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Development of Wind Rosettes for Farmstead Planning and Layout in North Central Nigeria

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ABSTRACT
The knowledge of the prevailing wind characteristics (speed and direction) in an environment is vital for proper farmstead planning, as it influences the appropriate location and orientation of structures in view of taking optimal advantage of the wind and minimizing the damaging effects. In North-Central Nigeria, the prevailing wind in many locations is generally unknown. This has created a shortfall in the planning, design, layout and orientation of farmsteads. It is therefore imperative to provide information about the wind speeds and directions in this region. This study made attempts to develop wind rosettes of various locations in North Central Nigeria, with a view of establishing the prevailing wind directions and speeds in the region. Wind data for 18 years (1994-2012) for Makurdi, Abuja, Ilorin, Minna, Jos and Lokoja were obtained from Nigeria Meteorological Agency, Abuja. The data were analyzed and the wind rosettes for these locations were developed using WRPLOT View. The Wind rosettes show that the predominant wind directions are; west, west, southwest, south, east, and south respectively for Makurdi, Abuja, Ilorin, Minna, Jos and Lokoja. Average wind speeds from these locations are also respectively 6.15m/s, 6.79m/s, 7.63m/s 7.72m/s, 12.28m/s and 5.43m/s. The prevailing wind speeds in the prevailing wind directions for the locations are within the range of 6-8m/s for Makurdi and Abuja, 4-6m/s for Lokoja and Minna, 8-10m/s for Illorin, and 12-14m/s for Jos. The maximum wind speeds within the study periods were respectively 25m/s, 30m/s, 30m/s, 44m/s, 52m/s and 19m/s for Makurdi, Abuja, Ilorin, Minna, Jos and Lokoja. This information is invaluable for farmstead planning and layout in North-Central Nigeria.

Keywords: wind rosettes, farmstead, North Central Nigeria, prevailing wind direction, WRPLOT View

I. INTRODUCTION

Wind is air in motion, produced by the uneven heating of the earth by the sun and it is an important factor in agricultural practice because of its positive and negative effects. The positive effects of wind include its application in farm house ventilation, crop drying and odour amelioration especially in livestock units thereby enhancing performance and minimizing the health hazards to which livestock workers and in some cases the animals may be exposed (MWPS, 1983). When wind is obstructed, it imposes a pressure on the obstructing structure which may be of such high magnitude as to cause damage. Damages caused by wind load on farm structures are costly to repair and sometimes livestock and human lives could be affected. Wind damage to farm structures takes the form of weakening and dislocation of joints especially in roofs, and separation of wall/foundation joints, sliding, overturning and uplift especially in metal silos, and cracking in concrete silos (Mijinyawa and Awogbuyi, 2011).

Proper arrangement and location of areas of activities especially in large farms where a lot of noise, odour, dust and smoke are generated is very important in order to maintain the desirable farm environment. As such, farmstead planningdemands that livestock and waste facilities are located down-wind from off-farm living centres as well as the family living areas (MWPS,1983) while the orientation of buildings should be based on the prevailing wind direction and its magnitude with a view to minimizing the damaging effect of wind on them (Davenport, 1968).

The severity of wind load on farm structures is affected by a number of factors the most,critical of which are the wind speed and the area of the structure exposed to the wind (Bengtsson and Whitaker, 1986). Efforts made at keeping the exposed area as small as possible are best achieved by orientating the side with the

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smallest projected area of the structure in the direction of prevailing wind. Shelterbelts and barrier strips used to reduce wind effect are located across the direction of the main wind.

To ensure adequately planned farmstead, the planner or designer must be knowledgeable in all aspects of wind characteristics. In practice and for a particular location, the wind speeds and directions vary from one period to another and this will give rise to a number of wind directions and speeds. These observations are always presented graphically in what is referred to as wind rosettes.

