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Spatial and Temporal Variations of Rainfall in Cagayan Province

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ABSTRACT

This study was conducted in order to provide information to the policy makers and farmers on the long- term variations of rainfall as affected by space and time in the province of Cagayan. The rainfall data obtained from the 4 rain gauge stations were tested using double mass curve analysis and were found out to have consistent trends. Tuguegarao Station covered the largest area which is 47.32% and Laoag had the least areal extent of 1.07%. The weighted average depth of annual rainfall at 80% dependability in Cagayan was 1450.53 mm. The optimal number of stations that should exist in the province to be used in estimating the annual rainfall at 10% allowable estimation of error is 2. On the other hand, the minimum length of rainfall record that could provide acceptable and reliable results of analysis related to spatial and temporal variations of rainfall on annual basis is 8 years. Elevation is insignificantly related to rainfall. Wet season starts from June and ends in January while dry season begins from February and ends in the month of May. The regression models developed can be used to predict rainfall data between the stations involved; however these model equations can only be used to estimate the rainfall values within the range of rainfall values used in this study. There were significant differences in the spatial and temporal distributions of rainfall in the province of Cagayan.

Keywords *– Cagayan, Cropping Calendar, Cropping Pattern, Rainfall, Spatial, Temporal*

Introduction

Climate change is threatening the normal hydrological cycle of river basins, due to rising temperature because of the global warming effect which is associated with the disturbance of the frequency and intensity of precipitation in a given climatic condition. This has an implication on the hydrologic events and the water resources availability (Sintayehu, 2015). In the Philippines, climate change is adversely affecting the production of the basic agricultural commodities like rice and corn, especially that water is the most important factor in rice and corn production. Productivity in agriculture, which indicates the growth of the economy of the state, depends on the amount of rainfall received, intensity and distribution of rainfall over a particular area.

Rainfall is a form of precipitation that fell on earth as one of the processes to complete the hydrologic cycle. According to Ismail (1994), rain is one of the forms of precipitation in liquid state where the diameter is more than 0.5 mm. Effectiveness or impact of rain on a system is dependent on its intensity and duration. Rainfall investigation is very important in similar domains such as agricultural planning, water resources planning, runoff prediction, climatological studies, conservational studies, stream flow estimation and human life activities. According to Subramaya, K. (1984), Hatzzian, A.N. et.al. (2007) and Gangadharabhat, H. et.al. (2013), the amount, concentration and areal distribution of rainfall are indispensable factors in many hydrologic studies. In addition, Mutreja, K.N. (1990) and Juny, H.S. et.al

(2001) stated that rainfall varies in space and with time. Spatial variation of rainfall is very important for water resource planning. Temporal variation of rainfall concentration are extremely necessary in the rainfall- runoff process in urban areas (Thiam, El. Et.al., 2002 and Ovuka, M. et.al., 2002). Occurrence of rainfall is highly influenced by other meteorological elements and elevation from sea level, and studies show that high correlations were found between these variables (Bruce, J.P. et.al. 1986).

Rainfall patterns usually have spatial and temporal variabilities. These variabilities affect agricultural production, water supply, transportation, the entire economy of a region, the existence and survival of its people. Agriculture is seriously affected by these increased variabilities in trends in the annual, seasonal as well as monthly characteristics of rainfall in an environment where one of the major limiting factors of agricultural production is the amount of water available through rainfall.

Changes in rainfall amounts can have drastic implications for policy makers and farmers- especially as different crop types thrive under different conditions, so changes in rainfall and surface temperature will affect them (Farnsworth, A.J., 2012). Hence, this study was conducted to find out the long-term variability of rainfall both on temporal and spatial scale over the Province of Cagayan to help policy makers and farmers to improve agricultural production.

Objectives of the Study

The general objective of this study was to determine concrete bases of rainfall occurrence that affect agricultural productivity in the Province of Cagayan. Specifically, it aimed to:

1. augment the missing rainfall data, screen using annual series, test the consistency;
2. assess the adequacy and density of rainfall stations situated within and nearby the province of Cagayan;
3. conduct rainfall frequency analysis for different rainfall stations and evaluate the adequacy of the length of record of the rainfall data;
4. determine the required minimum number of rainfall stations and additional rainfall stations to be put up in the province needed to estimate rainfall at an allowable error of 10%, 5% and 1%;
5. assess the influence of elevation on rainfall and establish a regression model that describes rainfall as a function of elevation;
6. establish and interpret the temporal and spatial variations of rainfall in Cagayan;
7. establish the rainfall distribution for Cagayan and develop cropping pattern and calendar for Cagayan Province; and
8. develop various maps on spatial and temporal distribution of rainfall using GIS software.

Methods

Data Gathering

The rainfall data obtained from the different weather stations within and nearby Cagayan Province that were recorded for 32 years acquired from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) Main Office, Quezon City.

Interpretation of Rainfall Data

Before the rainfall records of the stations were applied in the study, the data were evaluated for their continuity and consistency. The continuity of a record may be broken with missing data due to many causes such as damage or fault in a rain gage during a certain period. If the condition relevant to the recording of a rain gage station has undergone significant change during the period of record, inconsistency would arise in the rainfall data of that station. This inconsistency would be felt from the time significant change took place.

