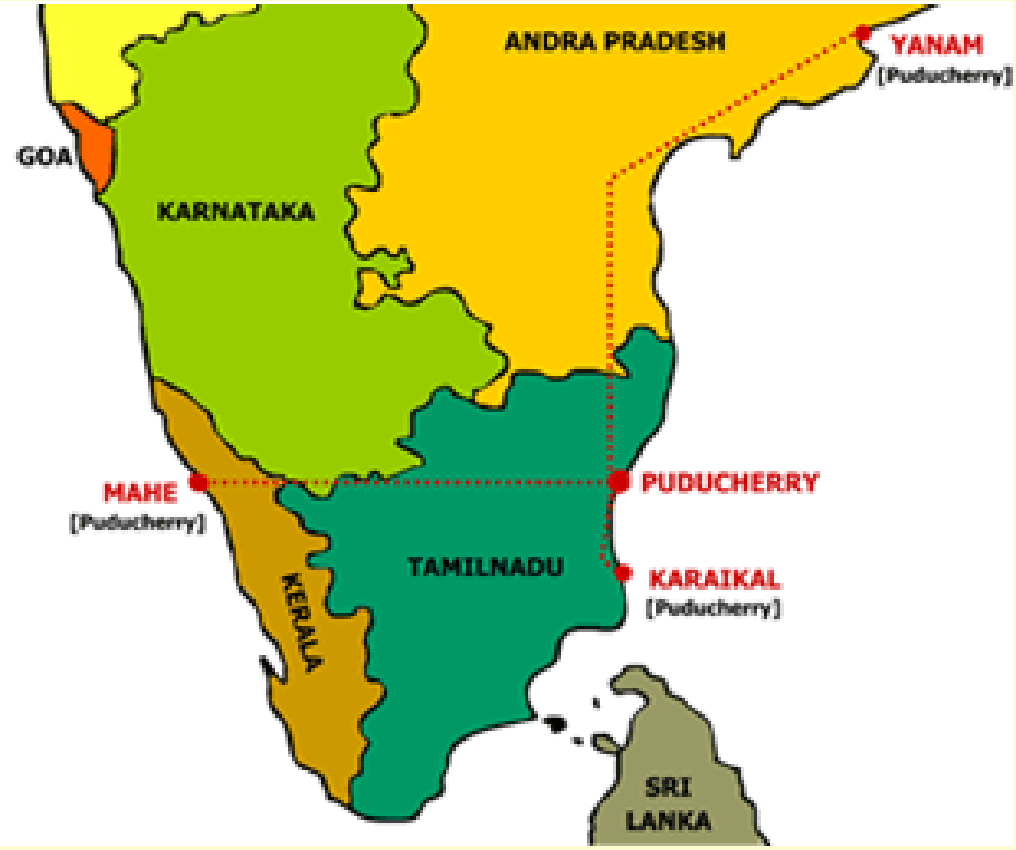
VULNERABILITY ANALYSIS ON CLIMATE CHANGE FOR U.T. OF PUDUCHERRY



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Government of Puducherry

GOVERNMENT OF PUDUCHERRY
DEPARTMENT OF SCIENCE, TECHNOLOGY & ENVIRONMENT
PUDUCHERRY

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Source: U.T. OF PUDUCHERRY ACTION PLAN ON CLIMATE CHANGE

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1.1. Introduction

Puducherry is a coastal UT in India which is disaster prone. Many of the vulnerabilities are driven by three important factors (1) socio-economic, (2) bio-physical and (3) climate sensitivity. They have their unique manifestation in the coastal region. Therefore the vulnerability with respect to climate change has to be examined more carefully in case of Puducherry. It has many contradictions as well. For example in terms of demography high population density exposes more people to climate change related events. But in the case of Puducherry low density pockets far from administrative units without requisite infrastructure makes them more vulnerable as compared to high density pockets (unique case is Mahe where the population density is high even though it is far from mainland). The Scheduled Caste population is about 16 per cent and majority are below poverty line from this segment. While increased densities of people and structures along the coast certainly account for a portion of these losses, other explanations include increased storm activity and the decreased ability of communities to rebound from disasters making them more vulnerable especially if they are very poor. The bio-physical factors have been extensively studied and vulnerability pockets have been identified in Puducherry. Some parameters include storm surge, erosion, mangrove loss, etc. In terms of climate sensitivity it also has only a single monsoon season and the reduction of rainfall coupled with urbanisation and tourist surge puts a lot of pressure on the groundwater.

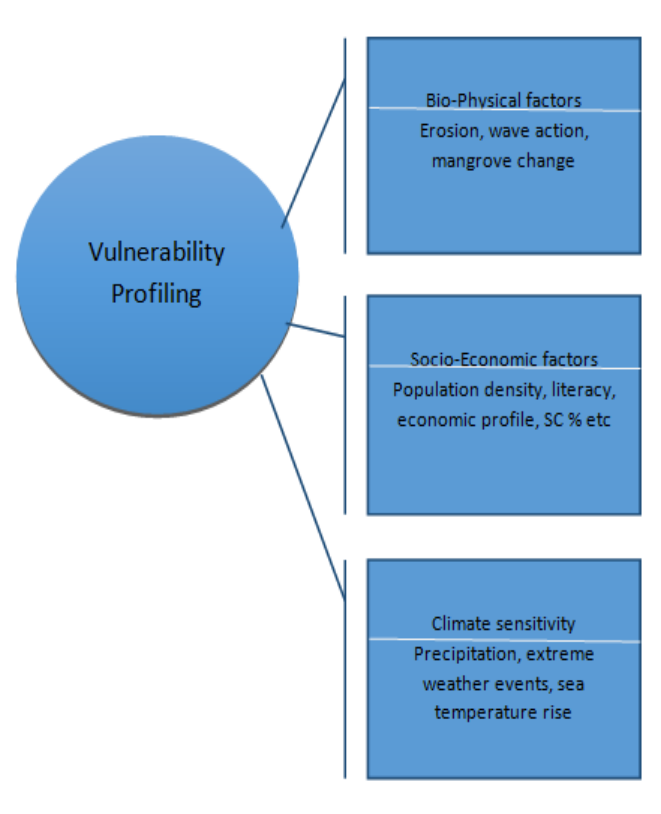

Figure 1: Vulnerability Profiling

1.2. Biophysical Factors

Climate change and associated sea-level rise changes the coastline. Not only ocean front but also shoreline dynamics around sheltered estuaries and minor ports make coastal infrastructure equally vulnerable.

