Science World Journal Vol. 18(No 3) 2023
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University
DOI: https://dx.doi.org/10.4314/swj.v18i3.13

A STATISTICAL STUDY OF WIND SPEED AND ITS CONNECTIVITY WITH RELATIVE HUMIDITY AND TEMPERATURE IN UGHELLI, DELTA STATE, NIGERIA

*[1]Siloko I.U. and [2]Uddin O.O.

[1]Department of Mathematics, Edo State University Uzairue, Nigeria.
[2]Department of Computer Science, Edo State University Uzairue, Nigeria.

*Corresponding Author Email Address: siloko.israel@edouniversity.edu.ng

ABSTRACT
One of the vital climatic parameters with significant roles in many natural phenomena is wind. The importance of wind cannot be overemphasized due to its role as a source of renewable energy. The understanding of wind is of great importance particularly for the purpose of prediction and management of severe weather events. However, wind as a climatic parameter depends on relative humidity and temperature as well as other weather parameters and several statistical approaches such as time series analysis, extreme value analysis and spatial analysis have been used to analyze wind speed data. This study uses the kernel density method in analyzing wind speed in Ughelli, Delta State and its connection with relative humidity and temperature using the Gaussian kernel function for a period of five consecutive years from 2018 to 2022. The performance measure employ is the asymptotic mean integrated squared error (AMISE) with the Pearson R test that measures the strength of the relationship that exists between parameters. The results of the investigation with regards to the AMISE shows that 2018 recorded best performance with wind speed and relative humidity while 2021 recorded best performance for wind speed and temperature but 2019 recorded unsatisfactory outcomes for wind speed and the two parameters. This implies that human activities that depend on these parameters for their performance did best in 2018 and 2021 respectively. Furthermore, in terms of connectivity, wind speed and relative humidity are negatively correlated in 2018 and 2022 but positively correlated in 2019, 2020 and 2021 while wind speed and temperature are negatively correlated which implies that as temperature increases, wind speed decreases.

Keywords: Climate, Kernel, Relative Humidity, Temperature, Wind Speed.

INTRODUCTION
Climate change is the greatest challenge been faced by humanity and global warming has altered the climatic patterns which has resulted in serious droughts in some places with intense heavy rainfall in other locations. It is not incredible any longer but a reality and the misfortunes of climate variations is one of the most threatening objections to human existence and the environment (Pörtner et al., 2022). The effects of climate alterations are been experienced at local and global level due to increase in the earth's temperature which is one of the most serious problems in the world at a moment. The environment and human activities have been impacted by numerous climatic variables which includes wind speed, relative humidity and temperature with other several vital climatic elements (Salman and Ahmed, 2020). Wind speed, relative humidity and temperature are the fundamental elements for the economic activities of a nation particularly agricultural activities that depend on rainfall and temperature. The distinctiveness in wind speed, relative humidity and temperature owing to climate change in the last decades have become the focal point by researchers in the world. The understanding of the variability of climatic variables is imperative because knowledge gain can be of great help to weather experts for forecasting and predictions when making policies that can positively impact the environment. The variability of climatic parameters can lead to natural disaster such as floods and droughts, but these negative effects can be mitigated with functioning management practices such as enlightenment campaigns, rescue operations and rehabilitation. In making policies with reference to agriculture and the environment in a country, the knowledge of trends and patterns of climatic parameters is very vital because the available information from the parameters can be of great help in the development of a country and its economy.
The analysis of wind speed has been complex and challenging to weather experts especially for the purposes of predictions and forecasting. Wind is one of the important weather variables that gives shape to the external environment and also determines the amount of wind energy that can be generated in relation to its speed. Hence, in maximizing wind energy resources, it is pertinent that the wind speed is examined with several techniques (Dec et al., 2018; Tang et al., 2022). As a climatic variable, wind is the pressure gradient that gives the momentum for air movement and whose outcomes oftentimes may be detrimental when it is accompanied by a storm. Wind plays a very crucial environmental roles such as cooling urban cities and also a major source of renewable energy. Despite the indispensable roles of wind energy as one of the main sources of renewable energy, the negative effects of wind such as hurricane, cyclone and windstorm have resulted in serious natural disasters to humanity (Zakaria et al., 2020).
Humidity is a vital climatic variable that measures the concentration of water vapor present in the atmosphere. Vapor is the gaseous state of water that plays the potent function of adjudicating the variability of the climate system and when the air contains vast amount of vapor, there will be a corresponding high humidity. The optimum level of humidity is usually between 30% to 50% and studies have shown that the amount of vapor present in the air relies on the temperature and pressure of the given area (Ukhurebor and Siloko, 2020; Siloko et al., 2022a). Generally, humidity affects temperature due to the fact that extreme environmental conditions can be spawned by warm temperature. Similarly, the formation of clouds and precipitation that produces rainfall for agricultural purposes is the basic responsibility of

Science World Journal Vol. 18(No 3) 2023
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University
DOI: https://dx.doi.org/10.4314/swj.v18i3.13

humidity (Pumo et al., 2018). Agricultural activities can be affected by humidity especially crops through evaporation, transpiration and condensation because crops are highly prejudiced by climatic variations (Oloruntade et al., 2018; Aweda and Samson, 2022). Humidity as a climatic parameter exist in different forms like absolute humidity, relative humidity and specific humidity. Absolute humidity measures the content of water present in the air and it is commonly expressed in gram per meter cube. On the other hand, relative humidity considers the ratio of the real vapor pressure in the air to the saturated vapor pressure and it is usually expressed in percentages. Humidity and wind speed are correlated weather parameters because the speed of wind over water surface affects the rate of evaporation of the water. A high wind speed reduces the humidity level while a low wind speed increases the level of humidity. Wind speed affects humidity because higher wind speed causes minimum evaporation of water and low humidity and lower wind speed causes maximum evaporation of water and high humidity (Ukhurebor et al., 2017).

Temperature ascertains the gradation of hotness or coldness of the environment and its effects are either positive or negative on the environment. Temperature is a key weather factor for the growth and development of plants. The intensity of rainfall is greatly affected by temperature because warm air result in excessive moistures which eventually produce rainfall. Pollination that is very important for the continuity of plants requires temperature either in minimum, optimum or maximum level depending on the species of the plants (Hatfield and Prueger, 2015; Siloko and Siloko, 2023). An increase in the atmospheric temperature leads to evaporation which ultimately results in high precipitation, however; high precipitation does not give rise to rainfall for human activities. Again, higher temperatures could result in critical heat which can potentially affect agricultural activities negatively particularly with species having difficulty with adaptability increase in temperatures (Siloko et al., 2022a; Wang et al., 2011). Temperature varies with respect to height above sea level, an increase in height above sea level leads to decrease in temperatures and vice-versa. Generally, wind as climatic parameter is generated as a result of temperature differences between two layers of the atmosphere and larger temperature differences produce stronger wind. The movement of wind is usually from areas of high pressure to areas of low pressure and this movement involves clouds which also carries the features of these areas such as temperature and humidity to other places. Studies have shown that the direction of wind determines the quality of clouds that will be formed in reference to temperature and humidity since clouds are the major source of rainfall and snowfall (Abodi et al., 2016; Marlina and Melyta, 2019; Abbood et al., 2021). In view of the different effects of wind speed, humidity and temperature on the environment, it is therefore obligatory to explore the trends in humidity, temperature and wind speed changes. This paper studies the effects of wind speed and its connection with relative humidity and temperature in Ughelli from 2018 to 2022 using non-parametric estimation techniques because variability of weather parameters is on the increase; hence recent information will enhance decision making. The exploration of the parameters is in two forms that is, wind speed and relative humidity as well as wind speed and temperature using the bivariate Gaussian kernel function. The choice of the nonparametric Gaussian kernel estimator is hinged on the fact that the study of weather variables should not be attributed to certain assumptions but the variables should determine if there are existence of trends and patterns.

