Abstract: ERSDAC has been responsible for the operation of ASTER (Advanced Spaceborne Thermal Emission & Reflection Radiometer) sensor loaded on Terra satellite ever since its launch in December 1999. One of the important functions of ASTER is "pointing" of up to 24 degrees. Pointing function is critical in carrying out an urgent observation, which enables data acquisition within three days, on the day of scheduling at the earliest. This function enabled ASTER to respond to various disasters since its launch. Acquired data has been utilized widely by various organizations and contributed to understand the damaged area and its condition. In the wake of Sumatra earthquake and tsunami, which triggered unprecedented destructions to coastal areas of Indian Ocean, ERSDAC has focused one month since 28th December 2004 for urgent observations of stricken areas, coordinating with other relevant agencies and organizations. Further, ERSDAC regularly monitors progress of rehabilitation at North Sumatra, which is close to the epicenter and thus suffered the severest damages. As a result of Terra/ASTER urgent observations, data of north Sumatra in Indonesia, Khao Lak in Thailand, Sri Lanka, east India and other places were acquired successfully. Also, as a result of analysis with normalized vegetation, soil and water indices (NDXI) and other data, influence of tsunami in Banda Aceh was recognized to be conspicuous in northern area, while in southern area damages were restricted due to its narrow coastline. Damages of tsunami were identifiable by NDXI analysis of Banda Aceh. The observation attested to the efficacy of ASTER urgent observation, as well as NDXI analysis in case of understanding the overall damages incurred by water related disasters like tsunami.

Keywords: ASTER urgent observation, ASTER, NDXI, ASTER/DEM

1. Introduction

Review and evaluation of practicality and efficacy of ASTER (Advanced Spaceborne Thermal Emission & Reflection Radiometer) urgent observation function are the main purpose of the report. ASTER is a high performance optical sensor developed by the Ministry of Economy, Trade and Industry of Japan (METI) loaded on Terra satellite, launched in December 1999 as initial the satellite of Earth Observing System (EOS). EOS is the core earth-observing mission of NASA. After launching Terra satellite, ERSDAC has been responsible for the operation of ASTER with NASA. Since ASTER is a medium spatial resolution earth observation sensor, it is classified in the same category of LANDSAT.

Immediately after the Sumatra earthquake and ensuing Tsunami on 26th December 2004, ERSDAC had engaged in one month of urgent observation and offered acquired data to relevant agencies and organizations both domestic and abroad for the purpose to understand the whole picture of damages, reconstruction planning and others. The main feature of the urgent observation is ①observation request accepted prior to GMT 6:00 will be subject to scheduling from the next day and ②off nadir angle of 8.55~24.00° enables VNIR-Only observation. In addition, data will be made available within 6 hours after observation. Data acquired by the urgent observation was made available at the website of ERSDAC (http://www.ersdac.or.jp/todayData/EDS/00.1/pict_e.html) and widely utilized by parties involved. Regular monitoring of North Sumatra including Banda Aceh, which incurred the severest damage, is still conducted to observe the progress of rehabilitation.

Result of ASTER urgent observation of Sumatra earthquake and tsunami is detailed in the report. Analysis of acquired data and NDXI (Normalized Vegetation, soil and water indices) has led to exemplify the efficacy of ASTER urgent observation in recognizing the whole picture of damages brought by water related disasters like tsunami and the status of recovery progress.
2. Data and Methodology

1) Data

In this study, we used LANDSAT 7 and Terra/ASTER data.

In comparison to LANDSAT, ASTER is characteristic with its higher spatial resolution of VNIR, high spectral resolution with 14 bands from VNIR to TIR, the acquisition of stereo data on single orbit and pointing function perpendicular to the orbit. On the other hand, LANDSAT has a history much longer than ASTER and equipped with “Blue Band”. Swath of LANDSAT is approximately 180km in comparison to 60km of ASTER, enabling coverage of huge area at once. Major specifications of ASTER and LANDSAT are compared in Table 1.

Since orbit of ASTER and LANDSAT is identical, to cover whole area of LANDSAT by ASTER, areas that fall in-between adjacent orbits should be covered by pointing to three directions of nadir, right and left. By extending the function, pointing is possible up to ±24° for VNIR.

Thanks to this function, ASTER can accommodate urgent acquisitions of data in response to natural and man-made disasters from distant orbit (Fig. 1).

