APPLICATION OF GIS & REMOTE SENSING IN TSUNAMI MAPPING IN CAR NICOBAR ISLANDS

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ABSTRACT The Great Indonesian Earthquake (M9.3) triggered at 6.30 IST and felt and damaged partially large number of buildings of the island. The first tsunami wave hit the island around 6.45 am due near tsunami field. The second Tsunami wave hit the island around 7.15 am and resulted in a great damage to the peripheral part of the island. The present studies deals with the assessment of the damages caused by the Great Tsunami. The GIS and multidate Remote Sensing (high resolution) data are used to delineate the various landuse patterns that are affected by the Tsunami. The assessment indicates the damages of the existing beaches, coral life, forest lands, urban areas, mangroves, coconut plantation, waterlogged areas etc. The extensive field surveys have been conducted in the island and followed by digital image processing of the satellite data. The generation of the damages caused by the tsunami has been evaluated in terms of the areas viz. Coconuts plantation (30ha), Coral (210ha), Edges rocks (117ha), Mangroves (49ha), Settlement (610ha), Submergence of the beach (126ha), Vegetation (878ha), and Waterlogged areas (56ha). The GPS measurement indicates the tilting of the island to a maximum of 0.6 mts towards the eastern side. The western uplifted part of the islands has been elevated to 1mts, as measured by the high resolution multidate satellite data. It has also been noticed during the field measurement that the approximate emergence of the islands is 70mts whereas the submergence is 100mts.The application of the high resolution satellite data and the integration through the GIS has been proved successful in assessing the tsunami damages in the Car Nicobars islands which is located about 200kms from the epicenter of the Great Indonesian Earthquake of 26th December 2004.

1. INTRODUCTION

The Nicobar Islands are situated in the South-east of the Bay of Bengal between $6^0 – 10^0$ North latitudes and between $92^0 – 94^0$ East longitudes. There are altogether 22 large and small islands, out of which only twelve have inhabitants. The most northerly island of the group is Car Nicobar, which is 143 miles (230km) from Port Blair and the ten degree channel about 75 miles (121km) separates it from Little Andaman. Chowra, Teressa, Bompoka, Katchal, Kamorta, Nancowry and Trinket form the central group of Nicobar Islands while in the southern group are Pulo Milo, Little Nicobar, Kondul, and Great Nicobar. The extreme southern point of Great Nicobar, previously known as ‘Pygmalion Point’ and now ‘Indira Point’, is also the southern most tip of India which is about 310Kms from Car Nicobar and barely 146.45km from Pulo Brass of Achin Head of Sumatra Island (Indonesia) (http://www.nicobar.nic.in/intro.htm). The Nicobar stretches over 36 miles, with an aggregate of 635 sq. miles.

The Nicobar Islands are part of a great island arc created by the collision of the Indo-Australian Plate with Eurasia. The collision lifted the Himalaya and most of the Indonesian islands, and created a long arc of highlands and islands, which includes the Arakan Yoma range of Myanmar, the Andaman and Nicobar Islands, and the islands off the west coast of Sumatra, including the Banyak Islands and Mentawai Islands (http://www.forest.nic.in/frst-island1.htm). These islands are the summits of a submarine mountain range lying on the great tectonic suture zone extending from the Eastern Himalayas along the Myanmar border to the Arakan and finally Sumatra and Lesser Sundas. The geological formations represent a period of sedimentation from Cretaceous to Sub-Recent period. The surface deposits of gravel beds and raised soil covers that are of recent origin seem to be of Holocene age (>10,000 yrs). The present configuration of these islands took shape only about 26 million years ago.

