Impact of tsunami of Sumatra-Andaman earthquake on vegetation of coastal swamps of South Andaman

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Received 20 September 2012; revised 03 July 2013

The 2004 Indian Ocean earthquake, known by the scientific community as the Sumatra-Andaman earthquake, was an undersea earthquake that occurred on December 26, 2004, with an epicenter off the west coast of Sumatra, Indonesia, and the consequent tsunami have caused considerable change on the vegetation of coastal swamps of Andaman. It caused remarkable damage to the mangrove population in the tsunami-wave affected areas, like Sipighat, Netaji Nagar, Wandoor, Chouldhari, Ograbranch, Tirur and Habdipur of South Andaman. In South Andaman, in particular localities 30–80% of mangrove stands got affected by the tsunami-wave. The devastating wave of tsunami trounced the standing crops, particularly paddy in many parts. The water level increased about 1.5-2.0 m. Damage was so severe which lead some barren patches in those mangrove areas. Level of salinity also increased significantly in the affected areas. Re-establishment of mangrove has been seen in many affected areas, such as Tirur and Habdipur.

Keywords: South Andaman, tsunami-wave, coastal vegetation, coconut plantation

Introduction

Indian Ocean experienced the world most deadly natural disaster in the early morning of 26th December, 2004. The 2004 Indian Ocean earthquake, known by the scientific community as the Sumatra-Andaman earthquake1, was an undersea earthquake that occurred on December 26, 2004, with an epicenter off the west coast of Sumatra, Indonesia. Earthquake triggered a series of devastating tsunami along the coasts of most landmasses bordering the Indian Ocean, killing large numbers of people and inundating coastal communities across South and Southeast Asia, including parts of Indonesia, Sri Lanka, India (Andaman and Nicobar Islands, coastal areas of Tamil Nadu and Kerala), and Thailand.

The magnitude of the earthquake was originally recorded as 9.0, but has been increased to between 9.1 and 9.3. At this magnitude, it was the second largest earthquake ever recorded on a seismograph. This earthquake was also reported to be the longest duration of faulting ever observed, lasting between 500 and 600 seconds (8.3 to 10 minutes), and it was large enough that it caused the entire planet to vibrate as much as half an inch, or over a centimeter2. It also triggered earthquakes in other locations as far away as Alaska3.

The tsunami has caused unprecedented impact on the aqua-terrestrial ecosystem in the coastal environment. The impact of that tsunami left a remarkable effect on the mangrove and coconut plantations near the seashore in Andaman and Nicobar Islands, India. Total area under mangrove vegetation in India is 4827 sq. km. as per the latest estimate of the Forest Survey of India (1999). Out of this, 966 sq. km area of mangrove vegetation occurs in Andaman and Nicobar Islands4, which means that one fifth of the country’s total mangroves occur in these islands. In Andaman district, area under mangroves is 929 sq. k.ms., while in Nicobar district mangroves occupy 37 sq. km. Area wise A & N islands are third in the country, but as far as density and growth are concerned, mangroves of these islands are probably the best in the country. The mangrove vegetation of these islands constitutes 9.4% of the land area or 10.85% of the total forest area. Mangroves occurring in these islands are mostly fringing the creeks, backwater and muddy shores.

Usually the mangrove plants can tolerate saline water. The main tolerance mechanism is to prevent much of the salt from entering by filtering it out at root level. Analysis of water inside mangroves has shown that 90% to 97% of salt has been excluded at the roots. The leaves of many mangroves have special salt glands. Another method is the retention of water in the leaves giving rise to leaf succulence in many species. Fourth method of coping with salt is to
concentrate it in bark or in older leaves which carry it with them when they drop.

About 60 species of mangrove occur throughout the world. Asia is the richest region of mangrove species diversity with 44 species reported to occur. As per available information from various sources 27 tree species, 5 shrubs, 1 climber and 2 species of palms and ferns each belonging to 17 genera are reported to occur in the mangrove ecosystem of these islands. Important mangrove species found in these islands include- *Rhizophora mucronata*, *R. apiculata*, *Bruguiera gymnorrhiza*, *B. parviflora*, *Avicennia officinalis*, *A. marina*, *Ceriops tagal*, *Heritiera littoralis*, *Sonneratia caseolaris*, *S. alba*, *Exoecaria agallocha*, *Xylocarpus granatum*, *Aegiceras corniculatum*, *Scyphiphora hydrophyllacea* and *Nypa fruticans*.

**Materials and Methods**

Soil was collected from Tsunami affected area of Chouldhari, Sipighat, Netaji Nagar, Ograbranch, Wondoor, Habdipur and Tirur of South Andaman, Andaman and Nicobar Islands. Soil pH, electrical conductivity (EC) and salinity (in dS/m) was estimated using standard protocol. Survey was done to find out the causes of mass destruction of mangrove and coconut plantation near the seashore of Ograbranch, Sipighat, Netaji Nagar and Wodoor. Information was collected from the local peoples of the above mentioned places on the nature of vegetation before permanent sea water inundation due to Tsunami and extent of submergence by the tidal water of sea before Tsunami. Those collected information were supported with the scientific research already done on the effect of tsunami on the coastal vegetation of Andaman and Nicobar Islands.