Estimating Missing Precipitation Data

Following the recommendations of Anderson, C.I. and Gough, W.A. (2018) when arithmetic means were calculated for each month of each year from daily data, the “3/5 rule” was applied. If more than three consecutive daily values were missing or more than five daily values in total in a given month were missing, the monthly mean was not computed and the year-month mean was considered as missing. Moreover, if any daily totals were missing and the corresponding accumulated totals were also missing, the monthly total was not computed and the year-month total was considered as missing. There are several methods of estimating missing rainfall data such as Simple Arithmetic Average, Normal-Ratio Method, Multiple Linear Regression and Quadrant Method. In this study, the Normal-Ratio Method was considered. Precipitation amounts were estimated from observations at stations as close to as evenly spaced around the station with missing record as possible.

Test of Consistency of Record

The checking for inconsistency of a record was done by the Double-Mass Curve Analysis. This technique was based on the principle that when each recorded data came from the same parent population, they were considered consistent.

Determination of the Average Depth of Rainfall

A rain gage represents only one point sampling of the real distribution of rainfall over an area. The average depth of precipitation over a specific area, on a storm, seasonal or annual basis, is required in many types of hydrologic problems. There are several ways of computing average precipitation over an area such as a) Arithmetic Mean Method b) Thiessen Polygon Method c) Grid-Point Method and d) Isohyetal Method, each of which may give a different answer. In this study, the Thiessen Polygon Method was considered.

The Thiessen Polygon method attempts to allow for nonuniform distribution of gages by providing a weighing factor for each gage. In the study, the weightage factors for each of the stations were obtained through the application of the Thiessen polygon tool of GIS Software. Then, the recommendation of Linsley (1988) was adapted in the computation of the weighted average of rainfall. The weighted average rainfall for the total area was computed by multiplying the precipitation at each station by its assigned percentage of area and totaling.

Adequacy of Length of Rainfall

The adequacy of the length of record at a given level of significance was assessed through the application of the formula recommended by Mockus (1960)

$$Y=(4.30t \log_{10} R)^2+6$$

where:

Y = minimum acceptable years of record

t = Student's statistical value at 90 percent level of significance with (Y – 6) degrees of freedom

R = ratio of magnitude of the 100-year of event to the 2-year event

Adequacy of Rain Gage Stations

The optimal number of stations that should exist in the province at an allowable percentage of error in the estimation of mean rainfall was obtained through statistical analysis suggested by Subramaya, (1944).

If there were m stations in the area, recorded rainfall values P1,P2,…PM in a known time, the optimum number of stations needed was calculated through the formula

$$N=(Cv/\varepsilon)^2$$

where:

N = optimal number of stations

ε = allowable degree of error in estimate of the mean rainfall, usually take n as 10%

Cv = coefficient of variation of the rainfall values at the existing m stations (in percent)

Elevation and Rainfall Relation

To determine the influence of elevation on rainfall, simple regression analysis was applied to the mean annual rainfall of the stations and their elevations in such a way that the mean annual rainfall was considered as the dependent variable and elevation as the independent variable. The relationship of rainfall and elevation was further established with the inclusion of the data from the adjacent area.

Spatial Variation Analysis of Rainfall

The spatial analysis of rainfall for annual and seasonal bases in the area was done through correlation analysis and the application of the Single-Factor Analysis of Variance. Comparisons of means were applied through the application of the Least Significant Difference (LSD) Test with the aid of Excel Software. Correlation analysis was done in order to determine the degree of association or relationship of rainfall observed from different rain gauge stations because it was expected that recorded rainfall data from one station to another may vary.

Interpretation of the Temporal Variation of Rainfall

The temporal variations of rainfall for each station were assessed based on the frequency distribution of rainfall determined through rainfall frequency analysis, while that for the whole province was determined by means of the result obtained in the rainfall distribution through the use of Thiessen Polygon Method.

Determination of Statistical Parameters for Rainfall Frequency Analysis

The purpose of the frequency analysis of an annual series is to determine a relation between that magnitude of the event and its probability of

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exceedance. The probability analysis may be made either by empirical or analytical methods. The Log-Normal Method was used in this study.

Development of Proposed Cropping Calendar and Pattern

Cropping pattern and calendar were developed based from the average monthly rainfall in the province. Main crops grown within the province were considered in the cropping calendar. The crops in the pattern were presented in a diagram indicating the whole growing period of each crop. The acceptable date ranges of land preparation, transplanting/planting, terminal drainage and harvesting for each crop were indicated by a line.

Results

Estimation of Missing Rainfall Data

The data for Laoag Station had two years (1988-1989) missing data which were considered missing and were estimated using Normal-Ratio Method. The other three stations had some missing monthly data as well and were estimated through the application of the same method.

Rainfall Consistency Test

Rainfall inconsistency may be affected by the changes in the location or exposure of a rain gage may have a significant effect on the amount of precipitation it measures. According to Subramanya (1994), changes in slope should be taken as significant only when it persists for more than five years. The trends as depicted in Fig. 1 showed that there were no significant breaks in slope for the four stations considered, thus it is considered that all rainfall data are consistent.

