



Rehabilitating coastal agriculture and aquaculture after inundation events: Spatial analysis of livelihood recovery in post-tsunami Aceh, Indonesia



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ABSTRACT

This paper presents GIS time-series land-use analysis of satellite images to quantify the recovery of rice cultivation and aquaculture following the 2004 Indian Ocean tsunami in coastal communities in Aceh, Indonesia. We supplement this with qualitative data to illustrate the post-disaster challenges faced by residents, and the extent to which coastal communities have adapted to post-tsunami realities. Our analysis shows that the rehabilitation of rice cultivation and aquaculture in areas inundated by the tsunami has been limited by extensive degradation of land, diversion of labor by tsunami mortality and transition to alternative livelihoods, and re-purposing of rice fields for residential use during the reconstruction phase. This is especially prominent in areas where subsistence activities are not the primary source of livelihood. The Aceh case study shows that social, economic, and environmental factors can be stronger determinants of how coastal livelihoods rebound and change following destructive inundation events than livelihood rehabilitation aid. Additionally, our case study suggests the human impact of coastal hazards can be felt outside the physical extent of inundation.

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1. Introduction

The impact of disasters upon livelihoods has become an increasing concern (IFRC, 2010; Pomeroy et al., 2006; UNDP, 2013). It is widely accepted that disasters can negatively impact economic productivity through destruction of productive assets, disruption of markets and supply chains, and loss of labour (Noy, 2009; Raddatz, 2009). In coastal regions, the mechanical damage and ecological changes caused by inundation events such as floods, storm surges and tsunami result in extensive damage to agriculture and aquaculture (FAO, 2008; Griffin et al., 2013; Marohn et al., 2012). Examples from storm and tsunami prone areas, such as the Caribbean, South Asia and Southeast Asia, demonstrate that economic impacts

of coastal hazards are felt at the household level, and can be difficult to recover from (Cutter et al., 2003; Fuentes-Nieva and Seck, 2010).

It has become increasingly common, especially in the developing world, for governments and humanitarian actors to emphasize the importance of increasing the resilience of coastal livelihoods, and to make sustainable subsistence livelihoods a core part of post-disaster reconstruction (IFRC, 2010; UNDP, 2013). Evidence from areas that experience regular and repeated inundation events suggests local economic systems may develop adaptive measures (Simmie and Martin, 2010; Vale and Campanella, 2005). However, it is not clear from the literature how systems respond following extraordinary or unanticipated events, such as major storm surges or tsunami (Ingram et al., 2006; Lettieri et al., 2009). This paper uses data from post-tsunami Aceh, Indonesia to discuss coastal livelihood recovery following high intensity and infrequent hazards that are not factored into, or greatly exceed, local adaptive measures.

The 2004 Indian Ocean tsunami caused massive loss of life,

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extensive damage to the built and natural environments, and reduction of livelihood opportunities for residents in Indonesia, Thailand, Malaysia, India, Sri Lanka, and the Maldives (World Bank, 2005; Jayasuriya et al., 2006; Suwat and Crookall, 2011; Thorburn, 2009; etc.). In Indonesia, the tsunami devastated local economies reliant upon subsistence livelihood strategies such as fishing, aquaculture (fish ponds), rice cultivation, and gardening (Thorburn, 2009). The physical impact of the earthquake and tsunami resulted in erosion, subsidence, coastal deformation, soil/water contamination, and widespread debris – all of which contributed to the degradation of rice fields and fish pond boundaries, water management systems, and seed stock necessary for both rice cultivation and aquaculture (Griffin et al., 2013; Marohn et al., 2012; Phillips and Budhiman, 2005; Subagyo et al., 2005; Tinning, 2011; etc.). The Food and Agricultural Organization of the UN (FAO) estimated the economic cost of the loss of rice cultivation in Aceh was approximately 270 million USD (FAO, 2006), whereas almost half the fish ponds used for aquaculture in Aceh were ‘severely damaged or lost’ (Phillips and Budhiman, 2005, p. 4); damage estimated at approximately 50 million USD (World Bank, 2005).

Significant resources were mobilized by governments, citizens, the private sector, and the international humanitarian system to rebuild tsunami-affected areas in Aceh (Daly, 2015; Daly et al., 2012; Daly and Brassard, 2011; Telford et al., 2006; etc.). Almost 400 million USD was allocated for rehabilitating agriculture and aquaculture in the Aceh province between 2005 and 2009, coordinated initially by the Indonesian Ministry of Agriculture, and then by the *Badan Rehabilitasi dan Rekonstruksi*¹ (FAO, 2006). A wide range of donor and government funded programs supported the physical rehabilitation of rice fields and fish ponds (which included clearing debris, rebuilding field/pond barriers and water management features, reconnecting roads and paths); provision of technical assistance (assessing levels of salinization, soil and water chemistry, introducing new approaches that combine mangrove planting and aquaculture, etc.); provision of productive assets (tools, seeds, fertilizer, fencing, new fish and crab species); grants and micro-credit programs; and small business skills training (FAO, 2006; Thorburn, 2009; Subagyo et al., 2005).

