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Development of an Equation to Estimate the Monthly Rainfall: A Case Study for Catarman, Northern Samar, Philippines

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ABSTRACT

This study aimed to derived an equation to estimate the monthly rainfall for Catarman, Northern Samar.The observed monthly rainfall data for Catarman N. Samar, Catbalogan Samar, Legazpi City and Masbate were obtained from the Philippine Atmospheric Geographical Astronomical Services Administration (PAGASA). The monthly rainfall records of the three (3) neighboring stations (Catbalogan, Legazpi, Masbate) were used to identify which of the existing rainfall prediction methods, namely, Normal Ratio Method, Distance Power Method and Multi Linear Regression Method is the basis in the development of a new equation.

The accuracy by which the existing methods predict the observed monthly rainfall in Catarman was evaluated using T-test for correlated samples and the Pearson's Correlation Coefficient. Since none of the methods produced estimates nearest to the observed monthly rainfall in Catarman, an equation has been derived:

$$y = \frac{21}{25}\left[Log\ \frac{13}{20}\frac{NR_A}{D_T}\sum_{i=1}^{n}\frac{P_i D_i}{NR_i}\right]^7$$

Using the neighboring stations of Catbalogan, Legazpi, and Masbate the equation became:

$$y = \frac{21}{25}\left\{ Log\ \frac{13}{20}\frac{NR_A}{D_T}\left[\frac{D_{CATBALOGAN}P_{CATBALOGAN}}{NR_{CATBALOGAN}} + \frac{D_{LEGAZPI}P_{LEGAZPI}}{NR_{LEGAZPI}} + \frac{D_{MASBATE}P_{MASBATE}}{NR_{MASBATE}}\right]\right\}^7$$

Keywords: *Monthly Rainfall, PAGASA, Normal ratio method, distance power method, Multi linear regression method*

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INTRODUCTION

Rainfall data are one of the most important and frequently used hydrological data in water resources planning and other climatological analyses. But rainfall is affected by climate change which is being experienced nowadays. One of its tremendous effects is the variably unexpected rainfall intensity. This phenomenon cannot be explained by natural variation under normal conditions. El Niño and La Niña phenomena affect the rainfall pattern and intensity.

Pajuelas (2000) observed that rainfall distribution over space and time during either El Niño or La Niña event is highly variable and causes major economic losses due to disastrous typhoons, floods, and droughts. It is during these extreme rainfall events that rainfall characteristics such as rainfall depth and rainfall intensity should be monitored and measured so that such data may be used for weather forecasting and planning purposes.

Rainfall data is very important and useful in the planning of agricultural development, water resources and disaster mitigation projects and programs. Hence, functional rain gages should be installed in all municipalities of the country or much better in every barangay. The more rain gages there are, the more accurate is the measurement of rainfall as well as the estimation of the average rainfall over an area where a development project is being proposed.

The problem, however, on rainfall monitoring and measurement is that, first and foremost, there is one rain gage for every 30,000 hectares (Linsley, et al., 1982). In the Philippines, a major problem is the continuous functionality of rain gages because many of them are destroyed during the typhoon months (September – December) and they are not immediately repaired or replaced by a functional one.

The continuity of precipitation data over time is also very important. For the rainfall forecasting to be credible, this should be based on a 30-year rainfall record. Almost all rainfall data have gaps not only due to loss of records because of fire accidents, wars, typhoons, floods, etc. but also due to occasional interruption abnormal function of the instruments used. Hence, numerous techniques were developed to estimate the missing precipitation data.

Pajuelas (2000) stated that estimation of missing data is known as the first stage of most climatological, environmental and hydrological studies. Spatial interpolation of precipitation data for imputation of missing records is an essential and crucial step in the development of continuous precipitation data without any gaps needed for hydrologic analysis, modeling and design (Teegavarapu, 2011).

