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Research Article

Shoreline Realities: A Situational Analysis of Coastal Impact Zones in Gubat, Sorsogon, Philippines

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ABSTRACT

This study examines how geostatistics play a vital role in analyzing geospatial models, interpreting risk patterns, and identifying land use policy areas. It aims to assist policymakers, community leaders, and stakeholders in visualizing the 1-km coastal impact zone, which is measured as a buffer zone extending both inland and seaward from the shoreline, to enhance understanding of coastal risks. By using hotspot analysis and binning techniques within GIS, the research identifies high-risk areas for coastal hazards. Coral reefs and mangroves, which serve as natural barriers, have low-risk scores due to their wave attenuation effect that protects the coastlines. The study highlights significant risk scores and vulnerabilities in coastal barangays (villages) in the Municipality of Gubat, Sorsogon, Philippines. It evaluates about 7,350 hectares that is nearly level with slopes ranging from 0-9%, making it particularly susceptible to storm surges hazards, tsunamis, storm surges, flooding, and liquefaction, balanced against natural barriers, while conserving 36 hectares of fish sanctuaries, mangroves, 16 hectares of seagrasses, 1,131 hectares stationary fishing ground or municipal waters, fishponds and other species in marine protected areas. The 1-km coastal impact area geospatial information model, spanning 3,647 hectares, reveals notable findings both inland and seaward from the shoreline. For the 1-km inland area (1,821.9 ha), it identifies 39% as a Cold Spot with 99% confidence in seascape resiliency, 9% as a Cold Spot with 95% confidence, 3% as a Cold Spot with 90% confidence, and a nearly flat area resilient to coastal hazards. For the area extending 1 km seaward from the shore, 43% is identified as a Cold Spot with 99% confidence in shore resilience, 3% in the outer impact area as a Cold Spot with 95% confidence, 3% with insignificant coastal risk, and 2% as a hotspot with 95% confidence in risk. These results underscore the model's effectiveness in assessing coastal hazards and identifying areas of varying resilience. Based on these findings, policymakers should leverage geospatial information models to create informed zoning regulations and engagement strategies that enhance coastal community resilience against hazards. In conclusion, integrating these geospatial information models with coastal community assessments and geostatistics underscores the necessity to sustain coastal management practices and proactive conservation efforts. Highlighting the shoreline's critical role, the study emphasizes the practical implications of using advanced geospatial tools, engaging communities, employing data-driven planning, and promoting sustainable development to effectively address climate change-driven coastal vulnerabilities.

Keywords: Geostatistics, geospatial, LUPA, coastal, hotspot, hazard, vulnerability, risk reality, shoreline

1. INTRODUCTION

Gubat, Sorsogon, situated at 12° 55' 15.60" N latitude and 124° 07' 22.80" E longitude, is a coastal municipality in the Philippines, renowned for its picturesque beaches, abundant marine life, and thriving agricultural sector. Approximately 600 kilometers southeast of Manila, it is accessible through both land and sea travel, offering visitors a scenic and culturally rich destination along the Pacific coast.

Coastal areas are increasingly facing the challenges posed by climate change (Lopez, 2015; Siringan & Villaluz, 2012) and human activities. Rising sea levels, intensified typhoon surges, and other natural and anthropogenic factors have made coastal areas more vulnerable, necessitating effective management and adaptation strategies. Gubat, a coastal municipality in the province of Sorsogon, Philippines, stands as a critical example. Located facing the Pacific Ocean, it meets severe coastal hazards, including flooding and storm surges. The local economy, heavily dependent on agriculture, fishing, and small-scale industries, underscores the urgency of implementing adaptation strategies to mitigate climate-related risks (Lopez, 2015; Siringan & Villaluz, 2012). The shoreline in the study area is a key feature bearing the effect of changing climate. Extreme weather events have placed the Gubat's ecosystems and communities at risk. These challenges directly affect progress toward the Sustainable Development Goals, especially SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 11 (Sustainable Cities and Communities). For instance, damage to Gubat's shoreline threatens local biodiversity and the livelihoods of its residents, who rely on natural resources for livelihood and survival. To protect its coastline and communities, it requires comprehensive adaptation measures, such as sustainable coastal management and proactive disaster risk reduction. These strategies are critical to maintaining the balance between ecological preservation and development while contributing to global SDG targets (Lopez, 2015; Siringan & Villaluz, 2012).

Located near the entrance of the San Bernardino Strait, the coastal town of Gubat were crucial in maritime defense strategies of the 19th century (Reyes et al., 2020; Siringan & Villaluz, 2012). The Gubat communities are leading efforts to combat climate change and its effect on sustainable development, influenced the social and cultural fabric of coastal communities near the San Bernardino Strait (Reyes et al., 2020; Siringan & Villaluz, 2012). This historical perspective enriches how natural features and traditional practices have long contributed to community resilience against external threats and environmental challenges (Reyes et al., 2020; Siringan & Villaluz, 2012). Similarly, authors Reyes et al. (2020) give emphasis to mangrove-lined shores and coastal ecosystems acted as natural barriers, while constructed fortifications and community-based strategies provided additional layers of protection. This not only safeguarded the coastal communities but also laid the foundation for a socio-cultural identity. Moreover, authors Siringan et al. (2012) and Lopez (2015) underscores the coral reefs, seagrasses, and mangroves are vital in reducing the impact of waves associated with storms and tsunamis. Their studies demonstrate that buffers or 1-km impact areas are heightened climate change scenarios. Further work by Baloloy et al. (2020) and Villanoy et al. (2012) consolidates the importance of maintaining ecosystems to sustain natural defense. Their findings highlighted how the integration of natural and engineered solutions has long been, and remains, central to Gubat's resilience strategy. The Local Government Unit of Gubat, Sorsogon has taken proactive measures by formulating a comprehensive land use plan and zoning ordinance that designates specific areas for sustainable development and environmental conservation. The "Gubat land Use Plan and Zoning ordinance" not only focuses on establishing marine sanctuaries and flood control areas but also on preserving cultural heritage sites that embody the town's historical legacy (Baguilat, 2004). Coastlines and beaches of Gubat are pristine areas that supports both the local economy—largely based on agriculture, fishing, and small-scale industries—and the long-term conservation of the coastal environment. According to Saleh et al. (2008), coastal communities in the Philippines face risk from sea-level rise, storm surges, and coastal erosion. These natural threats, compounded by high population density, insufficient infrastructure, and economic dependence on coastal resources (Darwish, 2024; Thia-Eng, & Bonga, 2018; Saleh et al., 2008).