MATERIALS AND METHODS

The data analyzed is the daily wind speed, relative humidity and temperature obtained from the depository of the Nigerian Meteorological Agency (NiMet) in Delta State (Ughelli) from 1st of January to 31st of December for a period five consecutive years of 2018 to 2022. The Gaussian kernel which is a nonparametric density estimator is applied in the investigation of wind speed, relative humidity and temperature due to the usefulness of the Gaussian distribution in modelling several real-life situations. The kernel estimator is widely used in several fields of studies for data exploratory analysis and visualization purposes (Sheather, 2004; Hu et al., 2017; Siloko et al., 2021; Somé and Kokonendji, 2022). The closed form of the univariate kernel estimator is

$$\hat{f}(\mathrm{y}) = \frac{1}{nh_{\mathrm{y}}}\sum_{i=1}^{n} K\left(\frac{\mathrm{y}-\mathrm{Y}_i}{h_{\mathrm{y}}}\right), \qquad (1)$$

with $K(\cdot)$ representing a kernel function while h_{y} is smoothing parameter which determines the smoothness level of the estimate, n is data size, y is the data range and X_i is data set (Silverman, 2018; Siloko et al., 2020). The kernel estimator must satisfy some conditions which are

$$\int K(\mathrm{y})dy = 1, \quad \int \mathrm{y}K(\mathrm{y})dy = 0 \quad \text{and} \quad \int \mathrm{y}^2 K(\mathrm{y})dy \neq 0. \qquad (2)$$

The conditions in Equation (2) implies that the kernel function must be a probability density function having the integral as one with mean of zero and variance greater than zero. One of the critical factors in kernel density estimation is the smoothing parameter and plethora of smoothing parameter selectors exist in literature (Siloko et al., 2018; Tsuruta and Sagae, 2020; Wang et al., 2020; Siloko et al., 2022b; Xie et al., 2023). The kernel density estimation method can be applied in analyzing several variables and the bivariate kernel estimator is given as

$$\hat{f}(\mathrm{y}\,,\mathrm{z}) = \frac{1}{nh_{\mathrm{y}}h_{\mathrm{z}}}\sum_{i=1}^{n} K\left(\frac{\mathrm{y}-\mathrm{Y}_i}{h_{\mathrm{y}}}, \frac{\mathrm{z}-\mathrm{Z}_i}{h_{\mathrm{z}}}\right) = \frac{1}{nh_{\mathrm{y}}h_{\mathrm{z}}}\sum_{i=1}^{n} K\left(\frac{\mathrm{y}-\mathrm{Y}_i}{h_{\mathrm{y}}}\right) K\left(\frac{\mathrm{z}-\mathrm{Z}_i}{h_{\mathrm{z}}}\right). \qquad (3)$$

Again, $h_{\mathrm{y}} > 0$ and $h_{\mathrm{z}} > 0$ are smoothing parameters for the two observations, say Y and Z while y and z denotes the ranges of the observations in the various axes (Siloko and Siloko, 2019). The performance of kernel estimator relies greatly on the smoothing parameter and the assessment of kernel estimator is mainly by the asymptotic mean integrated squared error (AMISE). The AMISE of the univariate kernel is given by

$$AMISE\left(\hat{f}(\mathrm{y})\right) = \frac{R(K)}{nh_{\mathrm{y}}} + \frac{1}{4}\mu_2(K)^2 h_y^4 R(f''), \qquad (4)$$

where $R(K)$ is roughness of kernel while $\mu_2(K)^2$ is kernel

Science World Journal Vol. 18(No 3) 2023
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University
DOI: https://dx.doi.org/10.4314/swj.v18i3.13

variance and $R(f'') = \int f''(\mathrm{y})^2 dy$ is roughness of the unknown function that is Gaussian kernel in this study (Wand and Jones, 1995). The AMISE of the bivariate kernel using the product kernel estimator is of the form

$$AMISE\left(\hat{f}(\mathrm{y},\mathrm{z})\right) = \frac{R(K)}{nh_{\mathrm{y}}h_{\mathrm{z}}} + \frac{h_{\mathrm{y}}^4}{4}\mu_2(K)^2 \int\int \left(\frac{\partial^2 f}{\partial \mathrm{y}^2}\right)^2 dydz + \frac{h_{\mathrm{z}}^4}{4}\mu_2(K)^2 \int\int \left(\frac{\partial^2 f}{\partial \mathrm{z}^2}\right)^2 dydz \quad (5)$$

The performance of the bivariate kernel estimator using the AMISE for two sets of data with standard deviations and correlation coefficient value can also be obtained as

$$\mathrm{AMISE}\left(\hat{f}(\mathrm{y},\mathrm{z})\right) = \frac{3}{8\pi\sigma_{\mathrm{y}}\sigma_z(1-\rho^2)^{5/6}}\left(1+\frac{\rho^2}{2}\right)^{1/3} \times n^{-2/3}, \quad (6)$$

where σ_{y} and σ_z are the standard deviations of the two observations while ρ is their correlation value (Scott, 2015). This AMISE depends on factors such as the sample size, standard deviations of the observations and correlation value which measures the strength of the relationship of the observations. If the correlations between the observation is zero, Equation (6) becomes

$$\mathrm{AMISE}\left(\hat{f}(\mathrm{y},\mathrm{z})\right) = \frac{3}{8\pi\sigma_{\mathrm{y}}\sigma_z n^{2/3}} \quad (7)$$

I
n this case, the AMISE depends only on sample size and standard deviations of the variables.

LOCATION OF STUDY AREA

Ughelli is the administrative seat of Ughelli North Local Government Area, Delta State, Nigeria. Delta State is situated in the rain forest of the Niger Delta in Southern Nigeria in the oil region and lies on latitude 5° North of the equator and longitude 6° East. The State is occupying an estimated landmass of $22{,}159{,}000\mathrm{m}^2$ with a population of about 4,098,398 people (National Population Census, 2006) and currently with a population of over 5.5 million people. The State is bounded by some other States which are Edo State in the North and Ondo State towards the North-West while Anambra State in the Eastern part with Bayelsa State in the South. Rivers State is in the South-Eastern direction and in the South-West is the Bight of Benin that occupies about 160km of the States in the coastline (see Figure 1).