Developing countries, like the Philippines, are often faced with this problem. There are many methods for estimation of missing rainfall data. According to Hasan, et al.(2013)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 as proven by the studies of previous researchers. Paulhus and Kohler (1952) explored two methods of interpolation, the normal-ratio and 3-station-average, to fill the missing values in monthly rainfall data. The Inverse Distance Weighting (IDW) methods estimate the rainfall amount of a location as a weighted average of the rainfall amount of adjacent stations and the weights are considered as a function of the distances (Teegavarapu and Chandramouli, 2005). The correlation coefficients between data series are also explored to estimate the weights (Ahrens, 2006). Regression based methods are also used for estimating missing precipitation values (Lo Presti et. al., 2010). Regression models consider climate data, elevation, topography, proximity to coastal area etc. as explanatory variables to estimate missing rainfall series of a station (Daly et. al., 1994).

Most of these methods in estimating missing rainfall data, however, were developed applying rainfall data from other countries, especially the USA, United Kingdom, Australia and other highly developed ones. The rainfall pattern, frequency and intensity in the Philippines is different from those countries. Moreover, the province of Northern Samar has different rainfall characteristics compared to the other provinces of the Philippines and so Catarman has different rainfall characteristics from the other towns of the province of Northern Samar.

These problematic realities challenged the researcher to develop an equation on estimating the monthly rainfall for Catarman, Northern Samar.

This study aimed to develop an equation to estimate a missing monthly rainfall specifically for Catarman, Northern Samar.

METHODOLOGY

This study was conducted in the Municipality of Catarman, the capital town of the Province of Northern Samar. It is a first-class municipality and is the largest town in terms of land area and population in the province. It lies on the northern part of the Samar Island. It is bounded to the East by Mondragon, to the west by Bobon, to the south by Lope de Vega and to the North by the Philippine Sea.

Catarman has a tropical climate. There is significant rainfall throughout the year in Northern Samar. Even the driest month still has lot of rainfall (Pajuelas, 2000). The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) Regional Office No. VIII has its Satellite Office in Catarman, Northern Samar situated at Brgy. Dalakit of this town.

This study employed the quantitative correlational study, a descriptive research design. In this study, the correlation of the rainfall data of Catarman and of the six identified neighboring stations, the Catbalogan, Tacloban, Borongan, Sorsogon, Legazpi and Masbate synoptic stations, was done to determine whether the data of the latter can be used to estimate for the missing monthly rainfall of the former.

As regards data gathering, the observed daily rainfall data for the period January 1, 1986 to December 31, 2015, at the Catarman Synoptic Station, Catarman, Northern Samar were personally obtained by the researcher from Mr. Felion C. Corona, the Chief Meteorological Officer of the said station.

For the six neighboring stations which were originally included in the study, the observed daily rainfall data for the same period were obtained from the Climatology and Agro meteorology Division ofthePhilippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) Central Office, Diliman, Quezon City.

The researcher looked for methods of estimating missing monthly rainfall in the different books and journal articles reviewed. Based on the data requirements and level of accuracy, the researcher has chosen three methods such as the Normal Ratio Method, Distance Power Method and Multi Linear Regression Method. 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. For the Distance Power Method and Multi Linear Regression, the available rainfall data should be at least for ten (10) continuous years.

The stations which qualified for the Normal Ratio Method are the Catbalogan, Legazpi and Masbate stations while those qualified for Distance Power and Multi Linear Regression Methods are Catbalogan, Legazpi, Masbate, Tacloban and Borongan Stations. For purposes of correlation and consistency of the data, the researcher decided to consider only the stations having the complete thirty years rainfall data set. Thus, only the stations of Catbalogan, Legaspi and Masbate were used in this study.

The data obtained were examined as to their completeness and sufficiency for the application of the three identified methods to be used for the estimation of missing rainfall. Based on this evaluation, only three neighboring stations qualified and these are the Catbalogan, Legazpi and Masbate Synoptic Stations.

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, instead of the original plan to use six stations because the Sorsogon, Borongan and Tacloban stations were excluded by reason of incomplete data series.

The daily rainfall gathered from the Catarman, Catbalogan, Legazpi and Masbate Synoptic Stations were summed up to find the monthly rainfall.

