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Comparison of Normal Ratio Method and Distance Power Method for Estimating Missing Rainfall Data with Three Neighboring Stations

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

This study compared the performances of Normal Ratio Method and Distance Power Method as a tool for estimating missing rainfall data. The data utilized are the rainfall data of the three neighboring station of Catarman, Northern Samar, Philippines. These stations are Catbalogan Station (Samar Province), Legazpi (Bicol Province) and Masbate (Masbate Province).

The observed daily rainfall data for the Catarman (Northern Samar), Catbalogan, Legazpi, and Masbate were obtained from the Philippine Atmospheric Geographical Astronomical Services Administration. The monthly rainfall were computed for the three (3) neighboring stations (Catbalogan, Legazpi, Masbate).

The evaluation used the T-test for correlated samples and the Pearson's Correlation Coefficient for the monthly rainfall data computed of the three neighboring Station of Catarman, Northern Samar with the three neighboring stations. Based from the results, Normal Ratio Method performs better than Distance Power Method as applied to three neighboring stations.

Keywords: Normal ratio method; distance power method; missing rainfall; rainfall data.

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1. INTRODUCTION

For a reliable rainfall data input for whatever water resources management planning, a continuous data, say for 10 years or 30 years is immense. But the reality, some rainfall data for a particular station have gaps which may be due toloss of records, fire accidents, wars, typhoons, floods, etc. and occasional interruption abnormal function of the instruments used [1]. According to Pajuelas [2] estimation of missing data is the first stage of most climatological, environmental and hydrological studies.

In the Philippines, there are synoptic stations having gaps on their rainfall data. Hasan, et al. [3] said spatial interpolation techniques are widely used methods for filling the gaps in daily rainfall series through estimating the unknown rainfall amount for a point from the known data of adjacent stations. Normal-ratio and 3-station-average was explored to fill the missing values in monthly rainfall data by Paulhus and Kohler [4] and The Inverse Distance Weighting (IDW) methods estimate the rainfall amount of a location was considered by Teegavarapu and Chandramouli (2005). Ahrens [5] stated that correlation coefficients between data series can also be explored to estimate the weights. And so are regression based methods are also used for estimating missing precipitation values according Lo Presti et al. [6] considering the climate data, elevation, topography, proximity to coastal area etc. as explanatory.

A number of tools to estimate missing rainfall data for a location were developed. And this study attempted to compare the performances of Normal Ratio Method and Distance Power Method for estimating missing rainfall data [7,8].

2. METHODOLOGY

This study employed the quantitative correlational study, a descriptive research design. The correlation of the rainfall data of Catarman to the three identified neighboring stations, the Catbalogan, Legazpi and Masbate synoptic stations was determined to know whether the rainfall data of the latter be used to estimate the missing monthly rainfall of the former employing Normal Ratio Method or Distance Power Method. Based on the data requirements and level of accuracy, the Normal Ratio Method can be used only if the available daily rainfall data for each of the stations involved in the study runs for thirty-years, from January 1, 1986 to December 31, 2015 and for the Distance Power Method the available rainfall data should be at least for ten (10) continuous years. However, for comparison, in both methods, the rainfall data analyzed was from January 1986 to December 2015.

This study utilized the daily rainfall from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) of Catarman and the three neighboring synoptic rain gage stations, namely, Catbalogan, Legazpi and Masbate. The daily rainfall obtained from the Catarman, Catbalogan, Legazpi and Masbate Synoptic Stations were summed up to find the monthly rainfall.

A Double Mass Analysis was performed to test the homogeneity of the rainfall data set of Catarman Station and the rainfall data sets of the identified three neighboring stations. To adjust the data, the formula below was used.

$$Pa = \frac{ba}{bo}\, Po$$

where:

Pa = adjusted precipitation
Po = observed precipitation
ba = slope of graph to which records are adjusted
bo = slope of graph at time Po was observed

As shown in Fig. 1, the observed rainfall of the three neighboring stations, namely, Catbalogan, Legazpi and Masbate and that of the test station (Catarman) possess homogeneity and consistency.

