SIMULATION OF TSUNAMI WAVE SPECTRA ON SRI-LANKA AND INDONESIA

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KEYWORDS: Quickbird, Tsunami, Canny, Tsunami Forecasting, Erosion, Sri -Lanka.

ABSTRACT
This work utilized the Quickbird satellite data to investigate the tsunami spectra run up along the coastal waters of Sri-Lanka and Indonesia. This work emphasized ocean wave propagation model provides with Delft software package to simulate the tsunami wave propagation in Malacca Straits. Edge detection algorithms of Soble and Canny used to determine coastal vegetation line changes due to the impact of tsunami event. The study obvious that the coastline of Indonesia exposed to high energy of tsunami wave compared Sri-Lanka coastline. The study shows too Canny algorithm has more precisely implementation in automatic detection of coastal vegetation line than Soble algorithm. It is interesting to predict next tsunami propagation in Malacca Straits. The forecasting model shows that tsunami wave will take 1 hour to reach Singapore coastal water within less than 4 m and takes 30 minutes to reach Penang Island within 15 m. It can be concluded that utilization different source of information and models can be used to draw good exploitation for tsunami mechanism impact and propagation.

1. INTRODUCTION

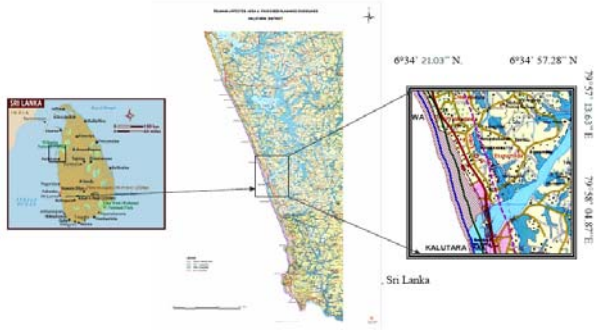
Recently there has been an increase of interest in the field of tsunamis due to frequently occurrences of earthquake and tsunami in few years ago in Indonesia. The tsunami, which struck the coastline of Indian Ocean and Sumatra, Indonesia on 26 December 2004, caused huge destruction to the environment and the world ecosystems despite killing thousands of people in the affected countries. Furthermore, tsunami waves have set off massive changes in shoreline geomorphology feature of numerous countries, especially in Banda Aceh, Indonesia and Kalutara, Sri Lanka. Scientists investigating the damage in Aceh found evidence that the wave reached a height of 24 m when coming ashore along large stretches of the coastline, rising to 30 m in some areas when traveling inland (Chandrasekharan 2005). However, there are no studies undertaken to assess the tsunami in South East Asia. In fact, sufficient knowledge and understanding of the tsunami generation and propagation mechanisms will assist to establish accurate warning system. Using remote sensing technology, the effect of tsunami can be mapped easily in a short time. This enables decision- makers to develop protection or defense system for future warning. The main objective of this study is to model rate change of shoreline due to tsunami impact by using high resolution satellite data such as Quickbird images.

2. METHODS

2.1 Study Area

This study utilized two locations for investigation. First is Kalutara coastline which is located in Sri Sri Lanka between 6°34’21.03” N to 6°34’ 57.28” N and 79°57’ 13.63” E to 79°58’ 04.87” E. Moreover, Sri Lanka is dominated by two monsoon periods. Indeed, southwest monsoon brings rain mainly from May to July to the western, southern and central regions of the Sri Lanka island, while the northeast monsoon rains

occur in the northern and eastern regions in December and January which are affected the coast of Sri Lanka frequently (Figure 1a). Second is coastline of Gleebruk, Banda Aceh, Indonesia which is located in 5°17’53.14”N to 5°15’57.42”N and 95°13’05.84”E to 95°15’01.21”E, facing the Indian Ocean (Figure 1b). In addition, this area is located on the ring of fire which makes it very vulnerable to earthquake disasters. Furthermore, it is located in West Coast Banda Aceh which is developed area with suburban and wooden houses. Gleebruk coastal area is mostly cleared for agricultural and residential development (DigitalGlobe, (2004) and Environment Waikato (2005).



