Training/Workshop on
Tsunami Evacuation Maps, Plans, and Procedures and
the UNESCO-IOC Tsunami Ready Recognition Programme for the Indian Ocean Member States
Hyderabad - India, 15-23 April 2025

Tsunami Inundation Modelling and Map

TIMM: Hazard Assessment Products and Hazard Assessment Report - Best Practices and Example

TEMPP 2025

Dr R S Mahendra
Scientist-E, INCOIS

Introduction

1. Hazard Identification Checklists

•**Purpose**: Systematically identify hazards in various environments (e.g., office, construction, lab).

•**Best Practices**:

- Specific requirement (disaster management and industries).
- Include physical, chemical, biological, ergonomic, and psychosocial hazards.
- Use clear, simple language with visual cues if possible.

2. Risk Matrix

•**Purpose**: Evaluate severity and likelihood of identified hazards.

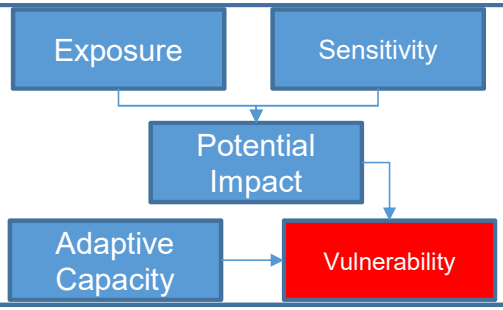
•**Best Practices**:

- Use a color-coded 5x5 or 3x3 matrix (e.g., low, medium, high).
- Define probability and consequence criteria.
- Use consistent scoring.

Vulnerability and Role of Geospatial Technology

Vulnerability is the degree to which a system is prone to harmful effects of climate change and its variability and extremes (IPCC 2001)**. V**ulnerability is a function of hazard, exposure and sensitivity of physical or biophysical components.

Approach: Deterministic and Probabilistic



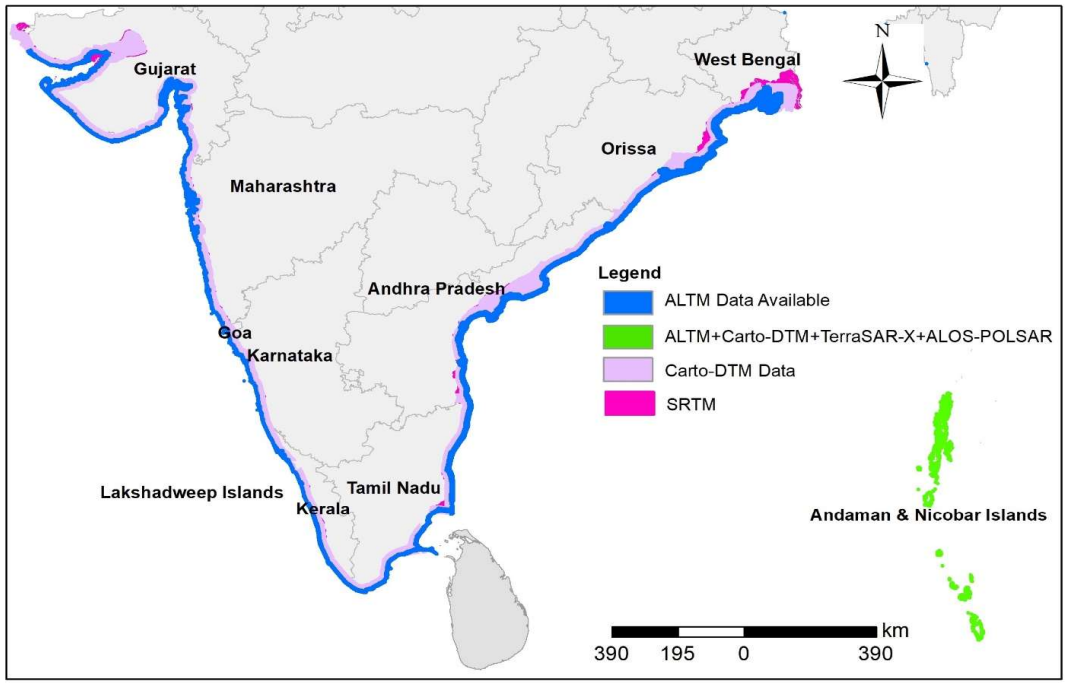
Geospatial Technology plays a vital role in the disaster management cycle for information and informed decisions

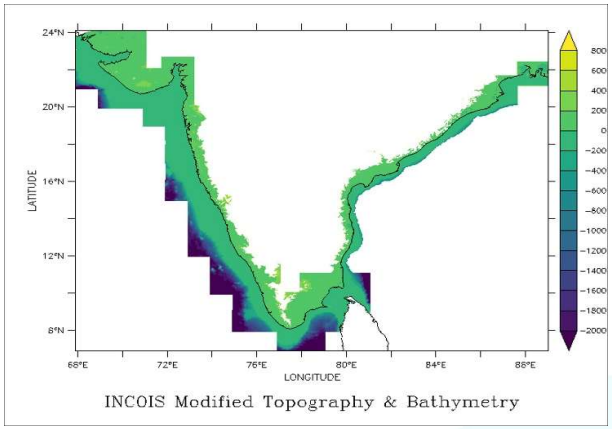
Components of Geospatial Technology

2018 Humanitarian Needs Overview (HNO)

BMKG

Tsunami Inundation modeling and vulnerability mapping



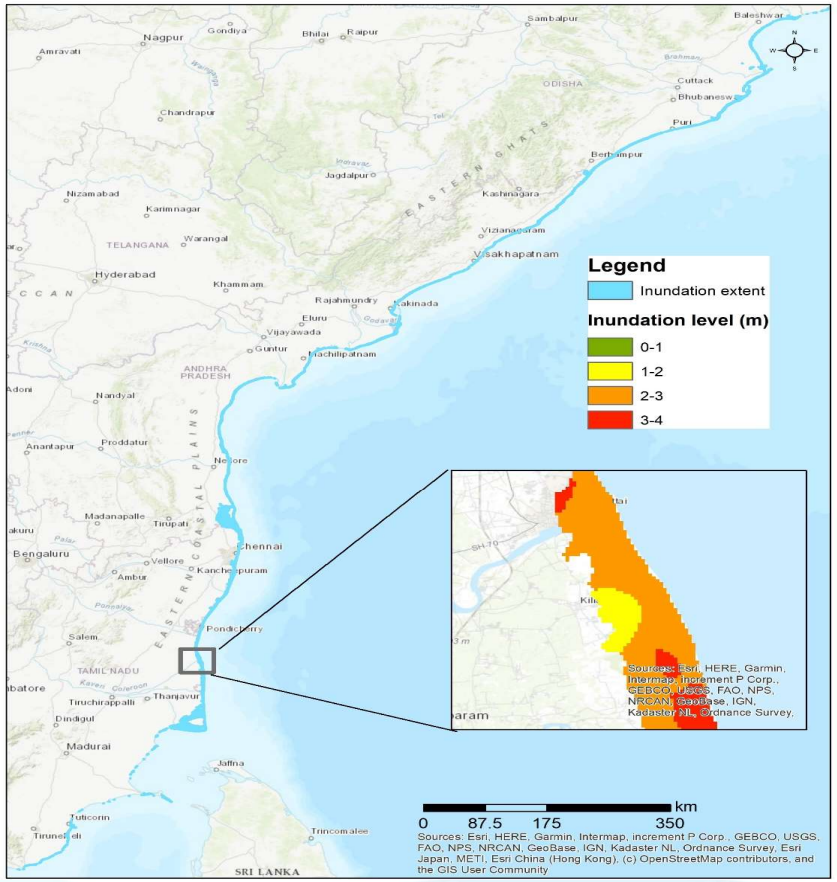


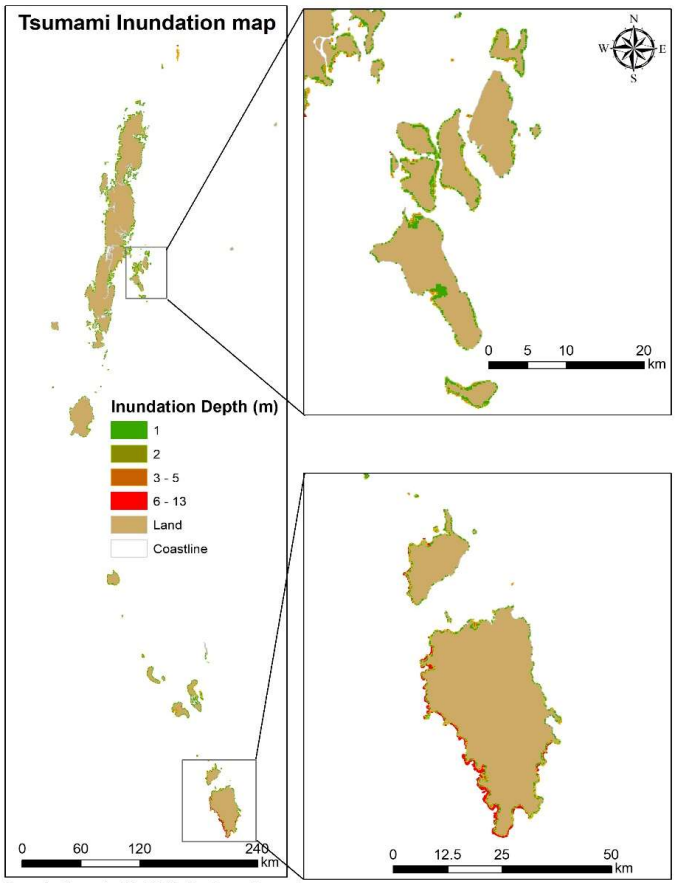
- ALTM data for the Indian Mainland
- Carto-DTM for the Indian Mainland.
- Merged hybrid data from ALTM, Carto-DTM and Terrasar-x data for Andaman and Nicobar Islands
- Bathymetry data available from all the sources

