



Contents lists available at ScienceDirect

## International Journal of Disaster Risk Reduction

journal homepage: [www.elsevier.com/locate/ijdrr](http://www.elsevier.com/locate/ijdrr)

## Coastal land use changes around the Ulee Lheue Bay of Aceh during the 10-year 2004 Indian Ocean tsunami recovery process

Syamsidik<sup>a,b,\*</sup>, Mirza Fahmi<sup>a,c,d</sup>, Eldina Fatimah<sup>a,b</sup>, Afri Fitrayansyah<sup>a,d</sup><sup>a</sup> Tsunami and Disaster Mitigation Research Center (TDMRC), Syiah Kuala University, Jl. Prof. Dr. Ibrahim Hasan, Gampong Pie, Banda Aceh 23233, Indonesia<sup>b</sup> Civil Engineering Department, Syiah Kuala University, Jl. Syeh Abdurrauf No.7, Banda Aceh 23111, Indonesia<sup>c</sup> Civil Engineering Department, Almuslim University, Jl. Almuslim, Matang Glumpang Dua, Bireuen 24261, Indonesia<sup>d</sup> Student at Civil Engineering Master Program, Syiah Kuala University, Jl. Syeh Abdurrauf No. 7, Darussalam-Banda Aceh 23111, Indonesia

## ARTICLE INFO

## Keywords:

Spatio-temporal  
Tsunami  
Recovery  
Land use  
Erosion  
Pond

## ABSTRACT

The sudden changes in coastal land use around the Ulee Lheue Bay of Aceh due to the 2004 Indian Ocean tsunami have greatly impacted the affected communities. Ten years of the tsunami recovery process, with assistance from international donors and the government of Indonesia, have also produced a number of learnings. This research is aimed at monitoring the recovery of coastal land use during 10 years of the recovery process and at investigating the influence of the recovery process on the community livelihood. After the completion of the formal rehabilitation and reconstruction process led by Aceh-Nias Rehabilitation and Reconstruction Agency (BRR Aceh-Nias), there has been no systematic process for monitoring the recovery process. Therefore, this paper is considered important for filling the gaps in understanding the mid-term recovery process. Spatio-temporal analysis and in-depth interviews were employed in this study. Quantum GIS was used to analyze eight satellite images of the coastal area around the Ulee Lheue Bay of Aceh. Twelve key respondents were interviewed and triangulated to understand the relation between the coastal land use changes and the community's livelihood. We found satisfactory recovery process rates for houses and paddy field areas. Meanwhile, ponds only recovered by about 19% during the 10-year recovery process. We also identify the need to immediately formulate Integrated Coastal Zone Management in the next phase of the recovery process.

## 1. Introduction

During the 10 years following the 2004 Indian Ocean tsunami, a massive reconstruction process was introduced in Aceh and Nias of Indonesia. The two regions were severely damaged by the tsunami. Land use recovery processes after an extreme event may reflect the recovery process of the affected community's livelihood. Sudden changes in environmental factors in the area could severely degrade the economic productivity of the area. The 2004 Indian Ocean tsunami eroded about 400 m of coastline in Banda Aceh and even created an island due to severe erosion, Ujong Seuden in Aceh [2,14]. Drastic changes in the environment after the extreme event forced a number of communities to seek temporary shelters or be relocated to different places. The number of people displaced internally after the 2004 Indian Ocean tsunami was about 635,000 [31]. Within one year after the tsunami, some of them decided to move back to the coastal area where the resettlement construction was still underway. Some of the resettlement programs were located in the same coastal area as that before

the 2004 tsunami [30].

One of the cases is the resettlement program for affected communities in the Ulee Lheue Bay of Aceh. The bay is situated between Banda Aceh and Aceh Besar District. The initial plan of the resettlement program to relocate the affected communities far from the coastal area was introduced by the government of Indonesia during the first phase of the reconstruction process. However, it failed due to the demands of the affected communities who did not want to go far away from their original place for several reasons [13]. The return migration rate of the tsunami-affected communities was, therefore, high [32].

During the 10-year recovery process, the area has undergone a number of interventions for rehabilitation using multi-sector development. The 10-year process has also brought new life into the communities. However, until now, there have been a limited number of studies that reveal the process and capture the challenges in managing coastal land use at the Ulee Lheue Bay of Aceh. Most of the published reports or articles have only investigated the process during the first five years after the tsunami [7,26–28]. During the period, massive interventions

\* Corresponding author at: Tsunami and Disaster Mitigation Research Center (TDMRC), Syiah Kuala University, Jl. Prof. Dr. Ibrahim Hasan, Gampong Pie, Banda Aceh 23233, Indonesia.

E-mail address: [syamsidik@tdmrc.org](mailto:syamsidik@tdmrc.org) (Syamsidik).

<http://dx.doi.org/10.1016/j.ijdrr.2017.07.014>

Received 3 April 2017; Received in revised form 28 July 2017; Accepted 29 July 2017

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were driven by external agents such as international donors and the Aceh-Nias Rehabilitation and Reconstruction Agency (BRR Aceh-Nias). After 2009, the lessons learned from the recovery process that specifically focused on land use recovery were not well documented or published.

The reconstruction process after a mega-disaster should be planned as mid-term as well as long-term processes. However, there are no formal documents after the closing of the BRR Aceh-Nias, in March 2009, that can be referred to for mid- and long-term reconstruction processes in Aceh. Although there was a new agency (*Badan Kesenambungan Rekontruksi Aceh /BKRA*) established to replace the BRR Aceh-Nias, the work of the new agency was neither well informed nor well integrated into other development sectors. The BKRA was expected to work under directives of the Aceh Governor. At the time of its establishment, it stirred confusions among government institutions on the operation of BKRA [25]. This caused difficulties in measuring the recovery process after the closing of the BRR Aceh-Nias. As demonstrated in other mega-disaster recovery processes, such as the 1995 Great Hanshin-Awaji Earthquake in Hyogo prefecture of Japan, the reconstruction process was planned for three periods: 5 years, 10 years, and 15 years [3]. Reconstruction of New Orleans after Hurricane Katrina had been monitored and planned for at least 11 years after the disaster. In this case, the recovery process was monitored to see economic factors, resettlement, and other livelihood factors [9].

