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Development of a Wind Rosette for Farmstead Planning in Ibadan Environ, Nigeria

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Abstract
The prevailing wind speed and direction in an environment are critical factors in farmstead planning as they influence the appropriate location and orientation of structures in order to reduce wind load impact and promote a healthy environment. The failure of farm structures especially with roof blown-off arising from wind load has become rampant in Ibadan environ in recent time and an urgent solution is desirable. In this work, an attempt is made to develop a wind rosette for Ibadan environ using 20 year climatic data. The prevailing wind direction was established to be southwesterly indicating that it originates in the south western direction and progresses in the northeastern direction while the average wind speed is 1.9m/s. A design speed of 2.1m/s being the highest recorded over the 20 year period is recommended for use in determining windload. In order to minimize the impact of wind loads, the least projected area of buildings should be oriented in the southeast direction; shelterbelts should also be planted in the southeast direction in order to offer maximum protection. Using this prevailing wind direction as a guide, all odour producing facilities such as livestock units and waste treatment plants should be located on the leeward side of residential buildings.

Keywords: Ibadan environ, prevailing wind direction, wind load, odour amelioration, southwesterly, wind direction, farmstead, farm structures

INTRODUCTION

Wind is air in motion, sometimes with considerable force which when obstructed imposes a pressure on the obstructing structure. Wind is very important in the farm environment because of its effects, which may be positive or negative. The positive effects of the wind include its application in crop drying, farm house ventilation and odour amelioration especially in livestock unit thereby enhancing performance and minimize the health hazard to which livestock workers may be exposed (Holmes, 1999; Don *et. al*, 2010; MWPS, 1983). The negative effects of wind are manifested in the destruction of various structures in the farm environment. The wind pressure imposed on obstructing structures may be of such high magnitude as to cause damage.Wind loads cause a lot of damage to farm structures which are costly to repair and in some cases livestock and human lives could be lost. Wind damage to farm structures takes the form of weakening and dislocation of joints especially in roofs, and separation of wall/foundation joints. In silos, wind loads lead to failures by sliding, overturning and uplift especially in metal ones and in those of concrete, craking is a problem. Under strong winds, cash crops especially those with shallow roots are uprooted and there is shedding of flowers and fruits especially at the formation stage (Anonymous, 2010a). Wind erosion is severe and the soil deposited causes poor aeration of root zones which affect plant performance. About 1,650 square kilometres of agricultural lands in the 19 northern states of Nigeria which were hitherto used for crop production have been turned to desert due to wind. The resultant consequences of this negative wind effect are increased cost of farm structures maintenance and declining agricultural production. In addition, another area where wind can cause damage is in aiding wildfires. Wildfire intensity can be increased by the moving wind which actually fan the fire and force it to follow its currents over the hills and valleys and thereby destroy valuable fauna and flora species (Anonymous, 2010b). Well planned farmstead demands that livestock and waste facilities be 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 wind pressure imposed on an obstructing structure is influenced by a number of factors which include the wind speed, the area of the structure exposed to the wind, the presence or absence of protection devices such as wind breaks (Bengtsson and Whitaker, 1986). Of all the factors that determine the severity of wind load, the wind speed and the area of the structure exposed to the wind direction are most critical as the load is a product of the pressure and area. Efforts are therefore usually made to keep the exposed area as small as possible. This is best

achieved by orienting the side of smallest projected area of the structure in the direction of prevailing wind. Shelterbelts are used to reduce wind effect and these must be planted across the direction of the main wind. In areas where wind erosion of agricultural land is a major problem, barrier strips have been developed to minimize this type of erosion. The strips can be in the form of soil ridges, crop strips, crops rows, or trees which act as wind breaks. They are oriented at a right angle to the wind in order to be most effective (Imaah, 2008; Koelsch and Franzen, 2006; Bengtsson and Whitaker, 1986)

