# MAPPING AND ASSESSMENT OF FLOOD EVACUATION SITES IN A GEOSPATIAL ENVIRONMENT: A CASE IN LAS NIEVES, AGUSAN DEL NORTE, PHILIPPINES

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**KEY WORDS:** Evacuation Centers, Flooding, GIS, Suitability Analysis, Web Application

**ABSTRACT:**

The municipality of Las Nieves is one of the most vulnerable areas prone to flooding, usually caused by tropical cyclones. With these, preparing for an emergency response is relatively significant, and one strategic response is planning for systematic management of evacuation shelters. Hence, this study assessed the spatial exposure to flooding, the spatial capacity and mapped the suitability of evacuation shelters using Geographic Information System and site suitability analysis. This study also developed a web-based application that will address the needs of the Las Nieves LGU, specifically in providing the locality with spatial information and other flood-related data. Weighted Overlay Analysis was performed based on Multi-Criteria Decision Making and weights from related literature to generate a suitability map for flood evacuation shelters. Factors included slope, elevation, land use/land cover, road networks, distance to water sources, distance to electrical supplies, and proximity to fuel stations. The results indicated that 85.1% of the areas were moderately suitable, 0.3% were highly suitable, and 14.6% were low suitable for flood evacuation sites in Las Nieves. From the analysis of 11 existing evacuation centers, there are ten evacuation centers moderately suitable for use during an emergency, while only the Maningalao Evacuation Center was not suitable because the location of the center was affected by the 100-year flood event. Moreover, the web mapping application developed in this study will help the stakeholders and community of Las Nieves to effectively manage evacuation centers and access real-time spatial data regarding evacuation centers' status and spatial capacity.

## 1. INTRODUCTION

In Asia, flooding is responsible for the highest number of disaster-related fatalities, an estimated 84% over the last two decades (Doocy et al., 2013). Studies anticipated that the frequency and magnitude of flooding events would be exacerbated by climate change (Hirabayashi et al., 2013) and could be further intensified by anthropogenic activities such as deforestation, urbanization, and poor floodplain management (Few, 2003). During the rainy season, rainfall-induced flooding is not a new phenomenon in the municipality of Las Nieves. Almost every year, a significant barangay of the municipality suffers badly from the impacts of flooding. Some highly dense areas with lower ground elevation submerge underwater even with intense precipitation for a few hours. Climate change will likely worsen the circumstances, leading to more frequent and extreme precipitation. With these, preparing for an emergency response is relatively significant, and one strategic emergency response is planning for evacuation shelters.

An evacuation shelter conventionally constitutes a vital role in mitigating flood-related hazards. However, the lack of produced evacuation maps and spatial data on existing evacuation centers makes local governments struggle to effectively implement sustainable emergency responses to flooding. The spatial analysis and mapping capabilities of Geographic Information System (GIS) technology have a great potential to bridge this gap by visualizing the existing and assessing new proposed evacuation centers, even in a resource-constrained setting. Thus, GIS with site suitability analysis can determine the right evacuation center that matches the criteria; it also offers a valuable tool in planning, responding, and recovering from incidents requiring evacuation and shelter (Cohen, 2006). With this, the researchers will identify the suitable evacuation sites in Las Nieves using GIS-Based multi-criteria analysis integrated with weights from established research and literature. The researchers considered relevant parameters affecting the suitability of evacuation shelters, such as accessibility and proximity to flood hazards. Moreover, the researchers will also develop a web-based monitoring system, which stakeholders can use, especially in providing information about the spatial capacity of a specific evacuation center and its availability/occupancy on a temporal scale.

The Project 2 of the Engage Caraga Program –Needs Assessments of LGUs on Building Flood Hazard Resilience and Reducing Vulnerability found out that the municipality of Las Nieves is one of the most vulnerable areas prone to flooding, usually caused by tropical cyclones. Hence, this study intends to assess the spatial exposure and spatial capacity of those existing evacuation centers and map the suitable sites for new proposed evacuation shelters using the integration of the Geographic Information System and site suitability analysis.

### 1.1 Evacuation Shelter

Evacuation is an immediate response to a risk management strategy widely used to mitigate the effects of an emergency. It involves the movement of people trying to get away or escape from an area with hazards or threats (Mustaffa et al., 2016). A collective or communal temporary shelter is where a large group of displaced individuals is given a temporary roof, food,

clothes, drinking water, health, and protection for a short period. If given the required resources, existing facilities such as schools, multi-sports gyms, and public buildings can serve as temporary shelters during emergencies (Nappi et al., 2019).

An Evacuation Center is primarily established to provide shelter to people directly affected by an emergency and those who do not have anywhere else to go. For example, they have been evacuated from their homes or cannot access them because of the incident. Evacuation Centers are usually established in halls or school gymnasiums to provide basic shelter. An evacuation must be appropriately planned and administered to be effective. Planning for an evacuation center specifically needs intensive attention to public health risks such as the possible transmission of diseases, especially during the COVID-19 pandemic. Factors such as the physical amenities and space required for well-being should be assessed when planning evacuation shelters, concerning minimizing the risk of communicable disease outbreaks and the need to promote the health of evacuees to prevent acute and chronic diseases (Mustaffa et al., 2016). Considerations should also be given to a disaster evacuation shelter's infrastructure and physical layout to ensure that critical public health principles relating to COVID-19 can be maintained as best as possible (WHO, 2020).

According to Mabahwi et al. (2021), all of the recommended criteria for suitable flood shelter locations can be summarized as follows:

1. Flood shelters should be located in a residential area to provide complete protection for planning units while minimizing the overall risk to vulnerable communities.
2. Flood shelters should be located outside flood-prone areas.
3. Flood shelters should be located on a slope not exceeding 7%, preferably between 2% and 3%.

## 2. METHODOLOGY

### 2.1 Study Area

The selected study area is Las Nieves, a second-class municipality in the coastal province of Agusan del Norte, Caraga region. According to PhilAtlas (2021), it covers approximately 582.69 square kilometers (224.98 square miles), accounting for 21.34 percent of Agusan del Norte. It has a population of 28,414 people as per the 2015 Census. It accounted for 8.02 percent of the province of Agusan del Norte and 1.09 percent of the total population of the Caraga region. The population density is 49 per square kilometer or 126 per square mile.