Historical & Worst case scenario

Parameters	Source	Longitude	Latitude	Magnitude
Sumatra 2004	Sumatra	95.85^0 E	3.32^0 N	9.3 Mw
Car Nicobar 1881	Car Nicobar	92.43	8.52	7.9 Mw
Andaman 1941	North Andaman	92.5^0 E	12.1^0 N	7.7 Mw
Marakan 1762	Arakan	94	19	8.8 Mw
Worst-Case	Car Nicobar	92.43	8.52	9.3 Mw
Worst-Case	North Andaman	92.43	8.52	9.3 Mw

Mapping of Coastal Vulnerability to Tsunamis





Scenario: December 26, 2004 Indian Ocean Tsunami

Source of Topograpghy: ALTM+TerrasarX

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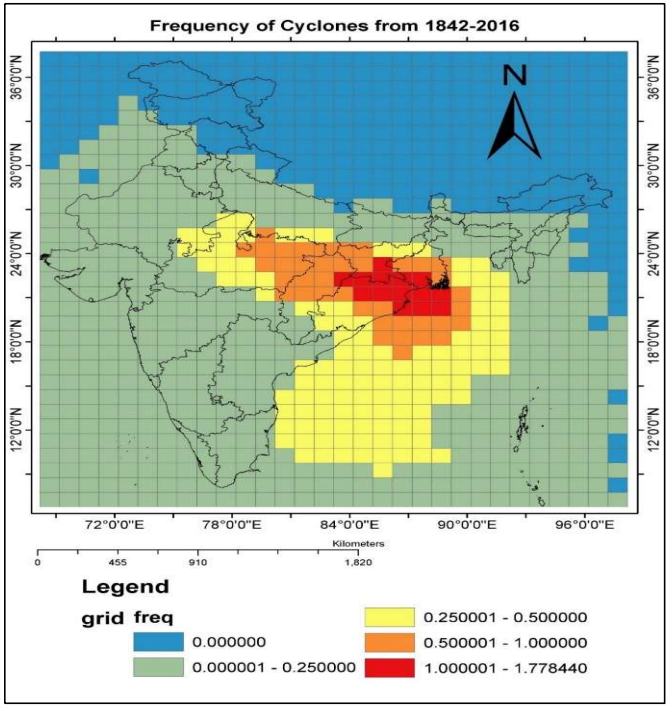
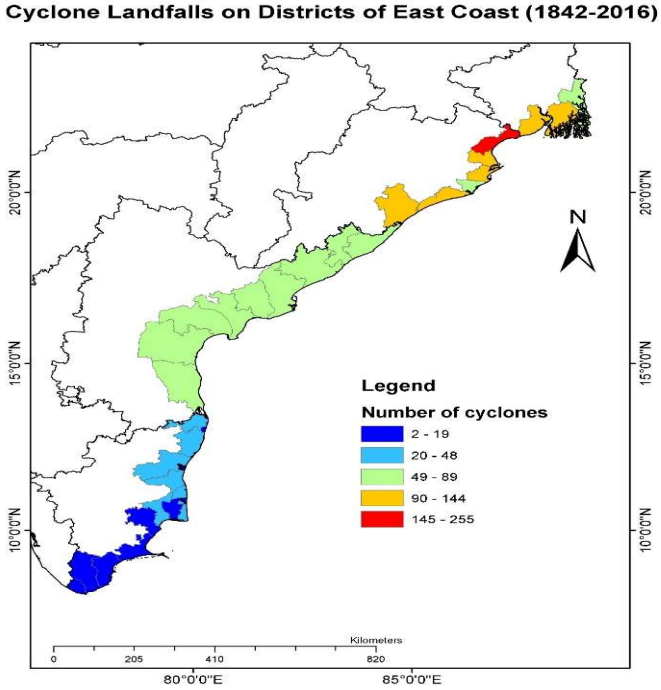
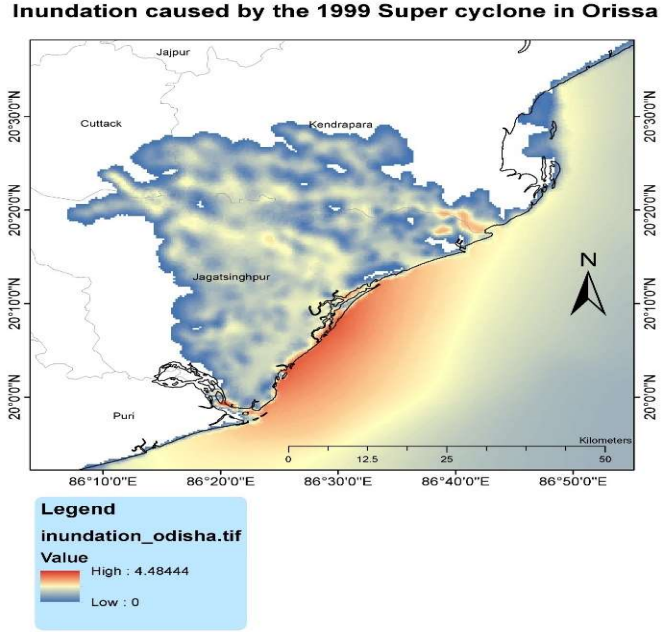
Mapping of Coastal Vulnerability to Cyclone (storm surge)







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Assessment of Coastal Vulnerability Indices (CVI)

Methodology

Input Parameters

- Geological: Coastal Geomorphology; Coastal Regional Elevations; Coastal Slope; Shoreline-change Rate
- Physical: Sea-level-change Rate; Mean Significant Wave Height; Tide Range

Analysis

Risk Rating

$CVI = \sqrt{[(a*b*c*d*e*f*g)/7]}$

Where

a = Shoreline change rate (m/y)
b = Sea level change rate (mm/y)
c = Coastal slope (degree)
d = Significant wave height (m)
e = Tide range (m)
f = Coastal regional elevation (m)
g = Coastal geomorphology

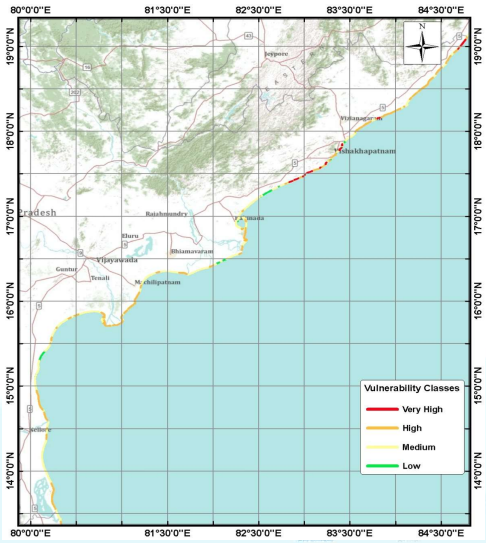
Output

CVI Maps

Coastal Vulnerability Atlas

Data Used

Parameter	Data
Geomorphology	IRS LISS-IV
Slope	GEBCO
Elevation	SRTM
Tidal Range	Astronomical tide from WXTide-32
Shoreline Change Rate	Landsat data (1972-2000)
Historical Sea Level	GLOSS long term tide gauge observation
Significant Wave Height	Simulated data from Mike model



Hazard: An event has the potential for causing loss or injury of life/property or environment Hazard

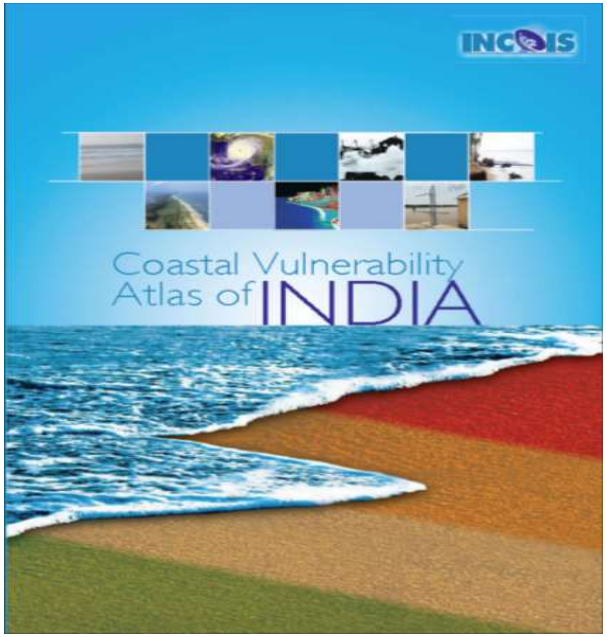
Disaster: An event characterized by destruction of life/property or environment by which a system can't cope itself and need external help.

