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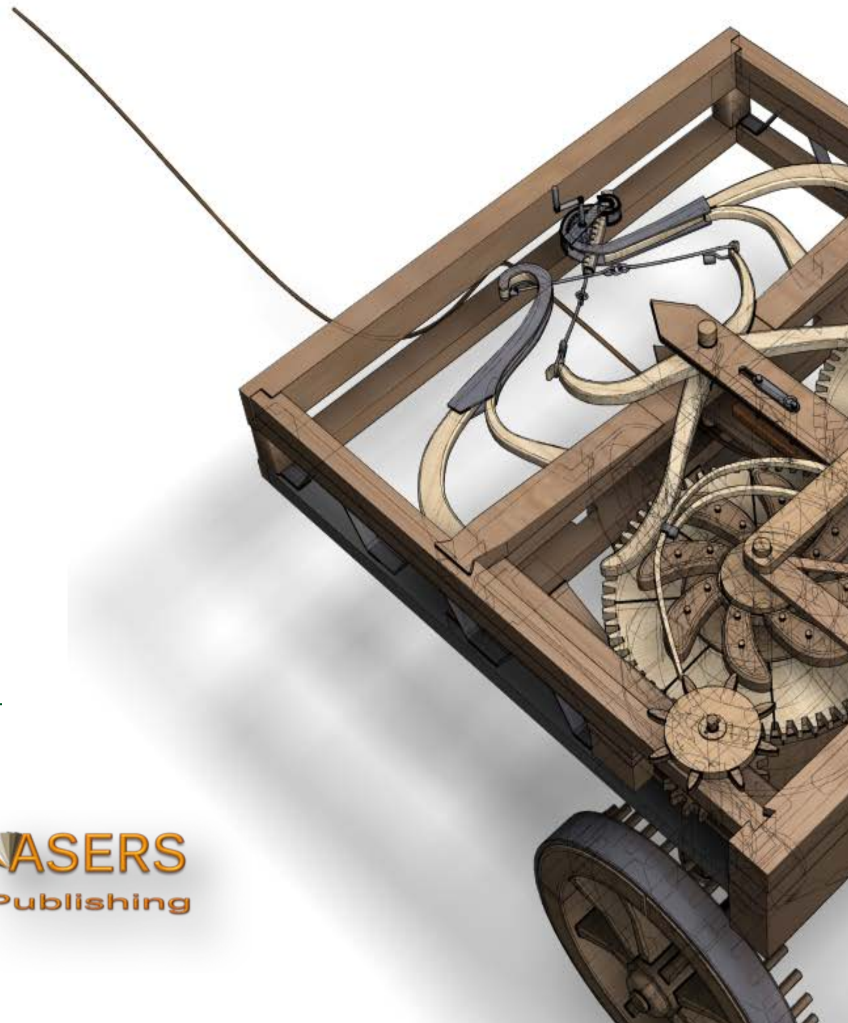

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Table of Contents

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Climate Change Impact Vulnerability Assessment: The Case of Coastal Communities in Central Zambales, Philippines

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Abstract: The Philippines is one of the countries most affected by climate change. As an archipelago country, coastal areas are at high risk of sea level rise due to climate change. This study investigated the vulnerability of coastal areas to sea level rise in selected municipalities in Zambales province, Philippines. The results showed that the coastal barangay of Iba City has a "moderate" to "high" level of vulnerability, while Botolan City has a "high" to "very high" level of vulnerability. Limited areas of nature reserves, such as mangrove, seagrass, and coral reef ecosystems, are one of the key factors contributing to high vulnerability. Concerted efforts of the local government units and the residents play a vital role to mitigate impacts of climate change including regular mangrove tree planting, coastal clean-up drive, and strict implementation of environmental policies. While there are many tools used in vulnerability assessment, a simpler yet reliable is recommended as an appropriate for barangay levels. With the identified vulnerability of the communities in sea level rise, possible mitigation measures to cope with the fast-changing climate could now be established.

Keywords: climate change vulnerability; adaptive capacity; coastal vulnerability; exposure assessment; sea level rise, vulnerability.

JEL Classification: Q53; Q54; R11.

