Tsunami Impact (2004): Rehabilitation Processes along South Indian Coastal Hamlets using Spatial Information Technology

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Abstract

This research is about the relief and reconstruction made available to the Coastal Communities of Cuddalore district, one among the 13 districts of Tamil Nadu which were affected by the Tsunami of December 26, 2004. The disaster caused severe damages, loss of lives and loss of livelihoods. The study, by way of mapping the rehabilitation and relief processes in place, uses the GIS and GPS technologies for mapping to show both temporal and spatial variations in relief and rehabilitation. Data sources for analysis are the IRS-P6 LISS III digital data. Mapping vulnerable zones based on the past incidences like the intrusion of sea water levels along the coast and the present construction of temporary and permanent shelters to the affected persons and for disaster reduction in future are also discussed. Geographical database for the Tsunami relief and rehabilitation including a base map in the scale of 1:50000 were obtained and converted into digital formats. IRS-P6 LISS III data dated 17 April 2004 and 19 March 2005 with a resolution of 23.5 meters are processed to obtain the pre- and post-tsunami conditions along the coastal zone.

The total relief distributed to the next of kin and kith with total relief in brackets was: male: 108 (10.8 million Indian rupees MIR); female: 281 28.1 MIR, children, male: 101 (10.1 MIR); female: 107 (10.7 MIR) missing persons (not traceable) male: 11 (1.1 MIR); female: 11 1.1 MIR); children: male:15 (1.5 MIR); female:13 (1.3 MIR); and orphaned: male: 7 (3.5 MIR); female: 14 (7 MIR). Measures were immediately taken to control the spread of vector borne disease in the tsunami affected villages. Temephos were applied to number of wells, tanks, and other water bodies after tsunami, to control the spread of diseases. It was estimated that fishing equipments/materials and the relief paid to individual owners were: wooden catamaran partially damaged: 840; relief 126 MIR, fully damaged: 4,690; relief: 1500 MIR; FRP catamaran partially damaged: 677; relief: 264 MIR, fully damaged: 192; relief: 143, mechanized boats partially damaged: 479; relief: 602 MIR, fully damaged: 28; relief: 54 MIR, fishing nets: 326; relief: 32 MIR. The fisheries department had paid relief and rehabilitation to the tune of 2,721 MIR. Five permanent shelter locations in different habitations were within 500 meters of the high tide. Remaining shelters were located above 500 meters from the seashore, which were in the safer locations. The permanent shelters were constructed within the Coastal Regulation Zone as fishing habitations and they cannot be relocated at longer distances from the seashore. The provision of shelters was based on the mutual consensus of the affected fishermen and the distances and shelters were: permanent shelters were constructed as part of rehabilitation process and fishing activity was restarted; ten shelters were constructed between 500 m and 750 m to give close access to sea and fishing activity. The second phase with seven shelters was constructed between 1000 and 2000 m off the coast. The paper discusses the strategies for future as part of the disaster prevention and management programmes of the Government and the role of the NGOs and private industry.

Key words: Tsunami, Rehabilitation, vulnerability, inundation, GIS, GPS, georeferencing

