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Spatial and Temporal Variations in Rainfall: Quirino Province

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Abstract— In order to adequately prepare decision makers for their diverse planning processes, it is necessary to comprehend historical and contemporary patterns of rainfall.Using rainfall data from seven (7) rain gauges in nearby provinces like Aurora and Nueva Vizcaya, the spatial analysis of rainfall in the Province of Quirino was conducted. Regression analysis and correlation analysis were used to assess spatial variation. The results of the significance test and annual correlation analysis showed that 12 pairs of stations had strong correlations. The months of May through December mark the start of the rainy season, whereas January marks the start of the dry period and concludes in April.

Keywords— Rainfall, Rainfall Analysis, Spatial Analysis, Spatial Variation Analysis.

INTRODUCTION

The Philippines, as an archipelago and tropical country located near the Pacific Ocean, experiences unpredictable rainfall intensity [4]. The seasonal patterns of rainfall on the Philippines' west and east coasts differ dramatically. The west coast region has a distinct dry season from winter to spring and a wet season from summer to fall. The rainy season typically begins in mid-May across the Philippines and progressively dissipates in the country's north by November. On the east coast, a significant increase in rainfall begins around late September [1].

According to Matsumoto (1992b), regional differences are characterized by seasonal transitions in atmospheric circulation as well as rapid changes over the Asian-Pacific monsoon region, which is an orographic influence. The link between topography and prevailing wind direction was a key element in determining regional variances in seasonal March rainfall over the Maritime Continent, including the Philippines [13]. While Akasaka et al. (2007) demonstrated the climatological aspects of seasonal rainfall marches in the Philippines, the interannual changes of seasonal marches in the Philippines have received little attention in comparison to those in other countries. Understanding previous and current rainfall patterns is necessary to effectively educate decision makers in their various planning procedures [3].

Rainfall is the initial indicator among the climatic factors that farmers and climatic analysts have ever considered since it is the most significant factor that affects the cropping pattern of an area generally, the type of crop to be farmed, and its success or failure in particular. [12]. Therefore, analyzing the spatial analysis in the province of Quirino has been conducted.

LITERATURE REVIEW

Spatial and Temporal Precipitation

The majority of the Philippines Archipelago is affected by the Asian-Pacific southwest monsoon system, which is part of the western North Pacific (WNP) boreal summer monsoon zone. While the combination of low-level

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easterlies and orography throughout boreal autumn and winter had a considerable impact on rainfall in the eastern part of the country, the southwest monsoon's influence was most visible in the western Philippines [1, 9].

Amiri et. al.. (2017) stated that precipitation variability can be investigated at various temporal scales using a stochastic model to examine the spatial and temporal variabilities of rainfall time series at various temporal scales and to explain seasonal effects of daily rainfall exceeding the threshold values under consideration. Thus, knowing the temporal and spatial patterns of precipitation is required when planning and managing water resources, especially in light of emerging evidence of climate change and unpredictability [8]. This data is used in agricultural planning, flood frequency analysis, flood hazard mapping, hydrological modeling, and water resource evaluations [5]. Clarifying regional and temporal differences in rainfall features, especially their long-term trends, is essential for forecasting possible changes in terrestrial hydrological cycle responses to these variations.

Regression Analysis

Analyzing historical data from previous periods to identify possible trends is an established method in analysis. The state of the atmosphere at a specific moment in relation to factors such as temperature, precipitation, and cloud cover is known as weather conditions. Predicting precipitation was possible using data mining techniques in the models that were in use at the time [11]. Predicting rainfall is essential for assessing agricultural yield and is a need shared by all farmers. The use of science and technology to forecast the state of the atmosphere is known as rainfall prediction. Precise rainfall measurement is crucial for agriculture productivity, water structure planning, and efficient use of available water resources. Rainfall predictions might be made with precision using data mining. The most popular methods for rainfall include linear regression, artificial neural networks, and clustering [10].

Mathematical statistics, one of the three fundamental pillars of data mining, use a variety of methodologies to search for patterns between variables. One of the best techniques for determining and measuring the relationship between variables is regression analysis. Regression analysis is also one of the most widely used mathematical fields in hydrologic data statistical analysis.

