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TREND ANALYSIS OF PRECIPITATION ON CENTRAL CEBU, PHILIPPINES APPLYING MANN-KENDALL TEST AND SEN'S SLOPE ESTIMATES

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ABSTRACT

Raising knowledge on rainfall trend is an important component for water resources planning and management of an ever growing population and climate change vulnerable region. This paper examines the monthly, seasonal and annual trends of rainfall in the central part of Cebu province, Philippines over the period between 1977-2005. Data collected and managed by the University of San Carlos-Water Resources Center were analyzed to find out increasing or decreasing monotonic trend of rainfall magnitude. Homogeneity of rainfall data were tested at different significance levels using RAINBOW software. Rainfall data of selected stations were found to be generally homogeneous. Non-parametric analysis by the Mann-Kendall test and Sen's slope estimate employing excel template application MAKESENS for detecting and estimating rainfall trends. Some significant upward and a downward trends were detected on monthly rainfall. However, no significant trend was found at .001, .01, .05 and .1 level of significance for seasonal (Northeast monsoon on December-February, Summer on March-May, Southwest monsoon on June-August and Transition on September-November) and annual rainfall among the selected stations in Central Cebu, Philippines.

Keywords: rainfall, trend analysis, Mann-Kendall test, Sen's slope estimates, Central Cebu

INTRODUCTION

The 2007 Intergovernmental Panel on Climate Change (IPCC) report confirms an increase in global average air and ocean temperatures; that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation (Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.), 2007). Philippines is "vulnerable to the impacts of climate change because of its geographical location, archipelagic formation and ever-growing population" (CCC, 2011). It is "now facing the very real impacts of climate change, which threaten to undermine our development prospects and exacerbate the vulnerability of our poorer communities" (PAGASA, 2011).

There have been limited studies on climatological data on the aspect of climate change in the Philippines and, if not mistaken, nothing is particular for the regional meteorological analyses in Central Cebu. However, PAGASA (2011) conducted studies on climate trends and generated projections of temperature increase and rainfall change in the Philippines for the period of 1971–2000 as the reference period.

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Raising awareness on the regional trend of meteorological data is an important component for water resources planning and management for an ever growing population and socio-economic activities that "put pressure on the environmental conditions" (Water REMIND, 2006) in Central Cebu. Although rainfall, as the main source of water, in the region is abundant and high needs to be assessed every now and then especially that there is a threat of an increasing "domestic water demand from 94 mcm/yr in 2005 to 210 mcm/yr by 2030" (Water REMIND, 2006) aside from the temporal variation during the dry months. This paper aims at investigating whether or not seasonal and annual totals increases or decreases by means of trend analysis.

DATA AND STUDY AREA

For this paper, daily rainfall data with a span of 20 to 28 years between the period of 1977-2005 of the seven (7) rainfall stations in Central Cebu were acquired from the University of San Carlos-Water Resources Center. Three of the five major watersheds of Lusaran, Kotkot, Mananga, Danao and Luyang in Central Cebu are represented in this study. Elevation of the stations ranges from 160-758 m above mean sea level. Location of the stations ranges between $10^0 22'58''$ to $10^0 29'19''$ latitude and between $123^0 46'32''$ to $123^0 53'43''$ longitude. Details on the period of study, coordinates and elevation of each station are shown in Table 1 and their specific locations are shown in Figure 1.

