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Geo-Mapping Safety: A Geographic Information System Review of Evacuation Centers in Malolos, Bulacan

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ABSTRACT

This study assessed flood risk and disaster management strategies in Malolos, Bulacan, a municipality highly susceptible to flooding due to its geographical location, urbanization, and climate change impacts. Using Geographic Information Systems (GIS), the study integrated residents' flood perceptions, flood susceptibility maps, and evacuation center assessments to provide a comprehensive overview of flood risks. The analysis categorized residents into two groups: At Risk and Not at Risk, based on their exposure to flooding and evacuation behaviors. The At-Risk group showed a reluctance to evacuate, often due to emotional attachment to their properties, while the Not At-Risk group evacuated proactively when needed. The study also examined the accessibility and suitability of evacuation centers. It was found that many centers are located in flood-prone areas, reducing their effectiveness during emergencies, and densely populated barangays like Sto. Rosario and San Juan lack adequate evacuation centers. Barangays were classified into four levels of vulnerability, with Level IV areas, such as Sto. Rosario and Bangkal require urgent infrastructure improvements. The results suggest that flood management strategies in Malolos should prioritize evacuation infrastructure upgrades, particularly in high-risk areas. The integration of GIS technology, community insights, and data-driven approaches to disaster management provides valuable insights for improving flood resilience. The study emphasizes the need for targeted interventions, including relocation of evacuation centers and community-based flood preparedness programs, to enhance disaster response and mitigate flood impacts in the region.

Keywords: *Accessibility, Disaster Preparedness, Evacuation Routes, GIS, Resilience*

INTRODUCTION

Malolos, located at 14° 50' North, 120° 49' East (14.8405, 120.8116), approximately 45 kilometers north of Manila, faces significant flood risks due to its geographical position and environmental factors. Bordered by various towns and waterways, Malolos has long been susceptible to flooding, a vulnerability exacerbated by climate change, rapid urbanization, and increasing storm frequency (Sado-Inamura & Fukushi, 2019). The historical and ongoing flooding events in the region underscore the need for effective flood risk assessment and disaster management strategies, particularly as urban sprawl continues to encroach on floodplains, amplifying the risks for local communities.

Recent studies highlight the growing frequency and severity of flooding in Southeast Asia, particularly in low-lying and deltaic regions like Malolos. Silva et al. (2023) emphasized how climate change, coupled with urban expansion, has made flooding events more frequent and intense, particularly in urbanized regions. Similarly, Abcede et al. (2022) explored the role of urbanization in exacerbating flooding risks in Metro Manila and nearby provinces, including Bulacan, noting that these areas are particularly vulnerable to flood hazards. These studies advocate for integrating sustainable urban planning practices and effective flood risk management strategies to reduce vulnerability in flood-prone regions like Malolos.

In parallel, the role of Geographic Information Systems (GIS) in flood risk mapping has gained

significant attention. Rincón et al. (2022) discussed how GIS-based flood hazard mapping is an effective tool for identifying high-risk zones and guiding disaster preparedness efforts. This approach has increasingly been adopted across the Philippines to enhance flood management and improve disaster response. Lagos et al. (2022) demonstrated how GIS, when integrated with hydrological and topographical data, improves flood prediction accuracy in regions like Bulacan, including Malolos. Their research also highlighted how GIS can optimize evacuation planning by identifying safer routes and evacuation areas, thus facilitating more efficient disaster responses.

The use of GIS combined with multi-criteria decision-making (MCDM) methodologies in flood risk assessment is another advancement discussed by Tomar et al. (2023). Their study showcased how spatial analysis tools can enhance flood management, particularly in urban and rural settings, providing valuable insights into flood-prone areas under varying climate scenarios. Similarly, Singh et al. (2024) emphasized that urban planning and flood mitigation strategies must incorporate structural resilience, such as building fortifications and strengthening infrastructure, to complement environmental flood management efforts.

In addition to technological innovations, Pérez et al. (2024) focused on community-based flood resilience strategies in flood-prone areas across Asia. Their study found that public awareness and local engagement in flood management were crucial for improving resilience, particularly in rural and suburban communities like Malolos. This perspective aligns with Malhotra's (2020) findings, which advocated for integrating community-level interventions with top-down policy approaches to enhance flood risk reduction and preparedness.

The identification and accessibility of evacuation centers have also been a critical issue in flood management. Tan et al. (2022) explored how GIS can enhance evacuation planning by analyzing transportation networks and optimizing evacuation routes during floods. This is especially important in areas like Malolos, where flood-prone regions are often intersected by inadequate transportation infrastructure, making timely evacuations more difficult. Ali et al. (2023) reinforced this by evaluating the effectiveness of GIS tools in identifying optimal evacuation sites and routes for marginalized communities, particularly in low-lying regions at high flood risk.