METHODOLOGY

Correlation Analysis

This method was used to determine how well a linear or other equation described or explained the degree of relationship between variables, based on the amount of variability in one character explained by a linear function of the other. The correlation coefficient, r, ranged from -1 to +1. The higher the correlation coefficient, the closer the link.

Simple Linear Correlation

When only two variables were involved, simple linear correlation was used; if X and Y were the variables under consideration, a scatter diagram depicted the placement of points (X,Y) on a rectangular coordinate system. If all of the dots in this scatter diagram appeared to be near a straight line, the correlation was considered linear; otherwise, it was considered non-linear.

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If Y tended to increase as Y increased, the relationship was said to be positive or direct correlation. Otherwise, the relationship was called inverse or negative correlation.

The coefficient of correlation, r, was computed through the formula,

$$r = \frac{\sum xy}{\sqrt{(\sum x^2 \sum y^2)}}$$

where x and y are deviations from the mean of the variables X and Y, respectively.

Multiple Linear Correlations

Multiple correlations refer to the degree to which three or more variables are related. The essential principles involved in situations with multiple correlations are similar to those of simple correlation. Since a linear link was established, the coefficient of multiple correlations was dubbed the coefficient of multiple linear correlation.

Test of Significance of the Correlation Coefficient

This was accomplished by comparing the computed r-value to the table's r-value with (n-2) degrees of freedom. The correlation coefficient was considered significant if the absolute value of the computed r-value exceeded the matching tabular r-value at the stipulated threshold of significance.

Coefficient of Determination

The coefficient of determination is calculated as the square of the correlation coefficient. It is the fraction of total variance in the dependent variable that is explained by the linear prediction of the independent variable using the constructed linear regression equation. It was computed using the formula:

$$r^2 = \left(r_{xy}\right)^2$$

Test of significance of the Coefficient of Determination

The importance of the coefficients of determinants was determined by comparing the computed F-value to the tabular F-value with F1=k and F2 = (n-k-1) degrees of freedom. The coefficient of determination was regarded significant when the computed F-value exceeded the matching tabular F-value at the stipulated level of significance. Given that the significance of the linear regression suggested that the linear function of the independent variables explained some of the variability in Y, the size of the r2-value revealed the extent of that portion. Obviously, the higher the r2-value, the more useful the regression equation was for describing Y. On the other hand, when the r2 value was low, even if the F-test was significant, the estimated regression equation was ineffective in estimating, let alone predicting, Y values.

Regression Analysis

Regression analysis generated an equation to describe the statistical relationship of the rainfall of one station (dependent variable) and rainfall of another station (independent variable) for simple regression or more than

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the rainfall stations (independent variable) for multiple regression model. Multiple regression analysis generates an equation to predict dependent variable as a function of several independemt functions [7].

The annual and monthly rainfall data were analyzed using correlation and stepwise regression. To determine statistical significance, correlations with p-values greater than 0.05 were removed from the equation during stepwise regression. It is common practice to utilize coefficient p-values to determine whether to include variables in the final model. To determine the statistical validity of the prediction equation, the coefficient of multiple determination (adjusted r2) was calculated using Microsoft Excel. The T-ratio tests each coefficient's value to see if it is zero, and if the p-value is less than 0.05, the estimated value is considered significant.

RESULTS AND DISCUSSION

Correlation Analysis

The spatial correlation structure of the rainfall provides essential data on the distribution of rainfall fields. It plays a major role in many alternative applications. It is expected that the measured rainfall from the various stations can vary from each other. The result of the correlation analysis confirmed and intensified the fact that there is a link between every rainfall station.

Spatial Variation Analysis Annual Basis

The coefficient of correlation was computed to assess if there is high association between stations. Some of the annual rainfall correlation coefficients were significant between all the reference station as shown in Table 1.

The outcome of the annual correlation analysis and test of significance indicated in Table 1 revealed that there were 12 pairs of stations that had a high degree of associations. The Baler and Casiguran had the highest coefficient of correlation (r-value) of 0.83 with an approximate distance between them of 78.105 km followed by Dumayup and Sto Domingo Stations with coefficient of correlation of (r-value) 0.82 with an approximate distance between them of 22.283 km, while Baler and Maddela separated by a distance of 65.081 km had the lowest coefficient of correlation (r-value) of 0.34.

