A Framework For Social Coastal Vulnerability In Indian Context

Parvathy P.B [*], Prof. Dr. Jolly John [**]

[*] (Student), Department of Architecture, TKM College of Engineering, Kollam
[**] Professor, Department of Architecture, TKM College of Engineering, Kollam

Abstract- Coastal areas are highly vulnerable to the climate change, especially to sea level rise & its related extreme events. Extensive research has been carried out in the past two decades on impacts of climate change with major focus is on the coastal zone. Several international approaches have been developed to assess the vulnerability of coastal zone due to climate change and sea level rise. In spite of India having a very long coastal line, very limited studies have been carried out to assess the vulnerability of its coastal zone. This highlights the need for preparing planning measures in India, where more than 1/3rd of the population is located in the coastal zones. This paper presents a framework for assessment of the social coastal vulnerability in Indian scenarios.

The paper draws information extensively from available reviews and reports on existing international frameworks & vulnerability mappings which act as a guide in the formation of the framework for the Indian context. Pressure & release model (PAR model), Socio-spatial model & Sustainable Livelihood Framework are examined to identify the parameters considered in the global level. Scotland's third National Planning Framework for flooding & Finland's Climate disadvantage mapping methods are reviewed to classify indices according to their dimensions of vulnerability. The indices used are sorted with their functional relationship with sea level rise vulnerability through detailed analysis and expert opinions. They were then classified into five categories (most relevant, relevant, partially relevant & negligibly relevant) according to its importance in sea level rise vulnerability in Indian context. Weightage has been given to each category for analyzing the social coastal vulnerability of Indian cities. Finally a general framework has been formulated with 10 domains & 26 indicators which can be used to understand the exposure possibilities, sensitivity & adaptive capacities of any coastal area in India.

Index Terms- Sea level rise, Vulnerability, Coastal vulnerability, Social coastal vulnerability index, Exposure, Risk, Adaptive capacity

I. INTRODUCTION

Sea-level rise (SLR) due to climate change is a serious global threat: The scientific evidence is now overwhelming (1).Recent studies shows that rise in sea level is much greater than the earlier estimation in the Intergovernmental panel for climate change (IPCC) and other scientific studies (2). From 1961 to 2003, the average rate of sea level rise (SLR) was 1.8 ± 0.5 mm/yr and for the 20th century, it was 1.7 ± 0.5 mm/yr (3). Based on revised estimates the sea level rise until 2100 will be between 1.0-2.0 m, compared to the earlier estimate between 0.4-1.0m.Vulnerability is the degree to which a system reacts adversely to the occurrence of a hazardous event. The quantification of vulnerability largely depends on the conception of the source of the risk and what element of value to humans is threatened. There is widespread concern regarding SLR induced coastal flooding &erosion on coastal communities and infrastructure (4).This is partly driven by the concerns related to climate & sea-level rise, and it reflects societal concern over the impacts on human infrastructure & activities rather than the sustainability of the coastal environment itself (5).

Extensive research has been carried out in the past two decades by many researchers on potential and observed impacts of climate change on natural and social systems (6) with major focus is on the coastal zone. Several international approaches have been developed to assess the vulnerability of coastal zone due to climate change and sea level rise (7)

In spite of India having a very long coastal line of 7517 km, very limited studies have been carried out to assess the vulnerability of its coastal zone. The computation of coastal vulnerability index involves the estimation of physical vulnerability index and social vulnerability index. Literature reviews reveal that the importance of social parameters is ignored in most of the studies. Also there is no framework for identifying social parameters that should be considered while studying a vulnerability assessment. This paper presents a framework for the social coastal vulnerability in Indian scenarios by analyzing the various existing frameworks through case studies.

II. METHODOLOGY

This paper is not a comprehensive literature review; it draws information extensively from available reviews and reports on existing frameworks in international level & vulnerability mappings which act as a guide in the formation of the framework for the Indian context. Initially an extensive literature review was carried out to understand the basic concepts of SLR, factors contributing to SLR, its impacts and coastal vulnerability. Various international & national case studies are reviewed to figure out the selection of parameters in vulnerability studies. Later three existing frameworks were studied and analyzed in order to understand indices considered in the global level. Then classification of indices according to their dimensions of vulnerability was analyzed through international case studies. Finally this paper draws a general framework with indices & their relative importance that can be used for assessment of sea level rise of any coastal area in India.

III. LITERATURE REVIEW

3.1 GENERAL STUDIES

(A) Climate change & Sea level rise

Climate Change refers to any changes in climatic condition over a period of time (usually 30 years) whether due to natural variability or as a result of human activities that increases the concentration of greenhouses gases (GHG) in the global atmosphere (3). A stronger greenhouse effect will warm the oceans and partially melt glaciers and other ice, increasing sea level. Ocean water also will expand if it warms, contributing further to sea level rise. (3) Thus Sea-level rise is one of the after effects of global warming. The change in sea level (mean sea level) at the coast is defined as the height of the sea with respect to a local land benchmark, averaged over a period of time, such as a month or a year, long enough so that fluctuations caused by waves and tides are largely removed (3).

