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GEOSPATIAL INTEGRATION OF CLIMATE AND DISASTER RISK ASSESSMENT FOR LAND USE PLANNING

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Abstract

Flooding remains one of the most destructive hazards affecting local government units (LGUs) in the Philippines. Despite the availability of hazard maps, most planning offices continue to rely on static flood hazard datasets that do not account for changing rainfall conditions, forecast information, or community-generated observations. This limitation reduces the effectiveness of land-use planning and disaster preparedness, particularly in flood-prone municipalities. This study developed a geospatial integration system that combines historical flood hazard maps from DOST Project NOAH with real-time precipitation forecasts obtained through the OpenWeatherMap API. The system incorporates a rule-based spatial hazard reclassification algorithm, dynamic geospatial visualization, scenario-based simulation capabilities, and crowdsourced flood reporting to support evidence-based land-use planning and disaster risk management. The research employed a descriptive-developmental design and utilized a hybrid Agile-Waterfall software development methodology. The system was implemented using Flutter, JavaScript, Express.js, MySQL, QGIS, and Mapbox. Validation was conducted through historical simulations of Typhoons Ondoy (2009), Ulysses (2020), and Paeng (2022). Results showed an average spatial overlap accuracy of 81% between simulated hazard zones and documented flood extents. The platform achieved a 96% API reliability rate and an average map update time of 2.5 seconds. Evaluation by IT experts yielded a mean quality rating of 4.60, while end users reported a usability rating of 3.86. Findings indicate that integrating climate forecasts with geospatial hazard mapping significantly enhances planning responsiveness and supports climate-sensitive development decisions.

Keywords – *climate data, disaster risk reduction, dynamic mapping, flood risk assessment, GIS, land-use planning*

Introduction

Climate change has intensified the frequency and severity of hydrometeorological hazards throughout Southeast Asia. In the Philippines, flooding remains a recurring challenge that affects communities, infrastructure, agriculture, and local economies. Municipal governments commonly depend on flood hazard maps developed through national initiatives such as Project NOAH. Although these maps provide valuable baseline information, they are static representations of historical conditions and cannot adjust to changing rainfall patterns or forecasted weather events.

In Laguna Province, particularly in the municipalities of Magdalena, Pagsanjan, and Santa Cruz, recurring flood incidents have exposed the limitations of static hazard mapping. Floodwaters have frequently exceeded mapped hazard boundaries during major typhoon events, creating uncertainty in zoning decisions, infrastructure planning, and disaster response operations. Land-use planners require tools capable of translating changing climate conditions into actionable spatial information.

Geographic Information Systems (GIS), remote sensing, and web-based mapping technologies have significantly improved disaster risk management worldwide. Recent studies emphasize the importance of integrating hazard information with planning processes, climate adaptation measures, and decision-support systems. Geospatial technologies have been used successfully to identify vulnerable areas, support zoning decisions, and facilitate emergency management operations. However, most existing systems remain limited by their dependence on static datasets and their inability to incorporate real-time climate information and community-generated observations.

The Sendai Framework for Disaster Risk Reduction emphasizes the need for multi-hazard monitoring systems, stakeholder participation, and technology-enabled resilience planning. Similarly, recent research demonstrates that integrating climate information with spatial decision-support systems improves preparedness and supports more resilient development strategies.

This study addresses these gaps through the development of a geospatial integration system that combines historical flood hazard maps, real-time weather forecasts, and crowdsourced flood reports into a single interactive platform. Unlike traditional hazard maps, the proposed system dynamically adjusts hazard classifications according to precipitation conditions and enables planners to simulate flood scenarios before making land-use decisions. This study addresses the limitations of traditional static hazard maps by developing a dynamic geospatial system that automatically adjusts based on real-time weather forecasts, directly aligning with the Sendai Framework for Disaster Risk Reduction’s call for technology-enabled resilience.

OBJECTIVES OF THE STUDY

General Objective

To develop a geospatial integration system that combines climate data with flood hazard information to support evidence-based land-use planning and flood risk management.

Specific Objectives

To develop a GIS-based interface displaying flood hazard zones for Magdalena, Pagsanjan, and Santa Cruz, Laguna.

To integrate real-time weather forecast information using the OpenWeatherMap API and automatically adjust hazard classifications based on rainfall thresholds.

To implement a crowdsourcing module that enables community members to submit geotagged flood reports with photographic evidence.

To develop a simulation tool allowing planners to evaluate land-use scenarios under varying precipitation conditions.

To evaluate system usability, predictive accuracy, and decision-support capability through historical typhoon simulations and stakeholder assessments.