Determination of Mean Depth of Rainfall

The average depth of rainfall was determined through the application of the Thiessen Polygon Method. The Thiessen polygon map shown in Fig. 2 depicted the area covered by each rainfall station.

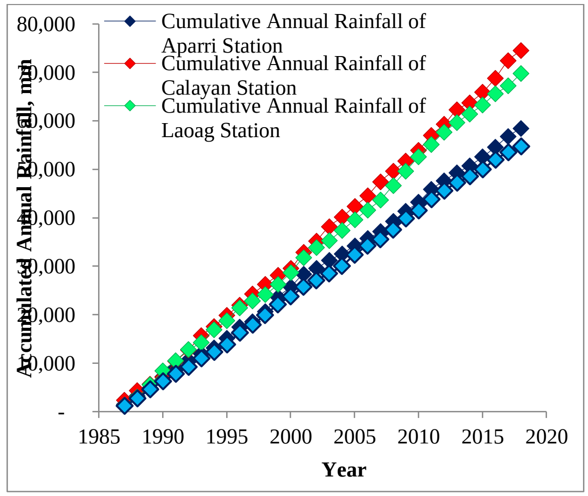

Figure 1. Double mass curve of the four (4) stations.

The figure shows that Tuguegarao Station covers the largest area which is 4170 sq.km, followed by Aparri Station with an area of 3963.48 sq.km, third is Calayan Station with 584.75 sq.km. area and the least is Laoag Station covering an area of 94.48 sq.km. The average depth of annual rainfall at 20%, 50% and 80% probabilities of exceedance are 2148.48 mm, 1730. 52 mm and 1450.53 mm, respectively as recorded in Table 1, whereas for seasonal basis at 20%, 50% and 80% probabilities of occurrence are 371.77 mm, 229.61 mm and 136.42 mm for dry season, respectively, and for wet season are 2022.25 mm, 1612.16 mm and 1382 mm, respectively. These data were recorded in Table 2 (wet season) and Table 3 (dry season).

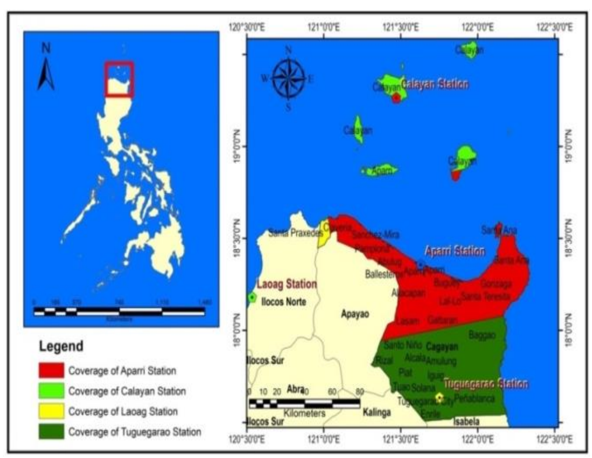

Figure 2. Thiessen polygon map of cagayan province.

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Table 1. Average Depth of Annual Rainfall in Cagayan at 20%, 50% and 80% Probabilities of Occurrence, mm (Thiessen Polygon).

Probability	Aparri (mm)	Calayan (mm)	Laoag (mm)	Tuguegarao (mm)	Total Weighted Average
Area of Coverage (sq.km)	3963.48	584.75	94.48	4170.80	
Weighting Factor	0.45	0.07	0.01	0.47	
20% Probability	990.25	198.31	28.13	931.79	2148.48
50% Probability	794.18	146.36	22.40	767.58	1730.52
80% Probability	632.29	127.19	17.66	673.40	1450.53

Table 2. Average Depth of Rainfall in Cagayan at 20%, 50% and 80% Probabilities of Occurrence during Wet Season, mm (Thiessen Polygon).

Probability	Aparri (mm)	Calayan (mm)	Laoag (mm)	Tuguegarao (mm)	Total Weighted Average (mm)
Area of Coverage (sq.km)	3963.48	584.75	94.48	4170.80	
Weighting Factor	0.45	0.07	0.01	0.47	
20% Probability	903.91	184.45	27.67	906.23	2022.25
50% Probability	725.37	131.96	22.26	732.56	1612.16
80% Probability	617.90	111.93	17.45	635.07	1382.35

Table 3. Average Depth of Rainfall in Cagayan at 20%, 50% and 80% Probabilities of Occurrence during Dry Season, mm (Thiessen Polygon).

Probability	Aparri (mm)	Calayan (mm)	Laoag (mm)	Tuguegarao (mm)	Total Weighted Average (mm)
Area of Coverage (sq.km)	3963.48	584.75	94.48	4170.80	
Weighting Factor	0.45	0.07	0.01	0.47	
20% Probability	172.69	32.51	3.78	162.79	371.77
50% Probability	100.73	20.90	1.97	106.00	229.61
80% Probability	58.46	13.14	0.93	63.89	136.42

Adequacy of Rain Gage Station in the Area

The summary of the optimum number of rain gauges that should exist in the province of Cagayan in the estimation of mean rainfall for annual, seasonal and monthly bases was listed in Table 4.

