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GIS-Based Analysis of Factors Associated with Flood Risk in Sta. Rosa, Nueva Ecija

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ABSTRACT: Flooding is one of the most common environmental hazards in low-lying areas of the Philippines, particularly in agricultural municipalities such as Sta. Rosa. This study used Geographic Information Systems (GIS)-based spatial analysis to examine the association between selected physical and environmental factors and the flood risk categories of barangays in Sta. Rosa. Secondary datasets from Project Noah, PAGASA, NAMRIA, and OpenStreetMap were analyzed to evaluate elevation, slope, land use/land cover (LULC), distance from river channels, and rainfall in relation to flood susceptibility. Spearman Rank Correlation was used to determine the strength of association between the selected variables and flood risk categories. Results showed that elevation showed the strongest observed association with flood risk, followed by slope, indicating that low-lying and flatter areas are showed higher observed flood susceptibility. The findings highlight the importance of GIS-based spatial analysis in supporting preliminary flood risk assessment and local disaster mitigation planning.

KEYWORDS: Flooding, Geographic Information Systems (GIS), Flood Susceptibility, Elevation, Slope, Spatial Analysis

I. INTRODUCTION

II. 1.1 Background of the Study

Flooding is one of the most common natural hazards in the Philippines due to heavy rainfall brought by typhoons and monsoon systems. Low-lying areas in Central Luzon, particularly in Nueva Ecija, are highly vulnerable to flooding because they serve as catchment areas for runoff from surrounding rivers and upland areas. Flooding causes damage to communities, agricultural lands, transportation networks, and public infrastructure.

The municipality of Sta. Rosa frequently experiences flooding because of its flat terrain, low elevation, and proximity to major river systems such as the Pampanga River and Rio Chico River. Several barangays are affected during heavy rainfall events, causing disruptions to transportation, livelihood, and public safety. These conditions highlight the need to better understand the factors contributing to flood susceptibility within the municipality.

Flood susceptibility is influenced by several physical and environmental factors including elevation, slope, land use/land cover (LULC), distance from river channels, and rainfall. Geographic Information Systems (GIS) provide an effective tool for analyzing these factors through spatial analysis and hazard mapping. Although flood hazard maps are available through Project NOAH, limited localized barangay-level studies have examined the statistical relationship between these physical and environmental factors and flood risk categories in Sta. Rosa.

This study aims to analyze the association between selected physical and environmental factors and the flood risk categories of barangays in Sta. Rosa using GIS-based spatial analysis. The findings of the study may support preliminary flood risk assessment, disaster preparedness, and local flood mitigation planning.

1.2 Statement of the Problem

This study aims to examine the relationship between selected physical and environmental factors and the flood risk categories of barangays in Sta. Rosa, Nueva Ecija using Geographic Information Systems (GIS) and existing hazard data from Project NOAH.

Specifically, this study seeks to answer the following questions:

1. What are the flood risk categories of the barangays in Sta. Rosa, Nueva Ecija based on Project NOAH data?
2. What are the spatial characteristics of each barangay in terms of:
   - elevation
   - slope
   - land use/land cover (LULC)
   - distance from river channels
   - rainfall
3. How are these selected factors associated with the flood risk categories of the barangays?
4. Which of the selected factors shows the strongest association with flood risk at the barangay level?

5. How can the identified relationships between physical factors and flood risk be used to support local planning and flood mitigation efforts?

1.3 Objectives of the Study

The main objective of this study is to analyze the association between selected physical and environmental factors and the flood risk categories of barangays in Sta. Rosa using GIS-based spatial analysis.

Specifically, the study aims to:

1. Identify the flood risk categories of the barangays in Sta. Rosa using data from project NOAH.
2. Quantify and map the selected physical and environmental factors, including elevation, slope, land use/land cover (LULC), distance from river channels, and rainfall at the barangay level.
3. Analyze the relationship between each selected physical and environmental factor and the flood risk categories using appropriate statistical and spatial analysis methods.
4. Rank the selected physical and environmental factors based on the strength of their association with flood risk.
5. Provide insights that may assist local government units (LGUs) and planners in identifying priority areas for flood mitigation and management.

1.3 Significance of the Study

This study is beneficial to:

Local Government Units (LGUs). This study may assist local planners and decision-makers in identifying flood-prone barangays and prioritizing flood mitigation projects and land-use planning strategies.