Vulnerability: A system is exposed to hazards which as being damaged or distributed

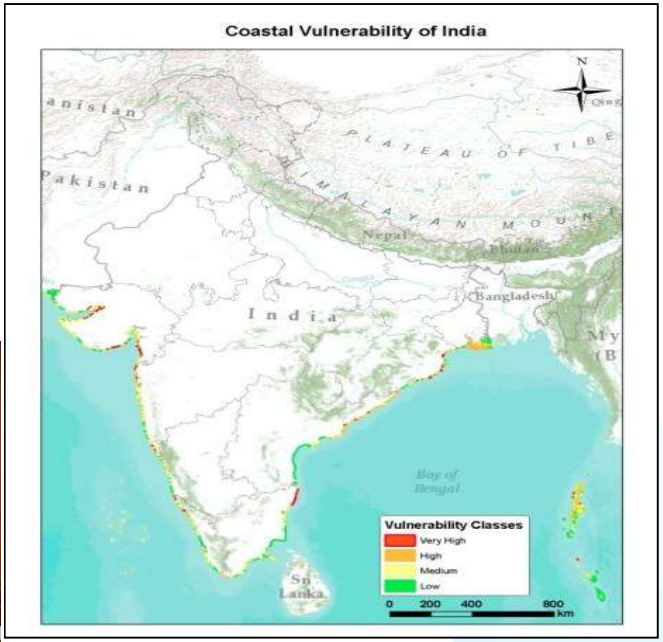
Risk: Measured expected loss due to exposed hazards in a given area at a particular time.

Coastal Vulnerability Atlas

CVI Atlas covering Indian coast comprising 156 maps on 1:1lakh scales has been prepared and released on May 09, 2012



Atlas Released
on 10/05/2012



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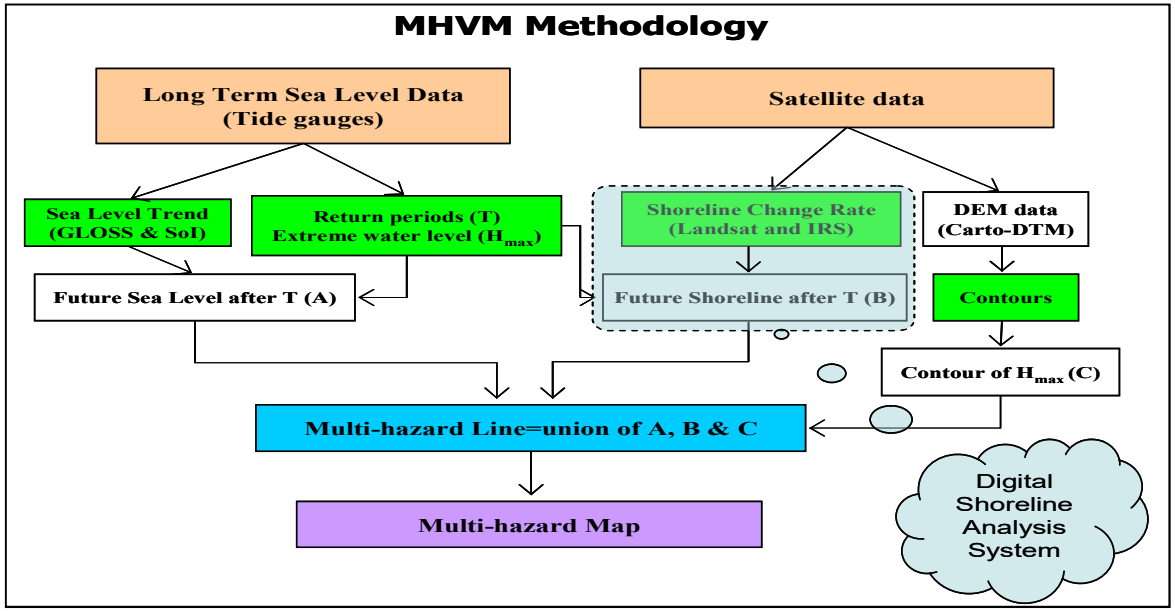
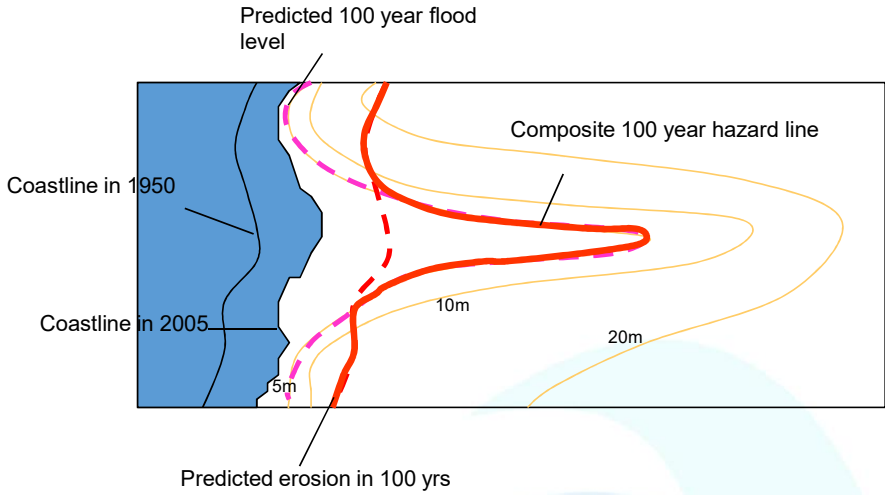
INCOIS, (2012). Coastal Vulnerability Atlas of India. INCOIS-ASG-CGAM-CV-2012-01, Pages 212, Maps 156, INCOIS, Hyderabad, India. ISBN 978-81-923474-0-0.

Coastal Multi-hazard Vulnerability Assessment

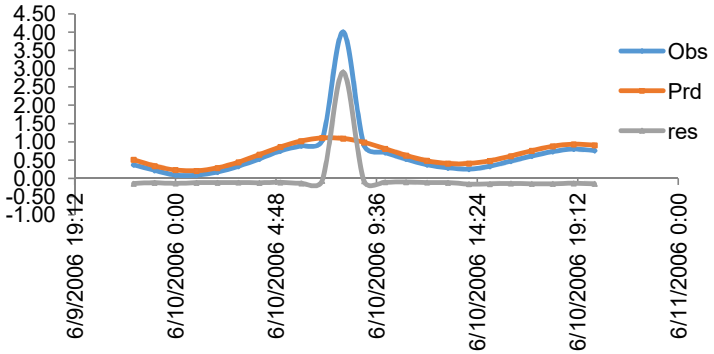
"The Multi-Hazard Map is a "composite, synthesized and overlay of multiple hazards"

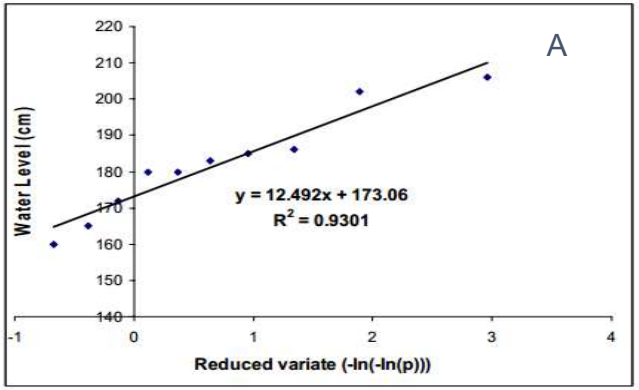


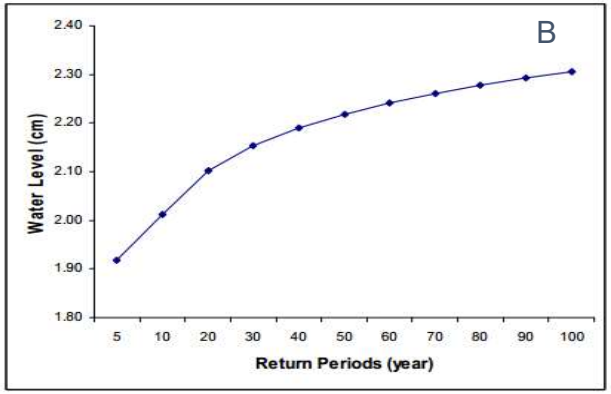


Data	Resolution (m)	Period	Parameters
ALTM	5	2007	Elevation Contours
Carto DTM	10	2006-07	
Landsat, MSS	57-30	1972-2000	Shoreline Change
Tide gauge	--	1952-2005	Sea Level Change
Hourly Tide gauge data and published literature	--		Extreme Water Levels

Assessment of extreme water level from historical tide data







Probability of non-exceedence

Where,
'm' is rank of the variable (Water level)
'N' is the total number of observations

Return Period

Where,
'U' is the extreme water level
'R' is the return period in years,
'a' is the slope (fig.A)
'u' is the intercept (fig.A)

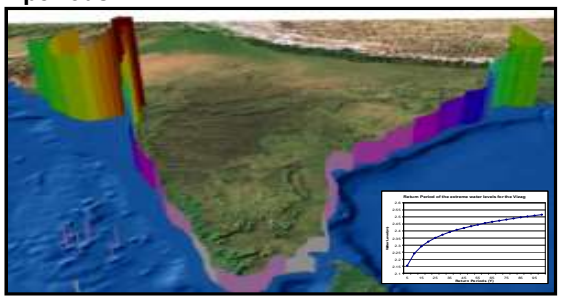
- The SLRP-2 has been used to calculate the predicted data to estimate the residuals
- Extreme Water level return period was estimated for the above stations based on the Grigorton probability distribution method