Initial assessments predicted that the damage to rice cultivation would be severe and long lasting – with some areas possibly never regaining pre-tsunami levels of productivity (World Bank, 2005; Marohn et al., 2012). However, a World Bank report in 2008 stated that by 2007 the agricultural sector had surpassed “pre-tsunami production by 5%” (World Bank, 2008). The same report concluded that by 2006 “the rehabilitation process has had a major impact in returning the agricultural sector to its previous level of productivity ... Whilst there are no data that can be used to make comparisons between pre- and post-tsunami rice yields, the yields obtained post-tsunami are reasonable and clearly indicate a return to normality (World Bank, 2008, p. 3).”

Other studies have indicated that a combination of post-disaster assistance, including the introduction of new species, aquaculture techniques, and fisher cooperatives, helped replace aquaculture productivity lost during the tsunami (Mills et al., 2011; Padiyar et al., 2012; Rimmer et al., 2012). However, one study on the impact of the tsunami on coastal resources showed that 92 per cent of fishponds in selected areas in Aceh were not rehabilitated as of 2011 (Griffin et al., 2013). With the exception of Griffin et al. (2013), livelihood assessments in Aceh lack data on the extent rice cultivation and aquaculture changed after the tsunami, and thus cannot comment fully on the success of rehabilitation efforts, and how

coastal communities have adapted.

In this paper we use GIS analysis of high resolution satellite images, coupled with qualitative data, to examine the macro-level changes to rice cultivation and aquaculture (consisting of fish-ponds) for three zones within the Aceh province of Indonesia that were affected by the tsunami. We conduct a time-series analysis to show changes in the number of hectares used for rice cultivation and aquaculture from the pre-tsunami period through 2013. We complement this with qualitative data obtained from local stakeholders to better understand the impact of the tsunami and the processes of rehabilitation. A more detailed understanding of the outcome of aid, and how local communities have adapted to altered environments, is important for formulating effective policies for managing coastal livelihoods at risk from inundation events.

2. Research sites

The Aceh province is located in northern Sumatra, straddling the Indian Ocean and the Straits of Melakka (Fig. 1). The province is 58,000 square kilometers, with a population of approximately 5 million as of 2015.² Situated four degrees north of the equator, the climate is tropical. The province is mountainous, with most of the population living on narrow coastal plains. Before the 2004 tsunami, Aceh's GDP was 3.7 billion USD. It increased to 9.6 billion USD by 2015 – growth largely resulting from the opening of Aceh's economy following the end of a long running separatist conflict in 2006.³ As of 2015 agriculture, forestry, hunting and fishing represent 29% of the GDP, increasing steadily from 25% in 2010. Nearly half the work force in Aceh works in agriculture, forestry, hunting and fishing (44.83%), a decrease from 48.47% in 2008. The unemployment rate in Aceh was 9.35% in 2004. After the tsunami, it increased to 14.0% in 2005. It decreased to 8.71% in 2009 and 7.57% in 2016, but is still higher than national unemployment rate of 5.61%.

When the tsunami hit, 28.37% of Aceh's population was below the poverty line, as compared to the overall national average of 16.66%. Poverty in Aceh increased slightly in the aftermath of tsunami to 28.69% in 2005. It fell to 21.80% by the end of post-tsunami rehabilitation period in 2009. The poverty level in 2016 was 16.43%. Although Aceh's current poverty rate is below its pre-tsunami level, it is still higher than the national level of 10.70% (Badan Pusat Statistik, 2017). Given the complex political dynamics over the past decade, it is not possible to clearly isolate how much of the economic changes in tsunami-affected regions are the result of reconstruction aid, and how much is related to wider macro-trends. However, the data suggests that Aceh as a province has made considerable economic strides since the ending of the conflict in 2006, with the share of GDP from agriculture and fisheries increasing slightly, and the related work force in these sectors decreasing slightly. This provides a crude baseline for relating rehabilitation of agriculture and aquaculture in tsunami-affected areas with province-wide trends.

This study focuses on three zones along the north and west coast of Aceh (Zones 1–3, Fig. 1). The zones were selected to provide a representative sample of areas impacted by the 2004 tsunami,

² The data in this section come from publically available data from the Aceh government and Indonesian national government (Badan Pusat Statistik, 2017; Statistics of Aceh Province, 2009; 2016).

³ The Aceh province was mired in a decades long conflict between the *Gerakan Aceh Merdeka* (GAM), a militant separatist group, and the Indonesian army. This severely limited development opportunities and local governance structures within Aceh, and was especially difficult for people living in rural areas. The conflict ended in 2006, partly as a result of the tsunami and international aid effort (Daly et al., 2012; Miller, 2009; Reid, 2006).

¹ The BRR was the Indonesian reconstruction agency that was established to coordinate the delivery of aid in Aceh until April 2009.

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