Flood management in coastal and riverside communities, such as Malolos, has also been addressed in recent research. Chua et al. (2023) proposed strategies to enhance flood resilience by incorporating coastal protection measures and floodplain zoning into urban planning, particularly in areas near Manila Bay. Their findings are particularly relevant as storm surges and rising sea levels compound flooding risks for coastal communities.

Furthermore, studies on the socio-economic impacts of flooding in rural areas, particularly in Bulacan, have highlighted the disproportionate effect floods have on small-scale farmers and vulnerable households. Briones et al. (2023) noted that flooding causes severe economic losses, especially for those in flood-prone rural areas, stressing the need for improved infrastructure and disaster response systems to alleviate these impacts.

Finally, recent innovations in flood monitoring and forecasting using GIS technologies have proven valuable in enhancing flood risk management. Martinez and Lim (2024) demonstrated how integrating real-time weather data with GIS and hydrological models has improved flood forecasting and early warning systems in the Philippines. Their work has shown how such technologies can facilitate timely evacuations and minimize flood damage, providing essential lessons for flood-prone areas like Malolos.

In summary, the integration of GIS technology, multi-criteria decision-making tools, and enhanced flood resilience strategies has proven crucial in addressing the growing flood risks in Malolos and similar areas. Recent studies from 2022 to 2024 emphasize the importance of comprehensive flood

risk management systems that incorporate environmental, socio-economic, and technological factors to improve disaster preparedness and response. This evolving body of research underscores the need for a more coordinated, data-driven approach to flood risk assessment, disaster response, and resilience building.as well as the role of technology in improving disaster preparedness and response.

MATERIALS AND METHODS

This study employed a mixed-method approach, combining both GIS-based spatial analysis and qualitative interviews to evaluate the effectiveness and accessibility of evacuation centers in Malolos, Bulacan. The research design integrated quantitative methods, including GIS overlay analysis, with qualitative insights from community members to assess evacuation centers' performance from both technical and human perspectives. The GIS component focused on mapping flood susceptibility, population density, and infrastructure distribution, while the qualitative interviews gathered residents' personal experiences and perceptions related to evacuation processes. This hybrid approach enabled a more nuanced understanding of evacuation center functionality in Malolos, considering both spatial data and the lived experiences of those impacted by disasters.

Sampling in this study was guided by GIS data and purposive selection of individuals with relevant experience in disaster evacuations. The GIS analysis identified high-risk flood zones and areas with limited access to evacuation centers, helping to target specific communities for interviews. Purposive sampling was employed to select key informants, including residents from these areas, local government officials, and disaster risk management personnel. This strategy ensured that the study captured diverse perspectives, focusing on those who had direct exposure to evacuation centers and disaster response processes, thus enriching the study's findings with both qualitative and spatial data.

For data collection, the study relied on geospatial data provided by the Local Government Unit (LGU) of Malolos, including boundary maps, flood-prone areas, and land use maps. These GIS datasets were critical in assessing the geographic suitability of evacuation centers. Interviews were conducted with residents from identified flood-prone zones to gather qualitative data on their experiences with evacuation centers, including access issues, safety concerns, and overall effectiveness. The data was analyzed through thematic analysis to identify key themes, such as challenges in accessibility and community preparedness, while GIS overlay analysis provided spatial insights into the potential risks and adequacy of evacuation sites. This integrated approach enabled a comprehensive evaluation of evacuation facilities, informing future improvements to disaster response strategies in the region.

RESULTS AND DISCUSSION

The flood risk assessment in Malolos, Bulacan, highlighted significant vulnerabilities related to residents' perceptions, evacuation center accessibility, and the flood susceptibility of different barangays. Through the integration of Geographic Information Systems (GIS) technology and community insights, this study provides a comprehensive understanding of flood risks and disaster preparedness.

Residents were categorized into two primary groups based on their exposure to flooding and evacuation behavior: the At Risk and Not at Risk groups. The At Risk group consists of residents who have experienced negative impacts from flooding but have not evacuated, often due to emotional attachment to their homes or skepticism about the severity of the flood. For instance, some residents in the At Risk group stated, "Dati po hindi kami binabaha, ngayon po inaabot na po tuwing may baha" (Flooding now affects areas that were previously safe), and "Para po mabantayan ang aming bahay" (I stayed behind to protect my home). These residents continue to stay in their homes despite the flood

risks, reflecting the complex relationship between perceived risk, attachment to property, and evacuation decisions. Conversely, the Not at Risk group consists of residents whose homes have remained unaffected by floods. These individuals tend to evacuate when necessary, prioritizing their safety over property concerns, as seen in the quote, "Mas safe po at mas mataas (mga classroom, 2nd floor)" (The classrooms, second floor, are safer and higher). This distinction indicates that residents' flood-related behaviors are not solely based on physical vulnerability but are influenced by social and emotional factors, which must be considered in disaster management strategies.