1. INTRODUCTION

Earthquake generated huge tsunami waves that devastated the Andaman and Nicobar Islands, East coast of India on 26th December 2004. The regions include South Kerala in India, and several other countries like Sri Lanka, Indonesia, Thailand and Somalia in the Indian Ocean. The tsunami claimed more than 250,000 human lives in these countries. The aftershocks, numbering more than 250 in the magnitude range 5 to 7.3 magnitudes, were located for a length of 1300 km from Sumatra in the South to the Andaman and Nicobar islands in the North, till 30 January 2005. Heavy loss to life and property were reported in the first 500m off the shore, where coastal hamlets were washed away/destroyed. Small differences in local run-up and coastal topography resulted in large differences in tsunami inundation and associated changes with the ***total ecosystem and morphology of the coastal region of Cuddalore in the South East coast of India***. The surge water elevations, together with water depths appear to be important parameters in tsunami hazard analysis. Low valleys behind shore-parallel dune ridges claimed several lives due to lateral flows from tidal inlets or from breaches in the dune ridges. Keeping in view the observations during the survey, a detailed study has been taken up to assess the affected areas along the Cuddalore coast relating to pre and post tsunami conditions and rehabilitation processes aftermath of tsunami. Cuddalore coastal district (spatial unit) is one of the districts in Tamilnadu, which was severely affected by Tsunami on 26th December 2004 (Figure-1) . There are severe damages to the life and property through out the district. The seawater inundation levels of 200m to 3000m are noted at different villages of the district. The worst affected habitations are Devanampattinam, Akaraigori, Sonankuppam, Ariyagosti, Koththattai, Gunduuppalavadi and Killai (Figure-2) where the maximum inundation level is approximately 3000m.

2. Literature Review

Tsunamis generated by earthquakes, landslides, and volcanoes threaten coastal populations and facilities globally significant tsunami hazards. Catalogues of tsunamis impacting Southern California are available (McCulloch, 1985; Lander et al., 1993), while detectable tsunamis strike Southern California almost every year; most events arrive from far away and are too small to cause much damage (Lander et al., 1993). Moreover, the last significant local tsunami in San Pedro Basin occurred more than 70 years ago (McCulloch, 1985). Tsunamis tend to be considered in light of these facts, without a careful analysis of what could happen. For example, most studies of waves impacting the POLA/LB (the “Ports”) consider either wind waves or tides. Tsunamis can be expected to have wave periods somewhere in between these limits, a region of wave periods called infragravity waves. Harbor response to tsunami attack has rarely been studied (Walker et al., 1998), including the potential disruptions that tsunamis can cause to harbor operations. The recent tsunami in Indonesia promotes the idea of carrying out careful analyses of what could happen. Wilson (1971) shows wave records from the Ports for four transoceanic tsunamis this century. The Chilean tsunami of November 11, 1922 produced 1.3 m waves just outside of the Ports. Only one of the three existing breakwaters was in place at the time. The Aleutian tsunami of April 1, 1946 generated 1 m wave heights, trough to peak, near the East Channel of the Ports, and slightly smaller waves elsewhere. All three currently existing breakwaters were in place at the time of tsunami attack. The Chilean tsunami of May 23, 1960 generated waves about 2 m in height (1 m in amplitude) throughout the Ports. The Alaskan tsunami of March 28, 1964 generated 3 m wave heights (1.5 m wave amplitudes) at the Ports. These events had tsunami periods between 60-90 minutes and all caused damage to the Ports (Wilson, 1971). Recent numerical simulations of these tsunamis explain their limited impact relative to places such as Hilo, Hawaii: Southern California does not experience bathymetric wave focusing for tsunamis originating from some of these source regions.

Earthquakes can be expected every 15 years along active offshore faults and may reach up to magnitude 7 in strength (Clarke et al., 1985; Working Group on California Earthquake Probabilities, 1995). Given the Pacific-wide probability that roughly 20 per cent of offshore earthquakes generate measurable tsunamis, at least one local earthquake tsunami can be expected every 75 years off Southern California. This simple estimate agrees with historic records of local tsunamis (McCulloch, 1985) and Monte-Carlo predictions of local tsunami frequency (Watts, 2004). Vertical coseismic displacement during the larger of these events could achieve 2 m for certain rupture mechanisms (Kramer, 1996; Geist, 1998). This also agrees with historic records of local tsunamis (McCulloch, 1985). Coseismic displacement is not the only source of local tsunamis during an

