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Geospatial Mapping Of Strongest Typhoon And Casualties With Predictive Analysis Using Linear Regression

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Abstract— *This study examines the strongest typhoons in the Philippines between 2013 and 2022, analyzing their paths, wind speeds, and casualties. Using geospatial mapping and linear regression, we predict future typhoon trajectories and identify high-risk areas. Eastern Visayas emerges as the most affected region, highlighting the need for targeted disaster preparedness. The findings offer valuable insights for disaster management agencies to enhance resilience and reduce casualties in typhoon-prone areas, especially in light of increasing storm intensity due to climate change.*
Keywords— *Typhoons, Philippines, Geospatial Mapping, Linear Regression, Disaster Management, Casualties, Predictive Analysis.*

INTRODUCTION

The Philippines is within the Pacific Typhoon Belt, making it highly susceptible to the disastrous effects of typhoons. It is particularly vulnerable to tropical cyclones due to its geographic location and socio-economic conditions [7]. Severe storms can lead to huge casualties and destruction, hence the need for effective disaster management strategies. Geospatial mapping and predictive analysis are important tools in understanding the impact of these storms and ensuring timely responses. Geospatial analysis involves the use of geographic data to visualize and analyze spatial relationships and patterns [5]. This study mapped the strong typhoons between 2013 and 2022, specifying the track of the storms, the strength, and the resultant casualties. In doing so, it hopes to address the gap in the literature, as previous works have covered all typhoons or used complex forecasting models. The study uses a less complex approach with linear regression and geospatial mapping, thus allowing for more straightforward and accessible analysis.

Existing research on typhoon patterns in the Philippines often looks at broader trends or utilizes complex models like dynamic simulations or artificial intelligence algorithms to predict typhoon paths [2].

However, the gap in the current body of knowledge lies in the lack of specific studies that focus on the strongest storms within a defined period. By focusing on the strongest typhoons, this study offers a more manageable yet focused approach to understanding the relationship between typhoon intensity and casualties.

This study makes use of historical data and uses linear regression to predict future typhoon paths. Geospatial mapping can then visualize the population and infrastructure impact of such storms [6]. Such methodology is straightforward, offering actionable insights for local government units and disaster management agencies in the Philippines, particularly for real-time disaster preparedness and response. This research contributes to enhancing disaster management strategies in the light of increasing frequency and intensity of typhoons due to climate change. That will provide valuable information that could help mitigate casualties and improve disaster resilience in typhoon-prone regions [8].

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METHODOLOGY

The conceptual diagram represents the process of analyzing typhoon paths and casualties from 2013 to 2022 using data-driven and geospatial methods. The workflow begins by collecting typhoon path data and casualty reports, which are grouped by region and stored in CSV format. The typhoon path data undergoes preprocessing, transformation, and linear regression to perform analysis and predict future storm paths. Simultaneously, casualty data is collected, grouped by region, and then integrated into the workflow to provide insights into the impact of the strongest storms. Using QGIS, the casualty data and predicted typhoon paths are visualized on a map.

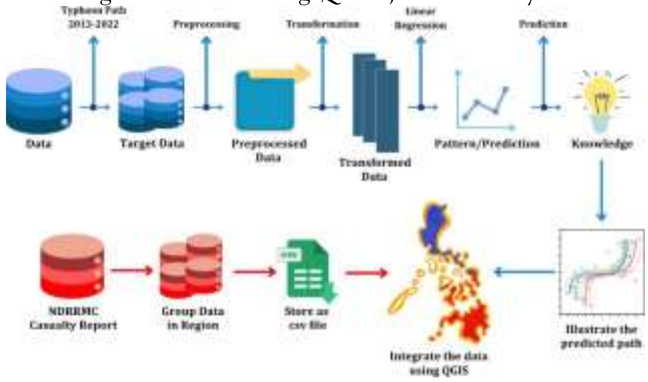

Fig. 1. Conceptual Diagram

A. *Data Description*

Data for this study is being collected from the Typhoon Track Database (1980–2024). The collected data will include the following variables:

- **SEASON:** The year in which the typhoon occurred
- **NAME:** The international name of the typhoon provided by the agency.
- **ISO_TIME:** The date and time of the typhoon, recorded in Universal Time Coordinated (UTC), in the format YYYY-MM-DD HH:mm:ss, with most points recorded at 3-hour intervals.
- **LAT:** The latitude, representing the degree north of the Equator.
- **LON:** The longitude, representing the degree east of the Prime Meridian.
- **USA_WIND:** The maximum sustained wind speed of the typhoon, measured in knots.
- **STORM_SPD:** The translation speed of the typhoon, calculated based on changes in its position (latitude and longitude).
- **USA_PRES:** The minimum sea level pressure of the typhoon. Additionally, data on casualties will be sourced from the National Disaster Risk Reduction and Management Council (NDRRMC) reports and cross-verified with relevant news articles to ensure accuracy and reliability

B. *Data Preprocessing*

Before the analysis and prediction of typhoon paths, the data underwent several preprocessing steps to ensure consistency, quality, and suitability for analysis

- **Handling Missing Values:** The dataset was examined for missing values, and rows with missing data were removed to ensure the dataset used for analysis was complete and reliable.
- **Converting Time Format:** The ISO_TIME column, which contained the timestamp of each observation, was converted into a proper datetime format.
- **Temporal Transformation:** A new feature, Time, was created to represent the number of hours elapsed since the first recorded observation for each typhoon, enabling the analysis of its progression over time.

C. *Tools and Software*

The study employed several technological tools and software for data processing, analysis, and visualization, including:

- **QGIS -** For geospatial mapping and visualizing typhoon paths.
- **Jupyter Notebook –** A web-based environment for executing Python code and conducting data analysis and visualization.

- **Scikit-learn** - A Python library for data analysis and prediction, with sklearn.linear_model used in this study to apply Linear Regression.
- **Pandas** - Used for data manipulation and analysis in Python, allowing efficient handling and processing of structured data.
- **NumPy** - Used for scientific computing in Python, providing support for large multidimensional arrays and matrices along with mathematical functions.
- **Matplotlib** - Used for creating a variety of plots, charts, and visualizations in Python.
- **Excel** - Used for organizing, storing, verifying data, and entering casualty information.

D. Limitations

This research focuses solely on the strongest typhoons that occurred between 2013 and 2022, excluding other typhoons from those years. The study aims to predict the future paths of these typhoons, rather than creating a predictive model. As a result, it does not explore the broader range of typhoon characteristics or modeling techniques. Additionally, the findings are limited to the data available for the specified period and do not account for potential variations outside this timeframe.

RESULTS AND DISCUSSION

Before analyzing the trajectory of the typhoons, let us first discuss their characteristics. Figure 2 illustrates the wind speed and storm speed of the strongest typhoons. In terms of wind speed, Typhoon Haiyan and Typhoon Goni stand out as the strongest, each reaching a maximum wind speed of 170 km/h, followed closely by Typhoon Mangkhut at 155 km/h and Typhoon Rai at 150 km/h. Regarding storm speed, Typhoon Haiyan is the fastest, with a storm speed of 25 km/h, followed by Typhoon Rammasun at 19 km/h, while Typhoon Mangkhut and Typhoon Rai share a storm speed of 18 km/h.