Geospatial studies emphasize advanced spatial analysis for coastal sustainability, with Perspectives (Bill et al., 2022) reviewing emerging methods and Abante (2020-2023) highlighting geographic naming in Gubat, Sorsogon using ArcGIS. Authors Reyes et al. (2020) examined nearshore currents in Palawan to assess coastal safety for recreation, while Mendoza and Valenzuela (2017) emphasized sustainable marine resource management in the Philippine blue economy. Author Sales Jr. (2009) incorporated climate variability and sea-level rise into Cavite City's coastal management, a strategy later reinforced by the World Bank (2024). Authors Allan & Kark (2023) and Abante (2021-2024) used geospatial models like the Getis-Ord Gi* statistic to map coastal risk hotspots from human activities, while authors Abante (2021), Corpuz (2013) and Baguilat (2004) examined legal and policy challenges in municipal water boundaries and sustainable land use using geospatial models. The enhanced Land Use Policy Area (LUPA) geospatial information model in this study employs ArcGIS, systematically analyses data (within the 1-km impact areas) across key policy sectors—protection, production, settlement, and infrastructure—to guide strategic land and water use decisions (Abante, et al., 2023; Abante, et al., 2021). This approach exemplifies how advanced geospatial tools transform environmental planning into a data-driven process (Puspita et. al, 2025; Abante, et al., 2023; Abante, et al., 2021).

Using geostatistics in environmental sciences, emphasizing its versatility beyond traditional fields like data mining and characterization (Abante, 2020-2023; Renard, et al., 2005; Getis & Ord, 1992), it highlights how geostatistics and geo-visualizations provide a probabilistic framework for spatio-temporal interpolation of environmental variables, both continuous and categorical. Additionally, it discusses the methodology's role in optimizing sampling and its relevance across diverse domains.

Figure 1. Illustrate how documents, maps, and geospatial shall guide coastal management, assess risks, and improve resilience. It reviews coastal vulnerability studies (Sales, 2009), categorizes land and water uses (NAMRIA & DENR, 2023; Downing et al., 1993), and ensures municipal water regulation follows standards (Baguilat, 2004). Using geospatial analysis, it identifies risk hotspots (Abante, 2020-2023; Getis & Ord, 1992) and highlights adaptation strategies that merge traditional methods with modern technologies to protect coastal communities (Siringan et al., 2012; Lopez, 2015; Reyes et al., 2020). It integrates several key components to assess and manage coastal areas including municipal waters within the study area: (i) vulnerability assessment and document review includes a comprehensive evaluation of potential risks and a thorough review of relevant documents. The land classification map, provided by the government, essential for vulnerabilities and understanding risk realities within the 1-km coastal impact area part of the municipal waters in the study area; (ii) exposure assessment to identify geographic locations vulnerable or at risk; (iii) capability concept model to promote sustainable development; (iv) Establishing risk realities and its significance. Additionally, the rubrics helped measure or described the significance of various risks and vulnerabilities hinting the challenges faced by the communities; (v) addressing gaps in land and water use policy maps essential for effective land use and

disaster risk reduction. Interpreting and measuring resilience across these contexts remain crucial for strategies to address the challenges and vulnerabilities; (vi) understanding resilience of host environment, planners, engineers, policymakers, and researchers can employ context-specific approaches to get preparted and sustain local development; and (vii) recontextualizing LUPA elements with emphasis on municipal waters and its coast: protection, production, settlement and infrastructure, involves integrating gaps related to climate change adaptation by implementing measures to address its impacts on land use (Abante, et al., 2023; Abante, et al., 2021).

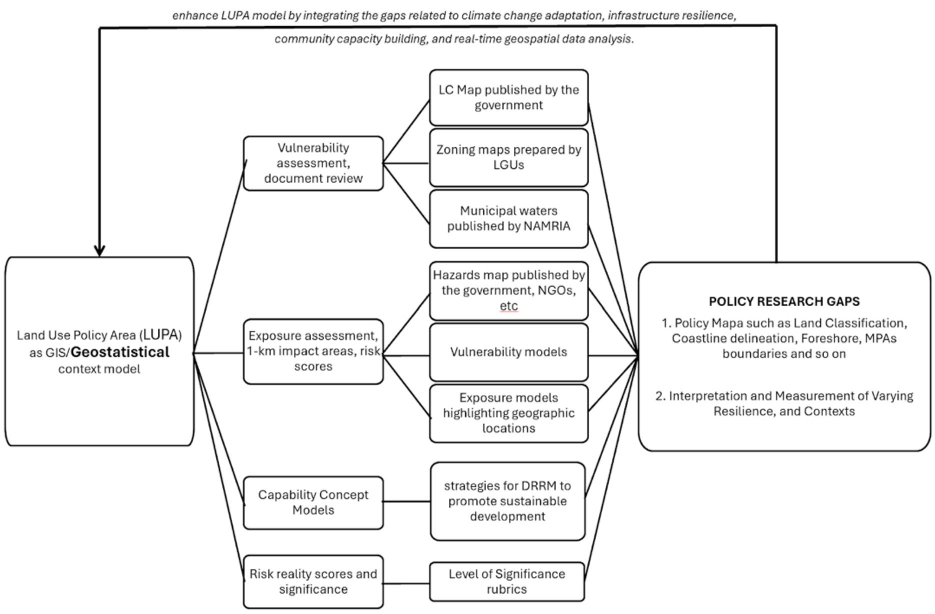

Figure 1. Land Use Policy Area (LUPA) recontextualized model for coastal regions (Abante, 2024)

