Sea Level Rise Vulnerability Assessment Model for Coastal Area of Nagapattinam

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Abstract:

Climatic variation is the important factor for sea level rise and associated problems such as increased coastal erosion, inundation, flooding due to storm surges and salt water intrusion along the coastal zone. Nagapattinam Taluk having coastal length 30.0 (km) of coastline including ecologically and socio economically important low lying coastal wetlands and deltaic plain should also be prepared for the impacts of sea level rise as well as other impact of climate change. Thus, a coastal vulnerability assessment for the Nagapattinam areas to sea level rise is the order of the day. Both coastal zone management policies for sustainable development and guidelines for resource allocation of adaptation options for upcoming problems due to sea level rise, as a scientific approach to coastal vulnerability assessment a coastal vulnerability matrix and a corresponding coastal vulnerability index of a region to sea level rise were developed. In the development of matrix and the index, indicators of impacts for sea level rise in which the commonly available datasets were used. The coastal vulnerability assessment model is used to determine the vulnerability of Nagapatinam coast. By implementing the CVI (SLR) to test the coastal areas, the sensitive of the model is tested. The results shows that, the model can be successfully incorporate with the local properties, with expected impacts of sea level rise and provide important information on the increased coastal erosion, salt water intrusion in the coastal region, especially for the decision makers for optimum resource allocation and adaptation planning.

Keywords: *GIS, CVI, SLR, Socio Economic Vulnerability and Coastal Zone Management.*

I. INTRODUCTION

The impacts of the December 2004 Indian Ocean tsunami has emphasized the importance of coastal zone vulnerability studies for better preparedness and disaster management in the event of such large scale natural disasters in the future. While a few studies have examined impacts along select areas of the Indian coastline after the tsunami, a comprehensive analysis of coastal vulnerability has not been conducted for the entire affected coastline (Mukherjee et al., 2007b). An earlier study by Madhusudan et al. (2007) provides a comprehensive analysis of the impacts of the tsunami on coastal habitats, human lives and infrastructure. However it stops short by speculating the possible role of physical features that might have played an important role in influencing the observed impacts. This study picks up from where the earlier work stopped and here we examine how much of the damage incurred as a result of the tsunami can be explained by an index of coastal vulnerability, based on various physical parameter such as land form and bathymetry along the coast. This study also provides a baseline assessment of coastal vulnerability which is important given large-scale coastal modifications being proposed and implemented after the tsunami.

II. STUDY AREA DESCRIPTION

Nagapattinam is a Taluk of Nagapattinam Coastal District of Tamil Nadu., 326 K.M, from south of Chennai, lies between Northern Latitude 10.7906 degrees and 79.8428 Degrees Eastern Longitude. A District known for its Rich Religious Heritage and Communal Harmony. In Nagapattinam Taluk total population 2011 is 102905.male is 52112 and female is 50793. Number of house hold in Nagapattinam taluk is 50793. The Taluk receives rainfall under the influence of both southwest and northeast monsoon. A good part of the rainfall occurs as very intensive storms resulting mainly from cyclones generated in the Bay of Bengal especially during northeast monsoon. The rainfall pattern in the district shows interesting features. Annual rainfall, which is1500 mm at Vedaranyam, the southeast corner of the Taluk, rapidly decreases to about1100 mm towards west of the district. The district enjoys humid and tropical climate with hot summers, significant to mild winters and moderate to heavy rainfall. The temperatures various from 40.6 to 19.3° C with sharp fall in night temperatures during monsoon period. The relative humidity ranges from 70 – 77% and it is high during the period of October to November