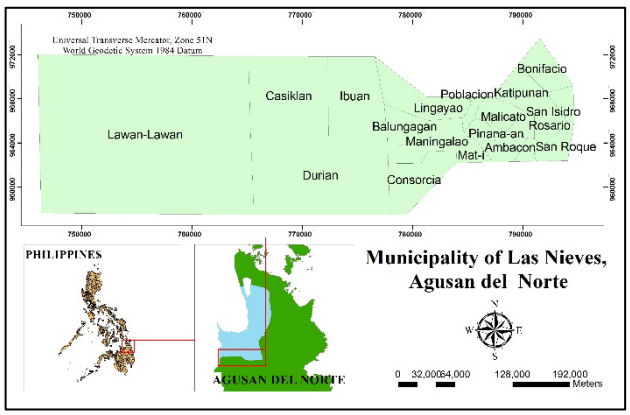


**Figure 1.** Map of the Study Area

### 2.2 Site Suitability Analysis

The evacuation area must be away from the flood-prone area and give a safer yet more comfortable for the evacuees to stay in the selected evacuation area. Thus, a Geographic Information System (GIS) with site suitability analysis can determine the right evacuation center that matches the criteria.

In determining the suitable areas for evacuation centers, the data collected was used to create maps of the criteria. Weighted Overlay Analysis was performed based on Multi-Criteria Decision Making and weights from related literature, which was integrated with multiple parameters this study considered. The obtained data were then inputted to process rasterization, Euclidean distance, and reclassification. The elevation, slope, and land use/land cover were converted into raster format with a pixel size of 10x10m and reclassified based on its standard suitability classification. The models on the distance to roads, electric source, water source, and fuel stations were generated using Euclidean Distance under Spatial Analyst tools and reclassified. Data processing involves reclassifying models and raster analysis to provide the initial output for the flood evacuation site suitability map. Lastly, the raster reclassified data were inputted into the weighted overlay with its corresponding weights based on related literature.

| Criterion | 2 – Highly Suitable | 1 – Moderately Suitable | 0 – Low Suitable | Sources |
|---|---|---|---|---|
| Elevation | 50-100m | 20-50m | 0-20m | Mabahwi et al, 2021 |
| Slope | <7% | 7% - 15% | >15% | |
| Land Use/Land Cover | Built-up, Bare land | Agricultural land, annual crop, grass land, open forest, perennial crop | Wet land, shrubs, inland water, barren land | |
| Access to Road Network | <1000m | 1000-2000m | >2000m | Mahmud Ali, 2000 |
| Distance to Electrical Supply | <500m | 500-1000m | >1000m | |
| Distance to Water Source | <500m | 500-1000m | >1000m | |
| Distance to Fuel Stations | <500m | 500-1000m | >1000m | |

**Table 1.** Reclassification Guide

The weights of each criterion were determined through research of related studies concerning Flood Evacuation Sites using the GIS approach to locate land suitability analysis in Las Nieves, Agusan del Norte, and there were seven criteria considered. The criteria were elevation, slope, land use/ land cover, road network, power distribution, water source, and fuel stations. Weights were determined from various related literature and accordingly assigned weights. From the study of Cabrera and Lee (2019), the weight of 0.17 is assigned for elevation; 0.136 for slope and 0.141 for the road network from Kittipongvises et al., (2020); 0.20 for land use/ land cover and water source has a weight of 0.07 both weights from Nsangou et al., (2022); power distribution has a weight of 0.09 and fuel stations has a weight of 0.072 based on the study of Masoumi et al., (2019). The

weights were normalized by dividing each criterion’s weight to the total weights to obtain a total of 1 or 100%.

| Criterion | Weights | Normalized Weights |
|---|---|---|
| Elevation | 0.17 | 0.193 |
| Slope | 0.136 | 0.155 |
| Road Network | 0.141 | 0.160 |
| Land Use/Land Cover | 0.20 | 0.228 |
| Proximity to Water Supply | 0.07 | 0.08 |
| Proximity to Electrical Supply (Power) | 0.09 | 0.102 |
| Distance from Fuel Stations and Flammable Materials | 0.072 | 0.082 |
| Total | 0.879 | 1 |

**Table 2**. Criteria and Weights

### 2.3 Flood Hazard Exposure

Datasets of the existing building footprints, particularly in Las Nieves, were digitized and updated using Google Earth Pro to compare and cross-check their exact location in Google Satellite, used as a base map in Quantum Geographic Information System (QGIS) application. Buildings from the Caraga Center for Geo-informatics (CCGeo) were digitized in a GIS environment, where structures were traced using the polygon feature type. The flood exposure assessments primarily used the building footprints and flood hazard maps.

### 2.4 Spatial Distribution of the Evacuation Shelters

**2.4.1 Calculation of each evacuation shelters building capacity.** An area of 3.5-5 square meters per person was used to calculate each evacuation center’s standard occupancy. Using the data in the attribute table, the shelter capacity was divided by each building area by a 5 square meters as maximum capacity per building through a “Calculate Geometry’’ in the attribute table, as well as using a presumed 10 square meter as a minimum capacity for social distancing, where the demand for additional space per person would considerably lower the capacity of crowded shelters, as the social distance was suggested to avoid the spread of COVID-19 (Australian Red Cross, 2021).

**2.4.2 Calculation of population density.** In calculating the population density, the population of each barangays is divided by the area of each barangay polygon, where the area was computed through the tool “Calculate Geometry” in ArcGIS 10.8 software. The corresponding calculated population density or the average number of people living in a particular barangay of the municipality.