A wind rosette is a graphical representation of the distribution of wind directions and speeds experienced at a given location over a considerable period of time usually not less than 15 to 20 years (Nwakonobiet.al. 2003). It consists of a circle from which eight or sixteen lines or spikes emanate one for each compass point. A windrose gives a succinct view of how wind speed and direction are typically distributed at a particular location. Presented in a circular format, the wind rose shows the frequency of winds blowing from particular directions. The length of each "spoke" around the circle is related to the frequency of time that the wind blows from a particular direction. Each concentric circle represents a different frequency, emanating from zero at the center to increasing frequencies at the outer circles. (Anand et al, 2013).

In North-Central Nigeria, the prevailing wind in many locations is generally unknown. This lackof information on the prevailing wind in many regions of the country has created a limitation in the planning, design, layout and orientation of farmsteads. Roof blown-off of farm structures and other structural failures due to wind load effect are common in North Central Nigeria. Odour complaints associated with livestock housing are also common in many farmsteads in this region. It is desirable to provide information about the prevailing winds in North Central Nigeria to aid effective farmstead planning and ameliorate some of these problems. Although there are various traditional methods of determining wind direction,the wind rosette is the most reliable method over theother methods which are limited to certain areas and transient giving only instantaneous information, which are inadequate for use in farmstead planning.Theobjective of this study therefore is to develop wind rosettesfor various locations in North Central Nigeria, with a view to establishing the prevailing wind directions and speeds in the region.

II. MATERIALS AND METHOD

Study Area

This study was carried out for North Central Nigeria,which comprises six states namely Benue, Kogi, Kwara, Nassarawa, Niger, Plateau and Federal Capital Territory, Abuja. The area is situated between latitude 7°N and 11°N; it has climatic characteristic of tropical rain forest towards the southern part and Guinea savannah towards the northern part. The zone has uniqueness of highly undulating terrain ranging between 26 m at Lokoja in Kogi State and 1205 m at Jos in Plateau State. The zone has prevalence of Guinea savannah climate. The study area is relatively warm and enjoys moderate amounts and duration of rainfall that ranges from 500 mm to 1,800 mm per annum, thus, giving the area a typical tropical ecological setting (Olayemi, 2014). The area is characterized by two distinct seasons namely, rainy (from May to October) and dry (December to March); with the two seasons often separated by somewhat transitional periods in April and November. While the months of February and March typify the peak of the dry season, with very high temperatures, the peak of rain is usually in August. The months of November through January are marked by cold and dry weather conditions (i.e., the harmattan) under the influence of the northeast trade wind. The vegetation of the study area is characteristically grass-dominated. Temperature varies in the zone with daily average maximum of 32°C except in Jos where temperature ranges between 18°C and 22°C (Ajileye et al, 2016). The prevailing climatic and ecologic conditions in North central Nigeria combine to support thriving agricultural practices that have earned the area the status of a ‘food basket’. Figure 1 is the map of Nigeria showing the six geopolitical regions with North Central region in green colour.