1.2.1 Erosion and shoreline change

A study by Anna University that assessed data from 1972 to 2010 has found that low to medium erosion is found to occur along 1 km of the 24 km coast of Puducherry. This is about 4.2% of the total Puducherry coast except in Puducherry town area.

Table 1: Low to Medium Erosion

Classification of Coast	Extent (km)	Percent Coast	Cumulative (%)	Locations
Length of coastline including river mouth and ports	23.62			From North of Puducherry port to Tingattittu.
High erosion zone				Bommaiyapalayam and Puducherry Old Port: some stability due to dune formation along a stretch near B. Palayam
Medium erosion zone	0.52	2.20		From North of Puducherry port to Tingattittu.
Low erosion zone	0.46	2.00		
Artificial coast, sea-wall / riprap	6.18	26.20	30.30	
Stable Coast	9.27	39.20	39.20	Kirumambakkam in North to River Mouth of Gadilam river in South
High Accretion Zone				Sivanthpuram in north to Manapattu in south
Medium Accretion Zone	2.19	9.30		Podukuppam and Periyamudaliyarchavadi (coast is stable)
Low Accretion Zone	5.00	21.20	30.40	
No of Ports/harbours	2.00			
No of Fish landing centres	21.00			
No of Groynes and backwaters	7.00	100.00		

(Source: National Assessment of Shoreline Change: Puducherry Coast by Ramesh et.al (2011))

Figure 2: Status of Shoreline change Puducherry Coast

**Source: National Assessment of Shoreline Change: Puducherry Coast by Ramesh et.al (2011)*

The Karaikal coast is about 17.3 km including river mouth; 3.98 km or 23% of the coast is "stable" where there is no shoreline change. About 46% of the total coast is accreting. Low erosion zone is about 11.5%.There is also no shoreline protection structure or ripraps.

The shoreline change also occurs due to littoral drift and shore structures. But the warming of the sea surface and resultant wave action, expedites the erosion rate. The entire coastal extent between Muthialpet and Kirumampakkam as well as the northern part of Kalapet is designated as the high vulnerability zone which constitutes 50% of the coastline. The region between the southern coastal extent of Kalapet and Lawspet is the medium vulnerability zone and the rest 25% is the low vulnerability zone based on this shore dynamics that include (slope, geomorphology of the coast, elevation, shoreline change, sea level rise, wave action).

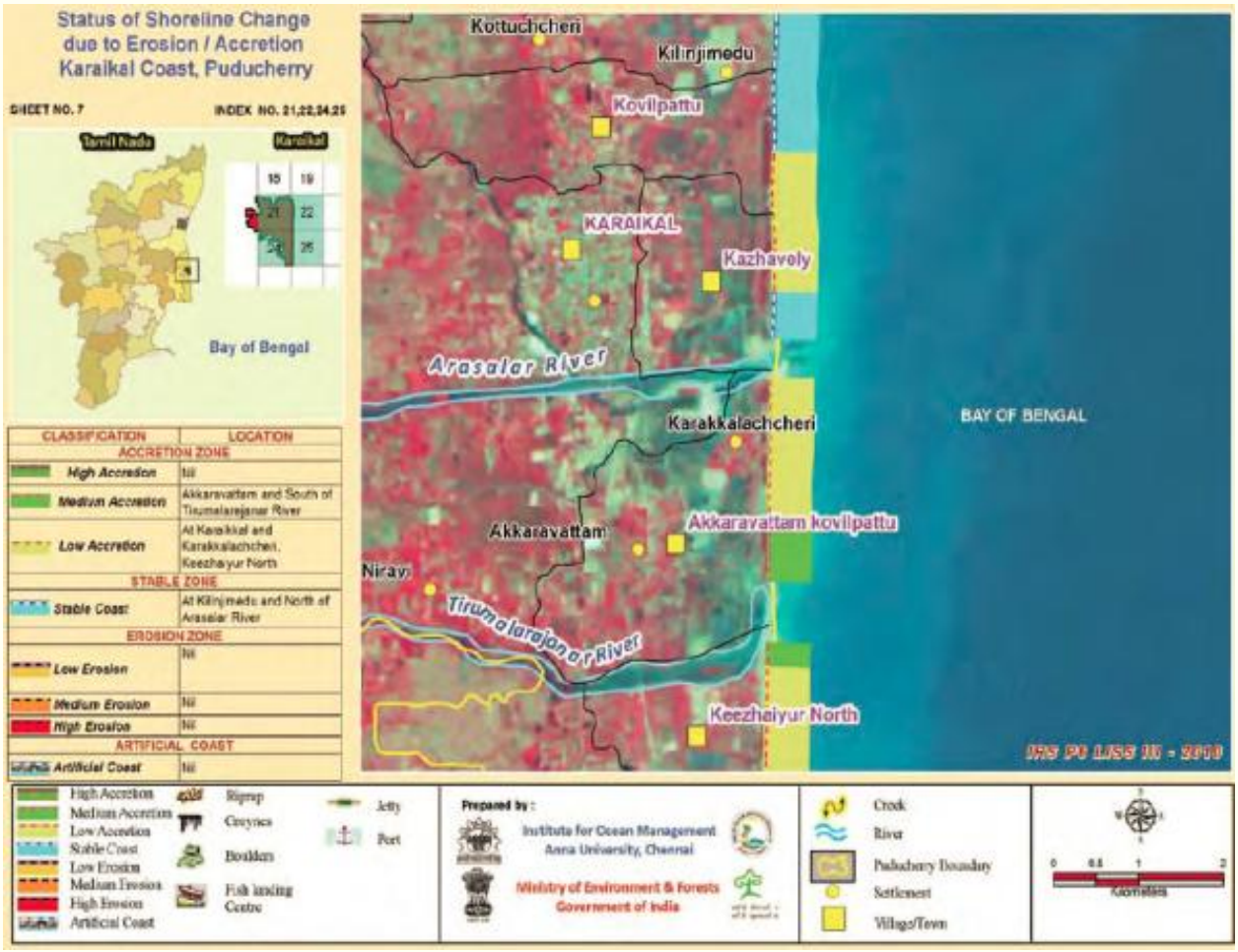

Figure 3: Status of Shoreline change Puducherry Coast

**Source: National Assessment of Shoreline Change:Puducherry Coast by Ramesh et.al (2011)*

In summary Puducherry coast is stabilised artificially and not all points due to shoreline change is at risk. In Karaikal protection structures are not there and many parts are low to medium erosion zones and may have high littoral drift. However, protection structures also can cause both active and passive erosion of the beach. An unstable coast and highly eroded beach causes the maximum vulnerability.