Table 4. Recommended Optimal Number of Rainfall Stations in Cagayan at Different Allowable Percentage of Error of Estimation.

[redacted]	Percentage of Error		
	10%	5%	1%
	Number of Stations		
Annual Basis	2	8	209
Seasonal Basis			
Wet Season	2	9	225
Dry Season	3	13	334
Monthly Basis			
January	87	349	8737
February	74	295	7384
March	50	198	4956
April	9	38	948
May	10	40	997
June	15	61	1534
July	29	114	2862
August	28	113	2816
September	11	43	1076
October	11	42	1055
November	32	128	3204
December	30	120	3010

It was calculated through the use of all available data. The optimal number of rain gauges obtained at 10% allowable error of estimation was 2, which means that the existing number of stations within the province is sufficient to give reliable data of rainfall for annual basis at 90% probability. However, for 5% and 1% allowable errors of estimation, the optimum number of rain gauge stations should be 8 and 209, respectively. For seasonal basis, at 10% degree of error, 2 and 3 rain gauges are needed for wet and dry seasons, respectively while at 5% and 1% degrees of error, 9 and 225 stations are needed during wet season, and 13 and 334 stations are needed during dry season, respectively. This could be attributed to the high degree of variability of rainfall during dry months and vice versa. The results obtained for monthly basis conformed to that of the seasonal basis. It can be noted that as the degree of error decreases, the higher the number of stations is needed.

Adequacy of Length of Rainfall Data

The test for the adequacy of length of rainfall data was done in order to identify whether the existing duration of rainfall data is already enough for the spatial and temporal variations analyses. The results were listed in Table 5, which indicated that for annual rainfall data, the length of record should be at least 7.05 years while for seasonal basis, the minimum length of record should be 7.12 years and 7.54 years for wet and dry seasons, respectively. The minimum number of years for monthly basis is ranging from 9.47 years to 21.12 years. With respect to the length of record of the rainfall data used in this study which is 32 years, these findings show that the data is very adequate to give reliable information about the variability of rainfall within the province of Cagayan.

Table 5. Minimum Acceptable Length of Rainfall Record.

	Minimum Years		
Annual Basis	7.05		
Seasonal Basis			
Wet Season	7.12		
Dry Season	7.54		
Monthly Basis			
January	21.12	July	13.52
February	19.67	August	13.44
March	16.70	September	9.81
April	9.47	October	9.75
May	9.60	November	14.10
June	10.91	December	13.77

Frequency Analysis

The summary of the Annual and Seasonal (Wet and Dry) probabilities of occurrence of rainfall are shown in Tables 6 - 8. The outcome of the frequency analysis of annual rainfall at 80% probability of occurrence for Aparri, Calayan, Laoag and Tuguegarao Stations were 1406 mm, 1917 mm, 1647 mm and 1423 mm, respectively. For dry season, the dependable rainfall at 80% probability were 130 mm, 198 mm, 87 mm and 135 mm for Aparri, Calayan, Laoag and Tuguegarao Stations, respectively, while for wet season, 1374 mm is for Aparri Station, 1687 mm for Calayan Station, 1628 mm for Laoag Station and 1342 mm for Tuguegarao Station.

Table 6. Annual Rainfall Amounts at Probabilities of Occurrence.

Station	Probability of Occurrence 10%	20%	30%	40%	50%	60%	70%	80%	90%
Aparri	2508	2202	2064	1875	1766	1651	1590	1406	1217
Calayan	3226	2989	2419	2298	2206	2150	2053	1917	1471
Laoag	2962	2624	2511	2311	2090	2059	1886	1647	1420
Tuguegarao	2293	1969	1864	1739	1622	2059	1516	1423	1323

Table 7. Dry Season Rainfall Amounts at Probabilities of Occurrence.

Station	Probability of Occurrence 10%	20%	30%	40%	50%	60%	70%	80%	90%
Aparri	409	384	283	254	224	195	168	130	88
Calayan	608	490	388	339	315	294	260	198	125
Laoag	449	353	260	240	184	145	109	87	29
Tuguegarao	390	344	323	269	224	169	157	135	92

Table 8. Wet Season Rainfall Amounts at Probabilities of Occurrence.

Station	Probability of Occurrence 10%	20%	30%	40%	50%	60%	70%	80%	90%
Aparri	2253	2010	1928	1749	1613	1527	1455	1374	1151
Calayan	2903	2780	2308	2208	1989	1855	1783	1687	1382
Laoag	2870	2581	2508	2294	2077	2023	1878	1628	1402
Tuguegarao	2194	1915	1714	1604	1548	1441	1382	1342	1232

Rainfall and Elevation Relation

In most of the regions it has been found that rainfall increases with elevation in a usually linear relationship due to the fact that it is connected to orographic updraft (Weisse and Bois, 2001). Mountainous landscapes facilitate the uplift of moisture that results in high rainfall intensities on the windward side of the mountains (Singh et al., 1995), where the rainfall stations tend to be placed. In the case of this study, the scatter diagram for rainfall and elevation shown in Fig. 3 indicates no significant effect of the elevation to the variation of rainfall in each station. This finding contradicts the results of the study of Weisse and Boise in 2001 as stated above. The result of this analysis may imply that at the existing elevation of the rain gauges being Tuguegarao as the highest (62 m- amsl) and Aparri as the lowest (3 m – amsl) are not enough to cause significant effect on rainfall. The variation on rainfall may be affected as well by the prevailing wind, especially on the Island of Calayan, where Calayan Station is located. On the other hand, Laoag Station being located in the western part of Luzon Island might receive lesser amount of rainfall especially during "amihan" or northeast monsoon due to the fact that between Cagayan Valley region and Region 1, there is a long stretch of mountainous area which is the Caraballo Mountain, where rainfall from eastern part fell on these parts.