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The study aims to integrate essential components—vulnerability assessment, exposure analysis, capability modeling, risk reality scoring, policy gap identification, resilience evaluation, and recontextualization of LUPA elements—to effectively assess and manage coastal areas and municipal waters within the study area. It focuses on coastal vulnerability from climate change and shoreline changes, by leveraging the LUPA geospatial information model alongside ICT, GIS, and remote sensing technologies. Grounded in insights from Abante et al. (2023), Puspita (2025), and Abante et al. (2021), the study seeks to support the development of strategic land use policies that promote resilience and sustainability. By employing a comprehensive geospatial framework, this research enables policymakers, community leaders, and stakeholders to visualize the 1-kilometer coastal impact zone, measured as a buffer extending both inland and seaward from the shoreline, and identify risks, vulnerabilities, hazards, hotspots, and cold spots. The approach also incorporates geostatistics, hotspot analysis, and binning techniques to pinpoint high-risk areas, guide mitigation strategies, and leverage natural barriers to enhance coastal resilience.

2. MATERIALS AND METHODS

This study employed shoreline delineation to establish a 1-km landward and seaward impact area within a Geographic Information Systems (GIS) platform, identifying hotspot areas using Abante (2020-2023) binning technique to pinpoint coastal risk realities. The coastal situational analysis focus on the 1-km impact are landward and seaward and the coverage of the municipal waters, not the elevated areas of Gubat. The coastal situational analysis focuses on the 1-km impact areas both landward and seaward, as well as the coverage of the municipal waters, excluding the elevated areas of Gubat.

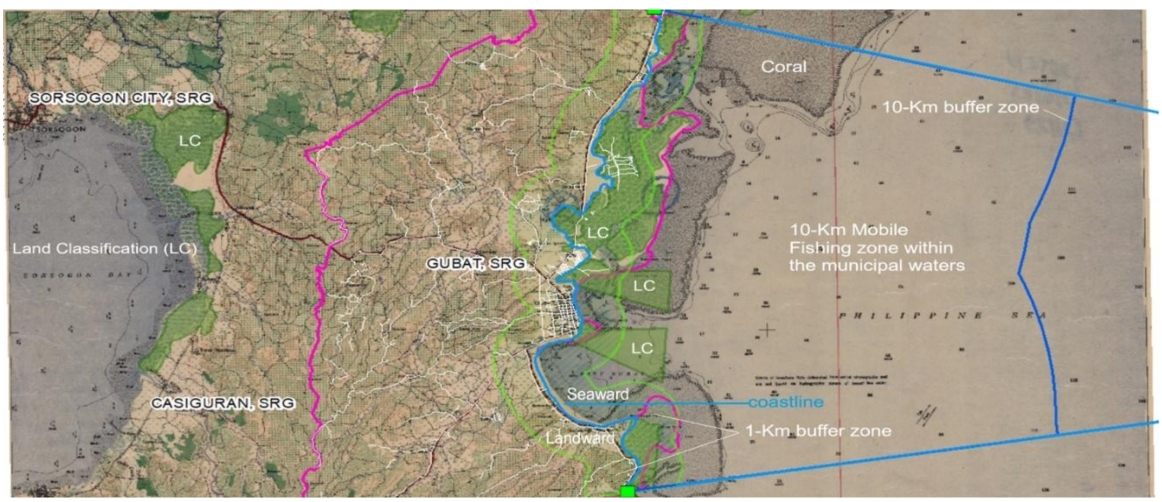

Figure 2. Beyond the Shoreline: Visualizing unreliable Land Classification (LC) in 1-Km coastal impact zone
Source: National Mapping and Resource Information Authority, 1950. Topographic Map of Gubat with 1:50,000, and Municipal Waters of Gubat, Sorsogon; Department of Environment and Natural Resources Region V. Land Classification Map of Gubat Sorsogon. Retrived from https://www.namria.gov.ph/downloads.aspx#gsc.tab=0.

Figure 2 shows the landward impact area covered 3,647 hectares within the 1-km buffer, including (i) the landward impact area with 1,821.9 hectares having slopes ranging from 0-9%, and (ii) the seaward impact area with 1,825.1 hectares featuring natural barriers like coral reefs and mangroves, which contributed to low-risk scores due to their wave attenuation effects. This approach enabled a detailed assessment of coastal vulnerabilities by collecting and analyzing geostatistical or geospatial data (Abante, 2020-2023; Renard, et al., 2005); Getis & Ord, 1992), including climate conditions, land classification, shoreline characteristics, tidal patterns, and municipal water boundaries. Geostatistical in this study refers to the application of statistical methods to geospatial data, enabling the analysis, modeling, and interpretation of geographic patterns and relationships. It encompasses tools and techniques to identify hotspots, assess risks, and make data-driven decisions for land use, disaster preparedness, and sustainable development. Geostatistical analysis, as a specialized application of statistical techniques to spatial data, played a crucial role in studying the model interpreting geographic risk reality patterns and LUPA relationships (Abante, 2020-2023; Renard, et al., 2005); Getis & Ord, 1992). It utilizes various tools to identify risk-prone areas, evaluate vulnerabilities, and support data-driven decision-making in fields like land use planning, disaster preparedness, and sustainable development. As a focused subset of geospatial data, geostatistical data integrates statistical processes to analyze spatial patterns, while geospatial data, in a broader sense, provides locational information without necessarily involving statistical analysis as shown in Figure 1 and Figure 3.

Advanced tools, including ArcGIS, topographic maps, and hazard maps extracted from Project NOAH data and Hazard Hunter, supported this process to generate base and analytical maps to simulate risk realities as shown in Figure 3. Additionally, input from Local Government Unit of Gubat and co-researchers' inputs provided valuable information pointed out in Table 5. The study also included municipal waters and a 10-km coastal buffer designated for municipal ground fishing, beyond which commercial fishing is permitted as shown in Figure 2. This visualization approach ensured a thorough understanding of coastal risks and the necessary resilience strategies.

