# Index Crimes: A Web Geographic Information System Platform for Crime Mapping Frequency in Butuan City

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# Index crimes: a web geographic information system platform for crime mapping frequency in Butuan City

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**Abstract:** *The Butuan City Police Office (BCPO) requires an efficient system to monitor index crimes in Butuan City, which is currently lacking, impeding effective crime prevention. This study aims to develop a user-friendly web mapping service adhering to Open Geospatial Consortium (OGC) standards, integrating statistical and graphical interfaces with geographic information systems (GIS) for crime mapping. The system will display data analysis by barangay from 2019 to 2023 using a GeoJSON map with gradient colors indicating crime frequency. Crime frequency will be classified into four color intervals, with bar graphs showing hourly and monthly data and pie charts depicting the annual percentage of index crimes per barangay. This GIS-based web interface will provide a comprehensive visualization and analysis of crime data, enhancing the BCPO's ability to effectively prevent and intervene in criminal activities.*

**Keywords:** Index Crime, Butuan City, Geographic Information System, Web Mapping

## 1. INTRODUCTION

Crime is unlawful actions subject to legal punishment and can reflect the level of progress within a government. Its existence serves as an objective measure for progressively enhancing moral consciousness. The occurrence of crimes is not evenly distributed across regions and can happen unexpectedly certain geographic areas experience lower crime levels than others [6]. The extensive prevalence of criminal activities within society can give rise to diverse challenges in terms of economic development. Crimes are categorized into Index and Non-index crimes, with the former referring to incidents involving casualties.

The progress towards achieving the 17 Sustainable Development Goals (SDGs) varies widely among nations. One study focused on developing a predictive model to evaluate the achievement status of SDG 11, which aims to create resilient and sustainable cities. This model, implemented using the Random Forest machine learning algorithm within the KNIME analytics platform, attained an overall prediction accuracy of up to 83.67%. The study highlighted the interconnectedness of SDG 11 with SDG 16, which emphasizes the promotion of peaceful and inclusive societies, access to justice for all, and the establishment of effective, accountable institutions. Achieving SDG 11 inherently requires strong, transparent governance structures and inclusive decision-making processes, which are fundamental elements of SDG 16 [2]. Utilizing geospatial techniques has become an emergent trend in monitoring the community in other several societal issue and applications. This involves GIS and Remote Sensing, which has significantly enhanced our ability to analyze and monitor urban dynamics, especially in relation to urban expansion and land use changes [3].

Index crime refers to major crimes that categorize murder and non-negligent manslaughter, forcible rape, robbery, aggravated assault, burglary, larceny, and motor vehicle theft [4]. On the other hand, non-index crime refers to petty or minor offenses. Non-index crimes include careless unlawful death, non-aggravated assault, forgery and counterfeiting, fraud, embezzlement, stolen property, vandalism, weapons-related offenses, prostitution and other vice crimes, sex offenses, narcotics offenses, gambling, offenses against children, driving under the influence, unruly behavior, and other crimes not listed in the index crimes. Offenses are unlawful acts reported to law enforcement agencies. At the same time, arrests involve individuals apprehended, detained, summoned, or cited by law enforcement agencies for participating in illegal activities [5].

In the Philippines, the index crime holds the highest record of delinquencies, as reported by the Philippines National Police (PNP). This phenomenon can be attributed to unplanned urbanization, migration, high unemployment, and poverty. The PNP employs several strategies to address this issue through web-based applications allowing for real-time reporting of crime situations. However, integrating a comprehensive crime information system, incorporating databases, and criminal records retrieval remains an underexplored avenue [4].

This study aims to unravel the intricate patterns of index crime frequency, concentrating on eight designated focus crimes spanning 2019 to April 2023, and to explore, assess, and utilize a GIS-based approach using a web-based platform to analyze and visualize the frequency of index crimes in Butuan City. Specifically, by creating a web mapping service that follows the standards of the Open Geospatial Consortium and by developing a statistical and graphical interface integrating a geographic information system for the crime mapping frequency of Butuan City. This localized approach enriches the understanding of crime dynamics and provides actionable insights for the BCPO and the community. The outcome could lead to additional insights for law enforcement agencies in developing effective crime prevention and intervention strategies.

