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Markov chain modelling of wind speed in middle belt of Nigeria

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Abstract

A Markov Chain Model was used to determine the transition probabilities of wind speed as well as the mean first return time for each state within North Central of Nigeria. A daily wind speed data for the period of 36years (1984-2020) was used. The work identified 3 wind speed states (calm air (CA), light air (LA) & light breeze (LB)). It was also observed that the probability of transition from CA to LB directly is not possible whereas CA to LA in both ways are possible. The most common wind speed within the zone is the LA which occur every 2days on the average. The CA is high in Kwara State (21days) and Niger State is the least (8days). The result of the LB in Kogi State is 5369days for the wind speed to return back to LB but it takes 19days for such wind speed to return back in Plateau State. The implication of this wind speed state to health is that any airborne disease that spread with LB should not be of major concern to middle belt particularly Kogi State but any spread with LA should be given utmost priority because it occurs every 2days on the average.

Keywords: Wind Speed; Light breeze; Light air; Calm air; Markov Chain; Steady state

1. Introduction

A Markov chain is a mathematical approach that revealed the probability of transiting from one state to another state within a countable number of possible states. It is a set of different states an event and probabilities of a variable given that the future state dependents only on immediate previous state. The probability distribution of a transition state is mainly described by Markov chain. Markov chains as postulated by the Russian mathematician, A.A Markov developed the theory of stochastic processes and revealed that it is an extension of sequences of independent random variables [1]

Wind speed also known as wind velocity is one of the three major component of air movement on par with wind direction and wind gusts. Air is the atmospheric movement from high to low pressure due to temperature changes. Wind speed in general is the distance covered by air at a particular time.

Wind speed characteristic is important in our world today because of its numerous importance ranging from energy generation, dilution of pollutant air and many others [10]. Energy generation from difference source is important now due to industrialization as well as energy crisis [5]. Variation in wind speed can affect wind farm efficiency and at the same wind turbine in energy generation [3].

A significant effect of the spread of diseases transmission is largely attributed to wind speed. A droplets containing bacteria from an infected person can be carried by the wind to another location. The distance covered by the droplet depends on the speed of the wind. The movement of this droplet can lead to the spread of such diseases [2].

Tuberculosis and Influenza are common airborne diseases that is been transmitted through high wind speed [13]. In addition, [8] revealed a positive relationship between climatic variables and pulmonary tuberculosis incidence.

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[6] revealed in his study that wind speed among other factors has a negative impact on the transmission of airborne diseases. Diseases transmitted by wind speed depend on several factors such as the size of the particles that is infected, the distance active virus/bacteria can travel, the strength of the wind as well as its direction [4]. They further pointed out that the transmission of respiratory infection diseases such as COVID 19 is more predominant in indoor spaces with poor ventilation as compared to outdoor since the transmission is with the aid of wind speed in addition to other factors.

[12] carried out a study on the effect of climatic variables on agriculture in India. The result revealed that changing in weather patterns which always affect a lot of climatic variable (wind speed) influenced crop production and hamper availability of food and its quality.

The summary of their research is that climate change affect Indian agricultural output.

[9] carried out a research on the impact of climatic parameters on human thermal comfort. Several climatic variables (parameters) were considered (air temperature, wind speed, humidity and solar radiation). Wind speed was said to have the most significant impact on the thermal comfort of the outdoor spaces in the region where intensive airflow was observed.

On the contrary, higher wind speed tend to scatter the droplet of the airborne particles and as such reduce its risk of been spread. Furthermore, despite the speed of the wind, some particle that are infected can stay in the air for long [14].

[11] defined Markov chain as a sequence of random variables $\boldsymbol{X_0}, \boldsymbol{X_1}, \boldsymbol{X_2}, \ldots$ with values in which the future depend on the immediate past and not the entire history. Markov chain has various application in various field varying from engineering, biology and several areas of human endeavours [7].

This research work become necessary since transmission of some airborne diseases and respiratory virus largely depend on wind speed. It has been established in literature that one of the effective condition for the transmission of respiratory virus is low wind speed which will allow the infected particles to remain intact in the air for long. The nature of the wind speed determine the size and distance for effective transmission of airborne disease.