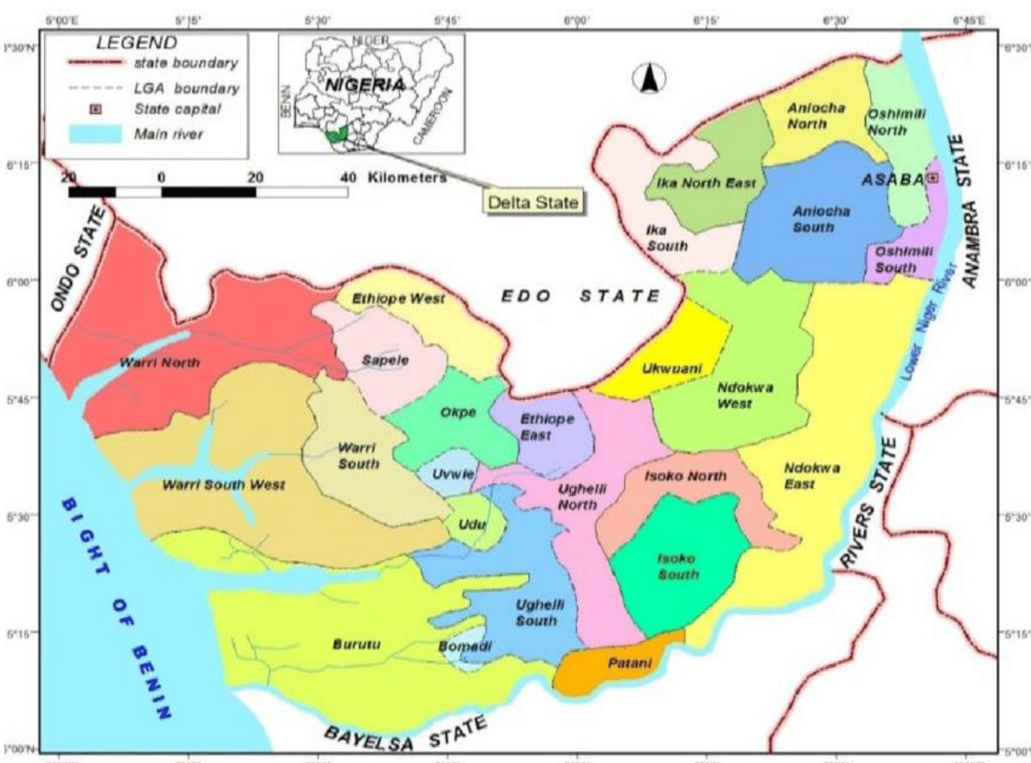

Figure 1. The Map of Delta State showing the Study Area and Neighboring States

DOI: https://dx.doi.org/10.4314/swj.v18i3.13
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

Ughelli is geographically situated in Delta Central and it lies between latitude 5°29'23.50"N and longitude 6°0'26.75"E. The National Population Census of 2006 placed the population of Ughelli North to be 321,028 people and it occupies an area of $818{,}000\mathrm{m}^2$. Ughelli is characterized by tropical vegetation with average annual temperature of 30.26°C and average annual precipitation of 2507mm (Ejemeyovwi, 2019).

RESULTS AND DISCUSSION

Wind speed and its connection with relative humidity and temperature is investigated statistically using a non-parametric approach. In non-parametric data estimation techniques, there are no imposition of distributional assumptions on the data and since the variables been examined are not from a particular family the nonparametric method is more appropriate. The computational analysis and graphical analysis of the observations is with the aid of Mathematica version 12 software. The relationship between the observations investigated is well established by the value of their Pearson's correlation coefficient which is a vital statistical tool that measures the strength of the relationship amongst two observations.

The need for the investigation of climatic variables such as wind speed, relative humidity and temperature is underscored due to the fact that winds and heat are vital factors in atmospheric modeling and other weather projects in relation to climate change. This follows that wind speed, relative humidity and temperature are fundamental weather variables for numerous processes and also very essential in environmental planning. Hence, it is critical that the patterns of changes in wind speed, humidity and temperature in Ughelli over some years be explored and recounted. The descriptive statistics of wind speed, humidity and temperature of Ughelli are in Table 1 and it can be observed that the minimum wind speed of 4.23 Kph is same for the investigated period while the maximum wind speed is 14.79 Kph which is recorded in 2020. Although the maximum wind speed is 14.79 Kph but it cannot be generalized that the maximum wind speed of Ughelli is 14.79 Kph. However, it is obvious that the minimum wind speed in Ughelli is 4.23 Kph while the maximum value of each year for the studied period ranges between 10 Kph and 15 Kph. Ughelli is windier for about four months between June and October while the windiest month is August with an average hourly wind speed of 4.7 miles per hour.

Table 1. Descriptive statistics of the three climate variables for the five years

Years	n	Variables	Min.	Max.	Mean	SD	Skewness	Kurtosis
2018	365	Wind	4.23	10.57	7.3071585	1.4513433	0.1582854	2.5079181
		Humidity	21.50	94.00	79.084699	11.800438	−2.8229769	12.421785
		Temperature	25.36	34.87	30.406202	2.0802613	−0.1799538	2.1740985
2019	365	Wind	4.23	13.74	7.8279452	1.8454507	0.5605514	3.2185642
		Humidity	41.00	92.00	78.479452	6.8826697	−1.3878729	7.2656816
		Temperature	25.36	34.87	30.495781	1.9050611	−0.4375669	2.5826461
2020	366	Wind	4.23	14.79	8.2998904	2.0300863	0.1691549	2.5276621
		Humidity	41.00	92.00	76.739726	8.6954380	−1.5312202	6.0419261
		Temperature	25.36	33.81	30.391425	1.7492234	−0.4118840	2.3609595
2021	365	Wind	4.23	12.68	7.7555890	1.6201891	0.36124326	3.2152776
		Humidity	41.00	97.00	79.969178	9.2948816	−0.9115198	4.0731391
		Temperature	24.30	36.98	30.171260	2.7524447	0.12434864	2.2556932
2022	365	Wind	4.23	13.74	8.0376230	1.6135675	0.61498952	3.5906034
		Humidity	38.00	95.00	80.013661	8.4329639	−1.3787841	6.3354927
		Temperature	24.30	35.92	29.765055	2.3704877	0.29492902	2.5099547

Again, the minimum relative humidity is 21.5% recorded in 2018 while the maximum is 97% recorded in 2021. Nonetheless, the average relative humidity of the study period is 94.2%. Similarly, the minimum temperature under the period investigated is 24.3°C which is recorded in 2021 and 2022 while the maximum temperature of 36.98°C is recorded in 2021. However, the annual average temperature of Ughelli is 30.26°C which is in the neighborhood of the mean temperature of each of the years of the period investigated as shown in Table 1 while the average maximum temperature of the period investigated is 35.29°C. Furthermore, on skewness, the wind speed data are all positively skewed while relative humidity is negatively skewed as shown in Table 1. Meanwhile, temperature is negatively skewed for three years which are 2018, 2019, and 2020 but positively skewed for 2021 and 2022 respectively.