## 2. STUDY AREA

The study will be conducted in Butuan City, a vibrant and rapidly developing urban center in Agusan del Norte province, within the Caraga Region of Mindanao, Philippines. Butuan City's postal code 8600 is an ideal location for the research on "Index Crimes: A GIS-based Approach using Web-based Platform for Crime

Frequency in Butuan City." Encompassing the entire land area of Butuan City, the study will delve into its diverse urban and rural settings, spanning approximately 816.62 square kilometers [6]. The city comprises 86 barangays [7], representing different demographic and socioeconomic characteristics, making it an intriguing and relevant study area for understanding crime patterns and strategies.

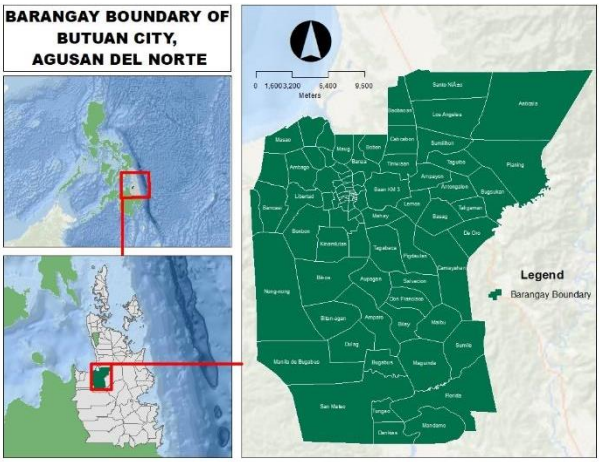


Fig. 1. Map of the Study Area

## 3. MATERIALS AND METHODS

### 3.1 Data Cleaning

Data cleaning involves eliminating redundancy and categorizing the data accurately. Conducting necessary data cleaning enhances the reliability, accuracy, and effectiveness of GIS-based crime analysis, leading to better-informed decisions, improved resource allocation, and increased community trust and engagement. First, raw data files undergo categorization, often based on predefined criteria, or categorized into physical injury, rape, murder, robbery, homicide, theft, and carnapping, as shown in Table 1.

Table 1. Index Crimes

| INDEX CRIMES |
|---|
| 1. Physical Injury |
| 2. Murder |
| 3. Homicide |
| 4. Robbery |
| 5. Theft |
| 6. Rape |
| 7. Carnapping |

After using the "Remove Duplicates" function in Microsoft Excel on a dataset of 7,449 rows and 73 columns, duplicates were identified and removed, resulting in a dataset with 7,447 rows.

### 3.2 Geodatabase

The geodatabase supports the web GIS application by handling spatial data and associated attributes. Designed for efficient storage and retrieval of geographic data, it uses an Entity-Relationship approach (see Fig. 3) and Unified Modelling Language (UML) (see Fig. 4) diagrams for conceptual and logical models. These models guide the design and implementation of the geodatabase, linking spatial attributes of crime incidents to the barangay boundaries in Butuan City for essential spatial analyses.

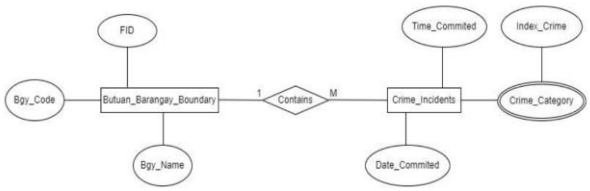


Fig. 2. Entity-Relationship (E-R Model)

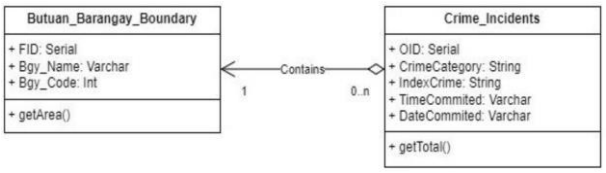


Fig. 3. Unified Modelling Language (UML) diagram

### 3.2 Open Geospatial Consortium (OGC) Standard for Web Mapping Services

The Web Mapping Services (WMS) is a key standard within the Open Geospatial Consortium (OGC) framework, enabling the retrieval and displaying of dynamic map images over the internet. WMS follows a generalized architecture for representing geographic features and supports various GIS applications by allowing users to access maps based on specified parameters, promoting interoperability in geospatial technology, as shown in Figure 5.