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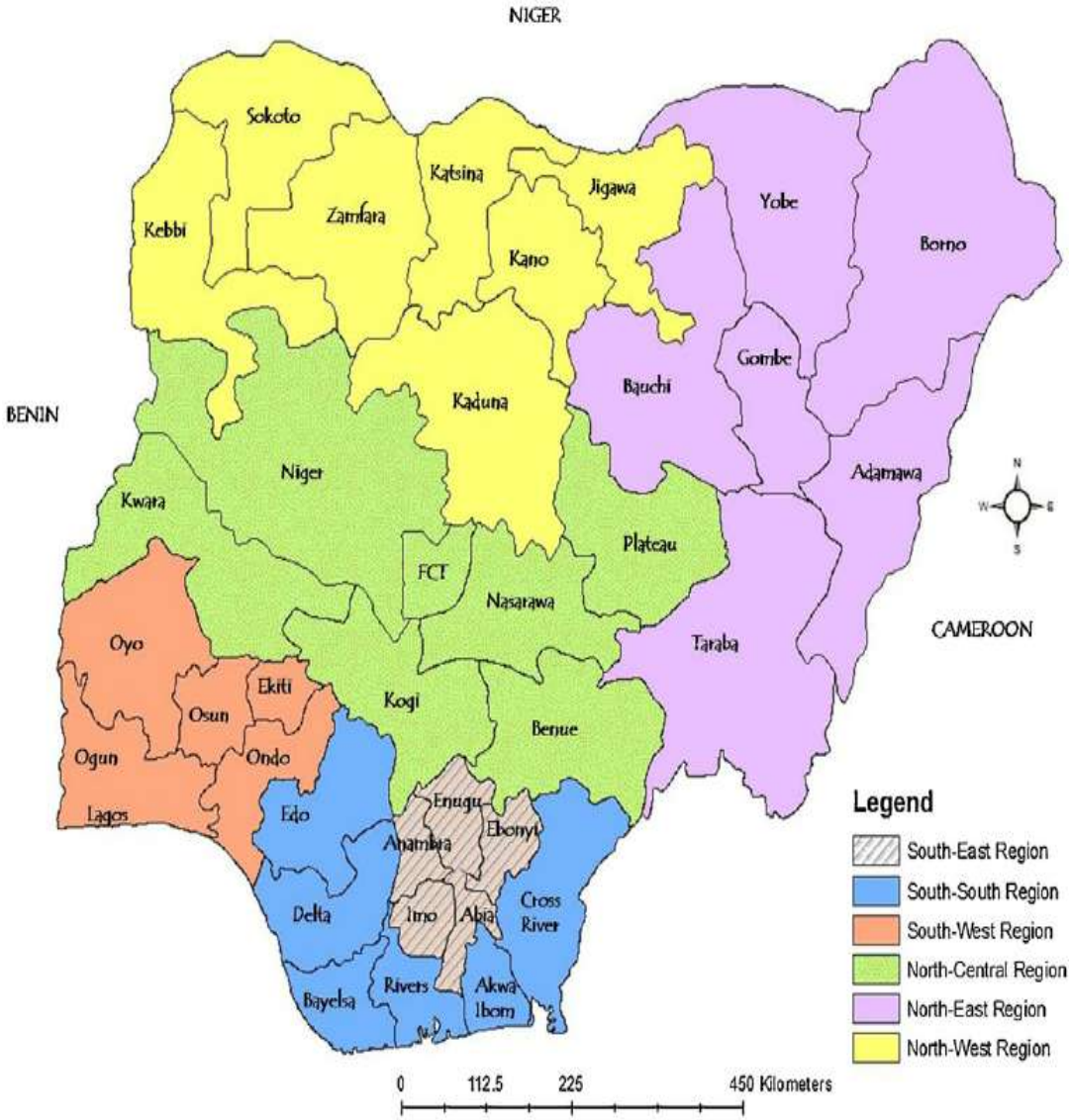

Figure 1: Map of Nigeria Showing Geopolitical Regions (North Central in Green).

III. DATA COLLECTION

The meteorological data used for this work were wind directions and speeds. These were obtained from the Nigeria Meteorological Agency (NIMET), Abuja. The wind direction was measured in degrees and the wind speed in meter per second. Daily data from 1995 – 2012 (18 years) were collected for the study.

IV. DATA ANALYSIS AND DEVELOPMENT OF THE ROSETTES

The wind rose data were analyzed intoFrequency Distribution tables using the Lakes Environmental Software, WRPLOT View. WRPLOT View is a software tool dedicated to the analysis of wind characteristics.The Frequency Distribution tables (table 1, 2, 3, 4, 5 and 6) contain the statistical percentages of the occurrences of winds in each of the wind direction sectors and wind speed classes. SAMSON (Solar and Meteorological Surface Observation Network) file format was adopted for this work. The import surface data from excel utility was used to convert daily surface data that were contained in Microsoft Excel spreadsheets files to the proper SAMSON file formats by the software.