Municipal Disaster Risk Reduction and Management Office (MDRRMO). This study may support disaster preparedness planning and flood risk reduction programs through GIS-based spatial analysis.

Civil Engineers and Planners. This study provides baseline information regarding the environmental factors associated with flood susceptibility that may support preliminary planning and infrastructure assessment.

Students and Researchers. This study demonstrates the application of GIS and spatial analysis in flood risk assessment and may serve as a reference for future studies related to flooding and disaster risk reduction.

1.4 Scope and Limitations

This study focuses on the municipality of Sta. Rosa using barangay-level spatial analysis. The research evaluates elevation, slope, land use/land cover (LULC), distance from river channels, and rainfall using secondary datasets from project NOAH, PAGASA, NAMRIA, andOpenStreetMap. GIS tools were used to process and analyze the spatial distribution of these variables in relation to flood risk categories.

The study is limited to barangay-level association analysis using secondary datasets and does not include hydrologic or hydraulic simulations such as flood depth, flow velocity, and drainage capacity analysis. The study evaluates statistical associations between selected physical and environmental variables and flood risk categories and does not establish direct hydrologic causation. Therefore, the findings are intended only for preliminary flood susceptibility assessment and planning purposes.

II. REVIEW OF RELATED LITERATURE

Flood hazard mapping is an essential tool in disaster risk reduction because it identifies flood-prone areas and supports planning for evacuation, drainage improvement, and flood mitigation projects. Project NOAH uses GIS technologies, LiDAR data, rainfall patterns, river systems, and topographic information to produce flood hazard maps across the Philippines (Lagmay et al., 2017). These maps classify areas into low, moderate, and high hazard zones and provide barangay-level information that improves local disaster preparedness and decision-making (Paringit et al., 2017). However, the effectiveness of hazard maps may still be limited by the quality of available datasets and localized drainage problems such as clogged canals and blocked drainage systems.

Elevation is a major factor influencing flood susceptibility because low-lying areas tend to accumulate water and experience longer flood duration. Cabrera and Lee (2019) stated that elevation is often given the highest weight in GIS flood models due to its strong effect on water retention and flooding. In Sta. Rosa, many areas are located below 25 meters above sea level, making them vulnerable to prolonged flooding as they serve as natural catchment areas for runoff from higher terrain (Mines and Geosciences Bureau, 2022).

Slope affects the movement of surface runoff, where flatter areas drain more slowly and are more prone to water accumulation and prolonged flooding. Rahmati et al. (2016) explained that areas with gentle slopes are often classified as highly flood susceptible. In Sta. Rosa, the predominantly flat to gently sloping terrain limits natural drainage and contributes to slow flood recession after heavy rainfall.

Land Use and Land Cover (LULC) affect flooding by influencing infiltration and surface runoff. Built-up areas such as roads, buildings, and paved surfaces reduce soil permeability, leading to increased runoff and higher flood risk. Rubio et al. (2020) explained that urbanization increases flood susceptibility by altering natural drainage systems, while the Department of Agriculture – Bureau of Soils and Water Management (2020) stated that land conversion and expansion of developed areas contribute to flooding due to reduced soil infiltration.

Geographic Information Systems (GIS) are important in flood studies because they integrate multiple spatial factors for flood analysis and susceptibility mapping. Cabrera and Lee (2019) found that combining elevation, slope, rainfall, and land use through GIS-based multi-criteria analysis improved flood prediction accuracy in Davao Oriental. Similarly, Swain et al. (2020) demonstrated that GIS and weighted overlay methods are effective in identifying and prioritizing flood risk zones for local flood management. GIS also supports barangay-level planning by identifying areas that need drainage improvement, flood control measures, and emergency preparedness.

III. METHODOLOGY

3.1 Research Design

This study employed a quantitative descriptive-correlational research design integrated with Geographic Information Systems (GIS) analysis. This framework was used to analyze the relationship between physical-environmental factors and the established flood hazard levels across the 33 barangays of Sta. Rosa, Nueva Ecija.

3.2 Research Site / Study Area

The research was conducted in Sta. Rosa, Nueva Ecija, located within the lowland plains of the Pampanga River Basin. This area was selected due to its significant vulnerability to recurring floods that impact agriculture and infrastructure.