Introduction

As an archipelago nation, the Philippines has one of the longest coastlines in the world (Capili 2005), with an estimated coastal area of 220 million hectares, or approximately 88% of its territory. The World Bank also ranked the country among the 12 countries most at risk from climate change. Droughts, floods, storms, rising sea levels, and growing agricultural instability are the biggest climate change threats facing this country. The country's limited resources and land area make it one of the countries most affected by climate change (Cruz and Jose 1999). Coastal ecosystems are threatened by the effects of climate change (Perez *et al.* 1999). The main causes of sea level rise due to global warming are the melting of ice sheets and glaciers and the expansion of oceans due to global warming (NASA, 2021). Sea level rise caused by climate change has significant impacts on coastal areas (Li *et al.* 2015). Each year, sea levels are rising at a rate of approximately one-eighth of an inch (Nunez 2019; Lindsey 2021), and this scenario is currently evident in this country. From 1980 to 1989, a sea level rise of almost

15 cm was observed in different regions of the country (Hilario 2008). These coastal areas are important areas for commercial, industrial, agricultural, and aquaculture activities in the Philippines, resulting in severe impacts such as loss of coastal structures, displacement of coastal residents, adverse livelihood impacts, and loss of wetlands. It has socio-economic and environmental impacts and loss of species diversity (Perez *et al.* 1999).

Vulnerability and adaptation assessments (VandA) are important for providing information to determine global evidence-based health impacts of climate change (Berry, *et al.* 2018). Therefore, a study was conducted on the vulnerability of the coastal areas of central Zambales in the Philippines to sea level rise.

1. Literature Review

Coastal regions are increasingly threatened by stressors caused by both climate change and anthropogenic factors. Vulnerability assessments are central to implementing climate change adaptation interventions. This will help decision makers prioritize interventions in coastal areas and identify adaptation strategies that target vulnerability factors (Yoo *et al.* 2014; Zhang *et al.* 2020) .Identifying particularly vulnerable coastal areas is critical for the development of coastal management plans. Physical and social vulnerability are important factors (Tragaki *et al.* 2018). Vulnerability to climate change depends on the interrelationship of key factors: exposure, susceptibility, and adaptability (Adger 1999). Vulnerability assessment can be performed using various methods. As suggested by Alberto *et al.* (2018), vulnerability assessments need to identify and quantify the bio geophysical impacts of climate hazards. This puts borders, resources, populations, and capital at risk. The Coastal integrated assessment tool (CIAT) framework can also be used for vulnerability assessment (Paquit *et al.* 2018). Exposure, susceptibility, and adaptability variables are described and evaluated based on community perceptions and biophysical evidence. Changes in precipitation and temperature, mangrove cover, and the occurrence of extreme weather events are used as indicators of exposure. Losses in property and income structures are used as sensitivity indicators, and human, natural, social, financial and physical assets are used as components of adaptive capacity (Evariste *et al.* 2018). Alberto *et al.* (2016) used remote sensing to measure geophysical changes in the coastline and rivers of Zambales Province, Philippines. The results showed that the satellite images used in the study had high positioning accuracy for small datasets.

Climate change affects not only ecosystems but also human health. Vulnerability and adaptation assessments are important for providing information on the scientific health impacts of global climate change (Berry *et al.* 2018). The most vulnerable people in the Philippines are unaware of the relationship between climate and land use (Acosta *et al.* 2016). Global studies have shown the potential of climate change for marine biodiversity, fish distribution, potential fisheries yields (Cheung *et al.* 2009; Stock *et al.* 2017), and the economy (Sumaila *et al.* 2012). It is reported that the impact is expected to be significant. In a study by Perez *et al.* (1999), the development of adaptation plans in the context of setback policies, building regulations, and integrated coastal zone management is needed to address short-term and long-term community participation issues in this region. It is stated that institutional measures such as these are necessary. In addition to technical and scientific contributions, information, education and communication are essential elements to achieve a balanced adaptation plan. Furthermore, Kreslake *et al.* (2016) stated that it is important to develop effective communication materials regarding the health impacts of climate change for vulnerable groups. Based on the study of Munang *et al.* (2013), vulnerable groups are interested in obtaining short-term advice on health care and protective behaviors related to chronic diseases.

Nanlohy *et al.* (2015), emphasized that coastal communities' knowledge of climate change will help them adapt to these environmental conditions, which is supported by the argument of Gomez *et al.* (2020) that alternative livelihoods and psychological education are needed to strengthen household resilience and increase human security in coastal communities. Ecosystem-based adaptation approaches harness nature's ability to protect human communities from the negative effects of climate change through the sustainable rovision of system services (Munang *et al.* 2013).

2. Methodology

A combination of field surveys, focus group discussions, and primary and secondary data collection was conducted to identify hazards as an impact of climate change in the region. The results showed that the main impact of climate change on coastal barangays is sea level rise (SLR).

Vulnerability assessments include the sensitivity or susceptibility of coastal areas to physical changes resulting from climate change, expected socio-economic and ecological impacts, and available adaptation options (Harvey *et al.* 1999). A risk assessment checklist was developed and used to assess sea surface exposure at the study site (Espaldon *et al.* 2016; Paz-Alberto *et al.* 2018).