In order to ensure the appropriateness of the data collected for the wind rosettes development, data check was carried out to ascertain the percentage completion of the data since meteorological data acquired from Nigeria Meteorological Agency occasionally have periods of missing data. The frequency distribution tables

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show the percentage completion of the data. All other locations except Lokoja, Kogi state had more than 90 percent complete data while Lokoja data was 81.1 percent complete. Jesse et al (2016) recommended the use of data that is up to 80 percent complete for wind rosette development, as such, missing entries were not replaced.

From the frequency distribution tables, the software generated the wind rosettes for the various locations under this study.

V. RESULTS

The wind rosettes generated are presented in figures 2, 3, 4,5,6 and 7.

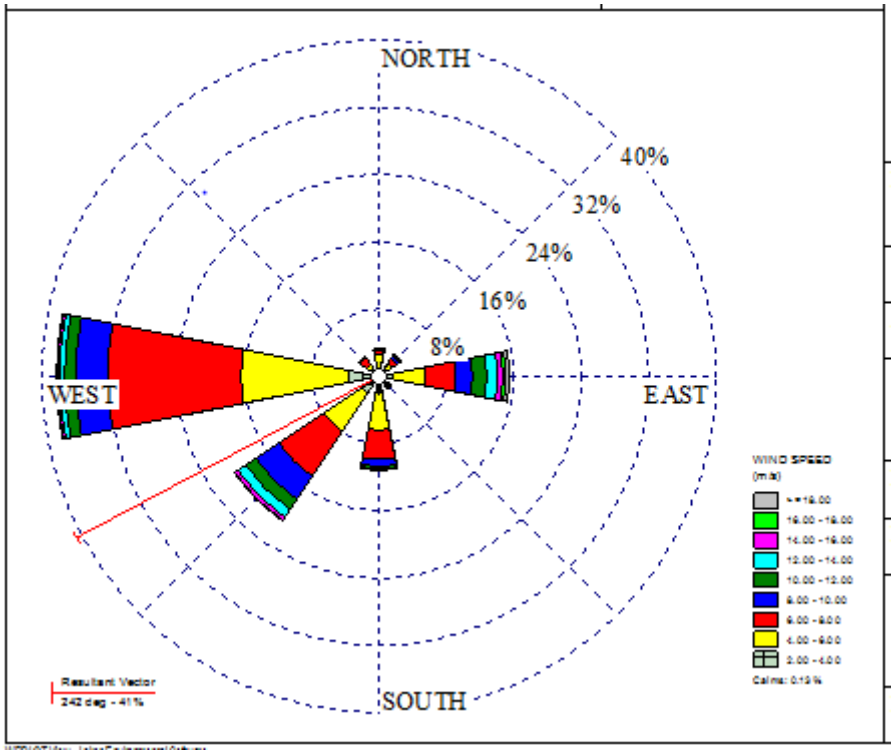

Figure 2: Wind Rosette for Makurdi

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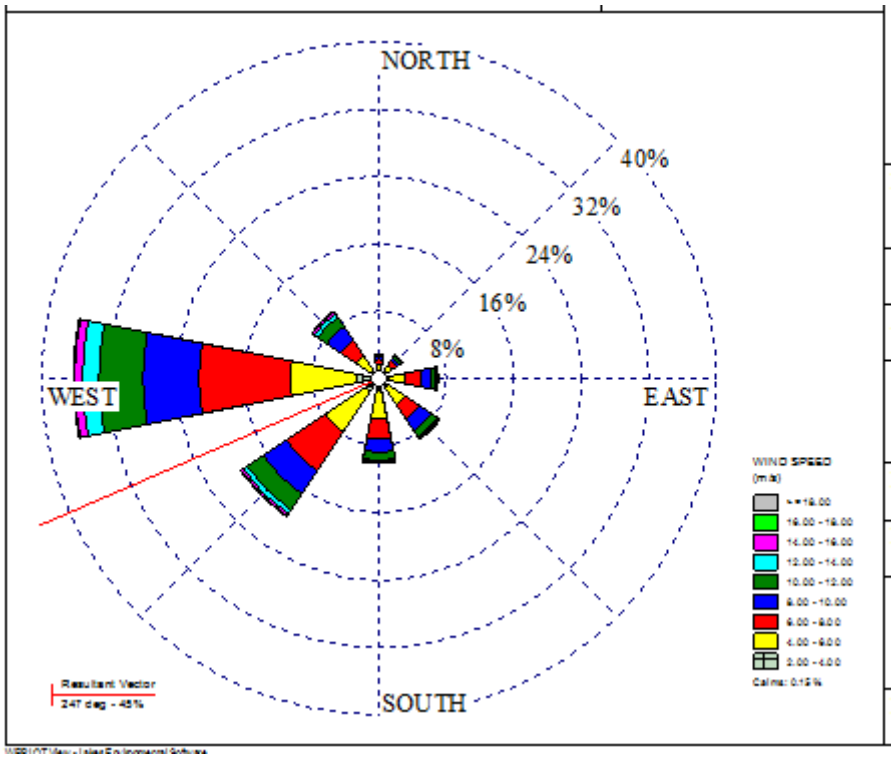