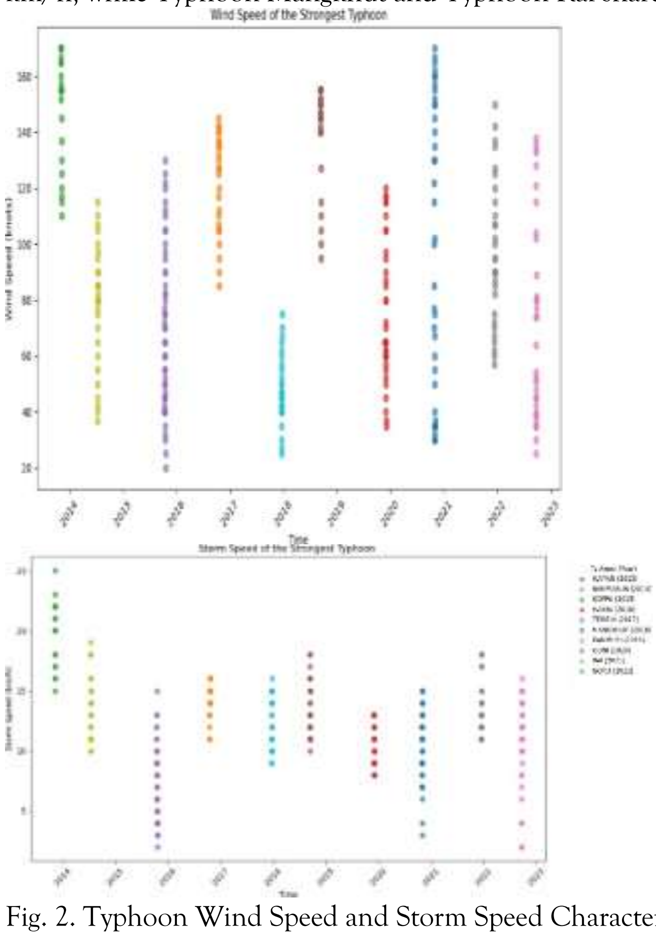

Fig. 2. Typhoon Wind Speed and Storm Speed Characteristics

Figure 3 illustrates the trajectory of the strongest typhoons from 2013 to 2022. The region's most frequently traversed by these typhoons, being hit at least twice, include the Ilocos Region, Cordillera Administrative Region (CAR), Cagayan Valley, CALABARZON, Bicol Region, MIMAROPA Region, as well as Central, Western, and Eastern Visayas. The northern Luzon regions generally experience fewer casualties from typhoon paths, partly because the Sierra Madre Mountain Range acts as a natural barrier, mitigating the intensity of storms that hit these areas [1]. The Sierra Madre helps shield northern Luzon, particularly Cagayan Valley and the Ilocos Region, from the full impact of typhoons. On the other hand, the Eastern Visayas region, which lies in the direct path of typhoons, tends to experience higher casualties due to its geographical vulnerability and the intense nature of storms hitting this area [3][4]. The Bicol Region and other affected areas also experience significant losses due to their exposure to strong typhoons and the challenges of preparedness and resilience [4].

In terms of casualties, the hardest-hit region is Eastern Visayas, with 5,924 deaths, followed by Western Visayas with 340 deaths and Central Visayas with 326 deaths. Notable casualties are also observed in the northern part of the Philippines, including the Cordillera Administrative Region with 144 deaths and Cagayan Valley with 16 deaths and Ilocos Region with 11 deaths.

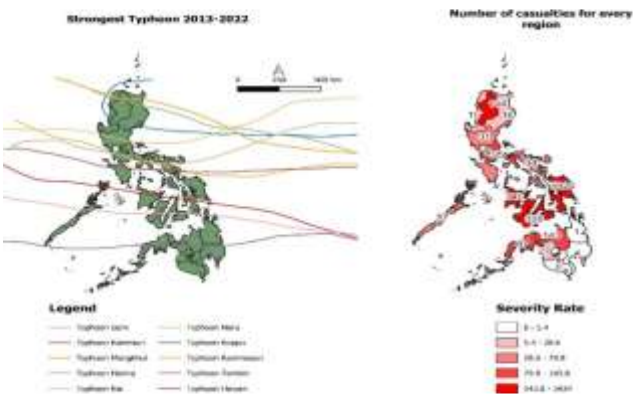

Fig. 3. Typhoon Path and Casualties in the Philippines (2013-2022)