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Table 1: Major specification of ASTER and LANDSAT

<table>
<thead>
<tr>
<th></th>
<th>ASTER</th>
<th>LANDSAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength (nm)</td>
<td>VNIR: 0.52-0.86 / 3</td>
<td>0.45-0.90 / 4</td>
</tr>
<tr>
<td></td>
<td>SWIR: 1.60-2.43 / 6</td>
<td>1.55-2.35 / 2</td>
</tr>
<tr>
<td></td>
<td>TIR: 8.125-11.65 / 5</td>
<td>10.4-12.5 / 1</td>
</tr>
<tr>
<td>Stereoscope</td>
<td>Band 3N &amp; 3B (B/H=0.6)</td>
<td>30</td>
</tr>
<tr>
<td>Spatial Resolution (m)</td>
<td>VNIR: 15</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>SWIR: 30</td>
<td></td>
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<tr>
<td></td>
<td>TIR: 90</td>
<td></td>
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<tr>
<td></td>
<td>VNIR: ± 24</td>
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<tr>
<td>Cross Track Pointing(°)</td>
<td>SWIR: ± 8.55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TIR: ± 8.55</td>
<td></td>
</tr>
<tr>
<td>Swath (km)</td>
<td>60</td>
<td>185</td>
</tr>
<tr>
<td>Recurrent Period (day)</td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>

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Figure 1. Concept of ASTER Urgent Observation

Observed data will be made available in about 6 hours in earliest cases for user.

Data acquired by the urgent observation was made available at the website of ERSDAC and widely utilized by parties involved.

Fig. 2 and Table 2 show data acquired by the urgent observation.
North Sumatra Area is selected for studied area because tsunami afflicted areas nearest to epicenter. In the area, ASTER data was collected in 7 separate periods from 1st June 2002 to 22nd December 2004 for pre-earthquake comparison, while post-earthquake data was acquired in 7 occasions from 28th December 2004 to 12th March 2005 (Fig. 3).
As regards to the analysis of Banda Aceh, since there were no favorable ASTER data acquired prior to the earthquake, following data were used in addition to LANDSAT ETM+.

- **Before earthquake and tsunami**: LANDSAT ETM+ data acquired on 15th October 2000
- **After earthquake and tsunami (1)**: ASTER data acquired on 21st January 2005
- **After earthquake and tsunami (2)**: acquired on 23rd June 2005

### 2) Methodology

In the analysis, NDXI (Normalized Vegetation, soil and water indices) was mainly used to analyze the differences before and after the disaster. NDXI method was proposed by W. Takeuchi & Y. Yasuoka (2004) to classify more than one environmental factors at the same time, where vegetations of all growth levels are mixed, and conditions of soil and water content varies. Category analysis method utilizing end member, VSW index and others are also available to simultaneously classify complex environment factors, however, NDXI effectively takes advantage of visible/near infrared and shortwave infrared data and the application is versatile. Based on three indices of NDVI (Normalized Vegetation Index) widely used for vegetation analysis, NDSI (Normalized Soil Index) and NDWI (Normalized Water Index), NDXI defines vegetation, soil and water, the principle elements of ground surface, according to the characteristics of spectrum patterns respectively. In the analysis, following combinations of ASTER bands are utilized to withdraw characteristics of vegetation, water and soil the most.

\[
\text{NDVI} = \frac{\text{NIR}(B3) - \text{VIS}(B2)}{\text{NIR}(B3) + \text{VIS}(B2)} \quad (1)
\]
\[
\text{NDSI} = \frac{\text{SWIR}(B8) - \text{VIS}(B1)}{\text{SWIR}(B8) + \text{VIS}(B1)} \quad (2)
\]
\[
\text{NDWI} = \frac{\text{VIS}(B1) - \text{NIR}(B3)}{\text{VIS}(B1) + \text{NIR}(B3)} \quad (3)
\]

As shown in the above 1~3, NDXI gained as a result of band calculation is effective and easy to understand the overall extent of damages caused by water related disasters like tsunami and flood, in comparison to category classification, VSW index and others.

For the calculation of NDXI using LANDSAT ETM+, band 2, 3, 4 and 7 are used to correspond to ASTER band 1, 2, 3, and 8, respectively. As for the analysis detailed hereinafter, green, red and blue are allocated to NDVI, NDSI and NDWI, respectively to produce color composite images.

