Assessment of Coastal Erosion: A Basis For A Salvage Zone Map

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***Abstract*— Coastal erosion has become a major problem that the world is facing for various reasons. This study analyzed the shoreline rate of change of the two barangays in Ballesteros, namely: Centro East and Centro West using the Last High Tide (LHTS) of the Sea Level Affecting Marshes Method (SLAMM), specifically the Shoreline Change SAMP (Special Area Management Plan). The coastal retreat for the past 14 years (2007-2021) and the predicted possible shoreline landward movement after 15 years (2021-2036) were identified. Overall, the average shoreline rate of change is 2.236 meters per year, the approximate area of the coastal retreat for the past 14 years is 4.8 hectares, and the possible coastal retreat if there is no human intervention for the next 15 years is 5.1 hectares. As the Philippines is prone to natural disasters such as typhoons, landslides, and climate change, which cause the triggers of coastal erosion, the government should take actions like reforestation and seawalls to mitigate the coastal problem.**

Keywords*— *coastal erosion, shoreline, salvage zone

I. Introduction

The Philippines is an archipelago consisting of 7,641 islands and along its 34,539 km coastline, the characteristic of the land is diverse it has fishing communities, ports, industrial hubs, urban settlements, agricultural plots, and sandy beach resorts, wetland, and mangrove areas. With all the characteristics of land, Filipinos are naturally drawn to the bounties and beauty of the sea. The Philippines' major cities developed near the coast where constant development and rapid land conversion are taking place. Thus, the coastal areas in the country are critical areas not only for their natural resources but also for their growing economic and social importance [1].

The coastline is where the land meets the sea, it forms the boundary between the land and the ocean or lake [2]. It is along the coastline where you can find some of the most astonishing beauty of nature. The various factors natural and man-made, it is constantly changing over time. One of these factors is Coastal Erosion, which is a result of human activities and natural environment changes making the coastal dynamic action (wave, current, wind) lose balance in the coastal process, and the long-term loss of sediments of the coastal zone results in the destruction process of coastline retreat and beach erosion [3].

The salvage zone is found along the coastline; it is an area measuring twenty (20) meters landward from the interior limit of the shoreline for easement purposes. Section 51 of the Water Code of the Philippines states that "No person shall be allowed to stay in the zone other than what is necessary for recreation, navigation, floatage, fishing, or salvage or to build structures of any kind." In 2014, the Salvage Zone Enforcement Team discovered that there are already residents and businesses within the salvage zones of the coastal areas of the Philippines [4]. Living in the area is dangerous due to the calamities that may occur. Aside from violating the law and their safety, residents within the area are suspected of having improper septic vaults and disposals that may harm the environment.

With the stated problem, coastal studies were done in the context of climate change to assess adaptive responses to such threats. The Philippines was evaluated for the possible consequences of accelerated sea-level rise, they found out that areas along the coast if inundated by a 1-meter sea-level rise would include coastal barangays from 19 municipalities of Metro Manila, Bulacan, and Cavite and would cover an area of 5555 has [6]. The same study was conducted in Rhode Island using a simpler method called the Sea Level Affecting Marshes Method (SLAMM). They studied the impact of coastal storms, sea-level rise, and the coastal retreat on the island. They found out that coastal and low-lying areas have increased erosion and will continue due to the increase in sea level rise in North America and throughout the world. The study found that the average annual rate of shoreline change is 0.57 meters per year [9].

Ballesteros, Cagayan is adjacent to the Babuyan Channel. The municipality also experiences typhoons and coastal erosion every year. Some residents in the Poblacion area attested that the coastal erosion is becoming drastically obvious and scary. Last 2020, during typhoon Ulysses, the beach of Ballesteros was washed out, and there were small hut houses that were hit by the waves. This study showed the physical changes of the coast and predicted the possible coastal damage. The output resented a historical and prediction map of the coastline of the Poblacion Area in Ballesteros, Cagayan with the use of the Sea Level Affecting Marshes Method (SLAMM), Last High Tide Swash, and the QGIS.