Table 1 outlines the importance of preparedness for coastal hazards. The following are the contextualized levels of preparedness for this study: (i) at the highest level of preparedness (Level 5), measures include the protection of existing mangroves as indicated by 2020 Land Classification (LC) maps, proposed Marine Protected Areas (MPAs) in Pinontingan, Bagacay, and Rizal, and tourism and beach areas in Ariman, Buenavista, and Rizal. These resources provide critical benefits such as reducing wave energy, trapping sediments, and preventing shoreline erosion.

Table 1. Situational Analysis: Preparedness based on the factors outlined in the Risk Reality Scores

Preparedness Level	Description of	Assumptions used in geospatial modeling
Highest Level (5)	Assumes an advanced preparedness, supported by various protective measures. Abante (2023) described advanced preparedness as an strategic approach to disaster risk reduction, emphasizing the use of geospatial information models to mitigate risks and promote sustainable growth.	▪ Protected by Land Classification (LC) maps, these mangroves provide critical benefits such as reducing wave energy, trapping sediments, and preventing shoreline erosion (Bunting, et al., 2023; Fajardo, 2001). ▪ Proposed Marine Protected Areas in Pinontingan, Bagacay, and Rizal, as indicated by the water use map of LGU-Gubat. These examples are essential for conserving marine biodiversity and reducing the impacts of human activities. They continue to provide essential benefits to people and the environment by enhancing resilience against coastal hazards (Beger, et al., 2004) ▪ Tourism and beach areas in Ariman, Buenavista, and Rizal, identified on the LGU-Gubat water use map, boosting economic activities while serving as vital zones for coastal protection. ▪ Marine resource protection based on Land Classification (LC) Map, Land Use and Zoning, MPAs, and Mangrove Satellite imagery in Gubat.
Moderate Levels (2 to 4)	Getting prepared includes natural resources visible in Mangrove Satellite imagery from 2020 but not explicitly protected by LC Maps. (Land Cover Map of Region 5, Philippines. NAMRIA. https://www.geoportal.gov.ph/	▪ 10-km mobile fishing zone and/or stationary fishing areas as hown in Figure 2, designated municipal waters where fishing activities are conducted sustainably. ▪ Coral reefs and potential seaweed areas, as illustrated in Figure 1 through topographic and Comprehensive Land Use Plan (CLUP) maps, are essential for sustaining and protecting marine ecosystems. ▪ Navigational zones designated for safe navigation and maritime activities as described in the comprehensive land use plan and zoning ordinance of Gubat, Sorsogon
Low Level (1)	Insufficient preparedness represents minimal preparedness within the Mobile Fishing zone. Abante (2018, 2019) defined insufficient preparedness as a state where communities or systems fail to effectively transition between receptiveness (prevention) and responsiveness (action).	▪ The mobile fishing zone, depicted in **Figure** 2 within the municipal waters, lacks sufficient infrastructure and protective measures, rendering it highly susceptible to coastal hazards

They are safeguarded based on LC Maps, Gubat Land Use and Zoning, and Mangrove Satellite imagery from 2020; (ii) moderate preparedness levels (Levels 2 to 4) involve natural resources visible in Mangrove Satellite imagery from 2020 but not explicitly protected by LC Maps, including stationary fishing areas, coral and seaweed areas, and navigational areas that maintain marine ecosystems and support local economies; and (iii) the lowest level of preparedness (Level 1) represents the Mobile Fishing zone within the municipal waters, with limited infrastructure and protective measures, making these areas highly vulnerable to coastal hazards. Implementing and maintaining high levels of preparedness is crucial for reducing the impact of coastal hazards and enhancing the resilience of coastal regions in Gubat Sorsogon.

While Table 1 illustrates a tiered preparedness framework for coastal hazards in Gubat where protected mangroves, proposed MPAs, and designated tourism areas mitigate risks, Table 2 highlights the concept of coping capacity levels, emphasizing the ability of coastal communities to adapt to challenges or adverse situations.

Table 2 reflects the coping capacity to balance priorities by addressing immediate needs while strengthening strategies to enhance resilience, as assumed and categorized as follows: (i) the highest level (4 to 5) is observed in areas outside the 1-km landward buffer zone with well-established road networks, enabling efficient movement of people, goods, and emergency services. These areas benefit from robust early warning systems, comprehensive disaster response plans, and effective community education programs, ensuring resilience to hazards; (ii) moderate levels (2 to 3) are found within the 1 km Coastal Impact Area, which faces greater risks from storm surges, flooding, and sea-level rise. While these areas have some infrastructure and preparedness measures, they are less equipped compared to higher-level zones; and (iii) in contrast, the low level (1) of coping capacity is associated with the Mobile Fishing Zone within municipal waters, where minimal infrastructure and limited access to emergency services heighten vulnerability to coastal hazards. These areas require substantial support and intervention to reduce risks and build resilience effectively.

Table 2. Assumptions on coping capacity level

Coping Capacity Level	**Description**	**Characteristics (Assumptions used in geospatial modeling)**	**Rating**
Highest Level	Found in areas outside the 1 km landward zone with well-established road networks. These areas have the highest capacity to cope with coastal hazards due to their infrastructure and accessibility.	▪ Efficient movement of people, goods, and emergency services (Kazimierczuk, et al., 2023; NDRRMC, 2024) ▪ Comprehensive disaster response plans (Domingo & Manejar, 2018). ▪ Effective community education programs (Joseph & Said, 2020)	4 to 5
Moderate Levels	Observed within the 1 km Coastal Impact Area. These areas have some capacity to handle coastal hazards but are not as well-equipped as those in the highest level. Proximity to the coast increases risks from storm surges, flooding, and sea-level rise.	▪ Some infrastructure and preparedness measures in place (NDRRMC, 2024). ▪ Limited resources and accessibility compared to areas outside the 1 km landward zone.	2 to 3
Low Level	Found within the Mobile Fishing zone within the municipal waters. These areas have minimal infrastructure and are highly vulnerable to coastal hazards.	• Lack of permanent structures. • Limited access to emergency services and resources (NDRRMC, 2024). • Require more extensive support and intervention to enhance coping capacity and reduce vulnerability (NDRRMC, 2024)	1

