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Statistical Evaluation of Rainfall Data in Owerri, Imo State, Nigeria

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Abstract: This paper evaluated the monthly and yearly average the rainfall data of Owerri from 2000 to 2016. Two-Way ANOVA was employed in the data and the result showed that the average yearly rainfall in Owerri is not the same but the average monthly rainfall in Owerri is not is not significantly different over the years of study.
Keywords: Rainfall, Rainfall Data, ANOVA, Least Significant Difference

I. INTRODUCTION

Rainfall is one of the climatologically data which is widely analyzed for a long time. Analysis of rainfall data is important as it facilitates policy decisions regarding the cropping pattern, sowing date, construction of roads and providing drinking water to urban and rural areas. Two season, wet and dry, are observed in the year.

The rainy season begins in April and last till October. Owerri as town in one the South Eastern region in Nigeria experiences climate variations following rainfall variability monthly and yearly. Every rainy season in Nigeria, wind gusts arising from tropical storms claim lives and property worth millions of naira across the country, Okorie *et al* (2014).stated that flash floods from Torrential rains wash away thousands of hectares of farmlands, Dam bursts were common following such floods.

Rainfall is one of the atmospheric driving forces responsible for climate variations and its effects in Imo State of Nigeria as in other parts of the world. Maduka (2009) indicated that 16% of the erosion in Owerri municipal of Imo state is caused by rainfall. Rainfall is a renewable resource, highly variable in space, time and subject to depletion or enhancement due to both natural and anthropogenic causes, Abaje (2010).

Climate is, with particular reference to rainfall, known to be changing worldwide and there has been growing concern as to the direction and effects of these changes on settlement and infrastructures, (Chaponniere and Smokhtin, (2006)). Many variations in rainfall have occurred for different climate regions and individual locations in Nigeria with associated disasters. These disasters which had led to many loss of property and human lives, and also contributed to about 91% of mosquitoes breeding responsible for malaria cases in Owerri, Imo State, are attributed to rainfall variability which meaning that rainfall promotes mosquitoes breeding. The earth has experienced cycles of temperature and precipitation changes on a geographical scale. Flooding remains the most common of all environmental hazards worldwide.

Estimation of flood damage potential helps in flood risk management. Recently at Ibeneme Street, Relief Market Junction in Owerri, flood submerged many houses and destroyed property worth millions of naira. This was as a result of rain which lasted for hours and shortly resulted in a flood disaster.

More so, Economic activities suffered a great set back in Owerri due to a heavy downpour that submerged residents and shops in Amakohia area of Owerri. There are several studies on climate change and rainfall data using statistical methods, see for example, Stern and Coe (1984); Arvind, et al (2017); El-Adlouni and Quarda (2010); Ologunorisa and Tersoo (2006); Gomathy, et al., (2022); Omar, (2022); Lana *et al*., (2001); Amjadi, et al (2021); Akinsanola and Ogunjobi (2014); Itiowe, et al (2019); Ogunride, et al (2019); Daramola, et al (2017); Animashaun, et al (2020) ; Igwenagu (2014); Shaharudin, et al (2020); Osarunwense (2013). It is on this premise, therefore, that this study focuses on the statistical analysis of rainfall data from 2000-2016 in Owerri Imo State, Nigeria in order to examine the variability of rainfall over the years.

II. MATERIALS AND METHOD

A. Presentation of Data

The data presented in Table 3.1 was of secondary source from Owerri Municipal Council in Imo State, Nigeria comprising the available data of monthly and yearly rainfall pattern of between 2000 and 2016

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Table 3.1: Rainfall data of Owerri from 2000 – 2016

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGU	SEPT	OCT	NOV	DEC
2000	39.1	0.0	53.2	354.2	47.3	391.8	382.7	356.4	344.0	246.5	116.5	5.5
2001	5.5	62.0	206.4	172.2	140.8	385.4	301.7	348.7	430.8	213.4	22.6	14.8
2002	0.0	27.9	90.4	241.7	265.6	250.6	391.5	358.7	293.5	372.4	40.9	0.0
2003	0.0	92.6	136.9	73.3	278.1	277.4	439.5	579.2	476.4	123.8	50.6	0.2
2004	5.4	73.5	32.4	173.3	163.1	225.2	240.6	185.4	309.1	332.9	37.0	0.0
2005	35.5	58.4	102.6	194.3	359.8	367.0	380.6	302.4	232.9	199.8	13.9	0.0
2006	78.5	48.4	108.1	104.1	157.3	349.9	397.6	232.1	537.6	303.3	33.3	0.0
2007	0.0	0.0	46.7	31.2	261.5	309.8	480.9	507.1	302.0	186.4	75.2	0.0
2008	0.0	0.0	117.4	169.2	169.6	470.6	630.2	289.6	433.6	382.9	9.2	25.2
2009	38.6	33.2	68.9	248.9	413.5	239.0	509.8	528.8	483.8	245.9	106.3	0.0
2010	0.0	53.0	34.1	164.2	292.1	255.1	272.0	453.2	237.8	294.6	22.1	1.6
2011	0.0	133.7	79.8	114.8	342.1	176.7	305.9	500.4	377.1	280.9	40.3	0.0
2012	0.0	74.1	22.1	138.1	234.4	284.2	415.0	285.4	501.9	192.3	113.2	0.0
2013	46.5	40.0	130.9	190.5	270.4	181.6	254.1	491.0	273.8	96.7	48.6	132.4
2014	0.0	21.4	99.7	162.3	288.2	236.2	122.0	360.2	350.7	214.4	91.3	12.0
2015	12.4	71.7	61.0	61.4	236.6	360.1	325.8	354.2	351.9	324.3	78.1	132.4
2016	0.0	29.4	192.7	133.7	224.9	272.6	378.1	413.2	457.2	144.4	12.2	0.0

