Tsunami Damage Detection at the Northwest Coast of Sumatra after the 2004 Indian Ocean Tsunami Using LANDSAT 7 Images.

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ABSTRACT. - The 2004 Indian Tsunami caused devastation along the Indian Ocean. Thanks to remote sensing the impact of this wave can be studied. The purpose of this research is to detect the effects of the tsunami in the northwest coast area of Sumatra, Indonesia. Landsat 7 images were obtained in order to study the vegetation change, soil exposure, and water within the soil with images before the tsunami and compare the data with images after the tsunami. This is done with the goal to give important qualitative data of the effects caused by this event. These images were processed extract information like NDVI, NDSI, and NDWI. After processing these images for these three factors the results revealed a significant decrease in vegetation after the Tsunami, an increase in soil exposure, and an increase in the water within the soil. Also, true color images and false color images were obtain in order to validate qualitatively the results obtained from the three indices mentioned above.

KEYWORDS. - ETM+, NDSI, NDVI, NDWI, Sumatra, Tsunami

INTRODUCTION

On December 2004, a magnitude 9.2 earthquake struck the Indian Ocean. The earthquake was cause by a thrust fault slippage in the convergent plate boundary where the Indo-Australian plate subducts beneath the Eurasian plate forming the Java trench (Figure 1a). It was the second largest earthquake in recorded history (Y. Hayashi, 2008). Because of this event, a 30 meter tsunami was generated which impacted several countries along the Indian Ocean rim. Thanks to advancements in remote sensing it has been made possible the use of remotely sensed imagery to study the damage and distribution of natural disasters like this one (K. Kouchi et al. 2006). Satellite images were obtained using ETM+ images aboard Landsat 7. This sensor has seven bands plus a panchromatic band. It has a 30 meter spatial resolution (15 m resolution for PAN and 60 m in the thermal infrared band). Also, it has a 16 days temporal resolution and a 0.45 µm -12.5 µm spectral resolution. In order to process these images the ENVI 4.8 software was used. ENVI is an image processing program used to analyze geospatial imagery.

The purpose of this project is to detect the effects of the tsunami in the northwest coast area of Sumatra in order to study the vegetation change, soil exposure, and water within the soil with images before the tsunami and compare the data with images after the event of the tsunami. This is done with the goal to give qualitative data of the effects and the extent from the coastal area caused of this

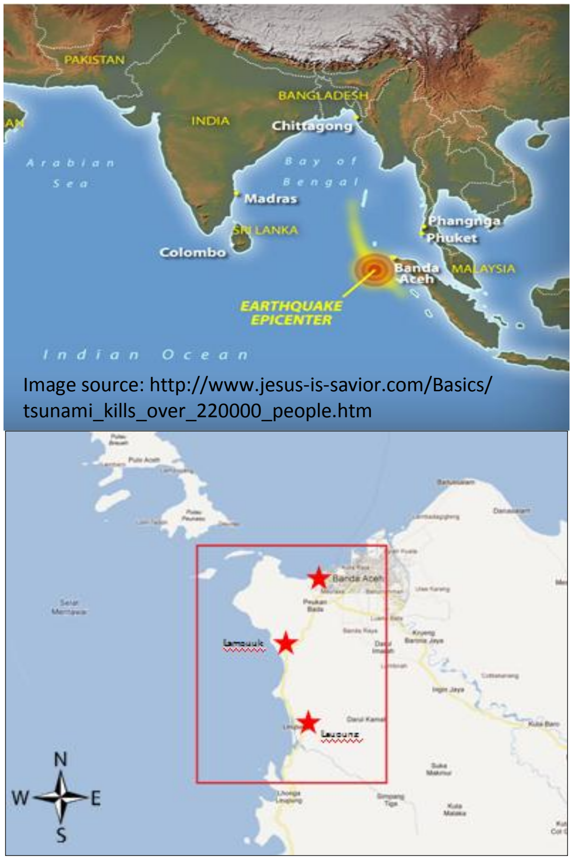

Figure 1. A) The Epicenter of the 2004 Indian Ocean earthquake. B) The study site at Northwest Sumatra.