Since the rainfall data for Catarman station and the three neighboring stations are homogeneous and consistent, the researcher started the computation of the estimated monthly rainfall for Catarman station using the monthly rainfall data from the three neighboring stations by the following formulas:

1. Normal Ratio Method

$$P_x = \frac{1}{n}\sum_{i=1}^{i=n} \frac{NR_A}{NR_i} P_i$$

Where,

P_x = the missing rainfall for Catarman station at a particular month

P_i = the rainfall for the same month at any of the neighboring station either Catbalogan, Legazpi or Masbate
NR_A = the normal monthly rainfall value for Catarman station
NR_i = the normal monthly rainfall value for any of the neighboring station either Catbalogan, Legazpi or Masbate
NR = normal monthly (mean of thirty 30 years of monthly rainfall data)
n = number of surrounding stations whose data are used in the estimation

2. Distance Power Method

$$P_x = \frac{\sum_{i=1}^{Mbase} P_{i,j}/D_i^b}{\sum_{i=1}^{Mbase} 1/D_i^b}$$

where :

P_x = missing monthly rainfall at Catarman station at time "j"
$P_{i,j}$ = observed monthly rainfall at any of the neighboring stations at time "j"
D_i = distance of Catarman station from any of the neighboring stations
M_{base} = number of neighboring stations taken into account; and
b = 2, power of distance D used for weighting rainfall values at individual station.

and the distance D_i is computed by the formula :

$$D_i = (x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2$$

where:

x, y, z = are the coordinates of the Catarman Station; and
x_i, y_i, z_i = are the coordinates of any of the neighboring stations.

The statistical procedures employed in this study were the following :

1. "T" test for Correlated Samples (to determine if there is significant difference between the estimated missing monthly rainfall (at Catarman station) using the three methods and the observed monthly rainfall at Catarman station):

$$t = \frac{\overline{D}}{\sqrt{\frac{\sum D^2 - \frac{(\sum D)^2}{n}}{n(n-1)}}}$$

where:

D = main difference between observed monthly rainfall at Catarman station and the estimated missing monthly rainfall by any of the three methods employed
n = sample size

2. Pearson's Correlation Coefficient (to determine the degree of correlation between the observed and estimated monthly rainfall for Catarman station)

$$R = \frac{\sum XY - \frac{(\sum X)(\sum Y)}{n}}{\sqrt{\left(\sum X^2 - \frac{\sum X^2}{n}\right)\left(\sqrt{\sum Y^2} - \frac{\sum Y^2}{n}\right)}}$$

where:

R = Pearson's Correlation Coefficient;
X = monthly rainfall in any neighboring station included in the study;
Y = the observed monthly rainfall data at Catarman station; and
n = population size.

3. RESULTS

The normal monthly rainfall for Catarman, Catbalogan, Legazpi and Masbate stations were computed and presented in Table 1.

Using these normal rainfall values, the monthly rainfall in Catarman, N. Samar was estimated by the Normal Ratio Method as shown in Tables 2a and 2b.

Usingthe geographical coordinates of Catarman, Catbalogan, Legazpi and Masbate stations, the computed distances Catarman-Catbalogan, 84,556.6087 m; Catarman-Legazpi, 197,338.71 mand Catarman-Masbate, 88,417.961 m. With these distances, the estimated monthly rainfall for Catarman were computed by the Distance Power Method as shown in Tables 3a and 3b.

Table 4 shows the results of the "T" test for Correlated Samples (to determine if there is significant difference between the estimated monthly rainfall at Catarman station) using the ttwo methods and the observed monthly rainfall at Catarman station) and the results of the Pearson's Correlation Coefficient computation (to determine the degree of correlation between the estimated monthly rainfall by the three methods and the observed monthly rainfall for Catarman station.

