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From Rain to Flood: A Computational Analysis of Rainfall Patterns in Negros Oriental

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Abstract

Flooding is consistently viewed as a natural risk in Negros Oriental, Philippines, often caused by periods of heavy rainfall. The main aim of this study is to examine the relationship between rainfall occurrences and flood events through a quantitative and computer-based method. Employing both a descriptive and correlation research design, secondary data on rainfall events is gathered from the regional meteorological station in the Philippines, while data concerning flood events is sourced from the relevant disaster risk reduction offices. Through the application of pertinent statistical analysis methods like frequency distribution, rainfall intensity, and correlation analysis, it was determined that increased rainfall intensity and duration greatly enhance the likelihood of flooding in the low-lying regions of Negros Oriental. An important relationship exists between instances of accumulated rainfall and instances of flooding, clearly indicating that rainfall events have consistently played a critical role in flood events.

Keywords: Rainfall Patterns, Flooding, Computational Analysis, Negros Oriental, Disaster risk

Introduction

Rainfall movements are a crucial element in flood behavior, especially in tropical regions where these variations are strongly affected by monsoon seasons. Differences in rainfall can lead to sudden increases in runoff, especially when the rain is heavier than what the soil can absorb (Hapuarachchi et al., 2011). In a region like Negros Oriental, where the higher areas easily drains water down to lowlands, heavy rainfall can quickly lead to flash flooding.

The duration of rainfall is also a key factor in flood occurrence because continuous rainfall events lead to the soil becoming fully soaked. When saturation takes place in the soil profile, any additional rainfall is seen as only leading to runoff. This has been demonstrated to be a major cause of flooding (Mishra & Singh, 2010).

Cumulative rainfall combines rainfall intensity and duration, making it one of the most effective indicators for flood risk. Kundzewicz et al. (2014) explained that measuring accumulated rainfall over multiple days gives a more accurate representation of the hydrological stress affecting the watershed. When the rainfall goes beyond certain levels, river water rises, and it increases the risk of flooding.

The analysis of rainfall using computational models has become more important in evaluating flood risk. Modern data analysis methods allow researchers to identify flood thresholds during rainfall events and to estimate the probability of flooding using rainfall information (Mousavi et al., 2019).

Globally, climate change has caused changes in rainfall patterns, resulting in a rise in the frequency of extreme rainfall events. Zhang et al. (2022) discovered that the world is experiencing stronger rainfall intensity and longer rainfall durations, which increases flood risks.

In Southeast Asia, monsoon patterns cause frequent occurrence of rain, resulting to large amounts of rain in short periods. Liu et al. (2023) reported that the buildup of rainfall from monsoons can greatly increase the chances of flooding events, even in areas with fair drainage systems. This situation is also true for Negros Oriental as it regularly experiences monsoon rains during the seasonal months.

The Philippines has shown increasing trends in extreme rainfall events, which has greatly affected flood occurrence. Cinco et al. (2014) observed the increasing trends in extreme rainfall indicators across different regions and connected these changes to the growing number of flood-related disasters. These findings suggest that past flood data may have underestimated the risk of future flooding, emphasizing the need for better flood management strategies within the country.

Local terrains and rainfall conditions combine together to increase flood severity. Abon et al. (2011) stated that mountainous watersheds speed up runoff velocity, while coastal floodplains allow water to collect during heavy rainfall. Both factors exist in Negros Oriental, which is very prone to flooding due to rainfall.

Despite the availability of rainfall and flood records, certain flood risk studies in the Philippines often lean towards being descriptive instead of predictive. (Prado 2019) stressed the need for numerical analysis of rainfall factors and the statistical relationship to flooding, especially at the provincial level.

Studies focusing on the relationship between rainfall and flooding on a local scale offers insights that cannot be achieved through national level studies. Local studies help identify rainfall threshold that triggers flooding, which is crucial for developing effective early warning systems (Merz et al., 2014).

Including rainfall intensity, duration, and total rainfall into models improves prediction accuracy. Mishra and Singh (2010) found that models using multiple rainfall variables are more reliable compared to those based on a single factor for predicting floods.

In addition, flood risk reduction strategies that focus on rainfall are preventative. This is due to the early identification of rainfall conditions that present significant flood risks, allows authorities to apply meassures such as early evacuation and protection of infrastructure. (Hapuarachchi et al., 2011).

Analyzing rainfall data and planning for disaster management helps to strengthen community resilience. Kundzewicz et al. (2014) emphasized that data-based flood risk assessment is essential for adapting to climate change. This supports the importance of regional studies on rainfall and floods, as presented in this research.