**Results and Discussion**

**Immediate effect of Tsunami on soil**

Cracks formed due to earth quack and thus salt water infiltration took place into deeper layer of soil. In most of the affected areas water intrusion changed the soil conditions and turned it to be unfavorable for immediate crop cultivation. The deep-brown coastal-fertile alluvial soil, which has slightly higher amount of clay content, normal pH and EC, and better drainage facilities have been altered after tsunami. The EC of such silty clay tsunami deposits vary between 6.7 dS/m and 23.7 dS/m. A saline soil has an EC of the soil saturated extract more than 4 dS/m. Water containing EC of 1 dS/m is approximately 640 ppm (9.5 ton/ha salt in 6 inch soil layer). Yields of most crops are substantially reduced as EC increases above 4.0 dS/m. Post tsunami soil EC level have increased by 5-15 times compare to normal season, while soil pH levels increased marginally. However, the sub-soil EC of the silty clay deposited is remarkably less than that of the surface soil.

During dry season, salt appears on the surface in the tsunami affected areas. In order to improve such situation removal of salt by surface scraping or flush or leach by huge water application is alternative to quick reclamation. If tillage operation is done through mechanical methods the salt will further mix and this will take long time to reclaim the soil. Traditional tillage practices and controlled irrigation water applications will help to keep the salt away from crop root zone.

**Impact of Tsunami on coastal paddy fields**

The devastating wave of tsunami trounced the standing crops, particularly rice in many parts of South Andaman (Fig. 1A). Rice is dominating in case of field crops in Andaman. C14-8 is the most popular variety of rice grown in Andaman Group of Islands. Harvesting time of this variety is the second fortnight of December. This variety of rice was mature stage in the field. Thus, a large area of rice land has damaged by the devastating tsunami. Sipighat (Fig. 1B), Netagi Nagar and Wandoor still remained under submerge condition by the water brought by the tsunami-wave or remained under submerged condition by the tidal wave due to raise in water level due to the tilting of earth plate by great Sumatra-Andaman Earthquake. Whereas, the tsunami-water ranback into the creek in the chouldhari area after few months of Tsunami. As there is heavy rainfall in Andaman Group of Islands, the salt and silt deposited by the tsunami-wave were some extent washed out or leached down by the rain water. Now it is possible to cultivate salt tolerant rice varieties in this area (Fig. 1C&D).
Fig. 1 – Rice field in tsunami-wave affected areas in South Andaman. **A)** Rice field at the next day of tsunami at Sipighat; **B)** Same rice field area in this figure ‘A’ inundated by tidal wave even after seven years of tsunami; **C)** & D) Rice field at Chouldhary tsunami-wave affected area after seven years (September, 2011).

*Impact of Tsunami on coastal coconut plantation*

Tsunami damaged more than 3900 ha of agricultural land of these islands. Coconut trees along coastal line uprooted/damaged heavily by the tsunami-wave. The causes of damage of the coconut plantation may as described herewith. Coconut plantation in Ograbranch completely damaged due to inundated tsunami water (Fig. 2A&B) leaving only few plants toward the mountainside, which is comparatively elevated land (Fig. 2A). Land lost its productive potential due to salt and waterlogging in embankment areas and/or low lying areas; even possibility of getting permanently waterlogged due to large scale embankment erosion and lost fertility of coastal lands due to sediment deposits. It also led sedimentation of drainage channels, creeks’ mouths, lagoons and water ways. In many areas, sediments of fine grey layer to grayish brown layer deposits of varying depths (5-35 cm) in the low lying areas. Residual high content of salt is in the layers of clay and silt left behind by the tsunami-waves. These layers can be easily identified by cracks that spread across the surface of the soil.
Impact of Tsunami on coastal vegetation of South Andaman

There was no immediate effect Tsunami on the mangrove, except physical damage by the tsunami-wave and backwash. Symptoms of damage of costal mangrove appeared after 9-12 months of Tsunami. The plant in the mangrove areas as well as the coconut plants near the seashore of the Tsunami affected areas started to die. Southern part of South Andaman Islands has suffered greater causalities. Mangroves along the creeks are all heavily damaged, where as the islands forests remained intact position. As per the record of Chaterjee et al., the percentage of heavily damaged mangrove area is 22, 23% least damaged, 15% moderately damaged and 40% of mangrove area remained intact. The mangrove area of Sipighat and Wandoor areas submerged with sea water and gradually they turn brownish leading to death of different species of mangrove plants. Those areas were dominated by Rhizophora mucronata, R. apiculata and Avicenia marina. A complete patch of aquatic sedge, Fimbrisstylis littoralis in the Sipighat creeck area remained submerged for a long duration by the inundated sea water leading to complete death of the patch. Still this area remained under the inundated sea water (Fig. 3A&B).