A Double Mass Analysis was performed to determine the homogeneity of the rainfall data set from Catarman Station and the rainfall data sets from the identified three neighboring stations. A break in the slope of the graph indicated a change in the precipitation regime in a particular station and the record of annual rainfall was adjusted using the formula

$Pa = \frac{ba}{bo}\ Po$ (equation 1)

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 Figure 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.

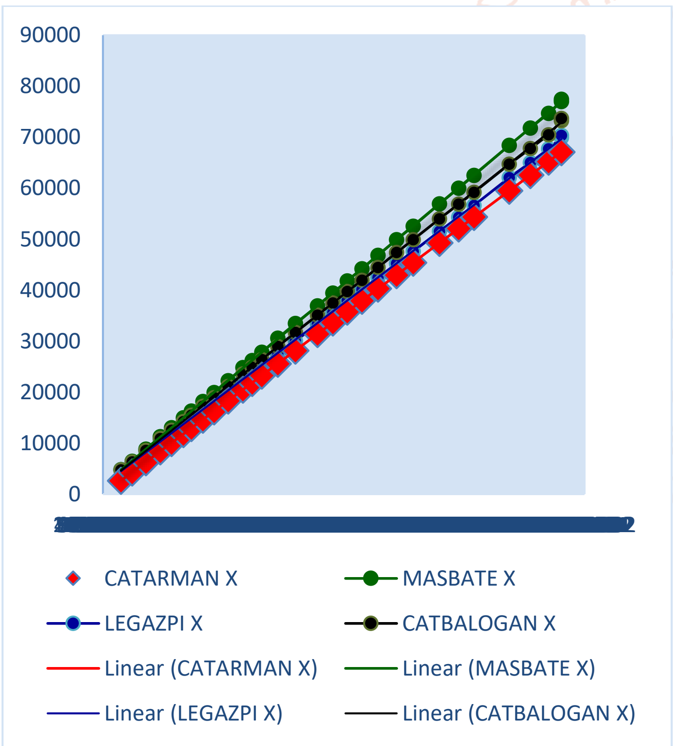

Figure 1 Double mass analysis curve for the four (4) sites

Having proven that 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:

A. Normal Ratio Method $P_x = \frac{1}{n}\sum_{i=1}^{i=n}\frac{NR_A}{NR_i}P_i$ (equation 2)

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

B. Distance Power Method

$$P_x = \frac{\sum_{i=1}^{Mbase} P_{i,j}/D_i^b}{\sum_{i=1}^{Mbase} 1/D_i^b} \text{ (equation-3)}$$

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.

3. Multiple Linear Regression Method

$y = b_0 + b_i x_i + b_2 x_2 + \ldots + b_n x_n$

where:

y = missing monthly rainfall of Catarman station

$x_1, x_2, \ldots, x_n$= monthly rainfall at the neighboring stations; and

$b_0, b_1, b_2, \ldots, b_n$ = partial regression coefficients determined by the statistical package using the monthly rainfall data from 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)

$$t = \frac{\bar{D}}{\sqrt{\frac{\sum D^2 - \frac{(\sum D)^2}{n}}{n(n-1)}}} \text{ (equation-4)}$$

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)

$$R = \frac{\sum XY - \frac{(\sum X)(\sum Y)}{n}}{\sqrt{\left(\sum X^2 - \frac{\sum X^2}{n}\right)\left(\sqrt{\sum Y^2} - \frac{\sum Y^2}{n}\right)}} \text{(equation-5)}$$

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.

Finally, a new equation to estimate monthly rainfall data was developed. A method was selected as a trial equation and was modified by incorporating new parameters of the stations (distance, elevation, etc.). The monthly rainfall for Catarman using the first trial equation is estimated and compared with the observed monthly rainfall in the Catarman station by T test values and Pearson's correlation coefficient. The trial equation was revised by adding empirical coefficients derived by mathematical transformation. This was repeated until the "t" value is very, very small and the correlation coefficient is almost 1.

RESULTSAND DISCUSSION

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

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

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.

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

Using the geographical coordinates of Catarman, Catbalogan, Legazpi and Masbate stations, the computed distances are: 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 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
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

The coefficients used in the Multi Linear Regression Method were computed using a statistical package and presented in Table 4.