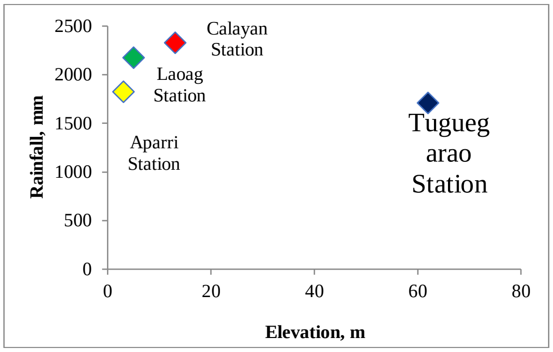

Figure 3. Scatter Diagram of Rainfall and Elevation Relation.

Spatial Variation Analysis

Annual Basis

The results of the correlation analysis for annual rainfall are listed in Table 9. Based from the Table, the average annual rainfall data of Aparri and Tuguegarao Stations with an approximate distance between them of 80.85 km has the highest correlation coefficient of 0.59 which is significant at 1% level. While Calayan and Laoag Stations with an approximate distance of 155.91 km between them gave the least coefficient of correlation of -0.18. Aparri and Calayan Stations which are separated by an approximate distance of 101.79 km have a coefficient of correlation of 0.11. For Aparri and Laoag Stations situated at an approximate distance of 117.54 km between each other exhibited a coefficient of correlation of 0.40, which is very close to the coefficient correlation (0.36) of Laoag and Tuguegarao Stations separated from each other at an approximate distance of 142. 48 km. Lastly, for the stations of Calayan and Tuguegarao at an approximate distance of 183.20 km between them has a coefficient of correlation of 0.11. The variations in the correlation could be attributed to the distances between stations and their location relative to the direction of rainfall, which suggest that the closer the distance between stations, the higher is the association. However, distance is not mainly the factor of variations in rainfall as presented by the results of the analysis. For example, Laoag and Tuguegarao Stations has a higher value (r = 0.36) as compared to Aparri and Calayan Stations (r = 0.11) considering that the latter has closer distance between them than that of the former pair. Other possible reasons could be due to the general direction of the prevailing wind and the type of climate with which these stations are situated.

Table 9. Results of the Correlation Analysis and Test of Significance for Annual, Dry and Wet Bases.

Stations	Coefficient of Correlation, r			Coefficient of Determination, r^2	Test of Significance		
	Annual Basis	Dry Basis	Wet Basis		Annual Basis	Dry Basis	Wet Basis
Aparri vs Calayan	0.11	0.43	0.03	0.012	ns	*	ns
Aparri vs Laoag	0.40	0.07	0.33	0.160	*	ns	ns
Aparri vs Tuguegarao	0.59	0.63	0.54	0.348	**	**	**
Calayan vs Laoag	-0.18	-0.03	-0.25	0.032	ns	ns	ns
Calayan vs Tuguegarao	0.01	0.43	-0.03	0.001	ns	*	ns
Laoag vs Tuguegarao	0.36	-0.08	0.27	0.013	*	ns	ns

* significant
** highly significant
ns not significant

Seasonal Basis

The outcome of the correlation analysis during dry and wet seasons is illustrated in Table 9. Dry season rainfall has the following coefficient of correlation: 0.43 (Aparri vs Calayan), 0.07 (Aparri vs Laoag), 0.63 (Aparri vs Tuguegarao), -0.03 (Calayan vs Laoag), 0.43 (Calayan vs Tuguegarao) and -0.08 (Laoag vs Tuguegarao). On the other hand, for wet season rainfall, the coefficient of correlation are as follows 0.03, 0.33, 0.54, -0.25, -0.03 and 0.27 for Aparri vs Calayan, Aparri vs Laoag, Aparri vs Tuguegarao, Calayan vs Laoag, Calayan vs Tuguegarao and Laoag vs Tuguegarao, respectively. The tests of significance revealed that Aparri versus Tuguegarao has the highest degree of association for both wet and dry seasons of 0.54 and 0.63, respectively. The rest of the comparisons were significant at 5% level while the others were not significant. These results might have been influenced by the type of climate where these stations are located.

Spatial Distribution of Rainfall

The degree of variations among the four stations was indicated by the correlation analysis done between stations and the influence of elevation on rainfall. As shown in Table 17, there are variations associated between stations. However, it is unclear whether these variations are significant. By using LSD, the means of rainfall for monthly, annual, dry and wet seasons were compared, in order to identify whether they are statistically different or the same. The summary of the analysis of variance and comparisons of means are shown in Tables 10 - 12.