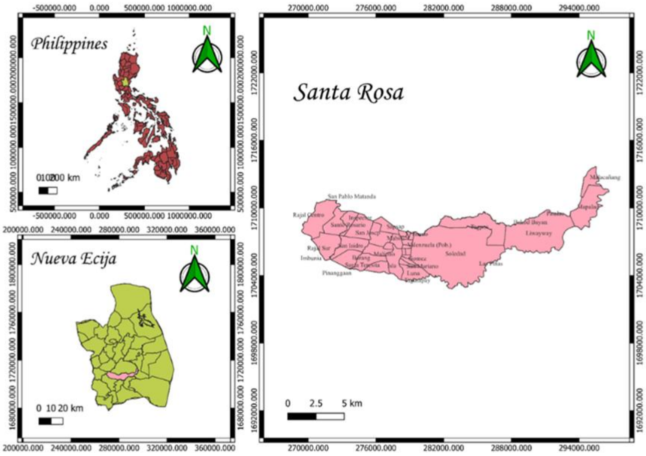

Figure 1.

3.3 Data Collection

The study used secondary data from reliable government agencies and GIS platforms. Data included flood hazard maps from Project NOAH, DEM data for elevation and slope, river data from OpenStreetMap, LULC data from Sentinel-2/Geoportal, rainfall data from PAGASA, and barangay boundaries from PSA/NAMRIA/LGU sources.

Table 1. Variables and Data Sources

Data Layer	Source	Purpose
Flood Risk Categories	Project NOAH	Dependent variable
DEM	SRTM / ALOS DEM	Elevation and slope
Rivers / Waterways	OpenStreetMap	Distance to river
Land Use / Land Cover	Sentinel-2 / Geoportal	Surface characteristics
Rainfall Data	PAGASA	Rainfall characteristics
Barangay Boundary	PSA / NAMRIA / LGU	Zonal analysis

3.4 Research Instruments

The execution of this study relied on a specialized set of software tools designed for geospatial analysis and quantitative data management. These instruments allowed for the transition from raw spatial data to the statistical identification of flood risk correlations.

The following software were used in:

- QGIS – for spatial analysis and mapping
- Google Earth – for visual reference verification
- Microsoft Excel – for statistical analysis and computations

3.5 Data Preparation and GIS Processing

All datasets were standardized into one coordinate system and clipped to the boundary of Sta. Rosa. GIS tools were used to extract barangay-level data such as mean elevation, mean slope, distance to river, dominant LULC, rainfall, and flood risk category. LULC categories were also converted into numerical codes for correlation analysis.

Table2.Coding of LULC

LULC Type	Code	Basis (Permeability)	Interpretation
Built-up	2	Low: Concrete and buildings prevent water from soaking in.	Associated with higher surface runoff and flood risk.
Agricultural	1	High: Open soil and crops allow water to soak into the ground.	Associated with lower runoff potential.

3.6 Variables of the Study

The study examined one dependent variable and five independent variables.

3.6.1 Dependent Variable

The Flood Risk Category serves as the dependent variable, based on the benchmark hazard maps provided by Project NOAH. To facilitate quantitative correlational analysis, the risk levels are transformed into numerical codes:

Table 3. Coding of Flood Risk

Flood Risk Category	Numerical Code	Description
Low	1	Areas with minimal to rare inundation.

Moderate	2	Areas susceptible to medium-depth flooding.
High	3	Areas with frequent and high-depth flooding.

3.6.2 Independent Variables

The following physical and environmental factors are evaluated to determine their association with the barangay-level flood risk:

Table 4. Definition and Measurement of Independent Variables for Flood Risk Analysis

Variable	Unit of Measurement	Description
Elevation	Meters (m)	The vertical height of the barangay above sea level.
Slope	Percent (%)	The steepness or gradient of the terrain.
Distance to River	Kilometers (km)	The proximity of the barangay centroid to the nearest river system.
Dominant LULC	Category	The primary land use/land cover type (e.g., Agricultural, Residential).
Rainfall	Millimeters (mm/year)	No spatial variation observed across the municipality.

3.7 Statistical Treatment of Data

The collected data were analyzed using descriptive statistics and Spearman Rank Correlation to determine the relationship between the selected factors and flood risk categories. Rainfall was excluded from correlation ranking analysis because identical values were observed across all barangays.

3.7.1 Descriptive Statistics

Descriptive statistics such as mean, minimum, maximum, and frequency distribution were used to summarize the characteristics of the barangays.