This research work is on the application of Markov chain to determine the probability of wind speed transiting from one state to another as well as the probability of remaining in a particular state using the middle belt of Nigeria (North Central) as a case study. Furthermore, to reveal the health implication of each state of the wind speed within the zone and the most predominant wind speed. Although, there are other climatic variables such as temperature, relative humidity air pressure that can contribute to disease transmission.

Nigeria lies between 4^0N and 14^0N latitude and longitude 4^0E to 14^0E located in West Africa. It shares border with the Republic of Niger to the North; Cameroon to the East; Benin Republic to the West and to the south is the Gulf of Guinea which is an arm of the Atlantic Ocean.

The North Central also refer to as middle belt is one of the six geopolitical zones in Nigeria. It is made up of six states which include Benue, Kogi, Kwara, Plateau, Niger and Nasarawa as well as Federal Capital Territory (FCT). FCT is not considered in this research work. The region is said to have a population of about twenty (20) million people which is about 11% of the country entire population. The most populous city in the zone are Jos (Capital of Plateau State) and Ilorin (Capital of Kwara State). The remaining part of this work comprises of methods, results, discussion of results and conclusion.

2. Material and Methods

2.1. Markov Chain

A sequence of random variable X_t where t is a discrete time points $(t = 1,2,\ldots)$ is a stochastic process. A stochastic process is a family of random variables X_t where t represents the time. This means that, at every given time t, a random number $X(t)$ is observed.

A Markov Chain also known as Markov process is a stochastic model that describe a sequence of events that are likely to occur in which the probability of each of the event depend solely on the immediate past and not the entire history.

Mathematically,

$P(\mathrm{X_{n+1}} = \mathrm{j}|X_n = i, X_{n-1} = K_{n-1}, \ \ldots) = P(i,j)$

Note: $P(i,j)$ depends only on the states i,j and not the entire history (states). Therefore, a stochastic process $X_t(t = 1,2,\ldots)$ is a Markov chain if it has Markovian property of not considering the entire history but the future state depend on the present state [7].

2.2. Transition Probability

One step transition probability is also known as conditional probabilities as given below

$P(\mathrm{X_{t+1}} = \mathrm{j}|X_t = i) = P(\mathrm{X_1} = \mathrm{j}|X_0 = i), t = 1, 2, \ldots.$ (1)

The conditional probabilities $P(\mathrm{X_{n+1}} = \mathrm{j}|X_n = i, X_{n-1}) = P(\mathrm{X_n} = \mathrm{j}|X_0 = i)$ (2)

Where $t = 0,1,2,\ldots$ is said to be n-step transition probabilities if

$P_{ij} = P(\mathrm{X}_{t+1} = \mathrm{j}|X_t = i)$ Then

$P_{ij}^{(n)} = P(\mathrm{X}_{t+1} = \mathrm{j}|X_t = i)$

$P_{ij}^{(n)}$ is called n-step transition probability. This means that the system may be in state j after n-step conditioned that it were in state i at a given time t.

The $P_{ij}^{(n)}$ must satisfy the following condition and it must be a nonnegative.

$P_{ij}^{(n)} = 1$ for all i & j: $n = 0, 1, 2, \ldots$

$P_{ij}^{(n)} \geq 0$, for all i & j: $n = 0, 1, 2, \ldots$

Using the Chapman-Kolmogorov Equations, the n-step transition probability $P_{ij}^{(n)}$ is the same as

$$P_{ij}^{(n)} = \sum_{k=0}^{L} P_{ik}^{(l)} P_{kj}^{(n-l)}, \begin{cases} i = 0,1,2,\ldots,L \\ j = 0,1,2,\ldots,L \\ l = 1,2,\ldots,n-1 \\ n = l+1, l+2, \end{cases} \quad (3)$$

$If\ l = 1$, then

$$P_{ij}^{(n)} = \sum_{k=0}^{L} \mathrm{P}_{ik} P_{kj}^{(n-1)} = \sum_{k=0}^{L} P_{ik}^{(n-1)} \mathrm{P}_{ik} \quad (4)$$