Figure 3: Wind Rosette for Abuja

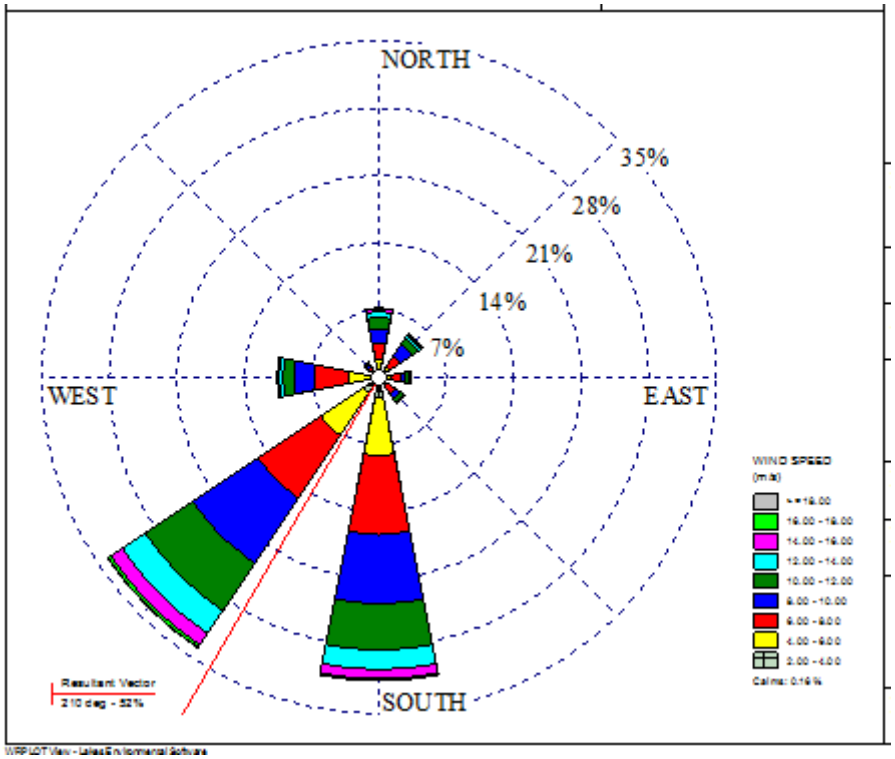

Figure 4: Wind Rosette for Ilorin

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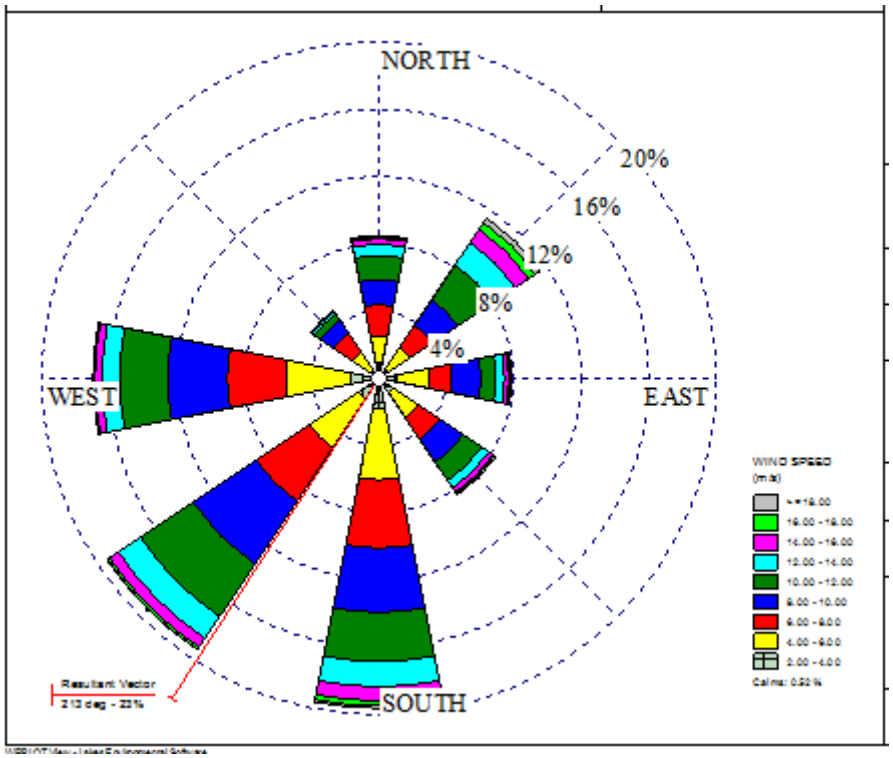