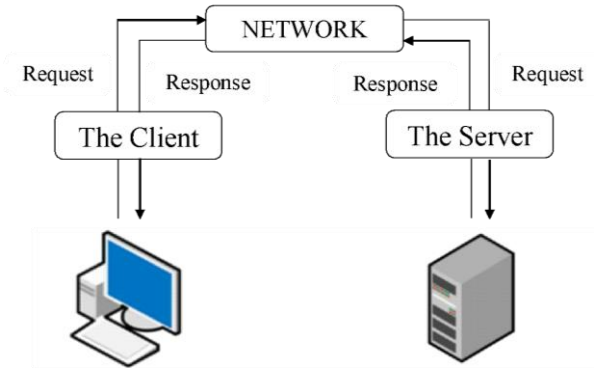


Fig. 4. Client and Server Architecture of Web-GIS System

### 3.3 Web Mapping Services (WMS)

WMS enable geographic data visualization online by generating georeferenced images viewable in browsers or mapping applications. WMS is interoperable through OGC-specified interfaces, supporting three main operations: GetFeatureInfo (retrieves information about map features), GetMap (requests map images), and GetLegendGraphic (retrieves map legends), facilitating comprehensive functionality shown in Figure 6.

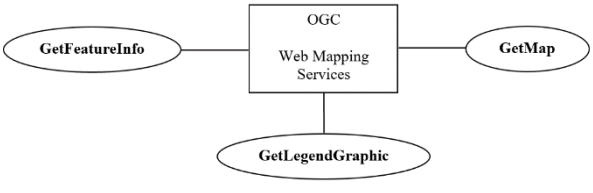


Fig. 5. Web Map Service (WMS) Interface

### 3.4 Web Architecture

The web GIS architecture shown in Figure 6 employs a client-server model for GIS over the internet, involving client interactions via web browsers and server-side processing. The architecture includes a data server using SQLite for spatial and non-spatial data, a map server generating map images with the Leaflet library, and geospatial web services like WMS for accessing external spatial data, enhancing the application's utility and interoperability.

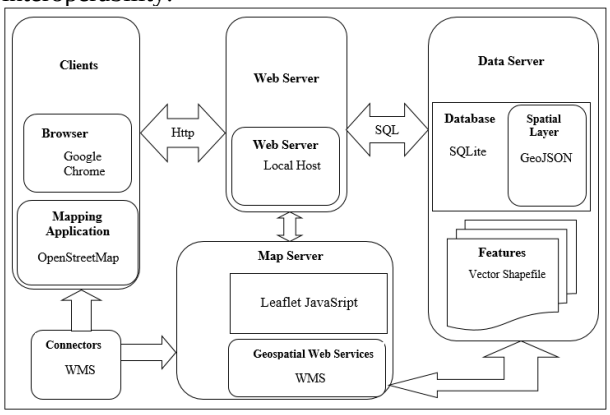


Fig. 6. Web GIS Architecture

## 4. RESULTS AND DISCUSSIONS

### 4.1 Elements of WEB GIS Applications

The Web GIS applications show the interface to the user, as shown in Figure 7. This interface provides the essential cartographic elements such as Map Title, north arrow, legend, scale, and the map. This application provides functionality tools for visualizing maps and querying spatial data in a mapping application. Also, access restrictions are provided between public users and administrators, which are implemented to maintain data integrity, privacy, and security within a web GIS application. The roles and functions are described in Table 1.

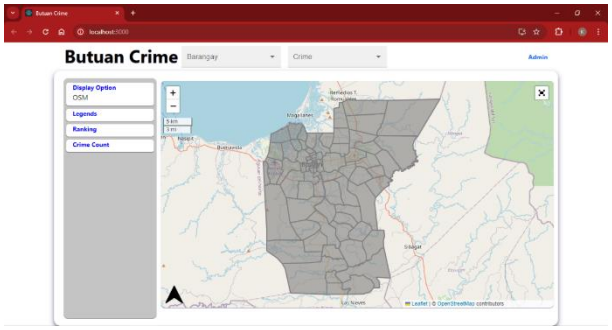


Fig. 7. Web Interface of Index Crime in Butuan City.