In this paper, a state of wind speed is considered within the zone. Three wind speed state were discovered from the data available (National Aeronautic and Space Administration (NASA) (Modern Era Retrospective Analysis Version 2 (MERRA-2)) for the period of thirty-six (36) years (1984-2020)). According to standard wind speed categorization, we have i) 0− calm (<1 mph) smoke rise vertically with little if any drift, ii) 1 − light air (>=1 to <4 mph) direction of the wind shown by smoke drift, not by wind vanes. Little if any movement with flags. It will barely move tree leaves. iii) 3 − light Breeze (>=4 to <7 mph) wind felt on face. Leaves rustle and small twigs move.

The transition probability in general is as given below

$$P_{ik} = \begin{bmatrix} p_{11} & p_{12} \cdots & p_{1n} \\ p_{21} & p_{22} \cdots & p_{2n} \\ . & . & . \\ . & . & . \\ . & . & . \\ p_{ik} & p_{ik} \cdots & p_{ik} \end{bmatrix}$$

where p_{11} is the probability of transiting from state one to one. This can be interpreted as remaining in state one.

For the wind speed with three states

$$P_{ik} = \begin{bmatrix} w_{11} & w_{12} & w_{13} \\ w_{21} & w_{22} & w_{23} \\ w_{31} & w_{32} & w_{33} \end{bmatrix}$$

where CA denote calm air, LA represent light Air and LB is light Breeze. w_{11} is the probability of wind speed transiting from calm air to calm air, w_{12} is a transition from calm air to light air, w_{23} is the transition from light air to light breeze and so on. The diagonal element w_{11}, w_{22} *and* w_{33} is the transition within the same state. For example light breeze to light breeze is w_{33} (Figure 1).

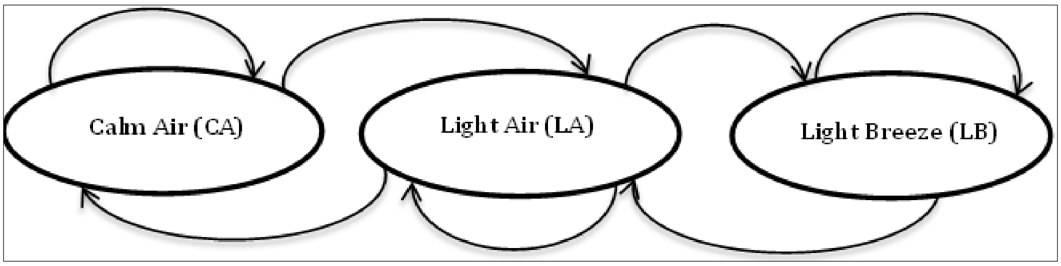

Figure 1 Transition Diagram for the Wind Speed State

As mentioned earlier, the wind speed state are Calm, light air and light breeze; they are coded as 0, 1 and 2 respectively. This research seek to determine the probability at which wind speed transiting from one state to the other. At the same time to determine the state that has the highest and the least transition probabilities and to advice accordingly as it relate the spread of airborne diseases.

Given the transition matrix above and let it be denoted by W. Then with an initial probability vector, $w^0 = \left\{a_j^{(0)}, j = 1, 2, \dots, n\right.$ the absolute probability denoted by

$a^{(n)} = \left\{a_j^{(n)}, j = 1, 2, \dots, n\right.$ provided $n > 0$

Therefore $a^{(1)} = a^{(0)}W$

$a^{(2)} = a^{(1)}W = a^{(0)}W^2$

$a^{(n)} = a^{(0)}W^n$

W^n is what is called n-step transition matrix for the wind speed.

The expected number of transition before the wind speed returns to a state j for the first time is called mean first return time. Let the mean first return times be denoted by μ_{jj}

$\mu_{jj} = \frac{1}{\pi_j}, j = 1, 2, \dots, n.$ π_j is gotten from the steady state transition matrix.

The above methods is implemented using R Studio software version 4.2.2 and excel spread sheet version 13.

