Sea Level Rise Vulnerability of Southeast Asian Coasts

Article · December 2008

13 authors, including:

Laura T. David
University of the Philippines

Rommel Maneja
King Fahd University of Petroleum and Miner…

Beverly P.L. Goh
Nanyang Technological University

Ivonne Radjawane
Bandung Institute of Technology

Scientific Highlights

Sea Level Rise Vulnerability of Southeast Asian Coasts

Laura T. David, Rommel Maneja, Beverly Goh, Felino Lansigan, Pich Sereywath, Ivonne M. Radjawane, Bernardette M. Manjaji Matsumoto, Pitiwong Tantichodok, Anond Snidvong, Nguyen Hoang Tri, Kim Anh Thi Nguyen, Yoshiki Saito, Jochen Hinkel

U. Philippines Marine Science Institute, Philippines; Nanyang Technological University, Singapore; U. Philippines Los Banos, Philippines; Department of Fisheries, Cambodia; Bandung Inst. of Tech., Indonesia; U. Malaysia Sabah, Malaysia; Walailak University, Thailand ; Chulalongkorn University, Thailand; Center for Environmental Res & Education, Vietnam; Nha Trang University of Fisheries, Vietnam; Geological Survey of Japan, Japan; Potsdam Institute for Climate Impact Research, Germany

Vulnerability of coastal areas to sea level rise is driven by both global environmental changes, socio-economic development, as well as the ability of affected communities to cope with such changes, which in turn, is influenced by interacting social, economic and environmental factors (Amadore et al., 1996; Mimura, 2001; Adger, 2003; Lasco and Boer, 2006; Nicholls et al., 2007). There is a necessity therefore for an integrated analysis to determine their collective effect on adaptation capacities of human communities.

This collaborative effort for Southeast Asia was conceptualized during the Inaugural Open Science Meeting for the second phase of LOICZ held in the Netherlands in 2005 with the active participation of representatives from Indonesia, Malaysia, The Philippines, Singapore, Thailand, Vietnam and Japan. The guiding principle of the whole endeavour led by the LOICZ Regional Node SEAsia is to effectively influence policy and decision makers in the selection of strategic and sustainable adaptive measures to reduce the future impact of GEC.

Our method of approach is to primarily focus on training workshops (funded by the Asia-Pacific Network, for Global Change Research, APN and the APN-START) which expose regional participants to available assessment tools and synthesize secondary and primary data from collaborating countries. There were two previous studies that involved participatory assessment with local scientists. One is the Regional Workshop on Climate Change Vulnerability and Adaptation Assessment in Asia and the Pacific sponsored mostly by U.S. and Philippine Institutions and the Asian Development Bank which highlighted the GEC vulnerability of islands and coastal nations in general and agriculture, water and forest resources in particular (Amadore et al., 1996). The other is the SURVAS project (Synthesis and Upscaling of Sea-Level Rise Vulnerability Assessment Studies) funded by the EU, the ENRICH Network, the APN, and the IGBP/IHDP-LOICZ core project. This endeavor resulted in inputs from China, Indonesia, Japan, Malaysia, Thailand and Vietnam and provided for validation of ongoing global assessment efforts in the DINAS-COAST Project (Nicholls and de la Vega-Leinert, 2001). It was the LOICZ affiliated DINAS-COAST project that produced the DIVA tool (Dynamic Interactive Vulnerability Assessment) which is one of the initial tools used in this study.

The Tools

Our method chosen for the regional assessment is to apply the DINAS-COAST DIVA model (Dynamic Interactive Vulnerability Assessment) which integrates natural and socio-economic variables in the analysis (http://diva.demis.nl/; Hinkel, 2005; Hinkel and Klein, 2008; McFadden et al., 2007).
Cases were simulated with different combinations of adaptive strategies and the scenarios derived from the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios (IPCC SRES) storylines (Figure 1).

