IMPACT OF TSUNAMI 2004 IN COASTAL VILLAGES OF NAGAPATTINAM DISTRICT, INDIA

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ABSTRACT

A quake-triggered tsunami lashed the Nagapattinam coast of southern India on December 26, 2004 at around 9.00 am (IST). The tsunami caused heavy damage to houses, tourist resorts, fishing boats, prawn culture ponds, soil and crops, and consequently affected the livelihood of large numbers of the coastal communities. The study was carried out in the Tsunami affected villages in the coastal Nagapattinam with the help of remote sensing and geographical information science tools. Through the use of the IRS 1D PAN and LISS 3 merged data and quick bird images, it was found that 1,320 ha of agricultural and non-agricultural lands were affected by the tsunami. The lands were affected by soil erosion, salt deposition, water logging and other deposited sediments and debris. The maximum run-up height of 6.1 m and the maximum seawater inundation distance of 2.2 km were observed at Vadakkupoyyur village in coastal Nagapattinam.

Pre and Post Tsunami survey on soil quality showed an increase in pH and EC values, irrespective of distance from the sea. The water reaction was found to be in alkaline range (> 8.00) in most of the wells. Salinity levels are greater than 4 dS m^{-1} in all the wells except the ring well. The effect of summer rainfall on soil and water quality showed the dilution of soluble salts. Pumping of water has reduced the salinity levels in the well water samples and as well as in the open ponds. Following the 2004 event, it has become apparent to know the relative tsunami hazard for this coastal Nagapattinam. So, the Tsunami hazard maps are generated using a geographical information systems (GIS) approach and the results showed 20.6 per cent, 63.7 per cent and 15.2 per cent of the study area fall under high hazard, medium hazard and low hazard category respectively.

Keywords: Tsunami 2004, impact, run-up levels, soil and water quality, hazard map

1. INTRODUCTION

A Tsunami on 26th December, 2004 by an earthquake of magnitude M 9.0 occurred along the plate boundary marked by subduction zone between the Indian plate and the Burmese micro plate near Sumatra Island of Indonesia with the epicenter located on the shallow depths of seabed (USGS, 2004). Tsunami is a Japanese word which translates as "harbor wave", now used internationally, refers to a series of waves traveling across the ocean with extremely long wavelength at an average speed of 800 km/hour in the open ocean. As it approaches the coast, the near shore bathymetry significantly increases the wave height resulting in inundation of low lying areas along the coast resulting in mass destruction and in many instances loss of life. Tsunami waves hit the Andaman and Nicobar group of islands within few minutes. The Tsunami waves hit Indonesia, Andaman and Nicobar islands, parts of East coast of India, Thailand, Sri Lanka, Maldives and West and East Africa. The Survey of India reported that the Tsunami hit Cuddalore at 08.00 a.m. (IST), Chennai at 08.40 a.m. (IST), and Paradip, Machillipatanam, Nagapattinam and Vishakhapatnam at 09.00 a.m. (IST) (Navalgund, 2005). In India, the states of Tamil Nadu, Andhra Pradhesh and the Union territory of Andaman and Nicobar islands were the worst affected by the impact of Tsunami. The states of Kerala and the Union Territory of Pondicherry were also affected. Among the different districts in Tamil Nadu, Nagapattinam is one of the worst affected districts by the Tsunami.

The Tsunami 2004 generated by the earthquake killed approximately 275,000 people, making it one of the deadliest disasters in modern history. Beyond the heavy toll on human lives, the Indian Ocean earthquake has caused an enormous environmental impact. It has been reported that severe damage has been inflicted on ecosystems such as mangroves, coral reefs, forests, coastal wetlands, vegetation, sand dunes and groundwater. Tusnami has lead to poisoning of the fresh water supplies and the soil by salt-water infiltration and deposit of a salt layer over arable land. The terrain coastal regions of India affected by the Indian Ocean Tsunami are mostly flat with few mountains. Remote sensing provided a great support during the disaster to get a preliminary idea on the damages caused by Tsunami. Here, the remote sensing and GIS tools were used to identify the extent of seawater intrusion and to estimate the land use and land cover changes.

2.0 STYDY AREA

The study was conducted in Nagapattinam district of Tamil Nadu State, India, which is bounded on the north by Cuddalore district, south by Palk Strait, east by Bay of Bengal and west by Thiruvarur district. The study area falls under fifteen revenue villages Nagapattinam and Kivalur taluks of Nagapattinam district, covering an area of 10,380 hectares. The area lies between 10^{o}34'32.69" and 10^{o}46'57.77" N latitude and between 79^{o}47'02.29" and 79^{o}51'38.24" E longitude (Fig. 1).

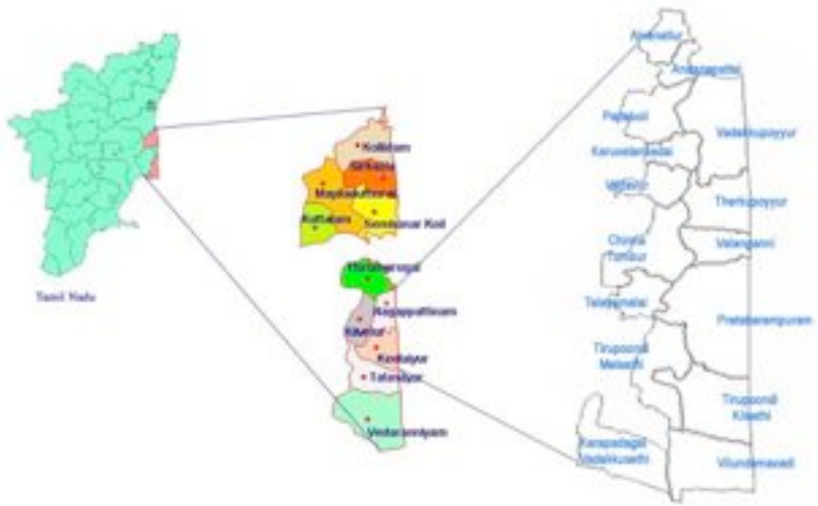


Figure 1. Location map of the study area

2.1 Geology

The geology of the study area comprises of both riverine and marine alluvial deposits. The alluvial deposits of the river Cauvery and its tributaries lie over the Tertiary sandstone. They consist of sands, gravelly sands, clays and sandy clays. The thickness of these formations ranges from 30 m to 400 m. The tidal deposits of Bay of Bengal is invariably seen up to 5 km range from the sea which consists of fine to coarse sand, sandy clays with marine features like shells.

2.2 Climate

The climate is semi-arid. The area receives a mean annual rainfall of 1,337 mm out of which 201 mm (15.03%) is contributed by Southwest monsoon and 921 mm (68.89%) by Northeast monsoon. The mean annual temperature is 28.79¼C and the mean maximum and mean minimum temperatures are 32.66¼C and 24.91¼C respectively.