Also, this study has the objective to detect the land cover changes and tsunami sensitivity of coastal vegetation. These images where processed to extract important information like the Normalized Difference Water Index (NDVI).

Materials And Methods

Study Site

The selected study area is at Sumatra, Indonesia. The region of interest is at the northwest coastal region of Sumatra which includes the towns of Leupung, Lampuuk, and the city of Banda Aceh (figure 1b). This area was selected because it was the closest land from the epicenter of the earthquake affected by the Tsunami. The images for this study site were obtained from the United States Geological Survey (USGS) Earth Explorer application. The images acquired were that of before the tsunami on August 15, 2001 and after the tsunami on December 29, 2004. Also, a recent image was obtained from October 14, 2010 in order to detect how the affected area recuperated after 7 years from the event.

Image Processing

After obtaining the images from the USGS web site the images were ready to process (Figure 2). Once they were opened in ENVI a special subset of the area of interest was made for the 2001, 2004 and 2010 all of equal area. Then a false color image was opened using the bands 4, 3 and 2 in the RGB channels (Figure 3 a and b). With the original subset the vegetation Index, soil index and water index was calculated using the following formulas:

1) NDVI = (NIR-RED)/(NIR+RED)
2) NDSI = (SWIR-NIR)/(SWIR+NIR)
3) NDWI = (RED-SWIR)/(RED+SWIR)

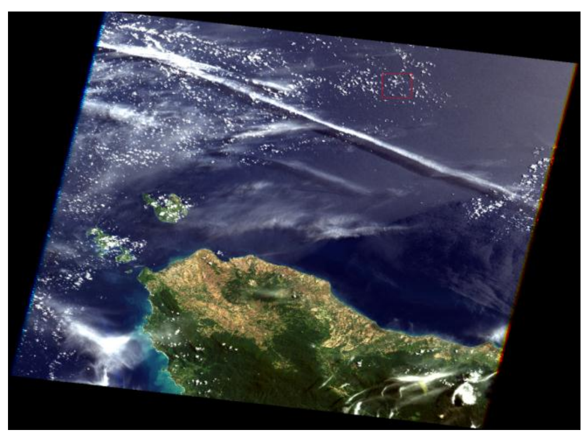

Figure 2. ETM+ image of northern Sumatra

A mask was built for the NDVI image and then applied. This Process will mask all pixels that do not represent vegetation. This