Table 1
Summary Table: Flood Risk Assessment and Evacuation Needs in Malolos, Bulacan

Category	Details
Residents' Perception of Flood Risk	At Risk: Areas where residents have been negatively affected by flooding but have not evacuated, often due to attachment to property. Not at Risk: Areas where residents have not been affected by flooding and evacuate when risks are imminent.
Evacuation Centers	Critical Locations: Various schools and community centers, including: - City of Malolos Integrated School (Babatnin) - Pamarawan Elementary School - Marcelo H. Del Pilar High School (Sta. Isabel)
Barangay Flood Vulnerability	Level I: Low flood susceptibility, low population density (e.g., Barihan). Level II: No evacuation center (e.g., None). Level III: Moderate flood risk, with available evacuation centers (e.g., Babatnin, Namayan). Level IV: High flood risk and population density requiring urgent improvements (e.g., Sto. Rosario, Bangkal).

The study also analyzed the accessibility and suitability of evacuation centers in Malolos. While various schools and public buildings serve as evacuation centers, some of these are located in flood-prone areas themselves, limiting their effectiveness during flood events. GIS-based assessments identified several evacuation centers situated in regions that could become inundated during extreme weather, such as in high-risk barangays like Sto. Rosario and Bangkal. In addition, densely populated areas, including Sto. Rosario and San Juan lack sufficient evacuation centers. This scarcity could result in overcrowding during floods, further compounding the risks faced by residents. These findings suggest the urgent need to reevaluate the locations and capacities of evacuation centers to ensure their functionality during flood emergencies.

The classification of barangays in Malolos based on flood vulnerability and population density also revealed critical patterns. The barangays were categorized into four levels, from Level I (low flood risk and low population density) to Level IV (high flood risk and high population density). Level I areas, such as Barihan, are at low risk with fewer residents, making them less of a concern in terms of evacuation infrastructure. In contrast, Level IV areas like Sto. Rosario, Bangkal, and Mojon have high flood vulnerability combined with dense populations, making them top priorities for infrastructure improvement. These areas urgently require better evacuation facilities and enhanced disaster response strategies to mitigate flood risks. Meanwhile, Level III areas, such as Babatnin and Namayan, face moderate flood risk and have existing evacuation centers, but these may need upgrades to better handle large populations during peak flood events.

The findings from this study underscore the importance of considering both physical and social vulnerabilities when designing flood risk management strategies. The integration of GIS technology with community insights provides a holistic view of the region's flood risks, enabling more targeted and effective disaster preparedness measures. The distinction between At Risk and Not at Risk groups

highlights the need for tailored disaster management approaches that address both infrastructure needs and behavioral factors. For example, the At Risk group requires more proactive engagement, including educational campaigns and measures to improve the perceived safety of evacuation centers. On the other hand, the Not at Risk group may benefit from enhanced evacuation facilities to ensure their safety during flood events.

The identification of evacuation centers in flood-prone areas, such as Sto. Rosario and Bangkal point to the need for strategic relocation or upgrading of these centers. According to recent studies on disaster resilience, evacuation centers should be situated in low-risk zones to ensure they remain operational during extreme weather events (Marcos et al., 2021). Additionally, densely populated barangays, like Sto. Rosario and San Juan require more evacuation centers to reduce the risk of overcrowding during floods. These findings align with recommendations from other research on improving evacuation preparedness, which emphasizes the importance of accessible, well-equipped shelters in high-risk areas (Aldaba et al., 2020).

Moreover, the barangay classification system provides a roadmap for prioritizing flood management interventions. Level IV areas, with their high vulnerability and dense populations, are in dire need of immediate infrastructure development. Recent studies on flood resilience have shown that prioritizing high-risk areas for infrastructure upgrades, including better roads, bridges, and evacuation centers, can significantly improve disaster response and reduce loss of life (Punzalan et al., 2020). Thus, the study's findings suggest that enhancing evacuation routes, expanding shelter capacity, and strengthening infrastructure in Level IV barangays should be a primary focus for local authorities.

