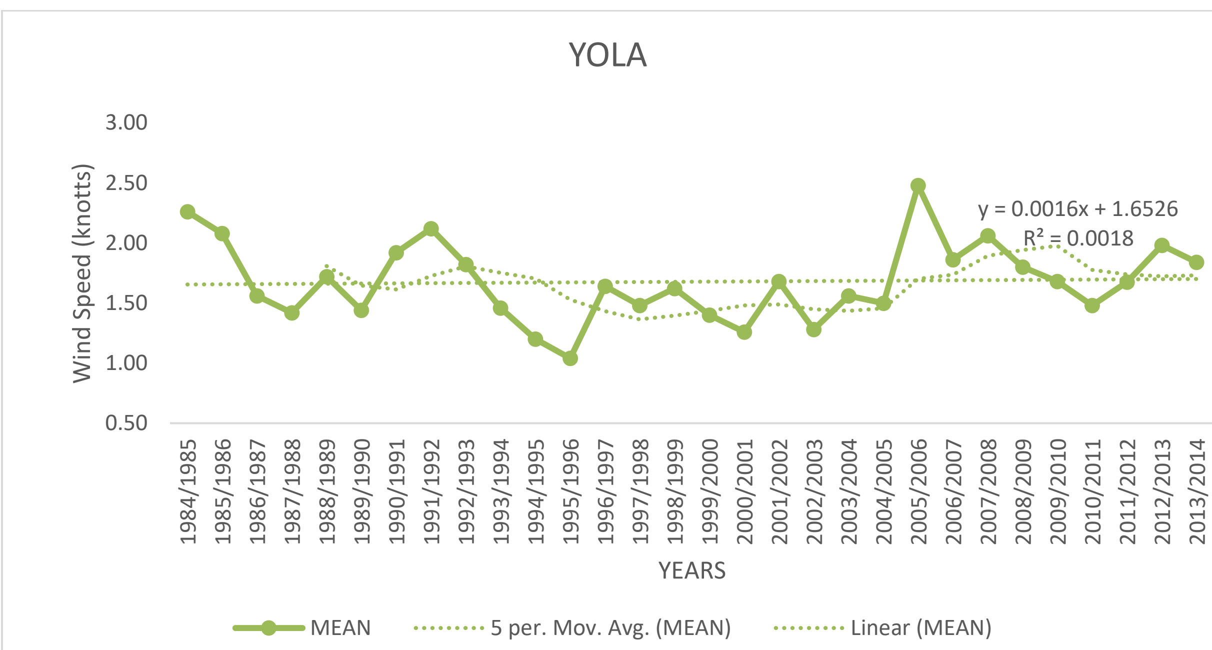

Figure 3f Seasonal Wind Speed Distribution at Yola (1984-2014)

