Tide-gauge records in the Philippines registered a rise in sea level in the past decades (Siringan et al., 2000). Over the next century, global sea-level rise is projected by the International Panel on Climate Change (IPCC) to range from 15 to 90 cm, with 48 cm as its best estimate (Wigley and Raper, 1992). The values may seem minimal, but the effect of rising sea level on gentle coastal plains, such as in the study area, would be significant as it would allow the sea to encroach farther landwards. Therefore, as sea level continues to rise, erosion will continue to threaten coastal communities.

On top of these natural causes, certain anthropogenic activities exacerbate coastal erosion. The most extensive, and probably the most detrimental, of these activities is the mining of magnetite sand by Filmag Inc. For 10 years, from 1964 to 1974, Filmag extracted approximately 2M cubic meters of magnetite along almost the entire La Union coast, which stretches for about 100 km The total volume of sand extracted would translate to an average deepening of 2 m and shoreline retreat of 10 m per meter of coastal segment. This is a conservative estimate because not the entire La Union coast was mined; hence, certain sections most likely have deepened and retreated more than the estimated values. Furthermore, extracting materials from the coast entails loosening of the substrate, thereby rendering the sediments more susceptible to transport by waves and currents. More importantly, the heavy magnetite sand serves as beach armor; thus, removing them is analogous to destroying the beach s natural protection.

Another human activity that contributes to erosion is the destruction of natural resources, such as coral reefs, sand dunes and native coastal vegetation (e.g., mangroves, aroma trees and the like), which act as natural wave buffers. In San Fernando, for example, coral reefs that extend out to the northeast of Poro and fringe Dalumpinas, Lingsat and Carlatan protect the coastal areas along San Fernando Bay by attenuating waves coming from South China Sea. At present, however, large areas of these reefs have been damaged already due to illegal fishing practices (e.g., dynamite fishing). Thus, erosion along these coastal segments can be due partly to increased impact of waves, which in turn is due to reef destruction. Furthermore, coral reefs contribute considerable amounts of sediments to the beach. The most prolific sand producers are the foraminifers, minute one-celled organisms that secrete $CaCO_3$ tests, which thrive in reef flats with healthy sea grass communities. Destruction of the reef flat or coral reef would deprive the beach of a major sediment source. This is critical for San Fernando, because the major rivers are far and are located downdrift of the bay.

Sand dunes also offer a natural means of protecting the coast. They take the brunt of the waves and also serve as sand reservoir. Sand dunes in Dalumpinas Oeste, according to anecdotal accounts, have been leveled to provide a mining company access to the beach sometime in the 60s to 70s. With the use of loaders, sand was also quarried for construction purposes. At present, the height of the remaining dunes in the area is only a third of its previous level. Further dune degradation is occurring to accommodate more houses and resorts in the area.

To protect properties from erosion, ripraps and makeshift seawalls in Carlatan were built using the exposed rock platform along the coast as primary material. According to a resident, attempts were also made to level this platform, which extends several tens of meters offshore, by blasting the protruding rocks so that Carlatan can have a sandy beach instead of a rocky shore. What the community is unaware of is that the rocky platform also acts as a wave buffer, similar to coral reefs; instead of waves breaking on the coast, incoming waves expend their energy offshore when they encounter the platform, hence reducing erosion.

Erosion is also aggravated by artificial structures that interfere with sediment distribution. A groin promotes beach accretion on the updrift segment of the coast but deprives sediments to the downdrift end, thus, enhancing erosion along that side. The series of groins in Aringay and Agoo (Fig. 6), therefore, is detrimental to the Sto. Tomas coast because they decrease the amount of sediments that normally reaches Sto. Tomas. Geomorphological evidence indicate that Sto. Tomas, a spit, was formed by the accumulation of sediments transported through the south-directed longshore drift. Piers can also serve as groins if the structure s design does not allow sediments to pass through. An example of this is the

Figure 6. Series of groins dotting the Agoo-Sto. Tomas coastline.

Bauang Power Plant Company pier in Pilar, which may enhance erosion to the south by trapping sediments on the north side of the structure. The presence of this structure is critical especially since the coastal stretch south of it has been undergoing severe erosion. Armoring the shoreline with seawalls and revetments, although effective in protecting properties and fixing the shoreline, cause beach narrowing and loss in retreating coasts as demonstrated in Oahu, Hawaii (Fletcher et al., 1997). These structures reduce sediment delivery to the beach by preventing the natural process of upland erosion, thus refocusing wave energy on the beach in front of the structure. Furthermore, decreased sediment amount in the updrift beaches means decreased supply to the downdrift segments, hence, amplifying erosion. This appears to be the case along several coastal segments in San Fernando wherein beaches in front of armored structures are either very narrow or completely lost. A similar scenario was observed in front of a series of resorts south of San Fernando through north of the Bauang River (Fig. 7), which indicates that these lighter structures may also induce an effect similar to seawalls and revetments.