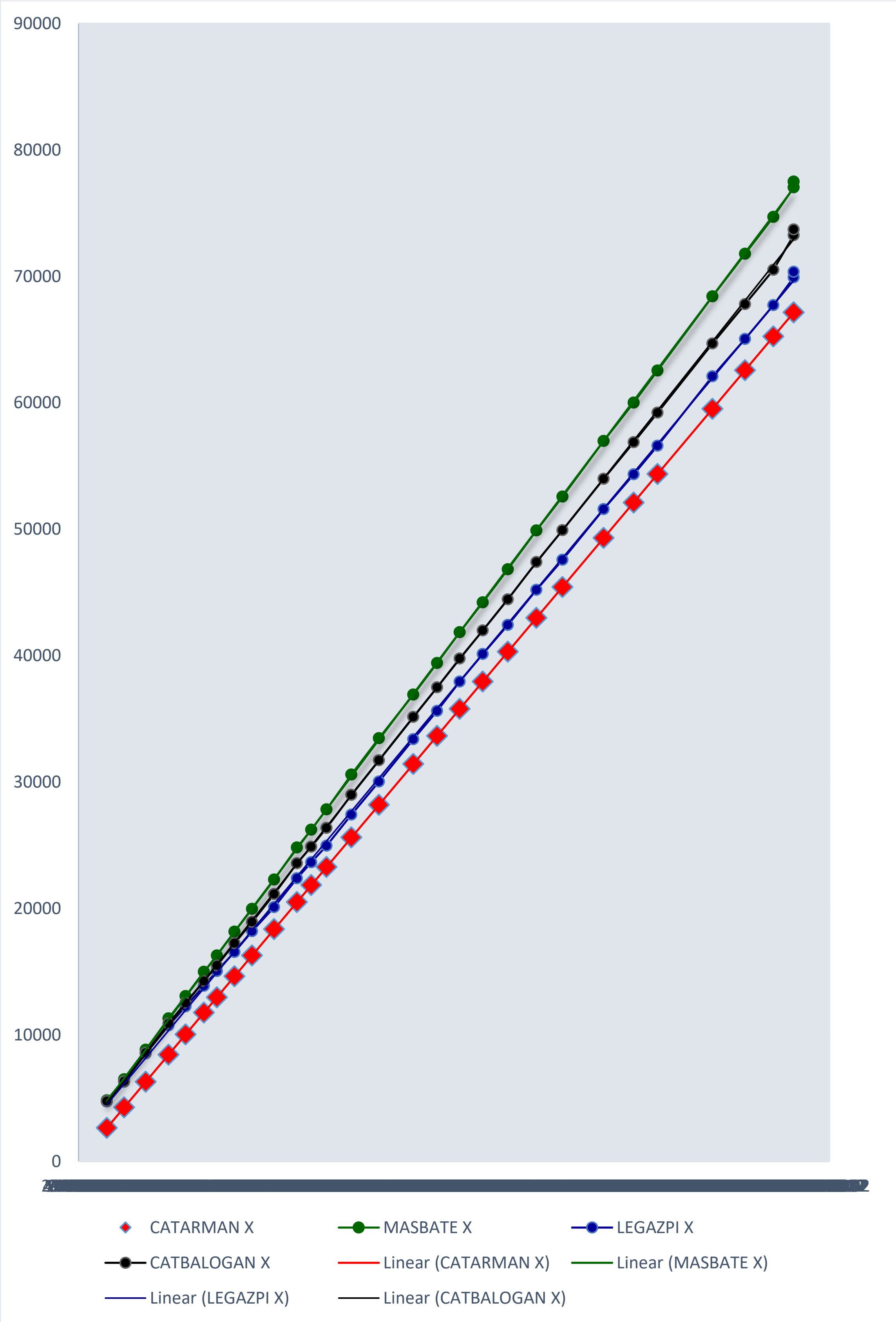

Fig. 1. Double mass analysis curve

Table 1. The normal monthly rainfall (mm) in the Catarman, Catbalogan, Legazpi, and Masbate stations

