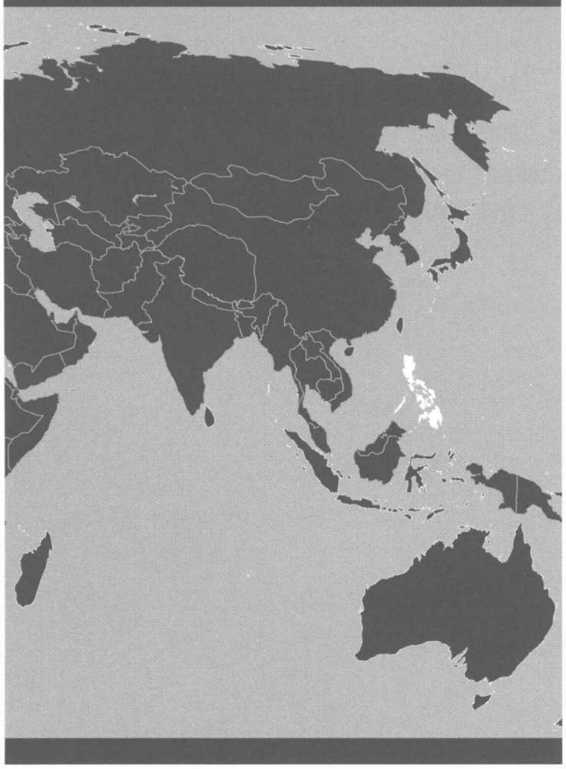
Philippines



Coastal erosion vulnerability mapping along the southern coast of La Union, Philippines

TEAM LEADER

Rose Berdin
<rose_nigs@yahoo.com>

TEAM MEMBERS

Christina T. Remotigue
Peter Zamora
Yvainne Y. Yacat

PROJECT ADVISOR

Dr. Fernando P. Siringan

SYMPOSIUM NOTES

Rose D. Berdin, Cristina T. Remotigue, Peter B. Zamora, and Ma. Yvainne Y. Yacat-Sta. Maria
National Institute of Geological Sciences, University of the Philippines
Diliman, Quezon City 1101, PHILIPPINES

INTRODUCTION

The coastal zone of the Philippines covers approximately 11,000 km^2, which accounts for less than 4% of the country's total land area but is home to almost 50 million people or 63% of the country's total population. As population and investments in infrastructures steadily grow along with rapid urbanization and expansion, coastal communities become more and more at risk or vulnerable to coastal hazards such as tsunamis, storm surges and erosion: the latter being the most widespread and persistent in the past several decades.

Coastal erosion is common in the Philippines despite the present-day elevated sediment yield of rivers. Erosion could be due to natural factors, for instance, river mouth switching in the bayhead of Lingayen Gulf (Mateo and Siringan, submitted), mass wasting as a result of rapid sedimentation at the mouth of the Bucao River in Zambales (Siringan and Ringor, 1996), and return to normal sediment yield of rivers years after a volcanic eruption in Pamatawan Delta, Zambales (Siringan and Ringor, 1996). However, there are just as many coastal segments where erosion is attributed directly to human activities. Erosion along the shores of Pampanga and Cavite in Manila Bay is attributed to dam construction and offshore sand mining, respectively (Siringan and Ringor, 1997; Doruelo, 2000). Thus, for proper mitigation, if amenable, the cause or causes of erosion should be established. Including the abovementioned work, only few studies, however, address this problem (e.g., Siringan et al., 1999; Siringan and Jaraula, 2002).

This study sought to develop a coastal vulnerability index for southern La Union. Coastal segments were classified according to the degree of vulnerability to erosion based on established shoreline trends, known coastal characteristics and available socio-economic information. Long-term or decadal trends of shoreline changes were derived from time-series analysis of maps and anecdotal accounts. Probable causes of shoreline changes and the common response of the government and affected communities are also presented. The results of this study hopefully will be used to guide the government and stakeholders to come up with development plans and disaster management strategies, and to refine or formulate policies that would consider the consequences of coastal erosion.