3.7.2 Spearman Rank Correlation

The Spearman Rank Correlation Coefficient was utilized as the primary inferential tool to determine the degree of association between the independent spatial factors and the ordinal flood risk categories. This non-parametric test is appropriate because the dependent variable (Flood Risk) is measured on an ordinal scale and the study utilizes a finite sample of ($n = 33$ barangays).

3.7.3 Ranking of Factors

To identify which environmental variables show the strongest observed statistical association with flood susceptibility in Sta. Rosa, the factors were ranked based on their absolute Spearman correlation values. A rank of 1 indicates the factor with the strongest statistical association with Project NOAH risk categories, while the last rank represents the variable with the weakest association. This ranking provides a ranking of factors showing stronger observed association with flood risk for local disaster mitigation.

3.8 Data Presentation

To ensure the findings are both visually intuitive and statistically rigorous, the results of this study are presented through the following formats:

- Thematic maps – showing the spatial distribution of flood risk and environmental factors
- Tables – presenting barangay-level data and statistical results
- Charts and graphs – illustrating trends and comparisons
- Statistical summary tables – summarizing correlation and descriptive analysis results

IV. RESULTS AND DISCUSSION

4.1 Flood Risk Categories of Barangays in Sta. Rosa, Nueva Ecija

Using Project NOAH flood hazard data and GIS-based spatial analysis, the 33 barangays of Sta. Rosa, Nueva Ecija were classified into high-, moderate-, and low-risk flood categories. Results showed that 11 barangays (33.33%) fall under high risk, 13 barangays (39.39%) under moderate risk, and 9 barangays (27.28%) under low risk. High-risk barangays are generally characterized by low elevation, flat terrain, and poor drainage conditions, which may contribute to water accumulation during heavy rainfall. In contrast, low-risk barangays are mostly situated in relatively elevated areas with more efficient natural drainage systems.

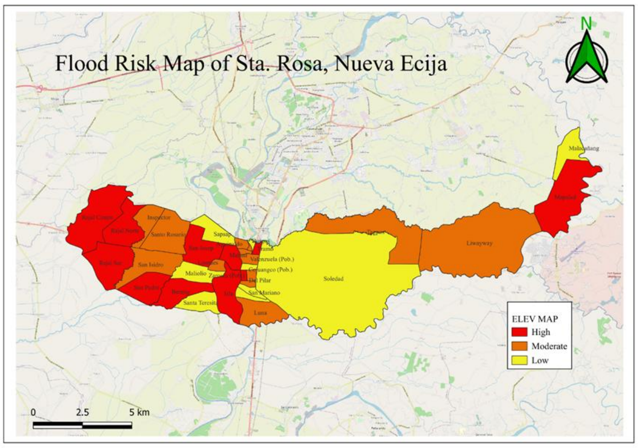

Figure 2. Flood Risk Map of Sta. Rosa from Project NOAH

4.2 Barangay Characteristics Based on Selected Factors

The study examined key environmental and physical factors associated with flood susceptibility, including elevation, slope, rainfall, distance to river channels, and land use/land cover (LULC). GIS-based analysis revealed spatial variation in terrain and land characteristics across the barangays. Lower elevation and gentler slopes were observed in areas classified with higher flood risk categories, suggesting possible reduced drainage efficiency and greater potential for water accumulation. Variations in built-up and agricultural land cover may also affect runoff behavior. Rainfall was treated as a contextual variable only because no spatial variation was observed across the municipality.

Table 5. Geospatial and Hydrological Data of the 33 Barangays in Sta. Rosa, Nueva Ecija