(B) Factors contributing to sea level rise

Two main factors contribute to Sea level rise are (i) thermal expansion of sea water due to ocean warming & (ii) water mass input from land ice melt and land water reservoirs (8). Warming of the ocean has contributed 0.8-1mm/yr of sea-level change during 1901-2010;whereas thermal expansion accounts for about 25% of the observed SLR since 1960 and about 50% from 1993 to 2003. Although not monotonic through time, glacier contribution to SLR from 1993 to 2009 may be ~30% and total land ice mass loss explains ~60% of the rate of SLR. (8)

(C) Historic & future SLR

Although mean sea level remained nearly stable since the end of the last deglaciation (~3000 years ago), tide gauge measurements available since the late 19th century indicate that sea level has risen by an average of 1.7 ± 0.3 mm/year since 1950 (8). Since the early 1990s, SLR has been routinely measured by high-precision altimeter satellites. From 1993 to 2009, the mean rate of SLR amounts to 3.3 ± 0.4 mm/year.

According to IPCC report, the predicted sea level fluctuation of 21st century gradually increases at the rate of 1-2 mm per year. The projected rise from 1990 to 2100 is 9–88 cm with a mid-estimate of 48 cm. Based on revised estimates the SLR until 2100 will be between 1.0 and 2.0 m, compared with 0.4 and 1.0 m estimated earlier (9).

(D) Impact of SLR

The immediate physical impacts of sea level rise are submergence, increased flooding of coastal land, as well as saltwater intrusion of surface waters. Long-term effects also occur as the coast adjusts to the new conditions, including increased erosion and saltwater intrusion into groundwater. Coastal wetlands such as saltmarshes and mangroves will also decline. These physical impacts in turn have both direct and indirect socioeconomic impacts, which appear to be overwhelmingly, negative (8).

(E) Most vulnerable countries

As the magnitude of climate induced SLR increases, the impacts will be more apparent, especially in certain low-elevation coastal zones. *Figure 1* shows the regions vulnerable to coastal flooding due to climate-induced sea-level rise around the world (8).
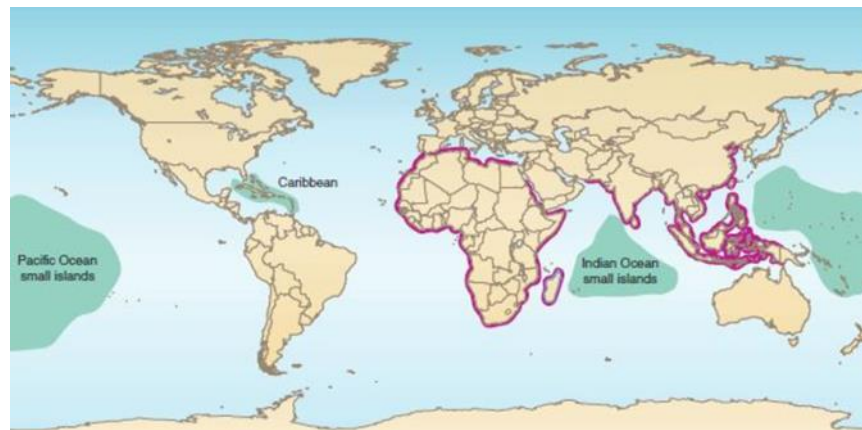
**Fig 1: World map showing regions vulnerable to coastal flooding due to
climate induced sea-level rise**

Vulnerable island region   Vulnerable coastal area
[Source : Sea-Level Rise and Its Impact on Coastal Zones ,2010]

Most countries in South, Southeast, and East Asia appear to be highly threatened because of the widespread occurrence of densely populated deltas, often associated with large growing cities (8). According to the studies, the most significant change estimated was in Asia and particularly in India. As India has a high population density, and a long coastal line, people living in low lying coastal areas will be at a higher risk than earlier estimates. More sophisticated revision of sea level estimates more than 3.5crore population at risk in India. The coastal line along Mumbai to Kolkata and Chennai to central Kerala, along with some parts of Gujarat will face a colossal risk in the next 30 years. (10)

(F) Coastal vulnerability

The concept of coastal vulnerability is based on human value judgments concerning risk to various elements of natural & human environment from a variety of sources (11). Since vulnerability is affected by a diverse range of parameters, it is common to refer it as 'indices' to express their combined effect (12). Several coastal vulnerability indices have been developed by researchers to assess the vulnerability of sea level rise to human activities and infrastructure (13).