2.3 Crop cultivation

Rice is grown during November-February rainy season. Large areas are under vegetable crops viz., brinjal, bhendi, chilly, cucumber, melons, gourds and groundnut besides coconut and mango. Fruit crops like mango, cashew, guava and sapota are also raised.

3.0 METHODOLOGY

3.1 Tsunami Damage Assessment

Extent of sea water inundated area, damage to agricultural fields, settlements, salt and other sediment deposition are visually interpreted using Pan sharpened Multispectral data of Quickbird sensor dated 31th December 2004 with a spatial resolution of 70 cm and compared with IRS 1D PAN and P6 LISS3 merged data (Date of pass 21-05-04 (PAN) and 04-06-04 (LISS3)) of spatial resolution of 5.8 m, to get a preliminary idea on the damages caused due to Tsunami occurred on December 26, 2004.

3.2 Land use and Land cover change detection

The land use and land cover changes due to Tsunami were studied using the IRS 1D PAN + P6 LISS3 (before Tsunami) merged data and Quickbird sensor (after Tsunami). The land use of the area were visually interpreted and digitized under ARC GIS 9.0 software. The digitized maps were ground verified and classified. The classified land use map of before and after Tsunami was intersected under Overlay module in the Analysis tool of Arc toolbox. The changes in area between land uses of before and after Tsunami were then extracted from the attribute data.

3.3 Impact of Tsunami on soil and water quality

The soil and water samples were collected after the incident of Tsunami (December 2004) and also after summer rainfall (March 2005) from the same fields where studies were previously conducted for

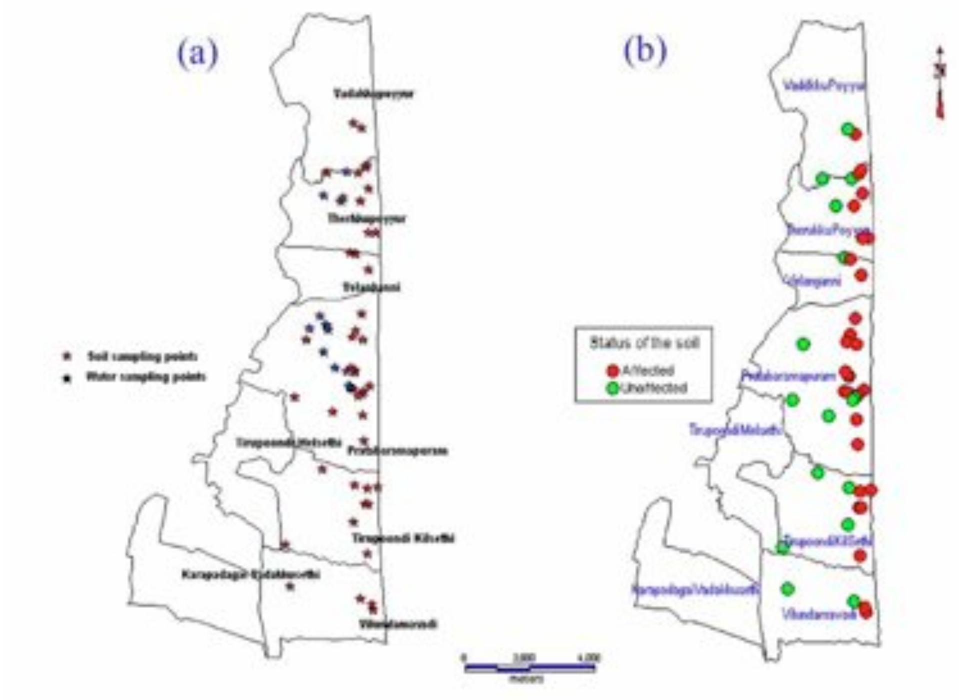


Figure 2. (a) Location of soil and water sampling points (b) Tsunami affected/unaffected points

the assessment of soil and water quality. Totally seventeen soil samples were collected at two different depths viz., 0-15 cm and 15-30 cm from the affected places ranged from 100 – 800 meters from the sea. Six representative water samples were collected from different sources viz., skimming well, ring well and open pond.. The Fig.2 shows the location of soil and water sampling and Tsunami affected and unaffected points, respectively. The soil and water samples were analyzed for pH and electrical conductivity as per the standard procedures.

3.4 Tsunami hazard mapping

Tsunami hazard maps were generated using GIS approach to depict the relative Tsunami hazard of coastal Nagapattinam. In contrast to previous mapping efforts that utilize a single line to represent inundation, hazard is displayed gradationally. A surface is constructed to represent this hazard. From the vicinity of sea about a wide strip of land 2 km area was considered for the study. A line was digitized to separate the sea and inland area. From the margin of sea, 2 km buffer line was created using buffer tool in GIS analysis. Criteria for each hazard zone were chosen in relation to elevation and attenuation. Three-arc second (90 m) resolution Digital Elevation Model (DEM) of Shuttle Radar Topographic Mission (SRTM) was used for elevation control and generation of elevation contours. Criteria boundaries were used to separate regions of varying hazard. Criteria boundaries defined by Patton and Dengler, (2004) were adopted to delineate the regions (Table 1). Zones were constructed

Table 1. Hazard area boundary criteria are initially defined for each zone based on elevation

Zone	Description	High	Moderate	Low	None
Open Coast	Everywhere within 2 km of coast	0-3 m elevation	3-10 elevation	10-35 m elevation	Above 35 m elevation
Coastal Estuary	Low lying flat topography of river valley and bottom lands within 2 km of coast	0-1.5 m elevation	1.5 – 6 m elevation	6-15 elevation	Above 15 m elevation
Bay lands	Low-lying flat topography adjacent to coastal estuary within 2 km of coast	0-1.5 m elevation	1.5 – 3 m elevation	3-5 elevation	Above 5 m elevation
Low-lying uplands	Low-lying flat topography within 2 km of coast	0-3 m elevation	3 – 7.5 m elevation	7.5 – 20 m elevation	Above 20 m elevation
Uplands	All other areas inland of open coast zone above 2 km of coast	Not applicable			

to further adjust the criteria with respect to a physically determined variable hazard. Hazard was displayed as a continuous gradational color scale ranging from high hazard through medium, low to no hazard. The maps were produced in GIS format to facilitate ready adaptation by planners and emergency managers. The methodology adopted for preparation of Tsunami hazard map is given in Fig. 3.