B. *Method Of Analysis*

The Two-WayAnalysis of Variance (ANOVA) was employed to test the hypothesis that the average monthly and yearly rainfall in Owerri, Imo state from 2000 to 2016, However, Analysis of Variance (ANOVA) is a statistical method for determining the existence of differences among several population mean. The technique requires the analysis of different forms of variances associated with the random samples according, see for example Nwobi (2003).

1) Two-*Way ANOVA Model*

The two – way ANOVA model used for this study is presented as;

$$\mathbf{X}_{ij} = \mu + \alpha_i + ß_j + e_{ij};\begin{Bmatrix} i = 1, 2, ..., a \\ j = 1, 2, ..., b \end{Bmatrix} \tag{1}$$

where,

X_{ij} denotes a random variable in the (ij)-th observation

μ denotes Overall mean

α_i denotes Treatment effects

$ß_j$ denotes Replication effects

e_{ij} denotes Error term

2) *Basic Assumptions of Two-Way ANOVA*

a) The mathematical form $\mu + \alpha_i + ß_j$, implies that row and column effects are additive (that is, a treatment effect is the same in all replications apart from experimental errors.
b) The error term, e are normally independent random variables, with mean, 0 and variance, σ^2. They represent the extent to which the data depart from the additive model as a result of experimental error.

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3) Hypothesis tests for the study

The null and alternative hypotheses adopted for this study include

$$\left.\begin{array}{l} H_0^1: t_1 = t_2 =, \ldots, = t_i \\ H_1^1: t_1 \neq t_2 \neq, \ldots, \neq t_i \end{array}\right\} \text{for treatment means}$$

and

$$\left.\begin{array}{l} H_0^2: b_1 = b_2 =, \ldots, = b_j \\ H_1^2: b_1 \neq b_2 \neq, \ldots, \neq b_j \end{array}\right\} \text{for block means}$$

4) Computation of the Two – Way Classification

Let x_{ij} represents the measurement obtained for the unit that is in the i^{th} row (treatment) and j^{th} column (replication). Row total, and means are denoted by $x_{.i}$ and $\bar{x}_i$ respectively, while $x_{.j}$ and $\bar{x}_{.j}$ denote column totals and means. The overall mean is denoted by $x_{..}$.

The table below demonstrates the general procedure for computing the Two-Way Analysis of Variance.

Table 1: Data layout for Two-way ANOVA

Treatment	Block						Totals
	1	2	…	J	…	b	
1	X_{11}	X_{12}	…	X_{1j}	…	X_{1b}	$X_{1.}$
2	X_{21}	X_{22}	…	X_{2j}	…	X_{2b}	$X_{2.}$
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
i	X_{i1}	X_{i2}	…	X_{ij}	…	X_{ib}	$X_{i.}$
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
t	X_{t1}	X_{t2}	…	X_{tj}	…	X_{tb}	$X_{t.}$
Totals	$X_{.1}$	$X_{.2}$	…	$X_{.i}$	…	X_{ij}	$X_{..}$

Correction factor: $$C = \frac{(\sum X_{ij})^2}{tb} \qquad (2)$$

Total Sum of Squares: $$TSS = \sum X_{ij}^2 - C \qquad (3)$$

Treatment: $$SS_t = \frac{X_{1.}^2 + X_{2.}^2 + \ldots + X_a^2}{b} - C \qquad (4)$$

Replication: $$SS_b = \frac{X_{.1}^2 + X_{.2}^2 + \ldots + X_b^2}{t} - C \qquad (5)$$

Error Sum of Squares: $$ESS = TSS - SS_t - SS_b \qquad (6)$$

Table 2: The corresponding Analysis of Variance table

Source of variation	Degree of freedom	Sum of Squares	Mean Squares
Treatment	$t-1$	SS_t	$MS_t = SS_t / t-1$
Blocking	$b-1$	SS_b	$MS_b = SS_b / b-1$
Error	$(t-1)(b-1)$	ESS	$MSE = ESS / (t-1)(b-1)$
Total	TSS		