Quite often a conflict arises as to how best to orient a structure with respect to the wind direction. While the orientation of the length side of open sided structures perpendicular to the wind direction is desirable for good natural ventilation, for closed buildings, this is a disadvantage as it increases the wind load imposed on the structure and a tendency towards failure.Imaah (2008) reported that buildings oriented at right angles to strong prevailing winds suffer greater damage than those at acute angles to the axis of the prevailing winds and it may well be safe to orient closed walled farm structures at acute angles to the prevailing winds. It is only a good knowledge of the prevailing wind that these measures can be successful taken. Other aspects of farmstead planning such as the location of windbreaks, siting of animal houses, silage and manure, feeding lots as well as farm waste treatment facility are all governed by a good knowledge of prevailing wind characteristics.
There are a number of traditional methods of observing the wind direction such as the flag tree and sand dunes which are however limited to certain areas (Tarara, *et. al*. 2005). Other more common methods such as the breeze are transient giving only instantaneous information, which is insuffient to decide the prevailing wind direction. This is why the wind rosette has become the most reliable tool in determining wind direction (Anonymous 2010c; Anonymous 2010 d)

A wind rose is a graphical representation of the distribution of wind direction and speed experienced at a given location over a considerable period of time usually not less than 15 to 20 years (Nwakonobi *et. al*. 2003; Curtis, 2007; Weigand 2008). It consists of a circle from which eight lines or spikes emanate, one for each compass point namely North (N), North East (NE), North West (NW), East (E), West (W), South West (SW), South East (SE) and South (S). The length of each line is proportional to the frequency of wind from that direction, and the frequency of calm conditions is entered in the center. Each spike of the wind rose comprises of a long and slender portion which represents the frequency of direction and a smaller and thicker section representing the mean wind speed in that same direction.

Wind rose through providing knowledge of the prevailing wind allows the development of prevention strategies to ameliorate the negative effects of the wind and exploitation of the positive effects.

MATERIALS AND METHODS

Study Location

The study area for this work is Ibadan and its environ which is located within the Southwestern part of the Nigeria between longitudes 3° and 4° E and latitudes 7° and 8° N and shown in Figure1.

Figure 1. Map of Nigeria showing the location of Ibadan

The area lies within the rainforest region and has two distinct seasons, the raining season from April to October with an August break and dry season from November to March. Because of its proximity to the Atlantic Ocean, the area is susceptible to the damp south-westerly winds that bring rains to the area. The annual rainfall ranges from 1,200 – 1,300. The temperatures vary from a minimum of 21°C in July to a maximum of 39°C in February. A good percentage of the populace are engaged in agriculture producing staple crops such as yam, cassava and cocoyam while plantation agriculture of cocoa, kolanut and oil palm produce is a major activity. The tse-tse fly infested forests limit large scale cattle rearing but a sizeable number of goats and sheep and large scale poultry keeping and fishing are done.

DATA COLLECTION

The relevant data for this work were the wind speed and direction and these were obtained from the Nigeria Meteorological Agency, Oshodi, Lagos where all data collected from all over the country are processed and stored. The data collected were recorded in eight cardinal points of N, NE, NW, S,

SE, SW, W and E. The monthly data for 20 years, 1990 to 2009 were collected.

DATA ANALYSIS

Wind Direction

The wind direction data collected were reduced to produce Table 1 from which the number of times each of the wind directions was repeated was obtained. The frequency of each wind direction was then calculated as a percentage of the total sum of all the wind directions as presented by Zaremba *et. al* (1999). Mathematically, this is expressed as follows:

Frequency of each wind direction = $$[Ni \div \sum_{i=1}^{i=n} Ni] \times 100 \qquad (1)$$

Where Ni = Total count of each wind direction for the 20-year period

∑Ni = Sum of all wind directions for the 20-year period

And i = i^{th} wind direction, while n = 8 for 8 cardinal wind direction.

The summary of this calculation is presented in the last row of Table 1.