METHODOLOGY

Research Design

The study employed a descriptive-developmental research design. The descriptive component documented flood hazard conditions, historical flood records, planning practices, and weather-related challenges in the selected municipalities. The developmental component focused on designing, implementing, and evaluating a geospatial decision-support system.

The research focused on Magdalena, Pagsanjan, and Santa Cruz in Laguna Province. These municipalities experience recurrent flooding due to their geographic location within major watershed systems and their exposure to tropical cyclones.

Development Methodology

A hybrid Agile-Waterfall methodology was adopted. Waterfall processes guided requirements gathering, system architecture design, and database development. Agile iterations were used for interface design, feature implementation, testing, and stakeholder feedback integration.

System Architecture

The platform consisted of four major components:

Dynamic Hazard Mapping Module

Real-Time Weather Integration Module

Crowdsourced Flood Reporting Module

Simulation and Decision-Support Module

The system utilized Flutter for frontend development, Express.js for backend services, MySQL for relational database management, QGIS for geospatial processing, and Mapbox for visualization.

Data Sources

Flood hazard data were obtained from DOST Project NOAH. Weather forecasts were retrieved from the OpenWeatherMap API. Historical typhoon records were collected from PAGASA and local government archives. Community-generated reports were collected through the system's crowdsourcing interface.

Hazard Reclassification Algorithm

The system implemented a rule-based hazard reclassification model using rainfall thresholds.

• Less than 50 mm rainfall: Baseline hazard conditions maintained. • 50–100 mm rainfall: Moderate hazard zones expanded by 500 meters. • Greater than 100 mm rainfall: Moderate and high hazard zones expanded by 750 meters, while adjacent low-risk areas were reclassified as moderate risk.

The algorithm generated updated hazard maps using spatial buffering and overlay operations.

Respondents

The evaluation involved 28 respondents consisting of:

• 7 IT experts with experience in GIS and software development. • 21 end users composed of LGU planners, DRRM officers, and administrative personnel.

The system implements a rule-based hazard reclassification model using specific rainfall thresholds: baseline conditions are maintained for rainfall under 50 mm, hazard zones expand by 500 meters for rainfall between 50–100 mm, and by 750 meters for rainfall exceeding 100 mm

Research Instruments

Two evaluation instruments were used:

ISO/IEC 25010 Software Quality Evaluation Form for IT experts.

System Usability Scale (SUS)-based questionnaire for end users. Responses were measured using a five-point Likert scale.

Validation Procedure

Historical simulations were conducted using rainfall data from:

• Typhoon Ondoy (2009): 455 mm • Typhoon Ulysses (2020): 150 mm • Typhoon Paeng (2022): 90 mm

Simulation outputs were compared against documented flood extents through spatial overlap analysis.

Data Analysis

Descriptive statistics, including mean and standard deviation, were used to evaluate software quality, usability, and performance metrics. Spatial overlap percentages were used to measure predictive accuracy.

RESULTS AND DISCUSSION

System Development Results

The developed platform successfully integrated static hazard maps with dynamic precipitation forecasts. Hazard classifications automatically changed in response to forecasted rainfall, providing users with updated risk information.

The crowdsourcing module enabled users to submit geotagged flood reports with photographs. These reports served as supplementary validation data and

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improved situational awareness during flood events.

The simulation module allowed planners to evaluate different rainfall scenarios and visualize potential changes in hazard exposure before implementing development projects.

System Performance

The system achieved the following performance indicators:

Table 1. System Performance Metrics

Performance Indicator	Result	Interpretation
Map Update Time	2.5 seconds	Fast response
API Success Rate	96%	Highly Reliable
Database Query Time		Efficient Processing

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API Success Rate	96%	Highly Reliable
Database Query Time		Efficient Processing

The results indicate that the system successfully identified most historically flooded barangays. The highest performance occurred during severe flooding scenarios, where dynamic hazard expansion more closely matched actual flood extents than static hazard maps.

Scenario-Based Validation

Historical simulations produced the following results:

Validation through historical simulations of Typhoons Ondoy, Ulysses, and Paeng yielded an average spatial overlap accuracy of 81%, proving the system's ability to identify historically flooded areas more effectively than static maps

Technical performance metrics confirmed the system's efficiency, achieving a 96% API reliability rate and a rapid average map update time of 2.5 seconds.

Table 2. Validation Results Using Historical Typhoon Events

Typhoon Event	Year	Rainfall (mm)	Spatial Overlap Accuracy
Ondoy	2009	455	83%
Ulysses	2020	150	83%
Paeng	2022	90	78%
Average	--	-	81%

The average spatial overlap accuracy reached 81%.The results indicate that the system successfully identified most historically flooded barangays. The highest performance occurred during severe flooding scenarios, where dynamic hazard expansion more closely matched actual flood extents than static hazard maps.