Figure 4 illustrates the predicted typhoon trajectory. The typhoon path prediction is based on the actual paths of the strongest typhoons, utilizing data such as ISO_TIME (converted to hours), USA_WIND (wind speed in knots), USA_PRES (pressure in millibars), and STORM_SPD (storm speed in km/h). These features are used in a linear regression model to predict the typhoon's trajectory, specifically its Latitude and Longitude over time. Similarly, the wind speed prediction model also incorporates the features ISO_TIME (converted to hours), USA_PRES (pressure in millibars), and STORM_SPD (storm speed in km/h). This approach helps simulate the typhoon's movement over time, offering valuable insights into its projected path and the regions that may be impacted. This approach aligns with recent advancements in meteorological forecasting, where the use of machine learning models has proven effective in enhancing the accuracy of cyclone predictions. [9] Applied similar data in their study, utilizing deep learning models to predict typhoon trajectories and wind speeds, which supports the use of regression models in simulating the behavior of typhoons over time.

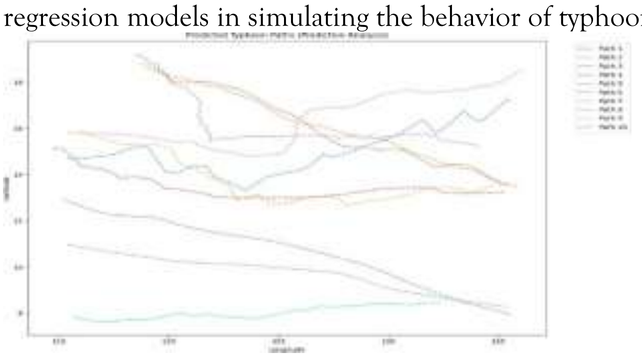

Fig. 4. Predicted Typhoon Path

Figure 5 displays a map of the Philippines overlaid with predicted typhoon paths and corresponding wind speed intensities, with the map colors representing the level of casualties in different regions. Each typhoon path is represented by a series of colored dots, with the color indicating the wind speed range at that specific point. This type of visual representation has been commonly used in recent studies to combine geographical data with cyclone intensity and casualty information, enhancing understanding of the impacts in different regions [10].

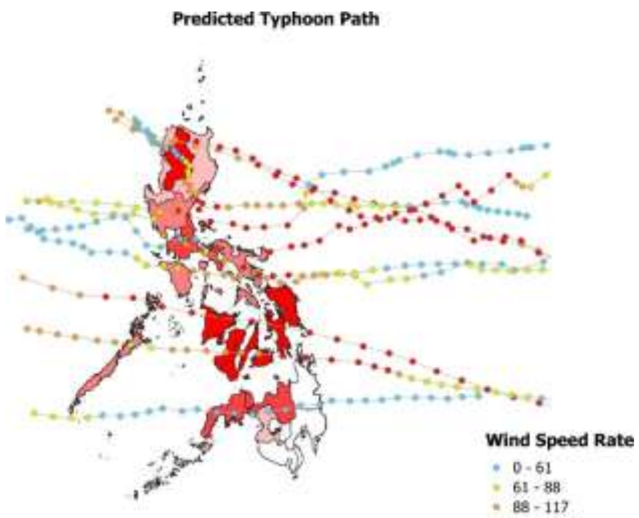

Fig. 5. Projected Typhoon Path and Wind Speed Levels in the Philippines

CONCLUSION

This study analyzed the strongest typhoons in the Philippines from 2013 to 2022, focusing on their paths, wind speeds, and casualties. Using geospatial mapping, the researchers visualized the most affected regions, including the Ilocos Region, Cordillera Administrative Region (CAR), Cagayan Valley, CALABARZON, Bicol Region, MIMAROPA Region, and Central, Western, and Eastern Visayas, which were hit multiple times by strong typhoons. Additionally, linear regression was employed to predict future typhoon paths based on factors such as time, wind speed, pressure, and storm speed. The predicted paths and corresponding wind intensities were visualized on a map, providing valuable insights for disaster preparedness and helping authorities anticipate potential risks to mitigate the effects of future typhoons. The study contributes to enhancing disaster management strategies in the Philippines, particularly in light of increasing typhoon frequency and intensity due to climate change.

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