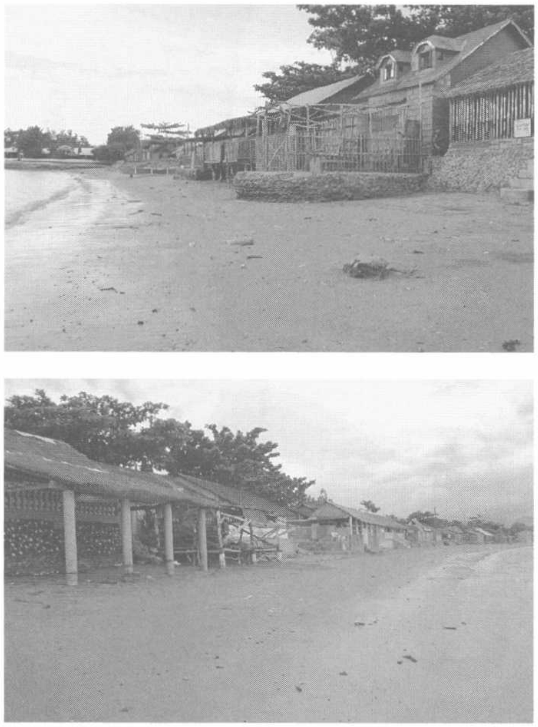

Figure 7. Resorts and restaurants line the southern coast of San Fernando and extends to north of Bauang. These structures provide very narrow shoreline setback for beach adjustment, thereby causing an effect similar to impermeable structures like seawalls and revetments. These photographs were taken in San Vicente; the top photo is the view looking north; bottom is looking south.

The net accretion in front of the Sta. Rita seawall, which at present sits behind 450 m of newly-accreted land, is a different case. This is because it is situated along the southern flank of Aringay delta where sediment supply is abundant and transport direction is towards the south. Furthermore, based on the maps (Fig. 1), the seawall and the Agoo-Damortis National Seashore Park are on top of newly-accreted land. Land gain, therefore, is not due to the structure.

Activities in the watershed may also contribute to coastal erosion. Initially, deforestation and urbanization would lead to rapid soil erosion in the uplands, which would translate to large sediment input to the coast and thus, allow progradation. However, as surfaces are covered by grass and cemented pavements, upland erosion decreases and sediment input to the coast declines. This then translates to shoreline erosion. To date, there are no data on the watershed history of the study area; however a decrease in the river s sediment yield due to changes in vegetation cover as documented by Kummer et al. (1994) in other parts of the Philippines could have also occurred in the watersheds of rivers draining into southern La Union.

Vulnerability mapping

Figure 8 shows the vulnerability map derived from computing the coastal vulnerability index (CVI) of each barangay. Coastal segments are marked according to their degree of vulnerability to erosion: extremely high, high, moderate and low. Also presented in the figure are the vulnerability profiles of each barangay represented as pie charts. This method was suggested by previous studies (Gornitz, 1993 in McLaughlin et al., 2002) to distinguish the relative strengths of each sub-index in a particular site. By viewing the index and the profile side by side, one can then have a better understanding of the factors that make an area vulnerable to erosion.

Barangays situated within the immediate vicinity of the mouths of Bauang and Aringay rivers ranked most vulnerable with respect to coastal characteristics. These coastal segments are classified as rapidly translating and thus, are easily affected by shifting of river mouths and sediment delivery from the watershed. The adjacent barangays in Agoo, Sta. Rita Central and Sta. Rita West, where a 1.5-km long seawall was built, also ranked highly vulnerable. Lowest scores were obtained for Poro, San Francisco, Canaoay and San Vicente, all situated in the Lingayen Gulf-facing southern communities of San Fernando City.