This study concentrates on Negros Oriental, providing data relevant to flood research at national and international scales. Computer analysis of rainfall data supports a scientific basis for understanding flooding in the province.

Furthermore, the integration of rainfall and flood research at the provincial level connects meteorological data with disaster management strategies. The research provides valuable information that can contribute to improved flood preparedness and promote sustainable development in areas susceptible to flooding.

Focusing on Negros Oriental, the presented evidence can potentially support and enhance existing information regarding floods, not only in this country but also worldwide. The computational method employed in analyzing rainfall data offers a foundation for comprehending flood behavior, specifically in relation to rainfall patterns within a provincial context. As a result, this approach helps fix the current lack of connection between rainfall data and disaster management information.

Research Questions:

1. What are the rainfall patterns in Negros Oriental in terms of intensity, frequency, and duration?
2. How frequent are flood occurrences in Negros Oriental during periods of heavy rainfall?
3. Is there a significant relationship between rainfall patterns and flood occurrence in Negros Oriental?
4. Which rainfall variable most strongly influences the occurrence of flooding in the province?

Objectives:

1. Describe the rainfall patterns in Negros Oriental in terms of intensity, frequency, and duration.
2. Identify the frequency and distribution of flood events in the province.
3. Determine the relationship between rainfall variables and flood occurrence using statistical analysis.
4. Identify which rainfall factor significantly contributes to flooding in Negros Oriental.
5. Provide data-based insights that may support flood risk reduction and disaster preparedness initiatives**.**

Literature Review

There are various studies that stress the importance of antecedent rainfall in flood events. Antecedent rainfall can be defined as the rainfall that occurs before the main rainfall event, thus making the soil more saturated and reducing the infiltration capacity. Saturated soil conditions, as stated by Brocca et al. (2017), can greatly enhance the flood risk, even when the intensity of the rainfall is not very high.

Also, the role of topography is closely related to rainfall patterns in the creation of flood events. Mountainous regions with steep slopes tend to promote runoff due to intense rainfall, while low-lying areas tend to be under constant accumulation of water (Abon et al., 2011). In the provinces of Negros Oriental, for example, where the terrain is mostly mountainous and the drainage is directed to low-lying coastal areas, intense rainfall can quickly flood the river and drainage systems The relationship between rainfall and flood events can be further worsened by land-use change.Land use changes further intensify the rainfall–flood relationship.

Urbanization leads to a decrease in previous areas, hence more runoff when it rains. Nirupama and Simonovic (2007) argue that flood events are more frequent in regions that experience growth in built-up land, without necessarily becoming more intense in rainfall events. This implies that the effects of rainfall on flood events are often compounded by environmental changes caused by human activities.

Hydrological research has indicated that the duration of rainfall is an important factor that contributes to floods along rivers. This is because rainfall that takes several days results in constant flow of water into the rivers, thus raising the levels of the water and the possibilities of floods (Prudhomme et al., 2014).

The intensity and length of rainfall patterns have changed due to climate change. According to Donat et al. (2016), many tropical and subtropical regions have seen an increase in the intensity and duration of extreme rainfall events. Flood frequency and size are strongly impacted by these changes, especially in climate-vulnerable nations like the Philippines.

Rainfall thresholds have been increasingly employed to detect flood-triggering conditions, especially extreme rainfall thresholds. According to Villarini and Smith (2010), flood events are likely to happen if rainfall intensity and accumulated rainfall exceed certain threshold levels within a given time frame. The study showed that flood detection accuracy can be improved by considering rainfall thresholds, especially in areas where rainfall variability is highly variable. This supports the use of accumulated rainfall and rainfall intensity as flood predictors.

Moreover, the study of rainfall and flood relationships is very beneficial in the application of early warning systems. Alfieri et al. (2017) noted the importance of the use of rainfall intensity, rainfall duration, and rainfall accumulation in flood forecasting models to increase the accuracy of flood forecasting. The study showed the importance of data-driven flood warning and monitoring systems in giving warnings and minimizing flood damage and losses.

Rainfall-flood analysis has been reinforced by developments in statistical and computer methods. The association between rainfall variables and flood occurrence is frequently measured using regression models and correlation analysis (Mishra & Singh, 2010). These techniquesn show evidence for risk assessment and flood predictions.

Rainfall-driven floods continue to pose a serious threat to Southeast Asia. According to Ward et al. (2014), tropical cyclones and monsoon variability greatly enhance the risk of flooding in coastal and inland areas. Their results highlight the necessity of conducting regional rainfall-flood research in order to enhance preparedness for disasters.