### 2.5 Real-Time Updating of Spatial Capacity of Evacuation Centers

The web mapping application was built using Geoserver to deliver the data (map server), PostgreSQL and the extension PostGIS to store the data (spatial database), and Open-Source Mapping Libraries such as Leaflet to develop the map client (web mapping technology). A web server developed using Apache Tomcat to host the application allows running Flask Python scripts as Common Gateway Interface applications to let the client or user manipulate the geospatial functionalities and processes of the application. In the development of the web application, Flask as a Web Framework was primarily utilized to successfully optimize web operations and functionalities. After installing the relevant flasks libraries, the PostgreSQL database driver--Psycopg2 was installed. It is mainly used to perform heavily multi-threaded applications and operations on PostgreSQL on the principle of the full implementation of Python Database API. Finally, to connect and execute SQL queries on the database, the command "pip install Flask psycopg2-binary" was used to install the Flask psycopg2-binary. The installation command for establishing the database connection in PostgreSQL after serving it on python. The python command, a backend function that calls the selected table of evacuation centers stored in the database and sends data to the client for real-time updating of evacuation status, particularly its spatial capacity on a temporal scale.

## 3. RESULTS AND DISCUSSIONS

### 3.1 Generated Suitability Map for Flood Evacuation Sites

A proposed map for flood evacuation sites was produced after taking the 100-year flood event as a constraint. The red areas indicate high suitability, whereas the dark and light greens indicate moderate and low suitability, respectively. White areas are part of Las Nieves boundaries that were not suitable for flood evacuation sites since it was prone to flooding. Most of the highly suitable areas are characterized with higher elevation, near and within the barangay centers, and gentle slopes. These conditions conform with the weights set on each criterion based on multi-criteria decision analysis.

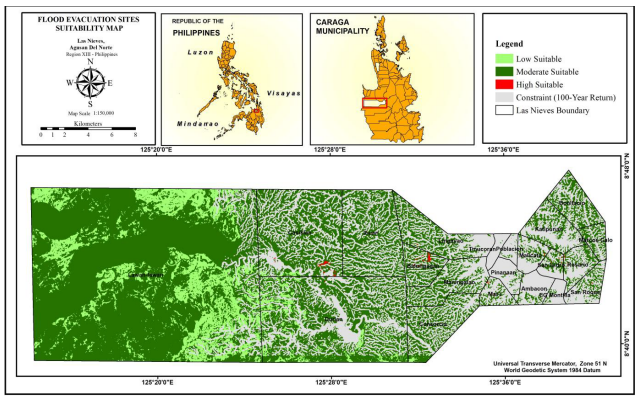


**Figure 2.** Flood Evacuation Sites Suitability Map in Las Nieves, Agusan del Norte

**3.1.1 Statistics of Area per Suitability Scale.** Figure 2 presents the result of suitability analysis of flood evacuation sites considering the 100-year flood constraint. The pie graph (Figure 3) shows the statistics of area per suitability scale. It indicates that in the municipality of Las Nieves, 85.1% or 50,763.29 hectares of the area were moderately suitable for flood evacuation sites while only 200.34 sq. hectares or 0.3% of the area is highly suitable for flood evacuation sites. Finally, the remaining 14.6%, or 8,681.74 hectares from the whole area represents the lowest suitable for flood evacuation sites in Las Nieves.

| Suitability Class | Area (has) |
|---|---|
| Highly Suitable | 200.34 |
| Moderately Suitable | 50,763.29 |
| Low Suitable | 8,681.74 |

**Table 3**. Statistics of Area per Suitability Scale

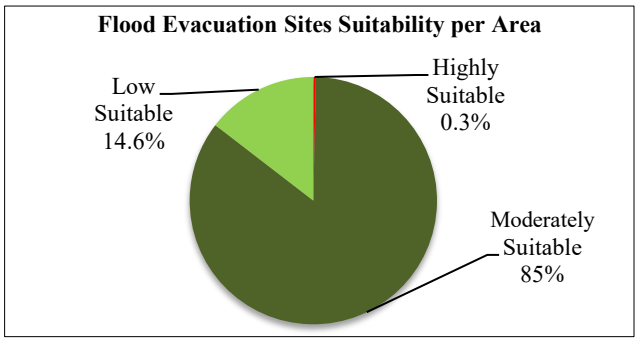


**Figure 3.** Statistics of Area per Suitability Scale Graph

**3.1.2 Statistics of Highly Suitable Area per Barangay.** Shown in Table 4 are the barangays that are highly suitable for Flood Evacuation Sites. Barangay Casiklan has the highest suitable area which is 31.2 percent followed by Barangay Balungagan and Barangay Mat-i with 27.6 percent and 16.2 percent, respectively. Barangay San Isidro has a suitability of 6.9 percent, and Barangay Rosario with 5.3 percent suitability. Moreover, Barangay Malicato has 3.5 percent suitability and Barangay Lingayao with 2.8 percent, followed by Barangay San Roque with 2.4 percent suitability and Barangay Pinana-an with 1.4 percent suitability.

| Barangay | Area (has) | Percentage |
|---|---|---|
| Balungagan | 55.25 | 27.6% |
| Casiklan | 62.48 | 31.2% |
| Durian | 2.45 | 1.2% |
| Katipunan | 0.18 | 0.1% |
| Lingayao | 5.53 | 2.8% |
| Malicato | 7.03 | 3.5% |
| Marcos Calo | 0.81 | 0.4% |
| Mat-i | 32.42 | 16.2% |
| Pinana-an | 2.71 | 1.4% |
| Poblacion | 2.14 | 1.1% |
| Rosario | 10.70 | 5.3% |
| San Isidro | 13.84 | 6.9% |
| San Roque | 4.79 | 2.4% |
| Tinucoran | 0.03 | 0.0% |

**Table 4.** Statistics of Highly Suitable Area per Barangay

**3.1.3 Statistics of Flood Evacuation Centers per Suitability.** In this study, the evacuation sites for both the location of the existing and proposed/candidates for potential evacuation sites were assessed according to the flood year return event. Whether the evacuation is safe or not varies depending on the flood event. Suppose a particular evacuation center is located at a site affected by a particular flood event, that site is not safe for building or positioning an evacuation center. Shown in Table 5 are the levels of suitability of each existing evacuation centers with its corresponding area in meters squared. The analysis was derived from overlaying the data of suitability analysis of flood evacuation sites and the spatial data of the existing evacuation centers while considering the 100-year flood return period as the constraint. The results show that the ten (10) evacuation centers were moderately suitable which is 95% of the total area, while only the Maningalao Evacuation Center was not suitable; this was because the location of the center was affected by the flood.