The vulnerability was then analyzed using the formula:

$$V = \frac{S+E+AC}{3} \quad (1)$$

where: V= vulnerability
S= Sensitivity
E= Exposure
AC = Adaptive capacity

Sensitivity. It was analyzed using seven indicators based on the classification of the wetlands, coral reefs, mangroves capability to migrate landward, capacity to withstand prolonged flooding, dominant seagrass, capacity to withstand wave impacts, and fishery catch (Table 1).

Table1. Sensitivity assessment for sea level rise

INDICATOR	CLASS	RATING	SCALE
a. Coastal wetlands (% of wetlands inundated)	>90	1.0	Very high
	71-90	0.8	High
	51-70	0.6	Moderate
	30-50	0.4	Low
	<30	0.2	Very low
b. coral reefs (% of living corals)	20	1.0	Very high
	21-30	0.8	High
	31-40	0.6	Moderate
	41-50	0.4	Low
	>50	0.2	Very low
c. Mangroves (capacity to migrate landward)	Over 50% of fishponds and other landward developments are active and not available for landward migration	1.0	Very high
	20-50% of fishponds and other landward developments are active and not available for landward migration	0.8	High
	Over 50% of fishponds and other landward developments are idle or abandoned	0.6	Moderate
	Absence of adjacent fishponds and other developments landward	0.2	Very low
d. Capacity to withstand prolonged flooding	*Bruguiera-Ceriops-Xylocarpus* dominated forest	1.0	Avicennia
	Avecennia-Sonneratia-Rhizophora-Aegiceras dominated forest	0.6	Moderate
	Avecennia-Sonneratia dominated forest	0.2	Very low
e. Seagrass (capacity to adapt to SLR)	*Halophila-Halodule* dominated	1.0	Very high
	Thallasia-Cymodecea-Halodule dominated	0.6	Moderate
	Enhalus-Thalassia dominated	0.2	Very low
f. Capacity of the meadow to stand wave impacts	Small-sized species: *Halophila-Halodule* meadow	1.0	Very high
	Thallasia-Cymodecea-Halodule beds	0.6	Moderate
	Root system extensive: *Enhalus acoroides* and *Thalassia* dominated	0.2	Very low
g. Fishes (catch of Tuna and small pelagic in 5 years, reduction of catch in %)	>20	1.0	Very high
	16-20	0.8	High
	11-15	0.6	Moderate
	5-10	0.4	Low
	<5	0.2	Very low

Exposure. Exposure to coastal environments is characterized by vulnerability (or sensitivity), resilience, and resistance. Vulnerability to sea level rise caused by climate change can be defined as the likelihood that a coastal system will be affected by sea level rise and can be assessed using any of the simple physical susceptibility indices (in Shaw *et al.* 1998 as cited in Koroglu, 2019) or a more integrated approach (*e.g.* IPCC-CZMS). Exposure was assessed by analyzing five factors; Extent of flooded coastal wetlands; range of settlements and population groups affected by flooding; population density; physical assets and infrastructure, including tourist facilities, submerged by floods, as well as affected farmland and coastal areas (Table 2).

Table 2. Exposure assessment for sea level rise

INDICATOR	CLASS	RATING	SCALE
a. Coastal wetlands (% of wetlands inundated)	>50	1.0	Very high
	41-50	0.8	High
	31-40	0.6	Moderate
	20-30	0.4	Low
	≤20	0.2	Very low
b. Extent of populations affected by flooding (% of area located within <1m elevation above MSL)	≥40	1.0	Very high
	31-40	0.8	High
	21-30	0.6	Moderate
	10-20	0.4	Low
	<10	0.2	Very low
c. Population density	≥ 300	1.0	Very high
	101-300	0.8	High
	51-100	0.6	Moderate
	20-50	0.4	Low
	<20	0.2	Very low
d. Physical assets and infrastructure submerged by floods (%), including tourist facilities	>50	1.0	Very high
	41-50	0.8	High
	31-40	0.6	Moderate
	20-30	0.4	Low
	≤20	0.2	Very low
e. Agricultural lands and beach areas affected	>50	1.0	Very high
	41-50	0.8	High
	31-40	0.6	Moderate
	20-30	0.4	Low
	≤20	0.2	Very low

Adaptive Capacity. This is the system's inherent ability to cope with exposure (Smit and Pilifosova 2003). It can be influenced by factors such as management skills, access to financial, technical and information resources, infrastructure, the institutional environment in which adaptation takes place, and political influence, among others (Smit and Wandel 2006). Adaptive capacity reflects resilience, allowing resilient systems to prepare for, avoid, mitigate, and recover from sea level risks and changes. The adaptive capacity of the local communities was analyzed using the parameters indicated in Table 3.

