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Evaluating Evacuation Centers Using Geographic Information System Technique in Malolos, Bulacan

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ABSTRACT

Malolos, located in the southwestern part of Bulacan, Philippines, faces significant flood risks due to its low-lying geography, proximity to Manila Bay, and dense river networks. These frequent floods cause considerable socio-economic harm, and current disaster management strategies, particularly regarding evacuation, are inadequate. This study uses Geographic Information System (GIS) technology and qualitative interviews to examine flood damage, the accessibility of evacuation centers, and route effectiveness in Malolos. Results show that evacuation centers are insufficient in terms of size, accessibility, and strategic placement. Interviews highlight reluctance to evacuate, driven by concerns about property security and poor conditions at evacuation centers. Additionally, although evacuation routes exist, impassable roads and low public compliance with evacuation orders undermine the effectiveness of disaster response efforts. The study demonstrates that GIS-based mapping significantly enhances the ability to assess flood damage and plan for evacuations. However, it emphasizes the need for a holistic approach that incorporates social factors and behavioral changes. Key recommendations include improving evacuation center infrastructure, developing better transportation logistics, and strengthening public trust and awareness to enhance disaster resilience in flood-prone areas.

Keywords: *Accessibility, Behavioral Interventions, Disaster Response, Evacuation Centers, GIS*

INTRODUCTION

Malolos is situated at 14° 50' North, 120° 49' East (14.8405, 120.8116), approximately 45 kilometers (28 mi) north of Manila, the capital of the Philippines. It is one of the major suburbs of Metro Manila, located in the southwestern region of Bulacan, within the Central Luzon Region (Region 3) of the island of Luzon, and part of the Metro Luzon Urban Beltway Super Region. Malolos is bordered by the municipalities of Calumpit to the northwest, Plaridel to the north, Guiguinto to the east, Paombong to the west, Bulakan to the southeast, and Manila Bay to the south. The municipality has a relatively flat terrain, with an average elevation of approximately 0.81% and a gently sloping gradient towards the west, southwest, and south.

The highest elevation in the area is about 6.0 m (19.7 ft) above sea level, while the lowest elevation is only 0.5 m (1 ft 8 in) below sea level. A network of natural waterways and rivers of various sizes and significance traverses the landscape of the town, eventually reaching Manila Bay. (City Government of Malolos, 2018) Like several municipalities in the country, flooding is one of the most prevalent natural hazards that places in Bulacan encounter. This phenomenon is frequently attributed to heavy rainfall, typhoons, storm surges, overflowing water bodies, and subsidence.

Flooding has resulted in catastrophic outcomes. One of the most recent catastrophic flooding events in Bulacan occurred in July 2021, when southwest monsoon rains exacerbated by Typhoon Fabian (International Name: In-fa) submerged over 50 villages within the province (Silverio, 2021). This event resulted in fatalities, the destruction of agricultural products and infrastructures valued at approximately PhP 155 million (equivalent to 2.7 million euros), and the evacuation of over 500 families (Balbin, 2021). Consequently, Hagonoy, Malolos, and Paombong, which are situated in a delta environment, are naturally susceptible to flooding. The numerous rivers and streams that traverse these towns and ultimately drain into Manila Bay tend to overflow whenever heavy rains occur (Lagos et al., 2022). Due to the aforementioned phenomena, natural disasters are becoming more frequent due to various factors, including climate change, particularly global warming. Heavy rainfall, rapid snowmelt, or storm surges from tropical cyclones or tsunamis in coastal areas often lead to floods, making them one of the most destructive natural disasters on the planet. Floods are natural phenomena that occur under various circumstances and are influenced by multiple meteorological, hydrological, and human factors. Floods possess destructive power and can destroy structures that lack the capacity to withstand the force of water, such as bridges, houses, trees, cars, and even human lives. Consequently, flood studies and prevention measures have experienced significant growth in recent years. The study focus has primarily shifted to metropolitan cities and their urban planning. While village development and increased attention are crucial in flood-prone areas, damage to land and structures in rural communities is often overlooked, placing them in an unsafe position.

Furthermore, despite the significance of assessing risks associated with building attributes, most risk assessment studies have concentrated on environmental factors with limited attention to building attributes (Singh et al., 2024). On the other hand, urban areas are susceptible to natural disasters and necessitate countermeasures to enhance resilience. Coastal cities and river-side urban areas are increasingly facing flood challenges. Urbanization, coupled with climate change, has led to an increase in localized torrential rainfall, resulting in more frequent floods in certain regions. Local governments have implemented both hard and soft measures to mitigate the potential impact of floods; however, public awareness of flood risk is essential for the effectiveness of these measures. (Sado-Inamura & Fukushi, 2019).