| Existing Evacuation Centers | Suitability | Area (sq. m) |
|---|---|---|
| Ambacon Center | Moderately Suitable | 342 |
| Katipunan Center | Moderately Suitable | 67 |
| Lingayao Center | Moderately Suitable | 138 |
| Maningalao Center | Not Suitable | 179 |
| Mat-i Center | Moderately Suitable | 571 |
| Pinana-an Center | Moderately Suitable | 169 |
| Poblacion Center | Moderately Suitable | 162 |
| Rosario Center | Moderately Suitable | 295 |
| San Isidro Center | Moderately Suitable | 1192 |
| San Roque Center | Moderately Suitable | 203 |
| Tinucoran Center | Moderately Suitable | 148 |

**Table 5.** Statistics of Existing Evacuation Centers Suitability

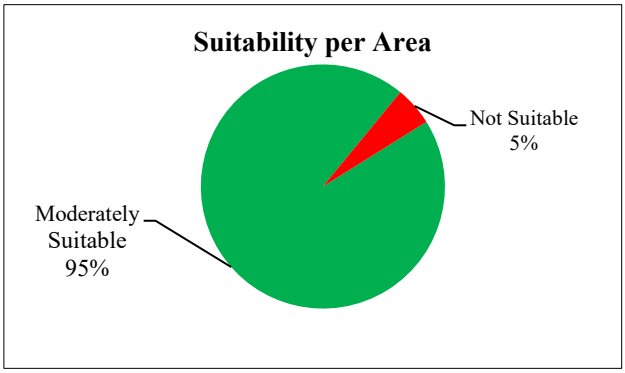


**Figure 4.** Suitability of the Existing Evacuation Centers per Area

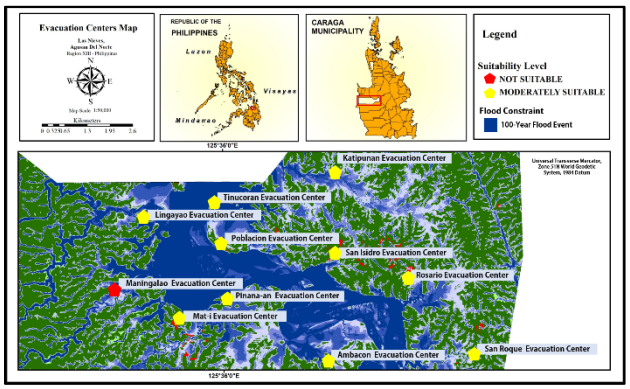


**Figure 5.** Existing Evacuation Centers Level of Suitability

### 3.2 Flood Exposure Assessment of Proposed Evacuation Shelters

From the assessment of evacuation sites according to flood events, results showed that as the flood year rain return period increases, the areas not affected or exposed to flooding also decrease. This study assessed evacuation shelter candidates for various flood hazard year returns such as 2-year, 10-year, and 100-year flood rain return events. Based on the 2-, 10-, and 100- year return events, 418, 379, and 288 buildings were not vulnerable to flooding, respectively, with total evacuation candidates of 497. Of the 497 buildings classified as the proposed/candidates for potential evacuation sites, including the existing shelters, 84% of the total evacuation sites are unaffected by flooding. At the same time, there are 16%

exposed to flood using the 2-year rain event. For a 10-year flood event, 24% are affected to flood, and 76% of the total 497 evacuation buildings were not affected by the flood. Using the 100-year rain return period, 42% of the entire sites were affected by flooding, and 58% of the evacuation shelters were safe as they were not affected by the flood event. Figure 6 presents the composite maps, which are the results from the assessment conducted to particularly determine how many structure/households and people are affected by flooding according to flood events, including the areas inundated by hazard level and according to land cover type, using the updated datasets.

It can be seen in the map that the polygons represent the proposed evacuation shelters classified according to their level of flood hazard (polygons ranging from light blue to dark blue), while green indicates the safe buildings that were not affected by flood events. The land cover type was overlaid to determine what land cover type the facilities are in and assess their suitability in terms of land use/land cover type.

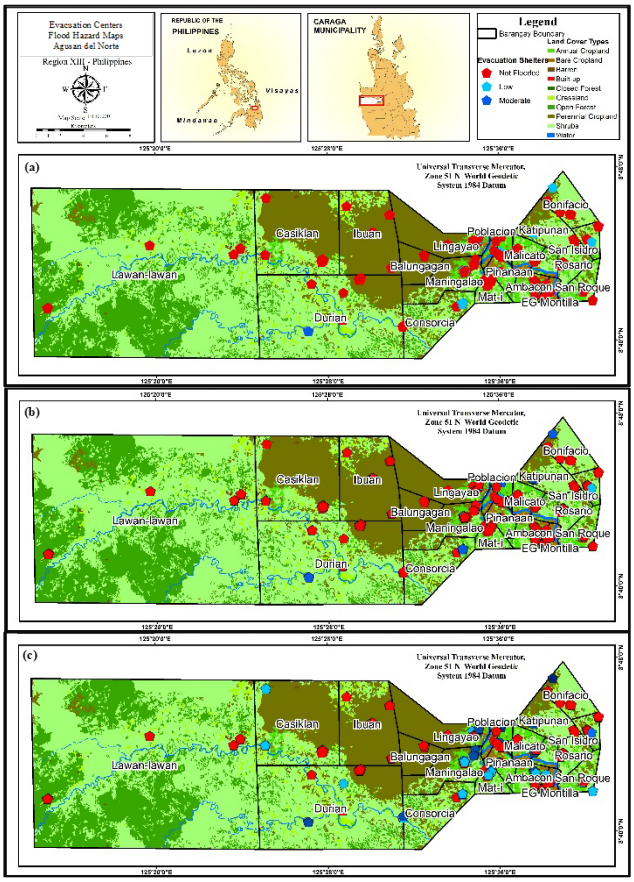


**Figure 6.** Assessment of Evacuation Shelters with (a) 2-Year Flood Event (b) 10-Year Flood Event, and (c) 100-Year Flood Event