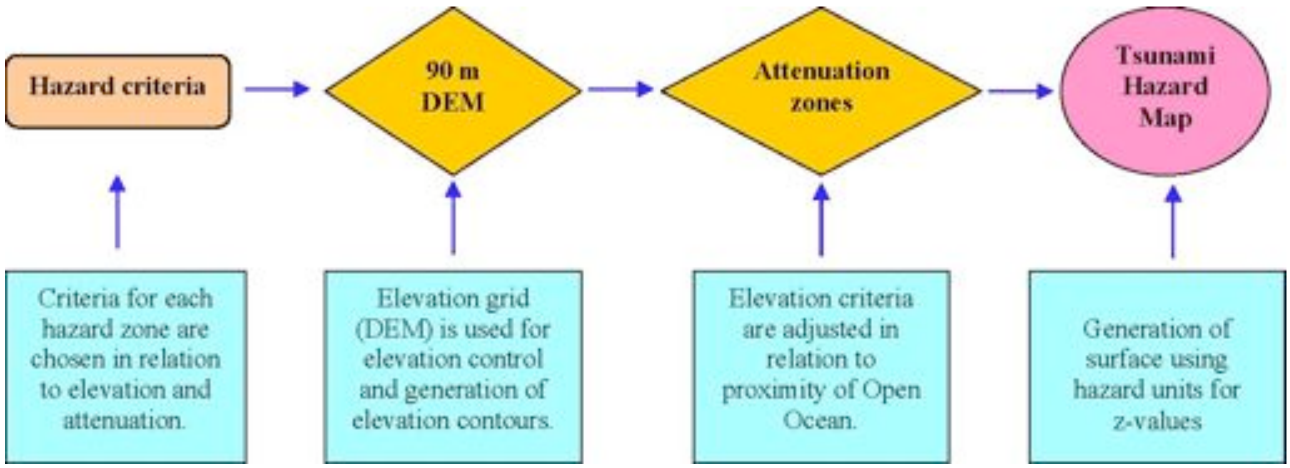


Figure 3. Flow chart showing the process for generation of tsunami hazard map (*Methodology source: Patton and Dengler, (2004)*).

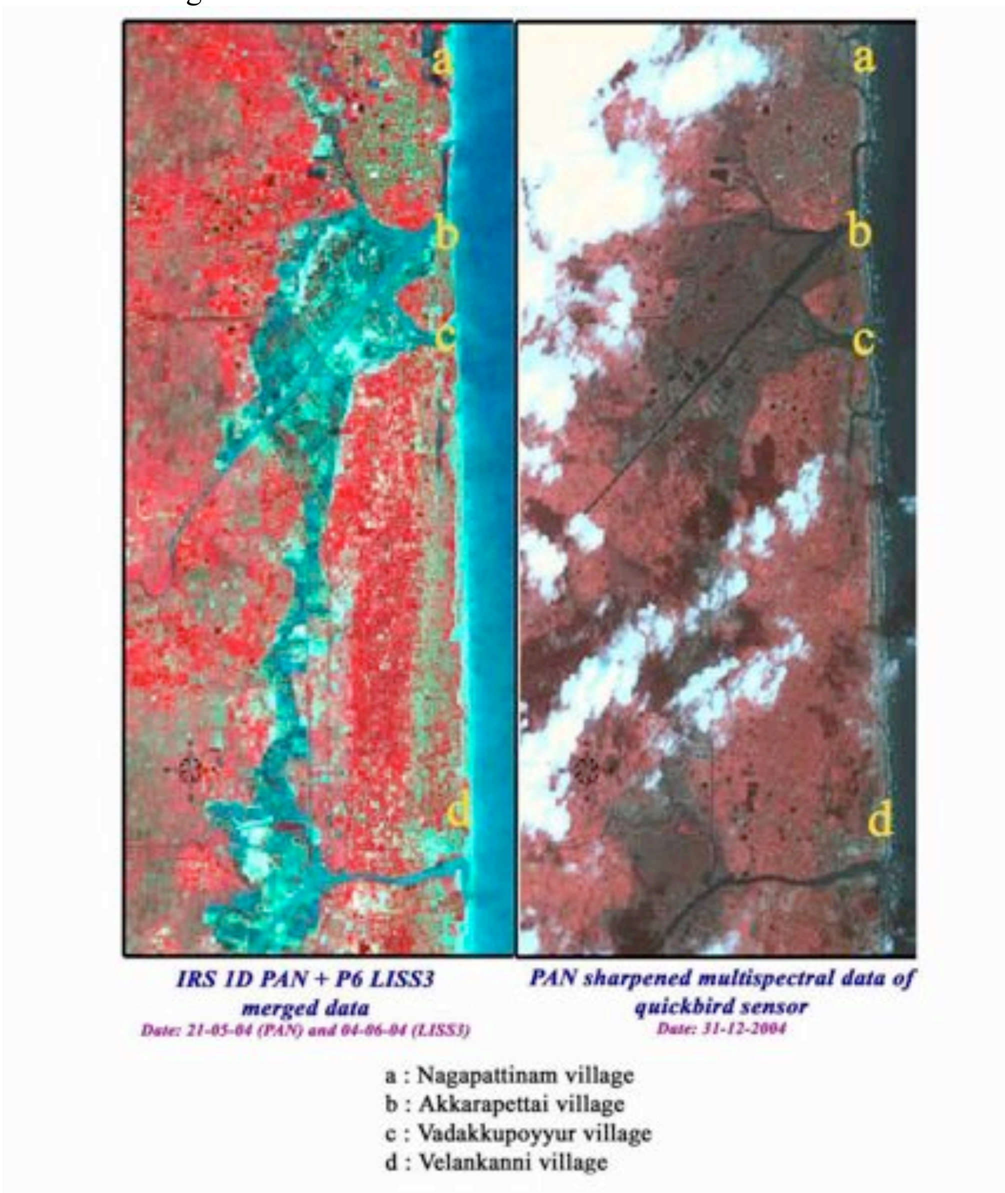
4.0 RESULTS AND DISCUSSION

4.1 Visual discrimination of satellite data

In Nagapattinam district, there are dense households from the coast up to 1.5 km. Tsunami has devastated the Nagapattinam area with a death toll of 6065 people and damaging as many as 40,000 houses (Source: www.tn.gov.in, dt. 14th Feb. 2005) Complete and partial destruction of buildings in Akkarapettai and Keechankuppam villages are clearly visible in the imagery (Fig. 4-9).