Although there are different perspectives on the meaning of coastal vulnerability, the main purpose of vulnerability assessment is to provide information to guide the process of adaptation and enhance society's adaptive capacity. A vulnerability index therefore aims to simplify a number of complex and interacting parameters, represented by diverse data types, to a form that is more readily understood and therefore has greater utility as a management tool. There is no 'one size fits all' index of coastal vulnerability' that can be applied at all scales. The components that contribute to vulnerability, the data availability and type, and the utility of an index approach vary with scale & place (14).

(G) Coastal vulnerability index (CVI) - components

A coastal vulnerability index (CVI) was used to map the relative vulnerability of the different segment of the coast due to sea-level rise. A multi-scale coastal vulnerability index uses a function of the physical nature of the coast (which controls its ability to respond to perturbation), the nature (frequency and magnitude) of the perturbation (the forcing factor) and the degree to which such changes impact on human activities or property (15). Hence computation coastal vulnerability index involves the estimation of physical vulnerability index and social vulnerability index.
Coastal Vulnerability = physical parameters + social parameters

(H) Importance of physical parameters

The physical variables can vary according to the selection to the specific target site, taking into account its geographical and morphological peculiarities, especially referring to a low-lying area. Generally, physical variables like tidal range, significant wave height, sea level rise, shoreline change rate, geomorphology, shoreline erosion/accretion, slope and elevation are used as the parameters (15). These parameters are dependent and show the direct impacts or reciprocal feedbacks. For eg: if the slope is low & gentle, there is high risk for inundation. Similarly

if the shoreline rate change is negative, that is, the shore is eroding, it becomes wider and gentler. Most of the vulnerability studies consider only physical parameters for their calculations.

(I)   Importance of social parameters

As per the reports of AR5 (IPCC, 2014b), the framing of vulnerability has shifted from the former natural science (physical) perspective towards a perspective where vulnerability is defined as a factor determined by the socio-economic, policy, and environmental context. Though, disasters might be of bio-geophysical origin, the actual impacts of all disasters are concerned with individuals & society. Moreover, the capacities of a population to resist & recover from impacts are largely determined by their socio-economic factors.

3.2 APPROACHES ON COASTAL VULNERABILITY

(A) INTERNATIONAL

The Coastal Vulnerability Index (CVI) was first developed by Gornitz (13) to climate change, particularly sea-level rise for United States coastal considering inundation, flooding and susceptibility to erosion. Many coastal vulnerability index (CVI) /coastal sensitivity index (CSI) was later developed with modifications to the original. CVI of Gornitz (1989) had included seven physical parameters in the vulnerability analysis along with the two social parameters such as population & population density. In the later studies, researchers began to consider more social parameters since vulnerability is understood in terms of people being vulnerable and so needs socio-economic variable. Location, infrastructure (economic value), institutional setup economic and human are some of the social variables considered in various studies.

Table :1 gives the summary of variables considered in vulnerability assessment from international researchers.

(B) Table 1: Summary of International literatures on vulnerability assessment

Reference	Area of study	Physical variables considered	Social variables considered	Remarks
Vivien Gornitz &Kanciruk,. (1989)	U.S.A	Rock type, Landform, vertical land movement, Shoreline displacement, tidal range, wave height, Shoreline length	Population & population density	Formed Coastal vulnerability index (CVI) considering inundation, flooding and susceptibility to erosion
Carter (1990)	Ireland	Shoreline change, slope, sea level changes, tidal range, wave height	coastal features, coastal structures, access, land use	Developed a Sensitivity index
Yamada K (1995)	South Pacific island countries	In the three "hard" systems, one is 'natural environment' In the three "soft" systems, which encompass the less tangible elements. One of them iscoastal system	In the three "hard" systems, 2 others are "people, and infrastructure" In the three "soft" systems , remaining are institutions, sociocultural factors, and economic system	Approach that uses relative scores to evaluate different adaptation options in a variety of scenarios
J.Shaw (1998)	Canada	Tidal level, surges, coastal retreat, rock type, sea level, wave height, soreline displacement rate, erosion rate	Not considered	Calculated as sensitivity index

| E. Doukakis (2005) | South Greece | Coastal slope, subsidence, displacement, geomorphology, wave height, tidal range | Not considered | Coastal vulnerability index (CVI) Most vulnerable – river delta & coastal lagoon |
| Boruff et al., 2005 | USA | Not considered | Principal components analysis was 'Census-derived social data' | Social coastal vulnerability index (SoVI) was calculated |

   Development in GIS brought a leap in analysis of vulnerability. A GIS based coastal vulnerability index for wave-induced erosion in Northern Ireland has been developed by McLaughlin et al., (2002) incorporating of socioeconomic variables such as population, cultural heritage, roads, railways, land use, conservation status.
   From these literature reviews it is concluded that the overall vulnerability index constitutes of the sum of three indexes; ie coastal characteristics, coastal forcing and socio-economic factors. Most of the studies had incorporated social indices for the better assessment of vulnerability.