METHODOLOGY

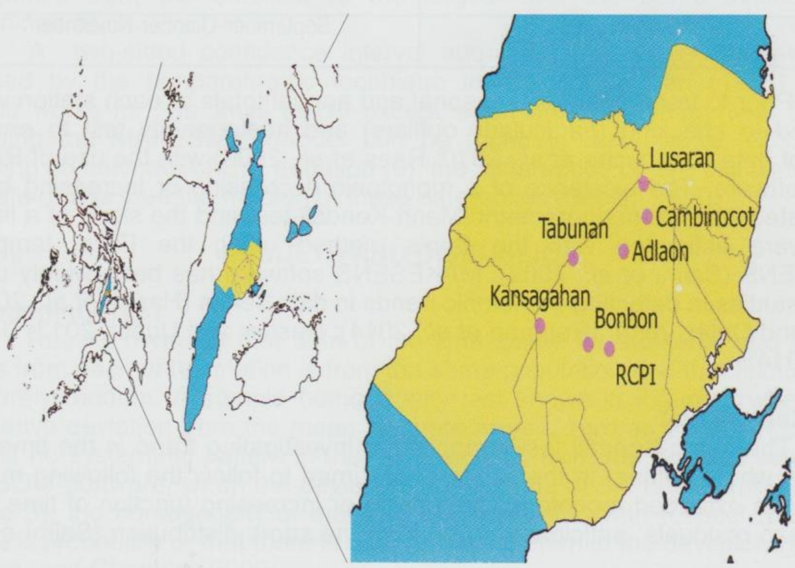

Figure 1. Study Area. (a) Map of the Philippines; (b) Cebu Province, Central Cebu (yellow); (c) Rainfall stations in Central Cebu.

Table 1. Stations information on period, coordinates and elevation.

Station	Watershed	Period	Coordinates		Elevation (masl)
			Latitude	Longitude	
Lusaran	Lusaran	1977-2005	10°29’19”	123°53’29”	160
Tabunan	Lusaran	1978-2005	10°25’59’	123°48’46’	656
Cambinocot	Kotkot	1978-2005	10°27’50”	123°53’43”	191
Adlaon	Kotkot	1978-2005	10°26’17”	123°46’09”	394
Kansaganahan	Sapangdaku	1978-2005	10°22’58”	123°53’29”	758
Bonbon	Mananga	1978-2005	10°22’07”	123°49’46”	215
RCPI	Mananga	1978-2005	10°21’55”	123°51’11’	715

Table 2. Seasons of Philippines.

Season	Months
Northeast Monsoon	December-January-February
Summer	March-April-May
Southwest Monsoon	June-July-August
Transition	September-October-November

Prior to trend analysis, seasonal and annual totals of each station were subjected to checking (particularly outliers) and homogeneity test to ensure quality of data (Chaouche *et al.,* 2010; Raes *et al.,* 2006) with the use of RAIN-BOW software. The existence of a monotonic decreasing or increasing trend were tested with the nonparametric Mann-Kendall test and the slope of a linear trend were estimated with the Sen’s method using the Excel template MAKESENS (Salmi *et al.,* 2002). MAKESENS software has been widely used among studies in detecting monotonic trends in data series (Hasan *et al.,* 2014); Vladut and Ontel, 2014; (Rahman *et al.,* 2014); Nasher and Uddin, 2013; Uddin *et al.,* 2014).

Mann-Kendall test

The Mann-Kendall test is applied in investigating trend in the time series data where values in the series is assumed to follow the following model where is a extended monotonic decreasing or increasing function of time with zero mean residuals anticipated to be from the same distribution (Salmi *et al.,* 2002).

Mann-Kendall method is also appropriate for monotonous trends with data having no seasonal or other cycle (Gilbert, 1987; Salmi *et al.,* 2002). Mann -Kendall statistic relies on the sign of differences of successive values, thus, outliers are not affecting the trend (Pal and Al-Tabbaa, 2009).

The test is based on (when) and (when) statistics as follows, where is the number of observed values in the series, and are observed values respectively at time and , . For , Mann-Kendall reported that is nearly normally distributed with the variance as follows, where is the number of tied groups and is the number of data values in the group. A positive (negative) value of (when) or (when) indicates an upward (downward) trend. The two-tailed test is used in MAKESENS for four different significance levels α: 0.1, 0.05, 0.01 and 0.001.

