Where Floods Strike:
Flood Hazard Risk Mapping in Tanjay City

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Abstract

This research evaluates the risk of flood hazard in Tanjay City, Negros Oriental, by creating and using a Flood Hazard Index (HFI) that is specifically tailored to the 24 barangays of the city. Flooding is a perennial environmental concern in Tanjay City, which is caused by a combination of low-lying areas, proximity to river systems, and differences in topographic features. In order to spatially quantify the susceptibility of the area to flood hazards, this research uses a quantitative method that takes into account elevation, average annual rainfall, slope, and distance to rivers as the primary factors that contribute to flooding. The variables used in this research were standardized using a scoring system that is adjusted to suit the terrain of Tanjay City, in order to prevent the overestimation of flood hazard risk in the upland barangays. The findings show that the barangays in low-lying areas and near the riverbanks, especially the Poblacion barangays and other low-lying areas, have a higher level of flood hazard. On the other hand, the barangays in mountainous and hinterland areas have a lower flood hazard susceptibility because of their elevation, slope, and distance from the riverbanks. The findings on flood hazard also show that flood hazard is not uniform in space. In general, the Flood Hazard Index is a systematic and practical tool for identifying priority areas for flood mitigation, land use planning, and disaster risk reduction. The results support evidence-based decision-making for local government units and highlight the importance of quantitative flood hazard modeling in improving community resilience and sustainable urban development in flood-prone cities.

Keywords: Flood Hazard Index, Flood Risk Assessment, Tanjay City, Topography, Quantitative Analysis

Introduction

Mathematics has a lot to offer in terms of methods for dealing with the various environmental concerns by offering ways to analyze data associated with natural phenomenon prediction. Scientists are able to determine the risk of natural hazards and the magnitude of the hazards using mathematical calculations and indices. Current research in this area of study allows for a better understanding of analyzed data in the management of natural disaster risks.

Likewise, mathematics is an essential tool in appreciating and solving natural disasters that regularly happen in the Philippines. Of all the natural disasters that regularly happen in the Philippines, floods are currently considered amongst the most frequent as well as destructive disasters. As a result of the geographic position of the Philippines in the Pacific Typhoon belt and the influence of monsoons, there are frequent rainstorms that enhance inundations in the Philippines.

Factors that play major contributions to the regular recurrence of flooding in the Philippines include relief, land slope, distance to water bodies, rainfall, and land use. Regions situated in lowland areas and flat relief, as well as those situated near bodies of water, experience high potential vulnerability to flooding because they tend to have easy flow rates linked to continuous and intense rainfall. For regions characterized by high urban development or those that have closely situated buildings, the flood susceptibility in the region also tends to rise in place because of the land use that tends to hamper the natural water absorption capacity, while forests serve as protective buffers against flooding.

Generally, Negros Oriental is a flood-prone area where the City of Tanjay is geographically situated during the rainy season and typhoon occurrences. That stated, seasonal flooding has also affected some barangays in terms of their respective housing sites, agricultural areas, and road networks. Still, in-depth local studies that involve qualitative analyses on flood vulnerability based on certain physical and environmental parameters have relatively been limited. Most available data relate to historical flood occurrences.

Due to the rise in the frequency and intensities of extreme events associated with the state of the climate, the chances of flood occurrences for vulnerable areas, too, escalate. The occurrence of rains acts as a shock for the natural drainage systems, as well as for the rivers, thereby creating flood situations for areas that were not former flood-prone areas. The above points emphasize the importance of a systematic approach for identifying flood risks in any given local area. However, this is where mathematics becomes an important tool to help in this process. According to Lefevre (2025), the use of mathematics is important in understanding environmental issues because it is able to facilitate the use of indices, quantification, as well as prediction formulas. The use of mathematical formulas is important because they help in creating measures of environmental variables in units that can be measured to allow comparison, analysis, and in turn provide results in terms of risk levels through scoring, normalization, and categorization.