   (C) NATIONAL
   The vulnerability of the Indian coastal region to the consequences of the estimated sea level rise has been studied by Indian researchers, considering only physical parameters viz elevation, exposure and slope. The table below shows the variables considered in vulnerability assessment by national researches.

(D) Table:0 Summary of national literatures reviews on vulnerability assessment

Reference	Area of study	Physical variables considered	Social variables	Remarks
Hegde and Raju, 2007	Mangalore coast, India.	Geomorphology, regional coastal slope, shoreline change rates	Population.	Here CVI was an indication of relative vulnerability Mangalore coast to coastal erosion hazards
Rao et al., 2008	Andhra Pradesh, India	Geomorphology, coastal slope, shoreline change, mean tidal range, significant wave height	Not considered	CVI was prepared by integrating the differentially weighted rank values of the five physical variables only
Dwarakish et al., 2009	Udupi coast in Karnataka state	Shore-line change rate, sea-level change rate, coastal slope, mean tidal range, coastal geomorphology	Not considered	Six variables are classified under geologic variables & physical variable. Finally inundation mapping is done
Srinivasa et al., 2010	Orissa coast, India	Geomorphology, coastal slope, shoreline change, mean tidal range, significant wave height, sea level change, coastal regional elevation, tsunami run up,	Not considered	They use 6 basic variables along with additional geologic process variable, i.e., coastal regional elevation &additional physical process variable, i.e., tsunami run-up. Most parameters are dynamic in nature& GIS processed.
Arun and Pravin, 2012	Chennai , India	a) Shoreline Change b) Sea Level Change Rate c) Significant Wave Height d) Tidal Range e) Coastal Elevation; f) Near-shore Bathymetry; g)	Not considered	Though the study claims that they have considered socio-economic conditions as additional important variables, no quantitative / qualitative data is given to establish that.

|		Geomorphology h) Extreme Strom Surges		
Murali et al., 2013	Puducherry coast. India	physical-geological parameters (slope, geomorphology, elevation, shoreline change, sea level rise, significant wave height and tidal range	population, Land-use/ Land-cover (LU/LC), roads and location of tourist places	Tsunami of Dec 2004& Thane cyclone of 2011 caused extensive human & economic losses. Devastation caused by these events highlighted the need for vulnerability assessment with more social variable

In the earlier studies of vulnerability assessments, researches were mainly focused on the basic parameters like Shore-line change rate, sea-level change rate, coastal slope, mean tidal range, coastal geomorphology etc. When the researches gets more focused into specific problems like erosion or coastal flooding, more physical or dynamic parameters were added according to the need. Thus coastal elevation, bathymetry, tsunami run up etc gets added. Only after the occurrence of extreme events like tsunami, researchers are highlighting the need for vulnerability assessment with more social variables, since the people & their socio-economic circumstances are the bottom end elements that finally get affected.

From the national literature reviews is seen that the importance of social parameters are ignored or not considered in studies with emphasis. This may be due to lack of a framework for identifying social parameters that should be considered while studying a vulnerability assessment. Therefore it can be presumed that the vulnerability studies may get biased results without focusing on the actual problems.