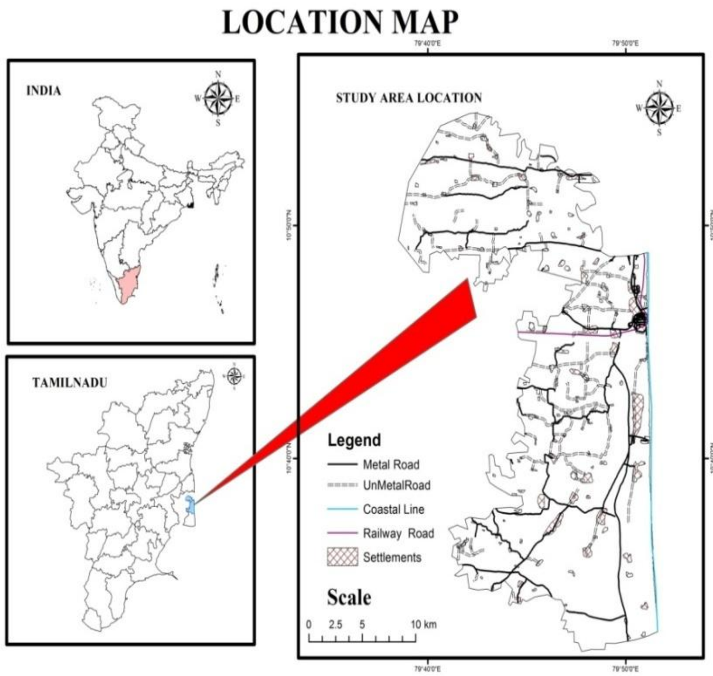

Fig.1.Study Area Location Map

III. METHODOLOGY

In order to develop a methods of coastal vulnerability assessment to sea level rise using indicators for both physical and socio economic vulnerabilities: first, the physical impacts were studied.
The physical impacts of sea level rise on coastal areas included in this study area are:

Table .1.Physical Parameters and Corresponding Ranges (Source: Özyurt, 2007)

				Range		
		Very low	**Low**	**Moderate**	**High**	**Very high**
Physical Parameters		**1**	**2**	**3**	**4**	**5**
Rate of SLR	mm/yr	<1	1-2	2-5	5-7	7-9 and over
Geomorphology		Rocky cliff coasts, fiords	Medium cliffs, indented coasts	Low cliffs, glacial drift, alluvial plains	Cobble beaches, estuary, lagoon	Barrier beach, sand beach, salt marsh, mudflats, deltas, mangrove, coral reefs

Coastal slope		>1/10	1/10-1/20	1/20-1/30	1/30-1/50	1/50-1/100
Significant wave high	m	<0.5	0.5-3.0	3.0-6.0	6.0-8.0	>8.0
Sediment budget		More than 50% of the shoreline is in accretion	Between 10-30% of the shoreline is in accretion	Less than 10% of the shoreline is in erosion or in accretion	Between 10-30% of the shoreline is in erosion	More than 50% of the shoreline is in erosion
	Range					
		Very low	**Low**	**Moderate**	**High**	**Very high**
Physical Parameters		**1**	**2**	**3**	**4**	**5**
Tidal range	m	>6.0	4.0-6.0	2.0-4.0	0.5-2.0	<0.5
Proximity to coast	m	>1000	700-1000	400-700	100-400	<100
Type of aquifer		Leaky confined		Confined		Unconfined
Hydraulic conductivity	m/day	0-12	12-28	28-41	41-81	>81
Depth to groundwater level above sea	m	>2.00	1.25-2.00	0.75-1.25	0.00-0.75	<0,00
River discharge	m^3/s	>500	250-500	150-250	50-150	0-50

Water depth at downstream	m	≤1	2	3	4-5	>5

Table .2. Parameters of Human Influence and the Corresponding Ranges (source: Özyurt, 2007)