Table 3. Adaptive capacity assessment for sea level rise

INDICATOR	CLASS	RATING	SCALE
a. Mapping of coastal habitats at risk	Fully surveyed, mapped, and zoned	0.2	Very high
	Partially surveyed, mapped, and zoned	0.4	High
	Partially surveyed and mapped but not yet zoned	0.6	Moderate
	Surveyed but not yet mapped and zoned	0.8	Low
	Not surveyed at all	1.0	Very low
b. Relocation of coastal settlements at high-risk areas (%)	>60	0.2	Very high
	41-60	0.4	High
	21-40	0.6	Moderate
	1-20	0.8	Low
	No relocation efforts	1.0	Very low
c. Wetlands protection program	Presence of coastal protection structure	0.2	Very high

INDICATOR	CLASS	RATING	SCALE
	Properly designed and very sturdy constructed and properly placed structures	0.4	High
	Less sturdy but properly placed	0.6	Moderate
	Ill designed and properly placed	0.8	Low
	Without coastal protection structures	1.0	Very low
d. Climate proofing and physical assets and infrastructures	With climate-proofing policy and projects fully implemented	0.2	Very high
	With some investments	0.6	Moderate
	No climate-proofing projects	1.0	Very low

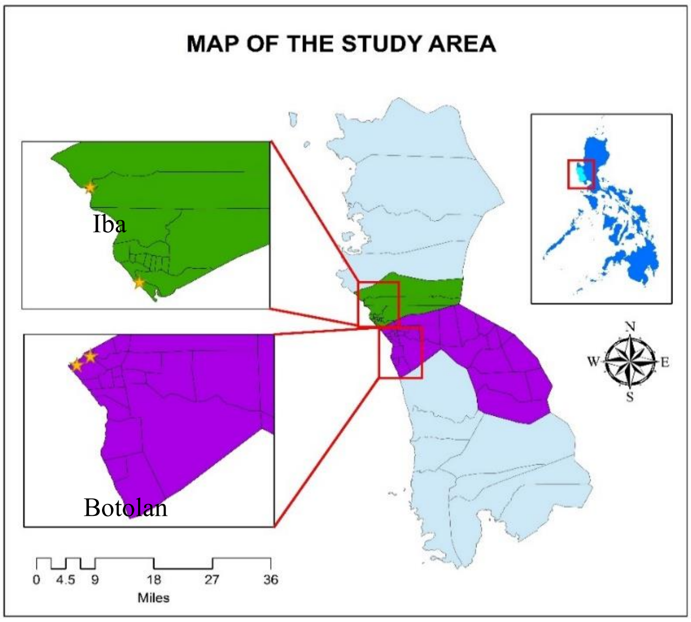
Computed and analysed data were then integrated as attribute data to the respective shapefiles of the different barangays to create the vulnerability map using ArcMap.

3. Results

The Study Area. Zambales is the second largest province in Central Luzon, Philippines. It has approximately 175 kilometers of coastline overlooking the West Philippine Sea. The city of Iba (15°20'N latitude, 119°59'E longitude) in the central part of the state was selected as the research site (Fig.1). The region is characterized by a mixture of the western coastal plain and the Zambales River. It has mountains to the west and east, and has a total area of 153.38 km2 (59.22 sq mi).The total length of its coastline is 12.70 km (Iba CLUP, 2021; Paz-Alberto, *et al.* 2021).The Municipality of Botolan, (15°17'N 120°01'E) home of one of the most active volcanoes in the country has a total area of 735.28 km2 (283.89 sq mi). Its coastline has a span of 14 km.

The province has two distinct seasons. One is the rainy season from May to October, and the other is the dry season. Additionally, the province experiences approximately seven typhoons each year. Iba and Botolan are located at an altitude of 4m and 0m above sea level, respectively, making sea level rise a major concern.

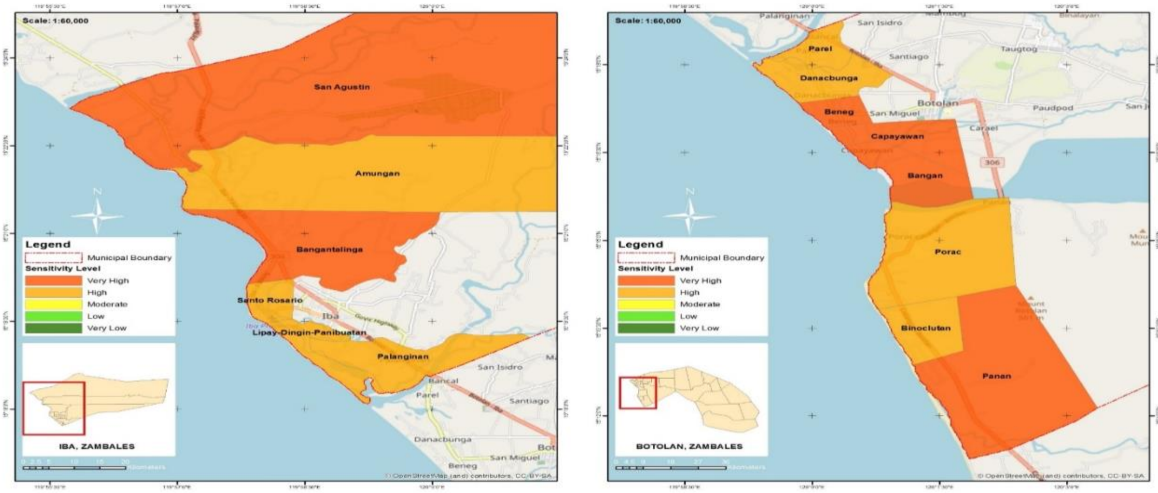
Figure 1. The map shows the locations of the different stations.