EXISTING FRAMEWORKS FOR SOCIAL COASTAL VULNRABILITY
(a) Framework 1- PAR Model

The pressure and release model (PAR model) is for showing how disasters occur when natural hazards affect vulnerable people. It is a systematic representation of four categories of the factors driving vulnerability. Their vulnerability is rooted in social processes and underlying causes which may ultimately be quite remote from the disaster event itself. (16) The basis for the PAR idea is that a disaster is the intersection of two opposing forces: those processes generating vulnerability on one side, and the natural hazard event on the other. The image resembles a nutcracker, with increasing pressure on people arising from either side – from their vulnerability and from the impact (and severity) of the hazard for those people. The 'release' idea is incorporated to conceptualize the reduction of disaster: to relieve the pressure, vulnerability has to be reduced (16). (Fig AA-1).
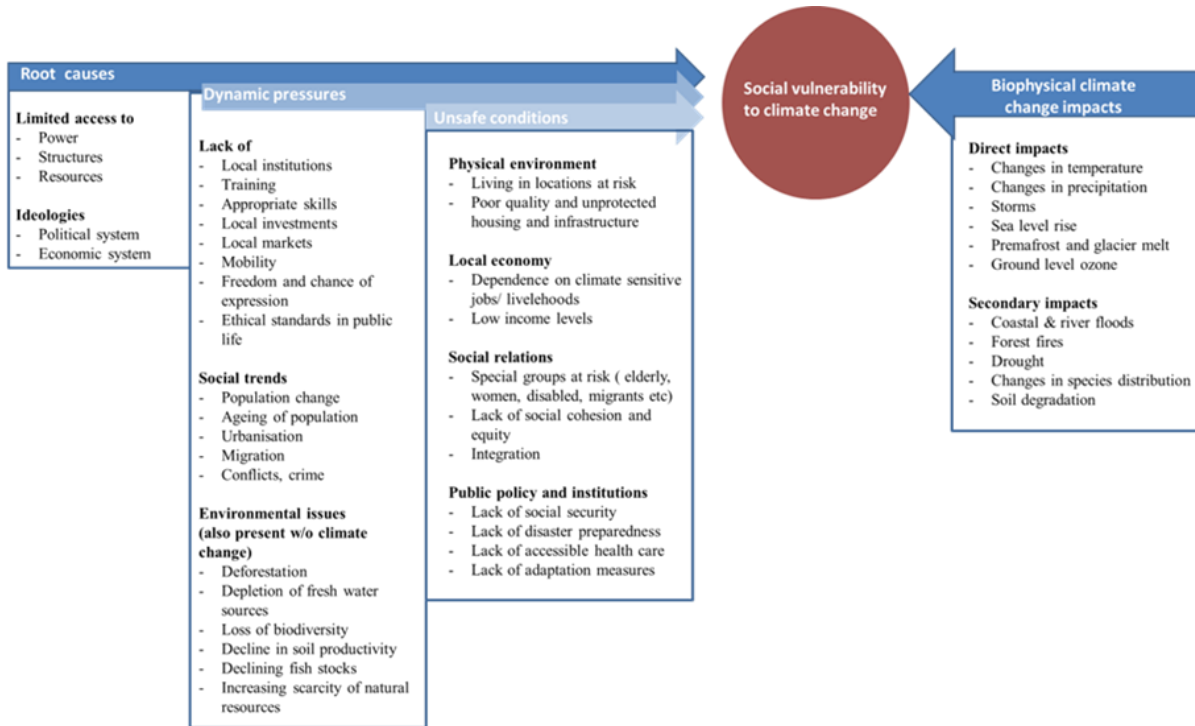
Fig 2: The drivers of vulnerability to social impacts of climate change
(Source : (17) adapted from: ; Blaikie, P. M. et al., 2003)

According to this scheme, drivers of social vulnerability are represented as a gradient of individual characteristics, which range from general systemic issues(distribution of power, and resources in society) to local/regional drivers (including governance, socio-economic situation in the area, and availability of natural resources) to finally socio-economic, institutional, and physical conditions of the individual's living conditions. These factors can contribute to reducing or increasing climate related vulnerability as much as biophysical climate impacts (18).

(b) Framework 2 - Socio-spatial model
        This framework was developed for a research project funded by the Joseph Rowntree Foundation in the United Kingdom. It is based on the concept of "risk triangle" where climate disadvantage (understood as the degree to which an external event has the potential to convert into losses in human well-being) is realized when vulnerability of communities coincides spatially with the hazard-exposure (19).(fig 3)
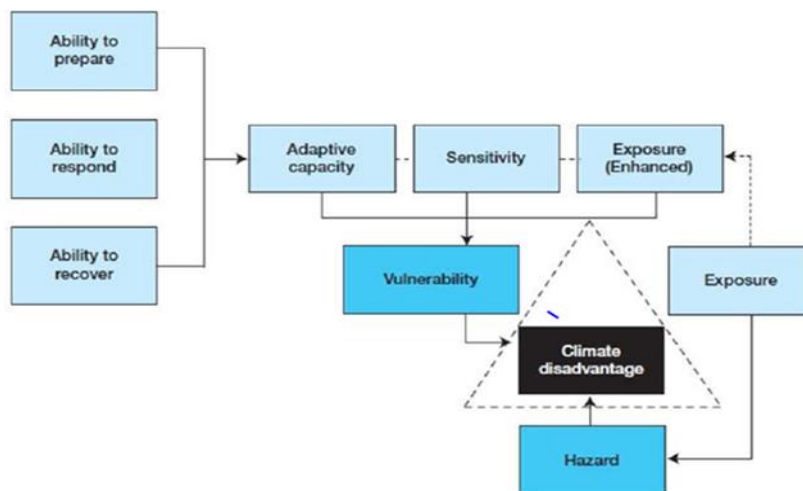
Fig 3 : Conceptual framework of climate disadvantage and vulnerability to climate change
*(Source : (Lindley, 2011))*

The concept of vulnerability is disaggregated into sensitivity (personal factors driving vulnerability, such as age and health), enhanced exposure (environmental factors, such as characteristics of housing or presence of green space that can either mitigate or exacerbate climate impacts locally),and adaptive capacity (social factors, such as income level, ability to speak the official language, length of residence in the area). Adaptive capacity in turn is split into the ability to prepare for respond to, and recover after extreme weather events (19). This framework is powerful for urban analysis as it brings together characteristics defining individual land social elements of vulnerability with spatial characteristics that define exposure and enabling features of the environment that promote preparedness, response capacity, and ability to recover.This approach has been used to map and assess climate vulnerability across the United Kingdom (19).

