Mapping Tsunami-Affected Coastal Aquaculture Areas in Northern Sumatra Using High Resolution Satellite Imagery

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Abstract: The December 2004 tsunami has caused severe damage to live, properties and infracture in Aceh, Indonesia. In this paper, we describe a still on-going project to map the tsunami-affected coastal aquaculture areas in the districts east of Aceh Besar (in the districts of Pirdie, Bireuen, North Aceh and East Aceh). The damage to aquaculture ponds has serious repercussions on the livelihoods of fishing communities in Aceh. The main objective is to produce base maps of the affected areas using high resolution satellite imagery, in order to identify previous aquaculture sites and to assess the damage. The maps would be used for village-level targeting and planning of rehabilitation of aquacultural activities as part of reconstructing the livelihoods of fishing communities affected by the tsunami.

Keywords: Tsunami, damage assessment, aquaculture, Aceh, high resolution, SPOT, IKONOS.

1. Introduction

A magnitude 9.0 earthquake occurred off the northwest coast of Sumatra on December 26, 2004. The earthquake triggered a tsunami that caused extensive damage in many coastal regions lining the Indian Ocean. Being closest to the epicenter of the earthquake, Aceh Province in Indonesia was one of the region severely affected by the tsunami. While the most severe damage to lives, property and infrastructure occurred in the western side and in Aceh Besar, the more extensive coastal pond aquaculture activities that are located in the districts east of Aceh Besar (in the districts of Pirdie, Bireuen, North Aceh and East Aceh) were also affected to varying degrees. This has serious repercussions on the livelihoods of fishing communities in Aceh.

Currently there is a strong need for planning and prioritization of livelihood rehabilitation efforts. One key aspect missing is good base maps that identify previous aquaculture sites and the current situation. This could lead to more detailed assessments and better targeted initiatives for rehabilitating affected aquaculture activities. The field workers require village level maps for participatory planning and currently do not have access to these. There is an opportunity for using high resolution remote sensing imagery to produce base maps that may be used for these purposes.

The main objective of the project is to produce base maps of coastal areas of Aceh province using high resolution satellite images such as those acquired by SPOT5 and IKONOS, to be used for village-level targeting and planning of rehabilitation of aquacultural activities as part of reconstructing the livelihoods of fishing communities affected by the
tsunami. Preliminary maps of aquaculture sites were produced and the conditions of associated structures such as the pond bunds are identified. The maps would be validated and updated with ground-checks.

2. Study Area and Satellite Data

Aquaculture activities are carried out predominantly on the north and east coast of Aceh. The study area in this project covers the districts of Aceh Besar, Pidie, Bireuen and Aceh Utara. Fig. 1 shows the location map of the study area.

Fig. 1: Location map of the study area (left) and the Terra MODIS image (right) acquired on 29 Dec 2004. The yellow frames in the location map show the coverage of SPOT images used in the study.

A wide coverage Terra-MODIS image is available on 29 December 2004 (Fig. 1). The locations of aquaculture ponds on the northern coast of Aceh can be seen in this image. However, the coarse resolution does not permit identification of damaged ponds. Higher resolution satellite images are required for assessing the conditions of the ponds. SPOT-5 multispectral images at 10-m resolution would be suitable for this purpose. Four pre-tsunami and four post-tsunami SPOT-5 scenes are used in the study. The dates of acquisition are listed in Table 1. In addition, a 1-m resolution IKONOS image is also available. As the IKONOS image covers only a narrow swath of about 10 km, it would be impractical to use IKONOS to cover the whole study area. The IKONOS image is used as “ground-truth” to validate the interpretation of SPOT-5 image with overlapping coverage.

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Acquisition Date</th>
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<tr>
<td>Pre-tsunami</td>
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<td></td>
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<tr>
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<td>2005-07-04</td>
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<td>IKONOS</td>
<td>2005-01-23</td>
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3. Methodology

The coastal aquaculture ponds were delineated from the pre- and post-tsunami images by visual interpretation and manual digitization. The post-tsunami images were used to assess the conditions of the aquaculture ponds. The ponds exist along the coastline that extends over 700 km in length. It would be too tedious to delineate the individual ponds. Instead, we decided to assess the conditions of the ponds in the post-tsunami images by visual inspection, and assigned the degree of damage into one of two classes: “intact” or “damaged”. A third “uncertain” class was assigned when it was difficult to tell from the image whether the ponds had been damaged. Delineation was performed by digitizing the boundaries of groups of ponds that suffered similar degree of damage. A commercial GIS system was used for displaying the satellite images and delineating the damage classes.

The output of this initial exercise was an image map showing the locations of the aquaculture ponds overlaid with the polygons of damage classes. The map would then be validated and updated by ground checks.

4. Examples of Results

An example of the damage map produced is shown in Fig. 2 for the coastal area around Sigli. This map shows the delineated polygons overlaid on the post-tsunami SPOT-5 image and annotated with “intact”, “damaged” and “uncertain” classes.

![Fig. 2: Part of a post-tsunami SPOT-5 image near Sigli overlaid with polygons of damage classes. SPOT image © CNES 2005.](image)

Comparison of pre- and post-tsunami images enables damage to the aquaculture ponds and other coastal features to be assessed. In Fig. 3, a sub-scene of a pre-tsunami (9 Jun 2004) SPOT-5 image shows the coastal area near the border of Pirie and Bireuen districts in east coast of Aceh. In this sub-scene, aquaculture ponds with intact dykes can be seen. The western part of the coastline is lined with long sand bars (annotated with 1, 2 and 3 in the image). The post-tsunami (2 Feb 2005) sub-scene of the same area shows the changes inflicted to the aquaculture ponds and the coastal features. For example, in the northwest corner of the pre-tsunami image, a small river can be seen flowing parallel to the coast, inside the long sand bar and it discharges to the sea at a point near to the west part of the image. In the post-tsunami image, the point of discharge of the river has shifted. Instead of flowing parallel to the coast and inside of the long sand bar, it now discharges directly into the sea (at location 2 in the image). The long sand bar is broken, and the sand seems to have been pushed in (locations 2 and 3 in the image). The stretch of beach in the northwest part of the image (location 1) seems to
be more intact. The pond dykes appear less distinct in the post-tsunami image, probably damaged. Many of the ponds also appear dry or deposited with sediments. The vegetation in this image seems to be intact.

Fig. 3: A pre-tsunami SPOT-5 image (9 Jun 2004) and a post-tsunami SPOT-5 image (3 Feb 2005) near the border of Pirie and Bireuen districts in the east coast of Aceh. © CNES 2004, 2005
5. Conclusion

This paper illustrates an application of high resolution satellite remote sensing imagery in damage assessment following a disaster. A preliminary damage map of aquaculture ponds in the eastern coastal areas of Aceh has been produced by visual interpretation of SPOT-5 multispectral images at 10-m spatial resolution. This project is still on-going at the time of writing. A ground-check field trip has been arranged. The delineated polygons and damage class will be validated or updated following the ground-checking exercise. The output of this project is expected to be used for village-level targeting and planning of rehabilitation of aquacultural activities as part of reconstructing the livelihoods of fishing communities affected by the tsunami.