II. Related Works

Coastal erosion is prevalent in countries in Southeast Asia including Malaysia [10], Vietnam [11], Indonesia [12], and Thailand [13]. In developed countries, like Canada, the United States, and Australia, coastal erosion/shoreline retreat is also considered an important issue so research on this subject matter has been very extensive. The Philippines is not exempted from coastal erosion, it is obvious in the eyes of the people that coastal erosion is affecting different communities in the country.

A methodology that determined the physical and economic impacts on a spatial scale of fewer than 10 km, a rapid and low-cost method is required. Geographic Information System, combined with the available data and two coastal behavior models; Brun-GIS Model and Aggradation Model. They are applied to simulate shoreline recession caused by a rise in sea level. The study also considered the potential impacts of a 50-year design storm in conjunction with sea-level rise. The monetary vulnerability was assessed and combined with the simulated recession, it provided the first estimate of the potential risk that the locality may face due to the sea-level rise and/or coastal storms. The modeling outcome showed that long-term erosion problems associated with rising sea levels are less significant in comparison with those impacts associated with short-term coastal storm events for Collaroy/Narrabeen Beach [14].

A methodology similar to Hennecke was applied in San Fernando City, Philippines. The researchers studied the area because they believed that coastal erosion can affect many lives of people and if nothing is done millions of Philippine pesos will be worth the damage. The planned protection strategy was the most rational approach to adopt, it is socially and politically acceptable, justifiable from an economic perspective, and also preserves the beaches along with the social services. The researchers studied the seven-kilometer coastline of San Fernando City because it was densely populated and was identified as a place where coastal erosion is already prevalent. Sea-level rise is a major concern across the Philippines and beyond. Its scale and impact are both expected to become more widespread due to climate change and sea-level rise. This makes the findings of this report particularly important and timely [7].

A Coastal Erosion study was also done on the Northern Coast of France. The impacts of storms on the upper beach and foredunes and their post-storm recovery were analyzed using nearly 10 years of offshore wave measurements, water level records, wind measurements, and in situ and airborne LiDAR topographic surveys of the beach and foredunes. Results of the study showed that coastal dunes located at a relatively short distance apart along a coastal stretch with the same wave exposure can have significantly different responses to storms. The study also analyzed that the maximum water levels reached during storms represented a major factor explaining dune erosion compared to wave energy which is of secondary importance along this macro-tidal coast. A strong correspondence was found between dune front volume change and initial upper beach width and with dune toe elevation, but a somewhat weaker relationship was observed between dune volume change and initial dune height [15].

A study in Miagao proved that coastal area loss is the major problem in their area. It was observed that the coastline is diminishing and the water is moving inward. The study characterized and estimated the value of Miagao coastline area losses in some barangays, through the valuation of lost land, buildings and structures, trees, economic activities, and docking areas using the market price method. The study found that coastal area loss amounted to Php 71 708 000 and about 60% of the coastal community was highly attached. The study suggested that coastal communities, non-government organizations, and the government should work together to formulate adaptation strategies that can reduce risk and potential damages due to coastal area loss [16].

Shoreline Change SAMP (Special Area Management Plan) was done in Rhode Island. Coastal Erosion was characterized by a storm-driven coastline. The study used the SLAMM (Sea Level Affecting Marshes) method where they used the Last High-Tide Swash (LHTS) as the baseline in measuring the shoreline per year. The study found out that one Shoreline Change SAMP analysis suggested that the RI south shore could experience a total change of 89 meters (292 feet) by 2065 and 216 meters (708 feet) by 2100 [9].

Given the complexities, some studies recommend methodologies that could be applied to assess coastal areas. Some contend that simple cost-benefit analyses may not be sufficient in assessing the desirability of the various options, and thus a multi-criteria approach is necessary. The use of integrated workflow, including coastline extraction, analysis of changes based on remote sensing technology, and GIS spatial analysis are used [17].

III. Methods

A. Study Area

Ballesteros is a coastal municipality adjacent to the Babuyan Channel. It has a total area of approximately one hundred twenty (120) square kilometers with nineteen barangays. Among the coastal barangays of the municipality, Centro East and Centro West are the most populated barangays. As of the 2020 census, the population of the Centro East and Centro West is 4174 and 2046, respectively. Fig. 1 shows the location of the study area in Ballesteros. In the North, the Babuyan Channel is located, it is where most of the fishermen go for their daily needs. On the East, South, and West, barangay Sta. Cruz, Mabuttal, and Cabuluan East are situated, respectively.