3. Results

This section present the result of the analysis of wind speed in all the states in middle belt of Nigeria. The data used is source from NASA, 1984-2020. The categorization of the wind speed was done using micro soft excel version 13. Three states of the wind speed were discovered from the data using the standard wind speed categorization. The states are Calm air, light air and light breeze as mentioned before. From the categorization, three state transition matrix was computed using probability vector approach. The matrix are as follows

$$\text{Benue} = \begin{array}{c} \\ 0\ (CA) \\ 1\ (LA) \\ 2\ (LB) \end{array} \begin{array}{c} \begin{array}{ccc} 0\ (CA) & 1\ (LA) & 2\ (LB) \end{array} \\ \begin{bmatrix} 0.4162 & 0.5838 & 0.0000 \\ 0.0514 & 0.9443 & 0.0044 \\ 0.0000 & 0.4472 & 0.5528 \end{bmatrix} \end{array}$$

$$\text{Kogi} = \begin{array}{c} \\ 0\ (CA) \\ 1\ (LA) \\ 2\ (LB) \end{array} \begin{array}{c} \begin{array}{ccc} 0\ (CA) & 1\ (LA) & 2\ (LB) \end{array} \\ \begin{bmatrix} 0.3316 & 0.6684 & 0.0000 \\ 0.0501 & 0.9499 & 0.0001 \\ 0.0000 & 0.5000 & 0.5000 \end{bmatrix} \end{array}$$

$$\text{Nasarawa} = \begin{array}{c} \\ 0\ (CA) \\ 1\ (LA) \\ 2\ (LB) \end{array} \begin{array}{c} \begin{array}{ccc} 0\ (CA) & 1\ (LA) & 2\ (LB) \end{array} \\ \begin{bmatrix} 0.2747 & 0.7253 & 0.0000 \\ 0.0624 & 0.9257 & 0.0119 \\ 0.0000 & 0.3372 & 0.6628 \end{bmatrix} \end{array}$$

$$\text{Niger} = \begin{array}{c} \\ 0\ (CA) \\ 1\ (LA) \\ 2\ (LB) \end{array} \begin{array}{c} \begin{array}{ccc} 0\ (CA) & 1\ (LA) & 2\ (LB) \end{array} \\ \begin{bmatrix} 0.3950 & 0.6050 & 0.0000 \\ 0.0974 & 0.8916 & 0.0110 \\ 0.0000 & 0.4476 & 0.55524 \end{bmatrix} \end{array}$$

$$\text{Plateau} = \begin{array}{c} \\ 0\ (CA) \\ 1\ (LA) \\ 2\ (LB) \end{array} \begin{array}{c} \begin{array}{ccc} 0\ (CA) & 1\ (LA) & 2\ (LB) \end{array} \\ \begin{bmatrix} 0.2030 & 0.7970 & 0.0000 \\ 0.04658 & 0.9332 & 0.02026 \\ 0.0000 & 0.3406 & 0.6594 \end{bmatrix} \end{array}$$

$$\text{Kwara} = \begin{array}{c} \\ 0\ (CA) \\ 1\ (LA) \\ 2\ (LB) \end{array} \begin{array}{c} \begin{array}{ccc} 0\ (CA) & 1\ (LA) & 2\ (LB) \end{array} \\ \begin{bmatrix} 0.2335 & 0.7665 & 0.0000 \\ 0.03977 & 0.9576 & 0.002667 \\ 0.0000 & 0.7955 & 0.2045 \end{bmatrix} \end{array}$$

The steady state probabilities in the zone are as follows using R studio:

The steady state probabilities for Benue State

$$B_{st} = \begin{bmatrix} 0.0803 & 0.9122 & 0.00897 \\ 0.0803 & 0.9124 & 0.00897 \\ 0.0803 & 0.9124 & 0.00899 \end{bmatrix}$$

Let the initial probability vector be $(1\ \ 0\ \ 0)$. This means that the state of the wind speed is calm air. Though, the initial probability vector does not matter since the system has attained stability.

The state of wind speed in Benue state assuming the wind speed is in calm air state is

$$(1\ \ 0\ \ 0) \begin{bmatrix} 0.0803 & 0.9122 & 0.00897 \\ 0.0803 & 0.9124 & 0.00897 \\ 0.0803 & 0.9124 & 0.00899 \end{bmatrix} = (0.0803\ \ \ 0.9122\ \ 0.00897)$$

In term of percentage, Calm is 8.03%, light air is 91.22% and light breeze is 0.90%.