(a)

(b)

Figure 1. Maps of Study Areas (a) of Kalutara, Sri Lanka and (b) of Gleebruk, Indonesia

2.2 Data Acquisition

In this study, the high-resolution Quickbird images were acquired from DIGITALGLOBE archive. The images of Quickbird were acquired before and after tsunami disaster of Kalutara coast, Sri Lanka and Gleebruk coast, Indonesia (Figure 2). The images consist of panchromatic and multispectral sensors with 0.61m-0.72m and 2.44m –2.88m resolution respectively, depending upon the off-nadir viewing angle (0-25 degrees). The sensor therefore has coverage of 16.5km - 19km in the across-track direction. In addition, the along-track and across-track capabilities provide good stereo geometry and a high revisit frequency of 1-3.5 days. These characteristics of the images enable easy management and observation of earth especially for disaster observation and mapping such as tsunami disaster. Moreover, the high-resolution images of Quickbird data provide detailed information for shoreline or vegetation line mapping and detection of changes

2.3 Modeling Rate Change of Shoreline and Tsunami Forecasting

Rate change of shoreline is modeled by using displacement difference method between vector layers (Figure 3). Edge detection algorithms of Soble and Canny used to extract historical vector layers from Quickbird data. In this study, Sobel edge detector was used to identify the edge pixel location of the vegetation lines on the image. This operation performs a 2-D spatial gradient measurement on the image and emphasizes regions of high spatial gradient that corresponds to edges Kaichichang et al., (2003). It enhances edges and outlines features along boundaries. The operator consists of a pair of 3×3 convolution, horizontal and vertical masks (Maged 2002). In addition, Canny algorithm is applied in Lineament Extraction Algorithm which consists of three stages, which is edge detection, thresholding, and curve extraction. The Canny edge detection

algorithm has three sub-steps: First, the input image is filtered with a Gaussian function whose radius is rely on size of Gaussian kernel. The larger the radius value, the less noise and less detail in the edge detection result. In the second stage, the edge strength image is thresholded to obtain a binary image. In the third stage, curves are extracted from the binary edge image. This step consists of several sub-steps: (i) thinning algorithm: applied to the binary edge image to produce pixel-wide skeleton curves, (ii) pixels in curve extracted from the image. (iii) Extracted pixel curve is converted to vector form by fitting piecewise line segments to it. The polyline resulted in an approximation to the original pixel curve where the maximum fitting error (distance between the two) is specified (.Jensen 1996 and Maged 2002).

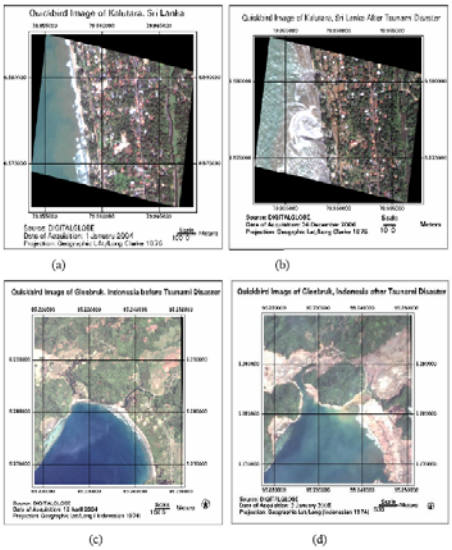


Figure 2. Quickbird Satellite Data before and after Tsunmai Events (a) Kalutara shore, (before tsunami): imagery acquired on January 1, 2004, (b) Kalutara shore, (after tsunami): imagery acquired on December 26, 2004 (c) Gleebruk shore, (before tsunami): imagery acquired on April 12, 2004 (d) Gleebruk shore, (after tsunami): imagery acquired on January 1, 2004