	Range				
	Very low	**Low**	**Moderate**	**High**	**Very high**
Human Parameters	**1**	**2**	**3**	**4**	**5**
Reduction of sediment supply	>80%	60-80%	40-60%	20-40%	<20%
River flow regulation	Not affected		Moderate affected		Strongly affected
Engineered frontage	<5%	5-20%	20-30%	30-50%	>50%
Groundwater consumption	>20%	20-30%	30-40%	40-40%	>50%
Land use pattern	Protected area	Unclaimed	Settlement	Industrial	Agricultural
Natural protection degradation	>80%	60-80%	40-60%	20-40%	<20%
Coastal protection structures	>50%	30-50%	20-30%	5-20%	<5%

Table .3. Coastal Vulnerability Index – CVI (SLR) Matrix for Nagappattinam Coast (source: Özyurt 2007)

Impact	**Physical Parameters**							**Human Influence Parameters**							**Total impact**	**Least Vulnerable Theoretical Case**	**CVI Impact**
	Parameter	1	2	3	4	5	**Total**	**Parameter**	1	2	3	4	5	**Total**			
	P1.1 Rate of Sea Level	1					1	H1.1 Reduction of			1			3			

	Rise							Sediment Supply									
	P1.2 Geomorphology					1	5	H1.2 River Flow Regulation			1			3			
	P1.3 Coastal Slope				1		4	H1.3 Engineered Frontage			1			3			
Coastal Erosion	P1.4 H⅓		1				2	H1.4 Natural Protection Degradation					1	5			
	P1.5 Sediment Budget				1		4	H1.5 Coastal Protection Structures					1	5			
	P1.6 Tidal Range				1		4										
	TOTAL	1	1	0	3	1	**20**	**TOTAL**	0	0	3	0	2	**19**	**19.5**	**5.5**	**3.54**
Flooding due to Storm Surge	P2.1 Rate of Sea Level Rise	1					1	H2.1 Engineered Frontage			1			3			
	P2.2 Coastal Slope				1		4	H2.2 Natural Protection Degradation					1	5			
	P2.3 H⅓		1				2	H2.3 Coastal Protection Structures					1	5			
	P2.4 Tidal Range				1		4										
	TOTAL	1	1	0	2	1	**11**	**TOTAL**	0	0	1	0	2	**13**	**12**	**4**	**3**
Inundation	P3.1 Rate of Sea Level Rise	1					1	H3.1 Natural Protection Degradation					1	5			
	P3.2 Coastal Slope				1		4	H3.2 Coastal Protection Structures					1	5			
	P3.3 Tidal Range				1		4										
	TOTAL	1	0	0	2	0	**9**	**TOTAL**	0	0	0	0	2	**10**	**9.5**	**2.5**	**3.8**
Impact	**Physical Parameters**							**Human Influence Parameters**							**Total impact**	**Least Vulnerable Theoretical Case**	**CVI Impact**
	Parameter	1	2	3	4	5	**Total**	**Parameter**	1	2	3	4	5	**Total**			
	P4.1 Rate of Sea Level Rise	1					1	H4.1 Groundwater Consumption				1		4			

Salt Water Intrusion to Groundwater Resources	P4.2 Proximity to Coast				1		4	H4.2 Land Use Pattern			1			3			
	P4.3 Type of Aquifer			1			3										
	P4.4 Hydraulic Conductivity	1					1										
	P4.5 Depth to Groundwater Level Above Sea	1					1										
	TOTAL	3	0	1	1	0	**10**	**TOTAL**	0	0	1	1	0	**7**	**8.5**	**3.5**	**2.42**
Salt Water Intrusion to River/Estuary	P5.1 Rate of Sea Level Rise	1					1	H5.1 River Flow Regulation			1			3			
	P5.2 Tidal Range				1		4	H5.2 Engineered Frontage			1			3			
	P5.3 Water Depth at Downstream					1	5	H5.3 Land Use Pattern			1			3			
	P5.4 Discharge				1		4										
	TOTAL	1	0	0	2	1	**14**	**TOTAL**	0	0	3	0	0	**9**	**11.5**	**3.5**	**3.28**