### 3.3 Spatial Distribution of Evacuation Centers

In the municipality of Las Nieves, Agusan del Norte, four hundred ninety-seven (497) buildings have been identified as designated evacuation shelters for the entire population, counting the existing and the candidate for potential evacuation centers as determined in the assessment of this study. In this study, the spatial capacity of evacuation shelters was assessed considering the standard capacitance and the distancing of the health and safety protocols for the COVID-19. Thus, a 5-meter distance was the basis for spatial capacity for the typical capacitance. In contrast, a 10-meter distance was used as the minimum capacity for social distancing in line with COVID-19. From the analysis, the researchers found that a barangay area with a population density with a corresponding spatial capacity of 5 meters squared per person can accommodate 381 occupants with a building area of 1904 meters squared, shown in Figure 7. The capacity of 10 meters squared per person can accommodate a total of 190 occupants with a building area of 1904 meters squared- as the social distance was suggested to avoid the spread of COVID-19 shown in Figure 8. From this, the School buildings, Existing Evacuation Centers, Religious Institutions, and Sports centers/Gymnasium/Covered Court were turned into evacuation centers when needed. Thus, disaster risk reduction and management factors have no relation to the location of these evacuation centers but were primarily based on the site of currently available facilities.

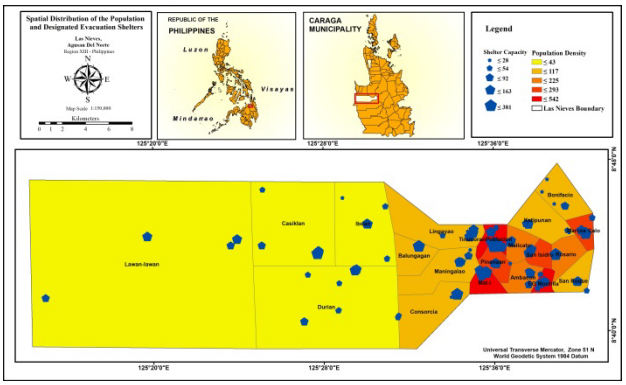


**Figure 7.** Distribution of Population and Designated Evacuation Shelters with a Standard Capacity of 5 meters squared

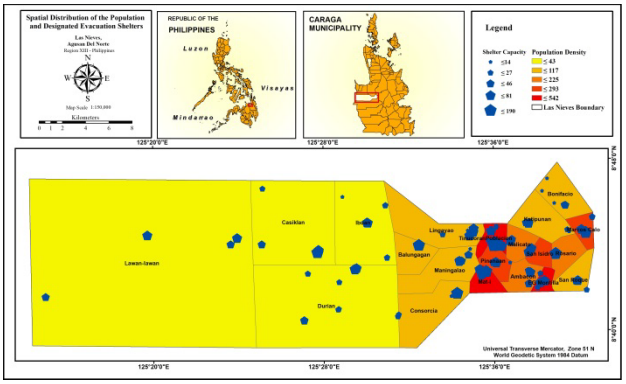


**Figure 8.** Distribution of Population and Designated Evacuation Shelters with a Standard Capacity of 10 meters squared

### 3.4 Web Mapping Application Features and Functionalities

The web mapping application was developed to provide local communities of Las Nieves with spatial data, specifically regarding the real-time status of a specified evacuation center and other related flood data. The web application was classified into three main functions: Location Tools, Display Options, and Assessment (see Figure 9). The Evacuation Center includes displaying the Existing Evacuation Centers, Candidate Evacuation Centers, and Suitable Areas for Evacuation Sites. The data inputted in these functions are from the suitability

analysis and mapping (Figure 10). In this function the extent of the spatial data and information are limited only to Las Nieves, Agusan del Norte.

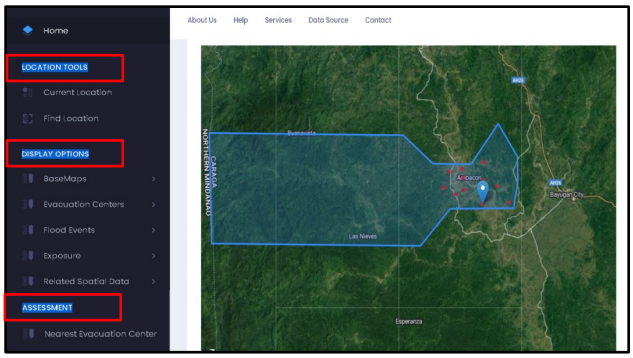


**Figure 9.** Main Functions in the Web Map Application


**Figure 10.** Operations of Evacuation Centers under Display Options

Under the Exposure function, the affected buildings and structures from various flood rain return periods are included as operations to let the user choose and see the spatial information regarding the affected or exposure of buildings to flooding. The spatial data inputted in this operation was the data from flood exposure assessments. Figure 11 displays the affected buildings from the 2-Year and 100-Year Flood Rain Periods. The figure shows that the buildings in yellow colors are very high in flood exposure, and buildings in red are highly exposed to specific flood rain return periods. In addition, blue and green colors in buildings depict moderate and low exposure to flooding.


**Figure 11.** 2-Year and 100-Year Flood Rain Periods from Flood Events under Display Options

For Show the Spatial Capacity, a specific evacuation center was assessed and processed to estimate its maximum capacity, considering the standard capacity or availability of persons allowed and the minimum occupancy of the evacuation center following the minimum distance protocol in line with COVID-19. Furthermore, Python and programming frameworks were used to provide the local community of Las Nieves with more comprehensive, reliable, and real-time spatial information. Figure 12 shows that on the admin page, specifically on the address http://localhost:5000/evacuation_centers, an administrator will update the spatial status of an evacuation center then; it will automatically reflect on the client, and the user will then be provided with real-time spatial information about the specific evacuation center.