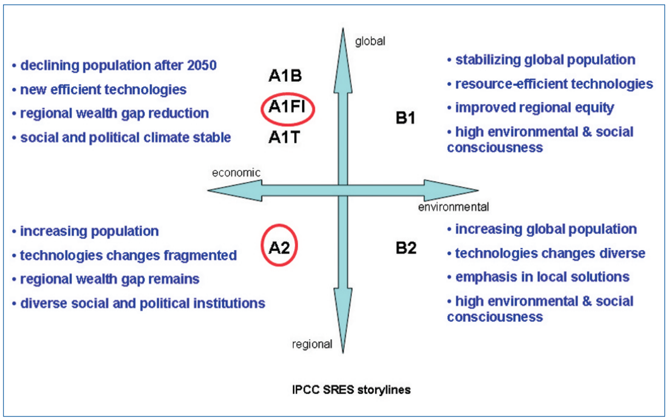

Figure 1: The IPCC SRES storylines from the 4th IPCC Report. Highlighted in red are the scenarios with the highest predicted carbon production from fossil combustion.

The analysis was done on a regional scale with a high regionalized sea level rise and on a per country scale with low, medium and high regionalized sea level rise. Two adaptation options for coasts under threat of sea level rise are considered in the DIVA model: dike protection and beach nourishment. DIVA implements these options according to several predefined adaptation strategies such as “do nothing”, full protection or protection according to a cost-benefit analysis of damage and adaptation cost. Dike protection strategies are further divided into different flood return periods against which to protect (e.g., 10 years, 100 years or 1000 years events).

In order to get a handle on the inter-country similarity and disparity country data and model results were further analyzed using a geospatial clustering tool produced during LOICZ I, the LOICZ-DISCO (Deluxe Integrated System for Clustering Operations),
(http://fangorn.colby.edu/disco-devel/index.php
Smith and Maxwell, 2002; Buddemeier et al, 2008).

Clustering was done using natural and socio-economic country parameters available in the coastal database of the DIVA model, as well as, all the scenario results of the DIVA simulations for the countries of Southeast Asia.

Regional Results

Overall vulnerability is seen in the number of people affected by flooding and the land being lost near the coast, including wetlands.

There is a high cost to doing nothing. For example, without any adaptation strategy results show a uniform linear increase of migration due to land loss from the present rate of 1000 persons per year to 3000 persons per year by 2040. After 2040 the response diverges with volume of migration depending on the IPCC SRES storyline (Figure 2).

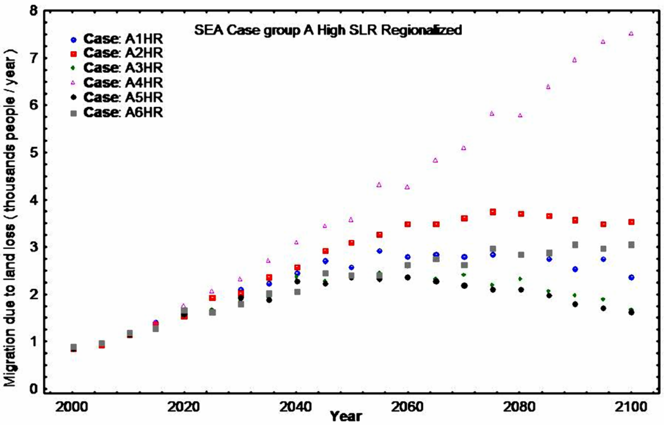

Figure 2: Predicted migration due to land loss if no adaptive strategy is applied. There is uniform linear increase expected until 2040 but after 2040 the response diverges with volume of migration depending on the IPCC SRES storylines.

Highest migration was seen for the A2 followed by the A1FI scenarios. With adaptation measures the migration can be reduced by 40–95 %.

Full nourishment seems to be the more cost-effective option with lower total adaptation cost and better efficacy towards minimizing loss of wetland areas, including coastal forests and mangroves; loss sand; net land loss and the consequent migration due to this land loss. It should be noted that sustainable coastal nourishment, in our point-of-view, should incorporate coastal cover rehabilitation (mangrove and seagrass).