The earthquake of December 26 that occurred off the west coast of Northern Sumatra took place at the interface between the India and Burma plates, where Burma plate has been referred by Andaman/Nicobar Ridge that acts as a small tectonic plate (Curray et.al., 1982). In this region the Burma plate is characterized by significant strain partitioning due to oblique convergence of the India and Australia plates to the west and the Sunda and Eurasian plates to the east. It is a typical oceanic-oceanic convergent plate boundary where the Indian plate moving at a rate of 6 cm a year relative to the Burma plate came together, collided and the Indian plate subducted under the Burma plate. Volcanic eruptions are commonly seen at such convergent boundaries. Two major plate tectonic features on either side of a narrow strip show how seismically active the region is.

The U.S. Geological Survey has called this event a mega thrust earthquake referring to the large cracking of the plate boundary. According to them, mega thrust earthquakes often generate large tsunamis that can cause damage over a much wider area than is directly affected by ground shaking near the earthquake's rupture. Tsunami was generated in the fast slip area (first 650 km at taut length) and the waves propagated in all directions. The propagation of tsunami waves is much stronger in east-west direction than north-south direction. Further, due to slow slip in the remaining northern areas, it appears that no tsunami was generated there. As a result, strongest waves hit the coasts of Thailand, Indonesia and other nearby areas (Nicobar Islands) which are closely located on the east of the epicenter. On 26 December 2004 the coast of the Nicobar Islands was devastated by a 10-15 m high tsunami following the 2004 Indian Ocean earthquake. At least 3000 people (possibly a conservative estimate) were believed to have been killed on the disaster. As the Nicobars apparently lie directly in the local line of greatest weakness, severe earthquakes are to be expected, and have occurred many times. Stocks of great violence were recorded in 1847, 1881 (with tidal waves), and many times during 20th century. The tidal waves caused by the explosion of Krakatoa in the Straits of Sunda in 1883, were severely felt (www.ngdc.noaa.gov/nmdc/servlet/showdatadatasets).

2. STUDY AREA

The Car Nicobar Island lies between 8.95^0 — 9.22^0N latitudes and 92.76^0 — 93.05^0E longitudes with a geographical area of 126.9 km^2 in the eastern side of the Indian continent (Fig 1). The total population as per 2001 census is 20,292 only. It has a tropical type of climate with temperature ranging from 22ºC to 32ºC and relative humidity of 70%. The island experienced very heavy rainfall, measuring around 2286mm and 4318mm each year, due to annual monsoons that extends over a period of eight months (http://www.nicobar.nic.in/loc_cli.htm). There is no major perennial fresh water river in the islands but several rain fed streams that dry up during summer drain the island. Car Nicobar is remarkably flat except for some cliffs in the north and small hilly areas in the interior. Soil cover is rather thin, varying from 2m to 5m. It is mostly alluvial on hill tops with diluvial in the ridges and valleys. The island is bordered by a silvery beach and areas of flat ground consisting of sand, silty clay and diluvial material with fine fragments of coral lime. The soil is, in general, mild to moderately acidic with high humus on top. The vegetation of the Nicobar Islands is typically divided into the coastal and mangrove forests and the interior evergreen and deciduous forests. Additionally, Kamorta, Katchall, Nancowry, and Car Nicobar all contain extensive interior grasslands, but these are thought to be anthropogenic in origin (Rao 1996; Daniels 1996). The grasslands are composed mainly of *Imperata cylindrica, Saccharum spontaneum, Heteropogon contortus, Chloris barbata, Chrysopogon aciculatus,* and *Scleria cochinchinensis,* along with many herbs and shrubs.