Consequently, flooding, a natural disaster, has caused significant and detrimental effects. The Organization for Economic Cooperation and Development (OECD) reported that floods result in over USD 40 billion in destruction annually. The United States alone incurs approximately USD 8 billion in flooding-related losses each year. Recently, the number of fatalities attributed to flooding has risen to roughly 100 deaths globally (Nunez, 2019), while approximately 6.8 million individuals were adversely affected by excessive flooding in the northeastern region of India (Malhotra, 2020).

Furthermore, the rapid urbanization and inadequate urban planning have contributed to the vulnerability of urban areas to flooding. For instance, in Metro Manila, Philippines, over 60% of the city's area is estimated to be at flood risk (Rodolfo & Siringan, 2006). In the context of flood relief and evacuation during emergencies involving flooding, the assessment of the extent of flooding, flood losses, and the needs of the impacted populations is crucial. Depending on the severity of the flood and the preparedness of the affected area, this evaluation may necessitate the completion of the assessment under unusual circumstances, characterized by a range of disorganized conditions, contingencies, and time constraints.

Given these disorganized conditions and the growing public pressure, initial approximations are often made arbitrarily. Subsequently, decisions regarding the revision of flood management policies and the planning of reconstruction are based on these initial findings. However, it is essential to adhere to fundamental guidelines to prevent overly optimistic projections and the subsequent consequences. In light of the aforementioned scenarios, various tools and methodologies have been developed for creating flood susceptibility maps. Multi-criteria decision-making (MCDM) in conjunction with a geographical information system (GIS) is one of the widely employed approaches for assessing flood susceptibility (Rincón et al., 2019). GIS-based flood hazard mapping serves as a crucial tool for identifying high-risk flood zones and estimating potential flood damage (Parker et al., 2009). The

Geographic Information System (GIS) is a technology employed to create, manage, analyze, and map all types of location-based data. It establishes a connection between data and a map, integrating location data with descriptive information.

Consequently, GIS proves instrumental in Flood Risk Assessment (FRA) by facilitating the creation and visualization of all spatial information pertaining to field data. Through GIS, planning decisions can be optimized, emergency and disaster response can be enhanced, environmental management can be improved, and business operations and marketing can be enhanced (Geoapify, 2024). GIS has gained widespread adoption for flood risk management and disaster mitigation (Tomar et al., 2021).

The integration of numerous spatial data sets, such as topography, land use, hydrology, and transportation networks, is essential for determining suitable evacuation zones and routes in flood-prone areas. Based on the aforementioned premises, the researchers are compelled to undertake this study to assess the spatial distribution and extent of flood damage, as well as to evaluate the suitability and accessibility of evacuation centers utilizing Geographic Information System (GIS) technology. This study aims to incorporate the following inputs for damage assessment, base map, and interviews. Subsequently, the damage assessment will inform the evacuation center assessment, which will assess whether the centers are suitable and accessible.

MATERIALS AND METHODS

This study adopted a hybrid mixed-method design, integrating Geographic Information System (GIS) analysis and qualitative interviews to assess the evacuation centers in Malolos, Bulacan. The concurrent method combines spatial data with resident perspectives to provide a comprehensive evaluation. The quantitative component involves overlay analysis to assess the suitability and accessibility of evacuation centers by examining hazard zones, population density, and facility distribution. By integrating these methods, the research aims to offer a holistic understanding of evacuation centers, focusing on their ability to serve communities effectively during disasters while accounting for both technical and human aspects.

The sampling approach in this research includes GIS-based selection of high-risk areas and purposive sampling of residents who are likely to provide pertinent insights. GIS data, such as flood susceptibility and land use maps, were obtained from the Malolos Local Government Unit (LGU) to identify key risk zones. Residents living in flood-prone areas, as identified by GIS, were prioritized for interviews. Additionally, local disaster risk reduction officers and barangay officials were consulted to enrich the qualitative data. This purposive strategy ensures that the findings reflect the experiences of those most affected by evacuation processes, thereby enhancing the relevance of the research outcomes.

Data collection involved two primary sources: GIS data from the LGU and qualitative interviews with residents in high-risk areas. The GIS data, including barangay boundary maps, flood susceptibility maps, and the land use map, provided essential information on evacuation site accessibility and safety. Interviews with community members focused on their experiences with previous evacuations and their views on the current evacuation centers' effectiveness. Thematic analysis was applied to the interview data to identify recurring patterns regarding evacuation center performance, while overlay analysis was used to assess spatial factors influencing evacuation site suitability. This combined approach ensures a thorough evaluation, guiding improvements in disaster preparedness and response strategies in Malolos.