Dike protection was found to be the better option specifically for mitigating the number of people actually flooded, land loss due to submergence and the costs of damage due to flooding from the sea. There is minimal advantage of the dike height that protect against the one in 100 year flood events over that of one in 10 year events until 2050. Thereafter, the cost-benefit advantage of the higher design return period is significant for the A1B and A1FI scenarios.

DIVA does not include adaptation measures that mitigate the problem of salinity intrusions to the groundwater induced by sea level rise.

Per Country Evaluation and Comparison

Vietnam ended up in a cluster by its self with a characteristic high coastal floodplain population. By 2040, it is expected to experience a relatively high land loss due to submergence resulting in migration of about 1100 people annually. By 2100, the continuing sea level rise is expected to result in a moderate net loss of wetland area and nearly 22 million people experiencing flood every year.

Malaysia, Thailand, and the Philippines exhibit an overall low land loss due to submergence and a moderate net loss of wetland area. This land loss will result in an average annual migration of about 150 to 200 people each for Malaysia and Thailand. No migration is expected for the Philippines. The moderate-size population living on the coastal floodplains is expected to experience flood with up to 2 to 5 million people affected by 2100 in each of these three countries. Overall, the Philippines are expected to fare a little better with a predicted lower total residual damage cost.

Cambodia and Singapore are clustered together due to their small total coastal length. Yet this similarity does not lead to similar consequences. Cambodia, characterized by low coastal exposure will experience only low land loss due to submergence, and a moderate net loss of wetland area. By 2100 about 25 thousand people are expected to experience annual flooding. Singapore also has a projected low land loss but no significant loss of wetland area. Being an island state however, it is expected that a higher amount of their population will experience flooding with around 800 people affected annually in 2040 and up to 660 thousand by 2100.

Indonesia is takes a unique position. Aside from the high coastal population, the vulnerable elements identified for this country include its high coastal forest and mangrove cover. It is expected to experience a high land loss due to submergence with around 800 to 1000 people expected to migrate annually due to land loss. In addition, a high amount of wetland area is expected to be lost by 2100 with up to 26 million people expected to experience flood every year.

The high land loss due to erosion, wetland loss, and migration in response to land loss in Vietnam and Indonesia was modelled to be more effectively mitigated by beach nourishment. In comparison, beach nourishment is only slightly advantageous as compared to dike protection for the mitigation of predicted wetland losses in Malaysia, Thailand, the Philippines, and Cambodia. For Singapore dike protection was recommended to mitigate the predicted land loss. In fact, protection from flooding of tens of millions of people living near the coasts in each of the countries in SE Asia requires dike protection.

Consequence of the Different SRS Storylines

In all the countries, the B1 Sea Level Rise Scenario (SRS) exhibits the least amount of damage in terms of natural resources loss due to sea level rise and actual number of people flooded or having to migrate due to submergence. Scenario A1T is also an acceptable alternative especially for the countries of Vietnam, Indonesia, Malaysia, and Thailand.

Surprisingly, the rather resource taxing A2 scenario also exhibited a lower total residual damage cost. However, it was noted that mitigation measures specifically addressing loss of total wetland and abating costs of sea flooding are significantly less effective for the A2 scenario.

Implications to Policy and Planning

Adapting to and preparing for the foreseen sea level changes in Southeast Asia needs a two-pronged approach. Engineering measures were seen as a necessity in order to ensure limited damage to the human population and coastal resources. The cost-benefit relation between beach nourishment and sea walls/dikes is country-specific and target-specific. The more vulnerable countries like Vietnam and Indonesia, for example, will benefit more from beach nourishment which will have to mitigate their predicted high rate of migration due to land loss. On the other hand, for Singapore whose vulnerability is determined by the 660 thousand people who will be flooded by year 2100, dike protection is recommended. At the same time however, analysis showed that the extent of impact anticipated to affect the coastal zone differs depending on the underlying IPCC SRES storyline. Therefore, on global political and governance scales, effort must be exerted globally towards targeting the B1 or A1T scenario, which in terms of concrete action translates to reduced demographic pressure, a balanced mix of utilized energy resources, and a substantial increase in equity among the global regions.