(c) Framework 3- 'Sustainable Livelihood Framework'

SLF focuses on people, it seeks to gain an accurate and realistic understanding ofpeople's strengths or "capitals" and identifies five types of assets or capitals upon which livelihoods are built, namely:
- human capital (education/health)
- social capital (networks/norms)
- natural capital (land/air/water)
- physical capital (infrastructure/ economy)
- financial capital (savings/income/social support).

The SLF views vulnerability as the context that frames the external environment in which people exist. This framework mainly deals with 'risk' & 'vulnerability'. Risk is defined as the likelihood of occurrence of (external) shocks and stresses plus their potential severity, whereas vulnerability is the degree of exposure to risk (hazard, shock) and uncertainty, and the capacity of households or individuals to prevent, mitigate, or cope with risk (20).(fig 4).
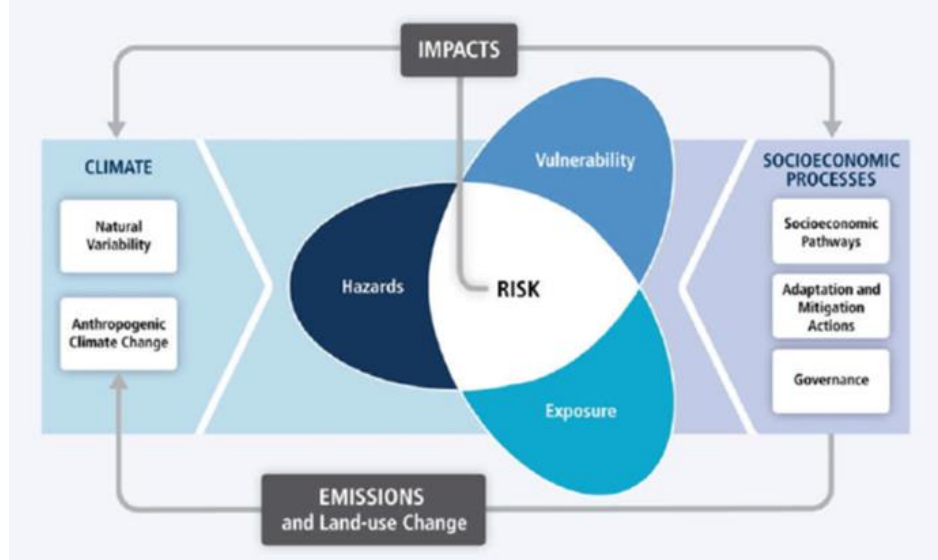
Fig 4: Concept of vulnerability and elements defining driving forces.
Source: IPCC (2014a)

The framework is intended to be a tool for planning and management to assess the many factors that influence poverty and how it can be eliminated. It is one of the most widely used livelihoods frameworks in international development practice. These were used in the studies from European context.

The analysis of the above frameworks related to social vulnerability shows some common traits with regards to specific issues, the most important one being the distinction between different aspects of social vulnerability, i.e. sensitivity, exposure and adaptive capacity. All indices are associated with these aspects. The potentials & problems of an area therefore can be logically assessed when organized in the terms of sensitivity, exposure & adaptive capacity. Moreover it can be seen that varies indices that are globally used in any studies are age, health, income level, institutional set up and housing.

IV.   CASE STUDIES

(a) Scotland

   The consequential increase of risk flooding is recognized in Scotland's Third National Planning Framework. As per their studies, by the 2050's, rainfall on the wettest day in winter is projected to change in the range of -5% to 25% across regions in Scotland, under the high emissions scenario, with a central estimate (50% probability) of 10% increase (UK Climate Projections, 2009). So in order to develop policy responses for vulnerable groups, a Mapping Flood Disadvantage Report for Scotland was prepared (21). It was made with 14 domains & 34 indicators. Their dimensions of vulnerability have been marked separately to understand its sensitivities & abilities. The assessment of the levels of social vulnerability has revealed the most vulnerable areas and number of people affected. (Table-3)