Table 2. Functions of administrator and public user

| Role | Functions |
|---|---|
| Administrator | Responsible for modifying and accessing sensitive information, configuring system settings, and overseeing data security. |
| Public User | Responsible for viewing and interacting with the web interface and features by performing basic tasks like searching for locations, viewing maps, and analyzing statistical data of index crimes. |

### 4.2 Digital Basemap

Digital base maps, as shown in Figure 8, are the foundational geographic context for the Web GIS application. This shows the reference as the backdrop against which operational layers are overlaid, providing users with spatial orientation and context for their analyses and visualizations.

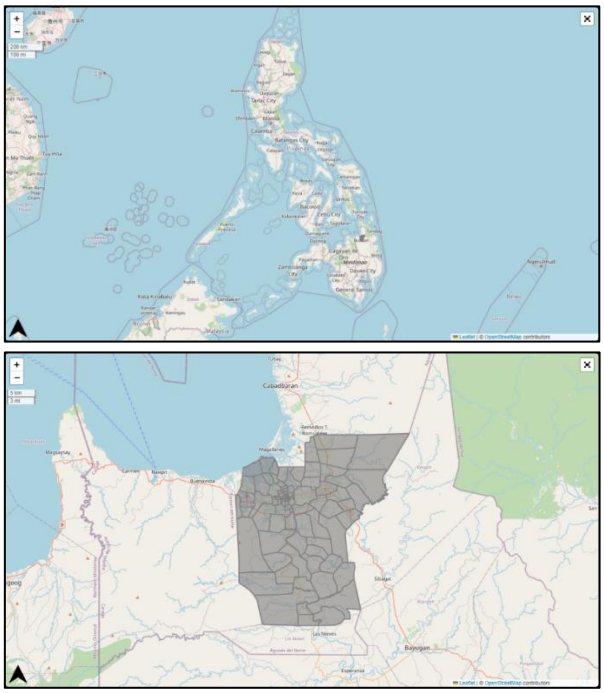

Fig. 8. OpenStreetMap (OSM) image of the Digital Basemap

### 4.3 Operational Layers

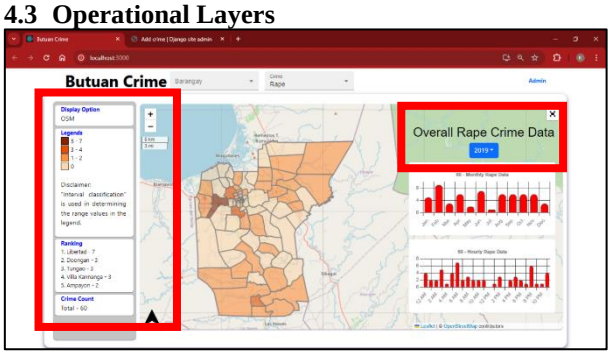


Fig. 9. Layer Panel: Legend, Ranking, and Crime Count

The operational layers of the WEB GIS application provide users with a direct interface to geographical data, an embedded framework of the WEB GIS application. These layers represent the "smallest set of layers" that users interact with directly or derive from operations such as queries tailored to specific user groups. Within this context, two crucial operational layers are Rankings and Crime Count, as shown in Figure 9. In the Rankings layer, users are presented with an overview of the top 5 barangays with the highest cases. For instance, in the provided example shown in Figure 12, Libertad ranks first, followed by Doongan, Tungao, Villa Kannanga, and Ampayon. Meanwhile, the Crime Count layer provides users with a comprehensive tally of total crimes and the corresponding number of each index crime. In the given example, the total count of crimes is 235, Physical Injury 146, Theft 25, Rape 22, Robbery 17, Homicide 13, Murder 9, Carnapping 3. These operational layers smoothly integrate spatial data from the database into

their corresponding layer panels by automating the analysis and display of that data.

### 4.4 Web Exploration of Butuan Crimes


Fig. 10. Primary Components Displayed on the Interface.

The interface, shown in Figure 10, serves as the primary platform for displaying essential elements of a web GIS, adhering to OGC standards. This includes digital base maps, such as OSM, that provide geographic context. Within the layer panels, users can access display options, legends for crime data interpretation, and metrics like Crime Count and Ranking for comprehensive analysis (see Fig. 11). Tasks and tools are also integrated, featuring dropdown search bars for efficient data retrieval and an admin button to manage login restrictions. Cartographic elements, essential for spatial understanding, are also present, ensuring compliance with OGC standards. Together, these components create a robust web GIS interface, facilitating intuitive navigation and meaningful spatial analysis for users.