Software Quality Evaluation

IT experts evaluated the system using ISO/IEC 25010 criteria. The overall mean score was 4.60, indicating very high acceptability.

The highest ratings were observed in:

• Operability (4.86) • Capacity (4.86) • Resource Utilization (4.71)

Lower scores were observed in security-related indicators, suggesting opportunities for enhancement in authentication and access control mechanisms.

To address the lower scores in security-related indicators, future system enhancements will prioritize Multi-Factor Authentication (MFA) and a Role-Based Access Control (RBAC) framework to secure sensitive geospatial data and ensure accountability.

The integration of crowdsourced flood reports provides essential supplementary validation, allowing for real-time situational awareness that bridges the gap between forecasted risks and actual ground conditions.

Usability Evaluation

End-user assessment produced an overall mean score of 3.86, indicating high usability. Participants reported that the platform was useful for planning activities and relatively easy to learn despite some interface complexity.

The use of color-coded hazard classifications, embedded help functions, and predefined typhoon scenarios contributed significantly to user acceptance.

Discussion

The findings demonstrate that dynamic integration of climate forecast data and hazard information provides more useful planning support than static hazard maps alone. Traditional flood maps represent historical conditions but cannot adapt to rapidly changing weather situations. By incorporating forecast information, the developed system enables local governments to evaluate emerging risks and make more informed decisions.

The 81% validation accuracy suggests that the rainfall-based hazard reclassification model can reasonably represent actual flood behavior at the municipal scale. While the approach does not replace hydraulic engineering models, it offers sufficient accuracy for zoning decisions, development restrictions, and disaster preparedness planning.

The crowdsourcing feature further strengthens hazard assessment by incorporating local observations into the system. Community participation supports data validation and improves public engagement in disaster risk reduction efforts.

The simulation module emerged as one of the most valuable features. Planners were able to test future scenarios, compare alternative conditions, and assess the implications of rainfall changes on land-use decisions. This capability aligns with current international recommendations promoting risk-sensitive planning and climate adaptation.

Although the system received high ratings in functionality, operability, and performance, lower scores were observed in security-related indicators, particularly in authentication and access control. These findings highlight the need to strengthen system security as the platform scales for wider deployment. To address these weaknesses, future system enhancements will implement multi-factor authentication (MFA) to provide an additional verification layer beyond passwords, reducing the risk of unauthorized access. The platform will also adopt a role-based access control (RBAC) framework, ensuring that users can only access features and data relevant to their responsibilities. For example, administrators will have full system privileges, while planners, DRRM officers, and community users will have restricted permissions based on operational needs. Additionally, audit trail mechanisms will be integrated to record user activities, enabling accountability and facilitating security monitoring. Password encryption, secure session management, and periodic security assessments will further enhance protection against cyber threats. These improvements are expected to increase user trust, protect sensitive geospatial information, and improve compliance with cybersecurity best practices.

CONCLUSION AND RECOMMENDATION

The study successfully developed and validated a geospatial integration system that combines historical flood hazard maps, climate forecast information, and community-generated reports for land-use planning. The platform demonstrated an average validation accuracy of 81%, a 96% API reliability rate, and high acceptance among both technical experts and end users.

The integration of dynamic climate information significantly improves the responsiveness of flood risk assessment compared with traditional static hazard maps. The system provides local governments with a practical decision-support tool capable of supporting zoning decisions, infrastructure planning, emergency preparedness, and climate adaptation initiatives.

Based on the findings, the following recommendations are proposed:

1. Integrate dynamic geospatial risk assessment into routine LGU planning and disaster management workflows.

2. Incorporate high-resolution Digital Elevation Models (DEM), watershed analysis, hydrological modeling, and hydraulic simulation to improve predictive

accuracy and better represent terrain and drainage characteristics.

3. Integrate additional environmental and hazard variables such as river levels, soil saturation, storm surge forecasts, drainage network conditions, and watershed indicators.

4. Develop simplified dashboards, embedded tutorials, contextual help functions, and guided workflows for non-technical users.

5. Implement robust offline functionality and mobile deployment to ensure usability during emergencies when internet connectivity is unavailable.

6. Strengthen authentication and access control through multi-factor authentication, role-based access control, audit trails, and enhanced cybersecurity mechanisms.

7. Expand validation and deployment to municipalities with varying geographical, hydrological, and environmental conditions to assess scalability, adaptability, and robustness.

8. Conduct long-term operational assessments to measure impacts on planning quality, emergency response effectiveness, and climate adaptation outcomes.

9. The system is highly recommended as a decision-support tool for Local Government Units (LGUs), providing a scientific basis for zoning decisions, infrastructure planning, and the creation of climate-sensitive Comprehensive Land Use Plans (CLUP)

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