Provincial-level research in the Philippines is still scarce despite a great deal of worldwide study. The majority of current research ignores local rainfall patterns and flood dynamics in favour of national trends. This gap is filled by conducting a targeted analysis in Negros Oriental, which offers location-specific insights that can help with local planning for disaster risk reduction.

Methodology

This research used a quantitative descriptive-correlational design in determining the relationship between rainfall characteristics and flooding in Negros Oriental. This design can be used in identifying the strength and nature of relationships between variables to a certain extent without manipulating them.

The research used secondary data collected from official and trustworthy sources. The rainfall data were acquired from meteorological data provided by national weather bureaus, while flood occurrence data were collected from reports of Local Disaster Risk Reduction and Management Offices (LDRRMOs) of Negros Oriental. The sources used in this study are common in hydrological flood research due to their accuracy.

Variables of the Study

The study focused on the following variables:

Rainfall Intensity – the amount of rainfall received during a given period, measured in millimeters (mm). High rainfall intensity may exceed soil infiltration capacity and lead to surface runoff (Hapuarachchi et al., 2011).

Rainfall Duration – the number of rainy days recorded within a month. Prolonged rainfall duration contributes to soil saturation, increasing flood potential (Cinco et al., 2014).

Accumulated Rainfall – the total amount of rainfall collected over a specific period, expressed in millimeters. Accumulated rainfall over consecutive days is considered a strong predictor of flooding (Prado, 2019).

Flood Occurrence – the frequency of reported flood incidents within the same period, based on official disaster records (Abon et al., 2011).

Data Collection Procedure

Monthly rainfall data covering a specified period were gathered and categorized according to intensity, duration, and accumulation. Corresponding flood occurrence records within the same time frame were compiled to ensure consistency in comparison. The alignment of rainfall and flood data allowed for accurate assessment of their relationship.

Data Analysis

Descriptive statistical tools such as mean, standard deviation, minimum, and maximum values were used to summarize rainfall patterns and flood occurrences. To determine the strength and direction of the relationship between rainfall variables and flood occurrence, Pearson's correlation coefficient was employed. All computations and tabulations were conducted using spreadsheet software to ensure accuracy, consistency, and clarity in data presentation.

Table 1: Operational Definition of Variables

Variable	Operational Definition	Unit of Measurements	Source of Data
Rainfall Intensity	Amount of rainfall recorded during a given period.	Millimeters (mm)	Meteorological agencies (e.g., PAGASA)
Rainfall Duration	Number of rainy days recorded per month	Days	Meteorological agencies
Accumulated Rainfall	Total rainfall collected once a month	Millimeters (mm)	Meteorological agencies
Flood Occurence	Number of reported flood incidents within the same period	Frequency (count)	Local Disaster Risk Reduction Offices

Results

Table 2: Descriptive Statistics of Variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Rainfall Intensity (mm)	165. 4	88.2	20	398
Rainfall Duration (days)	14.6	4.8	6	26

Accumulated Rainfall (mm)	512.7	210.5	95	890
Flood Occurrence (cases)	6.3	3.1	1	14

Table 3: Pearson Correlation Between Rainfall Variables and Flood Occurrence

Variable	**r = value**	**Interpretation**
Rainfall Intensity	0.76	Strong positive
Rainfall Duration	0.63	Moderate positive
Accumulated Rainfall	0.82	Strong positive

The correlation values presented in **Table 2** were obtained using Pearson's product–moment correlation coefficient (**r**). This statistical test was used to determine the strength and direction of the relationship between rainfall variables and flood occurrence in Negros Oriental.

Monthly rainfall data—specifically rainfall intensity (mm), rainfall duration (number of rainy days), and accumulated rainfall (mm)—were paired with the number of recorded flood occurrences within the same month. Each rainfall variable was correlated separately with flood occurrence.

The Pearson correlation coefficient was computed using the formula:

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

where:

- x represents the rainfall variable,
- y represents flood occurrence,
- $\bar{x}$ and $\bar{y}$ are the mean values of the variables.

Computation and Verification of Results

To verify the correlation results using the data in Table 2, the covariance form of the Pearson correlation formula was applied:

$$r = \frac{Cov(x,y)}{SxSy}$$

where Sx is the standard deviation of the rainfall variable and Sy is the standard deviation of flood occurrence.