The major causes of shoreline change are anthropogenic in nature:

(a) Construction in eco-sensitive zone

(b) Pollution through unregistered hatcheries

(c) Loss of bio-diversity due to agricultural land use change to aquaculture and loss of mangroves.

The vulnerable points identified in the high and medium erosion zones need attention for the future planning while effort is needed to maintain the shore stability in other areas (low accretion zone).

1.2.2 Forest and Land Use Change

As per the Forest Survey of India (2011) the forest cover in Puducherry is 50.06 sq. km which is about 10.43% of the geographical area of the UT.Low forest cover and rapid land use change is a major factor that contributes to the vulnerability in this region.

Table 2: Forest Area of Puducherry

District	Geographical Area	2011 Assessment				Percent of GA	Change	Scrub
		Very Dense Forest	Mod. Dense Forest	Open Forest	Total			
Karaikal	161	0	7.39	1.56	8.95	5.56	0.00	0.00
Mahe	9	0	1.36	3.54	4.90	54.44	0.00	0.00
Puducherry	293	0	24.62	8.59	33.21	11.33	0.09	0.00
Yanam	17	0	2.00	1.00	3.00	17.65	0.00	0.00
Grand Total	480	0	35.37	14.69	50.06	10.43	0.09	0.00

**Source: FSI (2011)*

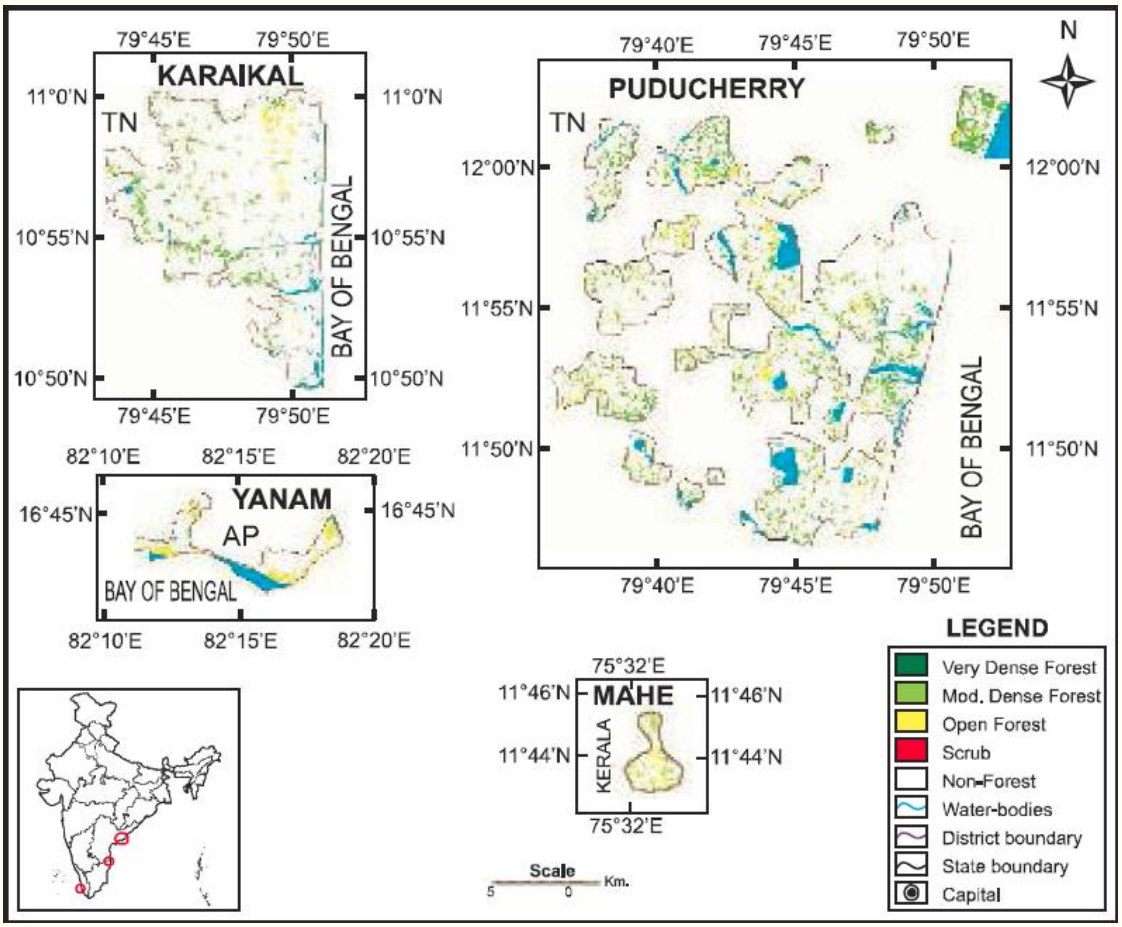

Figure 4: Distribution of Forest in Puducherry

**Source: FSI (2011)*

The change matrix shows that the change is only in Puducherry and in the category of open forest category (1.18 sq. km decrease) and gain of 1.27 sq. km in moderately dense forest category.

The land use pattern for Puducherry and Karaikal are given below.

Table 3: Land Use Pattern Puducherry

Sl. No.	Classes	Area (sq. km)	Percentage
1	Agriculture	15.25	10.80
2	Airport	0.10	0.10
3	Aquaculture	0.20	0.10
4	Dune with Vegetation	1.74	1.20
5	Dune without Vegetation	0.86	0.60
6	Fallow Land	4.99	3.50
7	Land with Scrub	6.45	4.60
8	Land without Scrub	4.49	3.20
9	Mudflat	0.33	0.20
10	Plantation	43.53	30.70
11	River	8.52	6.00
12	Sand	0.04	0.00
13	Sandy Beach	2.65	1.90
14	Settlement	37.47	26.50
15	Settlement with vegetation	13.03	9.20
16	Tank	1.58	1.10
17	Transportation (Helipad)	0.26	0.20
18	Water Logged Area	0.11	0.10

Table 4: Land Use Pattern Karaikal

Sl.No.	Classes	Area (sq. km)	Percentage
1	Agriculture	5.19	6.60
2	Dune with Vegetation	0.07	0.10
3	Dune without Vegetation	0.15	0.20
4	Fallow Land	10.71	13.60
5	Industry	0.17	0.20
6.	Land with Scrub	0.14	0.20
7	Plantation	37.78	47.80
8.	Port	1.34	1.70
9.	River	2.45	3.10
10	Salt affected Land	0.27	0.30
11.	Sand	0.59	0.80
12	Sandy Beach	1.21	1.50
13	Settlement	3.62	4.60
14	Settlement with vegetation	14.39	18.20
15	Tank	0.55	0.70
16	Water Logged Area	0.33	0.40
	Total	78.99	100%

From the la

vegetation (approx. 3% of the total land) comprises of those which are along the settlements. Only 3-4% of the total area comprises of the sandy beaches. The urban area covers about 9.8% of total land-use/land-cover. The main areas of urban agglomeration are Puducherry, Kalapet and hence have a very high to high vulnerability. Other areas have been ranked as low vulnerability as they have less urban built-up and are not entirely barren.

