TYPHOON ANALYSIS: INTENSITY, DAMAGE AND CASUALTY RELATIONSHIP IN FRACTAL CONTEXT

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ABSTRACT

The study made use of the descriptive design utilizing secondary data. The approximate histogram of the data was determined to probe the impact of the combined effect of frequency and intensity of storms on both damage and casualty. The histogram shows an exponential growth of the variable if there are lower values than larger values in a given data. The reported damage (D) and a number of casualties (C) of typhoons hitting the Philippines since 1960 were observed to obey an exponential distribution. The corresponding fractal random variables of these exponential variates were interpreted as X economic impact of the damage (D) and Y, the number of people affected by the casualty (C). While damage (D) and a number of casualties (C) were found to be significantly correlated, economic impact (X) and the number of people affected by the casualty (Y) were not. In order that these two latter variables be correlated, it is necessary to obtain more detailed information about the casualty (C), e.g., the casualty is a breadwinner or not. Likewise, the intensity of typhoons hitting a locality is not sufficient to predict both damage and casualty. The combination of frequency and intensity (how often a typhoon of certain intensity hits the locality) does predict both damage and casualty more efficiently.

Keywords: typhoon, intensity, damage, casualty, fractal analysis

Introduction

The Philippines is a vulnerable country because it is prone to successive encounters of the tropical storm since it is located in a geographic area facing the Pacific Ocean. The country encounters a tropical storm and is easily affected by low-pressure areas. The Philippines has an average of twenty-four (24) typhoons every year. The most frequent area affected by a typhoon in the Philippines is the Northern Luzon and Eastern Visayas areas according to PAGASA. The tropical storm that visited the country caused massive destruction in infrastructure and agricultural products not to mention the lives of the people claimed by such disasters.

Mendelsohn, R. et al (2012) stated that climate change has an impact on global tropical storm damage. Change in global temperature caused the most frequent formation of tropical storms in stronger intensities. According to the Global Climate Risk Index, the Philippines had the World's highest death toll caused by weather-related disasters last year and the News Analysis stated that killer typhoons in the Philippines blamed on Climate Changes, (Philstar, 2012). The German Watch Index on Climate Change also mentions that the Philippines placed on the top 5 on the list of the 10 most affected countries. The increase in storm intensity is expected to result from increases in sea surface temperature and the decrease in Tropopause-level temperature accompanying by the greenhouse warming, Free et al, (2004).

Common knowledge dictates that the magnitude of losses due to typhoons varies as the intensity of these storms. However, statistics reveal that even low-intensity storms can cause massive damages (NDRMMC, 2013) and high-intensity storms may likewise result in low damage counts provided that preparations are made prior to the event. In this study, we investigate the impact of the combined effect of frequency and intensity of storms on both damage and casualty statistics through fractal analysis.

Conceptual Framework

It is widely believed that the intensity of a tropical depression is associated with the damage and casualty attendant to the weather disturbance. That is, stronger storms are more likely to produce greater damage to a location than weaker storms would. However, the events of the recent past did not seem to support this belief. Some weaker typhoons have been observed to cause far greater damage than stronger one. This is particularly true in the part of the Philippines, where the citizen is alerted more aggressively when strong typhoons are expected and less cautioned when weaker weather disturbance are predicted.