Barangay Susceptible to Flooding	Mean Slope	Elevation (m)	Rainfall Amount per Year (mm)	Distance to River / Creek (km)
1. Brgy. Isla	2	26.4	1854.9	4.1
2. Brgy. San Mariano	2.1	26.8	1854.9	3.7
3. Brgy. Lourdes	1.9	29.6	1854.9	3.6
4. Brgy. La Fuente	2.4	27.7	1854.9	2.7
5. Brgy. San Joseph	1.8	27.6	1854.9	4
6. Brgy. Del Pilar	1.7	29.2	1854.9	3.1
7. Brgy. Liwayway	2.2	57.9	1854.9	2.7
8. Brgy. Malacañang	2.5	76.5	1854.9	1.2
9. Brgy. Inspector	1.8	26	1854.9	6.6
10. Brgy. Berang	2.3	25.1	1854.9	5.9
11.Brgy. Cojuangco	1.9	28.6	1854.9	2.4
12. Brgy. Rizal	1.7	30.3	1854.9	2.7
13. Brgy. Valenzuela	1.9	29	1854.9	2.1
14. Brgy. Zamora	3.2	27.3	1854.9	2.9
15. Brgy Burgos	1.8	30.7	1854.9	0.4
16. Brgy Aguinaldo	2.3	25.1	1854.9	0.9
17. Brgy Gomez	1.8	28.3	1854.9	3.4
18. Brgy Luna	2	27.1	1854.9	4.3
19. Brgy Mabini	2.5	28.4	1854.9	0.8
20. Brgy Maliolio	2.6	26.2	1854.9	4.7
21. Brgy Mapalad	3.8	85.5	1854.9	2.3
22. Brgy Rajal Centro	1.7	24.3	1854.9	4.7
23. Brgy Rajal Norte	1.9	24.9	1854.9	7.8
24. Brgy Rajal Sur	1.9	22.2	1854.9	2.3
25. Brgy San Gregorio	1.3	32.5	1854.9	0.5
26. Brgy San Isidro	2.3	23.5	1854.9	2.1
27. Brgy San Pedro	2	23.1	1854.9	1
28. Brgy Sta. Teresita	1.8	26.9	1854.9	5.4
29. Brgy Sto. Rosario	1.4	26.8	1854.9	5.6
30. Brgy Sapsap	1.7	28.5	1854.9	3.3
31. Brgy Soledad	1.9	33.4	1854.9	3.8
32. Brgy Tagpos	2.9	37.8	1854.9	5
33. Brgy Tramo	2	30	1854.9	0.2

Table 6. Descriptive Statistics of Selected Factors

Variable	Min	Max	Mean	Standard Dev
Elevation (m)	22.2	85.5	31.9	13.9
Slope (%)	1.3	3.8	2.1	0.5
Distance to River (km)	0.2	7.8	3.2	1.8
Rainfall (mm)	1854.9	1854.9	1854.9	0

Table 7. Dominant LULC per Barangay

Barangay	Land Use and Land Cover (low, moderate, high)
1. Brgy. Isla	Annual Crop
2. Brgy. San Mariano	Built-up
3. Brgy. Lourdes	Built-up
4. Brgy. La Fuente	Annual Crop
5. Brgy. San Joseph	Annual Crop
6. Brgy. Del Pilar	Built-up
7. Brgy. Liwayway	Annual Crop
8. Brgy. Malacañang	Annual Crop
9. Brgy. Inspector	Annual Crop
10. Brgy. Berang	Annual Crop
11.Brgy. Cojuangco	Built-up
12. Brgy. Rizal	Built-up
13. Brgy. Valenzuela	Built-up
14. Brgy. Zamora	Annual Crop
15. Brgy. Burgos	Built-up
16. Brgy Aguinaldo	Annual Crop
17. Brgy Gomez	Built-up
18. Brgy Luna	Annual Crop
19. Brgy Mabini	Built-up
20. Brgy Maliolio	Annual Crop
21. Brgy Mapalad	Annual Crop

22. Brgy Rajal Centro	Annual Crop
23. Brgy Rajal Norte	Annual Crop
24. Brgy Rajal Sur	Annual Crop
25. Brgy San Gregorio	Built-up
26. Brgy San Isidro	Annual Crop
27. Brgy San Pedro	Annual Crop
28. Brgy Sta. Teresita	Annual Crop
29. Brgy Sto. Rosario	Annual Crop
30. Brgy Sapsap	Annual Crop
31. Brgy Soledad	Annual Crop
32. Brgy Tagpos	Annual Crop
33. Brgy Tramo	Built-up

4.3 Descriptive Statistics of Selected Factors

Descriptive statistical analysis showed that elevation ranged from 22.2 m to 85.5 m, reflecting the presence of both low-lying and relatively elevated barangays. Slope values ranged from 1.3% to 3.8%, indicating that the municipality is generally characterized by gentle terrain conditions commonly associated with water accumulation. Distance to river channels varied across barangays; however, only a weak observed relationship with flood susceptibility was identified within the barangay-level dataset used in this study. Rainfall showed no spatial variation and was therefore considered a contextual variable only. Overall, the findings suggest that elevation and slope demonstrate stronger observed statistical association with flood risk categories compared to the other variables analyzed.