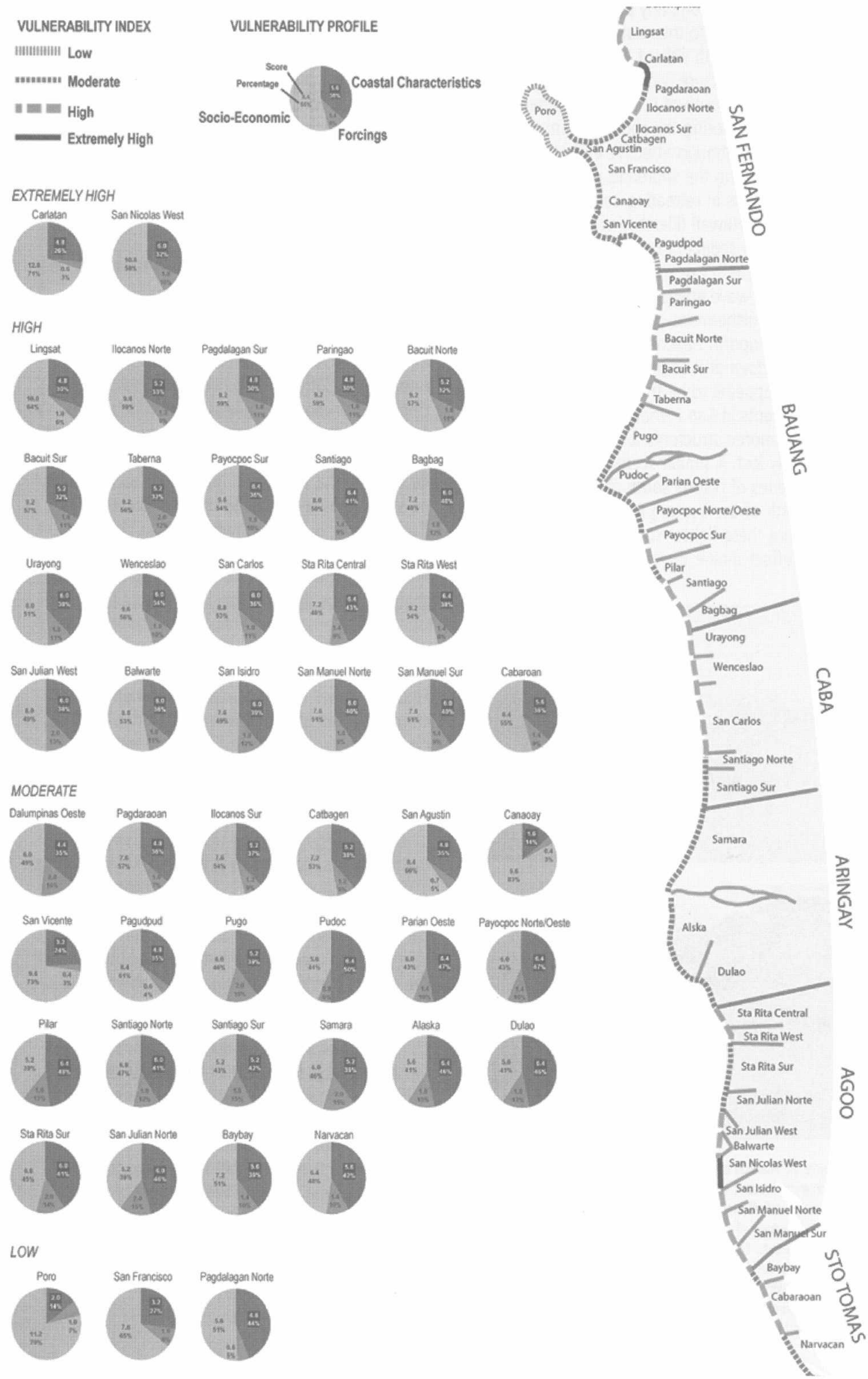

Figure 8. Vulnerability map of the southern coasts of La Union. Relative scores of the coastal characteristics, coastal forcing and socio-economic sub-indices are represented by pie charts.

In terms of coastal forcing, NW-facing areas where mining occurred in the past such as Dalumpinas Oeste in San Fernando, Taberna and Pugo in Bauang, Samara in Alaska, and Sta. Rita, San Julian Norte and San Julian West ranked highly vulnerable. Whereas, the more protected localities along coast of San Fernando City are the least vulnerable These include Carlatan and the barangays that ranked low in the coastal characteristics sub-index. Ironically, Carlatan had the highest socio-economic scores, together with San Nicolas West in Agoo. Carlatan hosts a number of industries and like San Nicolas West, has a rich cultural heritage. Even more ironic is the fact that the *barangays* that were previously classified as highly vulnerable with respect to the physical variables had the lowest scores