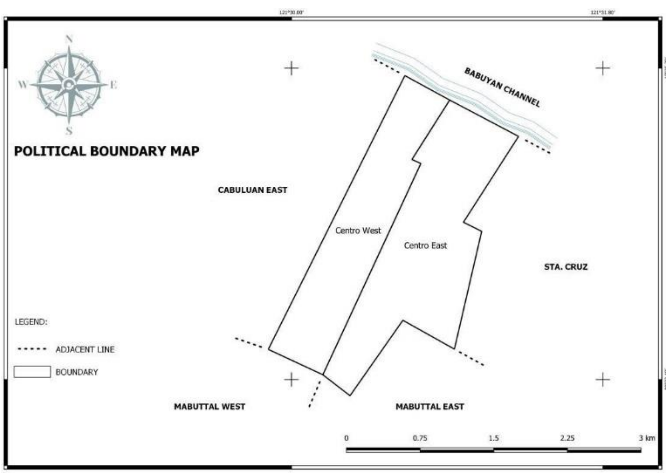

Fig. 1. Political Boundary Map of the Study Area.

B. Gathering of satellite images

Satellite images are the framework of this study. It served as the historical data of this paper. The researchers requested satellite images from different government agencies; Philippine Satellite Agency (PhilSA). The PhilSA emailed the Satellite Images of 2007 and 2021 of the Poblacion area. Elshayal Smart GIS was also used with Google Earth to download Georeferenced HD satellite images.

C. Determining the coastline retreat from 2007 to 2021

Using the Last High Tide Swash (LHTS) or the wet/dry land as the baselines, the researchers were able to measure the displacements from each of the assigned transects (transects are assigned on areas with noticeable change). From the data gathered, the Shoreline Rate of Change (SRC) per year on every transect was computed using the formula (1) where the number of years is 14 years (2007-2021) and displacement is measured on each transect.

$$\Delta shoreline = \frac{displacement}{no.of\ years} . \qquad (1)$$

D. Predicting the possible coastal retreat after 15 years

Using the Shoreline Rate of Change, the researchers multiplied it by 15 years (2021 to 2036) to get the predicted shoreline displacement on each transect after 15 years using formula (2).

$$Predicted\ Change = \Delta shoreline * no.of\ years \qquad (2)$$

E. Determining the salvage zone

According to Section 51 of the Water Code of the Philippines, the Salvage zone is the land measuring twenty (20) meters from the interior limit of the shoreline for easement purposes. This order is true to all foreshore lands including the marshy lands or lands covered with water bordering upon shores or banks of navigable lakes or rivers. The salvage zone of the area was delineated twenty meters landward from the shoreline of 2021 satellite images derived from the PhilSA and Google Earth to show the locations of the residential houses within the said area.

F. Map Creation

QGIS software was used to analyze the available images of the study area. QGIS has also been used to lay out the maps. Transect lines were assigned to the obvious eroded points to determine the shoreline rate of displacement per year. It was also used to lay out the predicted coastal retreat of the shoreline. The last High-Tide Swash (LHTS) was used as the reference point for the measurement of the shoreline change.

IV. Results and Discussion

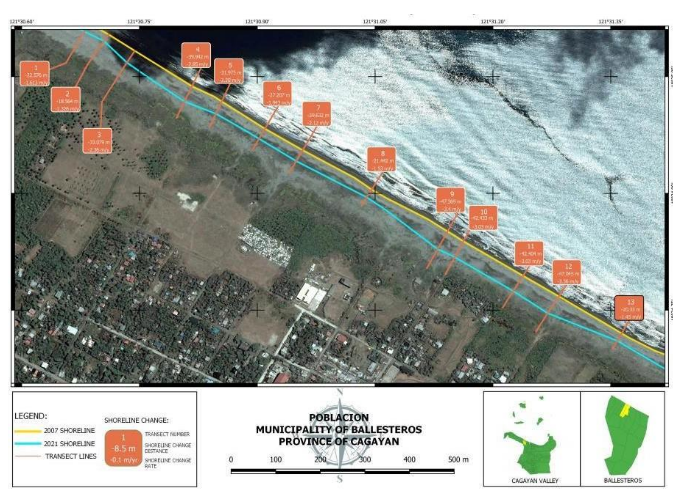

Fig. 2. Shoreline Retreat for the past 14 years.