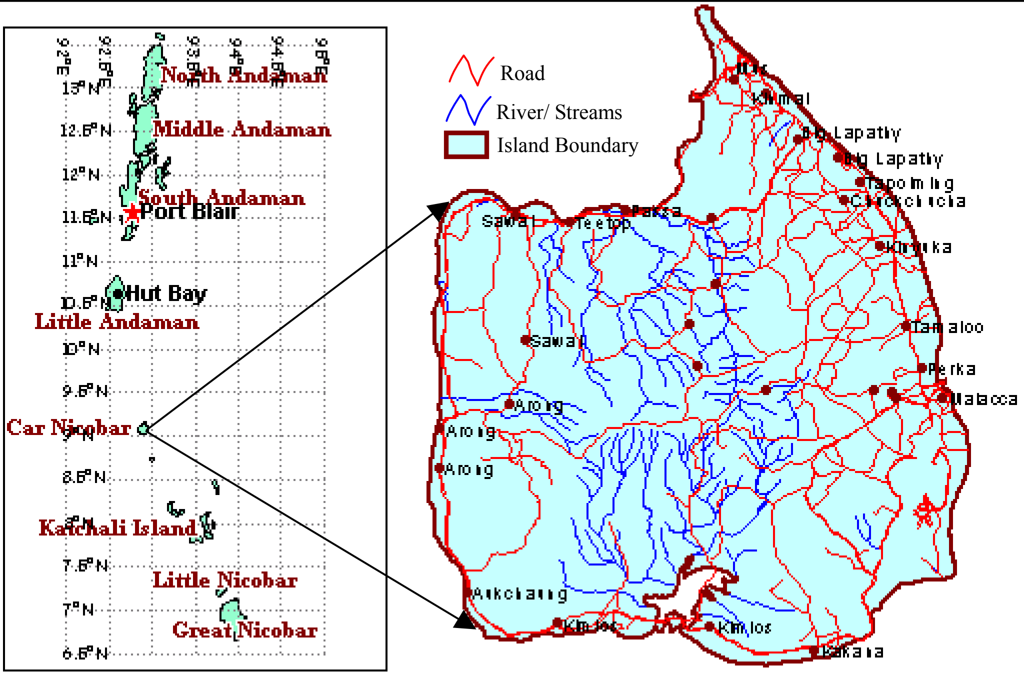

Fig 1 Location Map of the Car Nicobar Island

3. MATERIALS AND METHODOLOGY

Materials used: Survey of India (SOI) topographic Maps, Satellite imageries- IRS-IC LISS III (24 Feb. 1999), IRS-P6 (16 Feb. 2005 & 01 Feb. 2005), GPS- Garmin etrex & Garmin vista, Sony Handycam, Sony Digital still camera, High precision Oregon scientific Altimeter, Measuring tapes, Staff etc.

Methodology: The pre and post satellite data of the Car Nicobar Island are processed using the ERDAS IMAGINE 8.4. Both the data are projected to “Polyconic projection” with “Everest Spheriod” and “Undefined Datum” so that the measurements may be done with ease. The imageries have been enhanced using various enhancement techniques like contrast enhancement, piecewise contrast, breakpoints etc. These enhanced satellite data are then processed to obtain the true colour so that a natural view of the island may be obtained. The coastal features observed in both data (pre and post) are digitized in a GIS domain using ERDAS Vector and ArcView to map and assess the damages (Fig 2). A Digital Elevation Model (DEM) and Digital Terrain Model (DTM) of the island are also generated to assist in mapping and to assess the effects of tsunami of the Island. On the basis of the elevation data of the surface, a DEM/DTM creates topography by geometric surface in a computer environment. This method provides best approach (Alpar B et.al 2004) to a 3D terrain surface using elevation points which were defined on a horizontal plane, from various data sources such as measured data, topographic maps, bathymetric data and images. In the present study the DTM was produced using Survey of India topographic maps and SRTM data with a vertical resolution of +/-1m with a cell size of 22mts. The data of locations that were collected using the Garmin’s handheld GPSs and high precision altimeter during the field survey were used as overlay on the DTM to verify the effects caused by the great tsunami. A comparative analysis of the pre and post tsunami satellite data is also done to calculate the coastal subsidence, sediment deposition, damages and other changes along the periphery of the island. All the observations and analyses carried out are supplemented and verified by the field survey information.