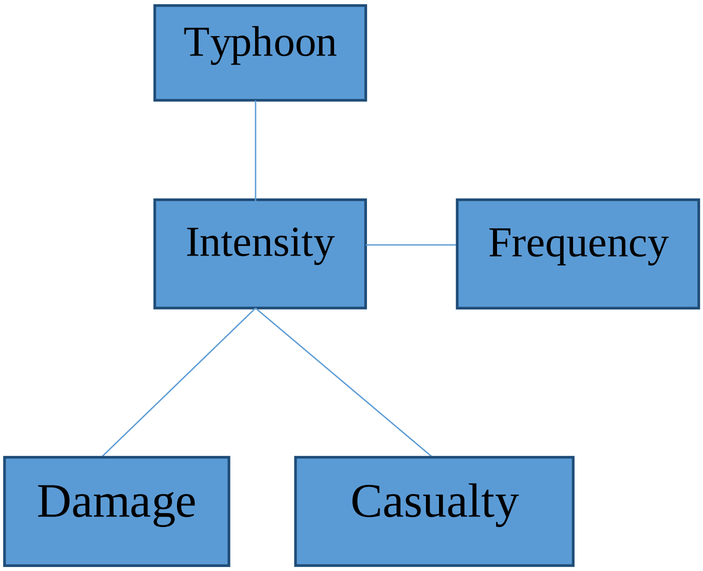

Figure 1. Schematic Diagram of the Study

The study posits that the combination of frequency and intensity of typhoons is a more reliable index for predicting the extent of damage (and casualties) in a given locality. Even the sturdiest and robust location reaches its threshold of tolerance when repeatedly pummeled by storms of wearer intensities. A location twice visited by a typhoon of wear intensities would have very little time to put things in order after the first visit when the second one arrives on its heel. Consequently, more widespread damage could be expected here than if it were visited only once by a typhoon of stronger intensity.

This hypothesis gains a more profound significance in view of the prevailing climate change. Climate Change is brought about by global warming, which in turn produce more frequent tropical depressions. In the Philippines, for instance, the average number of typhoons entering the Philippines area of responsibility (PAR) increased from 14-18 per year in the 1980's to 22-26 per year starting in 2005 to the present. These statistics imply that typhoons and weather disturbance of even weak intensities visit in the country with an average of two (2) per month. What appears even more disturbing is the fact that an increase in the intensity of these typhoons had been noted more recently. The combination of more frequent, high-intensity storms visiting the country parts a grim albeit gloomy future for the typhoon-prone areas of the country.

Methodology

The study made use of the descriptive design utilizing the secondary data based on the information provided from the study of *Sabandal M et al.* (2014) "Patterns in Frequency, Intensity, and Geography of Tropical Cyclones in the Philippines: An Ex Post Facto Analysis for Disaster Risk Reduction".

In order to probe the impact of the combined effect of frequency and intensity of storms on both damage and casualty, the approximate histogram of the data was determined. The histogram shows the exponential growth of the variable if there are lower values than larger values in a given data. The succeeding step is to obtain the logarithm of the data (data/minimum data). The histogram of the transformed data (log (data) is then determined. If the log (data) shows an exponential distribution, then there is sufficient evidence that the data obey a fractal distribution. The minimum of variable x is used to calculate the log of x by dividing the variable by its minimum (log ($\frac{x}{min}$)) and get the histogram of log(x) to determine the exponential distribution. The exponential distribution is used to determine the fractality of the gathered data. The fractal dimension is calculated by identifying the mean of log(x) and by getting the mean the fractal dimension is calculated by 1+ ($\frac{1}{mean}$).

Data gathered on the estimated damage (in million dollars) and the number of casualties reported for the various typhoons exceeding 150 kph intensity was obtained from the website of the Department of Science and Technology (DOST) Weather Bureau for the year 1960 to 2013. This information was analyzed through fractal statistics.

Results and Discussion

Figures 2 and 3 show the histogram of the number of casualties and estimated damage respectively.