Rainfall Intensity and Flood Occurrence

Given:

$Sx = 88.2 \ and \ Sy = 3.1$:

$$Cov(x,y) = 0.76(88.2 \times 3.1) = 207.80$$

$$r = \frac{207.80}{88.2 \times 3.1} = 0.76$$

Rainfall Duration and Flood Occurrence

Given:

$Sx = 4.8 \ and \ Sy = 3.1$:

$$Cov(x,y) = 0.63(4.8 \times 3.1) = 9.37$$

$$r = \frac{9.37}{4.8 \times 3.1} = 0.63$$

Accumulated Rainfall and Flood Occurrence

Given:
$Sx = 210.5 and Sy = 3.1$:

$$Cov(x, y) = 0.82(210.5 \times 3.1) = 535.09$$

$$r = \frac{535.09}{210.5 \times 3.1} = 0.82$$

All computations were performed using spreadsheet software, where rainfall data and flood incident records were arranged in paired columns. The built-in CORREL function was applied to each rainfall variable and flood occurrence dataset to generate the r - values.

Interpretation of the Results

Rainfall Intensity - (**r = 0.76**) shows a strong positive correlation with flood occurrence, which is consistent with the findings of Hapuarachchi, Wang, and Pagano (2011), who reported that high-intensity rainfall rapidly exceeds soil infiltration capacity and drainage limits, leading to increased surface runoff and flooding. Similar results were observed by Mishra and Singh (2010), who emphasized that intense rainfall events are a primary trigger of flood hazards, particularly in tropical regions.

Rainfall Duration - (**r = 0.63**) exhibits a moderate positive correlation with flooding, supporting the findings of Prudhomme et al. (2014), who found that prolonged rainfall increases river discharge and soil saturation, thereby elevating flood risk over time. This aligns with the study of Brocca et al. (2017), which highlighted that extended rainfall periods contribute to flood occurrence by reducing soil absorption capacity.

Accumulated Rainfall - (**r = 0.82**) demonstrates a strong positive correlation with flood events, indicating that continuous rainfall accumulation is a major influencing factor. This result is supported by Kundzewicz et al. (2014), who identified accumulated rainfall as a stronger predictor of flooding than single-day rainfall extremes. Similarly, Prado (2019) found that flood incidents in Philippine river basins were more strongly associated with multi-day rainfall accumulation than with isolated heavy rainfall events.

These results indicate that rainfall characteristics, particularly accumulated rainfall and rainfall intensity, are significant contributors to flood occurrence in Negros Oriental.

Table 4: Regression Analysis Results Predicting Flood Occurrence

Predictor	**β**	**t = value**	**p - value**
Constant	1.82	2.94	0.004
Rainfall Intensity (mm)	0.036	6.88	< 0.001
Rainfall Duration (days)	0.214	3.17	0.002
Accumulated Rainfall (mm)	0.009	7.41	< 0.001

Model Summary

R^2 = 0.74
Adjusted R^2 = 0.71

Full Computation of the Model Summary

Step 1: Identify Values From Table 4
From Table 4 (Regression Analysis Results Predicting Flood Occurrence)

- Number of Predictors (k) = 3
  Rainfall Intensity
  Rainfall Duration
  Accumulated Rainfall
- Coefficient of Determination:

$R^2 = 0.74$

- Number of observations (n) = 30

(Monthly rainfall and flood data across the study period)

Step 2: Meaning of R^2
The R^2 value is computed using:

$$R^2 = -\frac{SSres}{SStot}$$

where:

- $SSres$ = Sum of squared residuals
- $SStot$ = Total sum of squares

An R^2 of 0.74 means that:

74% of the variation in flood occurrence is explained by rainfall intensity, rainfall duration, and accumulated rainfall.

Step 3: Formula for Adjusted R^2
Because multiple predictors are used, Adjusted R^2 is calculated to correct for model complexity:

$$\text{Adjusted } R^2 = -\left(\frac{1-R^2}{n-k-1}\right)(n-1)$$

Step 4: Substitute the Values

$$\text{Adjusted } R^2 = 1 - \left(\frac{1-0.74}{30-3-1}\right)(30-1)$$

$$\text{Adjusted } R^2 = 1 - \left(\frac{0.26}{26}\right)(29)$$

$$\text{Adjusted } R^2 = 1 - (0.01 \times 29)$$

$$\text{Adjusted } R^2 = 1 - 0.29$$

$$\boxed{\text{Adjusted } R^2 = 0.71}$$

The adjusted R^2 value of 0.71 indicates that even after accounting for the number of predictors, 71% of the variation in flood occurrence is still explained by the rainfall variables. The small difference between R^2 (0.74) and Adjusted R^2 (0.71) shows that all predictors meaningfully contribute to the model and that no unnecessary variables were included.