The null hypothesis of no trend is rejected in favour of the alternative hypothesis if the absolute value of *S* equals or exceeds a specified value or the absolute value of is greater than , where is the smallest which has the probability less than to appear in case of no trend and is obtained from the standard normal cumulative distribution tables.

Sen's slope estimator

Estimating the true slope of an upward or downward trend, Sen's non-parametric test is used. It is applicable in instances where trend is assumed linear (Sen, 1968). The linear model in equation (1) is expressed as, where is the slope and is constant. The estimated slope of all pairs are calculated as, where . Thus, there will be as many as slope estimates if there are values of . The median of these slope estimates represents the Sen's estimator of slope (Sen, 1968); (Gilbert, 1987); Salmi *et al.,* 2002) wherein the slope estimates are ranked from the smallest to the largest and the Sen's estimator is determined as,

A two-sided confidence interval about the true slope estimate was obtained by the nonparametric technique introduced by Sen (1968). Such method works for as small as 10 except when there are many ties. Details regarding the MAKESENS model can be found in Salmi et al. (2002). In obtaining an estimate of B in equation (6), the differences of are calculated. An estimate of B is then the median of these differences (Sirois, 1998).

RESULTS AND DISCUSSION

Homogeneity Test

Results revealed that data of the time series for seasonal and annual values from each of the station is from the same population and that fluctuations are purely random. A sample homogeneity test shown in Figure 3 where the cumulative deviation from the mean fluctuate around zero as an indication that there is no systematic pattern in the deviations of from the average value . In RAINBOW software, when the deviation crosses one of the horizontal red lines (Figure 3), the homogeneity of the data set is rejected with respect to 90, 95 and 99% probability or that there is a systematic pattern in the deviations (Raes, Willems, and Gbaguidi, 2006).

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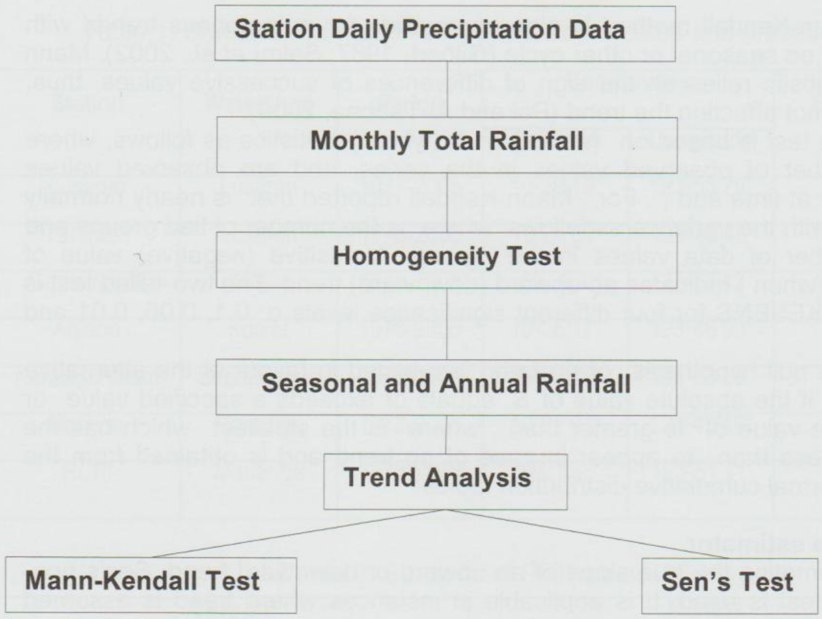

Figure 2. Stepwise Data Organization and Analytical Tools Used.