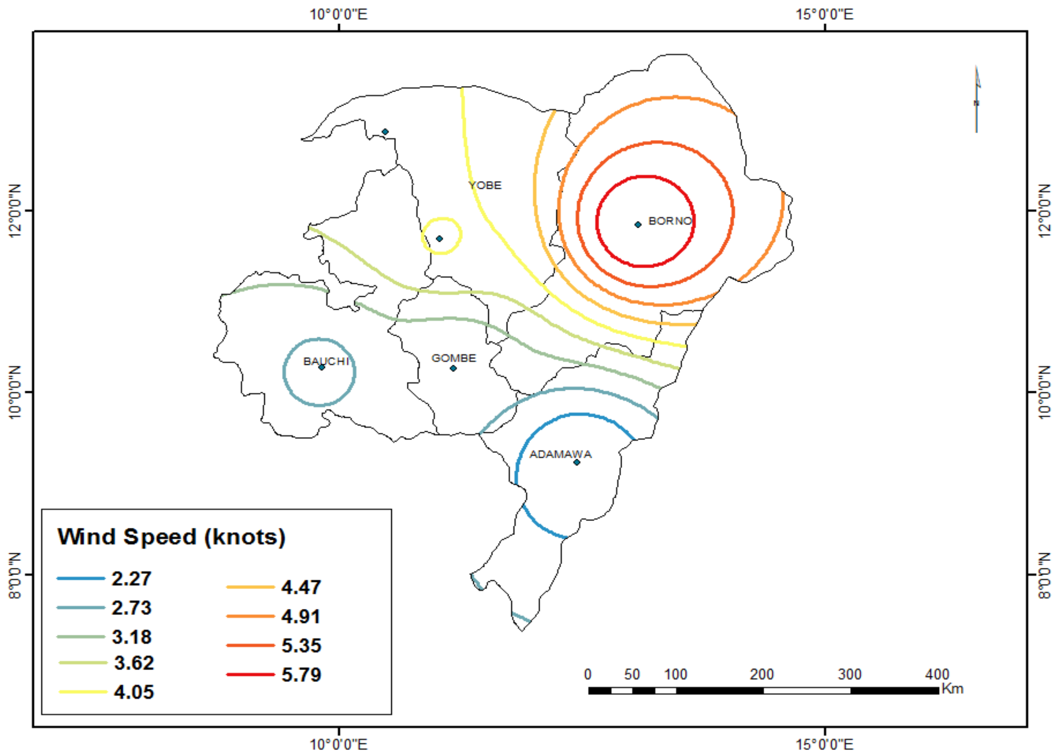

Figure 4a Spatial Wind Speed (isovents) Distribution over Northeastern Nigeria (19984/1985 – 1988/1989)

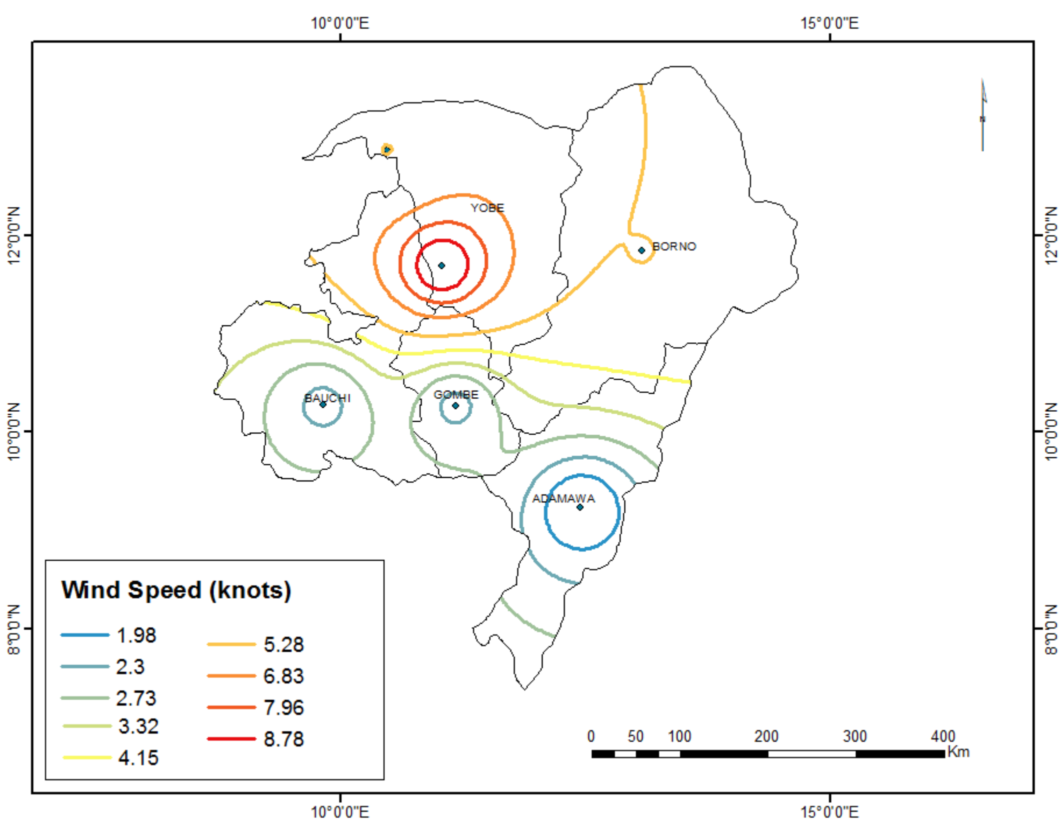

Figure 4b Spatial Wind Speed (isovents) Distribution over Northeastern Nigeria (1989/1990 – 1993/1994)