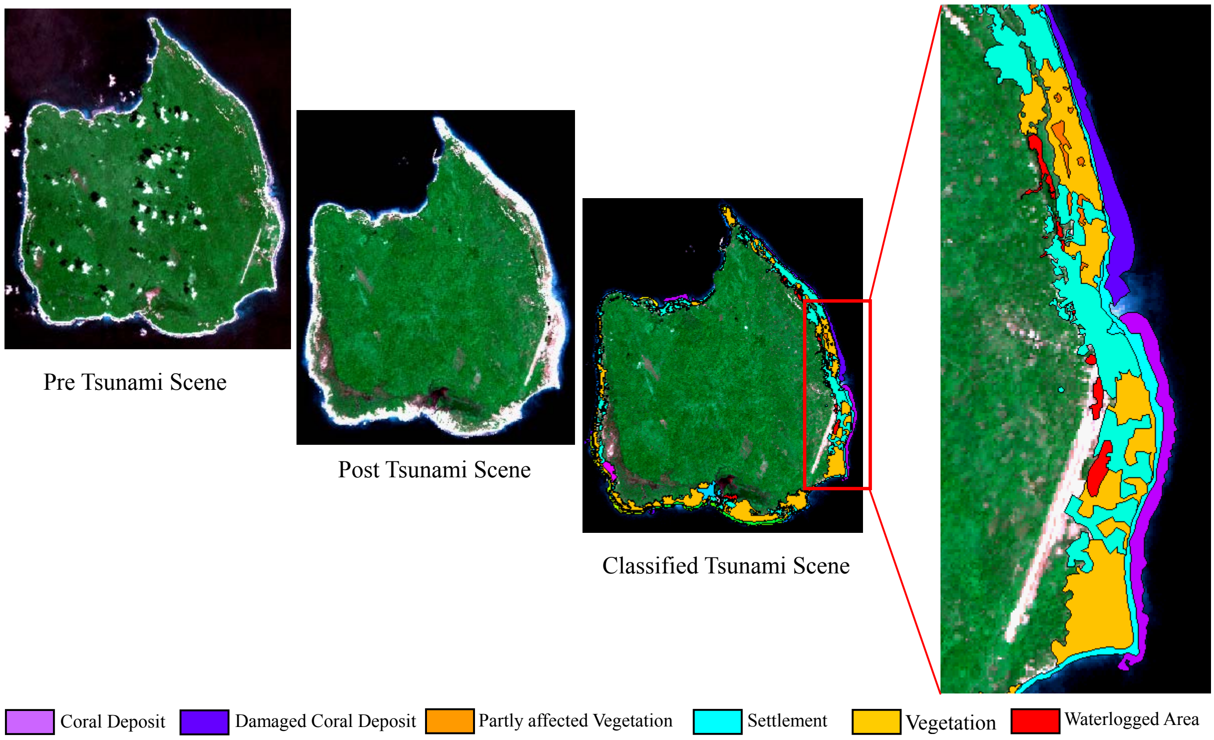

Fig 2 Stages of Mapping the Tsunami

4. OBSERVATIONS AND DISCUSSIONS

A team of experts from Manipur University studying the effects of the December 26 tsunami on Car Nicobar Island documented wave heights of 10 -15 m (30 to 35 ft) at the island's northwest, southeast, northeast and southwest ends and found evidence suggesting that wave heights may have ranged from 10-15 m (24 to 30 ft) along at least a 5-km stretch of the northwest coast including Malacca airport area. The survey was conducted from May 6-14, 2005 in the Car Nicobar Island. About a one third of the 20,292 residents of island, are dead or missing.

Among various observations made by many workers on the characteristics of past tsunami hazards mention may be of Yalciner et. al. (1999, 2001 and 2005), Altinok et. al. 1999; Musaoglu 2000; and International Coral Reef Initiative/International Society for Reef Studies (2005) that has provided a rapid assessment and monitoring are worth mentioning. In the present studies tsunami hazards are mapped, delineated and assessed by the various observations during investigations and the results have been finalized in terms of Wave heights at the beach and inland, Run-up elevation (the water's height relative to mean sea level at its farthest reach inland), Inundation distance (how far inland the water reached), Damage to structures, Sediment deposition, Coastal subsidence, Erosion and Coastal response.