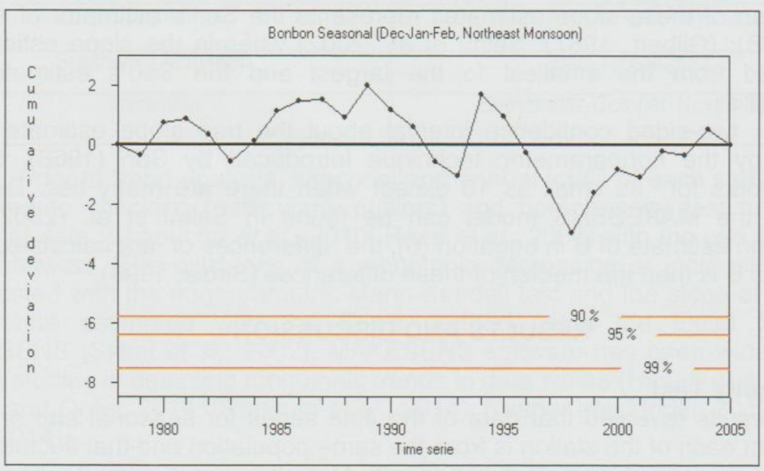

Figure 3. Cumulative deviations from the mean for the seasonal rainfall.

Rainfall Variability in Central Cebu

Figure 4, Figure 5, and Figure 6 show that in Central Cebu the monthly, seasonal and annual total of rainfall varies by location. Figure 4a shows the mean monthly rainfall pattern wherein different seasonal periods are distinguishable. Rainfall from November to February (northeast monsoon) has a decreasing trend and further decreases to April and May during summer. However, on the onset of southeast monsoon at June has an increasing but diminishing trend toward the transition period of September to November

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(Figure 4a and Figure 5a). The mean annual rainfall of Tabunan (Lusaran) is generally high (low) compared to all other stations while Cambinocot station has more or less the median mean monthly values. However, Tabunan (Lusaran) has higher (lower) variability of monthly rainfall while Cambinocot obtained the median variability values throughout the year (Figure 4b and Figure 5b) over the period between 1978-2005.

Likewise, Tabunan (Lusaran) has the highest (lowest) mean annual rainfall while Cambinocot obtained the median mean annual rainfall value considering the same period. In the same manner, Tabunan obtained the highest annual variability while Cambinocot the least variability and Adlaon has the median annual variability over the period between 1978-2005.

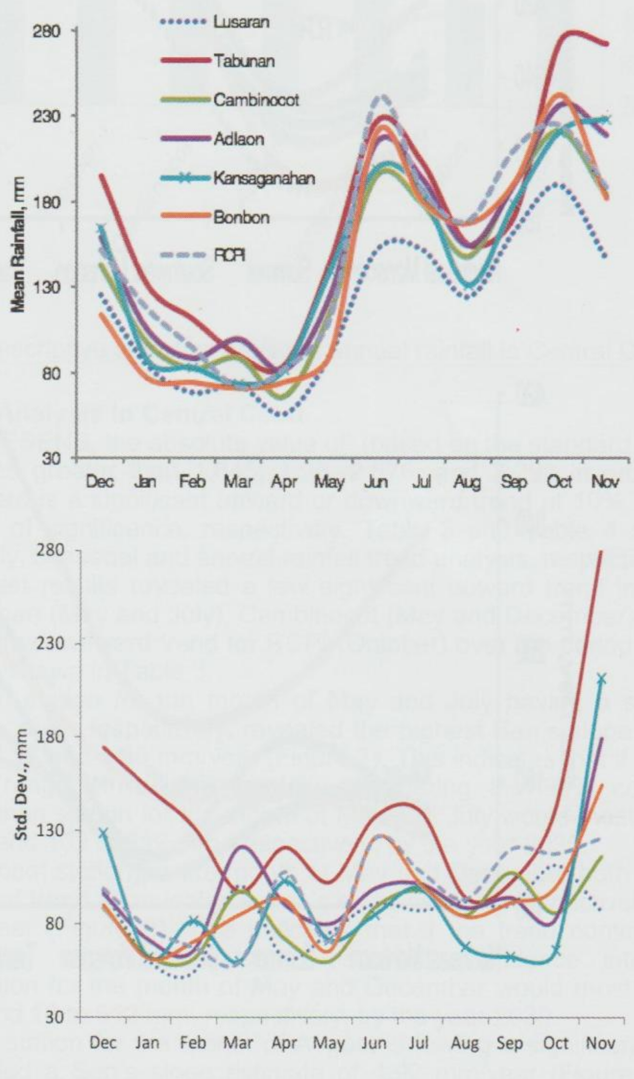

Figure 4. Descriptive statistics profile of monthly rainfall in Central Cebu.