CVI (SLR) =61 CVI-IMPACT= 3.20

a) Increased coastal erosion
b) Increased Flooding due to increased storm surge
c) Salt water intrusion to ground water resources
d) Salt water intrusion to River/Estuary

The model aims to determine the vulnerability of the region by governing the physical and human influence parameters of the physical impacts of sea level rise mentioned above using available local data. to determine the indicators, the governing parameters that are believed to represent the physical process of the impact of sea level rise were determined. THIELER and HAMMER KLOSE (2000) method for analyzing vulnerability of U.S. coast was used a baseline model however several other models were considered to define each of these parameters, such as Bruun rule for predicting coastal erosion and the Ghyben-Herzberg principles for salinity intrusion to ground water resources. On the other hand, Direct human activities in the coastal areas, such as settlement (land use that directly influence the evolution of the coastal areas.), as well as indirect activities, such as regulation of Rivers by dams and reservoir, considered to determine the level of influence of anthropogenic action .In light of these discussions, it was decided that twelve physical parameters and seven human influence parameters would be appropriate without reducing the quality of assessment.(OZYURT and ERGIN ,2009)

Vulnerability ranges determining the ranks of each parameter according to the regional data were based on distribution of available data related to each parameter at location around the world. Using regional data, each parameter is assigned a vulnerability rank of very low to very high vulnerability (1-5). For examples wave height parameters ranges from 0.5 (very low vulnerability) to more than 8.0 (very high vulnerability) around the world. Regional data of Nagappattinam wave height is 0.90 cm (Moderate vulnerability class).

The developed coastal vulnerability matrix (Table.1) Using vulnerability ranks of regional data, calculates the impacts, sub indices and the overall formulas presented below. (OZYURT, 2007).

Physical impact sub indices (CVI impact) are result of ratio of the sum of weighted parameters to the least vulnerable case result for the impact studied. (Formula.1) .The calculated indices ranges between 1 and 5 indicating the level of vulnerability accordingly.

$$CVI_{impact} = \frac{(0{,}5 \times \sum_{1}^{n} PP_n) + (0{,}5 \times \sum_{1}^{m} HP_m)}{CVI_{least\ vulnerable}}$$

(1)

CVI impact: physical impact sub- indices

PP: Physical parameters

HP: Human influence parameters

R: Rank of parameters

CVI least vulnerable: Calculated least vulnerable case for a particular physical impact

Coastal vulnerability Index CVI (SLR) is calculated according to the group the region is which in depends on the likelihood of the existence of the types of physical impacts. (Fornula.2). The Index is given as the ratio of the total value of parameter vulnerability ranks to the least vulnerability value of the corresponding group.

$$CVI\ (SLR)\ n = \frac{\sum \text{Parameters of impacts of group}}{\sum \text{Least vulnerable case of the group}}$$

(2)

One of the main assumptions model is weighting system. The weights are assumed to be equal to 1 for all the parameters and 0.5 for the effect of physical and human influence parameters on the overall vulnerability as a baseline analysis until further research on comparison judgments at different levels are available.

IV. CONCLUSION

By implementing the developed coastal vulnerability assessment model CVI (SLR) to test the coastal areas, the sensitive of the model is tested. The results show that the model can successfully incorporate the local properties with expected impacts of sea level rise and give important information on the vulnerability of the region especially for the decision makers for optimum resource allocation and adaptation planning. Integration of geographical information system will increase the accuracy of the model by eliminating the spatial restricts of compilation of detailed data should be considered better results as well as accurate prediction.

The sensitive of the model will also increase as the level of accuracy of data increases. Use of weights for parameter will also have a considerable effect on the accuracy of the result as well as. In order to achieve this, fuzzy logic implementation can be considered. The result of the model can also be used for coastal zone management practices since the impacts of sea level rise also the main problems of coastal areas whether significant sea level rice is observed or not. Thus the use development model can be broadened for other management practices. Integration of social vulnerability parameters is expected to finalize the development of the model in future.

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