Table 1. Results of the Annual Correlation Analysis and Test of Significance.

Stations	Coefficient of Correlation	Test of significance
Dumayup vs Sto Domigo	0.82	**
Dumayup vs Baler	0.33	ns
Dumayup vs Casiguran	0.52	*
Dumayup vs Maddela	0.60	**
Dumayup vs Nagtipunan	0.51	ns
Dumayup vs Saguday	0.49	**
Sto Domingo vs Baler	0.20	ns
Sto Domingo vs Casiguran	0.41	ns
Sto Domingo vs Maddela	0.59	**

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Sto Domingo vs Nagtipunan	0.39	*
Sto Domingo vs Saguday	0.40	**
Baler vs Casiguran	0.83	**
Baler vs Maddela	0.34	*
Baler vs Nagtipunan	0.29	ns
Baler vs Saguday	0.32	ns
Casiguran vs Maddela	0.42	**
Casiguran vs Nagtipunan	0.34	ns
Casiguran vs Saguday	0.29	ns
Maddela vs Nagtipunan	0.32	ns
Maddela vs Saguday	0.58	*
Nagtipunan vs Saguday	-0.06	*

* = significant at 1 % ** = significant at 5% ns = not significant

Dıstance between each station as shown in Table 2 and other factors such as the altitude and location relative to the direction of rainfall were likely the key factor that affect the degree of association. For example, Maddela and Nagtipunan had a coefficient of correlation of 0.32 with distance from each other of approximately 14.30 km.

Table 2. Distance Between Stations, km.

Stations	Dumayup	Sto Domingo	Baler	Casiguran	Maddela	Nagtipunan	Saguday
Dumayup	******						
Sto Domingo	22.283	******					
Baler	98.903	93.213	******				
Casiguran	97.613	109.136	78.105	******			
Maddela	50.77	60.454	65.081	48.689	******		
Nagtipunan	55.548	59.952	51.369	53.089	14.303	******	
Saguday	35.953	52.102	84.503	62.449	21.183	33.259	******

Monthly Basis

To assess the monthly rainfall trends, correlation analysis was also used between stations. It was computed to quantify the strength of correlation between each station. As shown in Table 3 to 4, the months of January, February, April, May, November, and December had the highest significant relationships. Based on the table of critical values of Pearson correlation, the months of January, February, April, May, November, and December has the number of stations with significant correlations at 1% level (r2 = 0.561) and 5% level (r2 = 0.444) are 10, 12, 16, 11,15 and 10, respectively.

Table 3. Results of the Correlation of Rainfall Between Each Stations on Monthly Basis.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dumayup vs Sto Domigo	0.89	0.93	0.70	0.53	0.85	0.78	0.27	0.31	0.56	0.79	0.86	0.35