The analysis of variance and comparisons of means for annual rainfall were shown in Table 10. It can be noticed that Calayan station having a mean annual rainfall of 2329.55 mm was not significantly different with the mean annual rainfall of Laoag station having a mean of 2179.70 mm. The same result was obtained for Wet season as shown in Table 12. For the dry season, there was no need to compare the means because there was no significant variation between stations as shown in the analysis of variance in Table 11.

The coefficient of variation (CV) is a statistical measure of the dispersion of data points in a data series around the mean. The coefficient of variation shows the extent of variability of data in a sample in relation to the mean of the population. This means that the higher the CV, the lower is the reliability of the experiment. In this study, dry season exhibited 18.27% over the wet season with a value of 14.99%, which indicated that there was higher rainfall variability during summer as compared to rainy season.

Table 10. Summary of the Results of the Analysis of Variance and Comparisons of Means for Annual Rainfall.

Sources of Variation	df	SS	MS	F-Computed	F- Table	
					5%	1%
Between Stations	3	8108785	2702928	11.5^{**}	2.66	3.91
Within Stations	124	29145989	235048.3			
Total	127	37254775				

CV = 14.45% ** = significant at 1% level

Comparisons of Means

Station	Rank	Mean
Aparri	3	1826.71^{b}
Calayan	1	2329.55^{a}
Laoag	2	2179.70^{ab}
Tuguegarao	4	1711.82^{b}

$LSD_{0.01}$=478 Means followed by a common letter are not significantly different at 5% level of LSD

Table 11. Summary of the Results of the Analysis of Variance for Dry Season.

Analysis of Variance

Sources of Variation	df	SS	MS	F-Computed	F- Table	
					5%	1%
Between Stations	3	225791.70	75263.88	2.64^{ns}	2.66	3.91
Within Stations	124	3540854.00	28555.28			
Total	127	3766646.70				

CV = 18.27 ns = not significant

Table 12. Summary of the Results of the Analysis of Variance and Comparisons of Means for Wet Season.

Analysis of Variance

Sources of Variation	df	SS	MS	F-Computed	F- Table	
					5%	1%
Between Stations	3	7690672	2563557	12.54^{**}	2.66	3.91
Within Stations	124	25358466	204503.8			
Total	127	33049138				

CV = 14.99% ** = significant at 1% level

Comparisons of Means

Station	Rank	Mean
Aparri	3	1692^{ab}
Calayan	2	2113^{a}
Laoag	1	2150^{a}
Tuguegarao	4	1600^{b}

$LSD_{0.01}$=446 Means followed by a common letter are not significantly different at 5% level of LSD

Temporal Variation Analysis

Among the three methods of analyzing the frequency distribution of rainfall, log-normal distribution method was sufficient to fit the frequency distribution of the annual rainfall of each station and the annual rainfall within the province of Cagayan. The trend showed that at 50% probability of occurrence, the highest amount of rainfall could be observed at Calayan Station with 2206 mm magnitude while the lowest could be observed at Tuguegarao Station with 1622 mm magnitude.

For monthly basis, the wettest months are expected from May to December with a rainfall magnitude ranging from 128.48 mm to 282.97 mm, which were observed during the months of May and October, respectively. On the other hand, the lesser magnitude of rainfall could be observed during the month of January to April with rainfall of magnitude ranging from 35.02 mm to 69.82 mm.

It is interesting to note that the results of the study resembled the modified Coronas Classification, in which, the province most likely have Type IV classification an indication that rainfall is more or less evenly distributed throughout the year and Type I which means two pronounced seasons; dry from November to April and wet during the rest of the year.

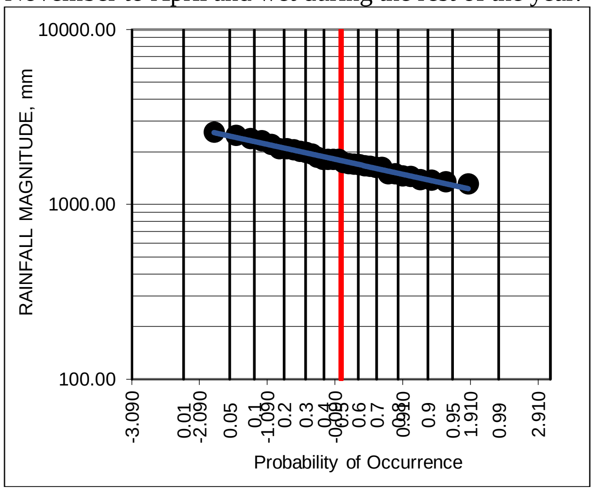

Figure 4. Annual Rainfall Frequency Curves Using Log- Normal Distribution for Cagayan Province (Thiessen Average).

Regression Analysis

Multiple regression analysis was done for the rainfall data gathered from Cagayan, in order to establish regression models considering rainfall of one station as the dependent variable and rainfall from other stations as independent variables.