Table 2 is the standard deviations, correlation values, covariance and AMISE of the climatic parameters investigated in Ughelli. The connectivity between wind speed and relative humidity together with wind speed and temperature is numerically analysed by the Pearson R test. The standard deviation is one of the factors in the computation of the AMISE as shown in Equation (6) and also show the evenly distribution of the observations in relation to the mean. In this study the standard deviations also serve as the smoothing parameter and it is obvious that in terms of performance when viewing wind speed and relative humidity, the minimum AMISE value of 0.00013713 is recorded in 2018 with the standard deviations of wind speed and relative humidity being 1.4513433 and 11.800438 respectively while the correlation coefficient is –0.0697337.

Science World Journal Vol. 18(No 3) 2023
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University
DOI: https://dx.doi.org/10.4314/swj.v18i3.13

Table 2. Correlation Coefficient, Covariance and AMISE of the climate variables for the five years

Years	Climate Variables	Standard Deviations		Correlation	Covariance	AMISE
2018	Wind and Humidity	1.4513433	11.800438	–0.0697337	–0.2105382	0.00013713
	Wind and Temperature	1.4513433	2.0802613	–0.0764836	–1.3098957	0.00077865
2019	Wind and Humidity	1.8454507	6.8826697	0.38720692	4.9181582	0.00021581
	Wind and Temperature	1.8454507	1.9050611	–0.47258051	–1.6614496	0.00085010
2020	Wind and Humidity	2.0300863	8.6954380	0.33018091	5.8285153	0.00014809
	Wind and Temperature	2.0300863	1.7492234	–0.25313684	–0.8989078	0.00070156
2021	Wind and Humidity	1.6201891	9.2948816	0.1431870	2.1563197	0.00015844
	Wind and Temperature	1.6201891	2.7524447	–0.1855999	–0.8276793	0.00054270
2022	Wind and Humidity	1.6135675	8.4329639	–0.0908784	–1.2365976	0.00017319
	Wind and Temperature	1.6135675	2.3704877	–0.2030254	–0.7765603	0.00063716

Again, on wind speed and relative humidity in the period investigated, the largest AMISE value of 0.00021581 is recorded in 2019 with the standard deviations of wind speed and relative humidity being 1.8454507 and 6.8826697 respectively while the correlation value is 0.38720692. Typically, in kernel density estimation, performance with respect to the AMISE is usually attributed to the magnitude of its numerical value and the minimum AMISE value is the best in relation to performance (Jarnicka, 2009). Hence, agricultural activities and other industrial activities that depend on wind speed and relative humidity will perform optimally in 2018 and better in other years but performance may likely dwindle in 2019. On the covariance of the data investigated, wind speed, relative humidity and temperature for 2018 and 2022 moves inversely, hence, the covariance is negative. Furthermore, in 2019, 2020 and 2021 the covariance of wind speed and relative humidity are positive indicating that the movement of the observations is in the same direction while the covariance of wind speed and temperature in 2019, 2020 and 2021 are negative indicating that wind speed and temperature move inversely.

Subsequently, the interaction between wind speed and temperature for the period investigated vividly revealed that the minimum AMISE is recorded in 2021 whose value is 0.00054270 with 1.6201891 and 2.7524447 as the standard deviations of wind speed and temperature respectively while the correlation coefficient is –0.1855999. The correlation value clearly shows that wind speed and temperature are weakly negatively correlated. Similarly, the largest AMISE value is in 2019 with a numerical value of 0.00085010 with standard deviations of 1.8454507 for wind speed and 1.9050611 for temperature while the correlation coefficient is –0.47258051. This also implies that activities that depend on wind speed and temperature for their effective performance will thrive fabulously in 2021 unlike 2019 with the largest AMISE. Again, the AMISE of wind speed and temperature of 2019 is larger than the other years which indicates poor performance as in the case of wind speed and relative humidity of 2019 that also produced the largest AMISE. It should be noted that while wind speed and relative humidity for 2019 are positively correlated with a correlation coefficient of 0.38720692, wind speed and temperature of 2019 are negatively correlated with a correlation coefficient of –0.47258051. The value of the correlation coefficient of 2019 for the observations examined is also higher than other years of the study period.

The two essential factors in the computation of the AMISE in Equation (6) besides the sample size are the standard deviations and correlation coefficients of the observations. As seen in Table 2, the product of the standard deviations of wind speed and relative humidity of 2018 whose AMISE is minimum is larger than the product of the standard deviations of wind speed and relative humidity of other years investigated. In the same vein, the product of the standard deviations of wind speed and temperature of 2021 with the minimum AMISE is larger than the product of the standard deviations of wind speed and temperature of other years as well. In the situation of wind speed and relative humidity with the maximum AMISE as in 2019, the product of their standard deviations is the minimum in comparison with other years of the studied period. A similar situation also exists in the product of the standard deviations of wind speed and temperature which resulted in the maximum AMISE value of 0.00085010 in 2019. Also, the correlation coefficients that resulted in the minimum AMISE values of wind speed and relative humidity in 2018 as well as wind speed and temperature in 2021 which are –0.0697337 and –0.1855999 are weakly negatively correlated in both cases. Hence, observations that the product of their standard deviations is maximum and are weakly correlated produces minimum AMISE while observations that the product of their standard deviations is minimum and are highly correlated produces maximum AMISE.

One of the fundamental roles of kernel density estimation in data analysis is the graphical presentation of data for the purpose of visualization especially in the bivariate kernel where the estimates can be viewed either in the form of wireframes or contourplots. The bivariate kernel estimator is very helpful in presentation of its estimates and also useful in understanding higher demensional kernel estimators since it bridges the gap between the univariate and other higher dimensional kernel estimators. The bivariate kernel estimates of wind speed and relative humidity alongside the kernel estimates of wind speed and temperature are in Figure 2 to Figure 6. As seen in Table 2, the covariance of wind speed and relative humidity as well as the covariance of wind speed and temperature in 2018 and 2022 are both negative and the kernel estimates of wind speed and relative humidity in both years are skewed towards the relative humidity as observed in Figure 2a and Figure 6a respectively.

Moreso, the bivariate kernel estimates of wind speed and relative humididty of 2019, 2020 and 2021 in Figure 3a, Figure 4a and Figure 5a respectively clearly depicts the positive covariance of 2019, 2020 and 2021 especially in their contourplots. Again, the bivariate kernel estimates of wind speed and temperature of 2019, 2020 and 2021 in Figure 3b, Figure 4b and Figure 5b supports the

Science World Journal Vol. 18(No 3) 2023
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University
DOI: https://dx.doi.org/10.4314/swj.v18i3.13

negative covariance of wind speed and temperature of 2019, 2020 and 2021. The inverse relationship of wind speed and temperature of 2019, 2020 and 2021 is obviously visible in their contourplots. Inherent hidden statistical structures of a data set are typically revealed by the kernel density estimation method for visualizations. This specific function of presentation of inherent statistical properties for visualization purpose is only performed by the kernel method because scatterplots that play a similar role of data visualization only attract the observer to the peripheries of the data cloud but the vital structures of the data is always hidden by the high density of the data points (Wand and Jones, 1995).