These results also have broader implications for disaster management. The study highlights the need for targeted disaster preparedness strategies that account for both the physical risks and social behaviors of communities. The At-Risk group's reluctance to evacuate points to the importance of community engagement and education in fostering a culture of preparedness. In addition, improving evacuation centers' accessibility, particularly in high-risk areas, will help reduce the risks faced by vulnerable populations. According to recent research on community-based disaster risk management, engaging residents in the planning and implementation of disaster preparedness measures significantly enhances their effectiveness (Santos et al., 2021). Furthermore, integrating behavioral insights with GIS-based assessments can lead to more informed and inclusive flood management strategies, as it takes into account not only physical risks but also social dynamics and residents' attitudes towards evacuation.

In conclusion, the findings from this study demonstrate the value of combining GIS technology with community insights to assess flood risks and improve disaster preparedness in Malolos. The results suggest that effective flood management requires a multi-faceted approach that includes improving evacuation centers, expanding infrastructure in high-risk areas, and considering residents' social and emotional responses to floods. By prioritizing Level IV areas for infrastructure development and focusing on community engagement and education, Malolos can enhance its resilience to floods and ensure that vulnerable populations are better protected during future flood events.

CONCLUSION

Flooding in Malolos, Bulacan, remains a persistent and growing challenge, posing risks to lives, property, and infrastructure. While efforts have been made to mitigate these impacts, substantial gaps still exist in flood damage assessment and the optimization of evacuation centers. A critical limitation identified in this study is the inadequate use of Geographic Information Systems (GIS), which hampers the ability to make real-time, data-driven decisions during flood events. Although GIS proves invaluable in mapping flood-prone areas and identifying at-risk infrastructure, it does not fully capture

the lived experiences and decision-making processes of residents. Interviews with local residents revealed that many prioritize the safety of their homes and possessions over evacuating, highlighting the need for disaster response strategies that integrate both spatial data and human perspectives.

The findings also underscore the inadequacy of evacuation centers in Malolos in terms of accessibility, capacity, and strategic location. Vulnerable groups, including the elderly, disabled individuals, and families with young children, face significant barriers to accessing evacuation centers due to long distances, road blockages, and a lack of transportation options during flood events. Even when evacuation centers are accessible, issues like overcrowding, insufficient facilities, and a lack of basic services make them unattractive and, at times, less reliable than staying home. Furthermore, some residents remain reluctant to evacuate due to concerns about property damage or theft. To address these issues, it is crucial to expand the capacity of evacuation centers, improve infrastructure, and ensure that centers are strategically located in flood-prone areas. Providing better transportation options and promoting community education on the importance of timely evacuations are also vital steps for improving disaster response.

In conclusion, this study emphasizes the importance of combining advanced technologies like GIS with a people-centered approach to flood disaster management. While GIS provides valuable insights into flood risks and infrastructure vulnerabilities, it cannot replace the need to understand residents' behaviors, perceptions, and decision-making processes during a flood. The reluctance to evacuate, coupled with overcrowded evacuation centers, calls for a more comprehensive disaster preparedness strategy that integrates technology with social interventions. Local authorities must not only optimize GIS-based evacuation plans but also address the concerns of the community, build trust in evacuation centers, and implement real-time monitoring systems. By combining technological tools with behavioral insights, Malolos can strengthen its flood disaster response, ensuring better protection for vulnerable communities and a more effective, timely evacuation process.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. **Adopt the GIS-based methodology used in this study**. This approach, which combines GIS mapping and aerial photography with local data collection (including surveys and interviews), should be applied to improve flood preparedness and disaster management strategies. This would enhance understanding of residents' decision-making processes and experiences with flooding, thereby improving overall disaster response.
2. **Improve the conditions of evacuation centers**. The study recommends that evacuation centers in Malolos be upgraded to offer sufficient space, sanitation facilities, medical care, food stocks, and sleeping accommodations. These improvements would make evacuation centers more practical and comfortable, encouraging residents to evacuate during times of need. Additionally, an emergency transport system should be established to ensure that residents in flood-prone areas can safely reach evacuation centers, especially in cases where flooding obstructs roads.
3. **Incorporate community needs into disaster planning**. It is essential to engage local communities in the planning and design of evacuation centers, transportation systems, and other disaster response mechanisms. By incorporating community input, local governments can ensure that the needs of residents are effectively addressed. Moreover, partnerships with non-governmental organizations, private stakeholders, and other local government units can help enhance disaster response capacity, improve resource distribution, and strengthen long-term flood resilience.
4. **Address concerns about property safety during evacuations**. One of the significant barriers to evacuation is residents' fear of property theft or damage while they are away. To address this, local authorities should enhance security in flood-risk zones and evacuation centers to ensure that residents' properties are protected. Building trust in the safety of evacuation centers and securing properties will help reduce residents'

reluctance to evacuate during emergencies.

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