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Dumayup vs Baler	0.60	0.25	0.46	0.61	0.47	-0.04	0.35	-0.12	0.14	0.44	0.46	0.57
Dumayup vs Casiguran	0.53	0.49	0.54	0.21	0.34	0.16	0.31	-0.06	0.37	0.63	0.57	0.53
Dumayup vs Maddela	0.26	0.73	0.81	0.94	0.84	-0.45	0.25	0.31	0.35	-0.08	0.40	0.95
Dumayup vs Nagtipunan	0.39	0.37	-0.36	0.94	0.31	-0.44	0.28	0.10	0.28	0.63	0.77	0.52
Dumayup vs Saguday	0.44	0.85	-0.60	0.53	0.18	0.57	0.41	0.49	0.48	0.02	0.67	-0.07
Sto Domingo vs Baler	0.57	0.27	0.38	0.45	0.38	0.16	-0.17	0.17	0.20	0.42	0.40	0.34
Sto Domingo vs Casiguran	0.60	0.42	0.43	0.33	0.37	0.37	-0.05	-0.13	0.54	0.51	0.59	0.24
Sto Domingo vs Maddela	0.27	0.63	0.51	0.56	0.81	-0.57	-0.24	-0.14	0.55	-0.03	0.23	0.27
Sto Domingo vs Nagtipunan	0.49	0.55	-0.44	0.42	0.33	-0.44	0.08	-0.35	0.42	0.41	0.61	0.34
Sto Domingo vs Saguday	0.77	0.93	-0.82	0.14	0.32	0.89	-0.04	-0.06	0.40	0.20	0.45	-0.23
Baler vs Casiguran	0.90	0.77	0.85	0.74	0.71	0.32	0.87	0.59	0.59	0.29	0.66	0.83
Baler vs Maddela	-0.01	0.54	0.70	0.73	0.50	-0.30	0.75	-0.25	0.38	-0.07	0.71	0.59
Baler vs Nagtipunan	0.80	0.39	-0.61	0.64	0.59	0.06	0.76	-0.32	0.21	0.37	0.55	0.79
Baler vs Saguday	0.27	0.18	-0.11	0.64	0.35	0.11	0.08	0.12	0.35	-0.14	0.66	-0.09
Casiguran vs Maddela	0.13	0.81	0.79	0.47	0.39	-0.47	0.61	0.37	0.87	-0.06	0.50	0.62
Casiguran vs Nagtipunan	0.87	0.18	-0.41	0.29	0.87	-0.49	0.90	0.20	0.57	0.50	0.32	0.67
Casiguran vs Saguday	0.42	0.25	-0.28	0.57	0.49	0.38	0.10	-0.07	0.21	0.21	0.30	0.08
Maddela vs Nagtipunan	-0.18	0.19	-0.27	0.92	0.34	0.23	0.58	0.80	0.87	-0.09	0.41	0.51
Maddela vs Saguday	0.28	0.52	-0.24	0.61	0.55	-0.37	0.22	0.12	0.19	0.67	0.72	0.16
Nagtipunan vs Saguday	0.34	0.51	0.29	0.51	0.55	-0.48	0.15	0.16	0.14	0.05	0.75	0.13

Table 4. Test of Significance for the Correlation Coefficient (Monthly Basis)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dumayup vs Sto Domigo	**	**	**	*	**	**	ns	ns	*	**	**	ns
Dumayup vs Baler	**	ns	*	**	*	ns	ns	ns	ns	ns	*	**
Dumayup vs Casiguran	*	*	*	ns	ns	ns	ns	ns	ns	**	**	*
Dumayup vs Maddela	ns	**	**	**	**	ns	ns	ns	ns	ns	ns	**
Dumayup vs Nagtipunan	ns	ns	ns	**	ns	ns	ns	ns	ns	**	**	*
Dumayup vs Saguday	ns	**	ns	*	ns	**	ns	*	*	ns	**	ns
Sto Domingo vs Baler	**	ns	ns	*	ns	ns	ns	ns	ns	ns	ns	ns
Sto Domingo vs Casiguran	**	ns	ns	ns	ns	ns	ns	ns	*	*	**	ns
Sto Domingo vs Maddela	ns	**	*	*	**	ns	ns	ns	*	ns	ns	ns
Sto Domingo vs Nagtipunan	*	*	ns	ns	ns	ns	ns	ns	ns	ns	**	ns
Sto Domingo vs Saguday	**	**	ns	ns	ns	**	ns	ns	ns	ns	*	ns
Baler vs Casiguran	**	**	**	**	**	ns	**	**	**	ns	**	**
Baler vs Maddela	ns	*	**	**	*	ns	**	ns	ns	ns	**	**
Baler vs Nagtipunan	**	ns	ns	**	**	ns	**	ns	ns	ns	*	**
Baler vs Saguday	ns	ns	ns	**	ns	ns	ns	ns	ns	ns	**	ns
Casiguran vs Maddela	ns	**	**	*	ns	ns	**	ns	**	ns	*	**
Casiguran vs Nagtipunan	**	ns	ns	ns	**	ns	**	ns	**	*	ns	**
Casiguran vs Saguday	ns	ns	ns	**	*	ns	ns	ns	ns	ns	ns	ns

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Maddela vs Nagtipunan	ns	ns	ns	**	ns	ns	**	**	**	ns	ns	*
Maddela vs Saguday	ns	*	ns	**	*	ns	ns	ns	ns	**	**	ns
Nagtipunan vs Saguday	ns	*	ns	*	*	ns	ns	ns	ns	ns	**	ns

* significant at 1%

** significant at 5%

ns not significant

Test for the Spatial Distribution of Rainfall

The data collected, evaluated and measured on the basis of the correlation analysis between each station indicated that there were distinct differences in rainfall between stations in the Province of Quirino and neighboring stations. However, it was not clearly stated if the variations in rainfall are significant or not. The annual and monthly rainfall were computed to determine whether they were statistically the same or not.