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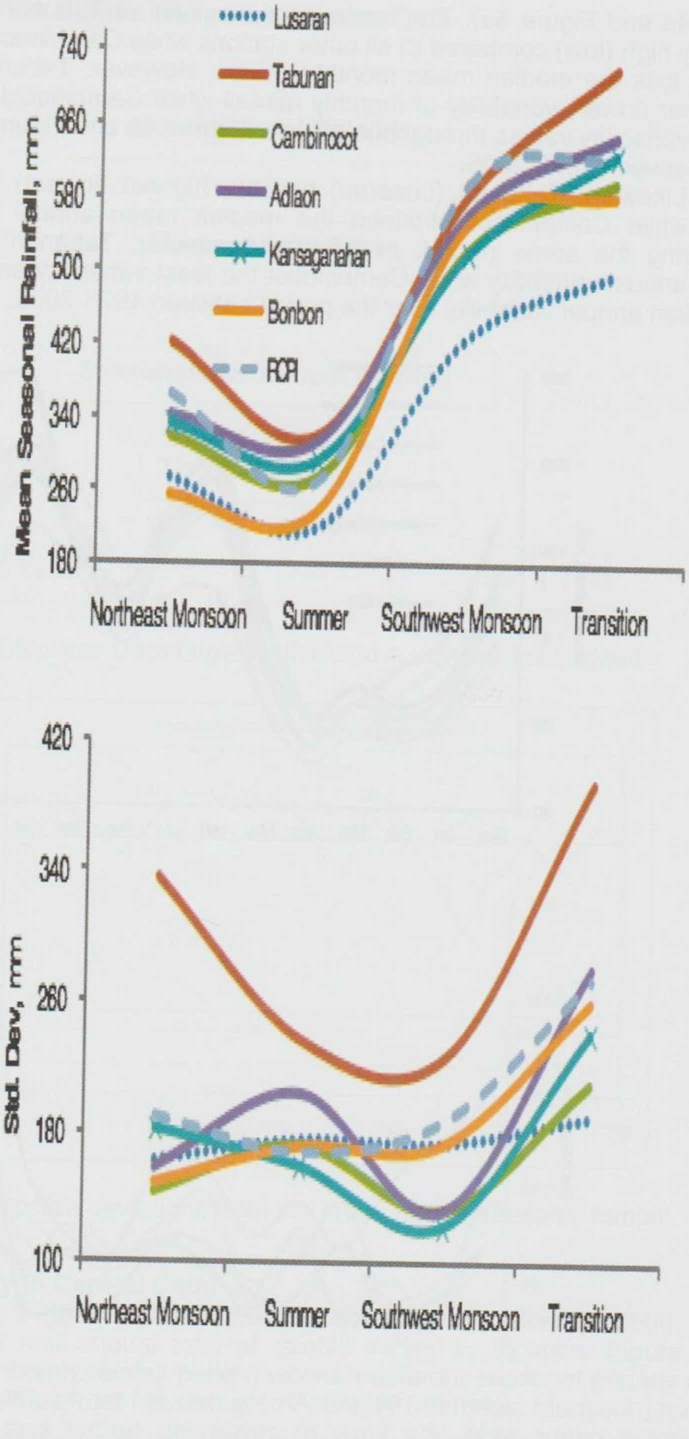

Figure 5. Descriptive statistics profile of seasonal rainfall in Central Cebu.