Tables 2 and 3 further emphasize the importance of coping capacity and natural resource competency in enhancing coastal resilience. Mangroves and coral reefs absorb wave energy, shielding coastal communities from storm surges and erosion, supporting the Climate Change Commission's call to combine natural resource management with infrastructure development for better disaster preparedness. This harmonious interaction between environmental conservation and infrastructure advancements is essential for mitigating risks and fostering sustainable coastal development (Thia-Eng & Bonga, 2018). Furthermore, the researchers highlight the significance of these strategies in safeguarding ecosystems while tackling socio-environmental challenges specific to Gubat (refer to Table 5).

Table 3 highlights the assumptions on levels of competency in terms of risk mitigation, emphasizing the role of natural resources in protecting coastal areas from hazards. It outlines the assumptions used in the geospatial modelling to categorize competency levels based on the presence or absence of natural coastal features. The assumptions on competency scale for this study, are: (i) a scale of 5 represents the highest competency level, where natural resources like mangroves and coral reefs help reduce coastal hazards. Mangroves and coral reefs absorb wave energy, prevent erosion, and protect coasts, ensuring resilience; and (ii) a scale of 1 indicates minimal competency, with the absence of coastal features such as mangroves and coral reefs leading to heightened vulnerability to hazards like storm surges, tidal waves, and sea-level rise. These areas face increased risks of erosion, flooding, and damage to infrastructure and livelihoods, requiring significant human-made interventions and adaptive strategies to build resilience.

Table 3. Assumptions on competency scale

Competency Scale	Description	Characteristics (Assumptions used in geospatial modeling)
Scale of 5	Indicates a high level of competency, where natural resources such as mangroves and coral reefs effectively mitigate coastal hazards.	▪ Mangroves: Reduce wave energy, trap sediments, and prevent shoreline erosion (Sanches, et al., 2019; Spalding, et al., 2014) ▪ Coral Reefs: Act as natural barriers, absorbing wave energy and diminishing the impact of storm surges and tidal waves (Villanoy, 2t al., 2012; Sheppard, et al., 2005) ▪ Provide substantial protection against coastal hazards, making areas with such resources highly resilient (Mcleod, 2010; Woodroffe, 1990)
Scale of 1	Represents a low level of competency, where there are no coastal physical features to mitigate risks posed by coastal-related hazards.	▪ Absence of Natural Features: No mangroves or coral reefs (Nichols, et al., 2019; Honda, et al., 2013) ▪ High susceptibility to coastal hazards like storm surges, tidal waves, and sea-level rise (Lapidez, et al., 2015; McInnes, et al., 2003) ▪ Increased risks of erosion, flooding, and damage to infrastructure and livelihoods (Siringan, & Sta. Maria, 2024; Acosta, et al., 2016) ▪ Requires more extensive human-made interventions and adaptation measures (Le, et al., 2019; Moya, 2018)

3. RESULTS AND DISCUSSION

The assessment of vulnerabilities and resilience in coastal areas of Gubat, Sorsogon, Philippines, using geospatial information models and techniques like hexagonal binning, is supported by studies such as those by Abante, et al. (2023) and Abante, et al. (2021), which emphasize the importance of spatial analysis in identifying high-risk zones prone to coastal hazards. Additionally, the integration of geospatial modeling for disaster risk reduction is highlighted in guidelines by United Nations Global Geospatial Information Management for Asia and the Pacific (UN-GGIM-AP), which advocate for the use of advanced geospatial technologies to enhance resilience and inform policy (ESCAP, 2020; Miyazaki, et al., 2015).

The researchers concur that these works collectively highlight the transformative role of spatial analysis in mitigating coastal hazards. By integrating multiple data layers, including climate information, land classification, coastline features, tidal patterns, and municipal waters, the model provided a comprehensive approach to identifying areas at risk from coastal hazards. The analysis supported targeted mitigation strategies and highlighted the importance of engaging local communities in resource management. Additionally, implementing strict development regulations was identified as crucial for enhancing the sustainable management and protection of coastal regions against the impacts of climate change and human activities. The recontextualized Land Use Policy Area (LUPA) model, embedded within an advanced geospatial information framework as shown in Figure 1, Figure 5 and Table 1 to 5, offers critical insights into the vulnerabilities along Gubat, Sorsogon's dynamic coastline, where climate change and rapid anthropogenic activities threaten key Sustainable Development Goals—particularly SDG 13 on Climate Action and SDG 14 on Life Below Water (Abante, et al., 2023; Abante, et al., 2021). By systematically analyzing data on floods, storm surges, sea-level rise, tsunamis, liquefaction, and coastal erosion, this integrated approach highlights how shifts in the coastline amplify disaster risks and ecosystem degradation (PAGASA, 2021; PHIVOLCS, 2023). For instance, severe storm surges, evidenced during Typhoon Pepito (Saudel) in 2020, and a high probability of tsunamis underscore the urgency for enhanced coastal defense measures (Agpalo, 2024). In 2024, Tropical Storm Kristine, internationally known as Trami, impacted the Philippines, particularly Luzon, and later affected Vietnam, Thailand, and China.

