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TSUNAMI 2004: REBUILDING AND RELOCATING RURAL VILLAGES

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ABSTRACT: *On 26 December 2004, the world first heard about the 9.1 magnitude earthquake off the northwest coast of Sumatra and the ensuing tsunami that tragically killed tens of thousands of people and reshaped many coastal environments around the Indian Ocean. The most devastated area occurred at the northern end of Sumatra around the city of Banda Aceh where over 100,000 humans perished and large portions of land were washed away. Much has been written about the impact of this event on the city of Banda Aceh and satellite images have illustrated the changes in the city's landscape. However, not much has been recorded about the small villages along the northwest coast of Sumatra that were among the first areas to encounter the tsunami, experiencing waves exceeding 10 m (33 ft) in height. Using a series of high resolution satellite images with accompanying ground information this paper initially explores the physical impact of the tsunami on the villages of Birek and Kareung and then examines the events associated with the two villages during their recovery and relocation. Due to limited access to the villages, especially after the tsunami, remotely sensed imagery provides an excellent means for observing and measuring changes within the villages. The destruction and recovery of Birek and Kareung offers an excellent case study of how two small, rural communities in a poor economic area dealt with a major environmental disaster.*

Keywords: *2004 tsunami, rural villages, Birek and Kareung, destruction and recovery, remote sensing*

INTRODUCTION

On December 26, 2004, a 9.1 magnitude earthquake occurred off the west coast of Sumatra and created a mega-tsunami that killed tens of thousands of people and reshaped many coastal environments around the Indian Ocean. This earthquake was the third largest that the World had experienced since 1900, only being surpassed by the 1960 Chilean (9.5) and the 1964 Alaskan (9.2) earthquakes (USGS, 2015). The ensuing tsunami killed 226,954 people and displaced another 1,768,263 in 14 countries in South Asia and East Africa. The greatest devastation occurred in the Special Territory of Aceh at the northwest end of Sumatra (Figure 1) where over 128,645 humans perished with another 37,063 listed as missing and presumed dead (USAID, 2005).

Aceh has several major administrative districts (*Kabupatens*), one being Aceh Besar (Figure 1). Aceh Besar contains a sub-district (*Kecamatan*) known as Lhoong, which has 28 rural, isolated villages situated in small, narrow valleys facing the Indian Ocean. These villages were among the first places to encounter the tsunami, experiencing waves exceeding 10 meters (33 feet) (Davis, 2014). Before the tsunami, Lhoong's 2004 population numbered 11,817. This number dropped in 2005 to 7,695, an almost 35% decline in population. In 2004 most of the villages in Lhoong had only a few hundred people. Three of these villages were completely destroyed, 21 severely damaged, and 4 not affected by the tsunami. Two of the destroyed villages were the adjacent settlements of Birek and Kareung. In 2004 Birek had a population of 418. After the tsunami this number plummeted to 144 in 2005, a 65% decrease. Kareung's population went from 344 to 94, a 73% change (Martin, 2006). Much has been presented in the popular media about the tremendous devastation inflicted upon the urban center of Banda Aceh but little has been written about the rural villages that encountered the initial force of the tsunami. Using a series of high resolution satellite images with ancillary information such as national and international government documents, reports from non-governmental organizations, and maps and ground pictures, this paper initially explores the physical impact of the tsunami on the villages of Birek and Kareung and then examines the events associated with the two villages during their recovery and relocation. Due to the destruction of the only road to the villages by the tsunami and the long, ongoing military conflict between the Indonesian Army and an insurgence group known as the Free Aceh Movement, access to the study area was limited, thus, the use of remotely sensed imagery became essential to observe and measure change in the villages and their environs. A third village, Seungko Mulut, is used throughout this study for comparison purposes. This village is located near Birek and Kareung but did not experience the degree of destruction as the other two villages due to it being farther inland and situated on higher ground.