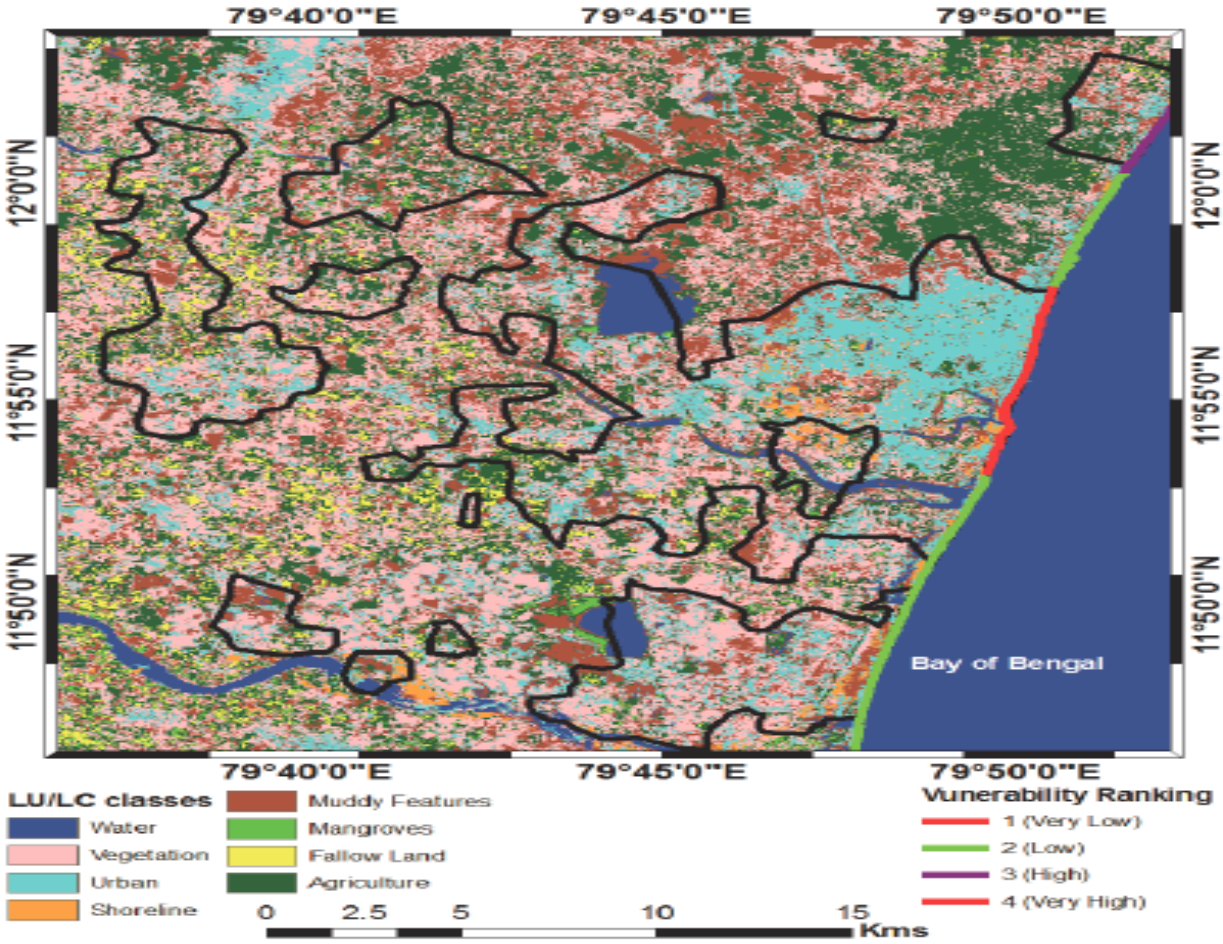

Figure 5: Coastal Vulnerability Puducherry

(Source: R Mani, Murali et.al (2011) Coastal vulnerability assessment Puducherry. p.554)

The above map depictsthe vulnerability from a land use perspective. The composite hazard line[1] when overlaid with the river systems that flow in Puducherry (one fault system near Vellar river (towards Cudallore (TN)-Villipuram coast and other along Yanam along the river mouth and second overlay on the land use/land cover map, suggests that the most dominant land use patterns were:

(1) Plantation

(2) Settlement with vegetation;

(3) Fallow land; and

(4) Sand dunes.

[1] *The composite 100 years hazard line incorporates the effects of recurrent coastal hazards, including potential incremental effects induced by climate change (most notably sea-level rise) within the ICZM plans. The composite hazard line helps coastal planners by providing a minimum elevation above sea level to be applied for future development and is a highly effective method of minimizing property damage due to coastal flooding and erosion.*

The maximum limits of inundation could be little more than 10 sq. km along this coastal stretch, and our analysis indicates that it is the most vulnerable settlement to flooding.

The combined vulnerability profile of the coast is given in the map below. In this case while computing the social vulnerability the following factors have been included:

(a) Cultural heritage

(b) Road network

(c) Land use and land cover change

(d) Population.

However, we have a separate section of social vulnerability later in this chapter.