earthquake there can be many tsunami sources during a single geological event, including numerous underwater landslides (Tappin et al., 2002a; Watts, 2001). Underwater landslides are usually triggered by offshore or nearshore earthquakes. A magnitude 7.0 earthquake can unleash thousands of landslides on land (Wilson and Keefer, 1985; Kramer, 1996) and numerous landslides offshore (Tappin et al., 2001). Despite an abundance of landslides from an offshore earthquake, observations of landslide tsunamis appear to be less common than those of earthquake tsunamis. For local tsunamis throughout the Pacific Basin, about 30 per cent of maximum run up measurements can be attributed to landslide sources, probably because most landslides are either too small or too deep to generate appreciable waves (Watts, 2003). Time of tsunami arrival (as opposed to tsunami amplitude) is a key means of identifying landslide tsunamis (Plafker et al., 1969; Tappin et al., 2001). The amplitude of landslide tsunamis does not correlate with earthquake magnitude (Watts, 2003, 2004); instead, tsunami amplitude varies over more than six orders of magnitude depending on landslide location and dimensions (Pelinovsky and Poplavsky, 1996; Watts et al., 2003). The theoretical maximum tsunami amplitude corresponds to the vertical center of mass displacement of the landslide (Striem and Miloh, 1976; Watts, 1998).

3. Geography of Cuddalore coast

Cuddalore also known as “Kuttalur” is the headquarters of Cuddalore District. It lies in the northeastern part of Tamil Nadu state, on the Bay of Bengal. The name is derived from Kuttal-ur (“junction town”) and refers to the location, near the junction of the Ponnaiyar River with its tributary, the Gadilam. Flooding occurs frequently in these rivers, causing damages to men and materials in this region. Cuddalore has an ***ancient seaport*** which was developed rapidly after the British East India Company obtained trading rights in 1682, but it later declined with the expansion of Madras (now Chennai). History of the systematic administration of the land revenue of South Arcot district begins with the acquisition from the Nawab in 1801. The district lies between 78 ^{o} 42’ and 80 ^{o} 12’ East latitude and 12 ^{o} 27’ 30” and 11 ^{o} 10’ 45” North longitude. The greater part of this area is covered with Archean rocks of the gneiss family, resting on the three great groups of sedimentary rocks belonging to different geological periods and overlying each other in regular succession from the coast on the east to the hills on the west.

4. OBJECTIVES

The specific objectives of the study are:

- To assess the impact of Tsunami along the Cuddalore Coastal villages using Indian Remote Sensing P6 LISS 3 digital data and digitally map the damages caused to men and materials;

- To design a Tsunami impact and relief maps using Geographical Information System for death toll, Loss to fishing equipments, agriculture and loss to live stocks and so on at village level and to show the progress of relief work being in progress; and

- To map the vulnerable zones based on the past incidences like the intrusion of sea water levels along the coast and the present construction of temporary and permanent shelters to the affected persons and for disaster reduction in future.

5. MATERIALS AND METHODS

To design a Geographical information base of the pre and post tsunami conditions and the subsequent relief and rehabilitation work, a base map in the scale of 1:50000 comprising taluk and village boundaries have been designed from the Survey of India topographical maps. The maps were scanned and merged to get digital formats. Geo referencing was done using software tool ArcGIS 9.0. Spatial features needed for the study are digitized in the Geo referenced map using Arc Map and extracted all the basic information and then converted into different shape files in Arc Catalog. Information regarding tsunami relief and rehabilitation work that were carried out in Cuddalore district was collected from tsunami relief and rehabilitation departments.

The data also from other departments such as relief amount paid by Human Resources, Fisheries, Agriculture and various recovery measures carried out by health were obtained from the concerned departments. The locations of the permanent and temporary shelters were located using GPS (Global Positioning System). The field survey has made awareness about the present condition of the affected people and it has also made to evaluate the relief and rehabilitation work carried out throughout the coast. For the digital image analysis of the affected regions in the coast zone, Indian Remote Sensing IRS-P6 LISS 3 data dated 17th April 2004 for pre-tsunami and 19th March 2005 for Post-Tsunami to Cuddalore district were obtained from National Remote Sensing Agency (India) for 23.5 m spatial resolution, to access the impact due to tsunami and the damages were estimated. The location of Temporary shelters and permanent shelters were surveyed by GPS and overlaid on the digitized maps and the corresponding data were added to the attribute table.