Table 4 the computed coefficients used in the computation of monthly rainfall in Catarman N. Samar by the Multi Linear Regression Method

Month	Catbalogan	Legazpi	Masbate
January	0.4160	0.0400	0.0507
February	0.1430	0.1525	0.2975
March	0.3150	0.0765	0.3975
April	0.1320	0.0915	0.2340
May	0.1305	0.0780	0.0225
June	0.3350	0.1625	0.1250
July	0.2165	0.1330	0.1870
August	0.2700	0.1520	0.2009
September	0.0900	0.0930	0.1785
October	0.3615	0.1770	0.1210
November	0.2015	0.1760	0.3270
December	0.2430	0.1305	0.4080

Tables 5a and 5b shows the estimated monthly rainfall using theMultI Linear Regression Method.

Table 5a the estimated monthly rainfall in Catarman, N. Samar by the Multi Linear Regression Method (January to June)

Year	Estimated Monthly Rainfall					
	January	February	March	April	May	June
1986	305.5	50.9	69.4	111.9	23.4	154.4
1987	74.7	35.9	26.2	14.9	7.8	104.0
1988	84.8	30.9	24.0	46.4	26.3	157.6
1989	589.9	239.7	204.8	53.2	69.6	152.8
1990	178.4	26.9	8.8	18.2	64.6	296.8
1991	61.3	64.9	147.8	37.2	40.9	186.2
1992	106.7	30.1	8.1	10.1	17.7	133.9
1993	57.6	52.7	116.4	7.9	12.4	87.1
1994	232.1	34.1	77.2	66.4	48.6	148.7
1995	147.6	32.2	52.2	35.4	23.5	108.2
1996	275.7	89.3	340.8	177.4	31.9	118.2
1997	121.2	82.4	40.4	13.9	33.8	111.0
1998	74.5	16.8	33.7	12.3	29.2	58.1
1999	336.9	166.0	217.5	59.3	36.0	109.2
2000	216.9	415.1	252.9	66.9	41.5	109.5
2001	356.7	231.0	190.4	18.5	36.4	168.6
2002	137.4	68.1	100.2	33.4	23.5	52.3
2003	185.8	20.9	44.3	13.5	38.9	239.1
2004	178.7	69.7	108.5	24.7	99.8	108.4
2005	87.6	31.3	80.7	24.8	23.4	87.8
2006	180.4	115.8	190.2	31.9	66.9	82.0
2007	295.2	27.1	71.0	20.1	47.8	66.2
2008	282.8	421.2	108.0	103.5	101.2	170.8
2009	250.5	155.4	82.0	146.0	71.8	250.9
2010	218.4	9.3	63.2	24.1	14.8	53.1
2011	696.1	56.4	469.1	53.6	125.5	191.6
2012	290.5	217.1	280.1	31.5	37.8	136.1
2013	312.1	143.4	93.7	43.5	33.6	291.8
2014	300.9	26.1	128.1	68.2	13.5	159.3
2015	305.5	50.9	69.4	111.9	23.4	154.4

Table 5b The estimated monthly rainfall in Catarman, N. Samar by the Multi Linear Regression Method (July to December)

Year	Estimated Monthly Rainfall					
	July	August	September	October	November	December
1986	118.7	147.8	73.8	301.2	171.5	67.2
1987	206.7	217.1	53.3	162.9	363.7	373.4
1988	103.1	60.8	63.6	474.2	521.9	359.2
1989	105.5	113.4	51.4	211.5	133.1	144.6