Table 8. Spearman Correlation Results

Factor	Spearman rho	p-value	Interpretation	Rank
Elevation	-0.641	0.001	Strong negative association	1
Slope	-0.517	0.003	Moderate negative association	2
LULC	0.304	0.085	Weak association	3
Distance to River	-0.015	0.940	Very weak association	4
Rainfall	Not applicable	Not applicable	No spatial variation	Not ranked

4.4 Relationship Between Factors and Flood Risk Categories

Spearman Rank Correlation analysis revealed that elevation exhibited the strongest observed statistical association with flood risk categories (ρ = -0.641), followed by slope (ρ = -0.517). The negative correlation values indicate that lower elevation and flatter terrain are associated with higher flood risk classifications. Land Use and Land Cover (LULC) showed only a weak observed association with flood risk, while distance to river channels demonstrated a very weak observed relationship within the barangay-level dataset used in this study. Rainfall was treated as a contextual variable only because it showed no spatial variation across barangays. Overall, the findings indicate that topographic variables, particularly elevation and slope, show stronger observed association with flood risk categories compared to the other factors analyzed.

Table 9. Ranked Factors

Rank	Factor
1	Elevation
2	Slope
3	LULC
4	Distance To River
-	Rainfall

4.5 Ranking of Factors Contributing to Flood Risk

Based on the absolute Spearman correlation values, elevation ranked first in terms of strongest observed statistical association with flood susceptibility, followed by slope, LULC, and distance to river channels. The results indicate that low-lying and relatively flat areas are more commonly associated with higher flood risk categories. Although land use patterns may influence runoff behavior, their observed association with flood risk was weaker compared to topographic variables. This ranking provides a comparison of factors showing stronger observed association with flood risk within the study area.

4.6 Implications for Flood Planning in Sta. Rosa

The findings emphasize the importance of terrain-based flood planning strategies in Sta. Rosa, Nueva Ecija. Barangays characterized by low elevation and gentle slopes may require greater attention in terms of drainage improvement, infrastructure planning, and disaster preparedness measures. Recommended actions include strengthening drainage systems, maintaining river channels to support water flow, enforcing land-use zoning in flood-prone areas, and improving evacuation planning for vulnerable communities. These measures are aligned with the spatial patterns and observed statistical relationships identified in the study.

4.7 Comparison with Previous Studies

The results of this study are consistent with previous flood susceptibility studies, which report that elevation and slope commonly show stronger observed association with flood risk in lowland environments. Similar studies have identified that areas with lower elevation and flatter terrain are more frequently associated with prolonged flooding due to limited drainage efficiency and slower water movement. The weak observed relationship between river proximity and flood susceptibility within the barangay-level dataset used in this study may reflect the influence of other terrain-related conditions. Rainfall was treated as a contextual variable only because of its uniform distribution across the study area. Overall, the study reinforces that topographic characteristics show stronger observed association with flood vulnerability at the barangay level.

V. SUMMARY, CONCLUSION, AND RECOMMENDATION

5.1 Summary of Findings

This study was conducted to analyze the associaThis study analyzed the association between selected spatial factors and the Project NOAH flood risk categories across the 33 barangays of Sta. Rosa using GIS and Spearman Rank Correlation. The results showed that 11 barangays were classified as high-risk, 13 as moderate-risk, and 9 as low-risk, indicating that flooding is a widespread concern in the municipality. Elevation showed the strongest statistical association with flood risk, followed by slope, because low-lying and flat areas tend to accumulate water and experience inefficient drainage. These conditions result in prolonged inundation and slower water recession during heavy rainfall events. LULC showed a weak association, while distance to river channels showed a very weak association. Rainfall was included as a contextual variable but did not serve as a differentiating factor because rainfall values were constant across all barangays. Overall, the findings highlight that the physical and topographic characteristics of the municipality play a major role in determining flood vulnerability.

5.2 Conclusions

The study concluded that flood risk in Sta. Rosa showed stronger observed association with the municipality's topographic profile, particularly low elevation and flat terrain. Elevation and slope showed stronger observed statistical association with flood risk than proximity to rivers, suggesting that flooding in the municipality may be characterized more by widespread ponding and possible poor internal drainage than by river overflow alone. Although LULC affects flood dynamics, topographic characteristics showed stronger observed association with flood susceptibility. The study also concluded that GIS and Project NOAH hazard data provide a useful framework for identifying vulnerable barangays and supporting localized disaster risk reduction and management. Furthermore, the findings emphasize the importance of integrating spatial analysis into local planning and flood mitigation strategies to help reduce the impacts of future flooding events.