Sensitivity to sea level rise. Sea level rise is one of the indicators of climate change in coastal areas and can pose threats and problems to coastal communities (Nicholls 2015; Kada and Van Schaik 2003). Global mean sea level rise per year is 0.14 in (3.55 mm) (Lindsey 2021) and the province of Zambales is experiencing an increase to about 0.25 in (6.35 mm) per year (Paz-Alberto *et al.* 2021). This corroborates with the study of Taguiam and Quiambao (2020) conducted in Zambales for the cognition of sea level rise affirmed that the coastal municipalities witnessed and experienced the impacts of sea level rise.

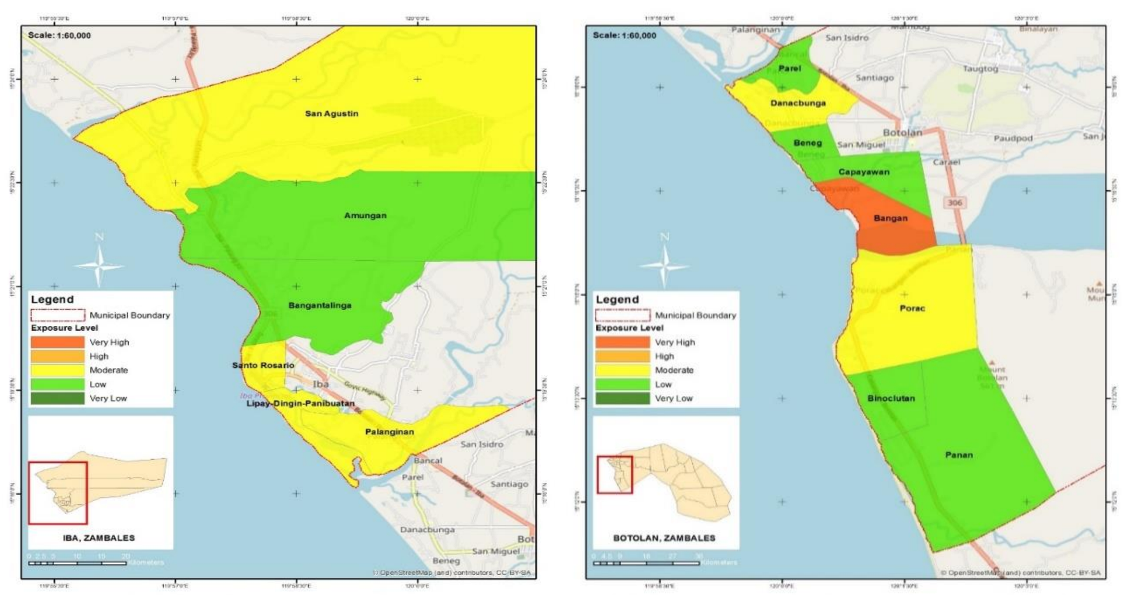
Figure 2 depicts the sensitivity levels to sea level rise in the coastal barangays in the municipalities of Iba (left) and Botolan (right), Zambales Philippines. Dark orange represents “very high” and light orange represents “high” sensitivity levels. Of the six coastal barangays in Iba, San Agustin and Bangantalina had “very high sensitivity levels. These areas are both low lying areas and had sandy beaches which are attributed to their very high sensitivity levels. This corroborates with the study of Abuodha and Woodroffe (2010) that rocky and steep coastal areas are the least sensitive, while sandy beaches with low lying areas are the most sensitive. Barangays Amungan, Sto. Rosario, Lipay Dingin, and Palanginan in the Municipality of Iba had natural barriers like mangroves, coral reefs, and seagrass ecosystems. However, due to its sandy beaches and unregulated use of resources in the different coastal ecosystems, sensitivity is still high. On the other hand, four barangays in Botolan had "very high" sensitivity levels: barangays Beneg, Capayawan, Bangan, and Panan these areas had sandy beaches and without natural barriers.