Mangroves and corals, depicted in Figures 3 and 1 respectively, are vital for shoreline stabilization and mitigating the effects of climate-induced hazards. These ecosystems offer significant protection against flooding and erosion, while aligning local land use policies with Sustainable Development Goals (SDGs). Specifically, SDG 13 (Climate Action) is advanced by enhancing resilience to natural disasters, SDG 14 (Life Below Water) is supported through the conservation and sustainable management of marine ecosystems, and SDG 15 (Life on Land) promotes the sustainable protection of coastal habitats. Geospatial information is equally critical in achieving SDGs by enhancing environmental conservation and resilience-building efforts. It enables the evaluation of vulnerabilities and adaptive capacities related to SDG 13 (Climate Action), aids in the mapping of marine ecosystems for SDG 14 (Life Below Water), and supports the strategic management of ecosystems as outlined by SDG 15 (Life on Land). Allan, Levin, and Kark (2023) underline the value of delineating coastal impact areas for analyzing interactions between natural processes, human activities, and climate change.

Tables 1 to 3 establish a comprehensive framework that categorizes coastal zones based on preparedness, coping capacity, and natural resource competency, providing critical criteria for assessing how well coastal areas can mitigate hazards. When combined with the quantitative findings in Table 4—detailing the spatial distribution of risk and resiliency in inland and seaward areas—this integrated approach validates the model's effectiveness in informing targeted coastal management and sustainable development strategies. Advanced GIS and remote sensing techniques have been employed to develop Coastal Risk Models, as noted by Seitz et al. (2014), within defined impact zones, facilitating the mapping of flood-prone areas and forecasting future risks. For example, the Ariman-Panganiban Coastal Road and Shore Protection project in Gubat, Sorsogon—a 374-meter road dike equipped with robust structural protections—exemplifies how development can be harmonized with conservation. The recontextualized LUPA framework exemplifies integrated approaches that guide policymakers and planners in achieving sustainable development, resilience, and infrastructure growth while safeguarding against hazards and fostering ecological and societal strength.

Table 4. Significant findings for both inland and seaward areas:

<table>
<tr><th>Impact Area</th><th>Attribute</th><th>Percentage</th><th>Confidence Level</th><th>Key role of recontextualized LUPA</th></tr>
<tr><td rowspan="4">Inland Area
(1,821.9 ha)</td><td>Cold Spot (inland/seascape resiliency)</td><td>39%</td><td>99%</td><td rowspan="4">Protection against hazards and risks
Production for economic sustainability
Settlement planning that supports resilient communities
Infrastructure development to sustain ecological and societal resilience</td></tr>
<tr><td>Cold Spot</td><td>9%</td><td>95%</td></tr>
<tr><td>Cold Spot</td><td>3%</td><td>90%</td></tr>
<tr><td>Nearly flat areas resilient to coastal hazards</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="4">Seaward Area
(1,825.1 ha)</td><td>Cold Spot (shore resilience)</td><td>43%</td><td>99%</td><td rowspan="4">Protection against hazards and risks
Production for economic sustainability</td></tr>
<tr><td>Cold Spot</td><td>3%</td><td>95%</td></tr>
<tr><td>Insignificant Coastal Risk</td><td>3%</td><td>N/A</td></tr>
<tr><td>Hotspot (Risk regions)</td><td>2%</td><td>95%</td></tr>
</table>

Table 4 presents the results that underscore the model's effectiveness in assessing coastal hazards and identifying areas of varying resilience. These findings support policymakers, community leaders, and stakeholders in making informed decisions to enhance coastal resilience and sustainability. The GIS analysis identified the inland region, characterized as a cold spot or resilient environment, spanning a total area of 1,821.9 hectares. The findings showed that 39% of the area is a cold spot with 99% confidence, 9% with 95% confidence, and 3% with 90% confidence. These results suggest that the nearly flat areas exhibit significant resilience to coastal hazards. Likewise, in the seaward area, which spans 1,825.1 hectares, 43% was classified as a cold spot with 99% confidence in shore resilience, 3% as a Cold Spot with 95% confidence, 3% as having insignificant coastal risk, and 2% as a hotspot with 95% confidence in risk. These findings demonstrate the model's capability in evaluating coastal hazards and pinpointing areas with differing levels of resilience in the coastal region of Gubat Sorsogon including its municipal waters. Tables 1 to 4 provide the critical empirical foundation for the insights and strategic directives outlined in Table 5. Together, these tables quantify coastal preparedness, coping capacity, competency in risk mitigation, and the spatial distribution of hazards and resilience, which inform the identification of key issues, guide precise policy interventions, and underscore the need for robust planning measures—such as updated mapping, zoning ordinances, and community engagement—to effectively manage and conserve coastal areas. Table 5 provides a thorough overview of the critical issues, proposed policy actions, and their practical benefits for protecting marine and mangrove (Baloloy, et al., 2020) ecosystems, along with additional contextual information to support effective land use and development planning.

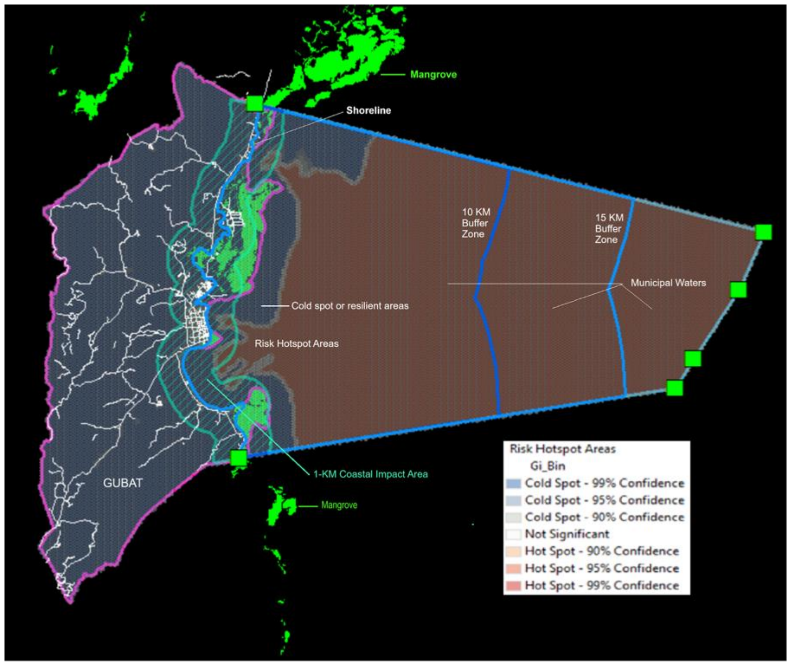

Figure 3. Shoreline Realities: A Situational Analysis of 1-km Coastal Impact area (Abante, 2024)