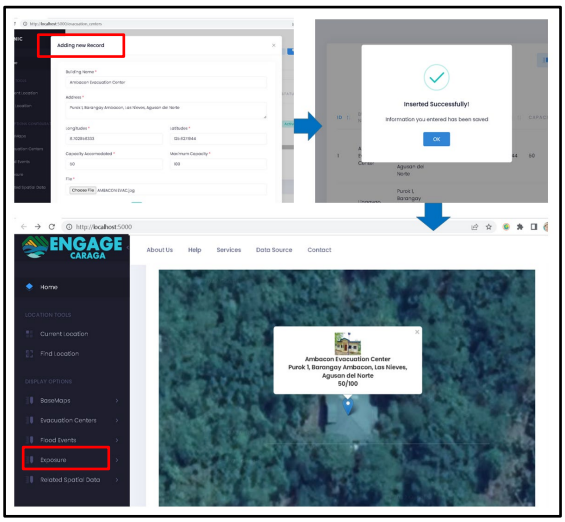


**Figure 12.** Operations to Provide Real-time Spatial Information

The Assessment function includes locating the nearest available evacuation center. In this operation, we use Leaflet Routing Machine, a routing controller primarily utilized for Leaflet mapping frameworks. With this function, the web application provided the user with an intuitive interface for routing paths between waypoints using the user's specified routing service (Figure 13). The researchers used K-Nearest Neighbour algorithm to find the close evacuation location. KNN is a supervised machine learning algorithm mainly used to solve classification and regression problem statements. The road networks used by the algorithm were the roads updated and digitized from Open Street Map and Leaflet.

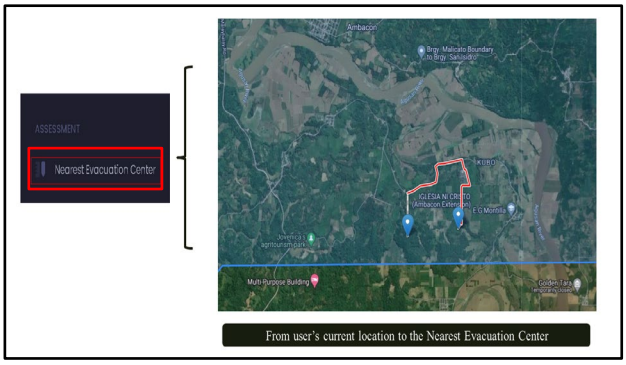


**Figure 13.** Finding the Nearest Available Evacuation Center from the User's Location

### 3.5 Additional Features of the Web Application and How It Works

In developing the web application, the researchers were able to find a free template of the evacuation centers' user interface that was available online (Evacuation Center Management System - Free Template 2022, 2021). With this, the template was integrated with the system first developed that provides the visualization of spatial data, particularly datasets of Las Nieves municipality. The source code of the template was downloaded, revised, and further developed to customize the specific needs of the Las Nieves communities, specifically regarding to the managing activities and services offered in the evacuation centers.

For the management of evacuation centers exclusively for Las Nieves LGU, the other major web page named as “Flood Evacuation Center Management System” were also developed. There are several web pages that specified must interact with in this system. There are pages which shares common toolbar while other varies depending on the type of information shown. There are buttons that are only available for authenticated site administrator of the system. For the time being, the system is temporarily deployed using free website hosting and served by LiteSpeed online Web Server at garagezone.tech_with Port 443. The admin login page for the system can be traced locally at the address, https://garagezone.tech/. In this page (Figure 14), the administrator of the system will have to input his/her credentials to fully authorize the usage of the application.

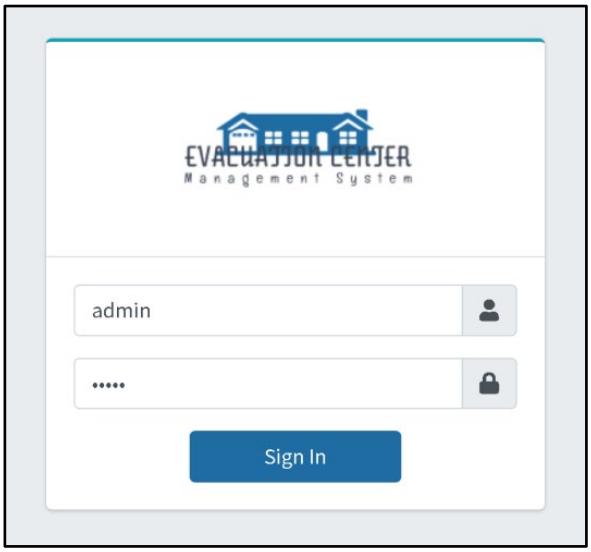


**Figure 14.** The Admin Login Page

The Dashboard, as shown in Figure 15 is the main or index page of the system which primarily serves as the homepage of the system where the administrator is redirected to when logged in to the system or after signing the login page. The dashboard's primary function is to summarize or consolidates the information provided by the system and to specifically display the number of family/households, number of evacuees, number of males and females, number of barangays, and number of evacuation centers available in the municipality of Las Nieves. Additionally, Figure 16 shows the form Type of Calamity which was included in the system for easy and specific allocation of evacuation centers as to the type of the calamity. With this function, stakeholders can appropriate their measures and relief goods accordingly with the type of calamity. In this form, the system administrator must input the name of the calamity that is the reason for the evacuation. The administrator can edit and/or delete the name of calamity before officially saving it for recording of the information.