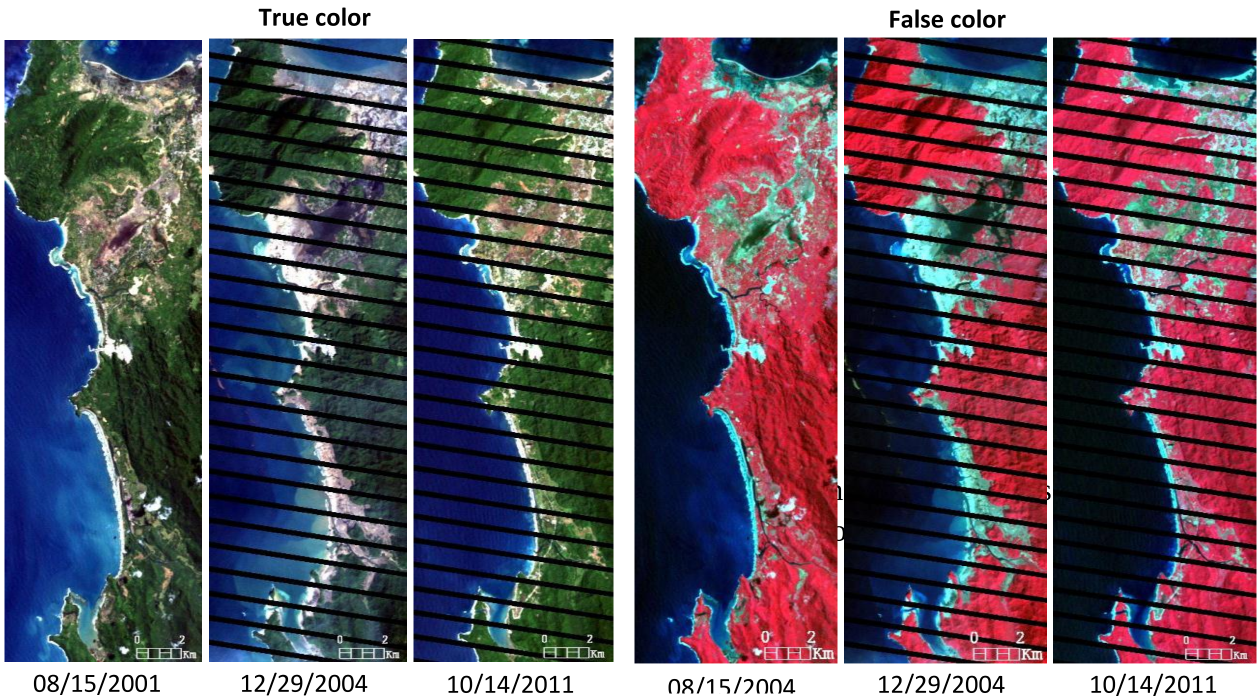

Figure 3. The three images to the left show a true color Image of the area of the study site before the tsunami (2001), after (2004) and a recent image of (2011). The three images to the right show false color images of the area of the study site before the tsunami (2001), after (2004) and a recent image of (2011).

way the image will show only those pixels that correspond to the vegetation indices.

Results And Disscusion

Pre-tsunami true color images show a true scene of how Sumatra truly was before the tsunami. When comparing it to a post-event and recent (2011) true color image a noticeable difference is immediately detected as seen in the three left images of figure 3. The false color images seen in the three right images of figure 3 shows how vegetation stands out in color red using the bands 4,3,2 in the RGB channels. After applying a mask to the images all the pixels that do not represent vegetation turned white with a value of 0 and only those that fall within 0 and 1 represent vegetation. Figure 4 shows the results obtained after calculating for NDVI. Here we see that after the 2004 Indian Ocean tsunami

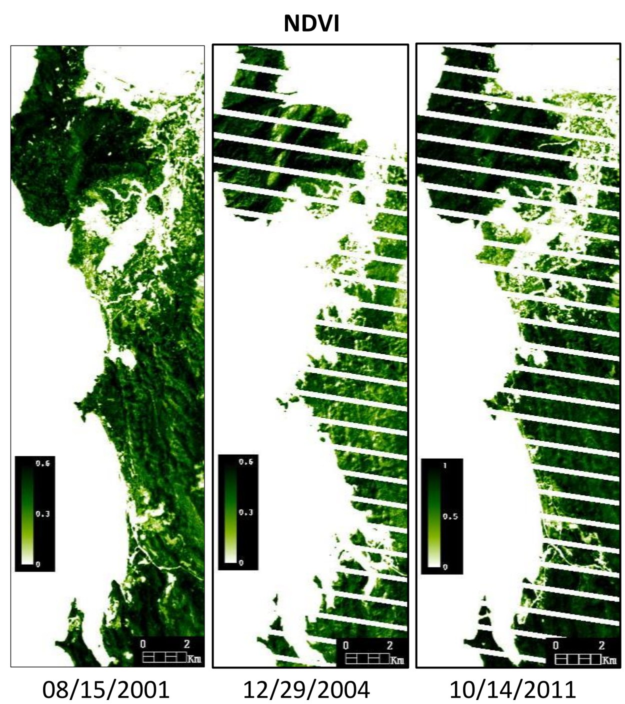

Figure 4. Normalized Difference Vegetation Indices (NDVI) for the 2001 (pre-event), 2004 (post-event) and 2011 (recent) images. The scale goes from a minimum of 0 to a maximum of 1 (highest amount of vegetation).