Month	Catarman	Catbalogan	Legazpi	Masbate
January	514.5	282.2	330.6	189.0
February	295.1	197.1	289.5	108.4
March	301.8	191.1	273.2	107.9
April	167.3	127.2	176.6	53.7
May	154.9	176.1	194.6	125.4
June	217.4	241.1	229.2	168.3
July	215.4	275.7	278.4	218.6
August	177.8	203.8	224.5	173.4
September	196.5	263.2	278.2	197.5
October	328.6	299.6	319.4	223.7
November	475.3	303.4	467.0	233.9
December	645.1	339.9	583.5	267.7

Table 2a. The estimated monthly rainfall in Catarman, N. Samar by the normal ratio method (January to June)

Year	Estimated Monthly Rainfall					
	January	February	March	April	May	June
1986	595.6	154.2	148.4	410.2	101.7	268.2
1987	171.4	91.5	57.4	51.2	21.7	164.8
1988	257.2	88.4	60.2	168.8	86.8	277.9
1989	1194.7	558.8	447.8	187.3	260.3	271.0
1990	489.2	78.6	25.3	68.5	202.2	413.9
1991	180.4	187.9	325.0	129.5	146.3	318.8
1992	284.9	86.1	26.1	37.1	93.5	166.0
1993	168.8	154.9	254.2	28.3	40.0	126.5
1994	655.5	85.1	190.7	237.7	182.0	213.9
1995	365.2	95.4	126.9	130.3	85.6	161.9
1996	653.3	242.4	824.6	685.2	124.8	212.5
1997	226.3	221.7	99.5	47.3	131.0	180.3
1998	195.9	52.2	90.4	43.2	92.6	80.3
1999	943.4	438.0	527.7	219.5	114.0	191.2
2000	515.9	1132.5	599.6	241.9	125.3	152.9
2001	730.6	610.6	430.3	64.1	134.6	280.5
2002	332.2	182.8	207.2	116.1	79.2	94.1
2003	400.5	64.9	107.6	47.6	155.5	332.7
2004	376.2	182.7	266.4	88.6	413.3	210.1
2005	228.1	93.3	175.6	94.3	98.9	151.2
2006	506.1	350.7	449.9	118.3	282.8	138.8
2007	640.1	62.2	184.3	70.5	191.2	96.8
2008	606.2	1256.6	254.9	383.6	379.0	242.0
2009	531.6	452.8	211.4	562.0	309.5	329.7
2010	446.6	25.1	133.1	84.5	58.3	78.4
2011	447.2	149.1	1010.6	201.4	296.0	327.2
2012	656.3	636.5	670.7	111.3	100.3	200.9
2013	692.8	384.9	225.9	46.3	125.8	444.5
2014	528.0	66.9	307.4	244.6	33.2	226.5
2015	611.8	704.2	595.8	156.5	30.9	245.1

Table 2b. The estimated monthly rainfall in Catarman, N. Samar by the Normal Ratio Method (July to December)

Year	Estimated monthly rainfall					
	July	August	September	October	November	December
1986	186.6	211.6	165.4	529.7	361.9	164.7
1987	308.7	299.2	126.4	256.6	791.7	857.0
1988	139.7	83.7	151.5	830.2	1126.2	819.7
1989	161.2	163.6	123.0	360.1	287.0	352.2
1990	155.2	152.0	184.2	396.8	445.4	290.8
1991	254.6	210.9	96.3	209.8	497.6	520.8
1992	282.7	162.3	170.3	285.8	384.7	297.5
1993	274.9	218.0	145.2	238.7	548.4	907.6
1994	290.6	99.7	293.6	177.4	244.2	473.6
1995	198.7	299.9	310.7	337.2	762.8	1299.1
1996	118.7	113.1	156.8	263.8	513.5	587.6
1997	273.9	98.1	246.8	174.6	264.7	272.7
1998	101.8	186.1	208.6	558.8	302.4	832.7
1999	106.2	198.3	152.9	302.4	705.7	883.7
2000	220.6	156.6	122.8	554.9	767.4	899.1
2001	2001	193.5	228.6	113.8	475.0	706.3
2002	2002	271.1	307.6	225.5	174.1	376.6
2003	2003	224.8	166.4	179.4	226.1	462.9
2004	2004	159.4	183.0	90.8	394.2	441.5
2005	2005	193.6	144.2	398.3	284.8	266.3
2006	183.6	184.7	307.6	220.8	389.4	725.4
2007	171.3	150.5	276.9	341.2	676.0	656.9
2008	163.9	203.1	190.3	237.7	366.9	849.1
2009	165.0	157.7	188.7	312.9	360.1	254.0
2010	236.9	213.1	212.5	359.2	332.7	735.1
2011	397.2	185.2	238.9	307.0	455.1	734.8
2012	322.5	46.7	239.4	431.4	379.5	540.9
2013	230.5	214.9	188.1	223.6	540.8	555.1
2014	374.6	203.1	307.7	338.8	347.8	1512.6
2015	138.4	141.2	146.3	165.5	310.6	513.4