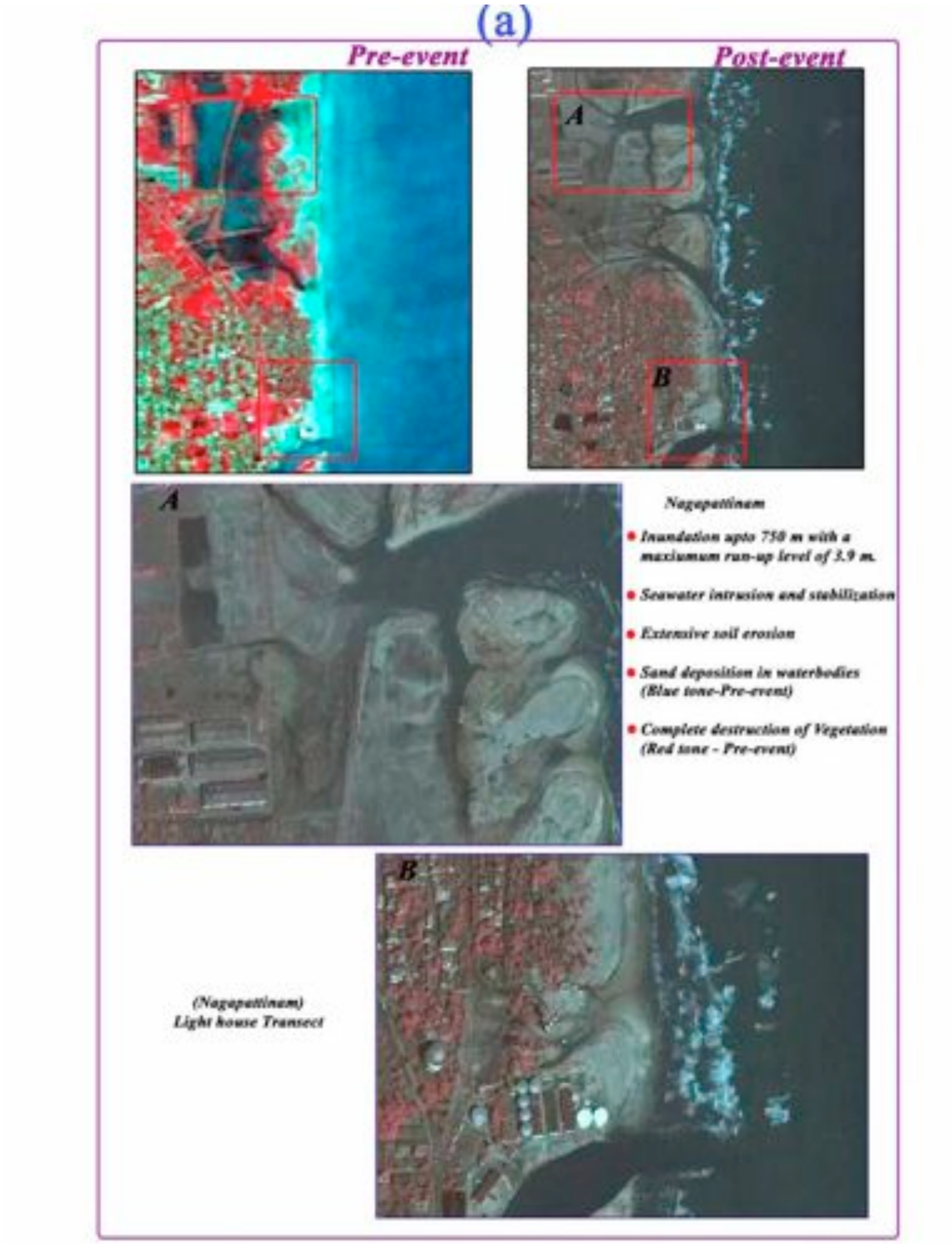
Satellite data indicate that Nagapattinam, Vadakkupoyyur, Therkupoyyur, Keechankuppam, Akkaraipettai, Velankanni, Seruthur, Pratabaramapuram, Tirupoondi Kilsethi and Vilundamavadi are the affected villages in Nagapattinam and Kivalur taluks of Nagapattinam district. The worst affected Nagapattinam (light house transect) showed longer penetration of seawater (750 m) up to an elevation of 3.9 m due to the gentle slope of coastal land combined with the effect of Tsunami wave (Table 2). Presence of creeks like Vedaranayam and Velankanni canal in Vadakkupoyyur and Seruthur village facilitated the seawater inundation up to 2.2 km and 1.95 km up to an elevation of 6.1 m and 5.6 m, respectively. In Velankanni village, the lands interrupted by streets and buildings and open beach led to the penetration of sea water up to 950 m with the maximum run up level of 4.3 m. Coastal lands with heavy plantation and sand dunes in Therkupoyyur, Pratabaramapuram and Tirupoondi Kilsethi. villages showed a sea water intrusion level of 250 m, 282 m and 528 m and up to an elevation level of 4.6 m, 3.3 m and 5.0 m respectively.

The inundated limit shows the vulnerability of the Nagapattinam district of the Tamil Nadu coast due to its flat topography. From the satellite data it was clearly inferred that the regions where the land unprotected by coastal dunes had higher inundation levels compared to places where the coast is protected by dunes. Also, wherever there are openings in the dunes (either due to anthropogenic activity or due to other reasons), inundation was higher as these openings provided a gateway for the water mass to travel through them into the hinterland.



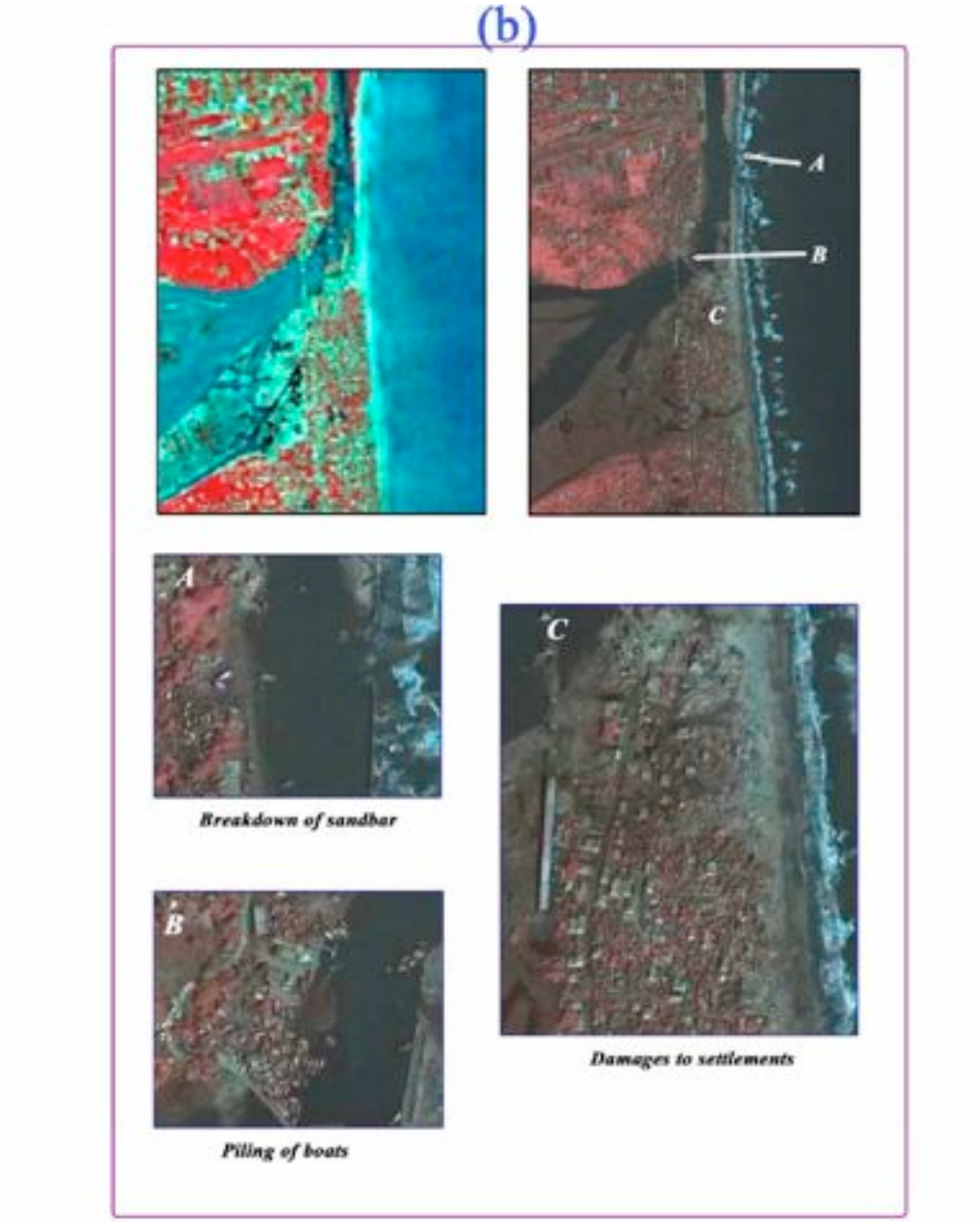
Source: IRS data- NRSA Data centre, Hyderabad; Quickbird data: Pacific-Disaster centre

