Rainfall Distribution Trend Analysis of the Philippine National Capital Region (2013-2016)

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Abstract: The Philippine archipelago is a tropical country that experiences only two major seasons annually: wet (June-November) and dry (December-May). Due to these conditions, the country is bound to experience significant amounts of rainfall, followed by drought. Hence, studying long-term rainfall trends is highly beneficial for the country's livelihood and safety. In this work, we studied the rainfall distribution in the National Capital Region covering the period of 2013 to 2016, and analysed the data using the Mann-Kendall Test and the Bootstrap procedure. Using a monthly scale, we found a negative trend, signifying a decrease in rainfall amount over the four years of data. Interestingly, we found a positive trend using a yearly scale, showing an increase of rainfall overall. Therefore it is quite risky to generalize a certain region's rainfall condition just by looking at it annually, but must consider as well its seasonal and monthly phenomena for a more detailed analysis. We note also that the area being studied was considerably large and the rainfall data varied with the location of the weather station where it was obtained. This work demonstrates the potential of using Big Data and the Internet of Things to measure and predict weather trends using various sensors and processors.

1 INTRODUCTION

The Philippines in general experiences most often record breaking typhoons as years go by which brings heavy rainfalls that consequently destroys a lot of properties mainly its agricultural resources which lead to production losses (Lansigan, 2013; Cinco, et al., 2016).

Because of this, rainfall activity poses a great point of attention in making a good preparation of what's to come to our distant future. This kind of study has actually been constantly the point of change assumption in a span of 30-65 years in the making particularly about climate change itself (Cinco, 2018). The climate trends accounted in the said studies also made use of the Mann-Kendall non-parametric test since it's basically used for identifying trends in time series data.

To further supplement this concept, we made use of the Bootstrap procedure used to study rainfall trends in Sicily (Cannarozzo, et al, 2006). The trends found within a span of several years will be categorized in a temporal manner (yearly, monthly), eliminating the autocorrelation of time series data that defeats an essential application of Mann-Kendall Test.

The Philippine Atmospheric, Geophysical, Astronomical Services Administration (PAGASA) is the national agency mandated to "provide protection against natural calamities and utilize scientific knowledge as an effective instrument to insure the safety, well-being and economic security of all the people, and for the promotion of national progress" (Presidential Decree No. 1149, 1977). This agency has gathered, among many others, rainfall data over several years and has made it public via the Freedom of Information website (https://www.foi.gov.ph/). We chose to collect data regarding the Philippine National Capital Region (NCR) due to its political and economic significance.

2 METHODOLOGY

2.1 Dataset

We used the rainfall data collected from three PAGASA weather stations located in the NCR

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(Ninoy Aquino International Airport in Pasay City, Science Garden in Quezon City, and Port Area in Manila). These data were made available to the public via the Freedom of Information website.

Figure 1: NCR Map showing 3 PAGASA weather stations: Science Garden in Quezon City, Port Area in Manila City, and NAIA in Pasay City.

The four year-long daily data acquired from PAGASA are designated in the three following weather stations as shown in Figure 1. From these selected stations, only NAIA station have missing data comprised of about 0.55% of its total and the consequent changes from over all stations shown were expressed in terms of its average monthly and annual rainfall amount.

To further show the variability of data, modified version of Oliver's Precipitation Concentration Index (PCI) (Oliver, 1980) was used which analyzes yearly, as well as monthly heterogeneity of rainfall amounts. This index is described as:

$$PCI = 100 \cdot \frac{\sum_{i=1}^{n} {p_i}^2}{\left(\sum_{i=1}^{n} p_i\right)^2} \quad (1)$$

where p_i is the rainfall amount for the i^{th} order of n which is either equal to twelve if analyzed annually and 29, 30, or 31 if the case is monthly analyzed. The resulting PCI with values below 10 is said to be uniform throughout the particular time scale, while for 11 to 20 values would mean seasonality in rainfall amounts, and values of 20 above corresponds to substantial variability in the specific time scale.