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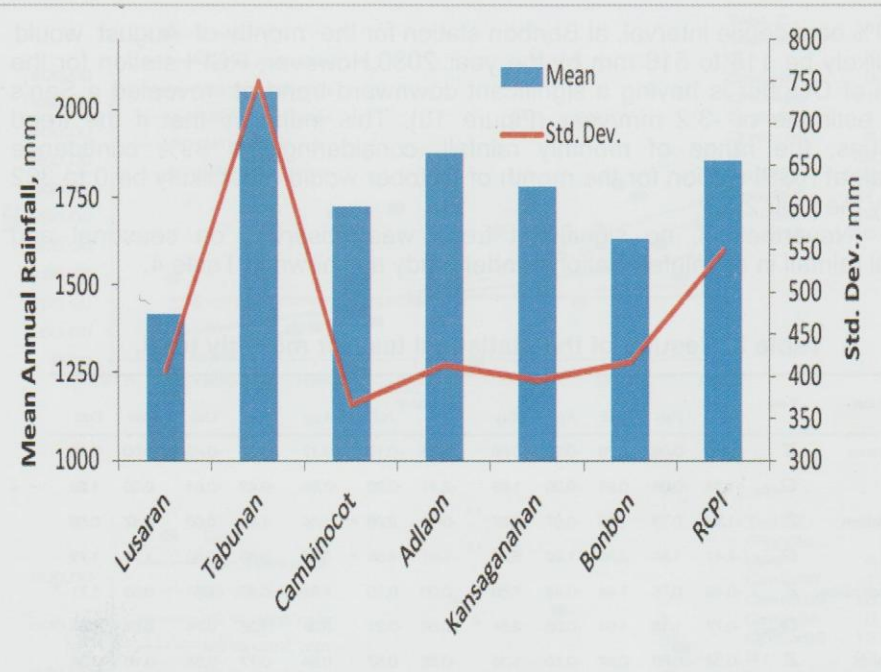

Figure 6. Descriptive statistics profile of annual rainfall in Central Cebu.

Rainfall Trend Analysis in Central Cebu

In MAKESENS, the absolute value of (based on the standard normal Z -table) has to be greater than 1.645, 1.96, 2.576, and 3.292 in order to be affirmed that there is a significant upward or downward trend at 10%, 5%, 1%, and 0.1% level of significance, respectively. Table 3 and Table 4 show the results of monthly, seasonal and annual rainfall trend analysis, respectively. The Mann-Kendall test results revealed a few significant upward trend in monthly rainfall for Tabunan (May and July), Cambinocot (May and December), Bonbon (August), and one downward trend for RCPI (October) over the period between 1978 to 2005 as shown in Table 3.

Tabunan station for the month of May and July having a significant upward trend at and , respectively, revealed the highest Sen's slope estimate respectively of 5.26 and 4.59 mm/year (Figure 7). This indicates that if the trend continues, the range of monthly rainfall, considering the 99% confidence interval, at Tabunan station for the month of May and July would most likely be 116 to 568 mm and 102 to 819 mm, respectively, by the year 2030.

Cambinocot station for the month of May and December both having a significant upward trend at revealed a Sen's slope estimate respectively of 2.84 and 3.54 mm/year (Figure 8). This indicates that if the trend continues, the range of monthly rainfall, considering the 99% confidence interval, at Cambinocot station for the month of May and December would most likely be 55 to 416 mm and 13 to 512 mm, respectively, by the year 2030.

Bonbon station for the month of August is having a significant upward trend at revealed a Sen's slope estimate of 4.92 mm/year (Figure 9). This indicates that if the trend continues, the range o f monthly rainfall, considering

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the 99% confidence interval, at Bonbon station for the month of August would most likely be 118 to 516 mm by the year 2030.However, RCPI station for the month of October is having a significant downward trend at revealed a Sen's slope estimate of -3.2 mm/year (Figure 10). This indicates that if the trend continues, the range of monthly rainfall, considering the 99% confidence interval, at RCPI station for the month of October would most likely be 0 to 362 mm by the year 2030.