### 3. Data analysis and results

#### 1) Regional Analysis (North Sumatra)

Mosaic image was produced out of ASTER data to cover the coastline of approximately 500km long at the southwest of north Sumatra, for pre and post earthquake comparison (Fig. 3). NDXI processing was conducted to grasp the whole picture of the damages (Fig. 4).
The coastline area was divided to north and south as areas A and B. In the pre-disaster image, both areas appear green, which indicates the color of vegetation, however, in a post-disaster image, area A appears reddish, indicating mixture of soil and water, due to tsunami that washed away the vegetation. On the other hand, area B appears unchanged after the disaster, exemplifying the fact that the area was not so much affected.

This difference is considered to have been brought by the topographical feature of the areas. In area A, relatively wide low land stretches along the coastline, where tsunami intruded widely. In the case of area B, tsunami could not intrude deeply because of narrow low land.

2) Simeulue Islands

Fig. 5 is ASTER false color images of northern part of Simuelue Islands off north Sumatra comparing pre and post earthquake. As indicated by arrows in the images, the color of coral reefs has changed from blue to white after the earthquake. It suggests that the coral reefs were risen near sea surface or above water in the wake of the earthquake. This suggestion is consistent with the local information that the western side of the island was elevated by approximately 1.3m after the earthquake.

![Figure 5. ASTER Images of northern part of Simuelue Island](image)

3) Banda Aceh

LANDSAT ETM+ data acquired prior to the earthquake and ASTER False Color Images acquired in January and June 2005, after the earthquake are shown in Fig. 6. NDXI images generated from those data are shown in Fig. 7.

In Fig. 6, LANDSAT ETM+ False color image acquired on 15th October 2000 prior to the earthquake shows fish ponds, swamp, towns and vegetations in inner land area and vegetations also extend along western coast. ASTER data acquired on 21st January 2005 shows extensive color changes from northern coast to deeper inland.

Also in western side, white area that may indicate sand appeared in place of vegetation and a wide water pool considered to have been generated by seawater trapped in a dent area appeared. In ASTER data dated 23rd June 2005, some places appear red, suggesting growth of vegetations after the disaster.

In NDXI image of Fig. 7 dated 21st January 2005, distribution of soil and water mixed ground condition and reduced vegetation appears clearer at the northwest of dotted line in comparison to other relatively unaffected areas in southeast. The contrast is more apparent than the one presented by False Color Images. Comparison of images dated 23rd June 2005 with the one in January helps to recognize the growth of vegetation that appears in green especially at the northwest of dotted line.
Figure 6. False Color Images of Banda Aceh

Figure 7. NDXI Images of Banda Aceh

The images illustrate the fact that topographical feature of the area greatly influenced on how tsunami affected the area.

Figure 8. NDXI Bird’s Eye View of Banda Aceh Area
4. Discussion and Conclusion

The urgent observation data of Sumatra earthquake and tsunami was used widely by related organizations and researchers of Indonesia and Thailand to understand the extension of damages and make rehabilitation plan. At the same time, ERSDAC publicly offered the data in a timely manner for use by researchers and other users both domestic and abroad.

Since right after the disaster, high spatial resolution data such as IKONOS and QuickBird has been offered for public use.

ASTER, LANDSAT and other satellite data are inferior to those data in terms of spatial resolution, however they proved effective in understanding extensive damages in regional scale.

NDXI method to be conducted by the calculation of bands proceeds promptly and thus possible to timely correspond to the understanding of water related disasters like tsunami and flood.

ASTER has acquired over one million scenes in 5 years of its operation, however, due to unstable weather conditions in tropical rainforest area like Banda Aceh, favorable scenes are sometimes difficult to be acquired timely.

As an earth observation system contributing to the understanding and prevention of disasters, factors such as ① high data accuracy, ②same or similar specification of ASTER, ③receive observation requests widely form public and ④low price setting would be indispensable in the future.

In addition, development of a method promptly responsive to urgent is urgently desired by utilizing SAR such as ALOS onboard PALSAR (joint development of METI (Ministry of Economy, Trade and Industry of Japan) and ERSDAC and JAXA,) to be launched at the end of this year, in addition to an optical sensor.

5. Acknowledgement

We highly appreciate and acknowledge contributions made by Remote Sensing GIS Forum in Indonesia of providing precious local information.

6. Reference