Wind Speed

The average wind speed in each of the 8 cardinal directions was also calculated using the procedure presented by Zaremba *et. al* (1999). Mathematically, this is expressed as follows

Mean Average speed = $$\frac{S_w}{N_w} \qquad (2)$$

Where

S_w = the sum of speeds for each direction for the entire period

N_w = Number of times the wind in that direction occurs for the entire period.

The result of this calculation is presented as Table 2.

Development of the Wind Rosette

The data for the wind rose extracted from Tables 1 and 2 are presented in Table 3 and the resulting wind rose is presented in Figure 2.

RESULTS AND DISCUSSION

Wind Direction

From figure 2, the prevailing wind direction for Ibadan is south west with a percentage occurrence of 63.85%. This should be expected in view of the proximity of the area to the Atlantic Ocean from where the south westerly wind originates. The relevance of this information is that in farmstead planning, precautions against wind effects are desirable along the south westerly direction. Specifically the following should be observed in the farmstead planning.

Orientation of Shelter Belts

Shelter belts are man-made or natural barriers on the path of the wind the objective of which is to reduce the wind speed and minimize its destructive effect on structures. In addition to this protective function, when properly planned, shelter belts also add beauty to the farm environment. Where these are to be used in the area under study, they should be oriented in the south east direction and located on the windward side of the farm.

Orientation of Buildings

Different buildings require different orientations to the prevailing wind direction and inappropriate orientation could either expose the structure to structural damage or reduce the efficiency. Structures which depend on natural ventilation such as drying platforms and cribs should have their long axis oriented in the southeast/northwest direction while for closed buildings such as greenhouses, the small axis or the side of least projected area should be oriented in the southeast/northwest direction. While the former ensures that an advantage is taken of natural ventilation, the latter ensures that as small wind load as possible is imposed on the structure.

REMEDIATION OF ODOUR EFFECTS

Odour complaints associated with livestock housing and manure storage are most common in many farmsteads, the frequency and duration of which are influenced by wind characteristics of an individual site and appropriate precautions must be taken to guide against this. If farm houses are on the farmstead, they should be located at the windward side of odour generating facilities so that the odour emanating from such places are carried away from residential areas. Using the prevailing wind direction as a guide, animal housing, manure storages and waste treatment plants should be located on the leeward side of the farmhouses.

Wind Speed

The prevailing wind speed in the prevailing wind direction is 1.9m while the highest average wind speed recorded in the study area is 2.1m/sec but in the south east direction. The wind speed in the area which is relatively low cannot be unconnected with the vegetation characterized with tall trees and closely packed which act as natural wind break reducing the wind velocity. Wind speed is the determinant of wind load responsible for the destruction caused to farm structures. In order to accommodate the most severe case, a wind speed of 2.1m/sec should be used in design.

CONCLUSIONS AND RECOMMENDATIONS

The knowledge of wind direction and speed is a very vital tool in farmstead planning as it enables maximum exploitation of the benefits of the wind and to ameliorate the negative effects. This study has established that the prevailing wind direction for Ibadan is southwesterly while the maximum wind speed which occurs in the southeast direction is

2.1m/sec. This information is useful in locating and orientating various structures within a farmstead. It has also provided information as to what speed should be used in predicting wind load so that erected structures would not fail in service due to wind load.

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APPENDIX

Table 3. Data for Wind Rose for Ibadan

S/N	Direction	Frequency %	Average Speed
1	N	0.42	2
2	NE	0.84	1.9
3	E	0.84	1.8
4	S	0.00	0.00
5	SE	15.83	2.1
6	SW	63.75	1.9
7	W	17.92	2
8	NW	0.42	1.5