Nevertheless, no significant trend was observed on seasonal and annual rainfall in all rainfall stations under study as shown in Table 4.

Table 3. Results of the statistical test for monthly total.

Station	Test	Trends											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lusaran	Z	-0.85	-0.06	0.79	-0.38	0.88	-0.85	-0.13	-0.17	-0.32	-0.43	0.00	0.85
	Q_{med}	-1.34	-0.05	0.91	-0.30	1.59	-2.11	-0.20	-0.56	-0.42	-0.61	0.00	1.59
Tabunan	Z	-1.24	0.73	1.50	-0.87	2.67 **	-0.79	2.08 *	1.64	1.60	0.06	0.47	0.58
	Q_{med}	-1.41	1.24	2.56	-1.20	5.26 **	-1.61	4.59 *	3.48	3.69	0.30	1.75	1.79
Cambinocot	Z	-0.49	0.75	1.44	-0.48	1.88 +	0.00	-0.10	1.52	0.47	0.54	0.28	1.71 +
	Q_{med}	-0.77	1.13	1.64	-0.96	2.84 +	0.06	-0.21	3.08	1.36	0.74	0.67	3.54 +
Adlaon	Z	-0.34	0.89	0.97	-0.10	1.36	-0.38	0.57	0.34	-0.77	-0.38	-0.10	0.34
	Q_{med}	-0.31	1.06	1.36	-0.19	3.28	-0.80	1.15	0.75	-1.78	-0.64	-0.25	0.91
Kansaganahan	Z	-1.07	0.03	0.81	-0.52	1.27	0.49	0.29	1.24	-0.82	-0.76	-0.45	1.42
	Q_{med}	-2.07	0.31	1.72	-0.65	3.01	0.81	0.57	3.18	-2.22	-2.38	-2.34	6.91
Bonbon	Z	-0.75	0.00	0.00	-0.79	-0.54	0.04	0.00	1.76 +	-1.25	-0.27	-0.42	-0.30
	Q_{med}	-0.73	-0.06	0.05	-1.14	-0.79	0.07	-0.13	4.92 +	-2.27	-0.82	-1.20	-0.96
RCPI	Z	-1.21	-0.24	-0.22	-0.57	-0.10	0.92	-0.70	0.96	-0.92	-1.67 +	0.39	1.18
	Q_{med}	-2.33	-0.26	-0.19	-1.42	-0.50	2.05	-1.67	1.39	-3.21	-3.20 +	1.67	2.42

Z: Mann-Kendall test, Q_{med}: Sen's slope estimator
** Statistically significant trend at 1% level of significance
* Statistically significant trend at 5% level of significance
+ Statistically significant trend at 10% level of significance

Station	Test	Trends				
		Northeast Monsoon	Summer	Southwest Monsoon	Transition	Annual
Lusaran	Z	-0.296	1.166	-0.581	-0.732	0.206
	Q_{med}	-1.062	4.485	-2.575	-3.272	2.802
Tabunan	Z	0.612	1.482	1.284	1.008	1.482
	Q_{med}	3.443	6.807	7.461	4.665	29.418
Cambinocot	Z	0.929	0.810	0.612	0.544	1.284
	Q_{med}	3.688	2.205	3.183	2.316	9.937
Adlaon	Z	0.792	0.968	-0.573	-0.415	0.375
	Q_{med}	3.053	4.146	-1.338	-1.968	7.175
Kansaganahan	Z	0.487	0.552	1.590	-0.755	-0.162
	Q_{med}	3.260	2.783	7.772	-4.792	-3.830
Bonbon	Z	-0.500	-0.709	0.652	-0.929	-0.459
	Q_{med}	-1.850	-3.651	4.443	-5.144	-7.387
RCPI	Z	0.217	0.178	0.169	-0.019	-0.138
	Q_{med}	1.324	1.264	1.034	-1.332	-2.756