The first mean return time for Benue with initial wind speed of (1 0 0) is (12.45 1.10 111.450)

For calm to calm is 12.45

For light air to light are is 1.10

For light breeze to light breeze is 111.45

The steady state probability for Kogi State

$$K_{st} = \begin{bmatrix} 0.06981 & 0.9315 & 0.0001864 \\ 0.06982 & 0.9317 & 0.0001863 \\ 0.06981 & 0.9315 & 0.000190 \end{bmatrix}$$

The state of wind speed in Kogi state assuming the wind speed is in calm air state is

$$(1\ \ 0\ \ 0)\begin{bmatrix} 0.06981 & 0.9315 & 0.0001864 \\ 0.06982 & 0.9317 & 0.0001863 \\ 0.06981 & 0.9315 & 0.000190 \end{bmatrix} = (0.06981\ \ 0.9315\ \ 0.0001864)$$

In term of percentage, Calm is 6.98%, light air is 93.15% and light breeze is 0.019%.

The first mean return time for Kogi with initial wind speed of (1 0 0) is (14.32 1.07 5368.49)

Hence, for calm to calm is 14.32

For light air to light are is 1.07

For light breeze to light breeze is 5368.49

The steady state probability for Nasarawa State

$$NA_{st} = \begin{bmatrix} 0.07673 & 0.8918 & 0.03145 \\ 0.07673 & 0.8918 & 0.03146 \\ 0.07666 & 0.8914 & 0.03192 \end{bmatrix}$$

The state of wind speed in Nasarawa state assuming the wind speed is in calm air state then

$$(1\ \ 0\ \ 0)\begin{bmatrix} 0.07673 & 0.8918 & 0.03145 \\ 0.07673 & 0.8918 & 0.03146 \\ 0.07666 & 0.8914 & 0.03192 \end{bmatrix} = (0.07673\ \ 0.8918\ \ 0.03145)$$

In term of percentage, Calm is 7.67%, light air is 89.18% and light breeze is 3.14%.

The first mean return time for Kogi with initial wind speed of (1 0 0) is (13.03 1.12 31.80)

Hence, for calm to calm is 13.03

For light air to light are is 1.12

For light breeze to light breeze is 31.80

The steady state probability for Niger State

$$N_{st} = \begin{bmatrix} 0.1358 & 0.8435 & 0.02073 \\ 0.1358 & 0.8435 & 0.02073 \\ 0.1358 & 0.8435 & 0.02075 \end{bmatrix}$$

The state of wind speed in Niger state assuming the wind speed is in calm air state then

$$(1\ \ 0\ \ 0)\begin{bmatrix}0.1358 & 0.8435 & 0.02073\\0.1358 & 0.8435 & 0.02073\\0.1358 & 0.8435 & 0.02075\end{bmatrix} = (0.1358\ \ 0.8435\ \ 0.02073)$$

In term of percentage, Calm is 13.587%, light air is 84.35% and light breeze is 2.07%.

The first mean return time for Niger State with initial wind speed of (1 0 0) is (7.36 1.19 48.24)

Hence, for calm to calm is 7.36

For light air to light are is 1.19

For light breeze to light breeze is 48.24

The steady state probability for Plateau State

$$P_{st} = \begin{bmatrix}0.05231 & 0.8951 & 0.05320\\0.05231 & 0.8951 & 0.05322\\0.05227 & 0.8947 & 0.05355\end{bmatrix}$$

The state of wind speed in Niger state assuming the wind speed is in calm air state then

$$(1\ \ 0\ \ 0)\begin{bmatrix}0.05231 & 0.8951 & 0.05320\\0.05231 & 0.8951 & 0.05322\\0.05227 & 0.8947 & 0.05355\end{bmatrix} = (0.05231\ \ 0.8951\ \ 0.05320)$$

In term of percentage, Calm is 5.23%, light air is 89.51% and light breeze is 5.32%.