1990	92.1	107.5	83.3	217.2	202.3	120.0
1991	160.0	154.1	42.7	132.2	221.4	210.8
1992	184.0	108.9	79.8	173.4	172.9	123.0
1993	180.1	150.1	61.5	138.6	260.6	383.0
1994	187.1	77.8	127.1	114.9	112.1	195.3
1995	123.7	214.6	135.1	185.8	355.1	530.8
1996	75.7	78.9	67.3	146.5	241.0	239.3
1997	177.1	64.1	109.8	121.5	122.2	105.4
1998	61.2	129.2	87.4	300.5	137.4	337.3
1999	94.3	140.2	69.1	168.0	317.4	371.7
2000	136.7	114.3	51.8	324.7	358.3	383.7
2001	120.6	152.3	49.1	257.6	325.9	247.3
2002	173.5	230.4	96.0	100.1	178.2	170.5
2003	153.3	117.2	81.1	138.2	204.9	118.5
2004	102.7	122.4	37.0	216.6	200.2	160.3
2005	120.6	99.0	170.7	172.9	123.5	550.5
2006	117.4	129.7	129.2	145.8	188.4	303.8
2007	114.7	104.6	122.0	215.3	309.1	260.1
2008	102.6	143.9	80.1	157.2	166.4	368.1
2009	100.0	116.8	85.4	183.9	166.3	104.1
2010	159.8	154.4	85.9	213.5	156.0	294.5
2011	248.0	133.3	97.3	210.4	214.6	300.9
2012	205.2	29.6	102.8	266.3	173.6	222.2
2013	144.3	154.2	80.9	128.3	254.0	227.0
2014	243.9	150.1	131.4	197.1	158.0	632.2
2015	86.3	99.6	62.6	89.2	145.5	217.2

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 three 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 are shown in Table 6.

Table 6 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	Multi Linear Regression Method	
T Test for Correla-ted Samples	– 0.3	– 10.0	– 17.5	1.645
Pearson's Correlation Coeffi-cient	0.84	0.76	0.84	0

After several statistical and data transformation procedures, an equation for estimating monthly rainfall atCatarman, Northern Samar has been derived, to wit:

$$[\frac{25}{21}y]^{\frac{1}{7}} = Log\ \frac{13}{20}\frac{NR_A}{D_T}\sum_{i=1}^{n}\frac{P_iD_i}{NR_i} \quad \text{(equation-6)}$$

simplifying

$$y = \frac{21}{25}[Log\ \frac{13}{20}\frac{NR_A}{D_T}\sum_{i=1}^{n}\frac{P_iD_i}{NR_i}]^7 \quad \text{(equation-7)}$$

where:
y = the monthly rainfall in Catarman
P_i = the rainfall for the same month at any of the neighboring station either Catbalogan, Legaspi or Masbate
D_i = distance between Catarman and the neighboring stations (Catbalogan, Legazpi and Masbate).
D_T = is the total distances between Catbalogan and Catarman, Legazpi and Catarman and Masbate and Catarman
NR_A = is the normal monthly rainfall value for Catarman station
NR_i= is the normal monthly rainfall value for any station
n = number of neighboring stations

Specifically, considering Catbalogan, Legazpi and Masbate as neighboring stations, the derived equation to estimate the monthly rainfall became:

$$y = \frac{21}{25}\left\{Log\ \frac{13}{20}\frac{NR_A}{D_T}[\frac{D_{CATBALOGAN}P_{CATBALOGAN}}{NR_{CATBALOGAN}} + \frac{D_{LEGAZPI}P_{LEGAZPI}}{NR_{LEGAZPI}} + \frac{D_{MASBATE}P_{MASBATE}}{NR_{MASBATE}}]\right\}^7 \quad \text{(equation-8)}$$

where:

y = is the missing rainfall amount of Catarman

$P_{Catbaloga}$ = is the rainfall for the same month at Catbalogan station

$P_{Legazpi}$ = is the rainfall for the same month at Legazpi station

$P_{Masbate}$ = is the rainfall for the same month at Masbate station

$NR_{Catarman}$ = is the normal annual precipitation value for Catarman station

$NR_{Catbalogan}$ = is the normal annual precipitation value for Catarman station

$NR_{Legazpi}$ = is the normal annual precipitation value for Catarman station

$NR_{Masbate}$ = is the normal annual precipitation value for Catarman station

$D_{Catbalogan}$ = is distance between Catbalogan and Catarman

$D_{Legazpi}$ = is distance between Legazpi and Catarman

$D_{Masbate}$ = is distance between Masbate and Catarman

D_{TOTAL} = is the total distances between Catbalogan and Catarman, Legazpi and Catarman, and Masbate and Catarman

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). These data shows that the three (3) neighboring stations have almost the same rainfall pattern with Catarman. These further shows that if there is an El Niño or La Niña in the area, this is felt in all these four stations at the same time. Hence, the choice of the three neighboring stations is justified.