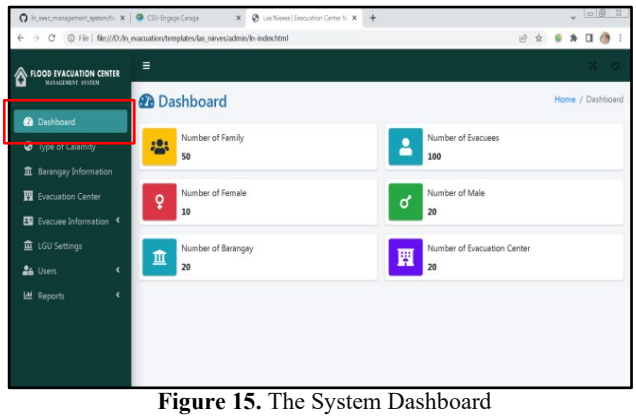


**Figure 15.** The System Dashboard

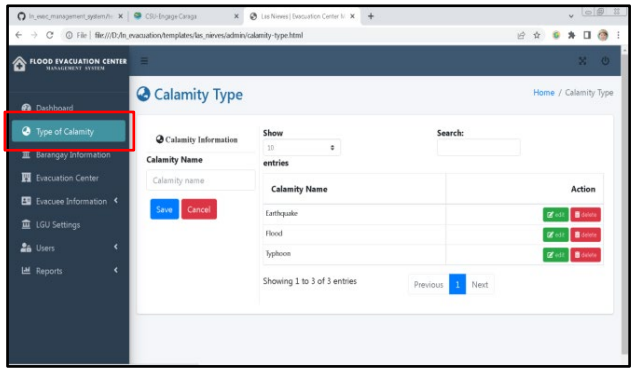


**Figure 16.** Form of the Calamity Type of the System

In Figure 17, the Barangay Information is a form that highly requires the system administrator to manage the barangay's details and information. The site administrator will have to specifically input the name of the barangay in the municipality. The administrator can also edit and/or delete the name of barangay before officially saving it for recording of the information. With these, it would then be easy to generate a report of lists of evacuees according to barangay. Next is the page of Evacuation Center, it is a form that requires the administrator or system officer to edit, update, and manage the information of every existing and designated evacuation center. The admin or encoder will have to input or enter the important information of the center, such as the name, address of the evacuation center, and the contact details of the person tasked to manage the specific shelter using the form (see Figure 18).

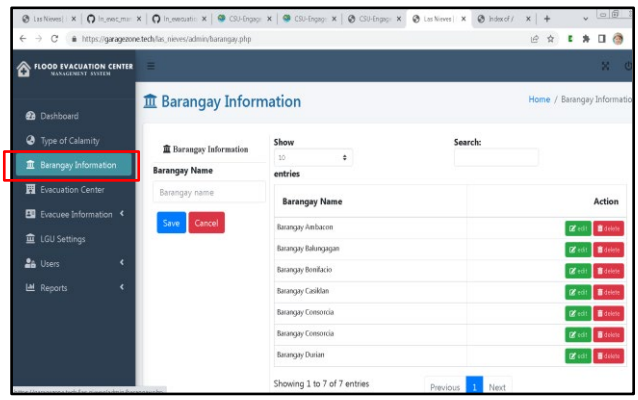


**Figure 17.** Barangay Information Interface

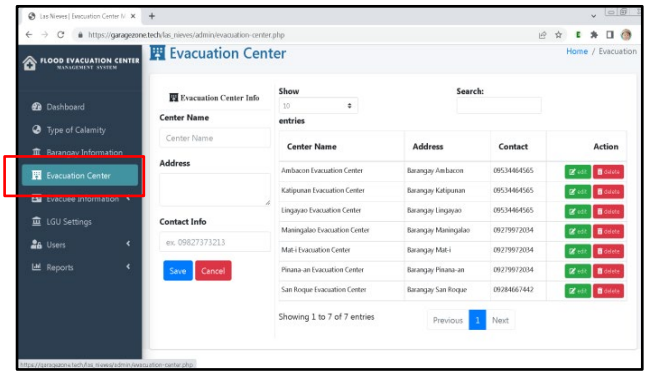


**Figure 18.** The Evacuation Center Interface

To effectively manage the evacuation centers according to their efficacy in providing temporary shelter to the people affected by a certain calamity, the web application also provides a tool where each evacuee's personal information is collected for the recording and management purposes. The web function Evacuee Information is particularly classified into two other web pages: New and Manage. For the New, it is where the administrator will have to input relevant information about the new evacuees of the specified evacuation center. Figure 19 shows the applications' function of adding new information on evacuees.

Moreover, the web page—Manage is where the administrator can edit/update and/or delete the existing name of evacuees for efficient management of the community’s information. The administrator will have to control or is authorized to use this web page ensuring that he/she will abide to the data privacy act since the system will acquire personal information of a person. See Figure 20.

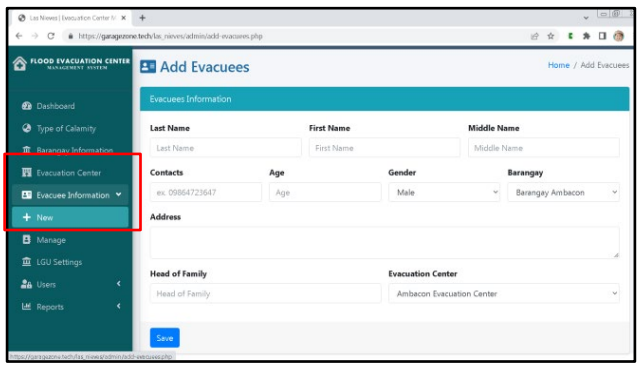


**Figure 19.** The Page where the Admin will add New Evacuee

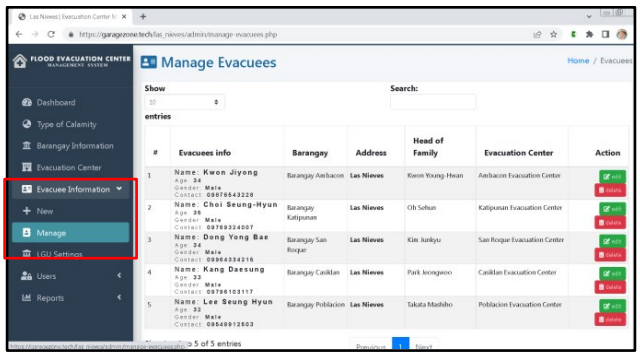


**Figure 20.** The Page where the Administrator will manage the Added Evacuees

The system also provides a specific function where the LGU of Las Nieves can register their respective social media accounts for the user's further queries and additional information about their services or details about their locality. Presented beside is Figure 21, which shows the LGU Settings function of the web system. The admin can opt to set the systems' details, such as Contact Info, Email Address, and Website.

For the efficient and effective management of the information provided by the web application, the tool Report allows the users to generate and download a list of specific reports. Figure 22, Figure 23, Figure 24, and Figure 25 are the reports that show the details and information specifically about the evacuees, such as the list of evacuees' names, gender, age, and barangay presented in graph or tabular forms. The report will display the list of evacuees occupying a specific evacuation center of the municipality. With this function, the LGU of Las Nieves will be provided with reliable and comprehensive information regarding the evacuees and their whereabouts as to the evacuation center they are occupying. Since the people are organized and managed effectively using this web application, the distribution of goods and services will also be easy to manage.