The first mean return time for Niger State with initial wind speed of (1 0 0) is (19.12 1.12 18.80)

Hence, for calm to calm is 19.12

For light air to light are is 1.12

For light breeze to light breeze is 18.80

The steady state probability for Kwara State

$$Ka_{st} = \begin{bmatrix}0.04920 & 0.9482 & 0.003179\\0.04920 & 0.9482 & 0.003179\\0.04920 & 0.9482 & 0.003179\end{bmatrix}$$

The state of wind speed in Niger state assuming the wind speed is in calm air state then

$$(1\ \ 0\ \ 0)\begin{bmatrix}0.04920 & 0.9482 & 0.003179\\0.04920 & 0.9482 & 0.003179\\0.04920 & 0.9482 & 0.003179\end{bmatrix} = (0.04920\ \ 0.9482\ \ 0.003179)$$

In term of percentage, Calm is 4.92%, light air is 94.82% and light breeze is 0.318%.

The first mean return time for Niger State with initial wind speed of (1 0 0) is (20.33 1.05 314.58)

Hence, for calm to calm is 20.33

For light air to light are is 1.05

For light breeze to light breeze is 314.58

Table 1 Steady State for the Middle Belt

State	CA	LA	LB
Benue	0.0803	0.9122	0.00897
Kogi	0.06981	0.9315	0.0001864
Nasarawa	0.07673	0.8918	0.03145
Niger	0.1358	0.8435	0.02073
Plateau	0.05231	0.8951	0.05320
Kwara	0.0492	0.9482	0.003179

Table 2 Percentage of Transition with a Given Initial Probability Vector for Middle Belt

State	CA	LA	LB
Benue	8.03	91.22	0.897
Kogi	6.98	93.15	0.019
Nasarawa	7.67	89.18	3.14
Niger	13.58	84.35	2.07
Plateau	5.23	89.51	5.32
Kwara	4.92	94.82	0.32

Table 3 Mean First Return Times For Middle Belt

State	CA	LA	LB
Benue	12.45	1.10	111.45
Kogi	14.32	1.07	5368.49
Nasarawa	13.03	1.12	31.80
Niger	7.36	1.19	48.24
Plateau	19.12	1.12	18.80
Kwara	20.33	1.05	314.58

4. Discussion

The initial probability vector doesn't matter once the system has attained stability and hence the state of the system at any point remain the same. For convenience, we started with initial probability vector of (1 0 0). This is interpreted as the state of wind speed been calm. The wind speed of Benue state from Table 1 attained stability at (0.0803 0.9122 0.00897). The implication of the above is that, at the long run, there is 8.03% chance of the wind speed in Benue state to remain calm, 91.22% chance of been light air and 0.897% chance of remaining in light breeze state (Table 2). Furthermore, the chance of light air is more as compared to the calm air and light breeze all put together. It is worth noting at this point that any airborne diseases that spread with light air should be of great concern to Benue State. On the other hand, if transmission of airborne disease only spread with a light breeze, little concern will be expressed since the chance is approximately 1%.

The mean first return times for the three states are 12.45, 1.10 and 111.45 (Table 3). This means that on the average, starting from calm state, it takes approximately 12.45 (13) transition to return back to calm state. Similarly, it takes 1.10 (2) to move from light air and return back whereas it takes 111.45 (112) to return from light breeze haven started from light breeze. 13 days, 2 days and 112 days are needed for the wind speed to start from and return to calm, light air and light breeze respectively since the data used is daily.

Observe that the wind speed of Benue is more of light air because it occurrence is frequent (2days) as compared to the rest. It is worth noting here that if this state aid in airborne disease transmission or any related infectious diseases, then between one to two days, outbreak of such diseases is likely to occur.

From the transition matrix above, the probability of transiting calm air to light breeze is not possible (0.0000) for all the states in the zone (Figure 1) and as such all the state does not communicate whereas transiting from light air to light air has the highest probability (0.9443). More so, transiting from light breeze to light breeze has the least probability (0.0044).