Coastal Multi-hazard Vulnerability Assessment

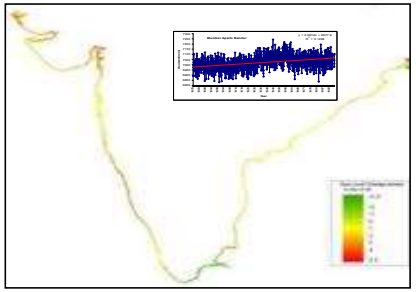
INPUTS

High Resolution Topography

Extreme Water Level and return periods



Sea-level Change Rate

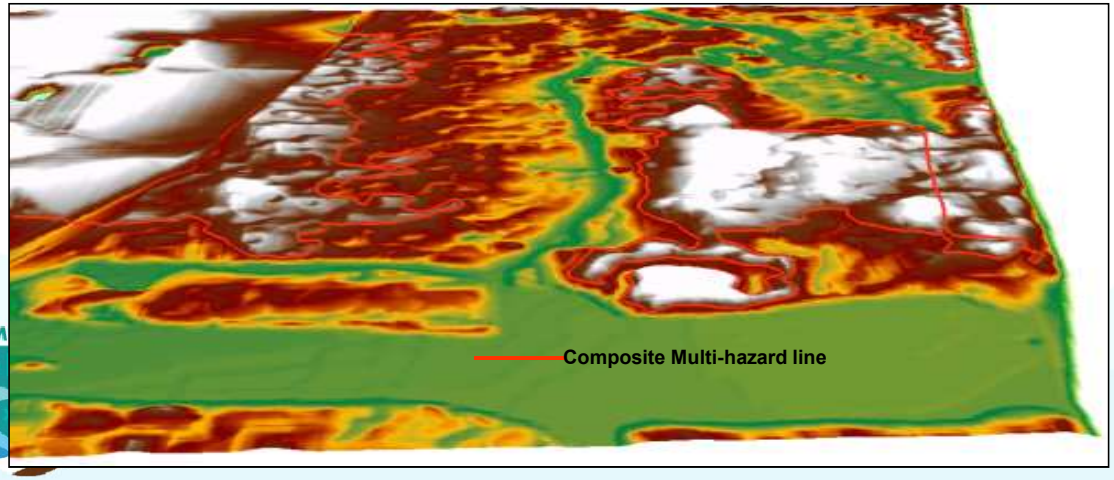


Shoreline Change Rate

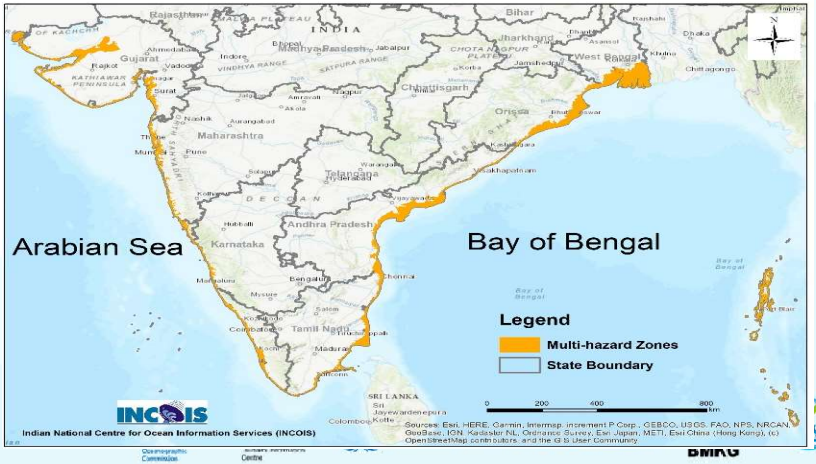
SYNTHESYZED SPATIAL OVERLAY ANALYSIS

OUTPUTS

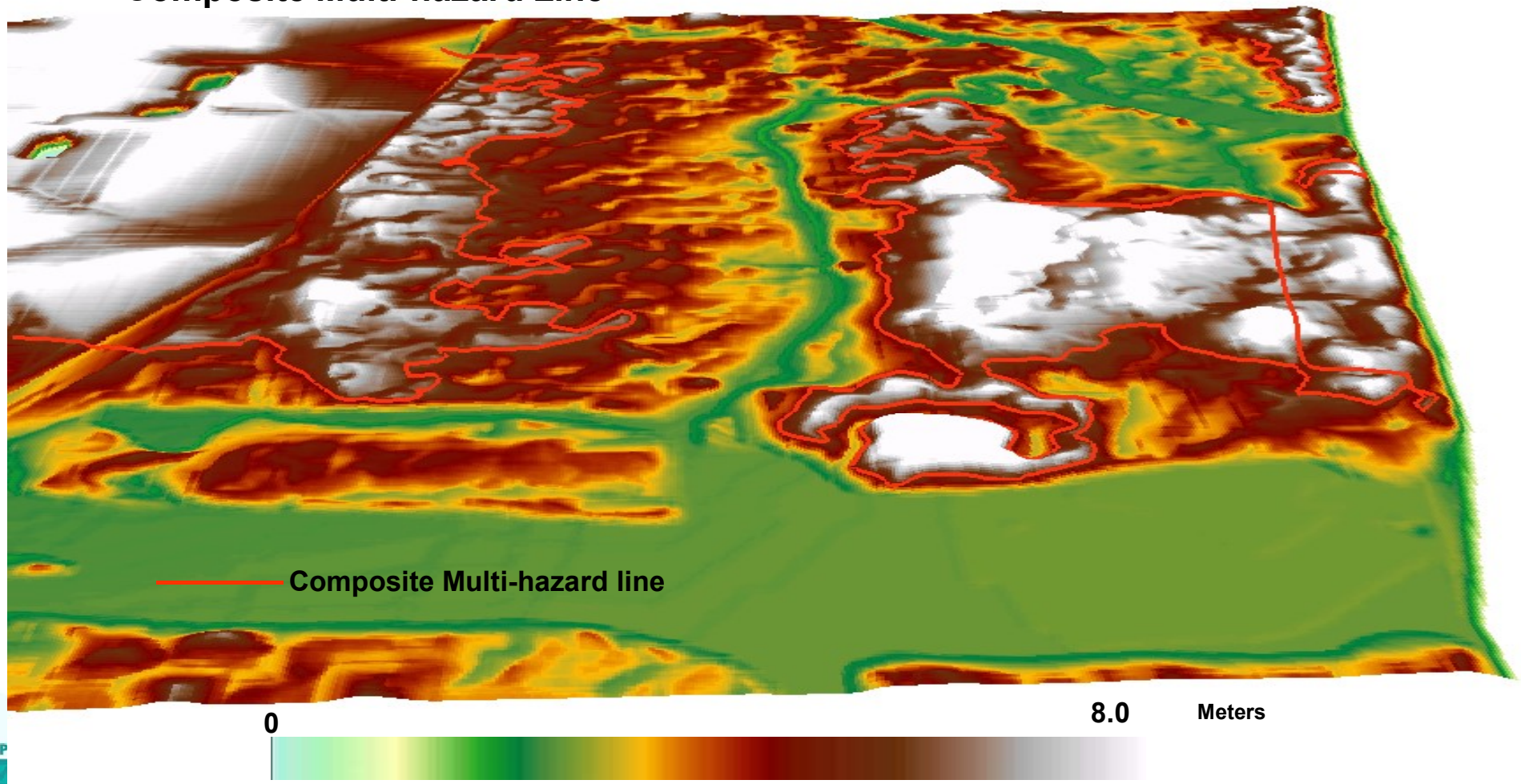