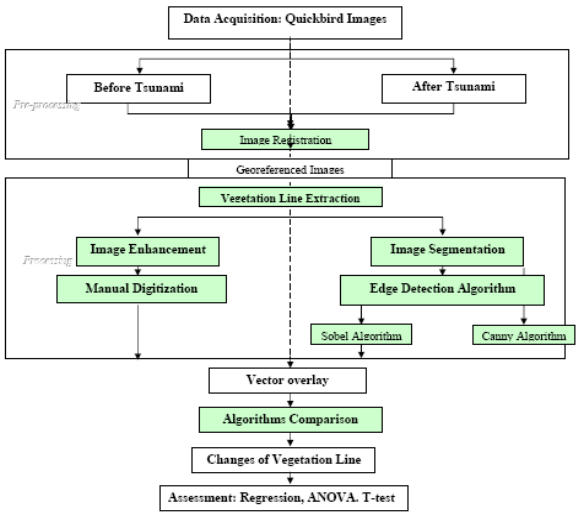


Figure 3. Block Diagram for Modeling Rate Change of Shoreline

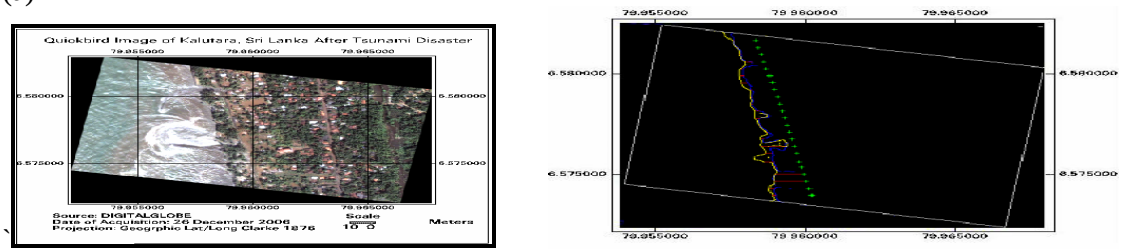
Finally prediction of next Tsunami has been done by using linear wave theory implemented by using Delft 3-D Hydrodynamic software. The selected area is the Malacca Straits.

3.0 RESULTS AND DISCUSSION

The result shows that Canny algorithm has a good performance for shoreline extraction from Quickbird satellite data (Figure 4). In fact, Canny algorithm detects very high details of shoreline edges and automatically generated

continuous line. Figure 4 shows that the maximum rate of shoreline change of Kalutara , Sri-Lanka is -4.5 m while for Gleebruk shoreline change rate is -1023.515m.The negative values shows erosion occurred along the shorelines due to tsunami wave run up impacts. The maximum rate of accretion occurred along Kalutara is approximately 1 m (Figure 5 a) while there is no any sediment accretion occurred along Gleebruk Banda Aceh, Indonesia (Figure 5b). Indeed , the Banda Aceh was first area received the tsunami wave energy of 5 megatons which induced strong runup might be reached to 40 m in some places along the Aceh coastline and moved as far as more than 10 km inland (Maged and Sufian 2005). The tsunami wave washed up all the wood houses located near the coastline and inland too causing maximum rate of shoreline change. The accretion can not be observed in coastline of Gleebruk Banda Aceh due to widespread flooding may be over more than 10 km inland which did not allow the water drain back into coastal waters off Gleerbruk. However, the Kalutara coastline dominated by low rate of shoreline change due to the huge density of coconut trees exist along the coastline. These trees are acted as natural wave breakers and reduced the amount of runup energy into inland (DigitalGlobe, 2004). This study confirms the necessity of protecting the vegetation covers with height of 20 m along any coastal zone dominated by nature disasters. Therefore, these vegetation covers can act as wall defense for certain type of natural disasters such as tsunami. It request too to keep all urban areas and infrastructures far away from the coastline by maximum distance of 20 km to avoid serious damages in future. It can be said that automatic edge detection techniques can be used as automatic geomatic tool for quick feedback on feature changes due to natural disasters.

(a)



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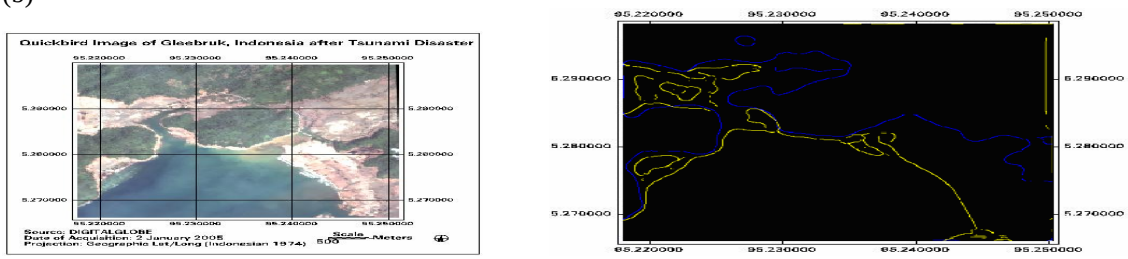

Figure 4. Shoreline extracted by Automatic Canny Edge detection Algorithm along Kalutara, Sri Lanka and Gleebruk Banda Aceh, Indonesia

It is assumed that the reacurreance of new epicenter will be existed along the trench found in Andaman Sea with trench upleft of 5 and downleft of -5 m. The output results are shown in Figure 6. Figure 6 shows the tsunami wave forecasting through Malacca Straits. The forecasting model shows that tsunami wave will take 1 hour and 20 minutes to reach Singapore coastal water within less than 4 m and takes 30 minutes to reach Penang Island within 15 m.