Table 3a. The estimated monthly rainfall in Catarman, N. Samar by the Distance Power Method (January to June)

Year	Estimated monthly rainfall					
	January	February	March	April	May	June
1986	320.9	86.7	95.1	261.5	107.8	274.0
1987	80.5	59.4	15.4	25.9	20.3	166.9
1988	98.9	36.7	4.0	80.4	89.2	277.3
1989	630.0	368.3	118.3	118.8	281.4	213.6
1990	203.3	33.5	12.3	38.6	215.6	432.6
1991	71.1	120.9	122.7	102.0	124.6	240.4
1992	113.3	28.8	1.9	20.1	80.7	193.6
1993	63.6	102.4	97.1	17.3	23.0	101.9
1994	252.0	49.3	89.6	150.8	210.5	221.5
1995	160.6	54.0	18.2	82.1	78.9	150.7
1996	302.3	164.9	477.2	357.9	126.0	163.1
1997	133.7	110.1	41.8	45.3	130.7	169.1
1998	81.2	42.8	28.9	23.5	62.7	87.9

Year	Estimated monthly rainfall					
	January	**February**	**March**	**April**	**May**	**June**
1999	378.4	283.0	258.5	134.2	120.5	176.9
2000	237.0	730.3	259.9	151.4	152.5	151.9
2001	370.9	385.7	181.3	39.4	143.5	278.0
2002	158.9	92.0	41.1	87.6	69.5	92.8
2003	196.3	24.6	21.5	20.7	152.8	356.4
2004	206.4	115.9	72.7	62.9	421.7	163.0
2005	98.2	40.7	59.1	25.9	101.6	118.3
2006	196.3	189.9	217.5	61.7	305.8	103.9
2007	309.7	50.6	50.9	42.9	180.1	99.0
2008	299.2	765.9	39.1	195.7	397.0	274.0
2009	264.9	263.9	43.5	301.8	235.2	367.3
2010	232.0	11.7	30.5	47.6	64.1	77.9
2011	755.4	107.7	431.8	130.0	529.8	246.4
2012	327.7	318.8	245.5	79.3	124.8	205.9
2013	346.0	249.4	93.8	35.7	139.4	482.3
2014	318.6	43.6	80.7	190.6	42.7	250.3
2015	301.8	143.9	39.5	77.3	19.4	227.7

Table 3b. The estimated monthly rainfall in Catarman, N. Samar by the Distance Power Method (July to December)