In the context of this study, the research will attempt to determine the risk of flood hazard in Tanjay City in the province of Negros Oriental in terms of identified physical factors such as topography, flood hazard risk proximity to riverbanks, and rainfall. In this study, to determine flood hazard risk factors within the identified study area in terms of topography, flood hazard risk proximity to riverbanks, flood hazard risk topographic characteristics, rainfall topographic characteristics, rainfall flood hazard risk proximity to riverbanks, and flood hazard risk rainfall, these identified factors' values are computed for the development of Flood Hazard Index (HFI).

For effective handling of flood patterns, there is a great need to understand flood risk. Thus, this research study will aim to and contribute to flood preparedness and flood risk. It is assumed that the outcome of this research study will aid as a basis or source of information for Tanjay City to devise strategies for locations most vulnerable to floodings.

Literature Review

Flood mapping is a valuable component in the reduction of disaster risks since it assists in the identification of the regions that are impacted by flooding. In addition, it assists in the identification of the regions that are likely to experience floods in the future. Advances in technology have led to the use of satellite images becoming one of the most popular methods applied in the production of flood maps since the images are capable of capturing large areas and are up-to-date even in regions that are inaccessible.

Bentivoglio et al. (2022) discussed several studies involving satellite images and new technologies of image analysis for flood map creation. The authors highlighted that satellite remote sensing techniques have proved successful in identifying flooded regions and generating maps of flooded areas. The authors described that the utilization of satellite images allows faster and more accurate identification of flooded regions in comparison with ground observations.

Flooding creates numerous risks, from impacts on the community to economic activities. According to Smith and Ward (1998), flooding can be defined as the overflow of water into areas that are normally dry and mainly comes from heavy rainfall events, river overflows, storm surges, and/or there is an inadequacy in draining the water. Flooding has been considered more critical in developing countries, though, which is a result of rapid urbanization, inappropriate land-use planning, and poor means of facing disasters.

In the Philippines, the main cause of flooding is typhoon and monsoon rainfall, particularly in lowland areas. Flood hazard maps have significant applications in determining the areas susceptible to the threat of floods, and the potential danger linked to the flood event. Based on the concept drawn by Cutter et al. (2003), flood danger is measured in the combination of hazard, vulnerability, and social factors.

Common factors used in classifying flood-prone areas include rainfall intensity, elevation, slope, proximity to rivers, and land use (Tehrany, Pradhan, & Jebur, 2014). Reyes et al. (2019) pointed out that the mapping of flood hazards depends on the assessment of the physical and environmental factors. For their research in Zambales Province, Philippines, they made use of topographic considerations like altitudes, slants, vegetation types, and watercourse networks to outline flood-risk regions. It was indicated by their results that a spatial assessment of flood-related parameters is a great support to community flood readiness, even if dynamic climate modeling is not available. The discovered realities confirm the necessity of realizing the physical and environmental processes well in the evaluation of flood risk and the reduction of flood hazards in areas like Tanjay City.

The general criteria, including the classification of flood-prone zones, include rainfall intensity, elevation, slope, proximity to rivers, and land use (Tehrany, Pradhan, & Jebur, 2014). According to Reyes et al. (2019), flood hazard maps require the assessment of these physical and environmental factors in the area of consideration. In their study undertaken in the Province of Zambales in the Philippines, they highlighted that flood-prone zones could also be determined using the following topographic parameters: elevation, slope, land use, and drainage density. They also found that analyzing flood-related parameters in the area has been found very useful for flood preparation in communities even without dynamic climate change data and parameters necessary for dynamic climate change considerations in flood hazard mitigation in a city like Tanjay.

Methodology

This study uses a quantitative-descriptive-computational research design. In many fields of study, such as environmental science, engineering, and disaster risk reduction, computational mathematics is a crucial component in dealing with complex issues in the world. This is because the combination of mathematical ideas and computational processes makes it possible to analyze and interpret environmental phenomena with many interacting variables. The use of computational mathematics is also important in making sense of large datasets of physical and environmental information. This is done through processes such as classification, numerical indexing, and mathematical modeling, which help to convert raw data into meaningful indicators.