The combined scored for the three sub-indices identified Carlatan and San Nicolas West as extremely vulnerable to erosion Carlatan, although low in natural and anthropogenic forcings, has the highest score in the socio-economic sub-index and also weighed heavily in the coastal characteristics sub-index As for San Nicolas West, high scores were registered in all three sub-indices. Classified as highly vulnerable to erosion are Lingsat and Ilocanos Norte in San Fernando, barangays north and south of Bauang River (except Pilar), barangays in Agoo (except Sta. Rita Sur, San Nicolas West), and Cabaroan in Sto. Tomas—all situated along west-facing coastal segments These areas ranked relatively high in the coastal characteristics and the forcings sub-indices and moderate in the socio-economic aspects. The rest of the barangays, mostly rural areas and situated along the flanks of Bauang and Aringay, are identified to be moderately vulnerable to coastal erosion. The least vulnerable areas are Poro and San Francisco in San Fernando and Pagdalagan in Bauang. Socio-economically, Poro and San Francisco ranked high, but low in coastal characteristics. Pagdalagan is not an industrial and commercial area unlike the two others

Closer examination of the weighted scores of the sub-indices shows that the coastal characteristics and natural and anthropogenic forcings do not vary much Excluding the scores for Poro (2) and Canaoay (1.6), weighted scores for coastal characteristics cluster from 3 2 to 6 4, Canaoay and Poro are atop bedrock whereas the rest are mostly on sandy coastal plain. Weighted scores for natural and anthropogenic forcings range from 0.4 to 2. What tipped the scale of the vulnerability index are the socio-economic characteristics wherein weighted scores vary from 5.2 to 12.8. This indicates the significant contribution of socio-economic information in assessing an area's vulnerability

LIMITATIONS OF THE STUDY

Direct relationships between rates of erosion, timing and ultimate causes cannot be established with the data gathered. The time frame provided by maps and aerial photographs is limited; therefore, more interviews are needed to obtain a more statistically reliable data set We are also constrained by the availability of secondary information, specifically the socio-economic profiles, because of poor record keeping of the offices concerned. The vulnerability index could be refined with more data.

CONCLUSIONS AND RECOMMENDATIONS

Anecdotal accounts are important sources of information on the changes of shoreline position. However, it should be filtered and tempered with other data.

Rates and primary cause/s of erosion vary along contiguous coastal segments; thus, mitigation measures, if still amenable, may also differ accordingly. The cause/s may also change through time. As coastal erosion is a complex problem, it should be studied seriously for more informed course of actions.

Uncontrolled rapid occupation of accreted coastal lands will lead to conflicts with the naturally changing landscape. The local government should, therefore, assert the public domain nature of these new lands to help lessen damages due to subsequent erosion. Since the problem transcends municipal boundaries, the actions for mitigation should therefore be agreed upon by the local government of affected municipalities.

There are three main stakeholders in the area, the marginalized group, the business group, and the government. However, the local government must at the outset protect the interest of the marginalized group, mostly fisherfolks, and look for alternative solutions without compromising or sacrificing their main source of livelihood.

Increase information advocacy to raise the level of awareness on the problem among stakeholders is vital. A shared understanding and recognition of the risk involved in coastal erosion may lead to the affected community's willingness to accept effective mitigation approaches and to support any sustainable use practice introduced. A well-informed community readily accepts the idea of relocating when mitigation through engineering structures may not be effective and relocation is the only best solution. Informed managers from all levels of the government can rechannel limited funds to other projects that can benefit the community.

Of equal importance is the need for the government to refine existing policies and formulate new ones that would specifically address coastal erosion. At present, there are no coastal laws, ordinances or decrees that directly tackle this extensive and persistent problem. Once effective policies are endorsed and approved, the next step is to have strong, political will to institute reforms.

ACKNOWLEDGEMENT

Our team greatly appreciates the enthusiastic assistance of Lea Soria, Nap Villanueva, Karen Rodriguez, Titan Qui a, Nelle Monteclaro, Nel Baluda, Eden Baliatan and Grace Asio in gathering field data. Special thanks to Zoan Reotita who provided the much needed help in organizing materials, data and a lot more other things. We also thank Rose Pang-ot for lending us those hard-to-look for reports and Kelvin Rodolfo for introducing us to the Emery method of beach profiling, which made surveying a lot more easier and fun for us. To the people of La Union, for sharing their knowledge about the coast, Dios ti Angina. To our resource persons, Samuel Sanchez, Mary May C. Diaz and the others who wanted to remain anonymous, we are very grateful To Ando, our mentor, thank you so much for the unwavering guidance and support.