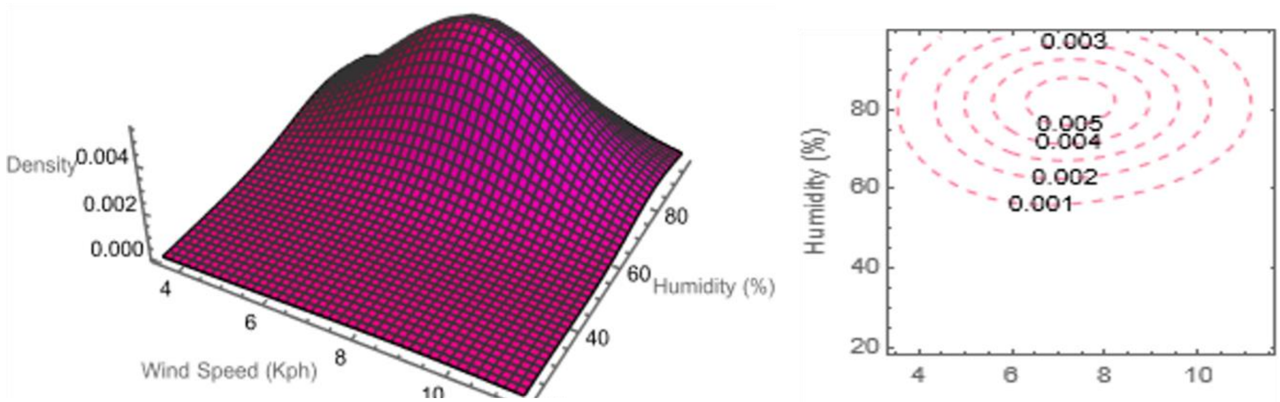

Figure 2a: Bivariate kernel estimates of Wind Speed (Kph) and Humidity (%) data of 2018

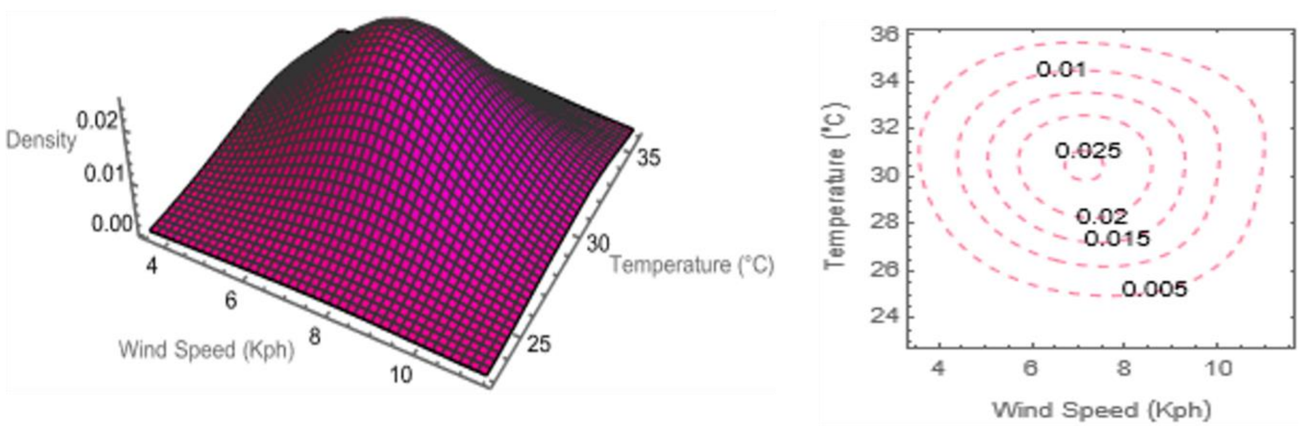

Figure 2b: Bivariate kernel estimates of Wind Speed (Kph) and Temperature (°C) data of 2018

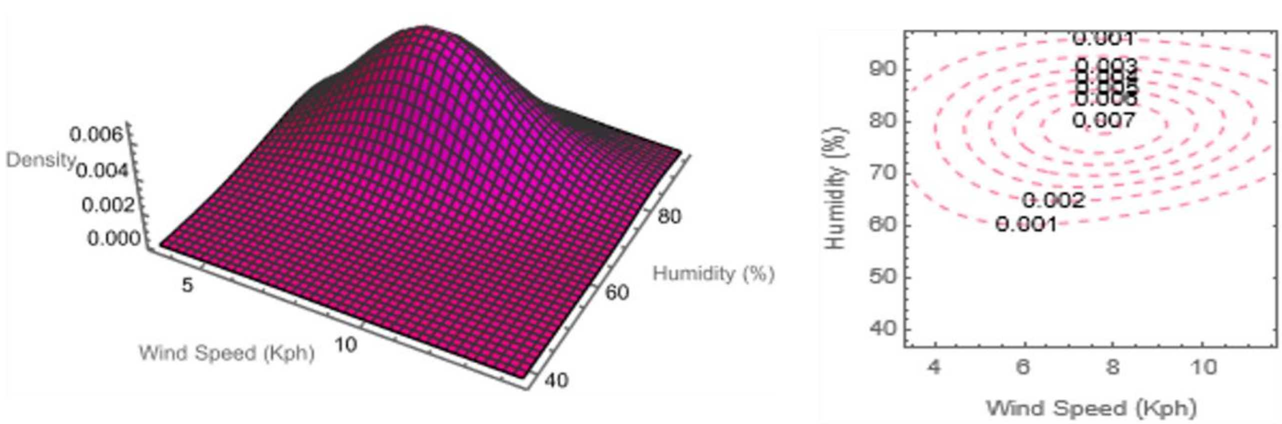

Figure 3a: Bivariate kernel estimates of Wind Speed (Kph) and Humidity (%) data of 2019

DOI: https://dx.doi.org/10.4314/swj.v18i3.13
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

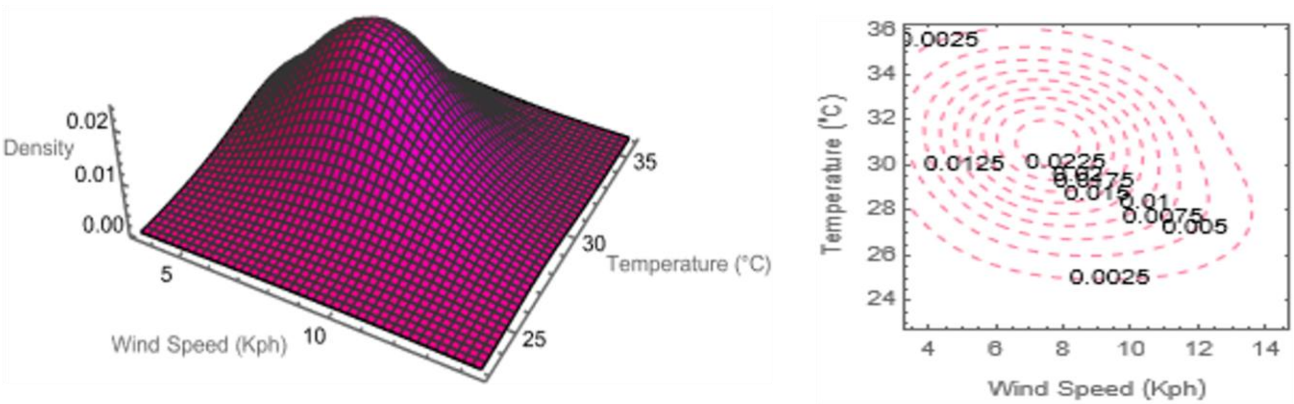

Figure 3b: Bivariate kernel estimates of Wind Speed (Kph) and Temperature (°C) data of 2019