Composite Multi-hazard Line



Multi-hazard Vulnerability Map



Composite Multi-hazard Line

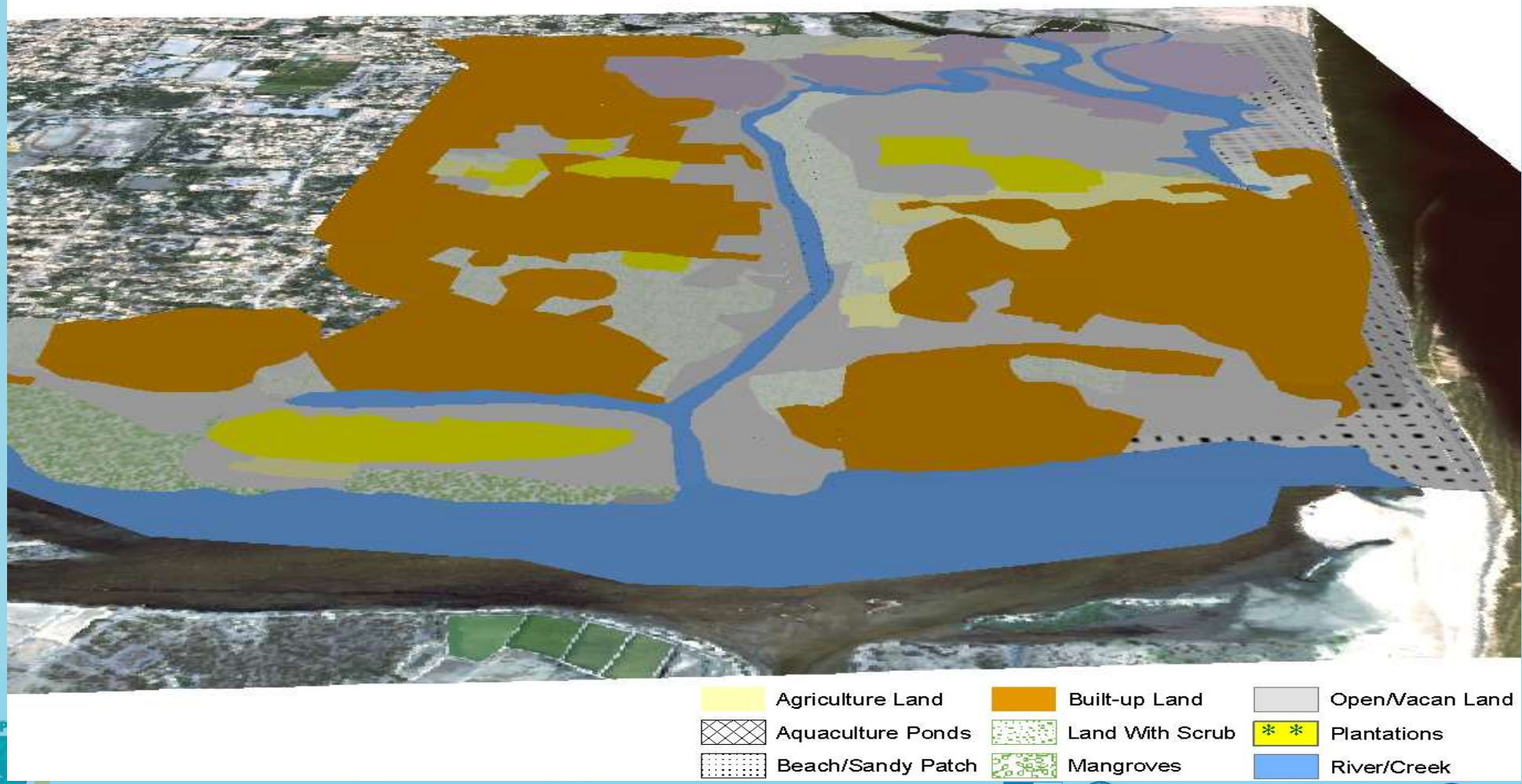


Multi-hazard Zones

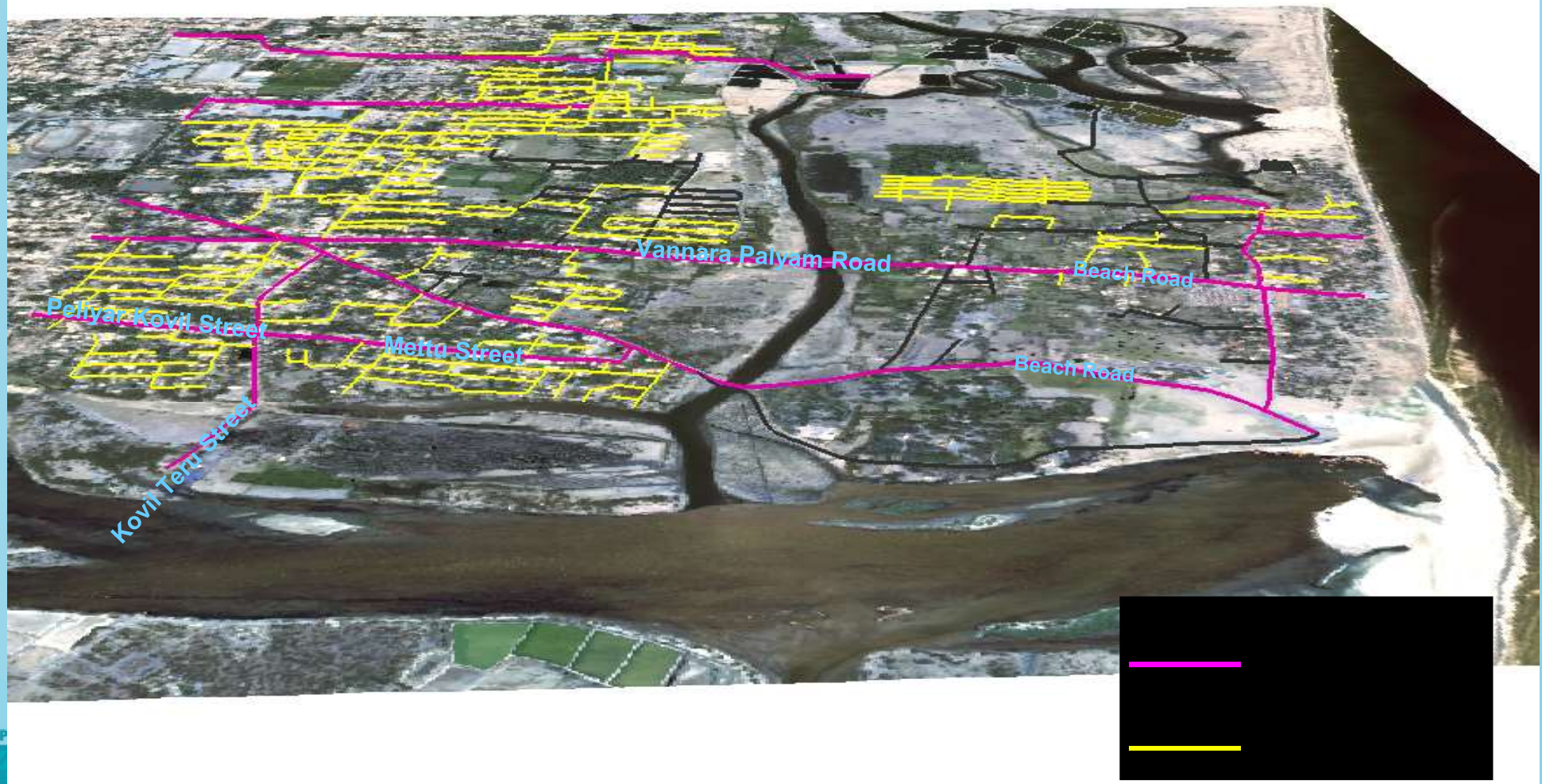
Hazard Zone

Safe Zone

Landuse/Landcover



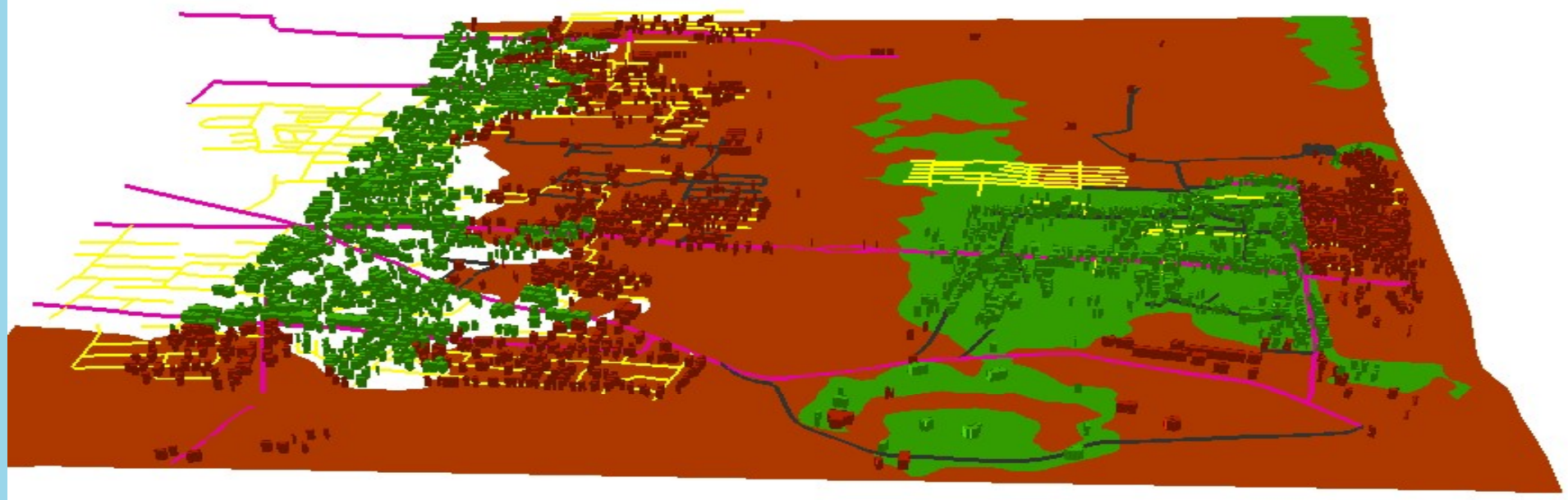
Roads


Vannara Palyam Road
Beach Road
Beach Road
Pelliyar Kovil Street
Meitu Street
Kovil Teru Street