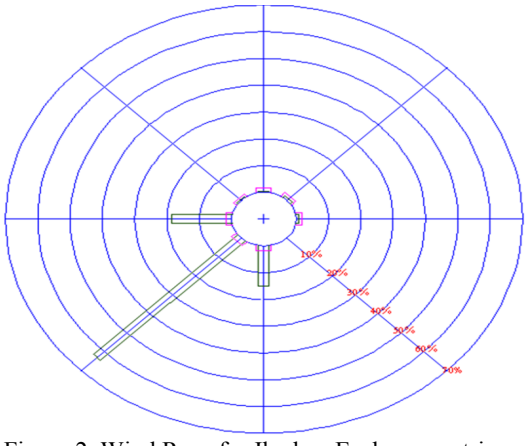

Figure 2. Wind Rose for Ibadan. Each concentric circle is equal to 10% wind frequency and 10m/s. *(Source: Drawn by authors from Data in Table 3, 2011)*

Table 1. Frequency of Wind Direction for Ibadan

S/N	Year	N	NE	E	SE	S	SW	W	NW	Annual Total
1	1990	0	0	0	0	5	7	0	0	12
2	1991	0	0	0	0	0	7	5	0	12
3	1992	0	0	0	0	1	8	3	0	12
4	1993	0	0	0	0	0	8	4	0	12
5	1994	0	0	0	0	0	6	5	1	12
6	1995	0	0	0	0	0	11	1	0	12
7	1996	0	0	0	0	3	8	1	0	12
8	1997	0	0	0	0	1	8	3	0	12
9	1998	0	1	1	0	0	7	3	0	12
10	1999	0	0	0	0	0	9	3	0	12
11	2000	0	0	1	0	0	9	2	0	12
12	2001	0	0	0	0	2	10	0	0	12
13	2002	1	1	0	0	3	7	0	0	12
14	2003	0	0	0	0	5	7	0	0	12
15	2004	0	0	0	0	1	10	1	0	12
16	2005	0	0	0	0	6	2	4	0	12
17	2006	0	0	0	0	8	2	2	0	12
18	2007	0	0	0	0	0	7	5	0	12
19	2008	0	0	0	0	1	10	1	0	12
20	2009	0	0	0	0	2	10	0	0	12
Total		1	2	2	0	38	153	43	1	240
%		**0.42**	**0.84**	**0.84**	**0**	**15.83**	**63.75**	**17.92**	**0.42**	**100**

(Source: Nigeria Meteorological Agency Oshodi, Lagos, 2010)

Table 2 Wind Speed Data for Ibadan

S/N	Year	N		NE		E		SE		S		SW		W		NW	
		F	T	F	T	F	T	F	T	F	T	F	T	F	T		
1	1990									5	12.7	7	15.4				
2	1991											7	13.7	5	9.41		
3	1992									1	4.9	8	1.2	3	7.5		
4	1993											8	13.6	4	8.2		
5	1994											6	11.9	5	7.7	1	1.5
6	1995											11	20	1	1.7		
7	1996									3	2.5	8	12.2	1	1.4		
8	1997									1	0.9	8	10.7	3	2.2		
9	1998			1	1.3	1	1.7					7	14.3	3	5.5		
10	1999											9	16.6	3	4.8		
11	2000					1	1.9					9	18.5	2	3.3		
12	2001									2	4.8	10	19.1				
13	2002	1	2	1	2					3	5.6	7	16.7				
14	2003									5	10.8	7	13.9				
15	2004									1	2.3	10	21.4	1	1.7		
16	2005									6	12.3	2	3.7	4	8.7		
17	2006									8	17.2	2	4.7	2	4.6		
18	2007											7	16	5	11.4		
19	2008									1	2	10	21.8	1	1		
20	2009									2	3.9	10	15				
Total		1	2	2	3.3	2	3.6			38	78.9	153	296.3	44	84.2	1	1.5
Average		**2**		**1.7**		**1,8**				**2.1**		**1.9**		**2**		**1.5**	

F = Frequency of Occurrence, T = Cummulative Speed in that direction (m/s)
(Source: Nigeria Meteorological Agency Oshodi, Lagos,2010)