6. RESULTS AND DISCUSSION

6.1 Pre and Post Tsunami Impact

Figure-3 shows the raw digital data of the affected villages of the Cuddalore coast from Gunduppalavadi to Akkaraigori derived from the optical digital data of IRS P6. For the image analysis eight region of interest were selected to map the tsunami destruction parameters in this coastal village. Table-1 infers the features like wetland, sand and water bodies thrown away/ dumped due to impact of tsunami waves; the table also indicates that huge sand particles were dumped along the coast and it seem to be an undulated plain. Figure-4 implies the classified map of the affected villages in Cuddalore coast. They provide very clear and indepth information about the selected three most affected villages namely, Devanampattinam, Singarathoppu and Uppalavadi regarding the changes in the coastal area due to turbulent Tsunami waves. Sand inundation had affected many places along the coast and in some places over wetlands and agriculture lands. Other feature such as huts, built ups, vegetation and barren land have been reduced in the post tsunami image. The computed values between the pre and post tsunami conditions reveal that there has been a change in the built-up areas of settlements and huts by negative 56 and 13 per cent. Barren land has been reduced by 5 per cent among the coastal samples. Wet land, increased by 83 per cent; agriculture land filled with sand and water bodies reduced to 30 per cent; sand inundation among the sample areas have been reduced by -83 per cent; vegetation cover along the coast has been reduced by 28 percent; water bodies have increased to 7 per cent due to upwelling of waves.

6.2 Tsunami and Rehabilitation

East coast of India has been experiencing frequent cyclonic storms, floods and drought and devastating this region seasonally. The coastal areas faced seven severe to very severe cyclonic storms in the last decade. The storms are more frequent in the Bay of Bengal and records indicate that from the beginning of this century about 400 cyclonic storms formed in the Bay of Bengal alone as compared to just 80 in the Arabian Sea. While the state is familiar with this kind of disasters, the tsunami that struck the coast of Tamilnadu on 26th December 2004 was totally unprecedented and very destructive nature because of its sudden actions. It was also widespread in scale of affecting villages and towns all along the coastline. The human death toll crossed 6000 persons and thousands of people lost their houses livelihood. The coastal economy has been paralyzed due to the loss of fishing gear and related infrastructure.

There were various relief and rehabilitation activities carried out, throughout the coast zone by various departments. They provided relief in the form of cash payments to the affected people; include Human resource, Fisheries, Animal husbandry department and son on. A geographical information base has been created for the above parameters for mapping the relief work carried out by various departments. Figure-5 implies the loss of population which includes male, female, children (male and female), post tsunami missing figures including male and female and orphans details. The details acquired from the District administration are as follows towards the loss of human life and the total relief distributed to the next kin and kith with total relief in brackets: male: 108 (10.8 million Indian rupees MIR); female: 281 28.1 MIR, children, male: 101 (10.1 MIR); female: 107 (10.7 MIR) missing persons (not traceable) male: 11 (1.1 MIR); female: 11 1.1 MIR); children: male:15 (1.5 MIR); female:13 (1.3 MIR); and orphaned: male: 7 (3.5 MIR); female: 14 (7 MIR). Measures were immediately

taken to control the spread of vector borne disease in the tsunami affected villages. Temephos were applied to number of wells, tanks, and other water bodies after tsunami, to control the spread of diseases. Number of fly attracting and breeding sites were treated for the control of vector borne diseases. The following are the details of the patents treated aftermath of tsunami: acquired respiratory infection among male: 268; female: 306; Figure-6 shows the information about the different cases of diseases and the corresponding medicines provided by the health department to the tsunami affected victims. The housing comprises repairs, relocation, and arrangement of temporary shelters to the affected habitations and reconstruction of houses in the affected areas. Land is being acquired to relocate families in safer locations with a sum of around 1500 million Indian rupees.