Buildings

Buildings

Layer Integration



Hazard Zone

Safe Zone

Buildings

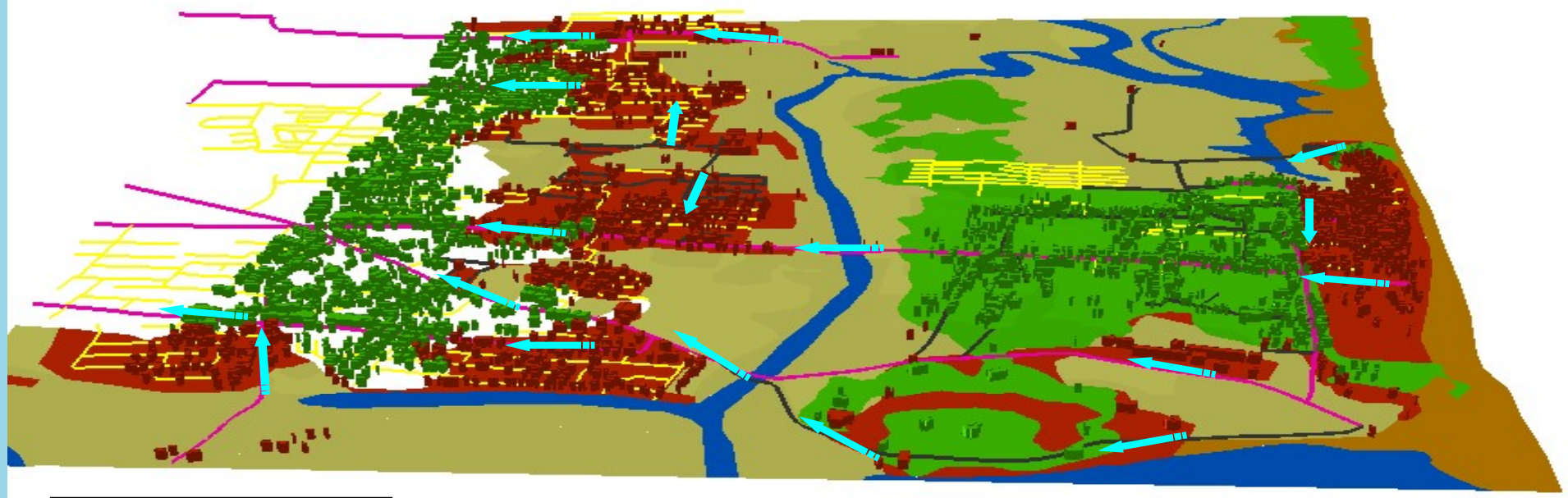
Hazard

Safe

Risk Map

Risk
High
Moderate
Low
No Risk

Hazard Management



Risk

- High
- Moderate
- Low
- No Risk

Buildings

- Hazard
- Safe

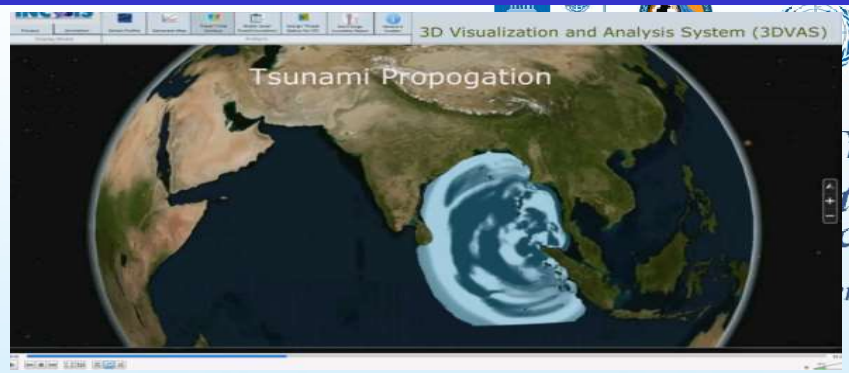
Roads

- Major
- Minor
- Streets
- Evacuation Routs

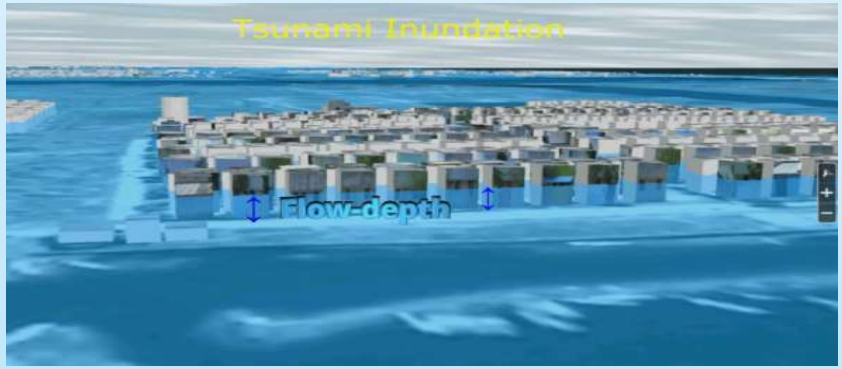
3D GIS Mapping

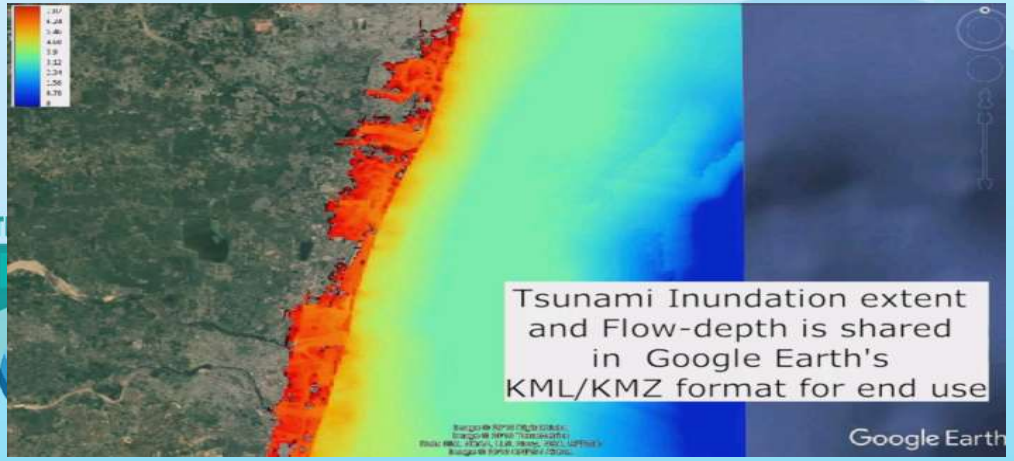
Coastal Risk Assessment at Building level

Inundation Modelling and risk assessment in 3DVAS

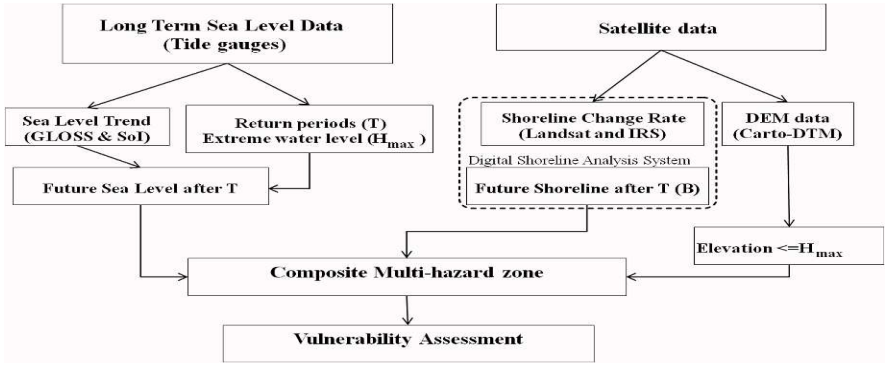


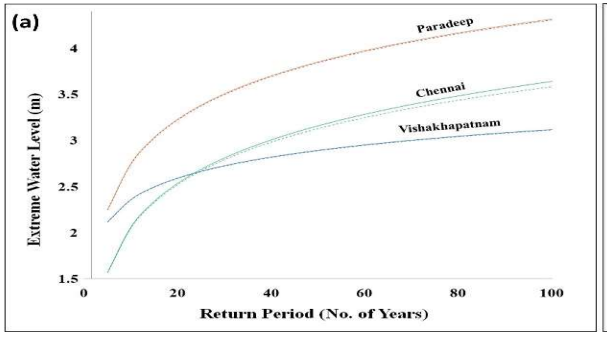
Model setup, propagation and inundating modeling,
Overlay of the modeling results and risk assessment at building level and generation of outputs

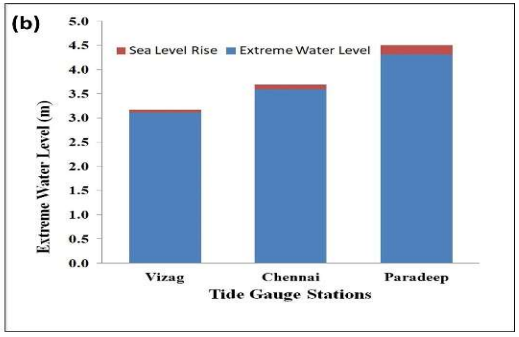


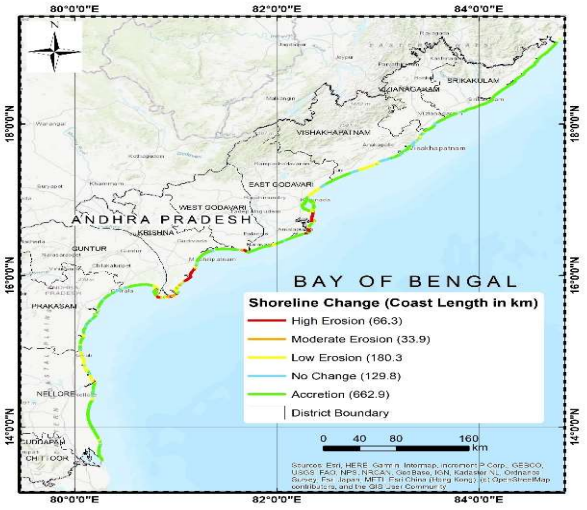


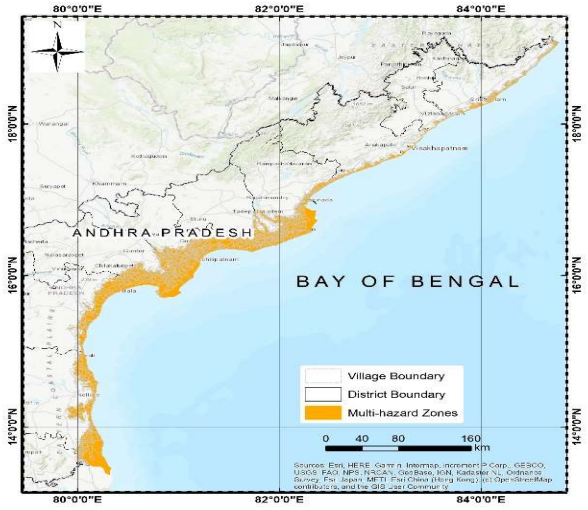
MHVM risk assessment up to village level