Table 3: Indicators used in Mapping Flood Disadvantage in Scotland 2015

Domain	Indicator	Sensitivity	Ability to prepare	Ability to respond	Ability to recover	Enhanced exposure
Age	% people under 5 years old	y				
	% people over 75 years old	y				
Health	% people whose day-to-day activities are limited	y				
	% households with at least one person with long term limiting illness	y				
Income	% people in routine or semi-routine occupations		y	y	y	
	% of long term unemployed people		y	y	y	
	% households with dependent children and no adults in employment		y	y	y	
	Number of Income Support claimants		y	y	y	
	Number of Job Seeker Allowance claimants		y	y	y	
	Number of Pension Credit claimants		y	y	y	
	Number of families receiving tax credits		y	y	y	
Information use	% people with <1 year residency in the UK		y	y	y	
	% people who do not speak English well		y	y	y	
Insurance	% new addresses located in flood risk areas		y	y	y	
	Number of historic flood events		y	y	y	
Local knowledge	% addresses in Flood Warning Target Areas		y	y		
	% new residents (< 1 year) arriving from outside the local area		y	y		
Tenure	% social rented households		y			
	% private rented households		y			
Mobility	% of Incapacity Benefit/Severe Disablement Allowance claimants			y	y	
	% people living in medical and care establishments			y	y	
	% households with no car or van			y	y	
Social networks	% children of primary school age			y	y	
	Number of voluntary organisations focused on local community			y	y	
	% single pensioner households			y	y	
Physical access	% people working further than 30km from home			y		
	Road density			y		
Crime	Number of domestic breakings			y		
Access to health services	Travel time to GP surgery (private transport)				y	
	Travel time to GP surgery (public transport)				y	
Housing characteristics	% households with the lowest floor level: ground floor					y
	% households with the lowest floor level: basement or semi-basement					y
	% caravans or other mobile or temporary structures					y
Physical environment	% urban land cover					y

(Source : Kazmierczak et al., 2015)

(b) Finland

In 2015, the Helsinki Region Environmental Services Authority (HSY) commissioned a data study and mapping exercise to identify the spatial distribution of social vulnerability to climate change impacts (high temperatures and flooding) in Helsinki Metropolitan Area (22).(Table-4)

Table 4: List of indicators used in mapping social vulnerability to climate change in Helsinki Metropolitan Area

Code[a]	Indicator	Aspect of vulnerability	Weight in vulnerability to flooding	Weight in vulnerability to heat	Sensitivity	Dimensions of social vulnerability to flooding				Dimensions of social vulnerability to heat		
						Ability to prepare	Ability to respond	Ability to recover	Enhanced exposure	Ability to prepare	Ability to respond	Enhanced exposure
i_1	Location within 1km from a railway station	Access	0.25	0			Y					
i_2	Accessibility zone	Access	0.25	0			Y					
i_3	Percentage of households with no car	Access	0.25	0			Y					
i_4	Access in case of emergency	Access	0.25	0			Y					
i_5	Percentage of people with basic studies	Information	1	1		y	y	Y		y	Y	
i_6	Percentage of children 0-6 years old	Age	0.5	0.5	Y							
i_7	Percentage of people over 75 years old	Age	0.5	0.5	Y							
i_8	Percentage of unemployed in labour force	Income	0.25	0.25		y	y	Y		y	Y	
i_9	Percentage of economically inactive people in the population	Income	0.25	0.25		y	y	Y		y	Y	
i_10	Percentage of long-term unemployed in the labour force	Income	0.25	0.25		y	y	Y		y	Y	
i_11	Median household income	Income	0.25	0.25		y	y	Y		y	Y	
i_12	Occupancy rate	Overcrowding	0.5	0			y	Y				
i_13	Percentage of households containing 7 or more people	Overcrowding	0.5	0			y	y				
i_14	Percentage of dwellings in flats	Housing	0	1								Y
i_15	Percentage of water area in the grid cell	Physical environment	0	0.33								Y
i_16	Percentage of total green space area in the land area	Physical environment	1	0					y			
i_17	Percentage of low vegetation area in the land area	Physical environment	0	0.33								Y
i_18	Percentage of area covered by trees in land area	Physical environment	0	0.33								Y
i_19	Percentage of students in the population	Social networks	0.33	0		y	y	Y				
i_20	Percentage of single person households	Social networks	0.33	0.5		y	y	Y		y	Y	
i_21	Percentage of school age children in the population	Social networks	0.33	0.5		y	y	Y		y	Y	
i_22	Percentage of rented households	Tenure	0.5	0.5		y		Y		y		
i_23	Percentage of dwellings rented from ARA	Tenure	0.5	0.5		Y		y		y		

(Source: Kazmierczak, 2015)

The analysis was based on the approach of Climate Just tool, i.e. a spatial analysis of social vulnerability determined by adaptive capacity (ability to prepare for, respond to and recover after extreme weather events), sensitivity (related to age), and enhanced exposure (type of housing and presence of green space) (18)

From the analysis of case studies, it is observed that certain indices are common in both the case studies. It is also evident that the selection of indices follows a similar pattern & considers personal factors like age, health, literacy; social factors like population, GDP, road and environmental factors like location &land use.

V.   INFERENCE

From the literature study, the indices used in various occasions were understood. The indices were sorted with their functional relationship with sea level rise vulnerability though the expert opinions and detailed analysis. These have been classified into most relevant, relevant, partially relevant, negligibly relevant & not relevant according its importance to SLR vulnerability in Indian context.

The indicators sorted were also given the weightage based on its importance. The red colour shows highly relevant index in sea level rise studies. The orange colour indicators are relevant & green colour indicators are negligibly relevant. As the number of indicators in the study increases, more precision can be obtained.