This research benefited so much from results of an ongoing work funded by the City Government of San Fernando, La Union and a previous study funded by Ms Lourdes Eristingcol.

BIBLIOGRAPHY

Asian Disaster Reduction Center (ADRC), 2002. Philippine Disasters Datasheets

Comprehensive land use plan of Agoo, La Union

Comprehensive land use plan of San Fernando City, La Union.

Comprehensive land use plan of Sto. Tomas, La Union.

De las Alas, J.G. 1986. Prediction of the levels and trends of non-oil pollutants in the Lingayen Gulf. University of the Philippines Science Research Foundation Diliman, Quezon City

Doruelo, J C S , 2000 The dynamics of sediment transport off the coasts of Cavite. MSc Thesis. Univeristy of the Philippines

Fletcher, C.H., Mullane, R.A. and Richmond, B M , 1997 Beach loss along armored shorelines on Oahu, Hawaii Islands. Journal of Coastal Research, 13(1) 209-215

Geomatrix Consultants, inc , 1995 Geohazard and seismic zonation mapping of the Agoo and Caba urban study areas, unpublished report

Kummer, D., Conception, R and Canizares, B , 1994 Environmental degradation in the uplands of Cebu. The Geographical Review. 266-276

Mateo, Z.R P and Siringan, F P, submitted Tectonic and sea level controls of high-frequency Holocene delta switching and fluvial avulsion in Lingayen Gulf bayhead, northwestern Philippines

McLaughlin, S , McKenna, J , and Cooper, J A G , 2002 Socio-economic data in vulnerability indices. constraints and opportunities. Journal of Coastal Research, Special Issue 36: 487-497.

Meimban, A O 1997 La Union The Making of a Province (1850-1921), 341 pp.

Municipal development report of Bauang, La Union.

Municipal development report of Caba, La Union

Municipal development report of Aringay, La Union.

PAGASA 2003 Information on tropical cyclone province of La Union (1948-2002)

PLUC-TWG 1996 La Union Physical Framework Plan (Cooperative Provincial Land Use Plan (1993-2002).

Rivera, P. C. 1997. Hydrodynamics, sediment transport and light extinction off Cape Bolinao, Philippines. Disseration submitted in partial fulfillment of the requirements of the Board of Deans of Wageningen Agricultural University and the Academic Board of the Internationl Institute for Infrastructural,Hydraulic and Environmental Engineering for the Degree of DOCTOR 244 pp.

Siringan, F.P., Berdin, R D., Doruelo, J S , Jaraula, C M B , Mateo, Z.R.P, Ong, J.B T and Yacat, M.Y.Y., 1999, Sediment transport patterns along Macajalar Bay and Cagayan de Oro River derived from geomorphic and sedimentologic parameters. Abstracts and Proceedings "Tectonics of Southern Philippines. Implications to Natural Hazards, Mineralization, Magmatism and Environmental Change", Aurelio, M.A. and Pajarillaga, N. (eds), Geological Society of the Philippines, Quezon City. pp 28-33

Siringan, F.P. and Jaraula, C , 2002 Land configuration changes along the Aringay-Bauang coastal zone: possible causes and mitigation measures, unpublished report

Siringan, F.P., Maeda, Y., and Rodolfo, K.S , 2001 Short-term and long-term changes of sea level in the Philippine Islands. Global Change and Asia Pacific Coasts (Mimura and Yokoki, eds): Proceedings of APN/SURVAS/LOICZ Joint Conference on Coastal Impacts of Climate Change and Adaptation in the Asia-Pacific Region, pp. 143-149. Siringan, F P, and Ringor, C. L , 1997, Predominant nearshore sediment dispersal patterns in Manila Bay, Science Diliman, 9 29-40

Siringan, F P. and Ringor, C. L., 1996, Changes in the position of the zambales shoreline before and after the Mt. Pinatubo eruption controls of shoreline change, Science Diliman, 7 and 8 1-13

Siringan, F P and Rodolfo, K S 2003. Relative sea-level changes and worsening floods in the northwestern Pampanga Delta causes and some possible mitigation measures. Science Diliman vol. 15, no 2, pp 1-12

Torres, R C., Paladio, M L O., Punongbayan, R S., Alonso. R A . 1994. Liquefaction inventory and mapping in the Philippines: a worst case scenario. National Disaster Mitigation in the Philippines DOST-PHIVOLCS, 71-98

Wigley and Raper, 1992. Implications for climate and sea level of revised IPCC emission scenarios Nature, 357, 293-300.