5.3 Recommendations

Based on the findings of the study, the Local Government Unit (LGU) and Municipal Disaster Risk Reduction and Management Office (MDRRMO) of Sta. Rosa may prioritize flood mitigation and preparedness programs in barangays identified as high-risk areas. Elevation and slope data may also be considered in local planning, zoning, and disaster risk reduction initiatives to support more informed land-use decisions and flood management strategies. In addition, further drainage assessment and improvement planning may be conducted in low-lying areas to help reduce water accumulation during heavy rainfall events. Future researchers are encouraged to include additional environmental variables, higher-resolution datasets, and hydraulic modeling to provide a more comprehensive flood risk assessment. Flood risk management literature consistently highlights the importance of integrating land-use planning, drainage assessment, and GIS-based spatial analysis in local flood mitigation strategies.

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REFERENCES

1. Ahmadlou, M., Karimi, M., Alizadeh, S., Shirzadi, A., & Shahabi, H. (2019). Flood susceptibility assessment using hybrid machine learning models. Geocarto International, 34(11), 1252–1272. https://doi.org/10.1080/10106049.2018.1474276
2. Alcantara-Ayala, I., & Lagmay, A. M. F. (2019). Integration of science and technology for disaster risk reduction in the Philippines. International

Journal of Disaster Risk Reduction, 39, Article 101155. https://doi.org/10.1016/j.ijdrr.2019.101155

3. Bulti, D. T., Abebe, B. G., & Gemeda, D. O. (2021). Flood hazard and risk assessment using GIS and remote sensing in urban areas. Heliyon, 7(1), Article e05868. https://doi.org/10.1016/j.heliyon.2020.e05868
4. Cabrera, J. S., & Lee, H. S. (2019). Flood-prone area assessment using GIS-based multi-criteria analysis: A case study in Davao Oriental, Philippines. Water, 11(11), Article 2203. https://doi.org/10.3390/w11112203
5. Chen, W., Hong, H., Li, S., Shahabi, H., Wang, Y., Wang, X., & Pradhan, B. (2021). Deep learning for flood susceptibility mapping. Environmental Modelling & Software, 140, Article 105148. https://doi.org/10.1016/j.envsoft.2021.105148
6. Cinco, T. A., de Guzman, R. G., Ortiz, A. M. D., Delfino, R. J. P., Lasco, R. D., Hilario, F. D., & Ares, E. D. (2016). Observed trends and impacts of tropical cyclones in the Philippines. Atmospheric Research, 168, 1–13. https://doi.org/10.1016/j.atmosres.2015.09.001
7. Costache, R., Arabameri, A., & Blaschke, T. (2023). Flood susceptibility assessment using GIS and remote sensing data. Hydrology, 10(7), Article 141. https://doi.org/10.3390/hydrology10070141
8. Dano, U. L., Balogun, A.-L., Matori, A. N., & Wan Yusouf, K. (2019). Flood susceptibility mapping using GIS-based analytic hierarchy process. Journal of King Saud University – Science, 31(4), 1318–1326. https://doi.org/10.1016/j.jksus.2018.03.006
9. Department of Agriculture – Bureau of Soils and Water Management. (2020). Soil characteristics and land use map of Nueva Ecija. https://www.bswm.da.gov.ph/
10. Jamali, B., Bach, P. M., Cunningham, L., & Deletic, A. (2020). A cellular automata approach for flood modeling using GIS. Journal of Hydrology, 587, Article 124951. https://doi.org/10.1016/j.jhydrol.2020.124951
11. Khosravi, K., Shahabi, H., Pham, B. T., Adamowski, J., Shirzadi, A., & Pradhan, B. (2019). Flood susceptibility modeling using multi-criteria decision-making and machine learning methods. Journal of Hydrology, 573, 311–323. https://doi.org/10.1016/j.jhydrol.2019.03.073
12. Kourgialas, N. N., & Karatzas, G. P. (2017). Flood management and GIS modeling of flood hazard areas. Hydrological Sciences Journal, 62(2), 212–225. https://doi.org/10.1080/02626667.2016.1174333
13. Lagmay, A. M. F., Racoma, B. A., Aracan, K. A., Alconis-Ayco, J., & Saddi, I. L. (2017). Disseminating near-real-time hazards information and flood maps in the Philippines through Web-GIS. Journal of Environmental Sciences, 59, 13–23. https://doi.org/10.1016/j.jes.2017.03.013
14. Li, Y., Zhang, Q., Yao, J., & Wang, H. (2022). Climate variability and increasing flood risks. Science of the Total Environment, 843, Article 154321. https://doi.org/10.1016/j.scitotenv.2022.154321
15. Llanes, F. V., Eco, R., Herrero, T. M., Briones, J. B. L., Escape, C. M., Sulapas, J. J., Galang, J. A. M., Ortiz, I. J., Sabado, J. M., Lagmay, A. M., & Rodolfo, R. (2022). Practices in disaster mitigation in the case of the 2015 Typhoon Koppu debris flows in Nueva Ecija, Philippines. Natural Hazards, 114, 665–690. https://doi.org/10.1007/s11069-022-05407-7
16. Mines and Geosciences Bureau. (2022). Geohazard assessment: Municipality of Sta. Rosa, Nueva Ecija. Department of Environment and Natural Resources. http://databaseportal.mgb.gov.ph/
17. Montefrio, M. J. F. (2020). State–society relations in disaster risk reduction in the Philippines. World Development, 134, Article 105043. https://doi.org/10.1016/j.worlddev.2020.105043
18. Nolasco-Javier, D., Kumar, L., & Tengonciang, A. M. (2021). Flood susceptibility mapping using GIS and machine learning in Metro Manila, Philippines. Applied Geography, 133, Article 102492. https://doi.org/10.1016/j.apgeog.2021.102492
19. Paringit, E. C., Santillan, J. R., & Makinano-Santillan, M. (2017). Nationwide flood hazard mapping using LiDAR technology in the Philippines. Philippine Journal of Science, 146(3), 219–230.
20. Philippine Atmospheric, Geophysical and Astronomical Services Administration. (2023). Climate change in the Philippines: Observed trends and projections. https://pubfiles.pagasa.dost.gov.ph/
21. Philippine Atmospheric, Geophysical and Astronomical Services Administration. (n.d.). Climatological normals. https://www.pagasa.dost.gov.ph/climate/climatological-normals
22. Pourghasemi, H. R., Kariminejad, N., & Pradhan, B. (2020). Flood susceptibility mapping using GIS-based machine learning models. Science of the Total Environment, 709, Article 136151. https://doi.org/10.1016/j.scitotenv.2019.136151
23. Rahmati, O., Zeinivand, H., & Besharat, M. (2016). Flood hazard zoning using GIS and multi-criteria decision analysis. Geomatics, Natural Hazards and Risk, 7(3), 1000–1017. https://doi.org/10.1080/19475705.2015.1045043
24. Rubio, C. J., Yu, I. S., Kim, H. Y., & Jeong, S. M. (2020). Index-based flood risk assessment for Metro Manila. Water Supply, 20(3), 851–866. https://doi.org/10.2166/ws.2020.020