Figure 2. The maps showing the sensitivity levels to SLR of coastal barangays in Iba (L) and Botolan (R), Zambales, Philippines



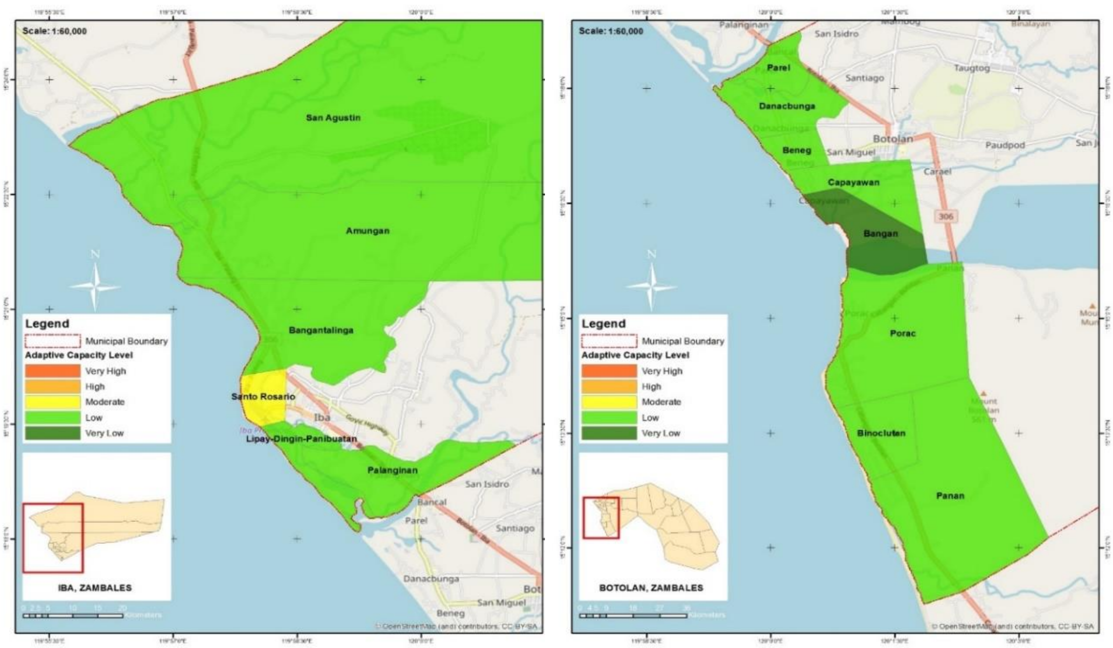
Exposure to sea level rise. Figure 3 presents the exposure levels to sea level rise in the study areas. Based on the assessment conducted, barangays Danacbunga and Porac in Botolan had "moderate" exposure levels. Further, majority (67%) of the coastal barangays in the Municipality of Iba had "moderate" exposure while barangay Bangan in the Municipality of Botolan had a "very high" exposure level to sea-level rise. This was attributed to three factors: physical assets and infrastructure including tourism facilities are highly inundated; a high number of populations affected by coastal flooding and erosion; and a large part of the area were affected during flooding. This conforms with the work of Oppenheimer (2019) that population and physical assets contribute to the severity of exposure to sea-level rise.

Figure 3. The maps showing the exposure levels to SLR of coastal barangays in Iba (L) and Botolan (R) Zambales, Philippines



Adaptive Capacity. In the Municipality of Iba, Barangay Sto. Rosario had “moderate” while the other five barangays had “low” adaptive capacity levels. In the Municipality of Botolan, barangay Banga had a “very low” adaptive capacity level and the seven others had “low” adaptive capacity levels (Fig 4).

Figure 4. The maps showing the adaptive capacity levels to SLR of coastal barangays in Iba (L) and Botolan (R), Zambales, Philippines



To adapt to the rising sea level, barangays Sto. Rosario in Iba and barangay Bangan in Botolan, the construction of sea wall was given priority, however, based on the observation during the field visits, these structures can’t withstand strong waves and erosion. Likewise, both municipalities already mapped and identified areas at risk and those that need to be relocated but, financial concern hinders the full implementation of projects identified.