STUDY AREA

Situated in northwestern Luzon is the 60-km north-south trending coastal stretch of southern La Union, from San Fernando in the north to Sto. Tomas in the south (Fig. 1). Except in San Fernando, wherein some coastal segments are made up of rocky headlands and some are fringed by coral reefs, the entire coastline of the study area is characterized by sandy beaches along gentle coastal plains. Two large river systems drain into the area, Bauang and Aringay Rivers, which have watershed areas of 516 km^2 and 397 km^2, respectively (Siringan and Mateo, 1999). Wind data indicate predominant winds coming from the northwest. At wind speed ranging from 2 to 6 m/s during normal conditions, waves with significant height of less than 1 m are generated; at 10 to 20 m/s, wave heights reach over 3 m (Woodward Clyde, 1999). Wind-driven circulation model by Delas Alas (1981) indicate the predominance of southerly currents in the area. Sediments coming from Bauang and Aringay Rivers, coupled with the predominant southerly longshore currents, formed the Sto. Tomas spit, an elongated sand body that extends from the delta flanks of Aringay southwards to approximately 12.5 km The study area covers the towns of San Fernando, Bauang, Caba, Aringay, Agoo and Sto. Tomas (Fig. 1), of which 48 coastal *barangays* (*barangay* is the smallest political unit in the Philippines) are included.

Figure 1. The study area consists of six coastal municipalities in southern La Union. Boxes show the coastline extent of each municipality.

METHODS AND DATABASE

Several steps were undertaken before the coastal vulnerability index (CVI) was developed. Physical and socio-economic data were acquired from primary and secondary sources. The physical data included establishing trends of shoreline and bathymetric (or water depth) changes. Shoreline trend analysis was complemented by interviews of long-time coastal residents. Collectively, these data were used to construct the coastal vulnerability index for southern La Union.

Shoreline trend analysis

Long-term changes in shoreline position were determined by overlaying digitized shoreline from old maps and from a recent GPS survey (Table 1). The present shoreline was mapped by taking GPS readings, with average accuracy of ±8m, every approximately 30 to 40 m while walking the coast. To properly position the GPS readings on the map, GPS fix of ground control points, such as major road intersections and bridges, were also obtained. The different shorelines were corrected for differences in projection and were superimposed on vertical aerial photographs taken in 1990, again using prominent features such as roads and intersections as control points Although the aerial photographs were not corrected for distortion, possible distortion was minimized by cropping the edges and making use of the central part of each frame before stitching them together using a graphics software

The maximum amount of shoreline translation was measured perpendicular to the shoreline orientation along a particular segment. In the succeeding sections, shoreline position based on the 1944 and 1956 maps is denoted as 1940s because the information used in the maps was based on aerial photography from the 40s Similarly, the 1970s shoreline is derived from the 1977 topographic map; although the data could have been acquired earlier as the source of information was not indicated in the map.

Ground-truthing of these changes was performed during the course of the GPS survey by taking note of coastal features associated with erosion and accretion. Photographs were also taken for documentation.

Bathymetric change

Although the year of the survey was not indicated, the 1977 map represents water depth information sometime within 1940s to 1970s because it contains information not reported in the early 1900s survey. The water depth data from the 1977 map were georeferenced and digitized to extract the old bathymetry.