Figure 5: Wind Rosette for Minna

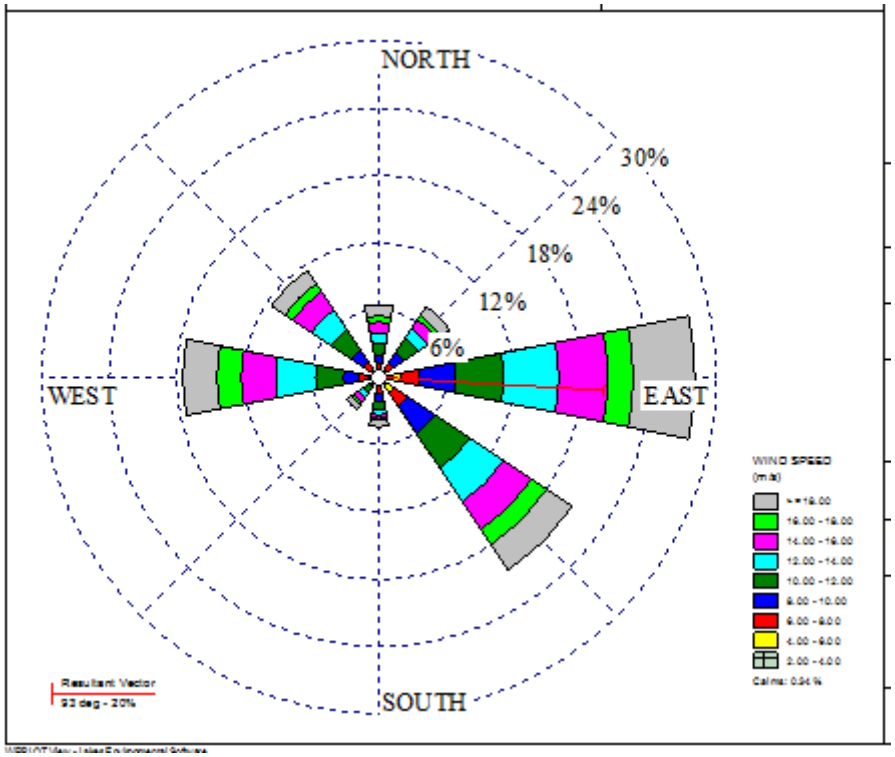

Figure 6: Wind Rosette for Jos

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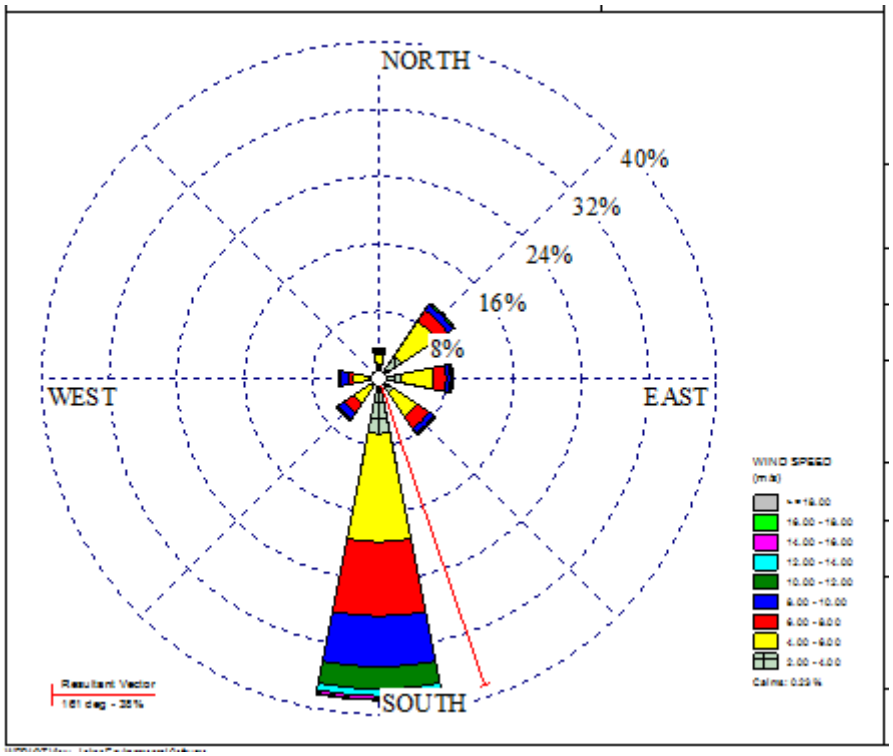

Figure 7: Wind Rosette for lokoja

VI. DISCUSSION

Wind Direction

The lengths of the rosettes bars represent the percentages frequency of occurrence of winds from each direction.The direction of the prevailing wind in each location is defined by the direction of the longest bar of the rosette. From the wind rosettes, the prevailing winds directions for the six locations in North- central Nigeria are as shown in table 7.These results are invaluable for remediation of odour effect and farm buildings orientation among other aspects farmstead planning in the region.

Table 7: Prevailing Wind Characteristics in North-Central, Nigeria

S/N	Station	State	Prevailing Wind Direction	Average Wind Speed (m/s)
1	Makurdi	Benue	Westerly	6.15
2	Abuja	FCT	Westerly	6.89
3	Ilorin	Kwara	Southwesterly	7.63
4	Minna	Niger	Southerly	7.72
5	Jos	Plateau	Easterly	12.28
6	Lokoja	Kogi	Southerly	5.43

Odour grumbles connected with livestock housing such as poultry houses, pigs' pens and manure storage as well as waste treatment sites are most common in many farmsteads. The wind characteristics of an individual site influence the frequency and duration of the odour, and appropriate precautions must be taken to guide against this. Using the prevailing wind direction as a guide for farmstead planning in North Central Nigeria, family living areas and other activity areas like canteen, and recreational areas on farmsteads should be located at the windward side of odour generating facilities so that the odour emanating from such places are carried away from these residential areas.