6.3 Assistance to Fisheries Sector

Figure-7 represents the relief distribution to the loss of fishing materials. It is obtained from the map that relief for wooden catamaran are provided high compensation when compared to other equipments Government of Tamilnadu had sanctioned a sum of 272.3 million rupees from Impact of Tsunami: Details of Loss of Fishing Equipment the Calamity Relief Fund as an immediate package of following assistance to the fishermen. Financial assistance to the tune of Rs.0.44 millions rupees have been sought for providing immediate financial relief to repair damaged fishing implements belonging to the Mudasoladai village fishing harbour. It was estimated that the following categories of fishing equipments/materials and the relief paid to individual owners: wooden catamaran partially damaged: 840; relief 126 MIR, fully damaged: 4,690; relief: 1500 MIR; FRP catamaran partially damaged: 677; relief: 264 MIR, fully damaged: 192; relief: 143, mechanized boats partially damaged: 479; relief: 602 MIR, fully damaged: 28; relief: 54 MIR, fishing nets: 326; relief: 32 MIR. The fisheries department has in total paid relief and rehabilitation to the tune of 2,721 MIR.

6.4 Assistance to House Property Damages

Damage to coastal settlements/ hamlets/ huts have been categorized as partially damaged and fully damaged. In some villages all the houses were fully damaged due to severe impact. In most of the villages both houses damaged partially and completely is found in mixed type (figure-8). An amount of Rs.2000 was provided for the houses that are damaged partially and a sum of Rs. 4000 was provided for houses destroyed completely. A total amount of 7,304,000 Indian rupees were paid in total for the houses damaged completely and 4,948,000 rupees for the houses partially damaged. Figure-9 shows an example of the affected village of the district that has provided permanent shelter. It is shown in the map the possible relocation of the permanent shelters that have been constructed in vulnerable site that is, it is constructed to the close proximity to the seashore less than 500 meters. The relocation has been provided on the basis of the land availability and distribution of natural and cultural features in the village. For relocation processes, the nature of job of the habitations must be taken into consideration. But the fact that, it is very difficult to relocate the fishing habitations to the higher distance from the seashore as they depend on the sea for their survival.

7. Vulnerability Zones: Permanent and Temporary Shelters

Figure-10 represents the location of Temporary shelters along the district. The map depict the information such as number of shelters and the distribution of temporary shelter in each village Information such as number of families living in each of the temporary shelters are added to the attribute table of the corresponding location. Apart from this distribution point from where the essentials materials to the peoples in temporary shelters have been shown. The Government has sanctioned a sum of 27.5 million rupees for building temporary accommodation at the rate of Rs. 8000 per family for 5670 families. Totally 925 temporary shelters have been constructed by the Government and the NGOs have taken up and Completed 1577 temporary shelters. A sum of 5.2 million rupees has been sanctioned for 1500 temporary shelters at Rs. 2000 per shelter for repairing the damaged roofs, to provide infrastructure facilities like toilets, bathrooms and community sheds around the shelters. A sum of 2.2 million rupees has been sanctioned for providing water supply and lighting to the temporary shelters in Cuddalore District. A sum of 1.5 million rupees have been sanctioned for providing compound well, bore well, cleaning, leveling the site etc., at temporary shelters. A sum of Rs.1.2 million rupees

has been sanctioned for Construction of 140 new transit shelters and provision of EB connection to Temporary shelters at Cuddalore district.

7.1 Permanent Shelters

Figure-11 shows the Permanent shelters locations in the Cuddalore district. The map visualizes the information such as Number and distribution of the permanent shelters in each village. Number of permanent houses constructed at each location, number of shelters allotted and name of the NGO aided the construction are given in the attribute table of each location. In the map the distribution point form where the information regarding the permanent shelters, assistance needed for the construction of permanent shelters for various Government and NGOs are provided. The Government has announced a massive housing programme to build 1816 houses in all the affected areas at an unit cost of 0.15 million rupees each. Additional 507 houses also allotted for construction. The government provides all Infrastructure facilities like roads, water supply, sanitation, Rain Water Harvesting structures, etc., will also be provided. The land is being provided free of cost by the Government, had sanctioned a sum of Rs. 16.4 million Rupees towards the cost of land acquisition for construction of houses and other infrastructure to the affected communities. So far 2080 permanent shelters have been constructed and handed over to the affected habitations.