2.2 Trend Detection

The Mann-Kendall (MK) test is often used to detect trends in a time series dataset with no apparent pattern, such as rainfall. MK does not require the data to be normally distributed, making it a non-parametric or distribution-free test. In using the MK test, we assume that there is no trend present, that the observations over time are representative of the true conditions at sampling times, and that the data to be analyzed is unbiased and representative of the underlying populations over time (Mann, 1945). Our assumed Null Hypothesis (H_0) is that there is no existing trend from the rainfall data, while the Alternative Hypothesis (H_1) is that there is an actual monotonic trend existing in the data. To either accept or reject these hypotheses, we have

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(T_j - T_i) \quad (2)$$

and specifically,

$$\mathrm{sign}(\mathrm{T_j} - \mathrm{T_i}) = \begin{cases} 1 \text{ if } \mathrm{T_j} - \mathrm{T_i} > 0 \\ 0 \text{ if} \mathrm{T_j} - \mathrm{T_i} = 0 \\ -1 \text{ if} \mathrm{T_j} - \mathrm{T_i} < 0 \end{cases} \quad (3)$$

where T_j and T_i are the values in the times j and i respectively, $j > i$. A positive value of S implies that a majority of the differences between earlier and later measurements are positive, suggestive of an upward trend over time. Likewise, a negative value for S implies that a majority of the differences between earlier and later values are negative, suggestive of a decreasing trend. A value near zero indicates a roughly equal number of positive and negative differences.

In conjunction with the MK test is the bootstrap procedure or approach which counteracts the correlation of time series data of rainfall amounts. We extract randomly one year of a time series, rearrange randomly the data for that particular year, then compare the resulting statistic S to the original unarranged data for the year.

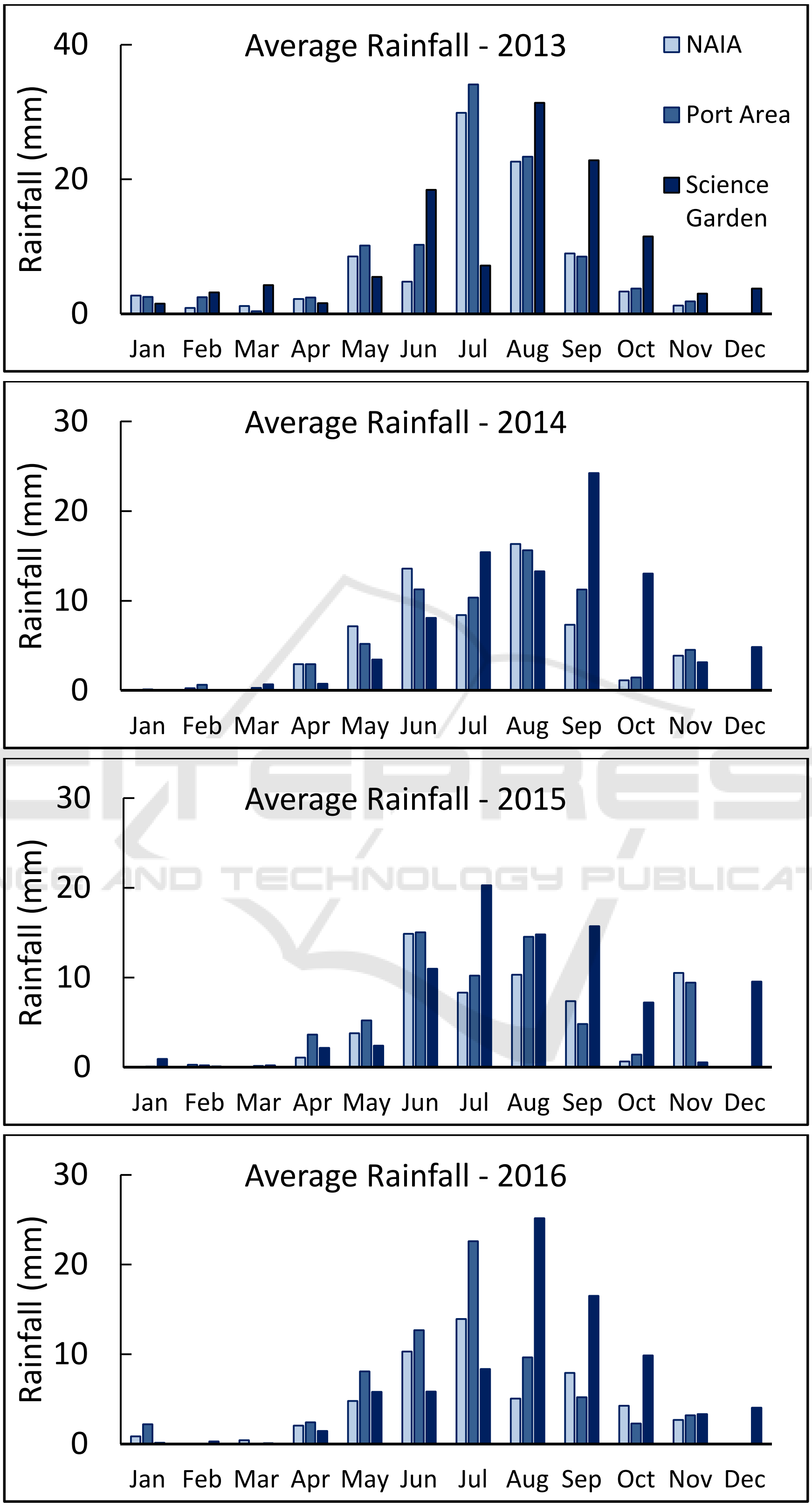

Figure 2: Daily rainfall in NCR averaged on a monthly basis.