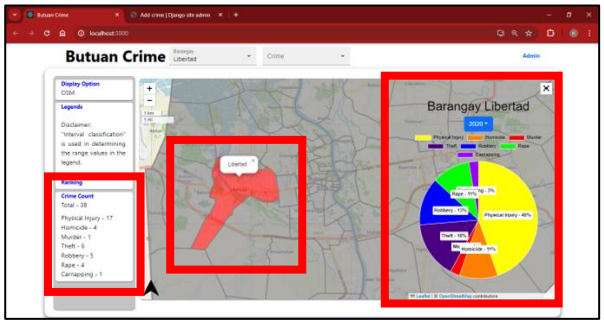


Fig. 11. Crime Count Layer Panel

In the upper right corner, adjacent to the Web Title labeled "Butuan Crime" (see Fig. 12), users are prompted to select a barangay of interest for monitoring safety and security concerns. For instance, if users opt for Barangay Ampayon, a series of features will automatically populate the screen to provide relevant insights. Within the layer panel, users will find details such as the total count of crimes reported within Ampayon and corresponding data on specific index crimes.

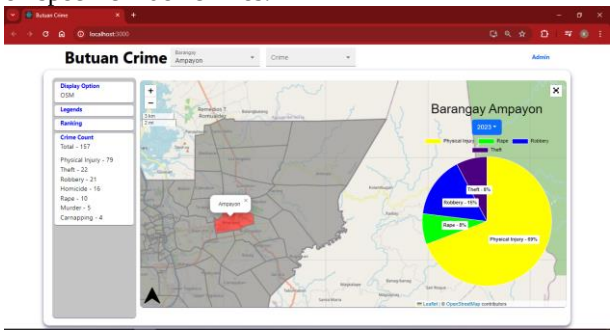


Fig. 12. Features explored just by selecting a Barangay.

Meanwhile, in the base map section, the geographic boundaries of Ampayon will be delineated and highlighted to enhance spatial understanding. Lastly, users will encounter the spatiotemporal pie chart, which integrates the values of each crime type into a percentile format, offering a visual representation of crime distribution over time within the selected barangay. This comprehensive suite of features empowers users to better understand crime dynamics in their chosen area, facilitating informed decision-making and proactive measures for enhancing community safety and security.

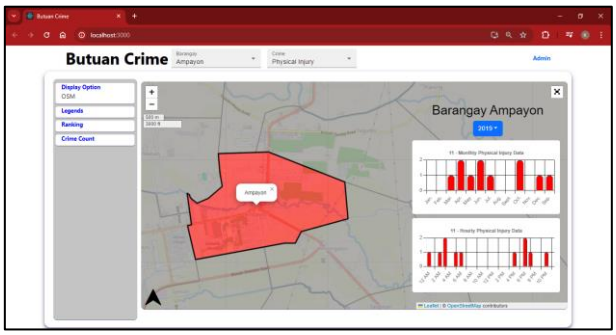


Fig. 13. Selecting a barangay and a specific crime.

Upon selecting a particular crime of interest within the web GIS interface, users access additional features that provide deeper insights into the temporal aspects of crime occurrences. One such feature is a bar chart illustrating each reported crime incident's recorded dates and times, as shown in Figure 13. This chart encompasses monthly data from January to December, offering a comprehensive overview of the distribution of crime occurrences throughout the year. Additionally, the chart provides hourly data, highlighting the significance of the time when each crime occurred. This detailed temporal analysis enables users to discern patterns and trends in crime activity, empowering them to make informed decisions about their safety and security. By understanding when certain crimes are more likely to occur, individuals can adopt a more vigilant mindset and take proactive measures to avoid potentially risky situations. Ultimately, this enhanced awareness fosters a safer environment for the community.

When selecting a specific crime, the web GIS interface shows the spatial information tailored to the user's needs. These features include a Legend, barangay ranking based on crime incidence, crime count statistics, a graduated map, and monthly and hourly data visualizations, as shown in Figure 14.