Findings, On-Going Work and Future Recommendations

All participating countries were tasked at the end of the 1st workshop to come up with case studies that highlight their respective country's coastal zone sensitivity to extreme events (Figure 3).

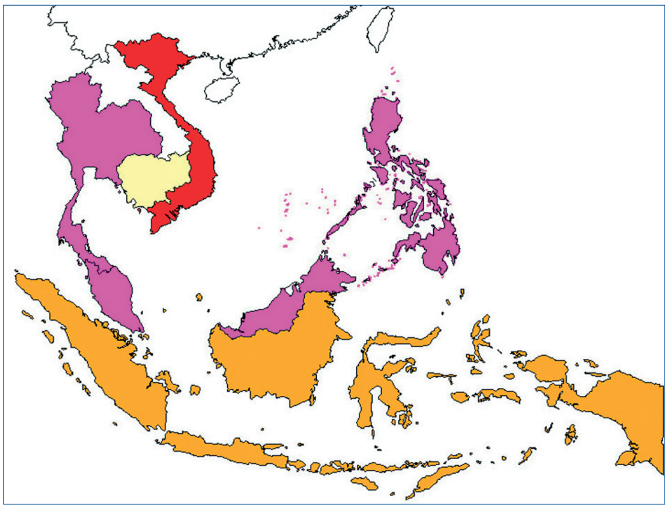

Figure 3: Clustering results highlight the inter-country similarity and disparity. Vietnam belongs to Cluster 1 characterized by very high coastal population; Thailand, Malaysia and the Philippines belong to Cluster 2 with moderate amount of exposure; Cambodia and Singapore belong to Cluster 3 and have a small total coastal area exposure; Indonesia belongs to Cluster 4 and has a very high people and wetland area exposure.

Each participant was also asked to mobilize a 'sub-network' of socio-economists in their country who participated in the 2nd workshop which was focused on vulnerability assessment with valuation analysis. The ensuing discussions regarding the case studies emphasized that the current DIVA vulnerability assessment is appropriate for vulnerability comparison between countries. However, site-specific case studies cannot be addressed adequately at the current scale of the model. In conclusion a regional higher resolution assessment tool (perhaps a regional DIVA SEAsia) may be a consequent future research target.

The DIVA tool in general is being further developed by the members of the former DINAS-COAST consortium. Recent efforts focus on updating the representation of the coastal slopes and population density based on newly available digital elevation models. A further activity aims to ingrate DIVA into standard GIS software in order to make it easier for users to run DIVA with their own data, a need that has frequently been expressed within this and other applications of the tool. On the longer run it is envisaged to develop regional versions of DIVA applicable at sub-national scales relevant for coastal-zone management. A major challenge to be faced thereby is to move beyond the one-dimensional representation of the coastal zone, a model that has proven to be powerful for the global scale dimension but less appropriate for smaller scale analysis.

In this ongoing project a 3rd workshop scheduled for March 2009 will focus on policy and cost-benefit analysis and will involve country experts in charge to identify policy conflicts and gaps relevant to management and governance of coastal areas specifically related to GEC adaptation strategies. The workshop will also address the analysis of the cost of not implementing suggested courses of action in order to effectively market the identified management strategies to policy makers.

Acknowledgment

Funding for this collaborative exercise was provided by APN and APN-START, as well as, IGBP/IHDP-LOICZ.