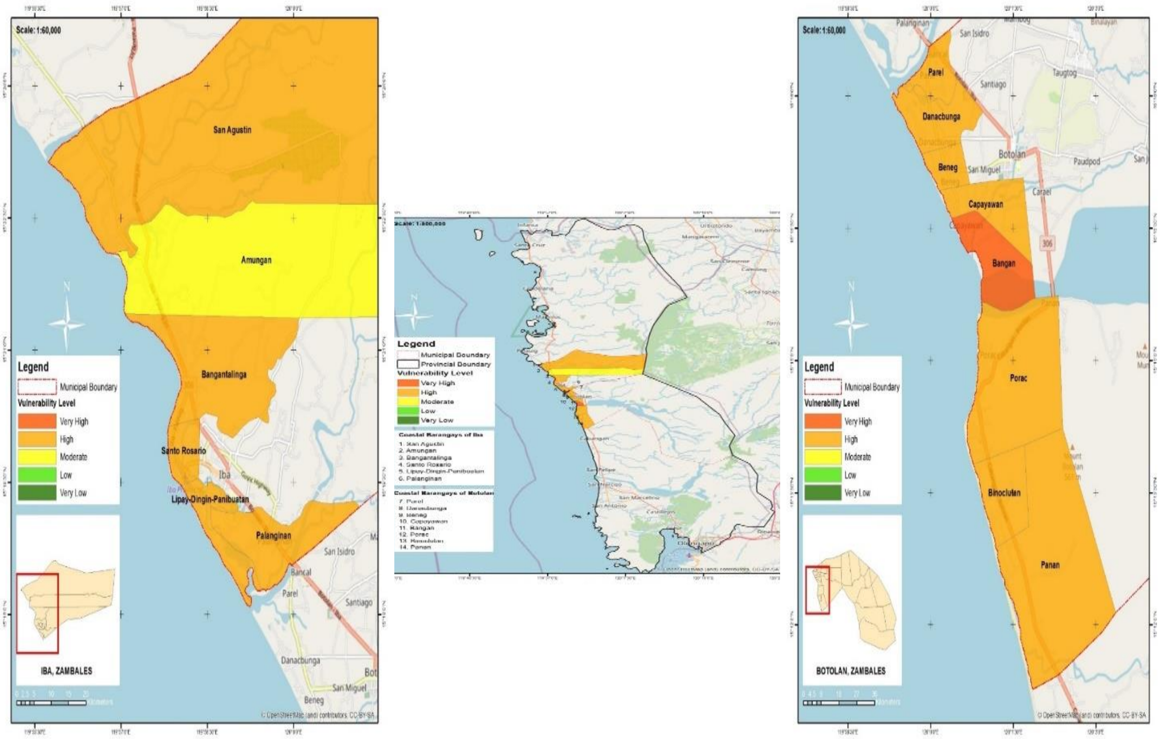
According to Oppenheimer (2019), without mitigation, sea levels will continue to rise for centuries, reaching between 2.3 and 5.4 meters by 2030 and even more beyond that, affecting all low-lying areas. Adaptation on coasts becomes very difficult, and even more so on intensively developed coasts.An urbanized coast is impossible. Local community action is critical in this scenario. Residents had a high level of awareness of the negative effects of sea-level rise in their health as well as to their economic stability. To help the local government in mitigating the impacts of climate change in general, residents with the leadership of barangay officials and youth organizations, a regular mangrove tree planting activities are being carried out in barangays Parel and Danacbunga, both in the municipality of Botolan and at Lipay-Dingin-Pinagbuatan and San Agustin in the municipality of Iba. All coastal barangays are actively participating in the annual coastal clean-up being implemented by the National government.

To maintain the cleanliness of the coastal areas, a regular clean-up drive is being conducted through the initiative of the Youth Leaders and members (Sangguniang Kabataan Federation). These activities increased people’s awareness and encouraged them to help in environmental protection and conservation. More so, strict implementation of the Philippine Clean Air Act, Ecological Solid Waste Management Act was highlighted. The Peoples’ Organization and the “Bantay Dagat” (guardians of the sea) had a significant contribution to safeguarding the coastal resources.

4. Vulnerability to Sea Level Rise

By integrating all collected sensitivity, exposure, and adaptive capacity data, the region's vulnerability to sea level rise was determined (Figure 5). Barangay Bangan in Iba City was at “very high” risk. The remaining seven barangays are at "high" risk. In Iba City, five (83%) of the coastal barangays were at “high” risk and only one barangay (Amungan) was at “moderate” risk.

Figure 5. The maps showing the vulnerability to SLR of coastal barangays in Iba (L) and Botolan (R), Zambales, Philippines.



High vulnerability of the areas was brought about by various conditions such as being low-lying in nature, high exposure to strong waves due to limited natural barriers, and short-term response/adaptive mechanisms. This conforms with Gesch (2018). The report notes that the low elevation, topography, or sea level of many coastal areas makes them vulnerable to negative impacts from rising water levels due to both chronic disease (SLR) and episodic events (storm surges and tide flooding).

Due to the outstanding characteristics of this area, it is now a fast-growing tourist destination. The influx of tourists led to the emergence of resorts, hotels, and other commercial establishments, leading to further destruction of natural resources. Vulnerability assessments are required and adaptation strategies can be programmed. Walker *et al.* 2003 asserted that the "adaptation" part of both governance and management is required at all stages of the adaptation cycle, as the stability landscape is constantly changing. What has received the least attention is the importance of back-loops, especially the flexible management needed to protect important ecological resources (adaptive management) and the rules that influence resilience when self-organizing. The importance of development (adaptive governance) was emphasized.