Overall Case

Comparisons between annual rainfalls for 7 stations for 20 years (1997-2016) was shown in Tables 5. The analysis of variance was used to determine whether the annual rainfall values between stations vary significantly from each other.

The coefficient of variation (CV) was calculated as a quantitative measure for the comparisons because CV is normalized with the number of observations and overall mean (Chaubet et. al 1999 as cited by Cho et. al. 2009). The CV for annual rainfall was 55.03% and for monthly rainfall, the CV from January to December were as follows: 89.56%, 103.60%, 97.73%, 56.07%, 48.22%, 48.51%, 31.03%, 25.12%, 28.16%, 49.49%, 77.19% and 87.61%, repectively. The higher the CV, the more variable the rainfall of a locality is because this statistic takes into consideration the deviations from averages by recognizing whether a province has a high or low rainfall.

Table 5. Summary of the Outcomes of Analysis of Variance and Annual Rainfall Means Comparison.

Analysis of Variance

Source of Variation	SS	df	MS	F
Between Stations	1110870	6	185145	65.476**
Within Stations	376079.6	133	2827.666	
Total	1486950	139		

** significant at 1%

cv = 55.03%

Comparison of Means

Stations	Mean
Dumayup	116.138a
Sto Domingo	125.123b
Baler	269.288c
Casiguran	349.129d

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Maddela	145.570e
Nagtipunan	130.289abe
Saguday	88.312f

Means with the same superscript are not significantly different at 1% level

Temporal Variation Analysis

The use of the rainfall distribution developed through the use of frequency analyzes as shown in Figure 1 represented the average monthly rainfall distribution of each station and the monthly rainfall for the whole province of Quirino. The annual series was utilized to filter each station's yearly rainfall data, while the province's average Thiessen rainfall was screened using the maximum period series method.

On a monthly basis, the months of October, November and December with a rainfall magnitude of 265.29 mm, 273.89 mm and 265.85 mm respectively were the wettest months, whereas the lowest rainfall amounts were 101.45 mm, 108.6 mm and 111.37 mm, respectively in the months of February, March and April.