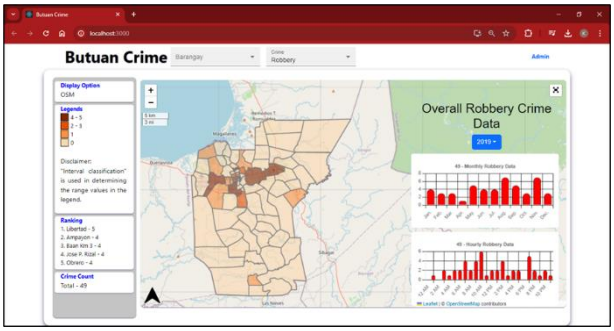


Fig. 14. Legend, Ranking, and Crime Count.

This amalgamation of features seamlessly complements each other, offering users a comprehensive understanding of crime dynamics within their chosen area. Users can readily discern the top 5 barangays with the highest crime rates among the 86 barangays, grasp the total crime count for the selected year, and delve into detailed insights on which months and times witness the highest crime occurrences. The graduated-color map, shaded according to Jenk's natural break classification, provides a clear visual representation of crime distribution across barangays, with legend values offering additional context. This wealth of information benefits civilians and police departments alike, fostering awareness, aiding in crime planning, and facilitating mitigation efforts for a safer and more secure community.

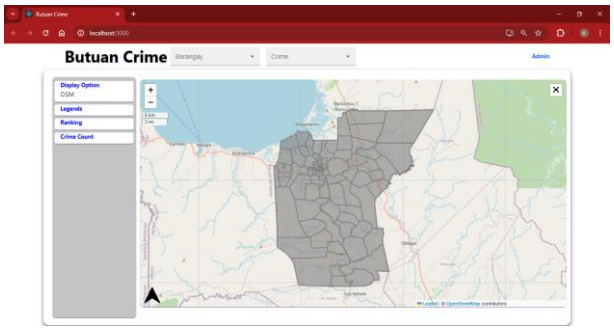


Fig. 15. Selecting “admin” to access data behind the public interface.

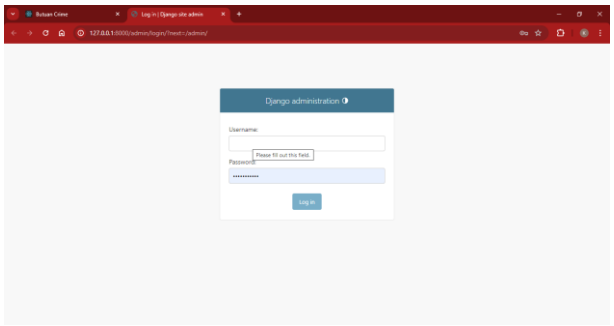


Fig. 16. Accessing admin login restriction.

By clicking on the "admin" option, as shown in Figure 17, located at the upper right corner of the interface, administrators must log in to gain access to the most intricate section of the database. With this access, administrators wield the highest level of authority, enabling them to manipulate the stored data to ensure its accuracy for public users (see Fig. 16). Administrators can input newly reported cases daily, maintaining a current and comprehensive database of crime incidents. Additionally, they can remove recorded cases from the database, ensuring that only relevant and accurate information is accessible to users. This level of administrative control is essential for maintaining the reliability and functionality of the web GIS platform, contributing to its effectiveness in serving the needs of administrators and public users.

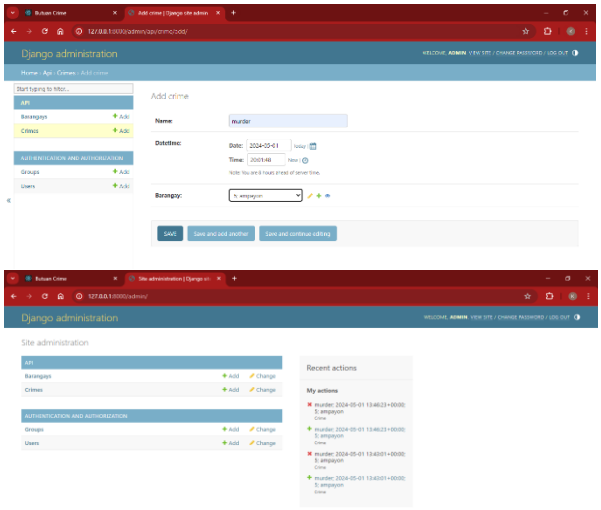


Fig. 17. Adding, deleting, and saving crime data.