RESULTS AND DISCUSSION

Overlaying of Maps

Flood risk assessment is a crucial component of disaster preparedness, planning, and mitigation. To effectively manage flood-related risks and improve evacuation strategies, a systematic approach involving the integration of geographic data, thematic mapping, and primary data collection is essential. This process involves several stages, from gathering geographic data and generating base maps to conducting surveys and overlaying primary data to evaluate flood risks.

The initial stage of the process involved requesting thematic maps and geographic data from the Local Government Unit (LGU). This data, including shapefiles and coordinates, was crucial for developing accurate and region-specific flood risk maps. By obtaining this data from local authorities, the project could utilize relevant and precise information for subsequent analysis. The LGU data also provided insights into various aspects of the local environment, such as infrastructure, land use, and flood-prone areas.

Once the data from the LGU was obtained, the next step was to generate base maps using Geographic Information Systems (GIS). GIS technology enables the creation of layered maps that can visualize and analyze spatial relationships. The base maps created for this project included several important thematic layers:

- Population Density. This layer highlighted the distribution of the population across the study area, which is crucial for identifying regions with high concentrations of people that may require more extensive evacuation planning.
- Land Use. This map depicts the diverse land uses within the region, including residential, commercial, and agricultural areas. It was crucial for comprehending how different regions might be impacted by flooding and how land use could influence flood effects.
- Location Map. A comprehensive map of the study area served as a reference for locating the regions under analysis.
- Flood Susceptibility. This layer represented areas with varying levels of risk from flooding, based on historical data and flood hazard models.
- Evacuation Center Locations. Finally, the map indicated the locations of evacuation centers within the area, which was essential for assessing their accessibility and capacity to accommodate displaced populations during a flood event.

Following the creation of the base maps, an evaluation map was generated using secondary data provided by the LGU. This map compared population density (with flood susceptibility, identifying areas that were both densely populated and highly susceptible to flooding. By overlaying these two datasets, it became easier to pinpoint regions at higher risk of significant damage during a flood event. This evaluation map proved invaluable for understanding where resources should be allocated and which areas required more attention in terms of evacuation planning and infrastructure support.

In addition to secondary data, the study also gathered primary data through surveys and interviews. These qualitative methods allowed the researchers to directly obtain insights from affected residents, local officials, and disaster responders. Interviews provided valuable information about the perceived severity of floods, the functionality of evacuation centers, and the community's overall readiness to cope with flood events. This primary data complemented the quantitative data collected through GIS and thematic maps, offering a comprehensive understanding of the real-world impact of floods.

Once the primary data (from the interviews) and secondary data (from the thematic maps) were collected, the next step involved correlating the two datasets. The researchers overlaid the coordinates from the interviews onto the base maps, enabling them to visually compare the locations of interviewees with flood-prone areas and evacuation centers. This step provided a deeper understanding of the spatial relationships between flood risks and the experiences of local residents. By overlaying the two datasets, the researchers identified areas where the community's needs might not be fully met by existing infrastructure and evacuation plans.

The final stage involved generating an evaluation map to differentiate between at-risk and non-risk areas. This map incorporated factors such as route maps, flood susceptibility, and risk levels across the region. By analyzing this map, decision-makers could clearly identify the most vulnerable areas and prioritize them for intervention. The map also provided valuable insights into the accessibility of evacuation routes and the adequacy of evacuation centers. Furthermore, it highlighted areas where future development or flood mitigation strategies should be focused to reduce overall risk.

This comprehensive approach to flood risk assessment integrates secondary geographic data with primary qualitative data. The process involves creating thematic maps through GIS, evaluating flood susceptibility based on population density, and incorporating local insights from interviews. This holistic view of flood risks within the study area helps identify at-risk areas, optimize evacuation planning, and improve disaster preparedness. By correlating these datasets and generating evaluation maps, the study contributes to more informed decision-making for local authorities, ensuring efficient and effective resource allocation to protect vulnerable populations during flood events.

Table 1
Thematic Classification of Residents' Perception of Flood Disaster Damages

Classification	Description	Sample Quotes
At Risk	The living conditions of residents have been negatively affected by flooding.	“Dati po hindi kami binabaha, ngayon po inaabot na po tuwing may baha.” (Flooding now affects areas that were previously safe.)
	Residents chose not to evacuate despite flood risks.	“Para po mabantayan ang aming bahay.” (I stayed behind to protect my home.)
Not at Risk	The living conditions of residents have not been impacted by flooding.	“Hindi po pinapasok ng tubig ang bahay namin.” (Water does not enter our house.)
	Residents evacuated when flood risks were present.	“Mas safe po at mas mataas (mga classroom, 2nd floor).” (The classrooms, second floor, are safer and higher.)