Indictors considered in the framework and their domains are listed below:

	DOMAIN	THEIR INDICATORS
1	AGE	**a.** Percentage people under 5 years old
		b. Percentage people over 65 years old
2	HEALTH	**c.** % households with at least one person with long term limiting illness
3	POPULATION	**d.** Population density
		e. Annual growth of population
		f. Population at a risk due to sea level rise
		g. % of working population
		h. Migration rate
4	LITERACY	**i.** Literacy rate
5	INCOME	**j.** Unemployment rate
		k. Proportion of alone-pensioners in household
6	FINANCIAL RESOURCE	**l.** Agriculture dependency
		m. 2ndry & 3rdy dependency

	DOMAIN	THEIR INDICATORS
	FINANCIAL RESOURCE	**n.** GDP
		o. Tourist arrival
7	PHYSICAL ACCESS & ACCESS TO SERVICES	**p.** Drainage
		q. Road density
8	HOUSING	**r.** No: of houses in flood exposed areas
		s. Legal entitlements
		t. % social rented households
		u. % of slum population
9	LOCATION	**v.** Proximity of CBD to sea
10	ENVIRON-MENT	**w.** Change in Land use
		x. % of urban area
		y. % of coast line
		z. Occupancy rate

■ Most relevant	■ Relevant
■ Partially relevant	■ Negligibly relevant

VI. RECOMMENDATIONS

The framework for social coastal vulnerability index can be framed with 26 indicators & 10 domains which can be used to understand the exposure possibilities, sensitivity & adaptive capacities of any coastal area in India. It considers demographic, economic, infrastructure as well as planning conditions of an area while examining its vulnerability along with the physical factors.
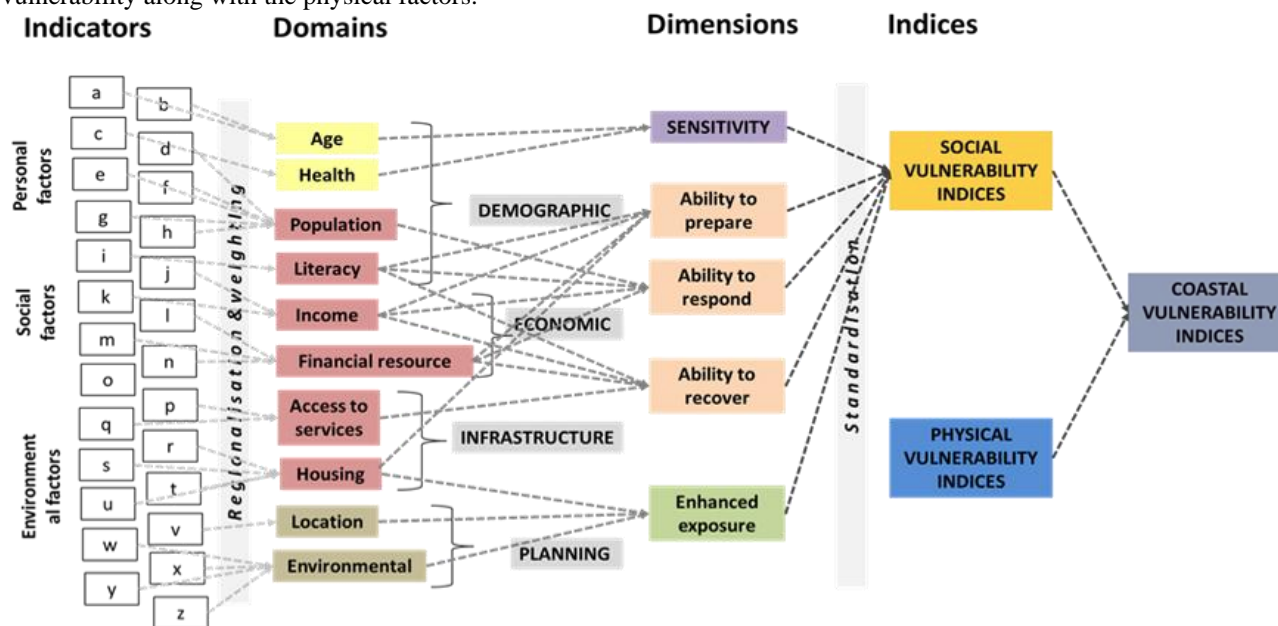
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AUTHORS

First Author – Parvathy P.B., Civil Engineer, B.Tech in Civil Engineering from M.G. University, M.Plan in Urban Planning (student) from TKM College of Enginnering, Kollam , Email : parvathy1994@gmail.com

Second Author – Prof. Dr. Jolly John, Architect, Urban Planner., B. Arch Degree from Anna University, M.Plan in City Planning from Indian institute of Technology, Khargpur, Ph. D Degree (Building Acoustics) from Kerala University, Professor in TKM College of Engineering, Kollam, Email : jollyjkollam@gmail.com