Exclusive to administrators, the capability to add or delete cases within the database is paramount. This function is facilitated through the "add crime toggle" (see Fig. 17), which allows administrators to input essential information such as the barangay name, crime name, date, and time before saving the data. Furthermore, the main interface for administrators features a log of recent actions undertaken within the database. This feature is a vital tool for tracking all activities performed on the web GIS platform, offering administrators comprehensive oversight, and facilitating accountability in database management.

### 4.5 Tabulated Cases of Index Crimes Per Year

Table 3. Annual Index Crimes of Butuan City from 2019-2023.

| CRIME NAME | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|
| MURDER | 65 | 43 | 48 | 52 | 13 |
| PHYSICAL INJURY | 348 | 250 | 322 | 319 | 89 |
| HOMICIDE | 76 | 60 | 53 | 61 | 14 |
| RAPE | 60 | 54 | 67 | 35 | 19 |
| THEFT | 119 | 57 | 68 | 74 | 16 |
| ROBBERY | 49 | 42 | 34 | 36 | 11 |
| CARNAPPING | 6 | 12 | 19 | 10 | 2 |

An in-depth examination of NAPOLCOM data from 2019 to March 2023 provides a foundational understanding of crime trends within Butuan City. While direct spatial analysis may not be feasible, a meticulous review of this data presents pivotal insights for the BCPO to strategize effectively.

Analysis of the six index crimes - Murder, Physical Injury, Rape, Theft, Robbery, and Carnapping - reveals notable fluctuations over the years. Of particular concern is the discernible rise in murder cases, peaking in 2022 with 52 reported incidents. This necessitates a focused investigation into potential motives, victim demographics, and geographical hotspots to discern underlying causes and identify preventive measures. Theft emerges as a persistent issue demanding sustained attention, while Robbery and Carnapping cases show signs of decline. However, maintaining vigilance is imperative. The BCPO can glean valuable insights to

disrupt criminal operations and fortify vulnerable areas by dissecting these crimes based on time, location, and stolen items. Augmenting the existing analysis with monthly data breakdowns would offer enhanced granularity, potentially uncovering seasonal trends crucial for targeted policing strategies. Integrating spatial analysis tools would further amplify insights by pinpointing crime hotspots and guiding resource allocation for proactive intervention. The NAPOLCOM data guides the BCPO's efforts in curbing crime and enhancing public safety in Butuan City. By delving deeper into available data, leveraging spatial analysis tools, and fostering robust community partnerships, the BCPO can craft targeted strategies to thwart criminal activities, fostering a safer environment conducive to the well-being of all residents. Effective data utilization and collaborative endeavors are pivotal in achieving the BCPO's overarching crime prevention objectives. The Tabular form of six index crimes for each year are presented in Table 3.

## 5. CONCLUSION

This study aimed to investigate and analyze index crimes in Butuan City through a GIS-based approach using a web-based platform for crime frequency assessment. Integrating GIS and a web-based platform provided a comprehensive and dynamic tool for visualizing, analyzing, and understanding the spatial patterns of index crimes in the city. The qualitative findings reveal changes in crime frequency, with participants noting how the visual representation of crime data has enabled law enforcement agencies to enhance their strategic allocation of resources.

Moreover, interviews and focus group discussions are recommended to highlight the benefits of the interactive web-based platform that allows for real-time monitoring and fostering community awareness and engagement. Community members expressed a greater sense of involvement and empowerment, indicating that the platform facilitated more effective communication between the public and law enforcement.

The results of this research contribute to the growing body of knowledge on data-driven crime analysis, showcasing the potential of GIS in providing actionable insights for crime prevention. The spatial analysis unveiled specific areas requiring targeted interventions, with participants identifying high-crime zones that necessitate focused attention. This enabled authorities to effectively address crime-related challenges, as corroborated by qualitative feedback from both law enforcement officials and community members.

However, it is crucial to recognize the limitations and challenges highlighted by the participants, including the need for ongoing data quality improvement, privacy considerations, and enhanced community involvement. Despite these challenges, the qualitative findings support the conclusion that the GIS-based approach effectively enhanced the understanding of index crimes in Butuan City and demonstrated significant potential for improving crime prevention strategies.

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