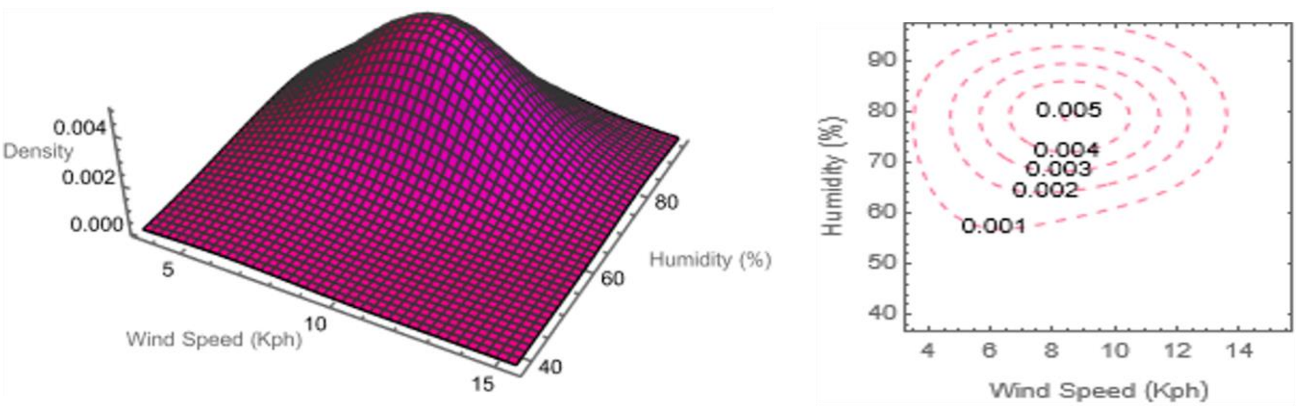

Figure 4a: Bivariate kernel estimates of Wind Speed (Kph) and Humidity (%) data of 2020

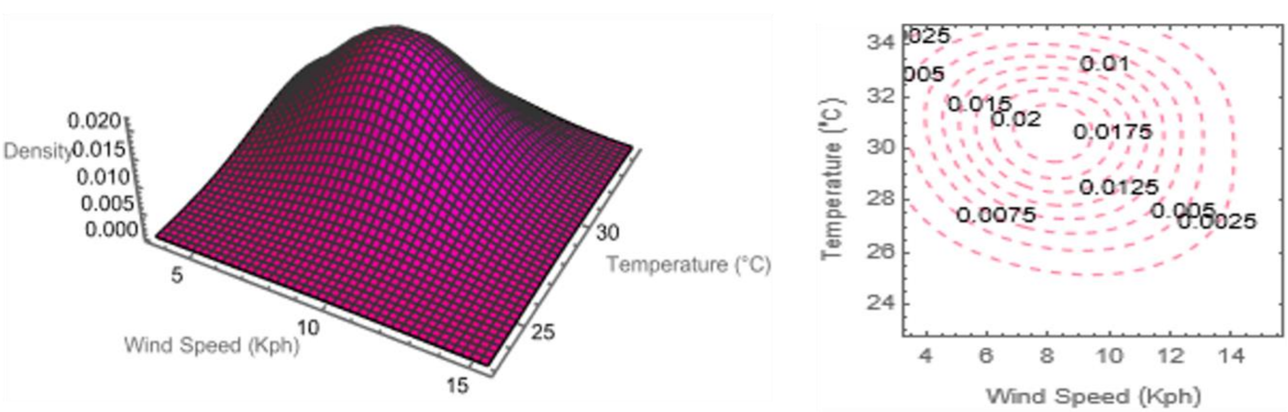

Figure 4b: Bivariate kernel estimates of Wind Speed (Kph) and Temperature (°C) data of 2020

Science World Journal Vol. 18(No 3) 2023
www.scienceworldjournal.org
ISSN: 1597-6343 (Online), ISSN: 2756-391X (Print)
Published by Faculty of Science, Kaduna State University

DOI: https://dx.doi.org/10.4314/swj.v18i3.13

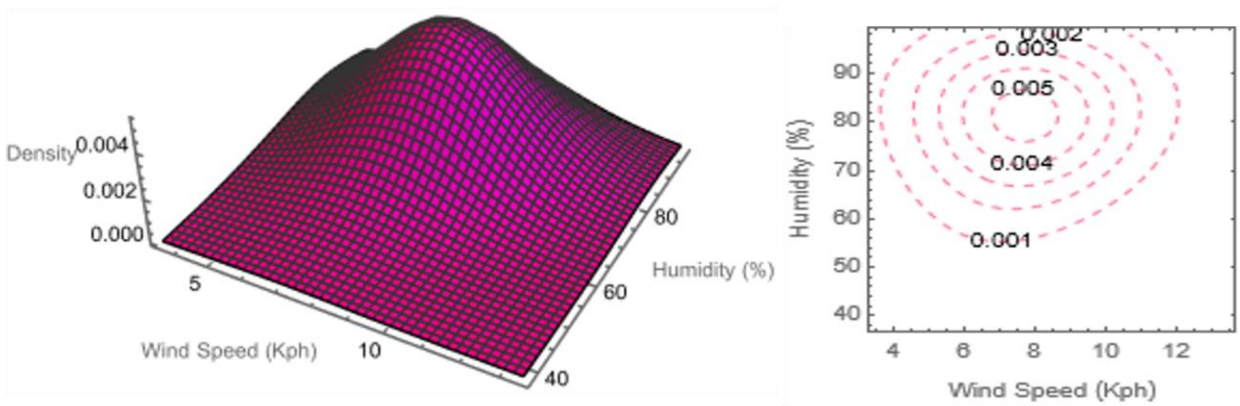

Figure 5a: Bivariate kernel estimates of Wind Speed (Kph) and Humidity (%) data of 2021

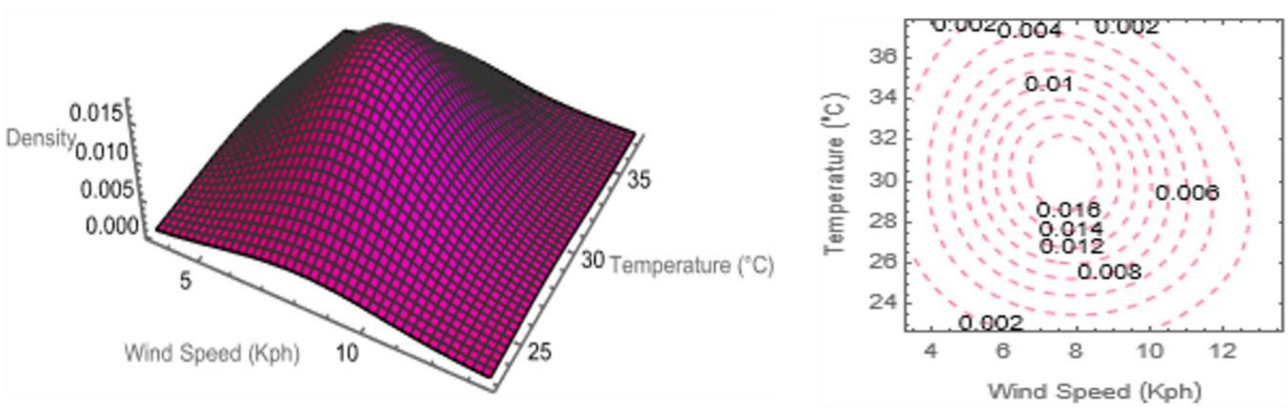

Figure 5b: Bivariate kernel estimates of Wind Speed (Kph) and Temperature (°C) data of 2021