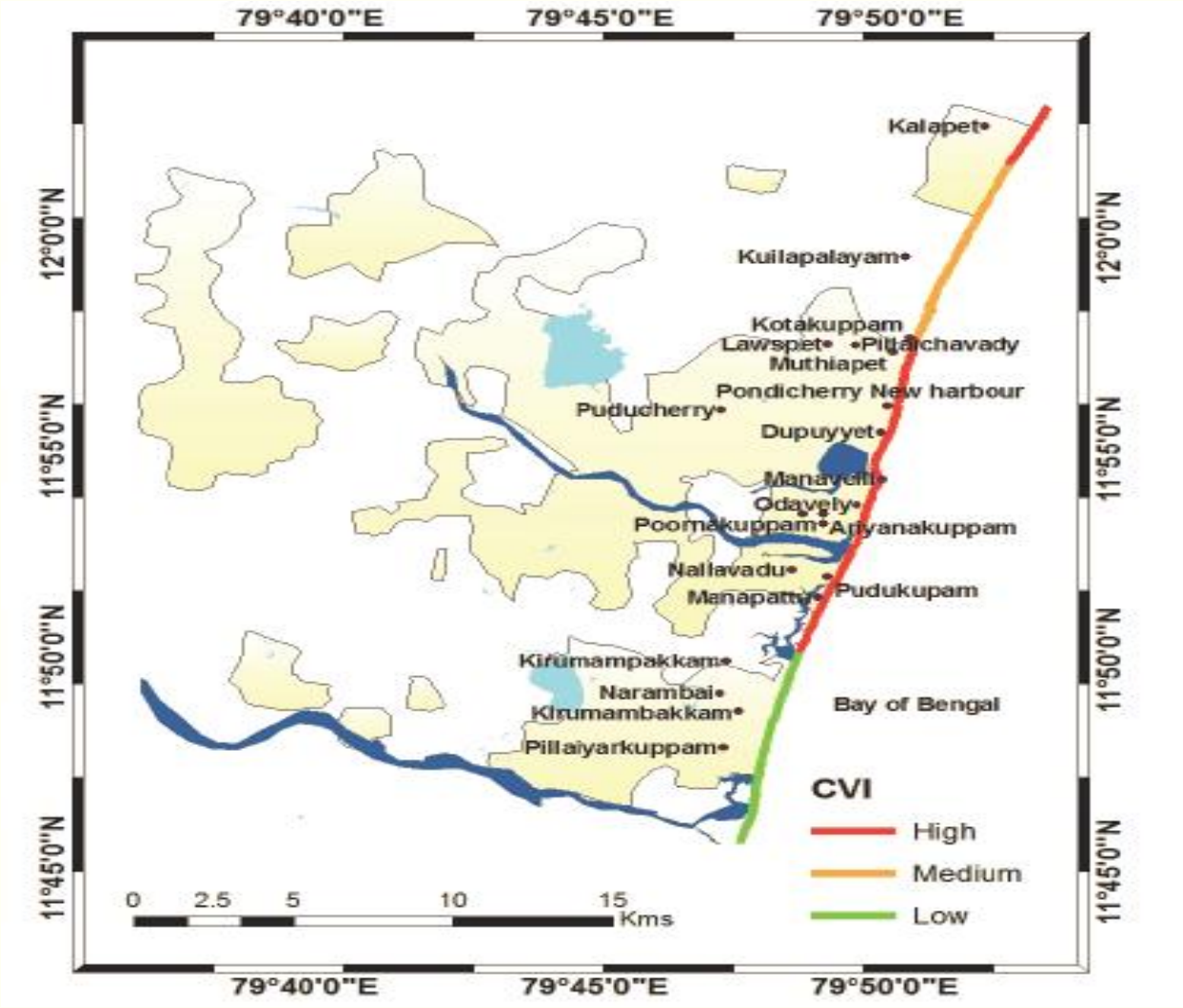

Figure 6: Combine Vulnerability along the coast

**Source: R Mani, Murali et.al (2011) Coastal vulnerability assessment Puducherry. p.554*

Apart from the social vulnerability parameters, the other bio-physical parameters include

(a) Tidal Range

(b) Significant Wave height
(c) Sea level
(d) Shoreline Change (explained in detail in the erosion section)
(e) Elevation
(f) Geomorphology
(g) Slope.

1.3. Socio Economic Factors

The socio economic factors considered for vulnerability mapping are as follows:

(a) Population density
(b) Literacy rate
(c) Percentage of SC
(d) Fisher population
(e) Fish production
(f) Worker Profile and work participation rate

The following table summarises the following parameter while trying to compute a relative combined social vulnerability in four regions of Puducherry.

Table 5: Social Vulnerability In Four Regions Of Puducherry

Location	Population Density	Literacy Rate	Marine Fish Prod.	Inland Fish Prod.	FishermenPopulation	SC %	Worker %
Puducherry	3,231.00	86.13	13,873.20	2,219.00	60,620.00	16.45	36.16
Karaikal	1,252.00	87.83	15,663.00	1,594.00	18,462.00	18.07	33.70
Mahe	4,659.00	98.35	5,302.00	-	4,000.00	0.33	25.27
Yanam	3,272.00	80.26	2,780.30	916.00	12,385.00	18.48	31.56

**Source: Statistical Handbook, 2011*

1.3.1 Population density

The empirical studies show that even though higher population density exposes larger number of people to climate change and extreme weather conditions, higher social capital makes them less vulnerable as compared to low density isolated areas. The cost of adaption is more and delivery is poor. In this parameter Mahe region is better than the rest.

1.3.2 Literacy Rate

Higher the literacy, lesser is likely hood of vulnerability as it enhances adaptive capacity. In terms of literacy rate Mahe region outperforms the rest.

1.3.3 Fishermen Population

Puducherry mainland has the largest number of fishermen population, followed by Karaikal. In extreme weather conditions as well as due to climate change these two regions are more vulnerable as the livelihood diversification has not been significant.

1.3.4 Fish production

Fish production both marine and inland is impacted by climate change. Climate change enhances vulnerability of people dependant on fish production.

1.3.5 SC Population

The scheduled caste population is relatively low as compared to the other regions. However, due to the high poverty prevailing in this segment they are considered more vulnerable.

1.3.6 Worker Profile

Work participation rate is an important factor that is associated with the socio-economic vulnerability. The share of primary sector is very low in the UT. A large percentage depends on service sector associated with tourism. This makes them extremely vulnerable in the context of climate change. The change in number of wet days and if it coincides with the tourist arrival and extreme weather conditions it affects the economic conditions of people adversely making them vulnerable. Work Participation Rate (WPR) in Puducherry is 35.2%. This is lesser than the figure for Tamil Nadu but close to the All India and Kerala figures. Female WPR in the UT (17.2%) is lesser than a third of the male WPR (53.1%). Among the districts, Puducherry, Karaikal and Yanam have male WPRs which are close - 53.6%, 52.6% and 52.3% respectively. Male WPR in Mahe is 44.7%. Female WPRs in the districts are at significant variance. The lowest female WPR obtain is in Mahe (8.2%) following Yanam (10.3%).