Except off the coast of Caba, which was surveyed in August and January, 2002 (Siringan and Jaraula, 2002), bathymetric survey for the rest of the study area was conducted in April and September, 2003 using Garmin GPS sounder with an accuracy of ±15 m for position and ±10 cm for water depth. Along a zigzag route perpendicular to the coast, at an average cruising speed of 10 km/h, water depth and

Year	Type of Data	Area of coverage	Reference
1901	Map	San Fernando	In Meimban, 1997. La Union The Making of a Province (1850-1921).
1944	1 50,000 topographic map	San Fernando to Bauang	USC&GS Map sheet 3160 I (based on 1944 aerial photography)
1956	1 50,000 topographic map	Bauang to Sto Tomas	Corps of Engineer, US Army map sheets 3068 I and 3069 II (based on 1946, 1947 and 1959 aerial photography)
1977	1.50,000 topographic map	San Fernando to Sto. Tomas	NAMRIA map sheets 7075 I and 7076 II (source of data not indicated)
1991	1 40,000 vertical aerial photographs	San Fernando to Sto Tomas	NAMRIA
2003	GPS survey	San Fernando to Sto. Tomas	This study

Table 1. Database used in determining long-term trends of shoreline changes.

position were acquired every two seconds Both old and new raw data were then gridded using a 50 x 50 m square grid. Changes in bathymetry were calculated by subtracting the gridded output. A blanking file was generated from the plotted new data such that only the changes within the area covered by the recent survey are considered. Correction for tides and waves was not applied.

Social survey

Interviews of longtime residents with good recall of events were conducted to validate, augment and complement field data and to understand how the locals perceive the cause of erosion and how they respond to it. The survey questionnaire, with emphasis on shoreline and land use changes, was modified from the instrument used by Siringan and Rodolfo (2002) and was first tested in Wenceslao, Caba (Siringan and Jaraula, 2002). In each municipality, *barangays* showing significant long-term shoreline changes as assessed from spatial data were selected: six from San Fernando City, four from Sto Tomas, three each from Caba and Agoo, and two each for Bauang and Aringay. From the 20 *barangays* chosen, 63 respondents aged 30 to 84 years old, mostly between 55 to 60 years old, were interviewed. Almost all of the respondents are fishermen and *barangay* officials.

Coastal Vulnerability Index

The Coastal Vulnerability Index (CVI) for the study area was developed following mainly the method of McLaughlin et al (2002) Variables contributing significantly to the study area s vulnerability to erosion were chosen and grouped into three sub-indices: coastal characteristics (wave buffers, substrate, shoreface slope and shoreline evolution), natural (wave exposure) and anthropogenic forcings (mining history), and socio-economic characteristics (population, land use, roads and bridges, cultural and historical landmarks, and conservation status). Each variable is then ranked on a scale of 1 to 5, with 5 being the most vulnerable and 1 the least, according to their perceived level of vulnerability. After the scores per sub-index are added, the final CVI score was calculated by getting the sum of the partial weight of each sub index: 40% for coastal characteristics, 20% forcing and 40% socio-economic. Calculation for CVI was limited to *barangay* level, which is the highest resolution of the available socio-economic data. Four categories were used in classifying the vulnerability of the coastal *barangays* low, medium, high and extremely high. A color code is then assigned to each category to derive a coastal vulnerability map Below is a brief description of the variables used and how they were ranked

Coastal characteristics

Coral reefs, sand dunes and mangroves are natural coastal features, which serve as buffers against the erosive energy of waves. Thus, the presence of these features lessens a coastal segment s vulnerability to erosion Areas where any of these natural buffers is present are given a score of 1 and where not one of these features is present, a score of 5.

In the study area, the substrates encountered are bare rock or cliff, mud and sand. Among the three, bare rock or cliffs are the least vulnerable to erosion because they are more indurated and therefore, more difficult to entrain Sandy beaches, on the other hand, would be the most vulnerable to erosion, although larger in grain size and heavier as opposed to mud, sand is less cohesive and therefore, relatively easier to erode A score of 1 is given to areas with bare rock or rocky beach, mud flats 3 and sandy beaches 5.