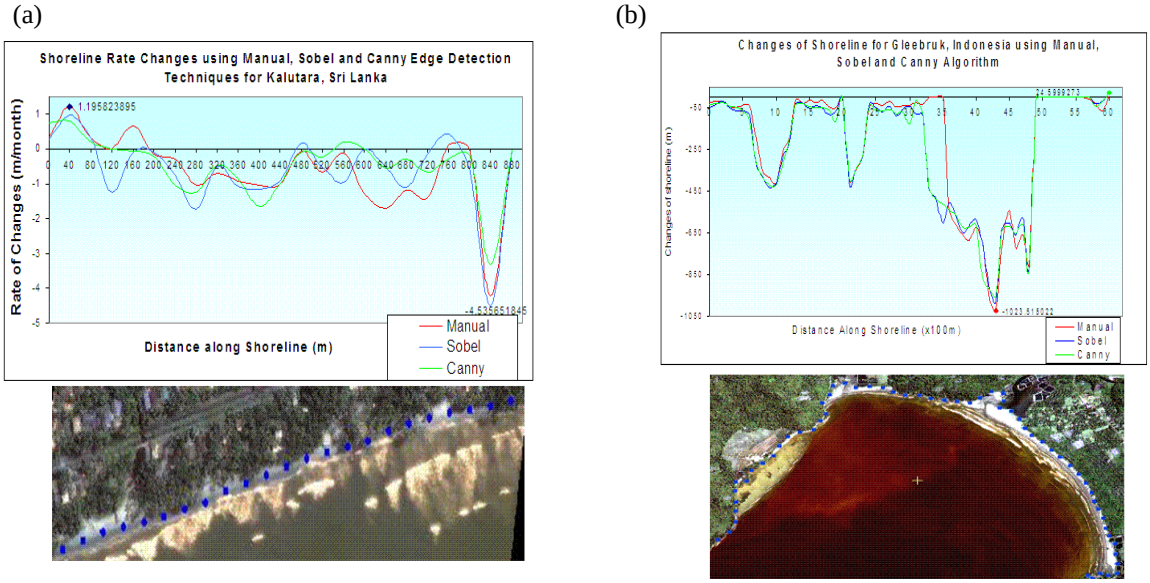

Figure 5. shoreline rate change for (a) Kalutara, Sri Lanka and (b) Gleebruk Banda Aceh, Indonesia

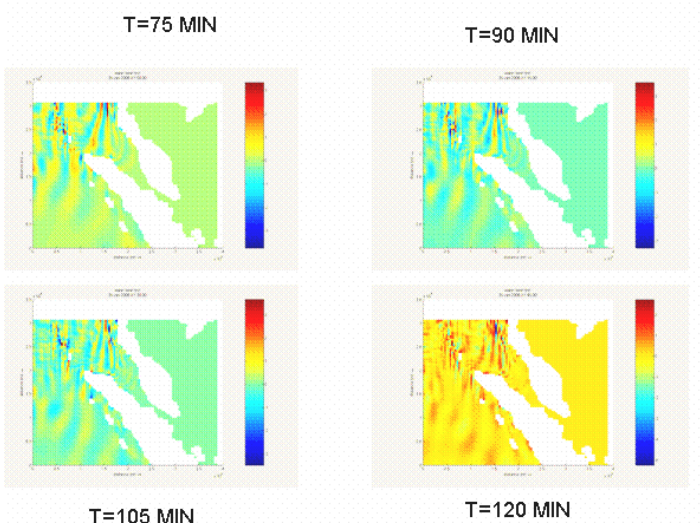

Figure 6. Forecasting of Tsunami Propagation Through the Malacca Straits

CONCLUSION

It was demonstrated methods to detect the impact of tsunami wave on shoreline change along Sri-Lanka and Indonesia. Canny algorithm is considered an appropriate for detecting and modeling rate change of shoreline. It can be concluded that the existence of heavy vegetation covers along coastline could be use as nature defense against any such environmental disasters such as tsunami. This study has predicted the possibilities of tsunami occurrence along the Malacca Straits. It is interesting to notice that the next tsunami will take

approximately 30 minutes to strike Penang Island in Malaysia and 1 hour and 20 minutes to reach to Singapore. This forecasting could be useful for decision -makers to avoid any massive destruction due to tsunami effect in future.

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