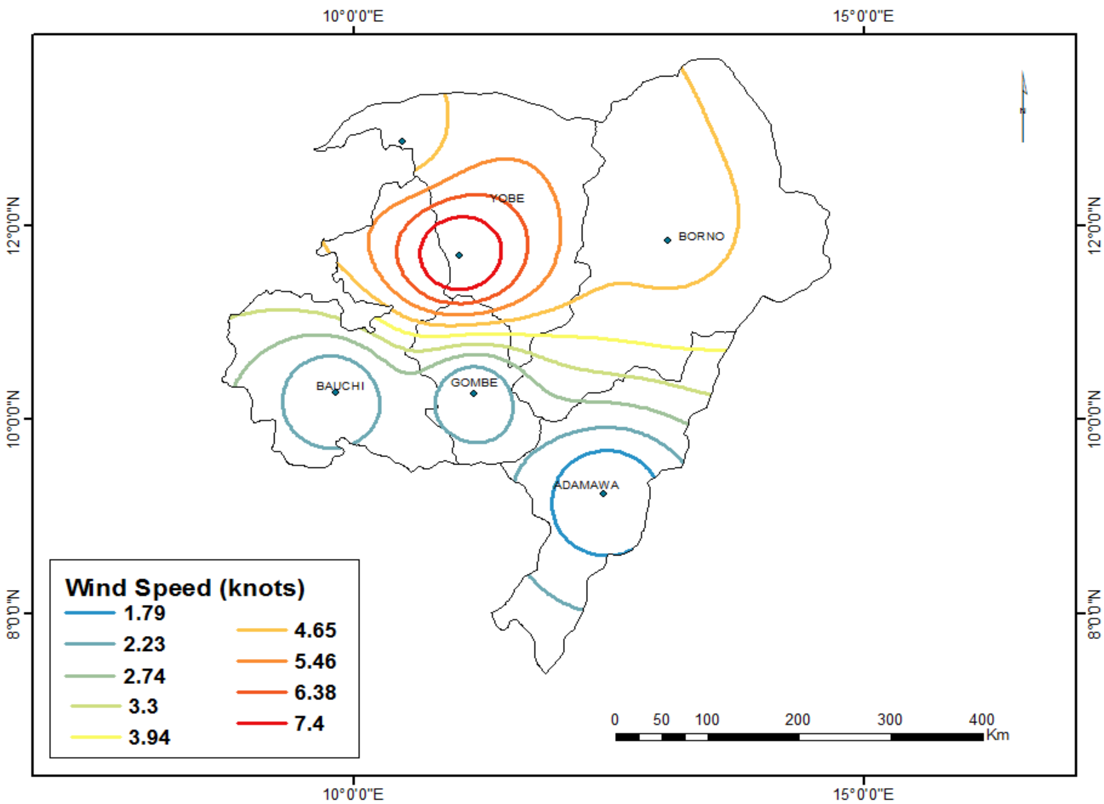

Figure 4c Spatial Wind Speed (isovents) Distribution over Northeastern Nigeria (1994/1995 – 1998/1999)