Shoreface slope on a regional scale affects the waves that reach the coastline. Areas with steeper slope allow waves to break closer to the coast and thus, enhancing erosion. Along coastal segments with gentler slope, waves approaching the shore break at a greater distance from the shore therefore, dissipating much of the wave energy before hitting the shoreline. Shoreface slope for each coastal *barangay* was calculated from the new bathymetric data Slopes values were divided into five equal ranges: the lowest range was given a rank of 1 whereas the highest range a rank 5

Ranking for the shoreline evolution variable is derived from the established long-term trend of shoreline changes in the study area (see Results and Discussion). rapidly translating, rapidly retreating, slowly retreating, highly variable and relatively stable This classification considers the time factor — how the coast behaved in the past several decades — which may also give us an idea of how it might respond to processes and events in the future Furthermore, it takes into account the geomorphological setting (e.g., delta, spit) and relative proximity to major sediment sources, which may or may not be an advantage (see Results and Discussion). *Barangays* along rapidly translating coastal segments, although not necessarily eroding, are given the highest score because of the high potential for erosion. Consistently rapidly eroding shorelines are ranked 4, and the retreating, but at a slower pace, shorelines ranked 3. Less vulnerable, with score of 2, are highly variable coastal segments, wherein no consistent trend of change occurs. Least vulnerable to erosion are the relatively "stable" coasts; in the past several decades, the shoreline along these coastal segments appears to have remained constant.

Natural and anthropogenic forcings

Only two variables are included in this sub-index: wave exposure and coastal mining history. In evaluating a coastal segment's relative exposure to waves, the predominant wind direction, which is northwest, was used as proxy. The most vulnerable segment, therefore, would be one facing northwest whereas a south-facing segment the least vulnerable.

Magnetite sand mining by Filmag in the 60s to 70s along almost the entire La Union coast negatively impacted the coast. This activity physically removed huge volumes of sand from the beach, loosened materials thereby making it easily transported by waves and removed a natural beach armor, the heavy magnetite sand. The negative effect of coastal mining trailed long after the operations stopped; therefore, we assigned a score of 1 for coastal segments not mined and 5 for those mined by Filmag.

Socio-economic characteristics

Information about the socio-economic variables are based largely on reports obtained from each locality namely, the comprehensive land use plan of San Fernando City, Aringay, Caba, Agoo and Sto. Tomas; municipal development report of Bauang and coastal development framework of La Union. These are supplemented by secondary data obtained from each municipal/city hall.

Instead of classifying the coast according to settlement type, population density, or the number of persons per hectare, was used. Population densities in coastal *barangays* range between 2 and 362 persons per hectare. Only Caba and Aringay registered lower figures than the average population density of 4 persons per heactare in the entire La Union. On the other hand, three *barangays* (Ilocanos Norte, Ilocanos Sur and Baluarte) have densities greater than 100 persons per hectare; hence, a rank of 5 was assigned to areas with at least 100 persons per hectare and a rank of 1 to areas with less than 10 persons per hectare. The difference between the upper and lower limits was equally distributed over the remaining ranks.

The ranking was simpler for the other categories. In land use, residential area has been omitted since it is already incorporated in the population ranking. The

Sub-index 1. Coastal characteristics.

VARIABLE	1	2	3	4	5
Natural buffers (coral reefs, dunes, mangroves)	present			none	
Substrate	Bare rock, cliff	Mudflat	Sandy beach/ Sand flat		
Shoreface slope	<0.8°	0.8-1.4°	1.4-2.1°	2.1-2.7°	2.7-3.4°
Shoreline evolution	Relatively "stable"	Highly variable	Slowly retreating	Rapidly retreating	Rapidly translating

Sub-index 2. Natural and anthropogenic forcings.

VARIABLE	1	2	3	4	5
Wave exposure relative to NW winds	S-facing	SW-facing	N-facing	W-facing	NW-facing
Mining history	none				present

Sub-index 3. Socio-economic characteristics.