3 RESULTS AND DISCUSSION

The daily rainfall was averaged over each month and shown in Figure 2. Rainfall is seen to coincide with the seasonal rainfall patterns prominent in the months of June to November (wet season) and December to May (hot season). Such trends are seen more clearly in Figure 3, which averages the monthly data from the three stations.

The trends in Figures 2 and 3 displayed consistency with minor differences between years. These differences are further expounded with the PCI calculations and the MK test trends. In particular, the yearly scaled trends in Figure 4 greatly vary when compared with the monthly scaled trends in Figure 5. We note that the same method of obtaining trends yields quite different results when scaled over different time periods, which reminds us to choose the region and scope of interest appropriate to our study.

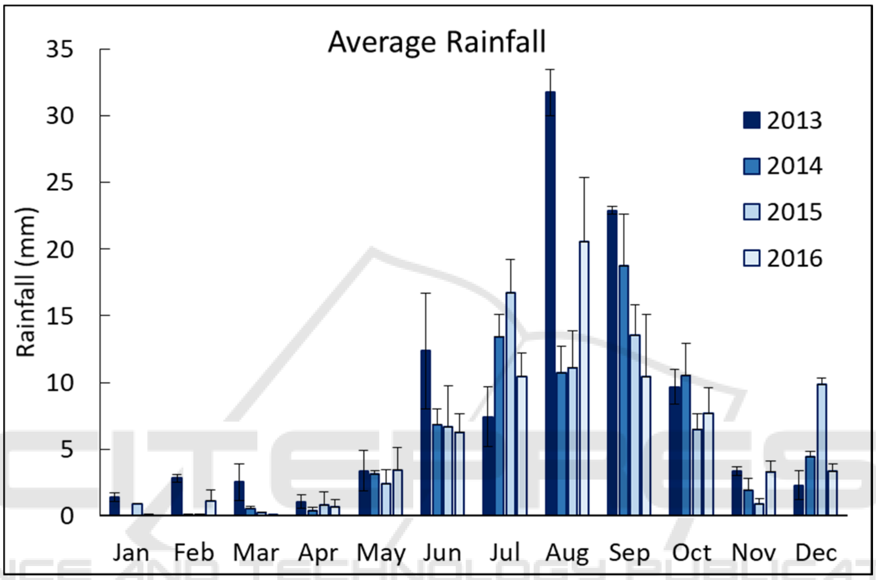

Figure 3: Daily rainfall in NCR averaged monthly for the three PAGASA stations.

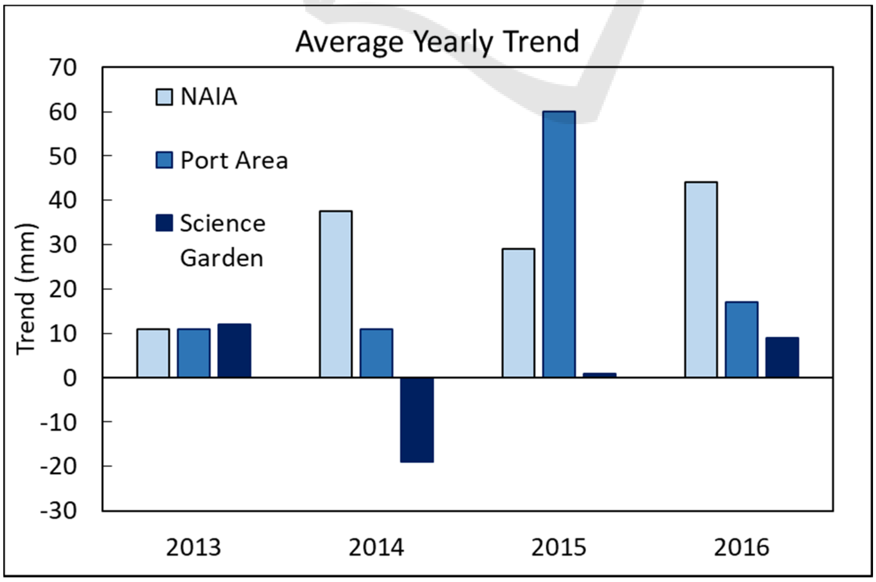

Figure 4: Average yearly trend of rainfall in NCR for the three PAGASA stations.