1.4. Social Vulnerability

Attempt was made to compute the social vulnerability due to climate change and the relative impact in the four regions of the UT. The socioeconomic variables were placed in a principal components analysis (PCA), using the varimax rotation option, all the scores were standardised.Two components explained 87% of the variance. Since the variables are scaled the positive scores indicate higher vulnerability and negative scores indicate that lower or reduced vulnerability.Component one is strongly associated with the fisheries sector (both in terms of workers and fishery production) whereas component two is associated with population density, literacy and work participation rates. The regression scores were put in the graph below.This shows the Mahe region to be relatively less vulnerable as compared to Puducherry and Karaikal and Yanam is moderately vulnerable considering all the socio-economic factors. Though many socio-economic variables determine the relative vulnerability the reason to use PCA was to determine the number of common factors needed to adequatelydescribe the correlations between the observed variables, andestimating how each factor is related to each observed variable. The correlation has been attempted through Kaiser Normalisation and it converged in three rotations. The limitation of this method is the auto-colinearity amongst the variables.

Table 6: Correlation Matrix Rotated

Normalised scores	Component	
	1	2
Population Density	0.480	0.594

Literacy rate	0.023	0.981
Marine Fish Production	0.941	0.048
Inland Fish Production	0.837	0.531
Fisher Population	0.821	0.205
SC %age	0.335	0.940
Worker percentage	-0.728	-0.675
Extraction Method: Principal Component Analysis.		
Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 3 iterations.		

This gives a fair idea about the spatial distribution of vulnerability in Puducherry. The scatter diagram below shows the relative distribution of factors when regressed and how the combined social vulnerability is mapped out. This has been presented in the table below:

Table 7: Composite Vulnerability Index of Puducherry

Location	CVI	Rank
Puducherry	17.64	1
Karaikal	16.70	2
Mahe	5.28	4
Yanam	9.87	3

The composite vulnerability index for the socio economic factor shows Puducherry is most affected and Mahe is least affected. If we plot the vulnerability and adaptive capacity, this would be as below:

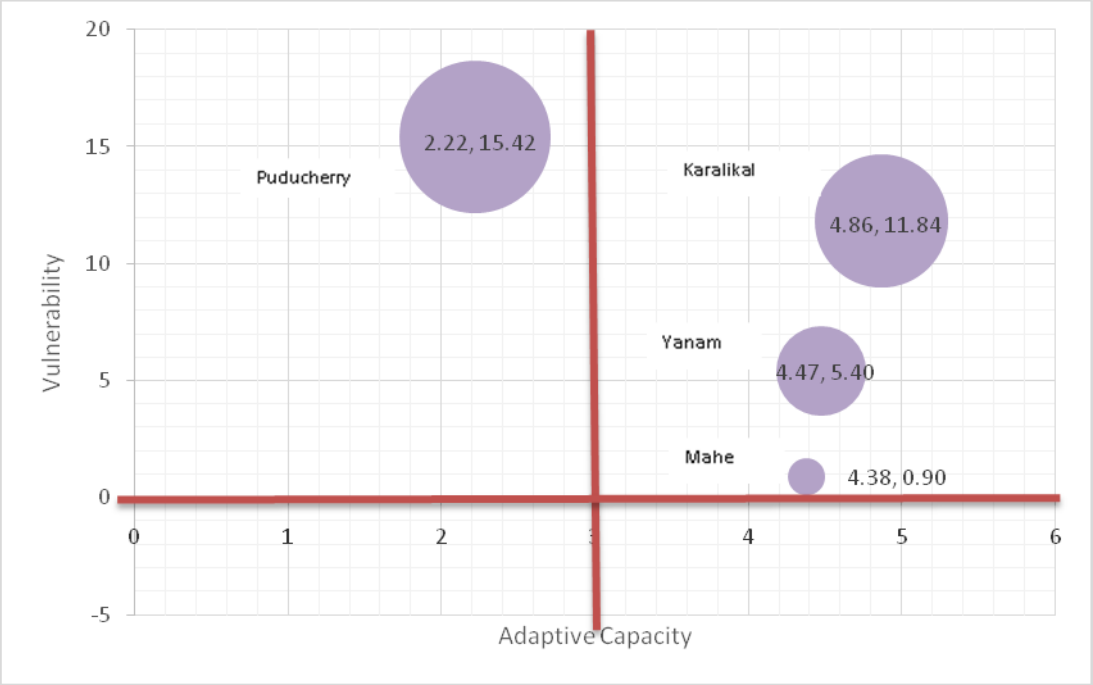

Figure 7: Spatial distribution of social vulnerability

From this figure it is evident that Puducherry is having the worst scenario (high vulnerability and low adaptive capacity. Even though Puducherry has higher population, when combined with urbanisation, resource congestion, it has higher vulnerability as compared to other areas. Karaikal has high adaptive capacity (as social capital in rural areas is relatively more and activities are comparatively more resilient than the urban areas) and high vulnerability and Mahe is low vulnerability and high adaptive capacity (higher literacy and high population density), so also Yanam.

1.5. Climatic Factors

Three distinct regions with unique climatic condition are there in Puducherry. Karaikal is part of the fertile Cauvery delta. Yanam region is skirted on the east and south by the Godavari River. The region is divided into two parts by the separation of the Godavari and Coringa Rivers. The Mahe Region is divided into two parts by the Mahe River flowing towards west. It is bounded in the south west by the Arabian Sea and in the north by the Ponniyam River. While Puducherry and Karaikal regions receive rainfall mainly from the North East monsoon, Mahe and Yanam regions receive rainfall from the South West monsoon.

1.5.1 Projected rain-fall and temperature under A1B scenario

INCCA report relying on global circulation models (GCM) indicates an increase of2.5–4°Crise in temperature from the current levels over the Indian subcontinent. Regional climate model (RegCM3) for developing future scenario on the Indian sub-continent in Cauvery Delta Zone that covers vast stretches of Tamil Nadu and delta facing part of Puducherry with horizontal

resolution of0.22° × 0.22° or 25 km × 25 km, with a sufficient buffer zone reveals the following picture. It shows a summer temperature rise of 3-4°C in moderate emission A1B scenario.