VARIABLE	1	2	3	4	5
Population	<10 per ha.	10-40 per ha.	40-70 per ha.	70-100 per ha.	>100 per ha.
Land use	Natural habitat/ Open spaces	Institutional/Parks/ Health Facilities	Aquaculture/ Agriculture	Commercial/Resorts	Industrial (plants and ports)
Roads and bridges	None		Provincial/Municipal/ Barangay	National	
Cultural/Historical landmarks	None				present
Conservation status	None				present

rest of the categories were ranked according to their relative economic significance in the area. Highest ranked are industrial areas, followed by commercial, agricultural, institutional and natural habitats. This ranking does not belittle the socio-economic importance of natural habitats; the presence of such habitats could make the shoreline more stable and therefore, less vulnerable to erosion.

Roads and bridges were categorized into *barangay*, municipal/city, provincial or national. Because of the difficulty to distinguish one from the other, *barangay*, municipal and provincial roads were lumped into a single category and given a rank of 3. National roads were assigned a rank of 5 due to its scale and higher construction costs, which translates to greater budgetary requirements for repairs, if and when needed.

The last two variables – landmarks and conservation status – are dichotomous and limited to presence or absence. Historical and cultural landmarks include lighthouses, bell towers, monuments, old churches and buildings and even railways. A major conduit to the north from early 1900s until the 1970s, the provincial government plan to restore the railways. In terms of the last category, many coastal areas in La Union are part of the Network of Protected Agricultural Areas (PLUC-TWG, 1996), which primarily limits further industrialization of important agricultural lands. Existing natural habitats such as Carlatan Lagoon are also under conservation status.

RESULTS AND DISCUSSION

Trends and causes of shoreline changes along the coast of southern La Union

Long-term changes

Time-series analysis of maps and images coupled with social survey results (Fig. 2) show that erosion from the 1940s to present is prevalent along the 60-km long coast of southern La Union. This is corroborated by changes in bathymetry, which indicate an overall deepening in the nearshore areas. Spatially, the coastal stretch can be divided into five types based on the magnitude and trend of shoreline change: rapidly translating, relatively "stable", rapidly retreating, slowly retreating, and highly variable coasts.

Coastal segments along the southern flanks of the Bauang and Aringay River deltas experienced large shoreline translations during the past six decades (Fig. 2). In Parian Oeste and Payocpoc Norte/Oeste in Bauang, the shoreline advanced by 650 m from 1940s to 1970s, 800m from 1970s to 1991 and 600m from 1991 to present. Shifting of river mouth and the elongation of the spit accompanied this series of net land gain from the northern end of the mouth towards the south. In contrast, the adjacent coastal stretch of Payocpoc Sur, Pilar and Santiago retreated by 550 m from 1970s to the present. Residents from Pilar, however, noted as much as 1700 m of land loss since 1940s. The land area of