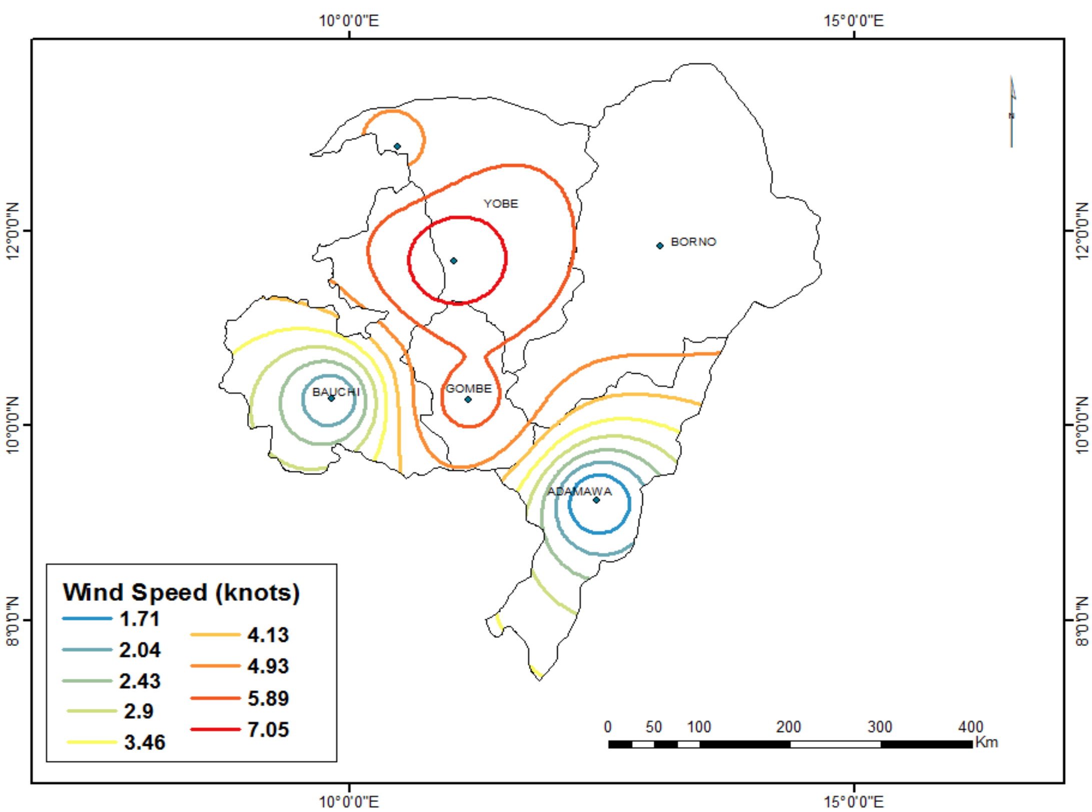

Figure 4d Spatial Wind Speed (isovents) Distribution over Northeastern Nigeria (1999/2000 – 2003/2004)

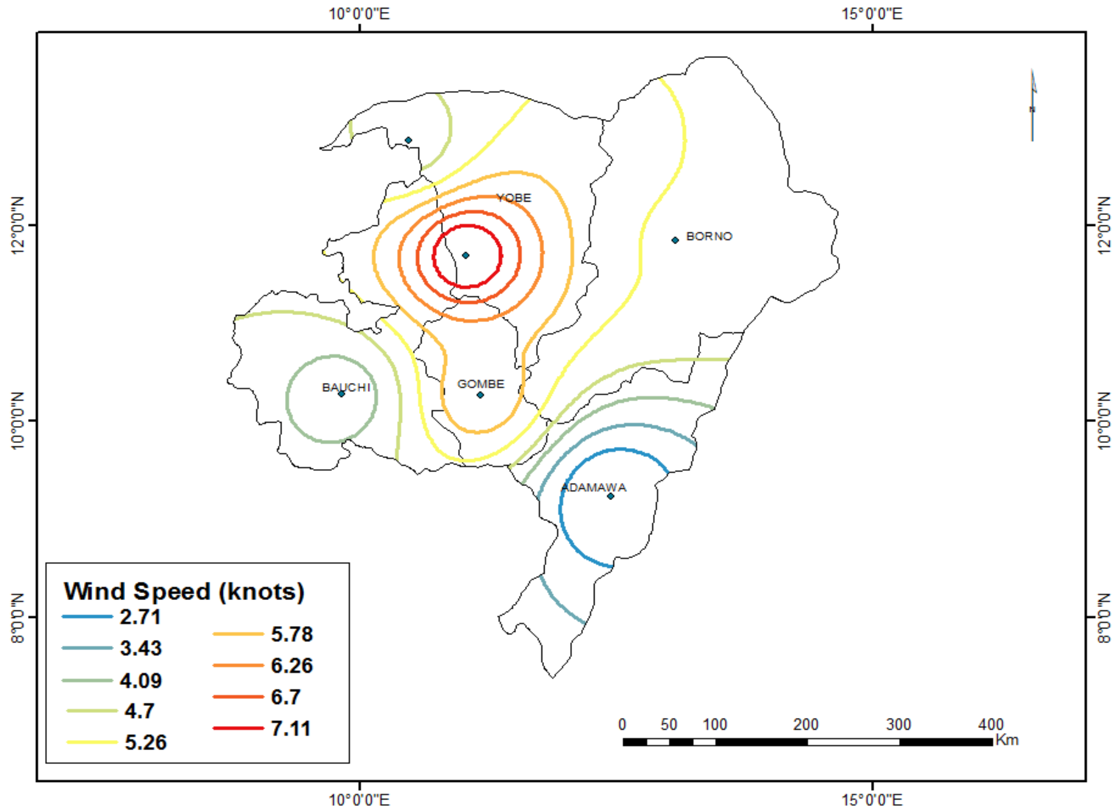

Figure 4e Spatial Wind Speed (isovents) Distribution over Northeastern Nigeria (2004/2005 – 2008/2009)