Figure 4. Visual interpretation of Tsunami affected area of Nagapattinam and Kivalur taluks using remote sensing data



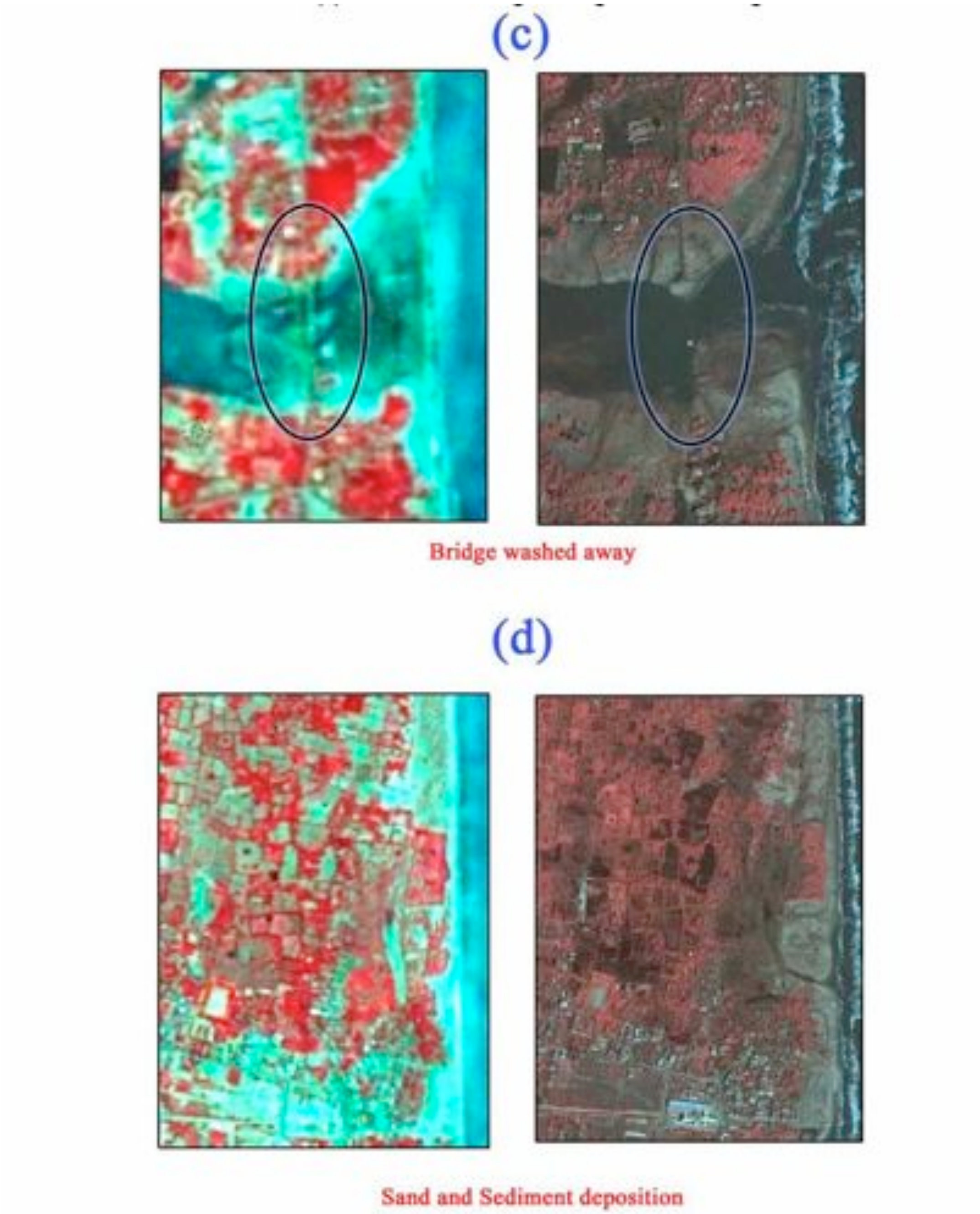
Source: IRS data- NRSA Data centre, Hyderabad; Quickbird data: Pacific-Disaster centre

Figure 5. Visual interpretation of Tsunami affected area of Nagapattinam village using remote sensing data



Source: IRS data- NRSA Data centre, Hyderabad; Quickbird data: Pacific-Disaster centre

Figure 6. Visual interpretation of Tsunami affected area of Akkaraipettai village using remote sensing data



Source: IRS data- NRSA Data centre, Hyderabad; Quickbird data: Pacific-Disaster centre

Figure 7. Visual interpretation of Tsunami affected area of (c) Vadakkupoyyur and (d) Velankanni villages using remote sensing data

Source: Pacific-Disaster centre

Figure 8. Impact of Tsunami on Agricultural and Horticultural lands in different villages of Nagapattinam and Kivalur Taluks Figure 9. Photographic views of Tsunami affected landforms and water bodies