The *At-Risk* group represents residents who have experienced the adverse effects of flooding but have not evacuated, often due to emotional attachment or skepticism about the severity of the threat. Some respondents shared that their homes were previously unaffected by floods but have now started to experience frequent inundation, as indicated by the statement, *“Dati po hindi kami binabaha, ngayon po inaabot na po tuwing may baha.”* This highlights the changing nature of flood events, where previously safe areas are now vulnerable. Furthermore, the quote “Para po mabantayan ang aming bahay” suggests that some residents stay behind to safeguard their homes and possessions, even when flooding becomes increasingly severe. This behavior reflects a lack of trust in the evacuation system or the belief that their property is more important than personal safety.

Conversely, the *Not-at-Risk* group comprises residents whose living conditions have not been significantly impacted by flooding. These individuals are more proactive in evacuating when flood risks are imminent, as shown by the quote, *“Mas safe po at mas mataas (mga classroom, 2nd floor).”* It demonstrates that these residents prioritize safety by moving to higher ground or evacuation centers when necessary. The fact that their homes are not directly affected by flooding *(“Hindi po pinapasok ng tubig ang bahay naming”*) indicates that these residents feel secure, but they still recognize the need for evacuation to minimize potential risk during severe flood events.

The distinction between *At-Risk* and *Not-at-Risk* groups reveals important patterns in flood response behavior. While some residents may underestimate flood risks or place more value on their property, others are more attuned to the dangers of flooding and take proactive measures. These findings highlight the need for public education and stronger evacuation plans that cater to the diverse perceptions of risk, ensuring that all residents understand the importance of evacuating in time. Additionally, addressing the emotional and practical concerns of the *At-Risk* group is critical to improving evacuation rates and overall disaster preparedness.

This section presents the perception of the residents based on their experiences in flood disasters. The researchers divided the perception of the residents in terms of the damage into (1) At Risk and (2) Not At-Risk.

In Table 1. The researchers coded the experience of at-risk residents based on the following: (1) The living condition of the residents has not been affected by flooding, and (2) The residents did not evacuate even though there are flood risks.

Many communities are at risk of becoming submerged in water, especially those living at lower altitudes. Residents respond differently to flooding, which defines their risk potential. According to the information provided, people can be divided into two categories: at-risk and not-at-risk people.

People who belong to the At-Risk group are those whose living situations have not been significantly impacted by flooding, but they still opt to remain in their homes. Their choice of staying could derive from their feeling of satisfactory security in their property, skepticism about flooding reaching extreme levels, or they have valuables that they need to safeguard.

One resident says, “Dati po hindi kami binabaha, ngayon po inaabot na po tuwing may baha.” This quote exemplarily explains how there is a gradual change in the floods over time as places that previously did not get submerged are now facing floods. This indicates there is an environmental change taking shape, most likely due to urban sprawl, deforestation, or climate change. Regardless, these residents tend to stay regardless of the many unbearable floods. A different respondent said, “Para po mabantayan ang aming bahay,” which reveals the fact that some residents are more concerned with monitoring their property than prioritizing their wellbeing.

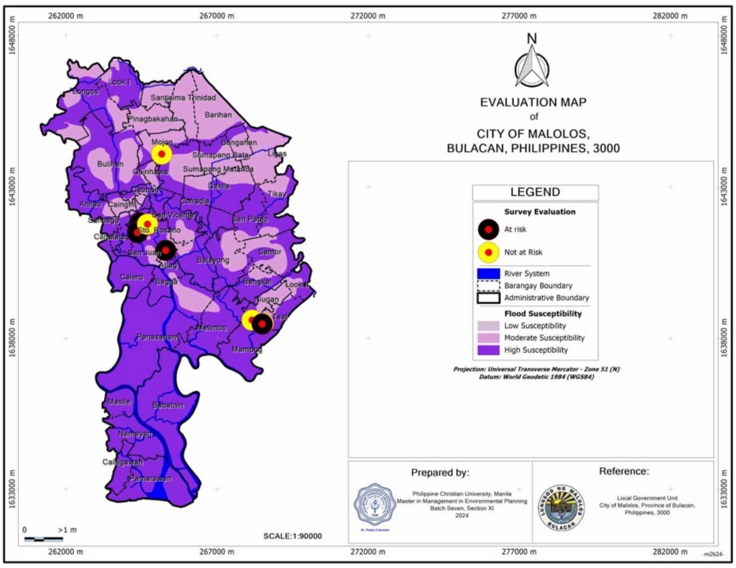

Figure 1. At-risk and not-at-risk points based on the Resident’s Interview

On the other hand, Not At Risk residents are those who took precautionary measures to evacuate the area before flooding impacted their living area. They respond to flooding’s risks unlike the At Risk group, which is versed in the reactive approach that involves increasing the level of harm inflicted before responding to potential danger.