In a global context, research on post-disaster reconstruction has gained momentum after several mega-disasters, such as the 2004 Indian Ocean tsunami, Hurricane Katrina, and the Wenchuan, China earthquake. Of about 122 reviewed journal papers published from 2002 until 2012 that focused on post-disaster reconstruction, about 26% investigated the stakeholder involvement in the process and about 23% discussed the reconstruction approach [19]. None of them reported land use changes during the reconstruction process.

Spatio-temporal changes in land use/cover (LUC) in Banda Aceh were reported between 2005 and 2009 [1]. This study and several available reports ended their observations during the BRR Aceh-Nias works that were completed in 2009. After 2009 until recently, the recovery process was difficult to monitor. This reveals minimal attention paid to the monitoring of the coastal LUC over a long period after being affected by the tsunami. Furthermore, a specific study to investigate the recovery process of the coastal land use and its relation to the community's life is scarce. Therefore, this study is considered an important contribution to identify gaps in studies regarding Aceh as the study area.

This study is aimed at monitoring the recovery of coastal land use during the 10-year recovery process and at investigating the influence of the recovery process on community livelihood. The study area is conducted around the Ulee Lheue Bay of Aceh, where the impact of the 2004 Indian Ocean tsunami was severe. Interestingly, some parts of the coastal areas around this bay recovered naturally. Spatial analysis was employed in this study coupled with in-depth interviews with key persons in the area to examine the correspondence between the coastal land use recovery and its impact on livelihood.

## 2. Study area

The Ulee Lheue Bay is situated at the northern tip of the Sumatra Island. This bay area is shared by Banda Aceh city and Aceh Besar district at their administrative border. The Ulee Lheue Bay has been famous for centuries as a safe area for international navigation, avoiding storm waves and extreme sea-weather generated around the Andaman Sea or in the Malacca Strait. Fig. 1 shows the location of this

study area. This study focused on the Ulee Lheue Bay in Aceh Besar District. Before 2004, this area was largely known for its aquaculture activities, namely, ponds. In the early 900 AC, there was a Hindu settlement in this area, and, at that time, the area was called “Indrapurwa.” However, Acehnese historians learned that around 960 AC, there was a tsunami that demolished the settlement [21]. The source of the tsunami is unknown. The settlement was re-activated around mid period of the Aceh Darussalam Sultanate era in the 1600s. In the Aceh Darussalam Sultanate era, the bay functioned as an important commercial port as well as a part of the Sultanate protection zone, protecting the Sultanate from foreign attackers [22–24]. Considering the long history of the bay, we can understand the significance of the bay for the Aceh civilization. Until 2004, fishponds and mangrove areas dominated the land use of the coastal area around the bay.

Morphologically, the bay is limited by a headland in its western part. The hillside of *Bukit Barisan* mountain is located in the southern part of the study area. One small island, Pulo Tuan island, is located about 3 km from the coastline of the Ulee Lheue. The Pulo Tuan island is a part of the marine conservation area, the rich biodiversity of which was destroyed by the 2004 Indian Ocean tsunami. Recently, coral reefs around the small island have been partly recovered.

## 3. Methods

In this study, we used two main methods to capture the coastal land use changes, i.e., spatio-temporal analysis of land use units around the Ulee Lheue Bay and in-depth interviews, and understand the connection between the land use changes and the community's livelihood. The spatio-temporal analysis used data from 2003 (one year before the 2004 Indian Ocean tsunami), representing the situation before the tsunami, until 2015. Nine series of satellite images were included in the analysis. Satellite images of the study area in 2003 and 2007 were obtained from IKONOS and Quickbird, respectively. Meanwhile, satellite images of the area captured in March 2005 (three months after the 2004 tsunami), 2009, 2010, 2011, 2013, 2014, and 2015, were obtained from Landsat. Table 1 shows detailed information of the images included in the analysis, such as the time when the images were taken, their source, and, their resolution. All the images were digitized to study land uses. Land use delineation processes for four major types of land uses were manually conducted by digitizing the boundary of each land use type. This was made possible due to the sufficient resolution of the images used.

Four types of land uses were taken into analysis, namely, houses, paddy fields (*Oryza sativa* sp.), coastal forest, and ponds. Within an interval of 100 m from the coastal line to the land, the land use units were calculated and plotted accumulatively to the distance of the land use unit to coastal lines. Quantum GIS (QGIS) was used to digitize and analyze the spatial changes. A spatio-temporal analysis to observe the coastal morphological changes in Aceh was conducted by Liew et al. [11]. However, the study only managed to observe the first three years of the process, until 2009. Furthermore, the area selected in the study was not located in Banda Aceh or around the Ulee Lheue Bay of Aceh. Another recent study that used spatio-temporal analysis on coastal changes after the 2011 Great East Japan Earthquake and Tsunami (GEJET) was reported by Tappin et al. [15]. The study revealed a significant detail of coastal morphological changes after the GEJET, such as the destruction of coastal dunes, ridges, and embankments.

In-depth or semi-structured interviews were attempted by interviewers to obtain elicited information from respondents by addressing some key questions [34]. In-depth interviews give the researcher an advantage at dealing with complex issues involving various aspects of

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