References

Amadore, L. W., C. Bolhofer, R. V. Cruz, R. B. Feir, C. A. Freysinger, S. Guill, K. F. Jalal, A. Iglesias, A. Jose, S. Leatherman, S. Lenhart, S. Mukherjee, J. B. Smith and J. Wisniewski, 1996 Climate change vulnerability and adaptation in Asia and the Pacific: Workshop summary. Water, Air, & Soil Pollution, Vol. 92, Numbers 1–2 (November, 1996), pp. 1–12

Adger, W. N. 2003 Social capital, collective action, and adaptation to climate change. Economic Geography 79(4): 387–404, 2003

Buddemeier, R. W., S. V. Smith, D. P. Swaney, C. J. Crossland and B. A. Maxwell 2008 Coastal typology: An integrative "neutral" technique for coastal zone characterization and analysis. Estuarine, Coastal and Shelf Science, Vol. 77, Issue 2, (10 April 2008) pp. 197–205 Land Ocean Interactions in the Coastal Zone, LOICZ: Lessons from Banda Aceh, Atlantis, and Canute

Hinkel, J., 2005 DIVA: An iterative method for building modular integrated models. Advances in Geosciences, 4, 45-50, 2005; SRef-ID: 1680-7359/adgeo/2005-4-45; European Geosciences Union.
http://www.adv-geosci.net/4/45/2005/adgeo-4-45-2005.pdf

Hinkel, J. and R. J. T. Klein, 2007 Integrating knowledge for assessing coastal vulnerability to climate change. In: Managing Coastal Vulnerability: An Integrated Approach, L. McFadden, R. J. Nicholls and E. C. Penning-Rowsell (eds.), Elsevier Science, Amsterdam, The Netherlands.

Lasco, R. D. and Boer, R., 2006 An integrated assessment of climate change impacts, adaptations and vulnerability in watershed areas and communities in southeast Asia. A Final Report Submitted to Assessments of Impacts and Adaptations to Climate Change (AIACC), Project No. AS 21.
http://www.aiaccproject.org/Final%20Reports/Final%20Report/FinalRept_AIACC_AS21.pdf

McFadden, L., R. J. Nicholls, A. Vafeidis, R. R. Tol, 2007 A methodology for modelling coastal space for global assessment. Journal of Coastal Research, Vol. 23, No. 4, pp. 911–920

Mimura, N., 2001 Distribution of vulnerability and adaptation in the Asia and Pacific region. http://www.survas.mdx.ac.uk/

Nicholls, R. J. and de la Vega-Leinert, A., 2001 Overiew of the SURVAS project.

Smith, C. A., Maxwell, B.A., 2002 Deluxe Integrated System for Clustering Operations (DISCO),
http://fangorn.colby.edu/disco-devel/DISCO.pdf

Nicholls, R., P. Wong, V. Burkett, J. Codignotto, J. Hay, R. McLean, S. Ragoonaden and C. Woodroffe, 2007 Coastal systems and low-lying areas. In: Parry, M., O. Canziani, J. Palutikof, P. van der Linden and C. Hanson (eds.), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 315–356.

LOICZ Affiliated Activities

EPOCA – A European Research Effort to Understand Ocean Acidification and its Consequences

J.-P. Gattuso, L. Hansson, and the EPOCA Consortium

Besides global warming, another consequence of man's use of fossil fuels is receiving increased attention from the marine and Earth System scientific community. Ocean acidification has been referred to as "the other CO_2 problem", a much less known but potentially as dramatic result of the approximately 79 million tons of carbon dioxide (CO_2) released into the atmosphere every day, not only as a result of fossil fuel burning but also from deforestation and production of cement. Over the past 250 years, the world's oceans have absorbed about one third of the CO_2 released due to anthropogenic activities. Whereas the chemical consequences of this CO_2 uptake are well understood (decrease in pH and shifts in seawater carbonate chemistry) the biological impacts of ocean acidification are poorly known. One of the most likely consequences is the slower growth of organisms forming calcareous skeletons or shells, such as corals and mollusks.

The European Project on Ocean Acidification, EPOCA, is