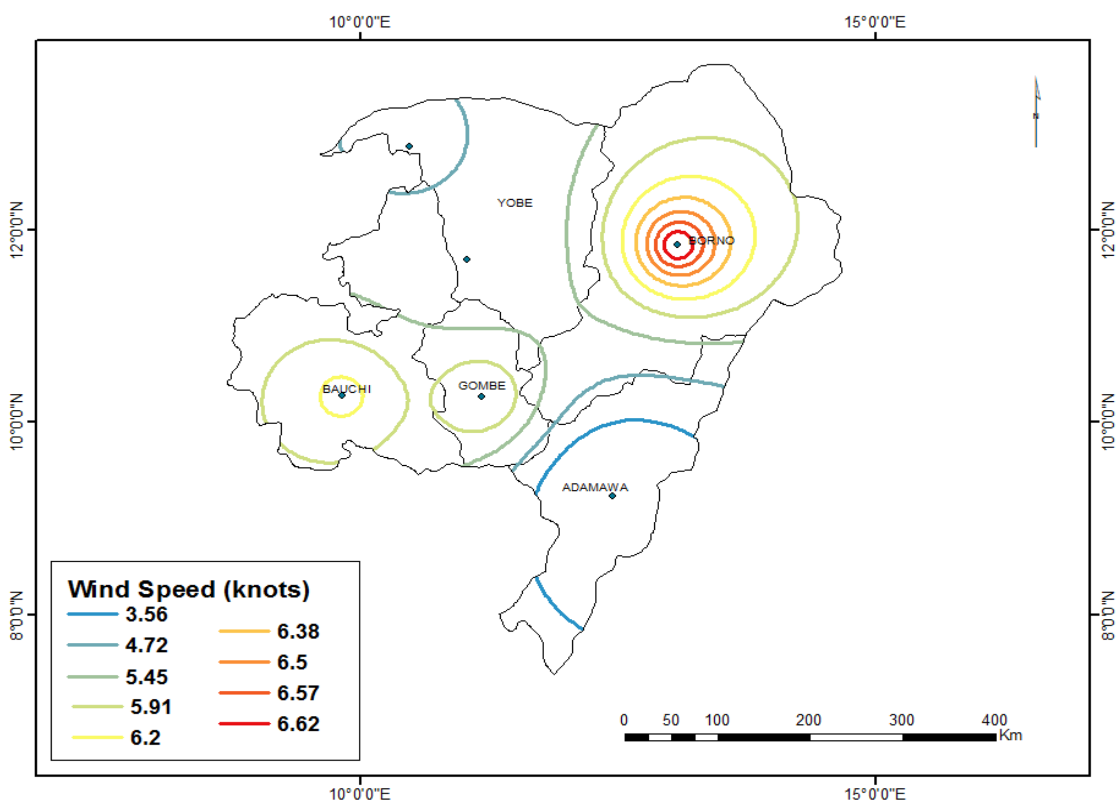

Figure 4f Spatial Wind Speed (isovents) Distribution over Northeastern Nigeria (2009/2010 – 2013/2014)

Table 2 Summary of Analysis of Variance (ANOVA) Results

Source	Sum of Squares	Degree of Freedom	MS	F	P-value	F-Critical
Between	541.19	5	108.24	39.36	6.32	2.27
Within	478.47	174	2.75			
Total	1019.66	179				

the low sun (winter period in the Northern hemisphere). The greater the pressure of the air, the faster the wind moves from the region of high pressure to the region of low pressure system. There is therefore, no gainsaying that the speed of the wind determines its potential for power generation. Therefore, going by the persistent nature of surface wind over the study area makes it of high potential for electric power generation. This opinion supports the findings of Ajayi (2010) and Idris et al, (2012).

Table 2 contains results for the analysis of variance (ANOVA) in respect of wind speed over northeastern Nigeria. This indicates significant difference in the spatial distribution of wind speed at the respective location (stations) in the region; meaning that the variations observed between the stations are statistically significant.

CONCLUSION

The study, based on its finding, supports the view that northeastern Nigeria has high potentials for Wind Energy Technology (WET) electricity generation. Seasonal wind speed distributions in all the six synoptic stations have been found to be quite stable and persistent during the Harmattan season. The spatial distributions of wind speed across the study area have shown that the speed of the Northeast trade wind varies slightly from one location to another within northeastern Nigeria. These characteristics of the wind speed make the region of high potential for electric power generation.

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