25. Santillan, J. R., Makinano-Santillan, M., & Paringit, E. C. (2016). High-resolution flood hazard mapping using LiDAR data in the Philippines. Journal of Flood Risk Management, 9(4), 345–356. https://doi.org/10.1111/jfr3.12137
26. Siddayao, G. P., Valdez, S. E., & Fernandez, P. L. (2014). Analytic hierarchy process (AHP) in spatial modeling for floodplain risk assessment. International Journal of Machine Learning and Computing, 4(5), 450–457. https://doi.org/10.7763/IJMLC.2014.V4.453
27. Swain, K. C., Singha, C., & Nayak, L. (2020). Flood susceptibility mapping using GIS and AHP. ISPRS International Journal of Geo-Information, 9(12), Article 720. https://doi.org/10.3390/ijgi9120720
28. Teng, J., Jakeman, A. J., Vaze, J., Croke, B. F. W., Dutta, D., & Kim, S. (2017). Flood inundation modelling: A review. Environmental Modelling & Software, 90, 201–216. https://doi.org/10.1016/j.envsoft.2017.01.006
29. Tian, H., Xu, K., & Tian, Y. (2020). Flood susceptibility mapping using support vector machine and GIS. Water, 12(2), Article 430. https://doi.org/10.3390/w12020430
30. Zhang, H., Chen, X., & Chen, J. (2019). Flood risk assessment using integrated GIS and remote sensing techniques. International Journal of Disaster Risk Reduction, 34, 45–54. https://doi.org/10.1016/j.ijdrr.2018.11.012