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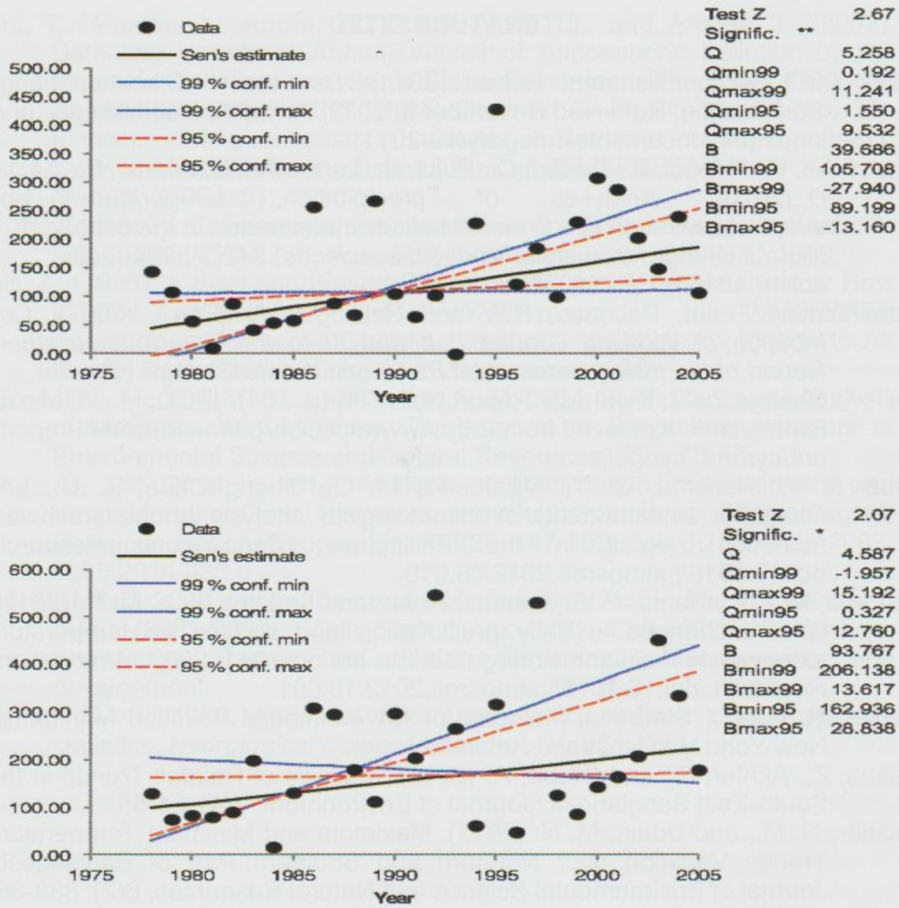

Figure 7. Monthly time series and trend statistics of Tabunan station.

CONCLUSION AND RECOMMENDATIONS

This study presents a trend analysis of monthly, seasonal and annual rainfall from rainfall stations distributed in Central Cebu, Philippines during the period between 1977 and 2005. Majority of the monthly rainfall while all seasonal and annual rainfall are having no significant monotonic trend applying Mann-Kendall test. Thus, most likely, seasonal and annual totals of rainfall in Central Cebu will remain having no monotonic trend over the next decade. However, the findings of the study show some positive and a negative trends in the monthly total of rainfall with 90% to 99% significance levels. If the current trend continues, it is unavoidable that such increasing and decreasing trends in rainfall will affect the region's socio-economic activities.

Further research is recommended that should be explored in number of wet and dry days, 10-daily rainfall and for monthly and annual extremes events. Extending the study period to recent observed data is likewise recommended.

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