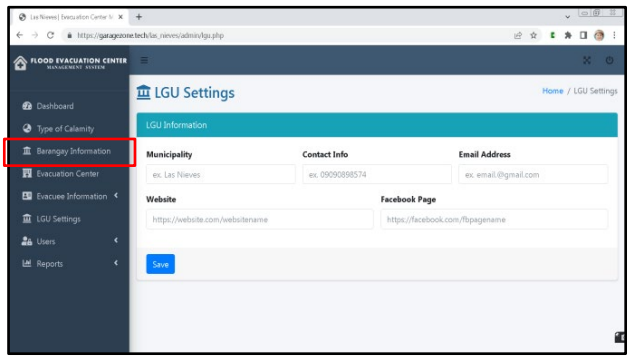


**Figure 21.** Function LGU Settings customized for the municipality of Las Nieves

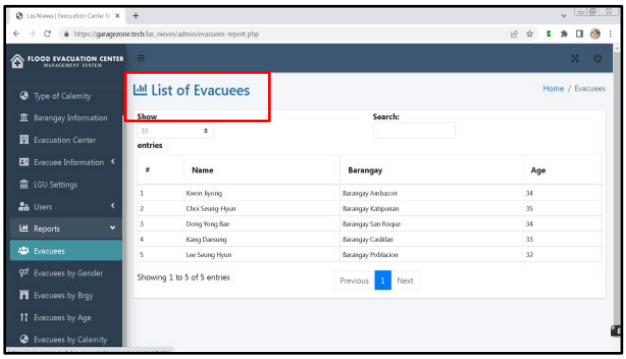


**Figure 22.** Reports on Lists of Evacuees

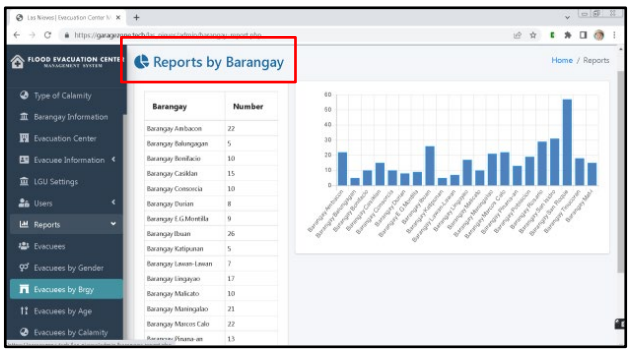


**Figure 23.** Reports of Evacuees by Barangay

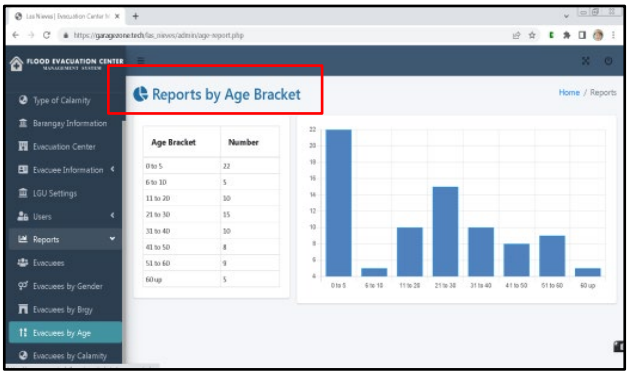


**Figure 24.** Reports of Evacuees by Age


**Figure 25.** Reports of Evacuees by Gender

## 4. CONCLUSIONS AND RECOMMENDATIONS

The integration of Geographic Information System (GIS) with Multi-Criteria Decision Making (MCDM) helped generate suitability maps for evacuation centers. The flood evacuation site suitability map considered land use/land cover as the top priority and access to fuel stations and water supply as the least. Evacuation centers must be built in an area with bare land or built-up. These land-use types matched the locations of the existing evacuation centers provided by the municipality. A suitable flood shelter must be located on land with higher elevation, following the set standard of flood shelters. The standard rule for building flood shelters is not to be located in any area most likely to be inundated. This is because shelters in flood-prone areas may be vulnerable to damage from rising floodwaters. Access to these supplies is primarily based on emergency supplies in evacuation buildings and not determining emergency accessibility. Sites in flood areas have low suitability for electric facilities because all electrical powers must be shut down in all affected areas and their vicinity. Finally, the created potential map for flood evacuation sites will assist the city of Las Nieves, Agusan del Norte, in planning and determining which areas are suitable for flood evacuation sites in consideration of the constraint map, which is a 100-year flooding event. The findings also showed that the municipality of Las Nieves is moderately vulnerable to the risk of flooding, necessitating quick attention from the decision-makers in order to implement plans for the eventuality of flooding. From the assessment of evacuation sites according to flood events, results showed that as flood year rain return period increases the sites not affected or exposed to flooding also decreases.

In a flooding scenario, there is a need for a comprehensive, reliable, spatially driven, and practical tool that intends to help people access spatial information to know where they should specifically evacuate and go for safety. With advanced GIS mapping and spatial analysis integrated with web technologies, spatial information will be provided effectively and efficiently to the public.

Local government units usually experience management issues such as inadequacy in distributing essential goods and supplies, errors in counting the number of people involved, and other activities like inefficient information recording. Thus, in this study, the developed web application is to help the management processes of evacuation centers, specifically in the locality of Las Nieves.

The researchers recommend having additional factors and criteria for selecting suitable evacuation sites. There is also a need to do a comparative analysis using the data from field experts, related literature-based, and an integrated community approach in determining suitable sites. The researchers further recommend performing a ground validation to ensure that the identified criteria/parameters are appropriately considered. There is also a need to implement rules and regulations regarding building shelters and determining site suitability for flood shelters. To protect vulnerable communities and areas, the municipality of Las Nieves must take precautionary measures to increase and maintain the usability and efficacy in managing flood shelters.

Moreover, the researchers strongly recommend the implementation of the developed web application. The system is highly commended for its effectiveness and reliability. The system will make evacuation center management convenient, fast, efficient, and accurate. The web application will assist the local government disaster risk reduction planning personnel, particularly in managing evacuees and their specific needs. Moreover, the development and implementation of the system will help improve the efficiency of the Las Nieves LGU in managing evacuation centers. Specifically, the researchers recommend that the LGU should install and implement the system to efficiently manage evacuation centers and to systematically keep records of evacuees and other records of the evacuation center safe and secured.

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