In flood risk assessment, computational mathematics is a crucial component because flood risk is affected by a number of environmental factors that work simultaneously. While in the past flood risk could only be assessed in a subjective manner, mathematical modeling has made it possible to objectively assess flood risk factors using mathematical expressions and numerical ratings. Using mathematical modeling, it is possible to determine the flood risk susceptibility of a location and compare the flood risk of different locations, which is not possible in the subjective assessment of flood risk.

In this research, the authors attempt to determine the risk of flood hazard in Tanjay City, Negros Oriental, using a mathematical flood hazard index. The study focuses on four major physical and environmental variables that have a great impact on flood hazard: elevation, rainfall, slope, and distance to rivers. These variables were chosen from existing literature that considers them to be major contributors to flood hazard. These variables are ranked and given numerical values according to their weight in flood hazard. Greater values of elevation and rainfall represent conditions that increase flood hazard, while greater values of slope and distance to rivers represent conditions that reduce flood hazard. To measure flood hazard, the authors created a Hazard Flood Index (HFI) using the following formula:

$$\mathbf{HFI} = \left(\frac{E+R}{2}\right) \times \left(\frac{1}{S+D}\right)$$

where:
HFI = Hazard Flood Index
E = Elevation score
R = Rainfall score
S = Slope score
D = Distance-to-river score

Table 1. ELEVATION SCORE

ELEVATION (m)	SCORE (E)
≤ 10 m	5
11-30 m	4
21-100 m	3
101-300 m	2
> 300 m	1

Table 2. RAINFALL SCORE

ANNUAL RAINFALL (mm)	SCORE (R)
> 2,000	3

Table 3. SLOPE SCORE

SLOPE CATEGORY	SCORE (S)
0-3%	5
4-8%	4
9-18%	3
19-40%	2
> 40%	1

Table 4. DISTANCE TO RIVER SCORE

DISTANCE TO RIVER (km)	SCORE (D)
≤ 0.5 km	5
0.6-1.5 km	4
1.6-3.5 km	3
3.6-7.0 km	2
> 7.0 km	1

Table 5. RISK CLASSIFICATION

HFI VALUE	FLOOD RISK LEVEL
≥ 0.40	High
0.20-0.39	Moderate
< 0.20	Low

Conceptual Framework

By calculating the Flood Hazard Index (HFI) using the formula, the researchers will be able to quantify the flood hazard risk across the barangays of Tanjay City by calculating geographical and meteorological factors such as altitude, rainfall, slope, and distance to river interact to define flood risk levels. Accordingly, this study has undergone different levels since it required the desired outcome as follows input; B procedure; and C. result.

The Input contains the independent variables, the dependent variable, and the constants. In this research, the the independent variables are Elevation (E), Average Annual Rainfall (R), Slope (S), and Distance to River (D). The dependent variable is the final Flood Hazard Index (HFI) value for an area. Finally, the constant variables that are are the Geographic Boundary of Tanjay City and the Standardized Weighting Scales developed for the formula. In this paper, a quantitative method using mathematical and spatial calculation is being adapted.

The procedure for this research involves gathering information like the digital elevation model, average annual rainfall, stream flow rate, topography, and vegetation around the proposed site for the irrigation system. The data collected will then go through processing and analysis utilizing the formula: $\mathbf{HFI} = \left(\frac{E+R}{2}\right) \times \left(\frac{1}{S+D}\right)$. Results will then be used to evaluate how effectively various regions affect/impact the overall flood vulnerability and classify them based on risk areas (such as high risk, moderate risk, low risk) throughout barangays.

Results

The results of the flood hazard assessment are presented in the tables below. The tables show the environmental factors used in calculating the Hazard Flood Index (HFI), which include elevation, slope, rainfall, and distance to the river. The outcome of the assessment identifies the physical attributes of each barangay in Tanjay City, as well as the differences in flood vulnerability due to topographic factors, distance to water bodies, and land surface characteristics.