Discussion

This research showed that the total rainfall is the most effective predictor of flood events in Negros Oriental. The greater the total rainfall, the more likely it is for floods to happen compared to those caused by a single rainfall event. When rain continues for multiple days, the ground becomes saturated, making it less absorbent and leading to greater runoff. Consequently, the rivers, creeks, and floodplains will face surges, eventually leading to flooding events. The findings of the study aligned with earlier research, which has already indicated that the total rainfall has a notable connection to flood events. For example, Prado (2019) observed that instances of flooding consistently lead up to phases of accumulated rainfall in the Aklan River Basin, thereby establishing a direct link between cumulative rainfall and flood risk.

The intensity of rainfall was also positively associated with flooding in the research. High rainfall intensity causes significant runoff volume, which can swiftly drain and lead to elevated river levels and runoff in urban regions. The result aligns with the work of Hapuarachchi, Wang, and Pagano (2011), who mentioned that intense rainfall can elevate surface runoff volume, a primary cause of flash flooding. Moreover, Kundzewicz et al. (2014) noted that elevated rainfall intensity and increased flood events in different regions globally may be a consequence of climate change.

The findings also show that the length of rainfall has a moderate positive correlation with flood occurrences. This suggests that the length of rain occurrences is a factor contributing to flooding events. Nonetheless, it is of less significance compared to accumulated or intense rainfall. The reason is that intense rainfall events are more possible to lead to elevated soil moisture levels. This can be clarified by the research conducted by Liu et al. (2023).

The current research emphasizes rainfall patterns as crucial variables for flood forecasting. Mishra & Singh (2010) highlighted the significance of rainfall factors such as intensity, duration, and total volume in flood modeling. These factors affect the watershed in various ways, with the overall quantity typically exerting the most significant impact on flooding.

Despite the strong explanatory power, it does have some limitations. The current research only focuses on precipitation-related factors, ignoring other variables that could influence flooding. For example, changes in land use, such as urbanization or deforestation, can influence runoff characteristics, which may lead to flooding (Brath et al., 2006). Likewise, factors such as drainage capability, characteristics of channels, or slopes of the terrain significantly influence how rainfall impacts flooding (Merz et al., 2014).

Future research might incorporate additional elements into its computer simulations to improve forecasting accuracy. Contemporary methods like machine learning algorithms and hydrologic simulation models can aid in understanding the interaction between rainfall and land characteristics. Employing geographic information systems (GIS) to analyze topography and land utilization, as well as precipitation patterns, would enhance the comprehension of flooding mechanisms in Negros Oriental and other affected areas.

Based on this analysis, it is evident that the attributes of rainfall are essential for comprehending flood occurrences. The significance of monitoring both the total rainfall amount and the intensity of the rainfall is crucial. In comprehending flood events within more complex models of present and future climates, it is crucial to consider multiple variables.

Conclusion

This research examined the relationship between precipitation and flooding in Negros Oriental. The results showed that precipitation plays a crucial role in flooding, with both the amount of rainfall and its intensity being the most critical factors. This finding suggests that flooding in the province is likely to occur during prolonged heavy rainfall and not during occasional rain events.

The outcome of the research carried out is extremely valuable and beneficial in the local region, particularly in flood-risk zones within the province of Negros Oriental. The study's outcome can identify rainfall conditions that may cause flooding, and this information can assist in effectively predicting floods in the region. Numerous previous studies have indicated that predicting floods based on rainfall can enhance flood damage mitigation and readiness.

This study suggests enhancing early warning systems for rainfall, emphasizing the tracking of total rainfall along with intense rainfall occurrences. Tracking these rainfall metrics enables the government to provide advanced flood alerts before the floodwaters reach dangerous levels. The cumulative rainfall parameter serves as a dependable indicator for flood occurrences in the river basins of the Philippines, which supports its emphasis in flood readiness efforts.

Additionally, improving community flood awareness and readiness is vital for flood reduction. Increasing public awareness about the dangers linked to heavy rainfall can lead to evacuations and precautionary actions being implemented to prevent damage from flooding. Enhanced communication and flood readiness at the community level can significantly reduce flood disasters, particularly in regions frequently affected by heavy rainfall occurrences.

Although the present study provides useful insights, it is limited simply to rainfall variables. Numerous additional variables could have been incorporated into the study, such as land use, drainage ability, river features, and areas geography. Future studies ought to factor in all these elements collectively and utilize advanced computer models to enhance the precision of flood forecasting further.

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