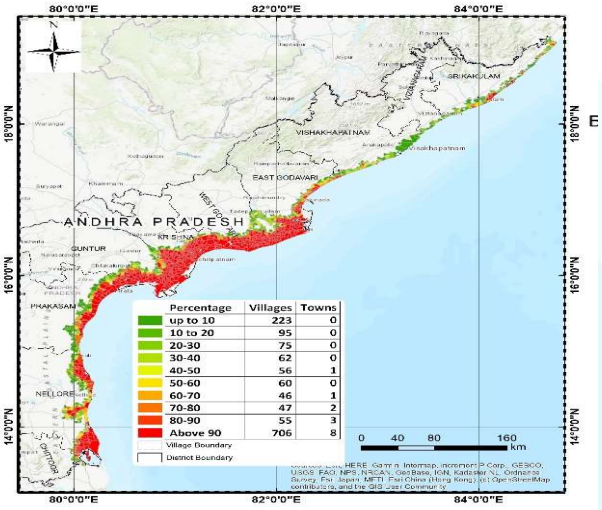










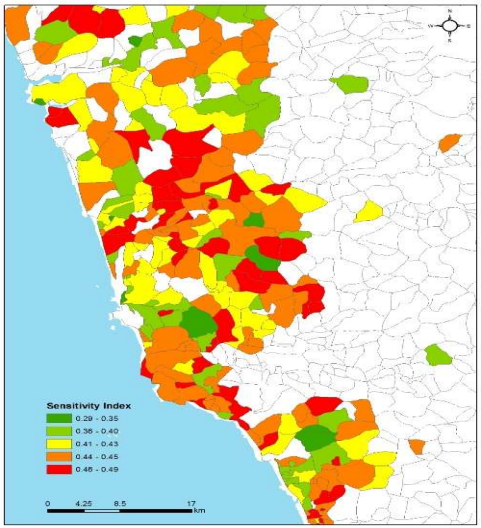


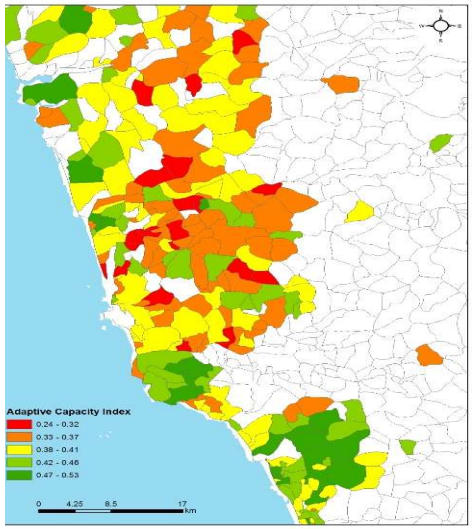
Mahendra et al., 2021

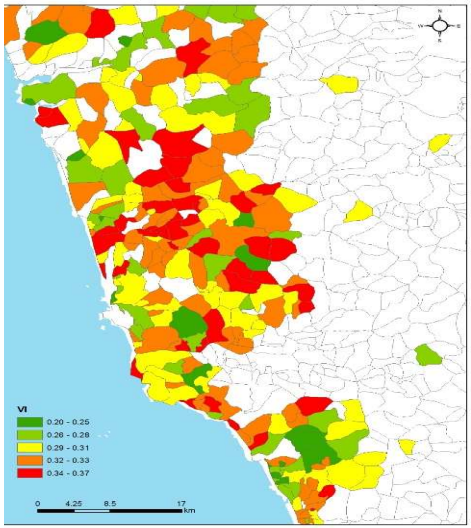
Socio-Economic Vulnerability Index case study1

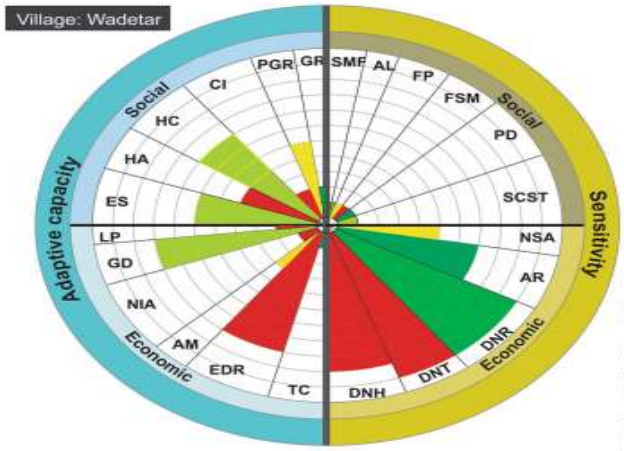
Sensitivity (social)	
(1)	Small and marginal farm(ers) (SMF)
(2)	Agriculture labourers (AL)
(3)	Fishers population (FP)
(4)	Malnutrition (FSM)
(5)	Population density (PD)
(6)	SC/ST population (SCST)
Sensitivity (economic)	
(7)	Net sown area (NSA)
(8)	Annual rainfall (AR)
(9)	Dependence on natural resource (DNR)
(10)	Distance to nearest town (DNT)
(11)	Distance to nearest hospital (DNH)
Adaptive capacity (social)	
(1)	Education status (ES)
(2)	Household amenities (HA)
(3)	Housing condition (HC)
(4)	Community infrastructure (CI)
(5)	Population growth rate (PGR)
(6)	Gender ratio (GR)
Adaptive capacity (economic)	
(7)	Transport and communication (TC)
(8)	Economic dependency ratio (EDR)
(9)	Access to market (AM)
(10)	Net irrigated area (NIA)
(11)	Groundwater development (GD)
(12)	Livestock population (LP)

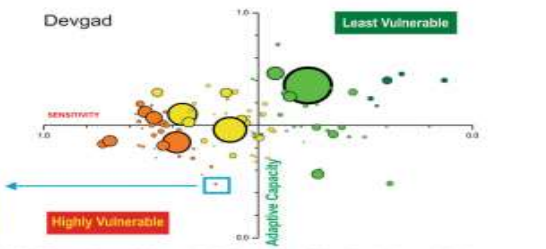
33-indicators











SMF-Small and Marginal Farmers, **AL**-Agricultural Labourers, **FP**-Fishers Population, **FSM**-Food Sufficiency/ Malnutrition, **PD**-Population Density, **SCST**-Schedule Castes/Schedule Tribes Population, **NSA**-Net Sown Area, **AR**-Annual Rainfall, **DNR**-Dependence on Natural Resources, **DNT**-Distance to Nearest Town, **DNH**- Distance to Nearest Hospital, **TC**-Transport and Communication, **EDR**- Economic Dependency Ratio, **AM**- Access to Market, **NIA**- Net Irrigated Area, **GD**- Groundwater Development, **LP**-Livestock Population, **ES**-Education Status, **HA**-Household Amenities, **HC**- Housing Condition, **CI**- Community Infrastructure, **PGR**- Population Growth Rate, **GR**- Gender Ratio

Fig. 8 Illustration of status of contributing factors for a representative village in Devgad for intervention planning (*red* most important, *green* least important)

Ambio
https://doi.org/10.1007/s13280-018-1061-8
KUNGL. VETENSKAPS AKADEMIEN
CrossMark
RESEARCH ARTICLE

Framework for mapping the drivers of coastal vulnerability and spatial decision making for climate-change adaptation: A case study from Maharashtra, India

Pandian Krishnan, Pachampalayam Shanmugam Ananthan, Ramachandran Purvaja, Jeyapaul Joyson Joe Jeevamani, John Amali Infantina, Cherukumalli Srinivasa Rao, Arur Anand, Ranganalli Somashekharappa Mahendra, Iyyapa Sekar, Kalakada Kareemulla, Amit Biswas, Regulagedda Kalpana Sastry, Ramachandran Ramesh

Socio-Economic Vulnerability Index case study2

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/envsci

Vulnerability assessment of coastal fishing communities for building resilience and adaptation: Evidences from Tamil Nadu, India

Thavasiyandi Umamaheswari [a], Gopalrajan Sugumar [a,*], Pandian Krishnan [b,*], Pachampalayam Shanmugam Ananthan [c], Arur Anand [d], Jeyapaul Joyson Joe Jeevamani [e], Ranganalli Somashekharappa Mahendra [f], John Amali Infantina [e], Cherukumalli Srinivasa Rao [b]