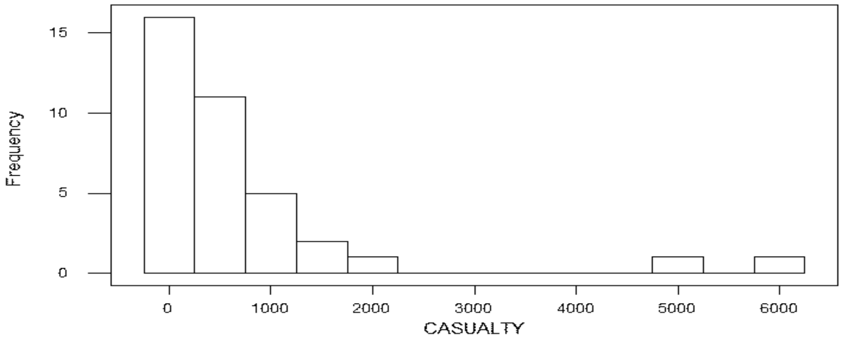

Figure 2. Histogram of the Number of Casualty

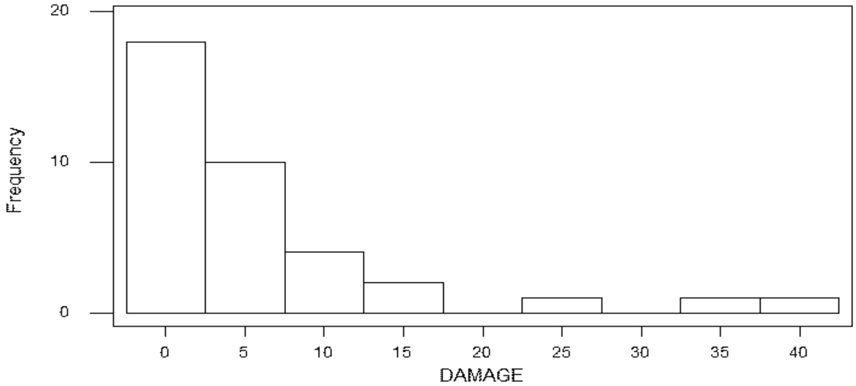

Figure 3. Histogram of the Estimated Damage

Both histograms reveal an exponential distribution with rate parameters $\beta_1 = 0.00137$ and $\beta_2 = 0.1531$ respectively. The Ryan- Joiner tests confirmed the hypothesis of exponentiality in both instances.

Representing the estimated damage and the number of casualties by D and C respectively, then the exponential behavior of these two random variables imply the existence of two (2) corresponding fractal variables X and Y given by:

19. $\frac{X}{\theta_1} = \exp(D) \; and \; \frac{Y}{\theta_2} = \exp(C)$

These fractal random variables can be interpreted as follows: X represents the impact to the economy of a locality sustaining a damage (D) when hit by a typhoon; Y represents the number of people directly affected when the number of casualties (C) is observed for the locality hit by a typhoon. We observe that a unit damage D (=1) translates into X = 2.7 (approximately 3) units of impact to the local economy and that this impact is exponentially growing with the sustained damage to infrastructure and agricultural production. Similarly, one casualty (C=1) affects Y=2.7 (roughly, 3 individuals) directly. In the Philippine context with the current family size of 3, this estimate is particularly informative.

Figures 4 and 5 show the histograms of X (economic impact) and Y (directly affected individuals by observed casualties).

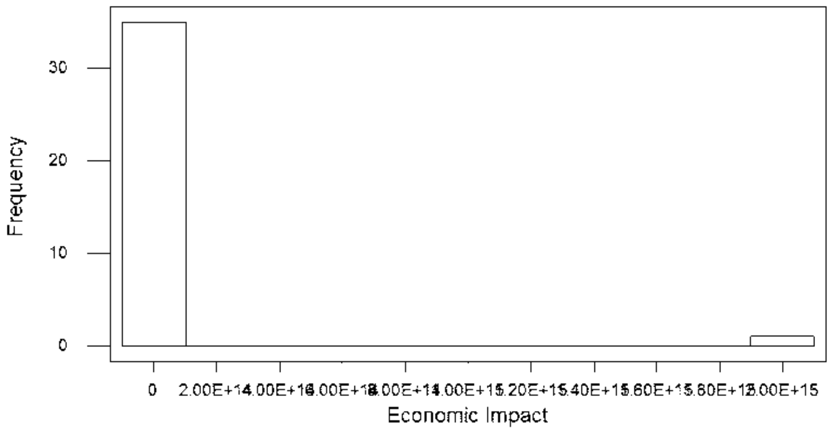

Figure 4. Histogram of the Economic Impact (X)