Figure 9. Photographic views of Tsunami affected landforms and waterbodies

Table 2. Run-up level of seawater during Tsunami at selected locations along the coast of Nagapattinam and Kivalur taluks

Villages	Maximum run up level (m)	Distance of seawater inundation inland (m)	Nature of coastal land
Nagapattinam (Light house transect)	3.9	750	Coastal land with gentle slope interrupted by settlement
Vadakkupoyyur	6.1	2200	Low lying coastal land and presence of creeks like Vedaranyam canal
Therkupoyyur	4.6	250	Gentle beach followed by sand dunes of different elevations
Velankanni	4.3	950	Open beach and lands interrupted by settlement
Seruthur	5.6	1950	Low lying coastal land and presence of creeks like Velankanni canal
Pratabaramapuram	3.3	282	Coastal land protected by sand dunes and heavy plantations
Kilsethi	5.0	528	Coastal land with heavy plantation and presence of creeks

The run up levels and the prevalence of lower elevations within a distance of 2.0 km, where moderate to large settlements occur close to the coast, indicate the need to consider elevation based setback line in human settlement planning along the coastal areas of the villages. In fact, it is well known that Nagapattinam is one of the low lying coastal areas of the country and has experienced the fury of storm surges several times as it is known to be one of the possible landfall points for cyclones. The present run-up levels and inundation distances can be used as guidance to determine the safe locations for resettlement of affected population for the future (Ramanamurthy *et al.,* 2005). Similarly, the low lying areas adjoining the creeks (Vedaranayam and Velankanni canal) facilitated travel of Tsunami waves far inland, are too vulnerable as indicated by the landward penetration of seawater up to 2.2 km from the creek in Vadakkupoyyur village. So, adoption of elevation based setback lines or vulnerability lines are recommended for human settlement planning along the coastal villages of Vadakkupoyyur and Seruthur.

The large extents of croplands were also affected by seawater intrusion. Paddy, casuarina and mixed plantation (cashew + mango + coconut + other crops) adjacent to the seacoast were the most affected agricultural and horticultural crops. With the action of sea waves, the lands were physically damaged by removal of soil by erosion and deposition of large amounts of sand and other debris. The canal, irrigation and drainage channels were damaged. In addition, the seawater intrusion led to development of soil salinity, damaging the crop as well as making the agricultural lands unsuitable for cultivation. Salinity developed in soil due to accumulation of soluble salts. Salt deposition in Seruthur and Pratabaramapuram villages are clearly visible in the imagery. As seawater contains considerable quantities of sodium salts, its intrusion creates soil salinity.

4.2 Land use and Land cover change detection

Major changes to land use and land cover due to Tsunami were found along coastline of Nagapattinam district. The damage does not occur in a uniform manner, but is determined (among other factors) by the orientation of the coastline with respect to the direction of the Tsunami wave propagation as well as the topography of the land and the seabed in the coastal margins. Because of local variations, nearly 1320 ha was affected in Nagapattinam and Kivalur taluks, yet adjacent lands remained intact.

The harbor wave affected the agricultural and horticultural croplands by means of seawater intrusion. The invasion and receding action of harbor waves lead to the removal of soil by erosion and deposition of large amounts of sand, salt and other debris. The results on land use and land cover change detection studies revealed that the total of 747.91 ha of agricultural and horticultural croplands were affected by Tsunami, which includes paddy (610.52 ha), mixed plantation (67.04 ha) and casuarina (137.39 ha). Paddy fields were affected by erosion, salt deposition, water logging and other deposited sediment and the extent of area affected are 52.71 ha, 101.97 ha, 116.08 ha and 43.75 ha respectively. The widening of canals, tanks and newly formed brackish water channels occupied an area of 296.01 ha in paddy fields (Table 3) (Fig.10). The land use of mixed plantation (before Tsunami) was affected by soil erosion (8.76 ha), water logging (2.95 ha), salt deposition (19.24 ha) and other sediment deposition (34.85 ha). In case of casuarina fields soil erosion, water logging, salt and sediment deposition registered an area of 54.63 ha, 3.68 ha, 8.55 ha and 3.49 ha respectively.

The intrusion and receding action of the waves caused widening of canals in some parts of the study area. Deposition of sand particles in canal and water body occupied an area of 39.65 hectares. Tsunami has also caused land cover changes in sea, sand dune and saltpan areas. The receding action of waves led to deposition of eroded sand particles into the sea and thereby 11.27 ha of sea area were occupied by sand. Similarly, in some parts of the study area the intruded seawater did not recede back and it occupied an area of 2.86 ha. In Nagapattinam district, there are dense households from the coast up to 1.5 km. Tsunami has damaged the settlement area to an extent of 138.98 hectares. The study was carried out in Tsunami affected villages of Nagapattinam district to know about the impact on soil and water qualities. During January, February and March 2005, the Nagapattinam district received a rainfall of 6.6 mm, 326 mm and 120 mm, respectively. So, the effect of summer rainfall on soil and water qualities was also studied.

Table 3. Land use and Land cover changes in Tsunami affected areas of Nagapattinam and Kivalur taluks

Before Tsunami	After Tsunami	Area (ha)
Canal	Sand deposited	17.32
Casuarina	Eroded surface	54.63
	Salt Deposited	8.55
	Sediments deposited	3.40
	Waterlogging	3.68
Mixed Plantation	Salt deposited	19.24
	Sediments deposited	34.85
	Waterbody	1.24
	Waterlogging	3.95
	Eroded surface	8.76
Paddy	Eroded surface	52.71
	Salt deposited	101.97
	Waterlogging	116.08
	Waterbody	296.01
	Sediment deposited	43.75
Saltpan	Eroded surface	38.62
	Waterlogging	242.55
Sand dune	Sediment deposited	109.54
	Sea	2.88
Sea	Sand Deposited	11.27
Settlements	Eroded surface	49.58
	Partial damage of houses	47.58
	Waterlogging	4.14
	Sediments deposited	26.66
Waterbody	Sand deposited	22.33
	Total area	**1320.38**