Source: All Hazard maps were retrieved from Project NOAH. https://noah.up.edu.ph/, and HazardHunterPH. https://hazardhunter.georisk.gov.ph/; National Mapping and Resource Information Authority, Municipal Waters of Gubat, Sorsogon; Department of Environment and Natural Resources Region V. Land Classification Map of Gubat Sorsogon. Retrived from https://www.namria.gov.ph/downloads.aspx#gsc.tab=0. Gubat baseline and hazards maps were retrieved from Zoning Ordinance, Volume 3, Gubat. Retrieved from https://www.scribd.com/document/612403824/CLUP-GUbat-Volume-3-Zoning-Ordinance-2021-2

Figure 3 demonstrates the coastline as a reference, this study delineates a 1-km coastal impact area—extending inland from the shoreline as a critical zone serve as the basis for analyzing ecological and socio-economic stressors, such as flooding, erosion, storm surges, and sea-level rise, thereby emphasizing the risks that threaten the achievement of SDGs 13 to 15.

Table 5. Shoreline realities: Overview of critical issues, policy actions, and practical benefits

Aspect	***Findings***	***Policy Recommendations***	***Practical Implications***	
Identification of Critical Areas	Unreliable maps may fail to accurately identify and delineate critical habitats, leading to insufficient protection measures for sensitive marine and mangrove areas. Current methods need adjustment to ensure robustness and reliability of data.	Invest in accurate and up-to-date land classification maps using advanced technologies like remote sensing and GIS. Use methodological triangulation combining LIT and photo-transect approaches.	Facilitate identification of critical habitats ensures targeted and effective protection measures. Advances results-based monitoring and evaluation techniques	Policy Map: Guides land use and development within a specific area, ensuring alignment with community goals and regulations. Enhance techniques for gathering data
Policy Decisions	Policies and conservation strategies based on inaccurate	Develop policies and conservation strategies based on reliable and	Well-informed policies lead to better-targeted	Gubat zoning ordinance defines how land within

	maps may not target the most vulnerable areas, resulting in ineffective or misplaced efforts. Fair diversity in MPA and non-MPA areas; target species contribute 49% of reef fish biomass. Current MPAs cover only 31 hectares (<1% of municipal waters), below the mandated protection level.	precise data to ensure efforts are appropriately directed. Enhance fishery management to sustain ecological stability and improve biomass. Expand MPAs to cover ideal reef sites and meet R.A. 10654 requirements.	marine conservation efforts, maximizing resource allocation and impact. Enhance fishing restrictions in high-biomass zones to ensure decisive disaster risk reduction, and empower fisherfolks inclusive participation and culturally sensitive practices Legislate and enforce expansion of MPAs to adapt to changing risks	certain zones can be used, specifying allowed activities and maintaining community character by preventing incompatible uses. A database or profile facilitates tracking the distribution of target species and their biomass and identify suitable reef areas for MPA expansion and conservation.
Environmental Degradation	Without accurate maps, harmful activities such as illegal logging, overfishing, and land conversion may go unchecked, leading to further degradation of marine and mangrove ecosystems. Erratic trends in live coral cover despite current results being the highest recorded. Climate change intensifies threats to coral reefs and ecosystems, creating interconnected risks that amplify their vulnerabilities.	Implement monitoring and enforcement mechanisms to ensure that activities within critical areas are regulated and sustainable Continue long-term monitoring using both LIT and photo-transect methodologies for triangulation. Implement adaptive management to mitigate climate change effects.	Reduce negative environmental impact on marine and mangrove ecosystems' health and biodiversity. Establish consistent monitoring protocols Integrate resilience strategies, including Cold spot analysis, into reef conservation plans, as illustrated in **Figure** 3.	A zoning map visually represents various zones and outlines permitted land uses, serving as a crucial tool for comprehending land use and development Map spatial trends in coral cover and analyze changes over time Model impacts of climate change on reef ecosystems.
Environmental Awareness	Limited awareness and technical knowledge in mangrove assessments and monitoring. Significant differences in coral lifeforms and habitat quality between Rangas and Namantaw reefs.	Reinforce environmental consciousness and community awareness through engagement and technical education. Utilize science-based protocols and backyard nurseries to grow sufficient, healthy seedlings.	Implement capacity-building programs for communities Develop adaptive reef management plans. Develop standards for mangrove rehabilitation	Map awareness and participation levels to identify areas needing intervention. Map reef biodiversity and habitat features to inform targeted actions. Identify and monitor site-specific requirements like soil type and species suitability.

Economic and Social Impacts	Communities that rely on these ecosystems for their livelihoods may suffer economically and socially due to the mismanagement of resources. Poverty and lack of alternative livelihoods leading to unsustainable practices.	Engage local communities in conservation planning and decision-making processes to address their needs and concerns. Provide alternative livelihood opportunities through LGUs and organizations.	Improved economic and social well-being of communities through sustainable resource management and conservation efforts. Support economic programs for community resilience.	Gubat zoning allocates distinct areas for economic, environmental, and tourism purposes, promoting sustainable development and the responsible use of coastal resources Identify and map regions where livelihoods and mangrove conservation overlap
Conservation Efforts	Conservation programs and initiatives may be less effective if they are based on flawed data, reducing their overall impact on preserving biodiversity and ecosystem services. Insufficient coordination and funding for sustainable management programs.	Ensure that conservation programs are grounded in accurate, up-to-date, and comprehensive data. Collaborate with agencies, NGOs, and private sectors for resource and funding support.	Enhanced effectiveness of conservation efforts, leading to better preservation of biodiversity and ecosystem services. Establish multi-agency partnerships and funding mechanisms.	Policy maps and zoning ordinances collaboratively regulate land use and development, fostering organized growth, community well-being, and sustainable progress Track collaborative projects and resource allocations.
Mangrove/Coral Rehabilitation Plan	Inadequate strategies to conserve, protect, and sustainably utilize mangroves. Seven assessments in 10 years highlight rare efforts but point to inconsistent methodologies.	Create an intensive rehabilitation plan focusing on conservation and coastal protection. Establish standardized, long-term frameworks for reef monitoring.	Formulate long-term conservation strategies. Allocate resources to support regular assessments.	Monitor the effectiveness of rehabilitation efforts and evaluate coastal protection. Track monitoring sites and results for consistency and analysis.