Year	Estimated monthly rainfall					
	July	**August**	**September**	**October**	**November**	**December**
1986	206.9	239.5	177.7	435.9	209.3	82.8
1987	412.8	362.6	148.9	222.6	497.7	444.3
1988	173.2	95.7	210.8	702.2	698.5	480.3
1989	197.5	173.6	101.9	329.5	177.5	168.2
1990	168.7	144.9	226.7	300.4	283.8	130.1
1991	298.2	228.3	100.7	174.4	335.1	272.3
1992	345.3	152.4	194.0	262.1	254.9	135.7
1993	320.3	208.1	148.8	158.2	296.5	447.9
1994	341.1	131.1	405.9	151.6	160.9	236.9
1995	204.6	329.9	385.9	287.0	445.8	579.5
1996	125.9	125.7	213.0	203.4	296.7	344.8
1997	323.4	101.0	290.6	165.1	158.0	119.8
1998	99.2	193.1	265.4	438.4	189.0	410.3
1999	178.2	217.8	207.8	226.6	466.1	448.9
2000	263.6	177.2	139.6	473.0	467.4	453.6
2001	227.9	238.8	107.9	370.3	453.3	311.1
2002	313.7	383.1	279.7	138.0	207.1	194.9
2003	303.3	192.1	198.3	178.1	322.9	158.8
2004	195.3	173.2	111.9	353.6	282.0	210.4
2005	216.2	155.4	443.2	220.3	153.4	702.9
2006	237.5	198.2	378.3	194.4	182.7	394.7
2007	221.1	154.8	277.2	255.4	427.1	356.4
2008	175.5	222.9	226.3	197.5	223.3	463.2
2009	172.1	182.1	220.8	232.4	215.5	148.7
2010	320.5	246.4	292.3	304.1	185.9	314.2
2011	404.1	189.4	307.5	278.9	254.5	367.2
2012	357.9	42.2	334.8	351.8	229.0	261.2
2013	252.5	226.5	233.1	193.7	304.0	300.0
2014	454.9	226.1	406.3	283.0	219.8	879.8
2015	151.6	154.9	167.1	108.1	169.9	235.5

Table 4. The result of the T test for Correlated Samples and the Pearson's Correlation Coefficient performed between the estimated monthly rainfall of the three methods and the observed rainfall in Catarman, N. Samar

Test Conducted	Observed Monthly Rainfall in Catarman Station versus Estimated Monthly Rainfall computed by the		Critical Value
	Normal Ratio Method	Distance Power Method	
T Test for Correlated Samples	– 0.3	– 10.0	1.645
Pearson's Correlation Coefficient	0.84	0.76	0

4. DISCUSSION AND CONCLUSION

The resulton Double Mass Analysis shows that rainfall data are homogeneous and also implied that the three neighboring stations have similar rainfall pattern with Catarman, hence the selection of these stations are justified. The normal annual rainfall, based on a 30 years rainfall data (1986 – 2015) for Catarman (Northern Samar) ranged from 154.9 mm (May) to 645.1 mm (December). For the same period, the normal annual rainfall in Catbalogan ranged 127.2 mm (April) to 339.9 mm (December); in Legazpi, it ranged from 176.6 mm (April) to 583.5 mm (December); and in Masbate, it ranged from 53.7 mm (April) to 267.7 mm (December).

The coefficients of correlation between the monthly observed rainfall at Catarman station and any of the three identified neighboring stations without using any estimating tool were also determined. For Catarman and Catbalogan, the correlation coefficient was 0.737; for Catarman and Legazpi, 0.622; and for Catarman and Masbate, 0.698. However, these correlation coefficients were very low.

The monthly rainfall in Catarman for 30 years was estimated by using the two methods. The estimated monthly rainfall using each of the two methods was compared with the observed monthly rainfall in Catarman. The estimated monthly rainfall by the Normal Ratio Method has the lower "t" value of – 0.3 compared that of Distance Power Method is -10.0 which means that the former method gave the nearest to the observed monthly rainfall. The estimated monthly rainfall using the Normal Ratio Methods had correlation coefficients of 0.84 while for the Distance Power Method had a correlation coefficient of 0.76 only. With these findings, the Normal Ratio Method performed better than Distance Power Method. The researcher believes that distance has some bearing on the rainfall pattern.

5. RECOMMENDATIONS

Based from the results, it is recommended that similar study be conducted comparing other missing rainfall data estimating tools which may either be classical methods or machine learning techniques and with more than three stations.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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