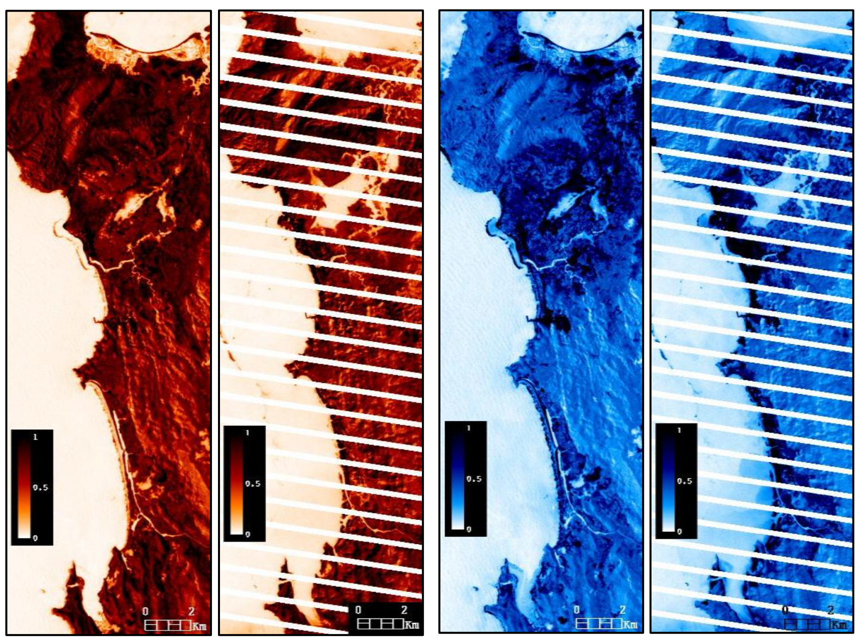

Figure 5. The Left image corresponds to NDSI calculations of images before the tsunami (2001) and after the tsunami (2004). The Images to the right show the results after processing the images for NDWI before and after the tsunami. The scale goes from a minimum of 0 to a maximum of 1, one being the highest soil or water content.

the amount of pixels that belong to vegetation decrease, meaning that vegetation decreased dramatically. In the 2011 image we see that the vegetation has recuperated significantly but not completely after more than seven years of recuperation. The left image of figure 5 shows the results for the Normalized Difference Soil Index. These results do not correlate with the true color images maybe because some error when entering the equation for NDSI in the band math option. Despite this, in true color images we do see soil exposed. For this reason we can decide that the Soil index increased after the tsunami.

The results obtained for Normalized Difference Water Index are seen in the images to the right of figure 5. Here we can see that the areas where the soil has high moisture content are darker in comparison to the image before the tsunami. Areas where there is over-saturation of water in the soil appears white. The pixels with very high value appear black near the shore showing that the water index increased after the tsunami. From what we see in the images the place the place with the most reduction in vegetation in conjunction with soil and water is in the hard-hit city of Banda Aceh (B. E. Jaffe, 2006).

Possible error sources could be that because neither atmospheric correction nor shadow corrections were made to the images before processing for the indices mentioned above. Also, the Scan Line Correction problem (SLC) was not fixed before processing. This could have introduced a possible error in the results obtained. Human error could also be a possible error source. If images were not processed correctly this could most likely will give false results.

CONCLUSION

The 2004 Indian Ocean Tsunami caused significant change in the topography of the land. The land subsided, uplifted, and marsh lands were widely covered with water; cities, towns and villages were devastated for hundreds of kilometers into the coast (B. E. Jaffe, 2006). Large areas over the land were devastated. In terms of the information extracted from the images, the large waves caused Vegetation o be removed, soil to be exposed, and soils to be saturated with water. When the vegetation decreases the area is prone to an increase in pollution. At the same time the vegetation is removed the soil is exposed. This causes erosion to increase in the area because vegetation served as a barrier. If the water increases in the soil it can cause a significant economic impact because the water within the soil is salt water. This means that the soil will have a high salinity making it impossible for agricultural fields to recuperate in many years.

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