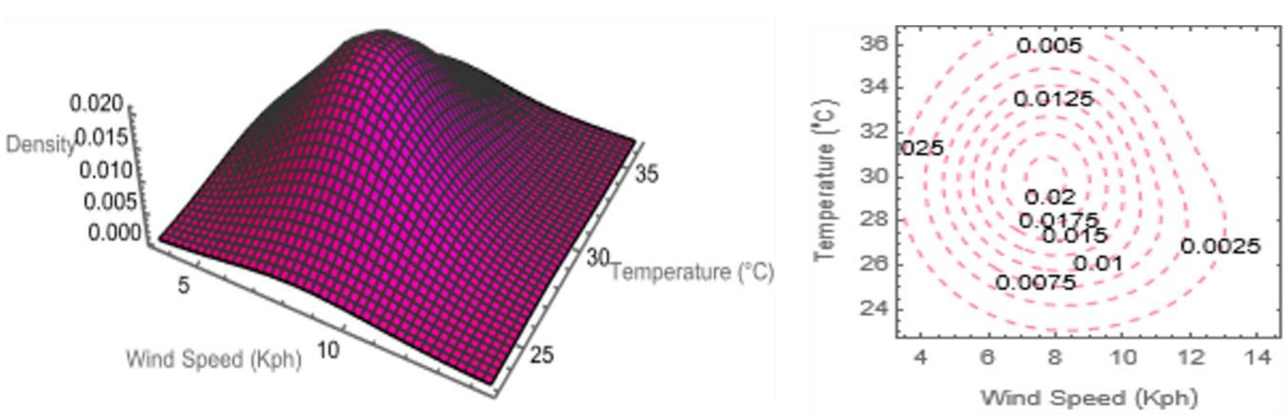

Figure 6b: Bivariate kernel estimates of Wind Speed (Kph) and Temperature (°C) data of 2022

DOI: https://dx.doi.org/10.4314/swj.v18i3.13

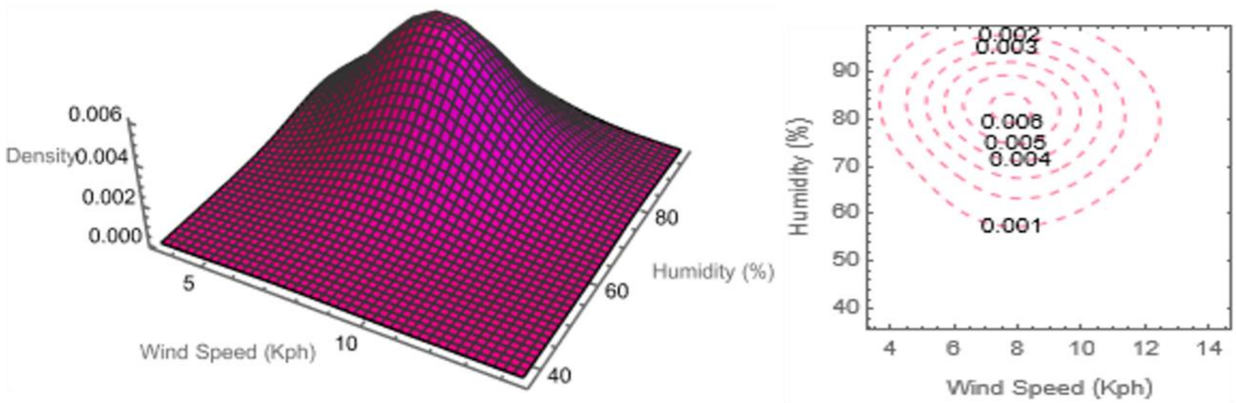

Figure 6a: Bivariate kernel estimates of Wind Speed (Kph) and Humidity (%) data of 2022

The results of this study obviously indicated that increase in temperature decreases wind speed and vice-versa due to their inverse relationship
and this also exist between relative humidity and wind speed in 2018 and 2022 respectively. However, in 2019, 2020 and 2021, increase in relative humidity resulted in corresponding increase in wind speed. Generally, wind speed is one of the sources of renewable energy especially in generation of electricity. Hence, it is imperative for the government and private individuals to investigate the effects of some climatic parameters
on wind speed before designing and installing wind power generating system in any location. Therefore, installation of wind power generation system in Ughelli may not be profiting due to the effects of temperature on wind speed and the dynamic pattern of relative humidity.

Conclusion

This study considers wind speed, relative humidity and temperature as well as the nexus that exists between wind speed and relative humidity
along with wind speed and temperature in Ughelli, Delta State, Nigeria. The minimum wind speed pattern is consistent while there are variations in the maximum wind speed with the highest value of 14.79 Kph been recorded in 2020. The investigation numerically reveals that a low relationship exists amongst wind speed and relative humidity as well as wind speed and temperature. On wind speed and relative humidity, a weakly negatively correlation exist in 2018 and 2022 while positive relationship exists in 2019, 2020 and 2021. In the case of wind speed and temperature, the variables are weakly correlated for the period investigated and that supports the inverse relationship that exist between wind speed and temperature. Despite the degree of the relationship amongst the three parameters, this study has established that a little relationship exists between wind speed and the other two parameters investigated. The AMISE that measures the performance of the parameters require standard deviations, correlation coefficients and the sample size in its computation. These factors show that weather variables whose product of their standard deviations is maximum and weakly correlated produces minimum AMISE while variables whose product of their standard deviations is minimum and highly correlated produces maximum AMISE. In terms of optimal performance of agricultural and industrial activities that depend on the parameters investigated, the AMISE shows that for wind speed and relative humidity, optimal performance is recorded in 2018. Similarly, optimal performance with respect to wind speed and temperature is recorded in 2021 while cases of poor performance in relation to the three parameters is recorded in 2019. Wind is a vital renewable energy resource and hence its connectivity with other weather variables should be investigated especially when installing wind power generation system and the results clearly indicated that installation of wind power system in Ughelli is not profiting due to the effects of temperature on wind speed and the dynamic pattern of relative humidity.

Acknowledgement

The authors are grateful to the anonymous reviewer for thoroughly going through the manuscript and making positive recommendations that improved the paper.

Conflict of Interest

The authors declared that they have no conflict of interest.