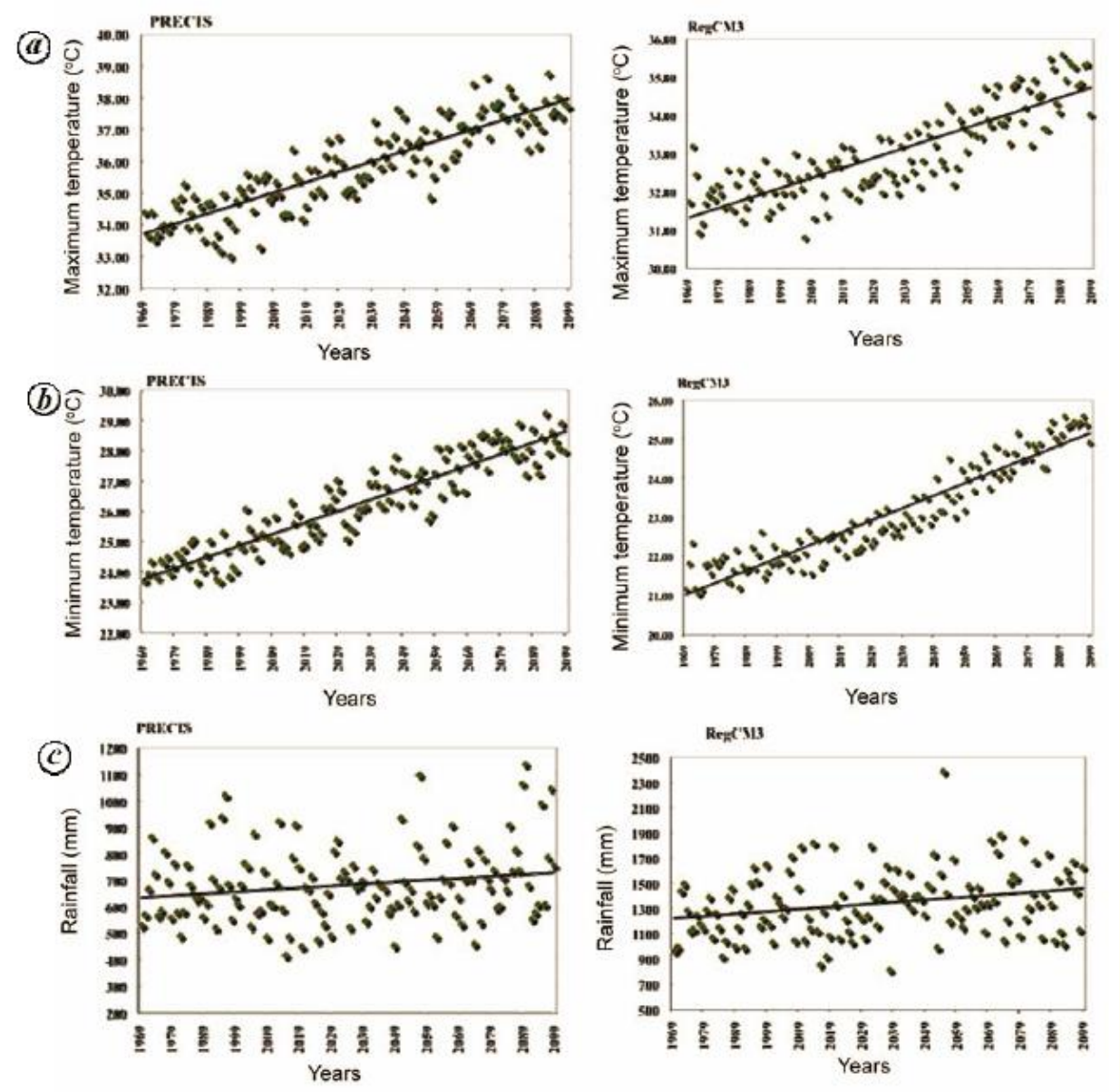

Figure 8: Temperature and rainfall projections for A1B scenario using PRECIS and RegCM3 models. a. Mean annual maximum temperature (°C). b. Mean annual minimum temperature (°C). c. Mean annual rainfall (mm/year.).

**Source: Geethalaxmi et.al (2011) in Current Science, Vol. 101, No. 3, 10 August 2011*

1.5.2 Monsoon Rainfall pattern

The monsoon rainfall has shown high degree of variability in Puducherry. The map by IMD shows the pattern of south west monsoon.