As one resident put it, "*Hindi po pinapasok ng tubig ang bahay naming*." It seems like their house is safe from floodwaters, which could be due to elevation or other protective measures taken around the structure. Besides, another said that for sure mas safe po at mas mataas (mga classroom, 2nd floor), illustrates another positive approach in seeking higher secure rooms like school buildings.

On the whole, these residents seem to safeguard their well-being and health by judging the danger of remaining in flooded areas and the risk of being displaced as far less dangerous. Thus, because of their willingness to be evacuated, their exposure is viewed as less challenging to non-hazardous conditions, and, therefore, people are grouped under Not At Risk.

In Figure 1, it pins the respondent's coordinates to fully visualize the context of their perception in terms of flood damage. This map shows that the hotspot for being at risk is the Barangay Sto. Rosario. Some respondents also expressed that they are at risk of flood damage around Barangay San Juan and Barangay Taal. The hotspot for at-risk groups shows that the area is highly susceptible to flooding and is densely populated. Thus, the high susceptibility and the population density will be considered in evaluating the evacuation centers.

Overall, At Risk and Not At Risk residents depict the failure to address flood risks or the lack of awareness, preparedness, and responsiveness. Some people are willing to endure an increase in flood levels, whilst some take a logical step and shelter themselves in the evacuation center.

The low-lying risk zones that can be severely flooded were marked within the danger maps (aerial imagery and base maps) that were produced. Such maps captured and marked the areas that are supposed to get flooded, along with regions that have a high concentration of water and structural damage.

In addition, some interviews brought to light the views and the truths of the citizens about the flood situation. While some citizens seem to become more worried about the flood situation as some regions which were not previously flooded are now being flooded often, some pointed out their logic behind either being in the house during such a risk situation or leaving for a safe place if required. These accounts, paired with the information gathered from the maps provided, created a context surrounding the data and illustrated the impact flooding has on livelihoods, infrastructure, and community support centers.

With all these sources, floods in Malolos, Bulacan could be assessed and the most affected areas determined, along with the integration of the aerial imagery, base maps, and the interviews conducted, which could be utilized in future steps towards coming up with a disaster preparedness program.

Evacuation Center Assessment

This section explores the effectiveness of evacuation centers in Malolos and examines how GIS technology can improve evacuation planning, ultimately enhancing disaster preparedness and response strategies for flood-affected communities. Figure 2 is an evaluation map that evaluates evacuation centers in Malolos, Bulacan, in terms of population density and flood vulnerability. This map gives a spatial analysis of whether evacuation centers are strategically located to serve high-risk communities.

The researchers evaluate the evacuation centers since successful disaster preparedness is dependent on the strategic location of evacuation centers to house affected populations with minimal exposure to flood risk. By superimposing population density information over flood susceptibility areas, the map determines locations where evacuation centers might be inadequate or poorly located. Areas of high population density with few evacuation facilities could suggest overcrowding, while facilities located in flood-susceptible areas could jeopardize evacuee safety. This analysis assists in disaster response planning by informing decisions regarding infrastructure upgrades, facility relocation, or the construction of new evacuation centers in safer, more accessible locations.

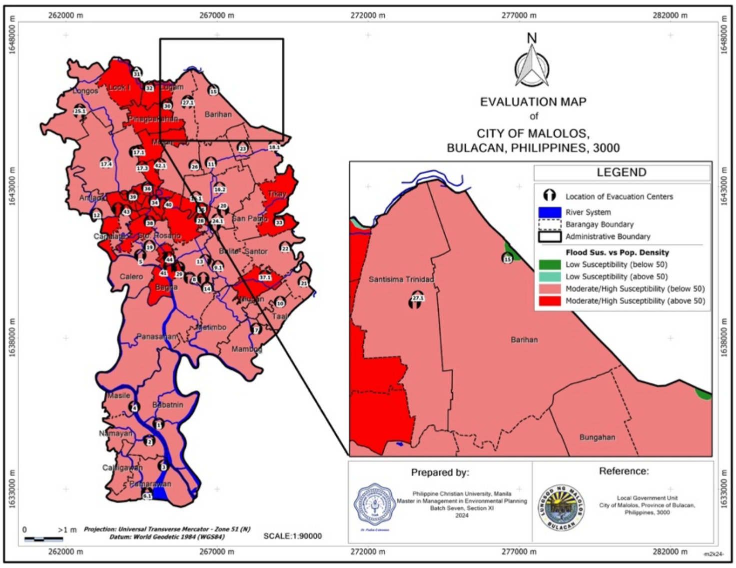

Figure 2. Evacuation Evaluation Map

The evaluation map classifies areas in Malolos, Bulacan, by population density (number of people per hectare) and flood vulnerability, from white to red to show rising levels of risk. This categorization can be used to evaluate whether the evacuation centers are strategically located to reach communities at flood risk. This research divided it into four levels:

Level I: 50 people per hectare, Low flood susceptibility (Green)
These zones are sparsely populated and are at low risk of flooding. Although evacuation centers in these areas can be beneficial to nearby communities, they are not likely to be high-priority locations because of the reduced number of affected residents.

Level II: Greater than or equal to 50 persons per hectare, Low flood susceptibility (Sky Blue)
Highly populated zones that have little risk of flooding. Although the necessity for evacuation will be less, the availability of evacuation centers in these places could still prove helpful for disaster management and emergency preparedness.

Level III: Less than 50 people per hectare, Moderate flood susceptibility (Light Red)
These regions are comparatively less densely populated but suffer moderate floods. Even though fewer individuals may be impacted directly, access to evacuation centers is still a concern, especially in the case of vulnerable groups like the aged and physically handicapped individuals.

Level IV: Greater than or equal to 50 people per hectare, Moderate to High flood vulnerability (Red)
These are risk areas where both population and flood vulnerability are high. People living in these areas are highly susceptible to displacement and need instant access to evacuation centers. Availability of well-sited and accessible shelters in these areas is vital to reducing casualties and facilitating effective disaster response.

This spatial analysis aids in evacuation planning optimization by prioritizing high-density, flood-vulnerable regions for infrastructure development and disaster preparedness initiatives. In Table 2, the

Evacuation Centers in Malolos have been coded. It consists of the number code, the name of the evacuation centers, and the Barangay.

Table 2
List of Evacuation Centers in Malolos, Bulacan

Number Code	Name of Evacuation Center	Barangay
1	City of Malolos Integrated School - Babatnin	Babatnin
2	Namayan Elementary School	Namayan
3	Caliligawan Elementary School	Caliligawan
4	Masile Elementary School	Masile
5	Calero Elementary School	Calero
6.1	Pamarawan Elementary School	Pamarawan
6.2	Pamarawan High School	Pamarawan
7	Mambog Elementary School	Mambog
8	Panasahan Elementary School	Panasahan
9.1	Balite Elementary School	Balite
9.2	Malolos Marine Fishery School and Laboratory	Balite
10	Taal Elementary School	Taal
11	Sumapang Bata Elementary School	Sumapang Bata
12	Anilao Elementary School	Anilao
13	Balayong Elementary School	Balayong
14	Gen. Isidro Torres Memorial Elementary School	Matimbo
15	Barihan Elementary School	Barihan
16.1	Marcelo H. Del Pilar High School	Sta. Isabel
16.2	Dakila Elementary School	Dakila
17.1	Regional Evacuation Center	Bulihan
17.2	Malolos Sports Convention Center	Bulihan
17.3	Bulihan Elementary School	Bulihan
17.4	Bulihan National High School	Bulihan
18.1	Ligas Covered Court	Ligas
18.2	Ligas Elementary School	Ligas
19	San Juan Elementary School	San Juan
20	San Pablo Elementary School	San Pablo
21	Look 2nd Elementary School	Look 2nd
22	Santor Elementary School	Santor
23	Bungahan Elementary School	Bungahan
24.1	Sta. Isabel Elementary School	Sta. Isabel
24.2	Sta. Isabel Elementary School	Sta. Isabel
25.1	Longos Elementary School	Longos
25.2	Longos II Elementary School	Longos
26	Sumapang Matanda Elementary School	Sumapang Matanda
27.1	Malolos City High School - Stma. Trinidad	Stma. Trinidad
27.2	Santisima Trinidad Elementary School	Stma. Trinidad
27.3	Malolos City High School - Stma. Trinidad	Stma. Trinidad
28	Mabolo Elementary School	Mabolo
29	Bagna Elementary School	Bagna