5) The F–Ratio of Two-Way ANOVA

The F-ratio for each one of the hypothesis test is the ratio of the appropriate mean square to the MSE. Thus, for the test of the equality of the treatment means, we use,

$$\mathrm{F}_t = \frac{MS_t}{MSE} \tag{7}$$

and for the test of whether blocking was done effectively, we use;

$$\mathrm{F}_b = \frac{MS_b}{MSE} \tag{8}$$

6) Test for Differences Between Pairs of Means

When we reject the null hypothesis, it follows that not all population means are equal. However, since ANOVA does not reveal in what way these means differ, other statistical tests have been developed which enables us to determine which of these means are different from the rest. Amongst them are the Turkey`s test, and the Least Significant Difference (LSD) test. Both procedures make a pairwise comparison of all the possible pairs of means. Both methods apply for ANOVA designs which are balanced (ie., designs in which every sample has the same number of observations). However, where the design is only slightly unbalanced (ie. Number of observations per sample differs only slightly) we can still apply the above tests to obtain approximate results by using the smallest sample size, instead of the equal sample size. For very unbalanced designs, we use other procedures such as the modified LSD approach. The Least Significant Difference (LSD) Test is given by

$$\mathrm{LSD} = \sqrt{\frac{2(MSE)F_\alpha}{t}} \tag{9}$$

where F is the F-ratio with $n-1$ degrees of freedom. The LSD criterion is then compared with each of the test statistics (ie. absolute differences in sample means) and any pair with a difference greater than the LSD-value indicates inequality of the respective population means.

III. EMPIRICAL EVIDENCE

Table 4 is the summary statistics of rainfall in Owerri. The table showed the average, minimum and maximum rainfall for each year with their various standard deviation. The highest average amount of rainfall was in 2009 with 243 mm^3 while the maximum amount of rainfall was 630.2 mm^3 in 2008

Table 4 Summary Statistics of the Yearly Rainfall in Owerri

Year	Count	Mean	Std. Dev.	Minimum	Maximum
2000	12	194.8	164.2	0	391.8
2001	12	192.0	149.7	5.5	430.8
2002	12	194.4	152.4	0	391.5
2003	12	210.7	197.2	0	579.2
2004	12	148.2	116.9	0	332.9
2005	12	187.3	143.6	0	380.6
2006	12	195.85	168.4	0	537.6
2007	12	183.4	186.8	0	507.1
2008	12	224.8	213.8	0	630.2
2009	12	243.1	198.6	0	528.8
2010	12	173.4	149.0	0	453.2
2011	12	196.0	162.8	0	500.4
2012	12	188.4	162.4	0	501.9
2013	12	179.7	129.9	40	491
2014	12	163.2	127.2	0	360.2
2015	12	197.5	139.7	12.4	360.1
2016	12	186.5	165.7	0	457.2

Table 5 ANOVA Result of yearly Rainfall Data from 2000 to 2016

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F-Statistic	P-Value
Factor	89907	16	5619	0.21	1.000
Error	4942289	187	26429		
Total	5032195	203			

Table 5 shows that the average yearly rainfall from 2000 to 2016 is not significant since the P-value (1.000) is greater than 0.05, we therefore do not reject the null hypothesis and that there is significant difference between the average yearly rainfall in Owerri. This means that rainfall pattern in Owerri are not the same over the years.

Table 6 ANOVA Result of Monthly Rainfall Data from 2000 to 2016

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F-Statistic	P-Value
Factor	3903570	11	354870	60.37	0.000
Error	1128661	192	5878		
Total	5032231	203			

Table 6 shows that the average monthly rainfall from 2000 to 2016 is significant since the P-value (0.000) is less than 0.05, hence, we reject the null hypothesis and conclude that the avaerge monthly rainfall in Owerri over the years are the same.

A. Fisher Pairwise Comparisons

Grouping Information Using the Fisher LSD Method and 95% Confidence

Factor	N	Mean	Grouping
AUG	17	385.1	A
SEP	17	376.1	A
JUL	17	366.4	A
JUN	17	296.1	B
OCT	17	244.4	B C
MAY	17	243.9	C
APR	17	159.3	D
MAR	17	93.1	E
NOV	17	53.62	E F
FEB	17	48.19	E F
DEC	17	19.1	F
JAN	17	15.38	F

Means that do not share a letter are significantly different.

The fisher pair wise comparison shows that average monthly rainfall of the month of July, August, September and July were the same. The average monthly rainfall of June and October are same. Also October and May average monthly rainfall was the same. March, November and February average monthly rainfall are the same.

IV. CONCLUSION

From the findings of this paper, we observed that the average yearly rainfall in Owerri was not the same while the average monthly rainfall in Owerri was the same over the years meaning the months of November, February, December and January average monthly rainfall were not significantly different. We, therefore, conclude there were variations in the yearly rainfall but does not vary in the monthly rainfall.

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