Conclusion

The study found that the region has moderate to very high vulnerability to the effects of sea level rise. Therefore, it suggests that maintaining a stable system requires only a qualitative ability to absorb and manage uncertain and unexpected changes, rather than aiming for the ability to accurately deal with future scenarios. Future research, such as predictive studies, can help local governments plan and prioritize adaptation and mitigation strategies. Evaluations using the tools used in this study could be adopted by communities to provide evidence-based information for developing local policies that are more beneficial to community health and economic stability. Finally, there should be strategic and comprehensive communication to policy makers and the general public about climate change in general and sea level rise in particular.

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Credit Authorship Contribution Statement

Shirly C. Serrano: Conceptualization, data gathering and writing - original draft.
Nipon Tangtham, Surat Bualert and **Suthee Janyasuthiwong**: supervising and guiding - original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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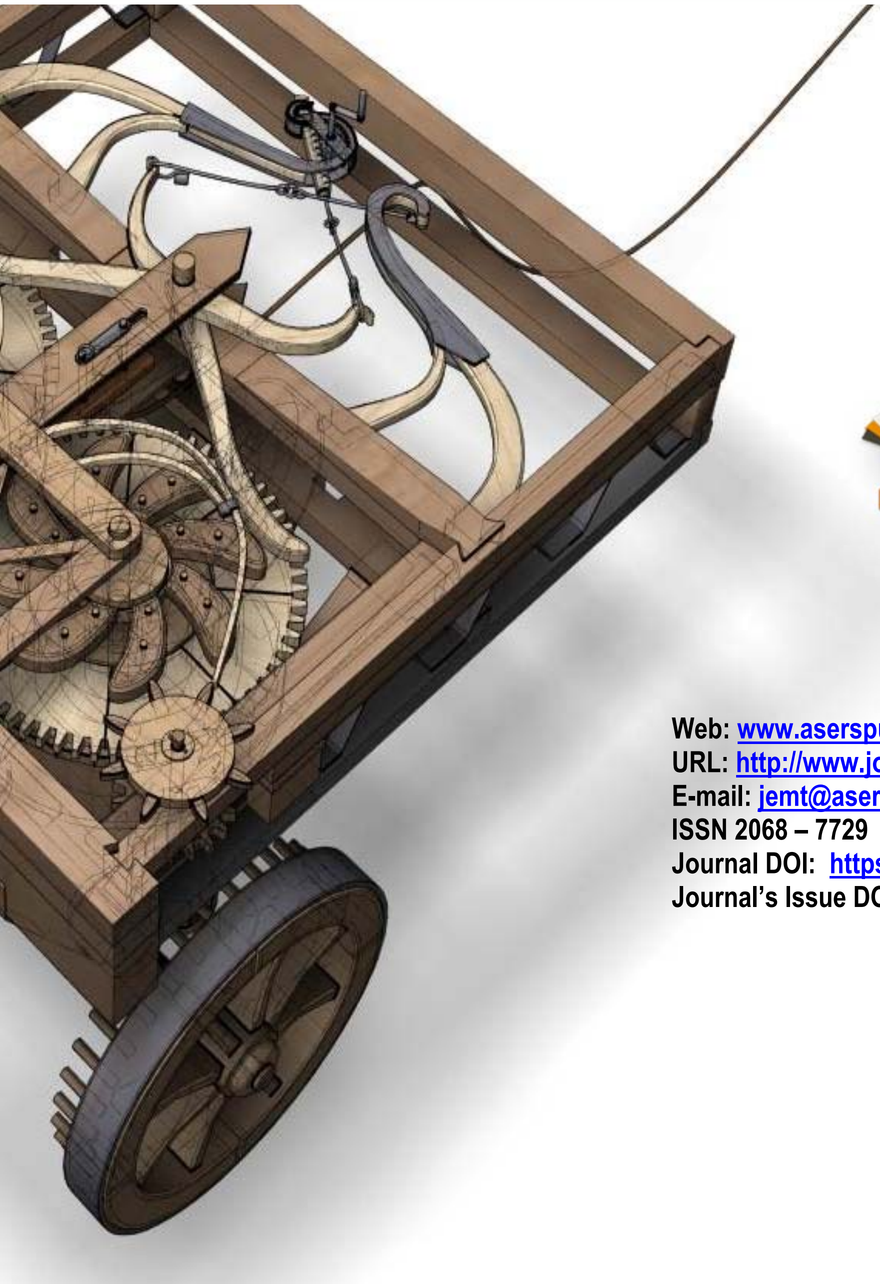

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