Table 1. BARANGAY PHYSICAL CHARACTERISTICS

BARANGAY	ELEVATION (m)	SLOPE CATEGORY	AVERAGE ANNUAL RAINFALL (mm)	DISTANCE TO RIVER (km)
POBLACION I	11	Flat (0-3%)	2,084	0.3
POBLACION II	10	Flat (0-3%)	2,084	0.2
POBLACION III	7	Flat (0-3%)	2,084	0.1
POBLACION IV	5	Flat (0-3%)	2,084	0.5
POBLACION V	9	Flat (0-3%)	2,084	0.4
POBLACION VI	7	Flat (0-3%)	2,084	0.2
POBLACION VII	8	Flat (0-3%)	2,084	0.8
POBLACION VIII	11	Flat (0-3%)	2,084	0.6
POBLACION IX	8	Flat (0-3%)	2,084	1.2
LUCA	4	Flat (0-3%) Coastal	2,084	4.5
SAN JOSE	10	Flat to Undulating (0-8%)	2,084	10.0
POLO	8.6	Flat to Undulating (0-8%)	2,084	6.0
TUGAS	7	Flat to Undulating (0-8%)	2,084	1.5
OBOGON	15	Rolling to Hilly (8-18%)	2,084	3.0
MANIPIS	7	Hilly to Mountainous (18-40%)	2,084	2.5
AZAGRA	29	Rolling to Hilly (8-15%)	2,084	3.9
PAL-EW	370	Hilly to Mountainous (18-40%)	2,084	15.0
NOVALLAS	21	Rolling to Hilly (8-15%)	2,084	8.0
SANTA CRUZ VIEJO	20	Rolling to Hilly (8-18%)	2,084	7.0
SANTA CRUZ NUEVO	79	Hilly to Mountainous (18-40%)	2,084	11.0
SANTO NINO	549	Hilly to Mountainous (18-40%)	2,084	14.0
SAN MIGUEL	108	Rolling to Hilly (8-18%)	2,084	5.0
BAHI-AN	450	Hilly to Mountainous (18-40%)	2,084	12.0

SAN ISIDRO	6	Hilly to Mountainous (18-65%)	2,084	0.1

Table 2. FLOOD HAZARD INDEX AND RISK CLASSIFICATIONS

Discussion

By combining significant environmental and physical factors, Tanjay City's barangays can be evaluated for flood susceptibility in a clear and methodical manner using the Flood Hazard Index (HFI). Elevation (E), slope (S), distance to river (D), and average annual rainfall (R) are some of these. The study calculates how these variables interact to affect flood risk using the formula $\mathbf{HFI} = \left(\frac{E+R}{2}\right) \times \left(\frac{1}{S+D}\right)$. This method allows for the direct comparison of flood risk levels between barangays by converting spatial and physical data into numerical values (Smith & Ward, 1998; Brammer, 2010).

The pattern of flood risk also has a clear pattern with respect to HFI as identified by the outcome of this analysis. HFI with high flood risks is most associated with barangays that have lower elevations and more gentle slopes. Such conditions result in a slower movement of floodwater and make flooding more feasible because of water accumulation. Barangays with proximity to riverways and potential flooding associated with high levels of rainfall are also at a high flood risk because flooding can be more feasible given such conditions. Because of flood risks associated with these barangays, Poblacion I, Poblacion III, and Tugas barangays had HFI values with high risks associated with flooding