Fig. 2 used a satellite image from 2007 and it shows the location of the shoreline from that year and its landward movement over the years. The shoreline was represented by a yellow line while the 2021 shoreline was represented by a light blue line. A variety of displacements is projected at each transect line with the shoreline rate of change per year.

TABLE I. SHORELINE RETREAT FOR THE PAST 14 YEARS (2007-2021)

Transect Number	Shoreline Displacement (M)	Shoreline Rate of Change (M/Yr)
1	-22.576	-1.614
2	-18.564	-1.326
3	-33.079	-2.300
4	-39.942	-2.850
5	-31.975	-2.280
6	-27.207	-1.943
7	-29.632	-2.120
8	-21.442	-1.530
9	-47.569	-3.400
10	-42.433	-3.030
11	-42.404	-3.030
12	-47.045	-3.360
13	-20.330	-1.450
Average	-32.631	-2.326

Table I shows the displacement distance and the rate of change of the shoreline from 2007 to 2021. It was portrayed in Fig. 3 that the greatest displacement of 47.569 meters is produced at transect 9 and the least displacement of 18.564 meters is at transect 2. All the displacements from the shoreline of 2007 bear negative values which denote that the shoreline has moved towards the land area until 2021 with an average of 32.631 meters. The average rate of change is 2.326 meters per year.

Coastal Erosion is inevitable, especially in areas without mangrove forests or sea walls. There are a lot of reasons for coastal erosion and one of these is the Storm Surge. Storm surge is the rise of the water caused by a storm and has a height measuring higher than the normal high tide. The combination of the Sea Level Rise and the increased intensity of storm surge made the lives of the people living within the area more dangerous. Sea Level Rise (SLR), one of the major impacts of climate change, is the current global problem due to the thermal expansion of the seawater caused by high sea surface temperatures such as in the Philippines [18]. The report of the Philippine Climate Change Assessment made by the Oscar M. Lopez Center showed that the SLR in the country is above the global average rate ranging from 5.7 mm to 7.0 mm per year. Similar to the studies in San Fernando City [6], the Philippines, Rhode Island [8], and the Northern Coast of France [2]. For the past years, there has been a coastal erosion that is happening in the study area. In Poblacion of Ballesteros Cagayan. The Remote Sensing of Ocean and Coastal Environment study quantified the average shrinkage of the coastline per year if the only natural phenomenon had happened in the area within the year, which is 0.5 meters to 2.0 meters [19].

In this study, the average displacement per year is 2.236 meters toward the residents, with this there is a human intervention that is happening in the study area. Residents are cutting and removing the male Pandan trees that are abundant in the area. With the use of its leaves, people are cutting it without planting new ones. Clearing up the seacoast makes the area vulnerable to more coastal erosion due to the softness of the coastal area when the trees are removed.

It was found that the area covered by the displacement is approximately forty-eight thousand five hundred eighty-four (48,584) square meters, more or less. This signifies that approximately 5 hectares have been lost from the land resources of the two barangays namely Centro East and Centro West in the municipality of Ballesteros. This finding is worth informing the LGU of Ballesteros for proper action.

Fig. 3. Predicted Shoreline in 15 years

TABLE II. PROJECTED SHORELINE DISPLACEMENT IN 15 YEARS

Transect Number	Shoreline rate of change (m/yr)	Shoreline displacement (m)
1	-1.614	-24.195
2	-1.326	-19.890
3	-2.30	-35.445
4	-2.850	-42.795
5	-2.280	-34.260
6	-1.943	-29.145
7	-2.120	-31.755
8	-1.530	-22.980
9	-3.400	-50.970
10	-3.030	-45.465
11	-3.030	-45.435
12	-3.360	-50.400
13	-1.450	-21.780
Average	-2.236	-34.963

Fig. 3 presents the possible shoreline retreat displacement 15 years from 2021 based on the trend in the past 14 years. The 2021 shoreline is represented by a light blue line while the predicted shoreline is represented by the red line. Based on Fig. 4, transects 9-12 have a residential area that is affected by coastal erosion.