Considering the state of been calm in Table 1, observe that Kwara State has the least steady state value of 0.0492 followed by Plateau State with value of 0.05271, Kogi State with a value of 0.06981, Nasarawa State is 0.07673, Benue State is 0.0803 and finally Niger State is 0.1358. The implication of this steady state values for a wind speed been in the state of calmness is that Kwara State has 4.92% chance of been calm, Plateau State has 5.3% chance of been calm, Kogi State (7%), Nasarawa State (7.8%), Benue State (8%) and Niger State (13.6%). It is seen that Niger State has the highest chance of been calm as compared to the rest of the state in the zone (Middle Belt). The chance of Kwara State in the state of calmness is less than that the rest of the state in the zone.

Similarly, for light air, Niger State has the least steady state which is translated to 84.5% (0.845) chance of the wind speed to remain in the state of light air and 2.1% chance of been in light breeze (0.02073). The wind speed of Niger State is more of light air than any other state (CA & LB), though the least among the zone. Furthermore, any airborne diseases that spread under a light air condition should be of great concern to the government within that region than that of calm air and light breeze.

Kwara State has the highest percentage of light air (94.8%) among other state within the zone. The chance of wind speed in Kwara State to remain in light air is high as compared to the rest of the state (CA & LB). Closely followed is that of Kogi State with 93.2% chance of remaining in the light air state (Tables 1 & 2).

Plateau State has the highest steady state probability for light breeze of 0.0532 which is translated to 5.3% chance of been in light breeze state. It then follow by Nasarawa State with 3.14% and the least on the list is Kogi State with 0.019% which is less than 1% chance of been in the light breeze state. The implication is that, the chance of Kogi State to experience light breeze is rear and as such any airborne diseases that its transmission is based on light breeze should not be a concern to Kogi State residence based on the data available (Table 1 & 2).

From Table 3, the mean first return times for CA revealed that Niger State has the least value of 7.36 which implies that it take approximately 8days on the average for wind speed from calm state to return to calm state. It follow with that of Benue State (13days), Nasarawa State (14days), Kogi State (15days), Plateau State (20days) and Kwara State (21day). Kwara State has the highest transition of returning to calm haven started from calm (Table 3).

The most frequent wind speed state for all the states in the zone is the LA with the maximum value of 1.19 for Niger Niger and 1.05 for Kwara which is the least. The implication of this is that, the most common wind speed observed in the north central (Middle belt) is light air. The mean return times is virtually two (2) days on the average.

Apart from Plateau State that the mean first return times of both CA and LB are approximately the same (19.12 and 18.80 respectively), every others are greatly different. Kogi State has the highest mean return times of LB (5368.49) which is more than a year (365days). This imply that the wind speed of Kogi State is rarely in LB state (Table 3). Kwara State has a mean first return of 314.58 (approximately 10 months), Benue State has a mean first return times of 111.45. This means that the chance of returning to LB haven started from LB is approximately 314days and 112days on the average respectively. Nasarawa has an approximately monthly return for the LB state. That is, it takes on the average 32days to return to LB starting from LB.

5. Conclusion

From the transition matrix for all the states, the state of the matrix are irreducible since all the class does not communicate i.e. the transition from LB to CA or CA to LB for all the transition matrices are not possible (Figure 1). This is because wind speed can't transit from CA to LB without first enter LA. Transition within LA and LB are possible in both ways. The result of the steady state revealed that most common wind speed in middle belt is LA and as such, an outbreak of any infectious disease that is been aided by this wind speed should be of great concern to the zone.

In calm state of the wind speed, Kwara State is the least (0.0492) whereas Niger State is the highest (0.1358) which is translated to 4.9% and 13.6% respectively. Furthermore for light air, Niger State has the least (84.4%) chance of remaining in the state and Kwara State has the highest (94.8%) chance of remaining in the same state. For light breeze, Kogi State has the least chance of remaining in light breeze state (0.019) whereas Plateau is the highest (5.3%) (Tables 1 &2).

From Table 3, Kogi State has the highest mean first return times of about 5369days of returning to LB from LB. Plateau State has the least (19days) on the average of returning to LB from LB. It is observed that the wind speed within the zone is more of light air since the chance of return is approximately 2days.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest concerning this work.

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