Number Code	Name of Evacuation Center	Barangay
30	Pinagbakahan Elementary School	Pinagbakahan
31	Look 1st Elementary School	Look 1st
32	Lugam Annex Elementary School	Lugam
33	Tikay Elementary School	Tikay
34	Canalate Elementary School	Canalate
35	Cofradia Elementary School	Cofradia
36	City of Malolos Integrated School - Catmon	Catmon
37.1	Teodulo C. Natividad High School	Bangkal
37.2	Bangkal Elementary School	Bangkal
37.3	Cong. Teodulo Natividad High School	Bangkal
38	City of Malolos Integrated School - Sto. Rosario	Sto. Rosario
39	San Agustin Elementary School	San Agustin
40	Caniogan Elementary School	Caniogan
41	Sto. Cristo Elementary School	Sto. Cristo
42.1	Barasoin Memorial Elementary School	Mojon
42.2	Pres. Corazon Cojuanco Aquino Memorial High School	Mojon
43	Caingin Elementary School	Caingin
44	City of Malolos Integrated School - Atlag	Atlag

Table 2 presents a comprehensive list of evacuation centers (ECs) across Malolos, Bulacan, serving as key locations for residents during disaster events, particularly flooding. The table includes the number code, name of the evacuation center, and the corresponding barangay. It is essential to recognize the spatial distribution of these centers, as their effectiveness in providing refuge during floods depends on their proximity to flood-prone areas and the population density of the surrounding regions.

The wide distribution of evacuation centers throughout Malolos, including schools, covered courts, and other public facilities, highlights a relatively robust evacuation infrastructure. However, the strategic placement of these centers is a critical factor in ensuring their accessibility and capacity to accommodate residents, especially in flood-prone areas with higher population density. For instance, evacuation centers located in barangays such as *Bulihan*, *San Juan*, and *Taal* may be better positioned to support those living in flood-vulnerable zones, but some areas, like *Babatnin* or *Atlag*, may have less access to evacuation facilities or require further development to support a larger influx of evacuees during extreme flood events.

By evaluating these evacuation centers in relation to flood risk zones and population density, local authorities can identify where additional resources, infrastructure improvements, or even the construction of new centers are necessary. The role of GIS tools in analyzing the accessibility of these centers is essential in creating more efficient evacuation routes, ensuring that all residents, particularly those in high-risk areas, can evacuate safely and promptly. The continued expansion and improvement of evacuation infrastructure in areas with high flood vulnerability and population density should remain a priority in future disaster management plans for Malolos.

Table 3

Classification of Barangays Based on Evacuation Center Levels

Level	Number Code	Name of Evacuation Center	Barangay
Level I	15	Barihan Elementary School	Barihan
Level II	NONE	-	-

Level	Number Code	Name of Evacuation Center	Barangay
Level III	1	City of Malolos Integrated School - Babatnin	Babatnin
	2	Namayan Elementary School	Namayan
	3	Caliligawan Elementary School	Caliligawan
	4	Masile Elementary School	Masile
	5	Calero Elementary School	Calero
	6.1	Pamarawan Elementary School	Pamarawan
	6.2	Pamarawan High School	Pamarawan
	7	Mambog Elementary School	Mambog
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	22	Santor Elementary School	Santor
	23	Bungahan Elementary School	Bungahan
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	24.2	Sta. Isabel Elementary School	Sta. Isabel
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	39	San Agustin Elementary School	San Agustin
	41	Sto. Cristo Elementary School	Sto. Cristo
	42.1	Barasoin Memorial Elementary School	Mojon
	43	Caingin Elementary School	Caingin
	44	City of Malolos Integrated School - Atlag	Atlag

Table 3 classifies the barangays of Malolos based on the population density and flood vulnerability of the areas they serve. The classification into Levels I, II, III, and IV assists in identifying priority areas for evacuation planning and the development of additional resources.

- **Level I** represents areas with low flood susceptibility and population density, where the need for extensive evacuation infrastructure is minimal. However, evacuation centers in these areas still play a crucial role for neighboring zones and can be useful in supporting emergency response when needed.
- **Level II** had no evacuation centers assigned, suggesting that such areas may either be underserved or are not considered at high risk in terms of both flood susceptibility and population density. This highlights a potential gap in the overall evacuation infrastructure for some areas of Malolos.
- **Level III** areas consist of moderately populated regions that face moderate flood risks. These areas require adequate evacuation centers with a moderate capacity to ensure that displaced residents have a safe refuge during flooding events.
- **Level IV** areas, characterized by high population density and significant flood vulnerability, demand immediate attention. These regions require well-equipped evacuation centers, strategically located in areas that ensure swift accessibility for the community. The inclusion of large facilities like the *Regional Evacuation Center* and *Malolos Sports Convention Center* in these areas is vital for accommodating a large influx of evacuees during peak flood events.