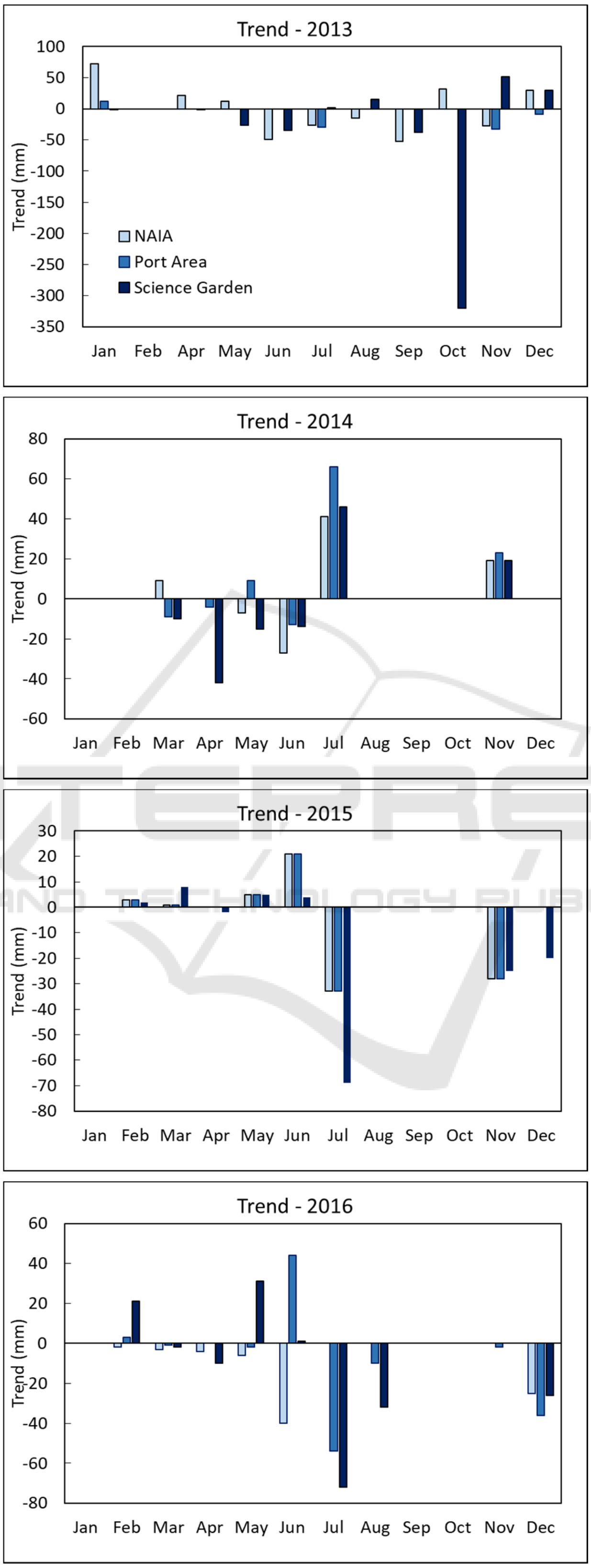

Figure 5: Monthly scaled trends in rainfall data.

While the trends vary with the location of the weather station, the yearly and monthly trends are generally the same for all locations. For rainfall data, monthly trends are more accurate than yearly trends, since the former are more finely resolved and show the variability of rainfall in the Philippines within a year. The next step would be to use these trends to predict data for the succeeding years, and determine the presence of climate change with regard to Philippine rainfall.

4 CONCLUSIONS

We can conclude that the MK Test is a very useful tool for analyzing rainfall and other meteorological data, which is optimized via Bootstrap resampling. The analysis made over the NCR is fruitful since the trends on temporal scale were successfully shown. The variance in monthly and yearly trends remind us of the inherent seasonal variability of rainfall within a year for the Philippines. The specific location is still an important factor in characterizing the distribution for areas as large as the Philippine NCR.

We can extend this study using the remaining PAGASA weather stations around the Philippines, as well as other data sources. The emergence of Big Data and the Internet of Things gives researchers access to an unprecedented wealth of meteorological data as well as the tools to measure possible trends and predict future ones.

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