Table II shows the approximate distances of the shoreline from 2021 to 2036. Figure 4 is the projected shoreline retreat of the subject area. The greatest displacement was recorded in transect 9 with a distance of 50.4 meters and the least displacement was recorded in transect 2 with 19.890 meters. It was also found that the average change in shoreline after 15 years is approximately 34.963 meters.

Sea Level Rise is very difficult to predict since it is a result of climate change. The global current SLR is estimated to be in the range of 50 centimeters to 3 meters. If this is not addressed properly, the most affected communities are those who are living on the coast of the country. As per the study, the Philippines is experiencing frequent severe flooding as a result of SLR and frequent cyclones. It also showed that by 2035, the informal settlers will be critical due to their graphical position like those who are located within the salvage zone of the Poblacion Area of Ballesteros, Cagayan.

It was discovered that the displacement of the transect points of the shoreline if there is no human intervention and the rate of change will stay the same of the area that will be lost in Poblacion is fifty-one thousand five hundred seventy (51,570) square meters.

Fig. 4. Predicted Shoreline in 15 years

Fig. 4 shows the actual salvage zone in the Poblacion area. Based on the study, it was found that the area of the salvage zone is twenty-eight thousand seven hundred nine square meters (28,709) more or less. The figure revealed that there are privately owned land parcels and residences that are situated in the said area. This tells us that residents of Ballesteros, Cagayan were already affected by the negative change in the shoreline. This information would like to inform the LGU of Ballesteros that there are residents needed to be relocated or to be prioritized in the application for the Alienable and Disposable areas of Ballesteros.

There is no doubt about the beauty of living and starting a business near the ocean but the Easements should not be occupied. In a study done by the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA), the country is experiencing an average of 20 typhoons per year which leads to the danger of living within the Salvage Zone [21]. The study of the Philippine Coastal Adaption stated that living within the area is dangerous because of the existing climate change and unavoidable catastrophes [20]. The observation revealed that along the salvage zone of the study area, there are residential areas. Their presence in the area indicates that since the shoreline is moving inward the said zone is also reaching the houses of the people. This points to the vulnerability of the people living within and after the salvage zone. Uncontrollable calamities will endanger their lives.

V. Conclusion

This study provided a coastal projection map of the Poblacion Area in Ballesteros. SLAMM has made possible the determination of the shoreline of the Poblacion and to predict the possible shoreline retreat. It was found out that the area of the coastal erosion for the past 14 years has drastically moved landward and is predicted to continuously move if there is no mitigation. The presence of settlements and the privately-owned land parcel is the now salvage zone which indicates that the private lands next to the said zone are vulnerable to the sea-level rise from physical standpoints. The Poblacion area is densely populated, especially the areas inhabited by the fishermen, they may survive in the area but are vulnerable to possible storm surges and typhoon flooding.

Coastal Erosion is the result of almost all the catastrophes here on the Planet, it is expected and cannot be avoided but what people can do is to have a good strategy in developing strong awareness programs about the importance of trees or reforestation. Sea Wall can be placed within the area. A seawall is a structure made of concrete, masonry, or sheet piles, built parallel to the shore at the transition between the beach and the mainland or dune, to protect the inland area against wave action and prevent coastal erosion. Seawalls are usually massive structures designed to resist storm surges. Sea walls are big and strong; however, this will deteriorate in decades, so while the sea wall is working, the community and LGU should start creating mangrove forests. Mangrove Reforestation Ecotechnology can mitigate ecological degradation, promote sustainable development, build green infrastructure, and increase biodiversity as well as coastal ecology resilience. To further improve the study, future researchers who would want to continue this endeavor can use a topographic map to have a more detailed map, compute the economic effect of the coastal erosion on the community, and determine the possible coastal retreat if there are mitigations and human interventions.

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