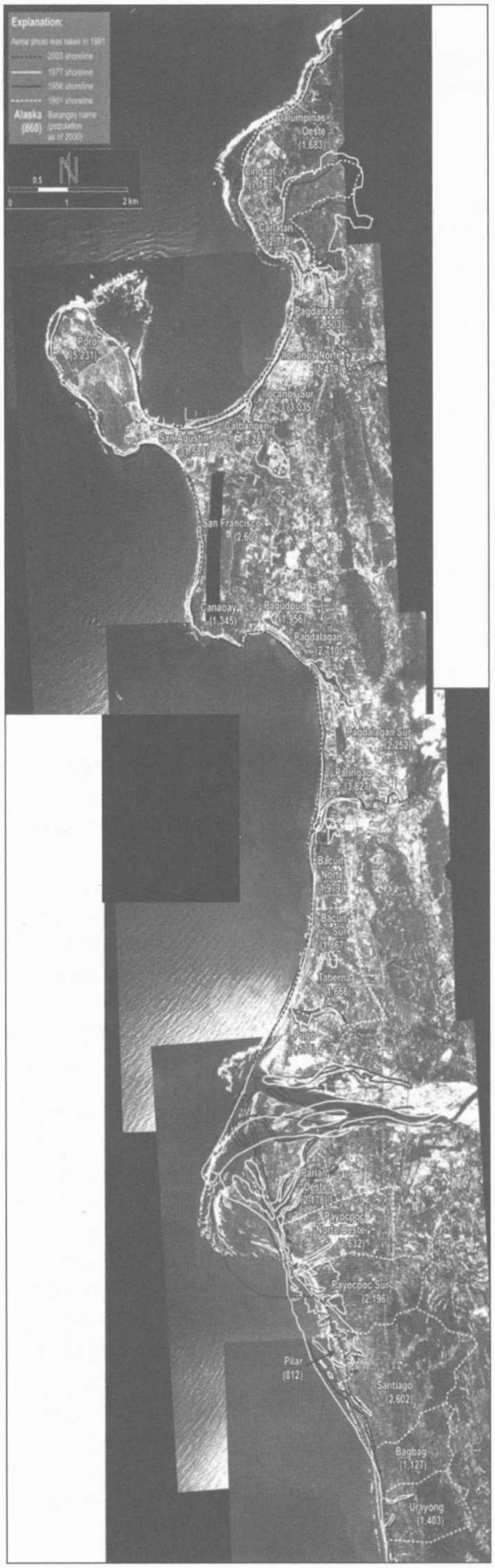


Figure 2. Changes in shoreline position over decadal time scales. Also shown are the *barangay* limits and corresponding population data for year 2000.

this *barangay* was reduced to 3 ha from the original 11.5 ha. The coastal segment immediately south of the Aringay river mouth, in Alaska, gained 400 m of land from 1940s to 1970s, but lost 500 m when the shoreline retreated since then. Locals from this *barangay* observed 480 to 1300 m of sea encroachment since the 1960s. Farther south, in Dulao, Sta. Rita Central and Sta. Rita West, the shoreline consistently prograded and is at present 800 m of its 1940s position. Respondents from Dulao reported a consistent trend, whereas Sta. Rita West folks had the opposite observation. These large and rapid changes have been occurring even prior to the 1940s as these regions are labeled as such in the 1940s maps.

A marked contrast occurs north of the deltas; along Pagdalagan Sur through Pugo and Santiago Sur through Samara, the shoreline appears to have undergone minimal changes (Fig. 2). Based on the maps, slight accretion occurred along these coastal segments. This is, however, inconsistent with the 200 to 500 m land loss observed by Baccuit Sur residents.

Shoreline retreat has been predominant since the 1940s along Bagbag through San Carlos in Caba, and Sta. Rita Sur through San Isidro in Agoo (Fig. 2). Maps indicate 150-250 m of net erosion, but the locals give larger estimates of land loss: 500 to 1000 m in Wenceslao and San Carlos, 1000 to 2000 m in Baluarte, and 300 to 535 m in San Manuel. At present, a series of groins and bulkheads line the coast of Agoo. Construction of these structures started in the 1980s. Similarly, the entire coast of San Fernando has been retreating, but at a slower pace (Fig. 2). Maps dating back to 1900s, indicate shoreline fluctuations throughout the San Fernando coast in the order of a few tens of meters. This trend is consistent with the anecdotal accounts: a maximum land loss of 70 m since the 1960s.

The western coast of Sto. Tomas is on a southeast-accreting spit. This thin strip of land includes Baybay, Cabaroan and Narvacan, the westernmost shoreline of which can be characterized as highly variable (Fig. 2). Based on the maps, no consistent shoreline trend exists and variation occurs along 1 to 3 km-long segments of the coast; however, residents from Narvacan narrated that 300 to 1000 m of retreat occurred since the 1960s. The most conspicuous change occurred in the southernmost terminus of the spit, which extended by as much as 1000 m in about 50 years.

The apparent inconsistencies between the magnitudes of erosion derived from the time-series analysis