The major portion of the island's coastline corridor are found be badly affected by the Great Tsunami of 26th December 2004. The total distance of coastline corridor being affected and damaged is about 37.52 km. And the majority of the damages were observed along the coast of 'Aukchung-Kimus-Kakana' and 'Malacca-Tapoiming-Lapathy-Mus' villages. It was observed that these areas were struck by the highest waves, some more than 15 m high. Waves that hit the north-facing coastline of T-top and Passa were lower, about 8-10 m high, but the low-lying nature of the area allowed those waves to penetrate far inland. It is observed during the survey that many two storied buildings are inundated by tsunami waves (Fig 3) and trees have the debris carried by tsunami water (Fig 4) indicating the height of the tsunami.

Fig 3 Damaged roof of the building indicates tsunami height

Fig 4 Debris on trees indicate tsunami height

The run up levels of the tsunami varied from 2 m to 19m with the distance of penetration (inundation) from the coast ranging from 295.87 to 1202.57m. It is observed that Nicobar Island, being very near to the earthquake source, the tsunami water inundated from all the sides and flown towards the inland. The flow direction of the tsunami water was from all sides of the island. A considerable part of all the beaches hosting mostly infrastructural, commercial and residential complexes have been fully damaged.

5. ASSESSMENT OF THE DAMAGES

In order to assess the damages caused by the Great tsunami in the Car Nicobar Island the pre and post tsunami satellite data are critically analysed in the GIS domain. For this a base map is generated from the SOI topographic map of the region. The Base Map is later on updated from the field data and information obtained from the Nicobar Island Administration office. Based on this map the coastal area of the two scenes (pre and post) have been classified and vectorised using the ERDAS vector and ArcView software. Overlay analysis of these classified vector data is performed to find out the changes in the coastal corridor of the Island and ultimate the assessment of the damages is done form this analysis. The result of the assessment is tabulated (Table 1).

Table 1 Damages assessment

Name	**Area (Ha)**
Coconut plantation	30.45
Coral	209.50
Edges rocks	117.37
Mangroves	48.91
Settlement	609.67
Submergence	125.65
Vegetation	877.71
Waterlogged areas	56.00
Total Area affected	**2075.26**

6. CONCUSIONS

The Great Indonesian Earthquake of 26 December 2004 and a subsequent Great Tsunami event has led to the wide spread devastation in the Indian Ocean coast and all islands in its vicinity. These events have created ways and means to explore the nature's mystery of natural processes/hazards in the Indian Ocean. The damages caused by these hazards are being accounted to the losses of millions of dollars and loss of life of lakhs of people and many more homeless. The application of High resolution Remote Sensing data and GIS techniques are used to assess the tsunami hazards in the Car Nicobar Island. Maximum tsunami wave height was 15 meters at the SE parts of the island and minimum of 0.7 meters with a distance from the shore line of 400 meters and 368.58 meters respectively. The run up levels varied from 2-19 mts and penetration distance from the coast ranges from 295.87-1202.57 mts on the inland. The tsunami water flowed from all the directions to the island. A considerable part of all the existing beaches hosting mostly infrastructural, commercial and residential complexes have been fully damaged. The sand deposits at Aukchung and Arong beaches are 2.5 and 1 meter respectively. The coastal subsidence near Malacca Jetty is 0.75 mts and a temple on Malacca beach is 1-1.25 meters. About 2075.26 ha area of the coastal region of the Island is badly damaged by the Great Tsunami. The Car Nicobar Island underwent significant coastal modification. The study indicates considerable coastal erosion at Aukchung, Kimus and Malacca villages.

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