REFERENCES

Abbood, Z. M., Al-Taai, O. and Nassif, W. G. (2021): Impact of wind speed and direction on low cloud cover over Baghdad City. Current Applied Science and Technology, 21(3):590–600.

Abodi, H., Thari, N. and Abbas, N. (2016): The relation between cloud cover and some atmospheric variable over Baghdad City. Global Journal of Advanced Research, 3(4):283–289.

Aweda, F. O. and Samson, T. K. (2022): Relationship between air temperature and rainfall variability of selected stations in Sub-Sahara Africa, Iranian (Iranica) Journal of Energy and Environment, 13(3):248–257.

Dec. E., Babiarz, B. and Sekret, R. (2018): Analysis of temperature, air humidity and wind conditions for the needs of outdoor thermal comfort. Web of Conferences 44, 00028, https://doi.org/10.1051/e3sconf/20184400028

Ejemeyovwi, O. D. (2019): Geographic information system assessment of the accessibility of public and private hospitals in Delta State: A study of Delta central senatorial district. International Journal of Development and Sustainability, 8(12):768–784

Hatfield, J. L. and Prueger, J. H. (2015): Temperature extremes: Effects on plant growth and development. Weather and

DOI: https://dx.doi.org/10.4314/swj.v18i3.13

Climate Extremes, 10:4–10.

Hu, B., Li, Y., Yang, H. and Wang, H. (2017). Wind speed model based on kernel density estimation and its application in reliability assessment of generating systems. J. Mod. Power Syst. Clean Energy, 5(2):220–227

Jarnicka, J. (2009): Multivariate kernel density estimation with a parametric support. Opuscula Mathematica, 29(1):41–45.

Marlina, N. and Melyta, D. (2019): Analysis effect of cloud cover, wind speed, and water temperature to BOD and DO concentration using QUAL2Kw model (case study in Winongo river, Yogyakarta). MATEC Web of Conferences, 280, 05006, https://doi.org/10.1051/matecconf/20192800500.

National Population Commission. 2006 Housing and population census result: Delta State National population Office, Asaba.

Oloruntade, A. J., Mogaji, K. O. and Imoukhuede, O. B. (2018): Rainfall trends and variability over Onitsha, Nigeria. Ruhuna Journal of Science, 9(2):127–139.

Pörtner, D. C. R., Tignor, M., Poloczanska, E. S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A. and Rama, B. (2022): Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press. In Press.

Pumo, D., Carlino, G., Arnone, E. and Noto, L. V. (2018): Relationship between extreme rainfall and surface temperature in Sicily (Italy). EPiC Series in Engineering, 3, pp.1718–1726.

Salman, M. A. and Ahmed, F. (2020): Climatology in Barishal, Bangladesh: A Historical Analysis of Temperature, Rainfall, Wind Speed and Relative Humidity Data. Malaysian Journal of Geosciences, 4(1):43–53.

Scott, D. W. (2015): Multivariate Density Estimation. Theory, Practice and Visualisation: Second Edition, Wiley, New Jersey.

Sheather, S. J. (2004): Density Estimation. Statistical Science, 19 (4):588–597.

Siloko, I. U. and Siloko, E. A. (2023): An investigation on interdependence between rainfall and temperature in Ekpoma, Edo State, Nigeria, Iranian (Iranica) Journal of Energy and Environment, 14(3):197–204.

Siloko, I. U. and Siloko, E. A., 2019. Density estimation and data analysis using the kernel method. Proceedings of 56th National Conference of Mathematical Association of Nigeria, Port Harcourt, Nigeria, 218–226.

Siloko, I. U., Ejakpovi, S. U., Ukhurebor, K. E., Siloko, E. A. and Ishiekwene, C. C. (2022): Comparison of kernel density function in detecting effects of daily emission of sulphur (iv) oxide from an industrial plant. Ethiopian Journal of Science and Technology, 15(1):53–66.

Siloko, I. U., Ishiekwene, C. C. and Oyegue, F. O. (2018): New gradient methods for bandwidth selection in bivariate kernel density estimation. Mathematics and Statistics, 6(1):1–8.

Siloko, I. U., Nwankwo, W. and Umezuruike, C. (2020): A discourse on smoothing parameterizations using hypothetical dataset. Journal of Applied Sciences, Information, and Computing, 1(1):80–88.

Siloko, I. U., Ukhurebor, K. E., Siloko, E. A., Enoyoze, E. and Ikpotokin. O. (2022): The interactions between temperature and relative humidity: Results for Benin City, Nigeria using statistical analysis. Current Applied Science and Technology, 22(1):1–15.

Siloko, I. U., Ukhurebor, K. E., Siloko, E. A., Enoyoze, E., Bobadoye, A. O., Ishiekwene, C. C., Uddin, O. O. and Nwankwo. W. (2021): Effects of some meteorological variables on cassava production in Edo State, Nigeria via density estimation. Scientific African, e00852, https://doi.org/10.1016/j.sciaf.2021.e00852

Silverman, B. W. (2018): Density estimation for statistics and data analysis, Routledge, New York.

Somé, S. M. and Kokonendji, C. C. (2022): Bayesian selector of adaptive bandwidth for multivariate gamma kernel estimator on $[0,\infty)^d$. Journal of Applied Statistics, 49 (7):1692–1713.

Tang, C., Tao, X., Wei, Y., Tong, Z., Zhu, F. and Lin, H. (2022): Analysis and Prediction of Wind Speed Effects in East Asia and the Western Pacific Based on Multi-Source Data. Sustainability, 14, 12089, https://doi.org/10.3390/su141912089

Tsuruta, Y. and Sagae, M. (2020): Theoretical properties of bandwidth selectors for kernel density estimation on the circle. Ann Inst Stat Math., 72:511–530.

Ukhurebor, K. E. and Siloko, I. U. (2020): Temperature and rainfall variability studies within South-South Region of Nigeria. Assumption University-eJournal of Interdisciplinary Research (AU-eJIR), 5(2), pp.1–19.

Ukhurebor, K.E., Abiodun, I. C. and Bakare, F. (2017): Relationship between relative humidity and the dew point temperature in Benin City, Nigeria. Journal for Applied Science and Environmental Management, 21(5):953–956.

Wand, M. P. and Jones, M. C. Kernel Smoothing. Chapman and Hall, London, 1995.

Wang, D., Hejazi, M., Cai, X., and Valocchi, A. J. (2011): Climate change impact on meteorological, agricultural, and hydrological drought in central Illinois. Water Resources Research, 47(9):1–13.

Wang, S., Li, A., Wen, K., and Wu, X., (2020): Robust kernels for kernel density estimation. Econ. Lett., 191, 109138.

Xie et al. (2023): Wind Power Interval Prediction Based on Robust Kernel Density Estimation. Journal of Physics: Conference Series, 2534 (2023) 012011, https://doi.org/10.1088/1742-6596/2534/1/012011

Zakaria, N. H., Salleh, S A., Asmat. A., Chan, A., Isa, N. A, Hazali, N. A. and Islam, M. A. (2020): Analysis of Wind Speed, Humidity and Temperature: Variability and Trend in 2017. IOP Conference Series: Earth and Environmental Science 489, 012013