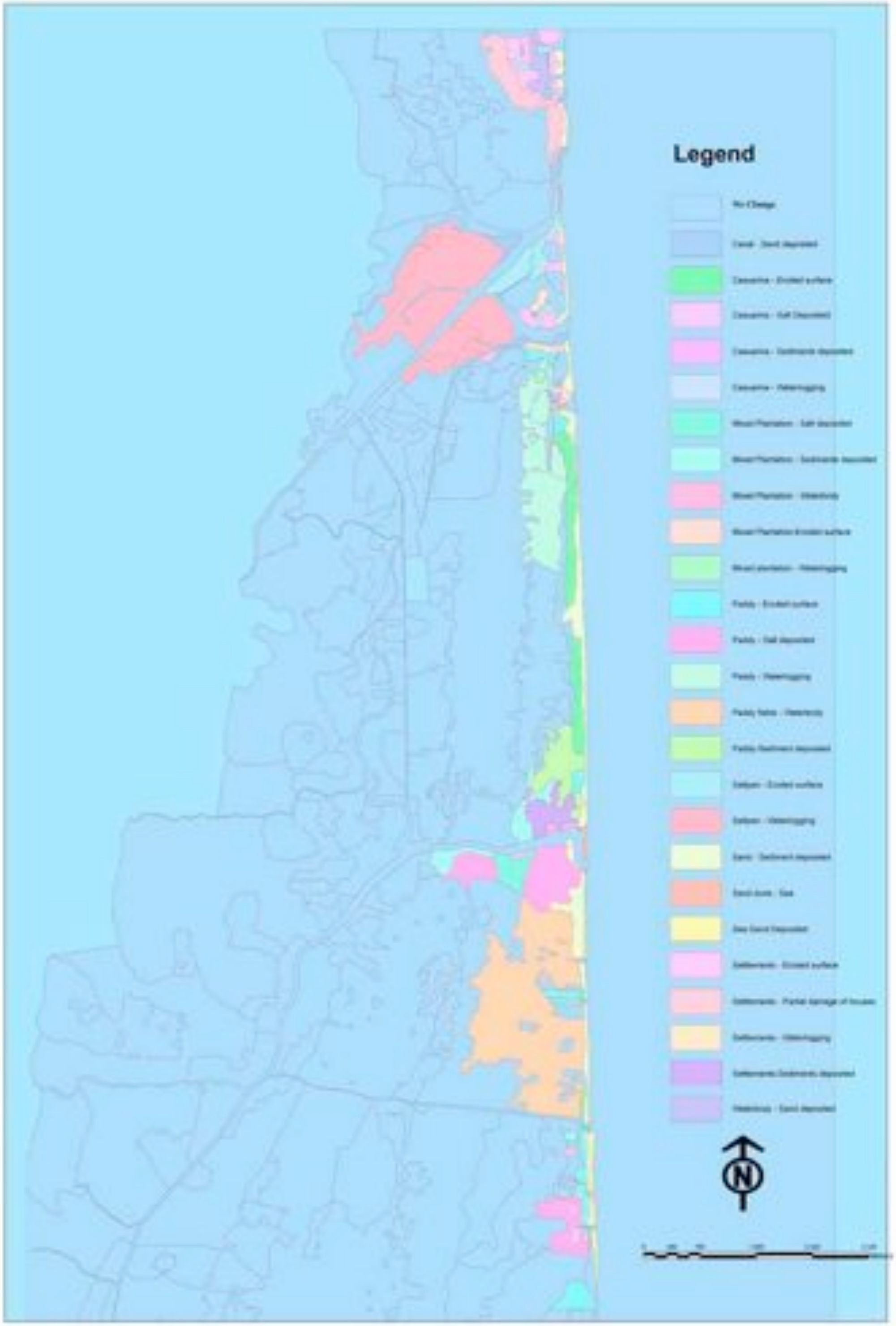


Figure 10. Effect of Tsunami on Landuse and landcover changes

4.3 Impact of Tsunami and effect of summer rainfall on Soil and Water qualities

4.3.1 Impact of Tsunami

In general, the results on soil qualities showed an increase in pH (0.34 – 2.64) and EC (0.00 – 3.86 dS m^{-1}) values in the Tsunami affected fields irrespective of distance from the sea and sampling depths. The pH and electrical conductivity values of soil samples received within 800 meters from the sea showed a varying trend and the values ranged from 7.35 – 8.64 and 0.03 – 3.94 dS m^{-1} respectively. However, the increase in soluble salt concentration and soil reaction does not occur in a uniform manner with the increase in distance from the sea, which showed the difference in the topography of the land and the barriers in the coastal margins. With the close view of the data, it was inferred that increase in pH values (1.67 – 2.64) was found to be higher in samples collected within 200 meters from the sea. Soluble salt concentration found to be higher in the samples collected between 500 and 600-meter distance from the sea and the values ranged from 3.84 – 3.86 dS m^{-1}. However the effect is marginal in irrespective of the sampling depth. The increase in soluble salt concentration with depth is evident within 300 meter and between 600 and 700-meter sampling distance from sea (Table 4).

The water reaction was found to be in alkaline range (> 8.00) in all the wells except one skimming well (SW 3) was in mildly alkaline range. Salinity levels are greater than permissible limit of 4 dS m^{-1} in all the wells except the ring well. Surface entry of seawater appears to be the primary cause for the salinity levels in the wells.

4.3.2 Effect of summer rainfall

The effect of summer rainfall on soil quality has benefited in leaching the soluble salts as a result of which, Electrical Conductivity has reduced in many locations. EC is harmless (below 1 dS m^{-1}) in most places (Table 5). A few fields registered high EC values (> 1 dS m^{-1}). These lands can be reclaimed with the receipt of another rain spell or by application of green manures or green leaf manures.

Table 4. Effect of Tsunami and summer rainfall on soil quality

Distance from sea	Depth (cm)	Before Tsunami		After Tsunami		Effect of Tsunami		After Summer Rainfall		Effect of Summer rainfall	
		pH	EC (dSm^{-1})	pH	EC (dSm^{-1})	pH	EC (dSm^{-1})	pH	EC (dSm^{-1})	pH	EC (dSm^{-1})
0-100	0-15	6.45	0.03	8.29	0.30	(+) 1.84	(+) 0.27	8.10	0.09	(-) 0.19	(-) 0.21
	15-30	6.56	0.03	8.64	0.52	(+) 2.08	(+) 0.49	8.10	0.15	(-) 0.54	(-) 0.37
100-200	0-15	5.78	0.01	8.42	0.32	(+) 2.64	(+) 0.31	6.26	0.06	(-) 2.16	(-) 0.26
	15-30	6.43	0.02	8.10	0.86	(+) 1.67	(+) 0.84	6.96	0.04	(-) 1.14	(-) 0.82
200-300	0-15	6.98	0.03	7.45	0.03	(+) 0.47	(+) 0.00	7.04	0.10	(-) 0.41	(+) 0.07
	15-30	7.01	0.01	7.35	0.05	(+) 0.34	(+) 0.04	7.04	0.10	(-) 0.31	(+) 0.05
300-400	0-15	7.08	0.04	8.38	0.62	(+) 1.30	(+) 0.58	7.59	0.07	(-) 0.79	(-) 0.55
	15-30	7.12	0.04	8.09	0.26	(+) 0.97	(+) 0.21	8.00	0.15	(-) 0.10	(-) 0.10
400-500	0-15	7.29	0.19	8.12	0.78	(+) 0.83	(+) 0.59	7.87	0.21	(-) 0.24	(-) 0.57
	15-30	7.43	0.08	8.27	0.54	(+) 0.84	(+) 0.47	8.03	0.36	(-) 0.24	(-) 0.19
500-600	0-15	6.77	0.08	7.75	3.94	(+) 0.98	(+) 3.86	7.66	1.84	(-) 0.09	(-) 2.10
	15-30	7.05	0.10	7.93	3.94	(+) 0.89	(+) 3.84	7.81	3.11	(-) 0.13	(-) 0.83
600-700	0-15	6.43	0.06	7.89	0.29	(+) 1.46	(+) 0.23	7.28	0.13	(-) 0.61	(-) 0.16
	15-30	6.73	0.06	7.54	0.48	(+) 0.80	(+) 0.42	7.35	0.24	(-) 0.19	(-) 0.24
700-800	0-15	6.91	0.09	7.96	0.84	(+) 1.06	(+) 0.75	7.58	0.18	(-) 0.38	(-) 0.66
	15-30	7.10	0.12	7.80	0.23	(+) 0.69	(+) 0.11	7.35	0.17	(-) 0.45	(-) 0.06