[a] Fisheries College and Research Institute, Tamil Nadu Dr. J. Jayalalithaa Fisheries University (TNJFU), Thoothukudi, 628 008, India
[b] ICAR-National Academy of Agricultural Research Management (NAARM), Rajendra Nagar, Hyderabad, 500 030, Telangana, India
[c] ICAR-Central Institute of Fisheries Education (CIFE), Versova, Mumbai, 400 061, India
[d] Regional Remote Sensing Centre, National Remote Sensing Centre (NRSC), ISRO, Nagpur, 440 033, India
[e] National Centre for Sustainable Coastal Management (NCSCM), Ministry of Environment, Forest and Climate Change, Anna University Campus, Chennai, 600 025, India
[f] Indian National Centre for Ocean Information Services (INCOIS), Ministry of Earth Sciences, Hyderabad, 500 090, India

54 indicators

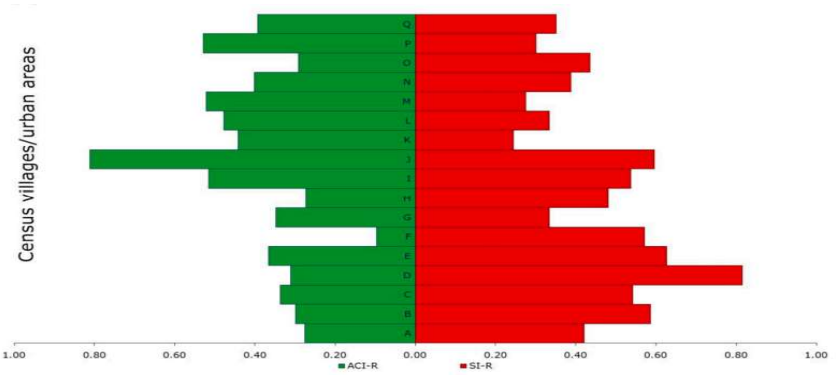


Fig. 4. Socio-economic sensitivity and adaptive capacity indices for (a) marine fishing villages ($SEVI_{PH}$) and (b) census villages corresponding to fishing villages ($SEVI_{SV}$) in the Thoothukudi district (Alphanumerics and alphabets indicate the names of marine fishing units and their corresponding census units, respectively, as shown in Table 2).

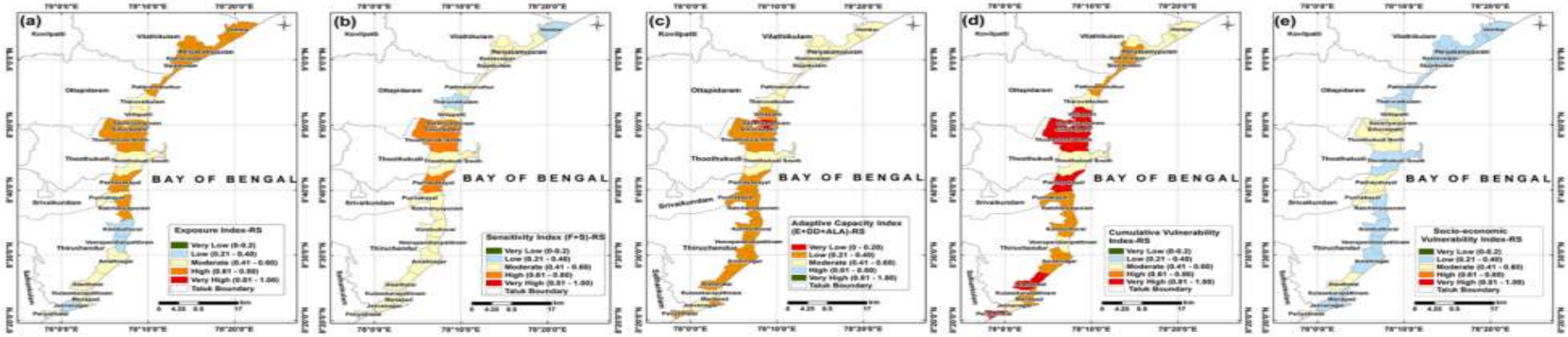
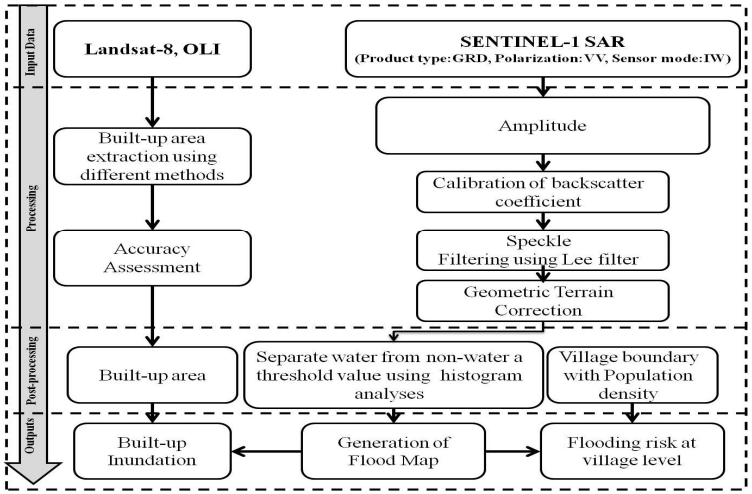
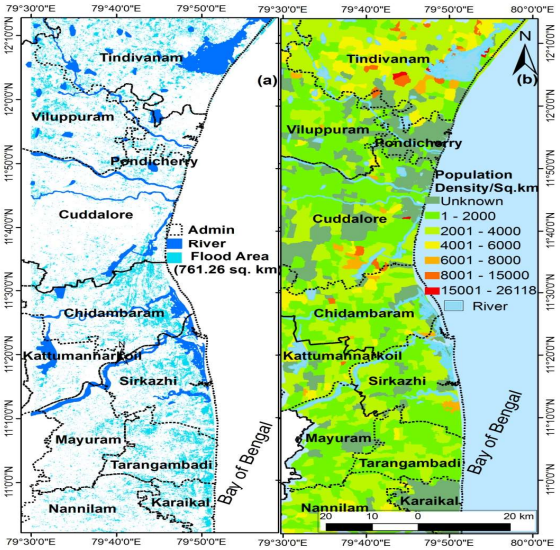


Fig. 3. Marine fishing village-wise (a) EI, (b) SI, (c) ACI, (d) CVI_{PH} and (e) $SEVI_{PH}$ obtained in relative scale (RS) [Note: Singithurai village is not shown in the map).

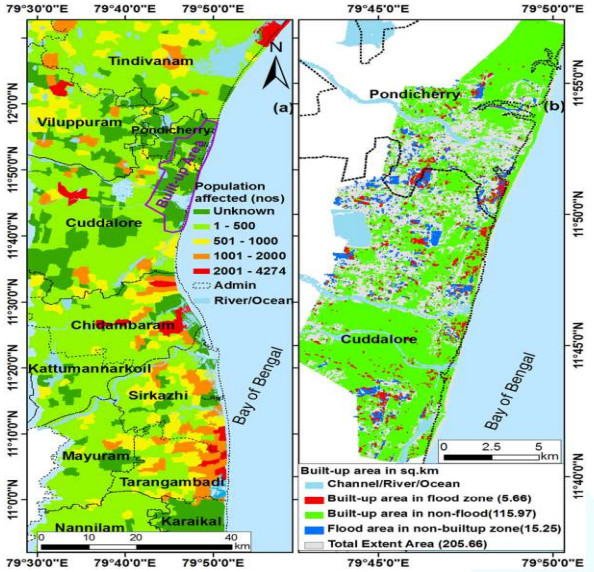
Geospatial assessment of flood hazard along the Tamil Nadu coast





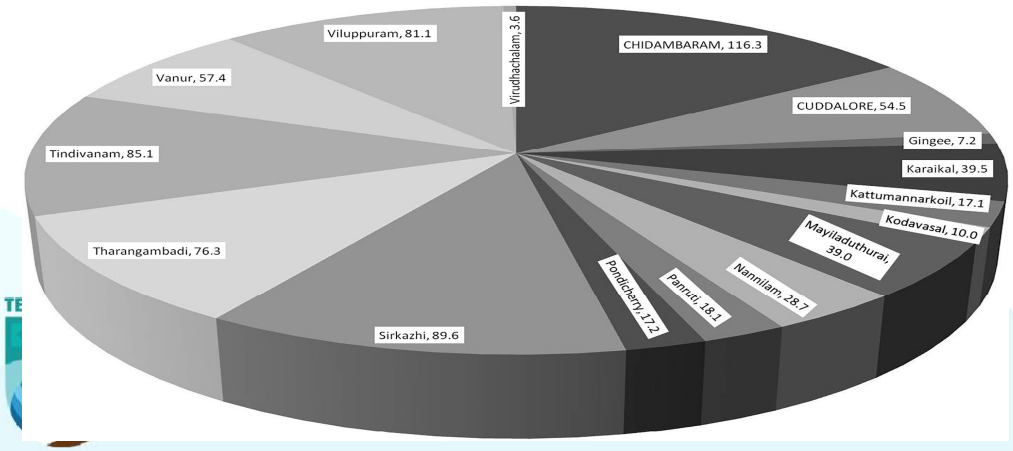
Flooding Areas

Population Density



Population In inundation

Built-up area In inundation



Flood period: November–December 2015

Mohanty et al., 2019

Thank you