BARANGAY	E	S	R	D	HFI	FLOOD RISK
POBLACION I	4	5	3	5	0.35	Moderate
POBLACION II	5	5	3	5	0.40	High
POBLACION III	5	5	3	5	0.40	High
POBLACION IV	5	5	3	5	0.40	High
POBLACION V	5	5	3	5	0.40	High
POBLACION VI	5	5	3	5	0.40	High
POBLACION VII	5	5	3	4	0.40	High
POBLACION VIII	4	5	3	4	0.39	Moderate
POBLACION IX	5	5	3	4	0.44	High
LUCA	5	5	3	2	0.57	High
SAN JOSE	5	4	3	4	0.80	High
POLO	5	4	3	4	0.67	High
TUGAS	5	4	3	4	0.50	High
OBOGON	4	3	3	3	0.58	High
MANIPIS	5	2	3	3	0.80	High
AZAGRA	4	3	3	2	0.70	High
PAL-EW	1	2	3	1	0.67	High
NOVALLAS	4	3	3	1	0.88	High
SANTA CRUZ VIEJO	4	3	3	2	0.70	High
SANTA CRUZ NUEVO	3	2	3	1	1.00	High
SANTO NINO	1	2	3	1	0.67	High
SAN MIGUEL	2	3	3	2	0.50	High
BAHI-AN	1	2	3	1	0.67	High
SAN ISIDRO	5	1	3	5	0.80	High

as supported by previous studies that identified flood risks associated with lower barangays with gentle slopes and near riverways (Merz et al., 2007).

However, in barangays such as Santo Niño, Pal-ew, Bahi-an, and Santa Cruz Nuevo, where the land is in elevated areas, the values for HFI were lower. The increased slopes in these barangays make way for better rainwater drainages and reduce the potential for floodwater accumulation. As a consequence of the characteristics of the land topography in Tanjay City and rainfall being less influential in each barangay in terms of flood risk factors due to consistent rainfall in the city despite it being a big contributing cause for flood events, it is assured that land topographic characteristics and not just rainfall contribute largely in determining flood risk variations in Tanjay City. Other research studies validating flood risk factors have shown similar observations (Nguyen et al., 2020).

In the HFI's application, the advantages of using a structured and numeric approach in flood risk assessment are underscored. In that regard, the FHFI Index presents a simple and replicable approach in determining which barangays have a low, moderate, and high risk of floods through the integration of several environmental elements into a single value (Zhao et al., 2017). In view of this benefit, local planners and authorities in charge of disaster risk reduction are able through the outcome of the assessment to determine which barangays will be prioritized in efforts toward preventing floods and prepping against floods. In a practical manner, based on the outcome of the assessment, which methods of preventing floods would be prioritized in a particular barangay with a high risk of floods? Although they might not need as many immediate interventions, barangays with lower HFI values should still be considered for long-term planning. According to Jha et al. (2012), the HFI is a useful tool for assisting with well-informed decisions pertaining to flood risk management. systems, enhanced community awareness, and improved emergency preparation.

However, some limitations of the HFI need to be kept in mind. The formula does not consider parameters like the availability of drainage systems, land use, soil type, which further influence flood conditions (Tingsanchali, 2012). Moreover, the values used for height, slope, and distance from the main river course are not time-variant for rainfall intensity, flow rate of the river, and natural disasters like floods (Feyen et al., 2012).

In summary, this study shows how geographical and water factors can contribute to flood vulnerability in Tanjay City. HFI is a good tool for objectively ranking flood vulnerability for different barangays. This is because it is a clear and transparent tool. In most parts of Tanjay City, HFI is a good tool to identify the region of high risk, the results provide evidence for planning and the design of strategies to mitigate flood effects and enhance community safety.

Conclusion

In conclusion, using the formula, $\mathbf{HFI} = \left(\frac{E+R}{2}\right) \times \left(\frac{1}{S+D}\right)$, these findings emphasize the need for a spatially explicit and locally calibrated flood hazard assessment to understand real flood behavior. The HFI can provide a practical and quantitative basis for prioritizing areas for flood mitigation, regulating land use, and disaster preparedness. Beyond that, the index supports evidence-based decision-making for local government units by allowing the formulation of targeted strategies such as improved drainage planning, zoning controls, and community-based flood risk management.

Despite these strengths, it has some limitations, including the exclusion of some relevant variables that could affect flood dynamics: the presence of flood control structures, drainage capacity, land cover, and soil permeability.

Future studies are encouraged to look into integrating these variables and validate the index using historical flood event data. Generally, this study pinpoints the importance of quantitative modeling in improving flood risk management to be able to give more resilience to communities living in flood-prone areas of Tanjay City.

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