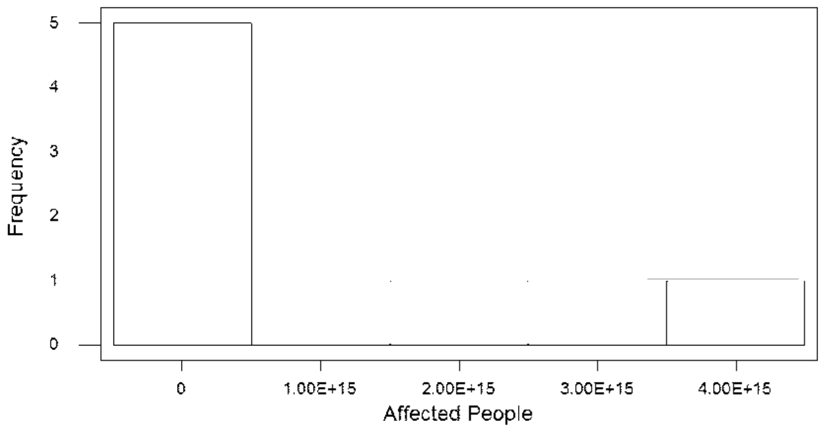

Figure 5. Histogram of the Number of Affected People (Y) by Casualties (C)

Of the two histograms, the first (Economic Impact) appears to behave more consistently with a power-law distribution (fractal distribution) than the second (Number of Affected People). The implication is that we are more certain about the extent of the economic impact of estimated damage (D) to infrastructure and agricultural production than about the number of people directly affected by casualties (C) of typhoon-led disasters.

Meanwhile, we computed the correlation between the random variables D and C, representing the correlation between two exponential random variates following the theory developed by Padua, (2014). The correlation coefficient obtained was $r(C, D) = 0.435$ with a p value of $p= 0.007$. Thus, damage (D) and the number of casualties (C) are significantly correlated beyond the .01 probability level. Using the h (.) transfer function obtained in Padua (2014), we estimated the correlation of the fractal random variables X (economic impact) and Y (number of people affected) to be:

$$r(X,Y) = .584 + .413 \log(r(C,D)) = .584 + .413 \log(.435) = 0.2402.$$

This result can be empirically compared with the value of $r(X, Y)$ from the data which is $r(X, Y) = 0.2258$ with a p-value of $p = 0.625$. The empirical formula for $r(X, Y)$ and the data-based computed correlation are in close agreement. However, we note that since the fractal dimensions of X and Y are respectively 1.1531 and 1.00137 (both less than 3), these Pearson correlation estimate needs to be viewed as a very rough estimate of the relationship between these two quantities.

In summary, we observed that while the estimated damage (D) and the number of casualties observed in a locality hit by typhoons correlate significantly, the corresponding economic impact (X) and numbers of people affected by the casualties (Y) are not. In order to link the latter two variables, it is necessary to obtain information about the casualties (C): whether or not they were primary breadwinners or not.

Finding an efficient predictor of damage and casualty. Typhoon intensity is often associated with both damage (D) and casualty (C). To test this hypothesis, we correlated the typhoon intensity with the two quantities to obtain the result below:

Table 1. Correlation Matrix for Intensity, Damage, and Casualty

	INTENSITY	DAMAGE
DAMAGE	0.250 0.135	
CASUALTY	0.058 0.732	0.435 0.007

Cell Contents: Pearson correlation
P-Value

Tabular values revealed that the intensity is not significantly correlated with both damage and casualty contrary to popular belief. However, it may be more prudent to examine the combination of intensity and frequency of typhoon visits as a predictor of the two quantities. Table 2 shows the regression analysis performed for this purpose:

Table 2. Regression Analysis of Damage versus Frequency-Intensity

The regression equation is
DAMAGE = 1.62 + 0.00714 Freq-Intensity

Predictor	**Coef**	**SE Coef**	**T**	**P**
Constant	1.616	2.804	0.58	0.568
Freq-Int	0.007137	0.003437	2.08	0.045

R = .331**R-Sq** = 11.0% **R-Sq(adj)** = 8.4%

The combined effect of frequency and intensity of typhoons produced a significant correlation with estimated damage (r = 0.331) beyond the .05 probability level. The scatterplot of the variables is shown below:

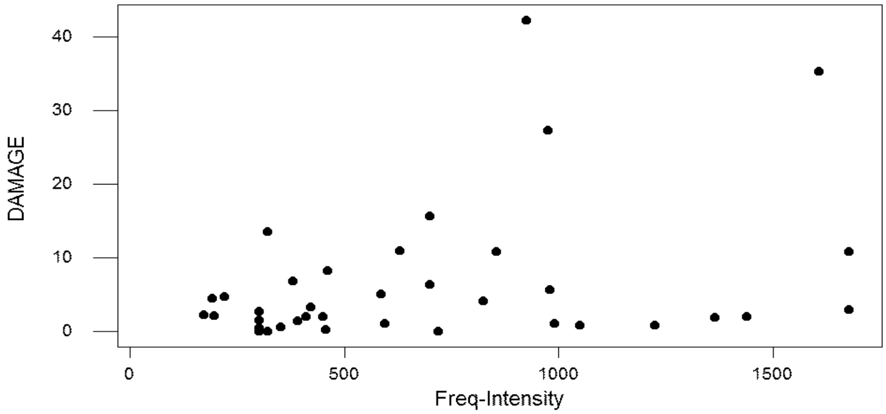

Figure 6. Scatterplot of Damage versus Freq-Intensity of Typhoons

Similarly, Table 3 shows the analysis done for number of casualty and frequency-intensity of typhoons:

Table 3. Regression Analysis of Casualty versus Frequency-Intensity

The regression equation is
CASUALTY = 50 + 0.986 Freq-Intensity

Predictor	**Coef**	**SE Coef**	**T**	**P**
Constant	50.4	356.5	0.14	0.888
Freq-Int	0.9862	0.4370	2.26	0.030

R = 0.356 R-Sq = 12.7% R-Sq(adj) = 10.2%

Again, frequency-intensity of typhoons has a significant correlation with the number of casualties observed (r= 0.356) beyond the .05 probability level. The scatterplot of these variables is shown below:

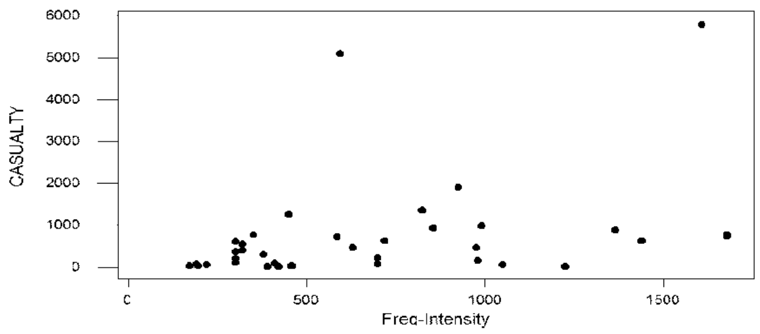

Figure 7. Scatterplot of Casualty versus Freq-Intensity of Typhoons

Results suggest that it is not just a matter of the strength of a single typhoon hitting a locality that determines the extent of damage or casualty but rather, how often a typhoon of certain strength hits the locality that determines the damage and casualties sustained by a locality. Thus, a single typhoon of intensity reaching 180 kph would inflict less damage than two typhoons of intensity reaching only 120 kph hitting the locality.

Conclusion

The reported damage (D) and a number of casualties (C) for typhoons hitting the Philippines since 1960 were observed to obey an exponential distribution. The corresponding fractal random variables to these exponential variates were interpreted as X, the economic impact of the damage (D) and Y, the number of people affected by the casualty (C). While damage (D) and a number of casualties (C) were found to be significantly correlated, economic impact (X) and the number of people affected by the casualty (Y) were not. In order that these two latter variables be correlated, it is necessary to obtain more detailed information about the casualty (C) , example, if the casualty is a breadwinner or not. Likewise, the intensity of typhoons hitting a locality is not sufficient to predict both damage and casualty. The combination of frequency and intensity (how often a typhoon of certain intensity hits the locality) does predict both damage and casualty more efficiently.

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