Source: Dioneda, R., Sr. (2024). Unpublished paper entitled "ASSESSMENT OF CORAL REEFS AND REEF-ASSOCIATED FISHES IN GUBAT, SORSOGON, PHILIPPINES"; Peregrino, J (2024). Unpublished paper entitled "ASSESSMENT OF MANGROVE COMMUNITIES IN GUBAT, SORSOGON;

Table 5 provides a comprehensive overview of shoreline realities by categorizing critical issues, policy actions, and their corresponding practical benefits. It serves as a valuable tool for understanding the challenges faced by coastal areas, the strategies needed to address them, and the positive impacts these measures can achieve. It is designed to inform evidence-based decision-making and promote sustainable shoreline management.

Unreliable maps hinder the accurate delineation of critical habitats, exposing sensitive marine and mangrove areas to insufficient protection. To address this, the use of advanced technologies like remote sensing and GIS for creating accurate land classification maps is recommended. Incorporating methodological triangulation, such as line intercept transect and photo-transect approaches, can ensure data reliability and robustness. These strategies facilitate precise identification of critical habitats, enabling targeted and effective conservation measures and guiding land use policies for community alignment. Conservation policies, as detailed in Table 5, may fall short in protecting vulnerable areas if they depend on flawed delineation methods to distinguish between zones designated for land and water protection or production. Table 5 outlines the current marine protected areas in Gubat cover only 31 hectares, below the mandated protection level, and target species contribute only 49% of reef fish biomass. Reliable data-driven policies are essential for expanding MPAs in Gubat to ideal reef sites, meeting national requirements to sustain ecological stability. Introducing fishing restrictions in high-biomass zones and legislating MPA expansion can optimize resource allocation and conservation impact while ensuring proper zoning and monitoring.

The lack of geostatistics and geospatial data hinders efforts to identify and mitigate harmful activities like overfishing and land conversion, leaving ecosystems vulnerable to exploitation. Without accurate mapping tools, enforcing environmental regulations becomes increasingly difficult. By integrating geospatial technology, communities and policymakers can effectively protect coastal environments and promote sustainable practices. Furthermore, unpredictable coral cover trends and climate change-induced threats underscore the need for robust monitoring and enforcement mechanisms. In this context, zoning maps of Gubat are invaluable for visualizing land use and development patterns, supporting climate impact modeling, and guiding conservation planning.

Limited knowledge of geostatistics and geospatial data hampers accurate assessments of ecosystems within the critical 1-km coastal impact area, as illustrated in Figure 3. Variations in coral habitat quality emphasize the significance of community education and involvement (see Figure 2). Capacity-building programs, standardized approaches to mangrove rehabilitation, and science-based strategies are essential to strengthening conservation efforts.

Biodiversity mapping within the coastal impact area enables the development of targeted action plans, while soil assessments ensure the success of mangrove rehabilitation initiatives. Communities dependent on coastal resources face challenges stemming from poverty and resource mismanagement. Conservation planning, alternative livelihoods, and zoning for environmental, economic, and tourism purposes are key to fostering sustainable resource use, particularly within the 1-km coastal impact zone. Mapping the intersection of livelihoods and conservation priorities within this area promotes a balance between ecological preservation and economic growth.

Conservation initiatives often encounter setbacks due to data inaccuracies and limited coordination. Accurate and comprehensive data is critical to enhancing biodiversity conservation and ecosystem service management. Collaborations among government agencies, NGOs, and private sectors can boost resources and funding. Intensive mangrove and coral rehabilitation plans, supported by standardized long-term monitoring frameworks, ensure consistent progress. Tracking rehabilitation sites and evaluating effectiveness strengthen sustainable coastal protection strategies. Multi-agency partnerships amplify the impact of conservation programs, aligning land use policies with community well-being and sustainability goals.

4. CONCLUSION

This study emphasizes how the interface between scientific innovation and community-based action, through the use of geospatial information systems (GIS), information and communication technologies (ICT), and remote sensing, establishes a solid framework for evidence-based policies and precise zoning regulations, advancing effective coastal land use planning. These tools enable the identification of risk areas (hotspots or cold spots) while guiding conservation efforts, such as mangrove rehabilitation and marine ecosystem protection. Active community participation strengthens resilience against environmental and socio-economic vulnerabilities. Furthermore, fostering multi-agency collaboration and leveraging accurate, up-to-date data maximizes resource allocation and addresses pressing concerns such as environmental degradation and unsustainable practices.

In conclusion, this study effectively leveraged the recontextualized LUPA model within an advanced geospatial framework to demonstrate that the combined impacts of climate change and rapid anthropogenic activities along Gubat, Sorsogon's dynamic coastline—especially within its critical 1-km impact zone—exacerbate hazards such as floods, storm surges, tsunamis, liquefaction, and erosion; these insights not only underscore the urgent need for precise hazard mapping, enhanced coastal defenses, and sustainable land use policies aligned with SDG 13 (Climate Action), SDG 11 (Sustainable Cities and Communities) and SDG 14 (Life Below Water), but also equip policymakers, community leaders, and stakeholders with the critical spatial data necessary to implement targeted risk mitigation and sustainable development strategies that fortify long-term coastal resilience.

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