7.2 Problem in the Allocation of Permanent Shelters

Figure-12 shows the distance of the permanent shelters from the seashore. Buffer zones up to three thousand meters from the seashore were shown and on the basis of it distance of the permanent shelters form the seashore is obtained and the permanent shelters with in the limit of five hundred meters form the coast line are identified. Nearly five permanent shelter locations in different habitations are within five hundred meters from the seashore. Remaining shelters are located above five hundred meters from the seashore which are in the safer locations. The permanent shelters are constructed within five hundred meters from the seashore as fishing habitations and they cannot be relocated to the longer distance from the sea shore and it may be a major constraint for the fishermen community. The provision of shelters in these locations was based on the mutual consensus of the affected fishermen and the distances and shelters are as follows: permanent shelters were constructed as rehabilitation processes and to restart the fishing activity and ten shelters were constructed 500 m to 750 m to have close access to sea and fishing activity. The second phase with seven shelters was constructed from 1000 to 2000 m off the coast.

8. CONCLUSIONS

The Relief and Rehabilitation Processes in Cuddalore coastal villages have been nearing completion. This can be concluded on the basis of the assistance provided by the various departments, especially provision of permanent shelters to the affected habitations. Nearly 90 per cent of the permanent shelters have been constructed and handed over to the affected habitations. In the present study area very few habitations have been allocated with permanent shelters, which is close proximity to the seashore. As these shelters are within the coast zone regulation they are unsafe during cyclonic storms and tsunami impacts. The administrators need to relocate these settlements so that the livelihood of the habitations will be safe. The district administration must teach the people about the vulnerability towards the natural disasters and make them to understand and then adopt re-location strategies after fulfilling their (fishermen) needs.

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Table 1
Satellite Image Classification Results
(Gunduvuppalavadi to Akkaraigori)

S.No	Region of interest	Pre Tsunami (Area in Sq. mt.)	Post Tsunami (Area in Sq.mt.)	Change in percentage
1	Built-up area	1610361	701358	-56
2	Huts	1337550	1156964	-13
3	Barren land	654416	621834	-5
4	Wetland	500891	946004	+83
5	Agriculture land	1032155	728417	-30
6	Sand inundation	1546300	261379	-83
7	Vegetation cover	481562	350126	-28
8	Water bodies	8232943	8831030	+7

Source: Indian Remote Sensing P6/ LISS-III Digital Data

Table 2
Satellite Image Analysis Results:
Pre and Post Tsunami conditions of Coastal Cuddalore

(Area in sq. meter)

S. No	Region of Interest	Gunduvupplavadi to Akkaraigori		Singarathoppu Village		Uppalavadi Village		Devanampattinam Village	
		PrT	PoT	PrT	PoT	PrT	PoT	PrT	PoT
1.	Built-up	1610361	701358	259005	113764	810703	354545	545623	234154
2.	Huts	1337550	1156964	224213	198258	624594	509175	497577	456711
3.	Barren land	654416	621834	272259	119286	489845	478249	258453	219796
4.	Wetland	500891	946004	404799	235259	1613674	1517583	208198	600848
5.	Agriculture	1032155	728417	5144208	5221524	483771	960363	483218	917287
6.	Sand	1546300	261379	156286	303185	143032	360067	389336	350679
7.	Vegetation	481562	350126	173406	73449	226422	329693	1054797	770941
8.	Water bodies	8232943	8831030	603057	1085724	470517	641715	2574037	2606068

Source: Indian Remote Sensing P6/ LISS-III Digital Data // **PrT: Pre-Tsunami // PoP: Post-Tsunami**