The orientation of farm buildings and structures in North Central Nigeria should also be guided by result of this work. The orientation of farm structures relative to the direction of the prevailing winds in North Central Nigeria could either expose the structure to structural damage or reduce the efficiency of the structure. As such,

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different buildings require different orientations to the prevailing wind direction. The orientation of structures such drying platforms and corn cribs which depend on natural ventilation in the study areas should have their long axes oriented in the direction of the prevailing wind as shown by the wind rosettes to take advantage of the natural ventilation while for delicate and closed structures such as silos and greenhouses should have their small axes or the side of least projected area in the direction of the prevailing wind to ensures that minimal wind load is imposed on the structure.

Wind Speed

From the wind rosettes, the prevailing wind speeds in the prevailing wind directions for the locations are within the range of 6-8m/s for Makurdi and Abuja, 4-6m/s for Lokoja and Minna, 8-10m/s for Ilorin, and12-14m/s for Jos. The average wind speed for each location is shown in table 7. The wind speed in the region is relatively high. This could be attributed to the vegetation of the area which is characterized with sparse deciduous shrubs and grasses that dry off at the end of rainy season. This type of vegetation coupled with indiscriminate bush burning in the area cannot serve as natural wind break hence the relatively high wind speed.

The high wind speed is the determinant of wind load responsible for the failures of farm structures observed in the region.These high wind speeds in North Central Nigeria hold good wind energy potential that can be harnessed for agricultural and other uses in the region. This has been observed earlier by Ojosu (1990a and b), Adekoya and Adewale (1992), Fadare (2010). Adekoya and Adewale (1992),Fagbenle and Karayiannis (1994),who pointed out that for investment on wind energy conversion system to be cost effective, the site average wind speed should be between 4-6m/s.The average wind speeds shown by this study for the various locations in North Central Nigeria are all above 4m/s. This is evident that North-Central Nigeria has enough wind energy resource and therefore, investment in it can help in solving agricultural energy and electricity crisis.

VII. CONCLUSION

Wind rosettes have been developed for North-Central Nigeriawhich haveprovided information about the prevailing winds for effective farmstead planning. The rosettes show that, the predominant wind directions are; west, west, southwest, south, east and south for Makurdi, Abuja, Ilorin, Minna, Jos and Lokoja respectively. Average wind speeds from these locations are also 6.15m/s, 6.79m/s, 7.63m/s 7.72m/s, 12.28m/s and 5.43m/s respectively. The prevailing wind speeds in the prevailing wind directions for the locations are within the range of 6-8m/s for Makurdi and Abuja, 4-6m/s for Lokoja and Minna, 8-10m/s for Ilorin, and 12-14m/s for Jos. The maximum wind speeds within the study periods were respectively 25m/s, 30m/s, 30m/s, 44m/s, 52m/s and 19m/s for Makurdi, Abuja, Ilorin, Minna, Jos and Lokoja.

This information is invaluable for farmstead planning and layout in North-Central Nigeria, in that it has provided a guide to farmstead planners for the location of animal houses, manure storages, waste treatment plants and other odour generating facilities relative to farm houses in order to remediate odour effects. The information is also useful in the orientation of farm structures relative to the direction of the prevailing winds for optimum benefits of the wind and minimizing its destructive effect. The study has also made available information as to what wind speed should be used in designing for wind load so as to prevent failures of structures in service associated with wind load.

RECOMMENDATIONS

The following recommendations are made by the study;

1. In farmsteadplanning, precautions against wind effects should be taken along the prevailing wind directions in North Central Nigeria. Where necessary, windbreaks and shelterbelts should be included in the windward side of farmsteads in the direction of the prevailing wind.
2. Similar work should be carried out in other areas or regions of the country.

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