Often, theory and experience give only general direction as to which of a pool of candidate variables (including transformed variables) should be included in the regression model. The actual set of predictor variables used in the final regression model must be determined by analysis of the data. Determining this subset is called the variable selection problem. There are many different strategies for selecting variables for a regression model. In this study, stepwise regression was applied with the aid of Microsoft excel.

The results of the analysis were presented in Tables 13-15. Based from the outcome of the analysis, the maximum computed number of predictor variables for annual basis was three and the least fell under linear regression analysis.

In the regression analysis, the computed coefficient of determination (r^2) is the most important factor to consider. The higher the computed r^2, the higher is the chance that the variation in the dependent variable is accounted for from the independent variable/s. For example, the regression analysis of Aparri Station produced a value of 0.33, means that 33% of the annual rainfall variations in this station were accounted for by the variations in the annual rainfall of the three stations (Calayan, Laoag and Tuguegarao).

Table 13. Summary of Regression Analysis of Annual Rainfall.

Dependent Variable	Regression Equation	Adjusted R-Squared
Aparri	A = 448.31 + 0.81 T	0.33
Calayan	No Variable Meet Criteria	0.00
Laoag	L = 1356.20 + 0.45 A	0.13
Tuguegarao	T = 913.08 + 0.44 A	0.33

Table 14. Summary of Regression Analysis of Wet Season Rainfall.

Dependent Variable	Regression Equation	Adjusted R-Squared
Aparri	A = 615.63 + 0.67 T	0.27
Calayan	No Variable Meet Criteria	0.00
Laoag	No Variable Meet Criteria	0.00
Tuguegarao	T = 863.10 + 0.44 A	0.27

Table 15. Summary of Regression Analysis of Dry Season Rainfall.

Dependent Variable	Regression Equation	Adjusted R-Squared
Aparri	Ap = 78.09 + 0.69 Tug	0.38
Calayan	Cal = 210.36 + 0.52 Ap	0.16
Laoag	No Variable Meet Requirement	0.00
Tuguegarao	T = 99.84 + 0.58 A	0.38

Where: A_{ds} = Dry Season Rainfall of Aparri
C_{ds} = Dry Season Rainfall of Calayan
L_{ds} = Dry Season Rainfall of Laoag
T_{ds} = Dry Season Rainfall of Tuguegarao

Proposed Cropping Calendar

The cropping calendar designed for the province of Cagayan is shown in Fig. 5. This was established using the monthly rainfall distribution at

80% probability of occurrence as illustrated in Figure 48.

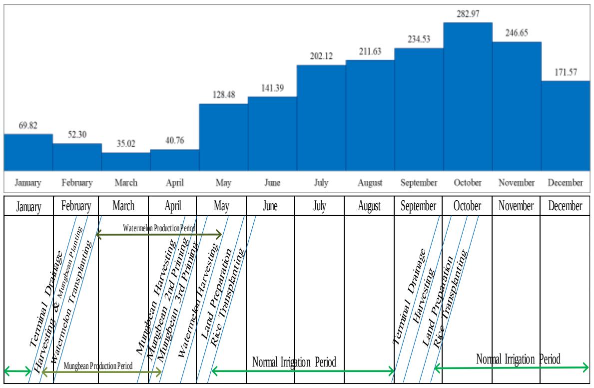

Figure 5. Proposed cropping pattern and calendar for cagayan province.

The cropping intensity is 300% and the cropping pattern is mung bean and watermelon – rice - rice. The first cropping will start in the last week of January and ends in the first week of April for mung bean and for watermelon, the start is at the first week of February and ends in the last week of April, the duration of mung bean and watermelon (Sugar Baby Variety) are different, because mung bean could be cultivated at most 70 days (up to third priming) while watermelon is up to 80 days. The rice production on the other hand will be cultivated for 120 days each cropping and will be planted between second week of May to first week of September; and last week of September to third week of January, for First cropping and second cropping, respectively.

GIS-based Rainfall Variation Maps of Cagayan Province

The generated maps using the probabilities are shown in Fig.6 to 8. It can be noticed that the highest magnitude of rainfall can be observed in the northern part of Cagayan, specifically at the Calayan Group of Islands.

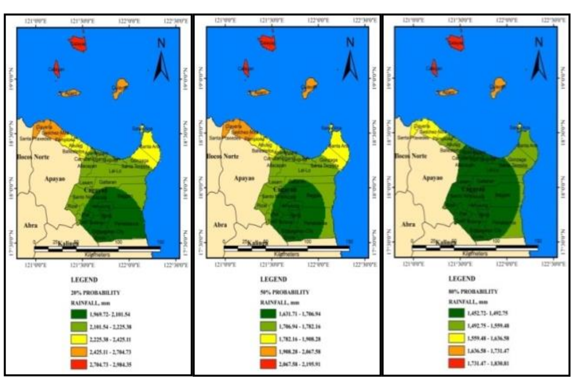

Figure 6. Spatial distribution of annual rainfall in cagayan at 20%, 50% and 80% probabilities of occurrence.