Table 5. Effect of Tsunami and Summer Rainfall on water quality

Well I.D.	Before Tsunami		After Tsunami		Effect of Tsunami		After summer rainfall		Effect of Summer rainfall		Remarks
	pH	EC ($dS\ m^{-1}$)	pH	EC ($dS\ m^{-1}$)	pH	EC ($dS\ m^{-1}$)	pH	EC ($dS\ m^{-1}$)	pH	EC ($dS\ m^{-1}$)	
SW1	7.59	0.89	8.30	4.11	(+) 0.71	(+) 3.22	7.79	1.03	(-) 0.51	(-) 3.08	Continuous pumping
SW2	6.94	0.83	8.04	7.30	(+) 1.10	(+) 6.47	7.89	5.85	(-) 0.15	(-) 1.45	No pumping
SW3	7.74	1.24	7.81	8.04	(+) 0.07	(+) 6.80	7.53	6.10	(-) 0.28	(-) 1.94	No pumping
RW	7.85	1.26	9.00	1.42	(+) 1.15	(+) 0.16	8.97	0.40	(-) 0.03	(-) 1.02	Continuous pumping
OP1	7.66	1.09	8.60	15.60	(+) 0.94	(+) 14.51	8.17	2.77	(-) 0.43	(-) 12.83	Continuous pumping
OP2	7.78	1.73	8.80	18.62	(+) 1.02	(+) 16.89	8.15	2.56	(-) 0.65	(-) 16.06	Continuous pumping

Note: SW – Skimming well; RW – Ring well and OP- Open pond

The effect of summer rainfall on water quality showed the dilution effect of soluble salts. Pumping of water has reduced the salinity levels in the well water samples and as well as in the open ponds. However, water from open ponds could not be used for irrigation till the EC falls below 3 dS m^{-1}. The well water samples showed an EC levels ranging from 1.94 to 3.08 dS m^{-1}. Even though there is a reduction in salinity level in these waters due to rainfall and continuous pumping, irrigation should be restricted to salt tolerant crops and varieties. Water reaction is within the normal range and only one ring well registered the pH values of 8.97, which may require application of gypsum.

5. TSUNAMI HAZARD MAPPING

Tsunami hazard maps are generated using a geographical information systems (GIS) approach for coastal Nagapattinam. Hazard maps are displayed as a continuous gradational color scale ranging from high hazard through medium, low to no hazard (Fig. 11). Hazard maps shows 20.6 per cent, 63.7 per cent and 15.2 per cent of the study area are coming under high hazard, medium hazard and low hazard category respectively (Table 6). The remaining percent shows no hazard to Tsunami.

Table 6. Tsunami hazard area (ha) in villages of Nagapattinam and Kivalur taluks

Hazard category	A	B	C	D	E	F	G	H
High hazard zone	335.28	42.43	40.11	55.95	43.75	229.17	119.88	93.37
Medium hazard zone	472.51	23.24	18.19	288.23	199.98	913.97	600.67	458.8
Low hazard zone	195.11	4.83	-	159.36	38.68	40.92	72.51	200.85
No hazard	20.96	1.34	0.65	-	-	-	-	-
Total area (ha)	1023.86	71.84	58.95	503.54	282.41	1184.06	793.06	753.02

A: Vadakku Poyyur; B: Karuvelankadai; C: Papakoil; D: Therkupoyyur; E: Velankanni;
F: Pratabaramapuram; G: Tirupoondi Kilsethi; H: Viulundamavadi

In this study, the main focus was to generate hazard mapping to quantify the extent of the area prone to Tsunami. The criteria taken into consideration for assessment of hazard mapping were types of land adjoining the coast and the topographical difference pertaining to the land. These maps are GIS based to facilitate ready adaptation

Figure 11. Tsunami Hazard Map generated using GIS approach

by planners and emergency managers. The maps are intended for educational purposes, to improve awareness of Tsunami hazards and to encourage emergency planning efforts of local and regional organizations by illustrating the range of possible Tsunami events. Criteria boundaries defined by Patton and Dengler (2004) were adopted to delineate the regions and it has to be refined by comparing with the Tsunami events. Factors like Tsunami strength and its character were not considered in the hazard mapping.

6. CONCLUSIONS

A total of seven revenue villages in the coastal taluks of Nagapattinam and Kivalur were affected due to Tsunami 2004. Prevalence of lower elevations in the study area has led to the landward penetration of seawater up to 2.2 kilometers. The study on land use and land cover changes due to Tsunami revealed that a total of 747.91 ha of agricultural and horticultural crop lands were affected, which includes paddy (610.52 ha), mixed plantation (67.04 ha) and casuarina (137.39 ha). The lands were affected by soil erosion, salt deposition, water logging and other deposited sediments and debris. Tsunami affected fields showed an increase in pH and EC values, irrespective of distance from the sea. The water reaction was found to be in alkaline range (> 8.00) in most of the wells. Salinity levels are greater than 4 dS m^{-1} in all the wells except the ring well. The effect of summer rainfall on soil and water quality showed the dilution of soluble salts. Pumping of water has reduced the salinity levels in the well water samples and as well as in the open ponds.

Tsunami hazard maps generated using GIS approach depicts the relative Tsunami hazard of coastal Nagapattinam. The criteria taken into consideration for assessment of hazard mapping were types of land adjoining the coast and the topographical difference pertaining to the land. Hazard maps showed 20.6 per cent, 63.7 per cent and 15.2 per cent of the study area fall under high hazard, medium hazard and low hazard category respectively. Criteria boundaries adopted to delineate the regions have to be refined by comparing with the existing Tsunami events. Further, the factors like Tsunami strength and its character has to be considered in the hazard mapping.

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