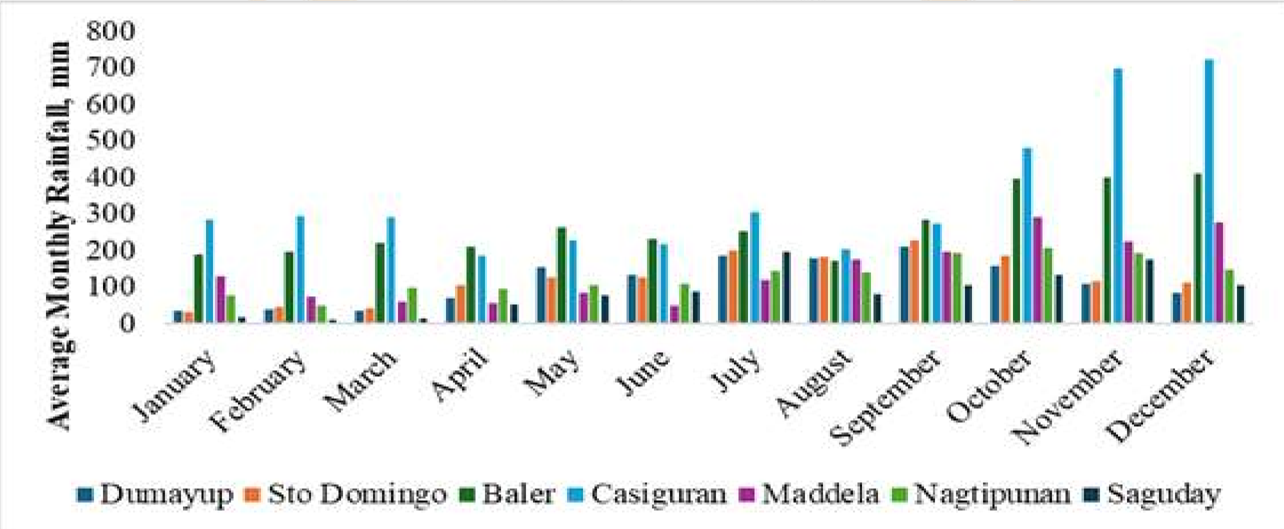

Figure 1. Mean Monthly Rainfall Distribution of the Different Stations

It can also be observed that based on the Philippine Climate Map which is the Modified Coronas Classification, the province of Quirino is situated within the Type IV climate. This is characterized by a more or less even distribution of rainfall throughout the year. The result of the study of the rainfall frequency analysis however revealed otherwise. According to Köppen-Geiger climate classification the province of Quirino is under tropical climate with a significant amount of rainfall during the year even during the driest month (climate-data.org).

Regression Analysis

Regression analysis generated an equation to describe the statistical relationship of the rainfall of one station (dependent variable) and rainfall of another station (independent variable) for simple regression or more than the rainfall stations (independent variable) for multiple regression model. Multiple regression analysis generates an equation to predict dependent variable as a function of several independendemt functions (Lachniet et. al., 2006).

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The annual and monthly rainfall data were analyzed using correlation and stepwise regression. To determine statistical significance, correlations with p-values greater than 0.05 were removed from the equation during stepwise regression. It is common practice to utilize coefficient p-values to determine whether to include variables in the final model. To determine the statistical validity of the prediction equation, the coefficient of multiple determination (adjusted r2) was calculated using Microsoft Excel. The T-ratio tests each coefficient's value to see if it is zero, and if the p-value is less than 0.05, the estimated value is considered significant. The results of the analysis are shown in Table 5.

The results showed that only Casiguran station had two (2) predictor variables and obtained the highest computed adjusted r2 value of 0.74. Dumayup, Sto. Domingo and Baler stations obtained an adjusted r2 values of 0.66, 0.66 and 0.68, respectively. The adjusted r2 value value indicated the percentage of variation explained by the independent variables on the dependent variable. The regression equation of all stations except for Casiguran had a single independent variable. The coefficient of the independent variable indicated how much the dependent variable was expected to increase or decrease when the independent variable was increased by one unit.

Table 5. Summary of the Results of Annual Rainfall Regression Analysis Between Ranfall Stations

Station	Regression Equation Developed	Adjusted r-square
Dumayup	Dum = 20.54 + 0.76Sto	0.66
Sto. Domıngo	Sto = 22.34 + 0.88Dum	0.66
Baler	Bal = 76.81 + 0.55Cas	0.68
Casıguran	Cas = -24.51 + 1.12Bal + 0.62Dum	0.74
Maddela	Mad = 41.79 + 0.89Dum	0.32
Nagtıpunan	Nag = 72.57 + 0.50Dum	0.22
Saguday	Sag = 22.04 + 0.57Dum	0.20

Where : Bal = Baler Station; Nag = Nagtipunan Station
Cas = Casiguran Station; Sag = Saguday Station
Dum = Dumayup Station; Sto = Sto. Domingo Station
Mad = Maddela Station

Owing to potential colinearity between supposedly independent variables, the effects of the multiple stepwise regressions was viewed with some caution. For example, the Saguday station has the lowest adjusted r2 of 0.20 which means that only 20% of Dumayup's annual rainfall variations are accounted for by the independent variables' variations in the annual rainfall. It only shows that the regression equation cannot account for 80% of the variance and can not be useful in forecasting Saguday's annual rainfall.

Summary

Some of the annual rainfall correlation coefficients were significant between all the reference station. The outcome of the annual correlation analysis and test of significance revealed that there were 12 pairs of stations that had a high degree of associations. The months of January, February, April, May, November, and December had the highest

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significant relationships. With the use of correlation and stepwise regression analyses, the annual and monthly rainfall data were analyzed. The results indicated that only Casiguran station had two (2) predictor variables and exhibited on the r2 value of 0.74. The months of October, November and December with a rainfall magnitude of 265.29 mm, 273.89 mm and 265.85 mm respectively were the wettest months, whereas the lowest rainfall amounts were 101.45 mm, 108.6 mm and 111.37 mm, respectively in the months of February, March and April.

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