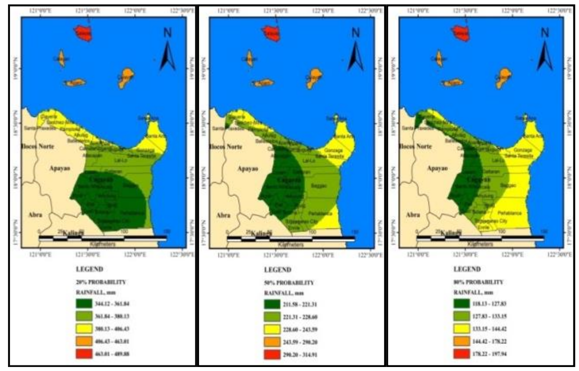

Figure 7. Spatial distribution of dry season rainfall in cagayan at 20%, 50% and 80% probabilities of occurrence.

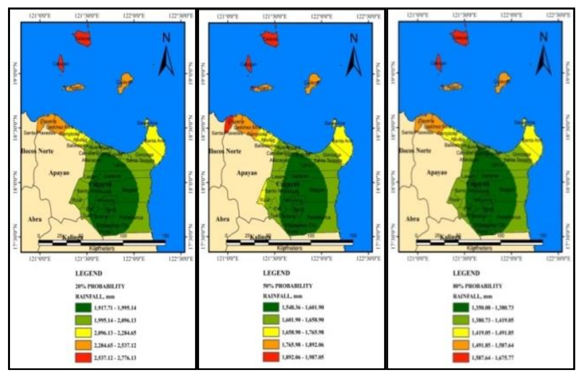

Figure 8. Spatial distribution of wet season rainfall in cagayan at 20%, 50% and 80% probabilities of occurrence.

Conclusion and Future Works

Conclusions

Based on the results of the study, the following conclusions were established:

1. There are four (4) rainfall stations situated within and nearby the Cagayan Province that have 32-year rainfall data obtained from PAGASA.
2. The rainfall data obtained from Laoag Station has 2-year missing data.
3. The rainfall stations used in the study have consistent records of rainfall data.
4. The optimal number of stations that should exist over the province of Cagayan for the estimation of annual rainfall at 10%, 5% and 1% allowable errors of estimation are 2, 8 and 209, respectively.

5. The number of stations within the province is sufficient to estimate a reliable value of mean annual rainfall.
6. The minimum length of record of rainfall in years that can result to a reliable estimated value of mean annual rainfall, wet and dry seasons are 7.05 years, 7.12 years and 7.54 years, respectively.
7. The existing length of rainfall data of 32 years is more than adequate for both for spatial and temporal analyses.
8. At 80% probability of occurrence, the mean annual rainfall expected to occur in Aparri, Calayan, Laoag and Tuguegarao Stations are 1406 mm, 1917 mm, 1647 mm and 1423 mm, respectively.
9. For dry season at 80% probability of occurrence, the mean rainfall that can occur at Aparri is 130 mm, Calayan is 198 mm, Laoag is 87 mm and Tuguegarao is 135 mm.
10. For wet season, at 80% probability of occurrence, the mean rainfall expected to be received at Aparri, Calayan, Laoag and Tuguegarao Stations are 1374 mm, 1687 mm, 1628 mm and 1342 mm, respectively.
11. There is no significant effect of elevation on the variation of rainfall recorded between stations.
12. Wet season starts from June to January and Dry season is between February to May.
13. There are significant differences in the spatial and temporal distributions of rainfall in the province of Cagayan.
14. The rainfall distribution developed for Cagayan is suited to a cropping pattern and calendar of mung bean and watermelon – rice – rice for a 300% cropping intensity.

Recommendations

Based on the results of the study, the following recommendations were made:

1. After 5 years, the rainfall data from the existing rain gauges installed 3-4 years ago within the province of Cagayan are recommended for a more detailed follow up study about temporal and spatial variations of rainfall.
2. It is advised that rain gauges be regularly checked and properly maintained in order to avoid missing data.
3. Rain gauges could be installed at higher elevated areas like mountainous areas to evaluate the possibilities of significant effect of elevation to the variation of rainfall.
4. In order to minimize the percentage of error from 10% to 5%, it is recommended that at least 8 rainfall stations be established within the province of Cagayan.
5. The NIA should utilize the proposed cropping calendar and pattern for the province of Cagayan.
6. The regression models developed from this study is recommended to be used only to predict the amount of rainfall at the given duration used in this study. The coefficient of determination should be taken into consideration when using these models. Lower r2 denotes lower reliability of the given equation to predict rainfall at a given station.

For further studies, the following are recommended:

1. Rainfall frequency analysis on daily and weekly basis.
2. Intensity and prevalence of drought.
3. Influence of rainfall in soil erosion especially in the mountainous areas utilizes for upland crop productions and soil erosion mapping using GIS.
4. Spatial and temporal variation of rainfall on daily or weekly basis and development of rainfall maps using GIS.

Ethical Considerations

This section includes the declaration of protocols followed as part of the ethical considerations of your study especially when dealing with human and animals as subject of your study. (10)

Acknowledgement

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Dr. Editha F. Ausa served as Vice President for Academic and Related Affairs. She authored different research papers and served as panelist to different research studies conducted by students in the undergraduate and graduate levels.

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