This classification of barangays and evacuation centers based on flood risk and population density helps prioritize emergency response efforts and ensures that evacuation resources are allocated where they are most needed. Moving forward, it is essential to conduct further assessments of evacuation center capacity, accessibility, and conditions in high-risk areas to enhance overall disaster preparedness and response strategies. The use of GIS technology can optimize this process by allowing for real-time monitoring of flood-prone areas and efficient management of evacuation routes.

The classification of evacuation centers and their distribution across Malolos highlights several critical needs for improvement in disaster management. Specifically, areas classified under **Level IV** with high flood risk and population density should receive the most attention. These areas may require new evacuation centers or the expansion of existing ones to better handle large numbers of evacuees during a disaster. Moreover, Level III areas should also be carefully monitored to ensure that evacuation centers are sufficiently equipped and accessible.

In conclusion, this classification system provides a valuable tool for optimizing evacuation strategies in Malolos. It emphasizes the need for strategic placement of evacuation centers and the development of better transportation and infrastructure in flood-prone regions. Integrating GIS tools and community feedback will help in refining evacuation planning and improving disaster preparedness across the region.

CONCLUSION

Flooding in Malolos, Bulacan, continues to pose significant challenges to both residents and infrastructure, threatening lives, property, and livelihoods. Despite ongoing mitigation efforts, there remain substantial gaps in both assessing flood damage and optimizing evacuation center usage. One key limitation is the insufficient integration of Geographic Information Systems (GIS), which reduces the ability to make informed, real-time decisions during flood events. GIS is invaluable in mapping flood-prone areas and identifying at-risk infrastructure, but it does not fully capture the lived experiences and decision-making of residents during these disasters. Interviews with locals revealed that many prioritize safeguarding their homes and possessions over evacuating, indicating the need for disaster response strategies that combine both spatial data and human insights.

The study also highlighted the shortcomings of evacuation centers in Malolos, particularly regarding their accessibility, capacity, and location. Spatial analysis, along with feedback from residents, shows that vulnerable groups—such as the elderly, disabled, and families with young children—face significant barriers in accessing evacuation centers. Issues like long distances, road obstructions, and the lack of transport during high floods exacerbate the problem. Even when centers are accessible, overcrowding, inadequate facilities, and a lack of basic services make evacuation centers an unpleasant and less trusted option for many. Furthermore, some residents are hesitant to evacuate due to concerns about property loss or the belief that evacuation centers are not significantly safer than staying at home. To address these challenges, it is critical to increase the capacity of evacuation centers, improve infrastructure, and ensure that these centers are strategically located in flood-prone areas. Additionally, providing transportation solutions and promoting community education to encourage timely evacuations are essential steps to improve disaster response.

Ultimately, the findings of this study emphasize the need to combine advanced technologies like GIS with a people-centered approach in flood disaster management. While GIS provides valuable spatial insights on affected areas, infrastructure vulnerabilities, and population density, it cannot replace the importance of understanding residents' behavior and perceptions during floods. The reluctance to evacuate, compounded by overcrowded evacuation centers and inadequate facilities, calls for a more comprehensive disaster preparedness strategy that integrates technology with social interventions. To enhance evacuation routes and ensure their effective use, authorities must not only optimize GIS-based evacuation plans but also address community concerns, build trust in evacuation centers, and create real-time monitoring systems. By combining technological tools with behavioral insights, Malolos can improve its flood disaster response, ensuring better protection for vulnerable groups and a more effective, timely evacuation process.

Recommendations

Based on the findings and conclusions of the study, the following recommendations may be considered for various stakeholders:

1. This research recommends applying the methodology applied in this study. This research merged Geographic Information System (GIS) mapping and aerial photography with local data gathering, including surveys and interviews, to improve residents' decision-making and

experiences with flooding.

2. This research also recommends to improve the conditions of the evacuation centers. Upgrade evacuation centers to offer sufficient space, sanitation, medical facilities, food stocks, and sleeping facilities to make them a more practical and comfortable choice for evacuees. Also, this research recommends creating a special emergency transport system to help residents reach evacuation centers safely, especially in places where flooding blocks roads.
3. This research also recommends integrating the needs of the people in disaster response and recovery. Engage local communities in planning evacuation centers, transportation, and response mechanisms to disaster events in order to address their needs. Also, LGUs must engage in partnerships with local government units, non-governmental organizations, and private stakeholders to enhance disaster response capacity, enhance resource distribution, and increase long-term flood resilience.
4. LGUs must address the fear of the resident of being robbed on their home while they are in the evacuation center. Boost security in flood-risk zones and evacuation facilities to assure people that their properties are safe and will be protected, so they feel less resistant to evacuation.

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