Mangroves are very sensitive to even minor transition in costal conditions, like altered drainage patterns, salt water intrusion, accretion or erosion in response to sea level variations. The causes of death of vegetation in the tsunami-wave affected areas are many. Some of them are being discussed here. Deposit of silt may lead to clogging of pores of the aerial roots of mangroves and caused total destruction of the plant species of the areas. Mortality of mangrove is mainly due to low respiration as a result of burying of pneumatophores by silt deposition of tsunami-wave. Similar opinion has been given by other researchers. Usually the mangrove grows in the brackish water near the seashore and remains in the submerged condition for a short period in a day during high tide. But, they cannot tolerate the continuous submergence of the root areas as they perform root respiration through breathing roots called pneumatophores. Breathing roots are special vertical roots form from lateral roots in the mud, often projecting above soil permitting some oxygen to reach the oxygen-starved submerged roots. Root system is adapted to the peculiar conditions also found in the mangrove forests such as still root in Rhizophora (Fig. 4) and knee roots in Bruguiera. Stilt roots are the main organs for breathing especially during the high tide. They are very common in many species of Rhizophora and Avicennia. Aeration occurs also through lenticels in the bark of mangrove species. Tsunami-wave caused raises the water level by about 1.5-2.0 m as reported by Dam Roy and Krishnan. Due to continuous and complete submergence for 2-3 months by the sea water or non-exposure of the breathing roots to air for 6-8 hours a day the mangrove suffered from root respiration leading to heavy mortality of the mangroves.
Another reason for death of mangrove was the increase in salt concentration of sea water and the soil of the tsunami-wave affected areas. Tsunami-wave brought salt in the non-saline areas too. This has been supported by other researchers. This high salinity caused physiological stress to plants. Similar situation was observed in Wandoor, Netaji Nagar area and very little two patches at Haldipur and Tirur. Still this area is under remained under the inundated sea water.

Figure 3— Tsunami affected area of Sipighat and Netaji Nagar. A) Ariel view of submerged area of Sipighat; B) A two floored building submerged by the Tsunami water even after seven years at Sipighat; C) Ariel view of submerged area of Netaji Nagar; D) Ariel view of mass destruction of mangrove in the Sipighat area after 2.5 year of tsunami.

Figure 4— Breathing roots of mangrove. Still root of *Rhizophora*
Re-establishment of mangrove and preventive measures for future

While a good sign for the post-tsunami on in few areas such as Tirur (Fig. 5A&B) and Habdipur mangrove species started to re-establish. In this harsh environment, mangroves have evolved a special mechanism to help their offspring survive. Mangrove seeds are buoyant and therefore suited to water dispersal. Unlike most plants, whose seeds germinate in soil, many mangroves (e.g. Red Mangrove) are viviparous, whose seeds germinate while still attached to the parent tree. Once germinated, the seedling grows either within the fruit (e.g. Aegialitis, Avicennia and Aegiceras), or out through the fruit (e.g. Rhizophora, Ceriops, Bruguiera and Nypa) to form a propagule (a ready-to-go seedling) which can produce its own food via photosynthesis. The mature propagule then drops into the water which can transport it great distances. Propagules can survive desiccation and remain dormant for over a year before arriving in a suitable environment. Once a propagule is ready to root, its density changes so that the elongated shape now floats vertically rather than horizontally. In this position, it is more likely to lodge in the mud and root. If it doesn't root, it can alter its density and drift again in search of more favorable conditions.

Preventive measures

To protect or to reduce the extent of casualties of tsunami-like catastrophe in future, in most of the mangrove area bunds have been constructed along the coastal-line (Fig. 6A). This also restricts the entry of salt water during the high tide. Planting of casuarinas (Casuarina equisetifolia) plants was also done along the constructed bunds (Fig. 6B). One-way valves have been provided at regular distance along the bunds for one-way flow of water from inner side of the bunds to sea.

Fig. 5 – Re-establishment of mangrove in the tsunami affected areas. A) Re-established plants of *Rhizophora* in the seashore at Ograbranch; B) Re-established plants of *Rhizophora* in tsunami affected area of Tirur.

Fig. 6 – Structure to prevent tidal wave to enter in the low laying areas near the sea. A) Bund along the coastal-line; B) Casuarinas plants (*Casuarina equisetifolia*) along the bunds.
Conclusion
Sumara-Andaman earthquake on 26th December, 2004 caused noteworthy damage to the mangrove population in the tsunami-wave affected areas, like Sipighat, Netaji Nagar, Wandoor, Chouldhari, Ograbranch, Tirur and Habdipur of South Andaman. In South Andaman, in particular localities 30–80% of mangrove stands got affected by the tsunami-wave. The devastating wave of tsunami trounced the standing crops, particularly paddy in many parts. The water level increased about 1.5-2.0 m. Level of salinity also increased significantly in the affected areas. It is worth mentioning in many tsunami-affected areas re-establishment of mangrove has been seen, such as Tirur and Habdipur and cultivation of crops in Chouldhari.

References