To ascertain if the monthly rainfall at Catarman station can be predicted by the monthly rainfall in any of the neighboring stations, the coefficients of correlation between the monthly observed rainfall atCatarman station and any of the three identified neighboring stations were also determined. For Catarman and Catbalogan, the correlation coefficient was 0.737; for Catarmanand Legazpi, 0.622; and for Catarman and Masbate, 0.698. However, these correlation coefficients were very low.

Based on the available rainfall record in the three (3) neighboring stations and level of accuracy, three methods to estimate missing monthly rainfall such as the Normal Ratio Method, Distance Power Method and Multi Linear Regression Method were identified.

CONCLUSIONS

In this study, the monthly rainfall in Catarman for 30 years was estimated by the three (3) methods. The estimated monthly rainfall using each of the three (3) methods was compared with the observed monthly rainfall in Catarman. The estimated monthly rainfall by the Normal Ratio Method has the lowest "t" value of – 0.3 which means that these estimated values are nearest to the observed monthly rainfall. The estimated monthly rainfall using the Normal Ratio and Multi Linear Regression Methods had correlation coefficients of 0.84 while the estimated monthly rainfall using the Distance Power Method had a correlation coefficient of 0.76 only.

With these findings, the Normal Ratio Method was selected together with the Distance Power Method to be developed into a new equation for Catarman. The researcher believes that distance has some bearing on the rainfall pattern. An equation to estimate the monthly rainfall in Catarman has been derived.

The "T" test for correlated samples on the observed monthly rainfall in Catarman versus the estimated monthly rainfall using the derived equation revealed a "t" value of 0.021 (<<<1.645) which means that the estimate monthly rainfall data is not statistically different from the observed monthly rainfall data in Catarman. The Pearson correlation coefficient for the same set of data was computed as 0.869 which means that the two data sets is highly correlated. The researcher further computed the estimate of missing annual rainfall for Catarman using the newly developed equation and gave a 0.986 degree of correlation which means that said equation can accurately estimate the missing rainfall data for the subject location. It can be concluded that the derived equation is acceptable and can estimate monthly rainfall in Catarman, N. Samar.

LITERATURE CITED

[1] Ahrens, B. 2006. Distance in spatial interpolation of daily rain guge data. Hydrol. Earth Syst. Sci., 10: 197-208.

[2] Daly, R.P. Nielson and D. L. Philips. 1994. A statistical topographic model for mapping climatological precipitation over mountainous terrain. J. Appl. Meteor., 33:140-158.

[3] Hasan, M. M. et. al. "Filling Gaps in Daily Rainfall Data: A Statical Approach". 20th International Congress on Modelling and Simulation, Adelaide, Australia, 1-6 December 2013. Available@www.mssanz.org.au/modsim2013 (retrieved on January 9, 2016)

[4] Linsley, R.K., M. A. Kohler and Joseph LH Paulhus. 1982. Hydrology for Engineers. Third Edition. McGraw-Hill Book Company, New Yrok, USA.

[5] Lo Presti, R., E. Barca and G. Passarella. 2010. A methodology for treating missing data applied to daily rainfall data in the Candelaro River Basin (Italy). Environ. Monit. Assess (2010) 160:1-22.

[6] Pajuelas, Bonifacio G. A Study of Rainfall Variations in the Philippines: 1950-1996. Diliman, Quezon City, Philippines. Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA), 2000. Available @ www.journal.upd.edu.ph (retrieved on January 10, 2016)

[7] Paulhus, J. L .H. and M. A. Kohler. 1952. Interpolation of missing precipitation records. Monthly Weather Review 80.

[8] Teegavarapu, Ramesh S.V. 2011. In Filling Missing Daily Rain Gauge Data using NEXRAD Rainfall Data.

Gainsville, Florida. Water Resources Research Center (WRRC), University of Florida.