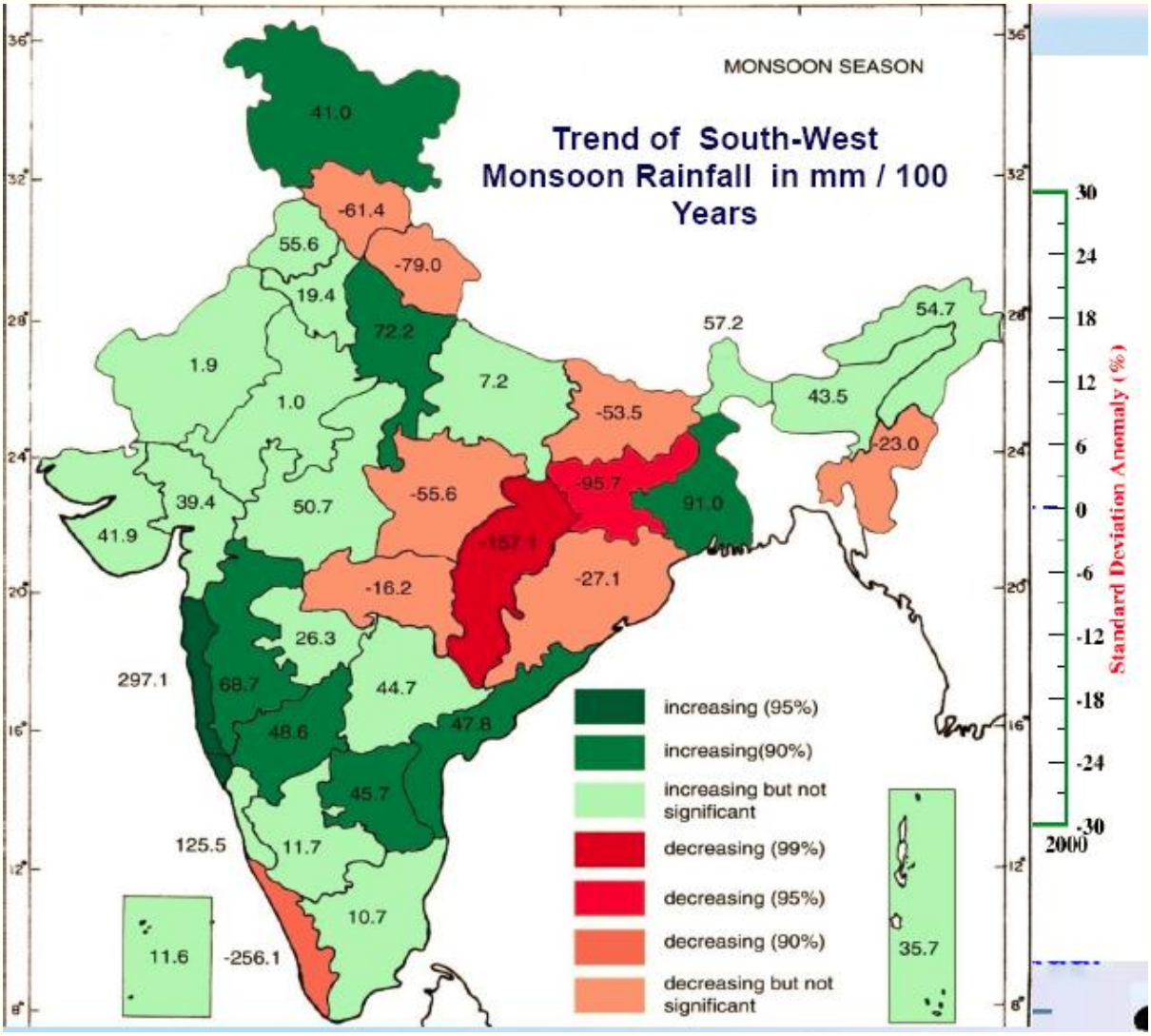

Figure 9: Monsoon rainfall pattern

The figure shows, that the monsoon rainfall is increasing but is not significant in this region. Since temperature is increasing and there is also increase in rainfall the climate would be hot and humid in the near term, requiring temperature adaptive agronomic practice and even varieties to withstand water logging and salinity in some low lying areas to reduce vulnerability.

1.5.3 Cyclonic storm and Flood Hazard

Yanam area adjacent to East Godavari district (Andhra Pradesh) with a coast line of 177 km is prone to cyclones and depressions. The villages viz. Chollangi, Chollangipeta, G.Vemavaram, Patavala, Coringa, Polekurru, Neelapalli and P.Mallavaram falling under Tallarevu Mandal and Bhairavapalem and Gokullanka falling under Ipolavaram Mandal are highly cyclone/ storm prone. Coastal part of this area is also flood prone. Environmental impacts of flood include soil erosion, silting, water pollution, denudation of land, ingress of saline water in cultivable land.

1.5.4 Tsunami

Tsunami devastated several parts of Puducherry and Karaikal and added additional dimension to the vulnerability of the region.

The map below shows the situation report 2005:

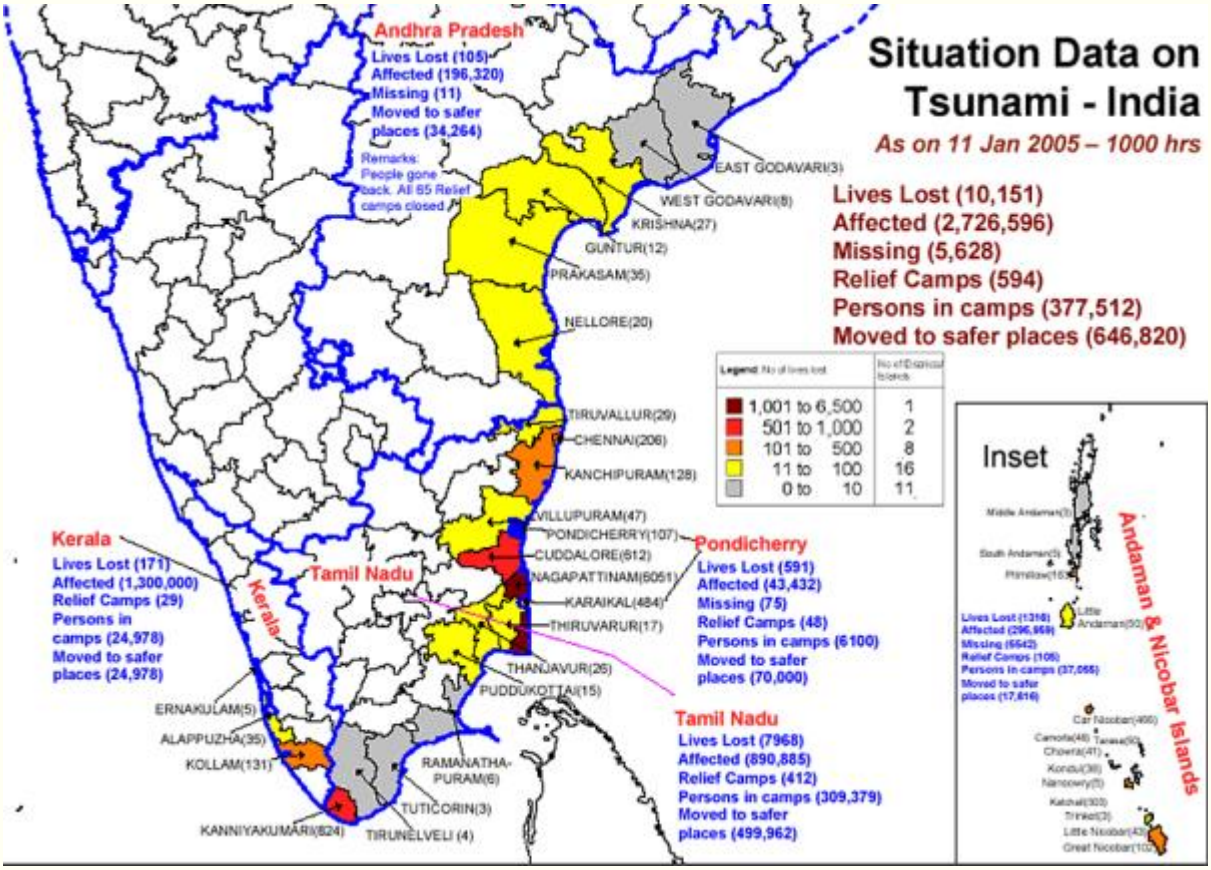

Figure 10: Situation data on Tsunami India

**Source: WHO*

1.6. Pollution

While pollution is not strictly a direct outcome of climate change the over-drawal of ground water in many areas of Puducherry and industrial units in Mahe and Yanam affects the water quality. Large number of unregistered aquaculture units discharge pesticides into water and also there is methane emission.

Puducherry being in a fragile coastal ecosystem is highly disaster prone and extremely vulnerable .It has been scientifically established that climate change enhances the occurrences of extreme events. The UT has been impacted by several bio-physical, socio-economic and environmental factors and some of these factors may worsen due to climate change. Some areas are more vulnerable than others. Areas like Puducherry and Yanam are multi-hazard points. Karaikal has some high erosion zones and a fragile coast line. Mahe even though it is

far from the mainland has relatively better adaptive capacity. To enhance resilience the UT has to invest in physical infrastructure, build adaptive capacity of the community to enhance resilience and reduce vulnerability.

The good sign of it can be seen in the CDRP project conceived by the UT which has already recognised the vulnerability of the UT due to climate change and heavily invests in climate proofing infrastructures, building capacity of the community, strengthening the early warning systems, etc.