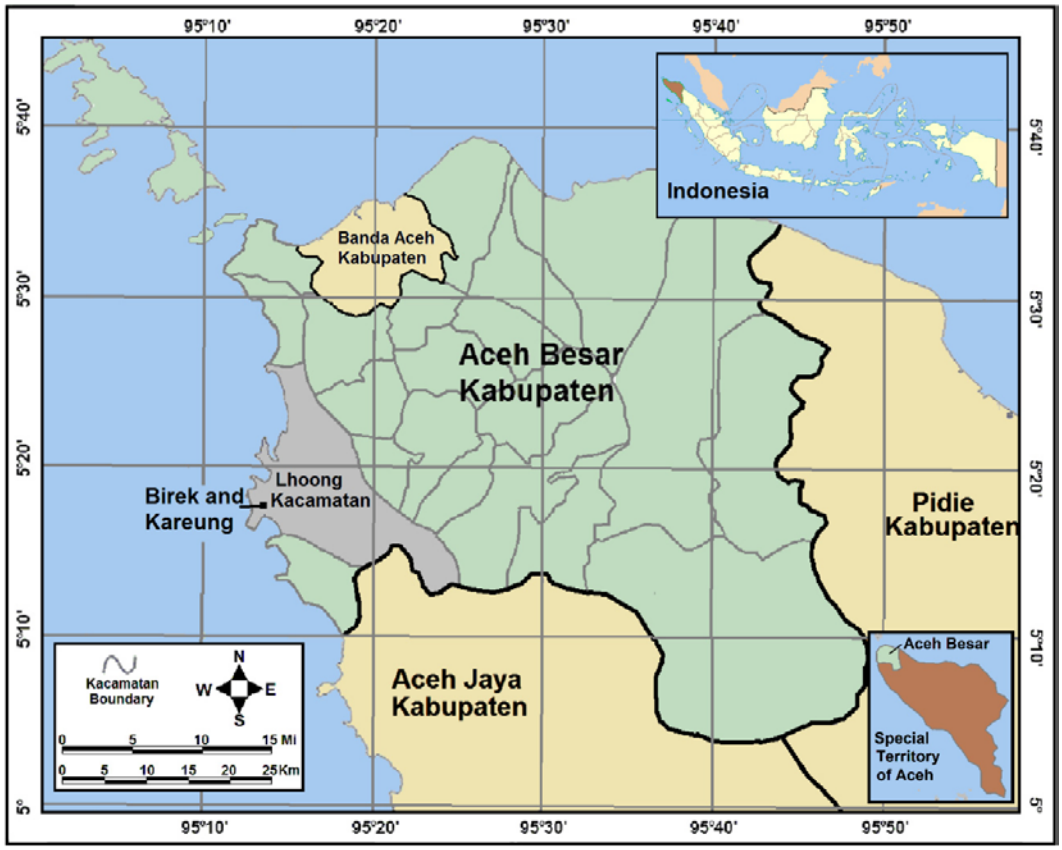

Figure 1. General location map.

IMAGERY

Five high resolution image data sets were used throughout this study, four from DigitalGlobe's QuickBird and one from CNES-Astrium's Pléades. The data sets were pansharpened with the QuickBird images at ≈60 cm and the Pléades image at ≈50 cm pixel resolution. The first image data set was recorded on April 12, 2004, about eight months before the earthquake and tsunami occurred. The second data set was acquired on January 2, 2005 - seven days after the tsunami had devastated the coastal areas. The third data set was taken on May 16, 2006, over seventeen months after the tsunami. The last QuickBird data set was attained on February 17, 2010. The Pléades data set was taken on Jan 27, 2014, nearly 10 years after the earthquake and tsunami. Cropped from these data sets were smaller data sets that contained Birek and Kareung and their environs. The new data sets covered the same geographical area but were not geometrically rectified to each other. The first two data sets relate to the physical destruction of Birek and Kareung. The last three data sets deal with the problems that Birek and Kareung encountered during recovery and relocation. The five data sets provide a progression of satellite coverage clearly showing the devastation and recovery of these two small villages. These data sets have four multispectral bands, three bands in the visible portion and one in the near infrared portion of the electromagnetic spectrum. The multispectral bands of these data sets made it possible to create several different color composites using the image process software package, Earth Scenes. From these composites and the high resolution of the imagery visual analyses and measurements were done to chronicle the changes resulting from the tsunami. Ancillary information was used to corroborate the visual findings and simple air photo interpretation techniques were used to make measurements.

PRE-TSUNAMI – APRIL 12, 2004

Figure 2 (top, 2004) shows Birek and Kareung, before the tsunami, nestled in a small coastal valley facing the open Indian Ocean. The valley extends back from the coastline and is mainly surrounded by hills that have gentle to steep sides and are covered by tropical rainforest vegetation. At the west end of the valley is a white, sandy

beach. The beach receives large waves from the ocean, especially during the southwest monsoon period. A large dune area exists immediately behind the beach. Covered with groves of coconut palm trees and a variety of non-commercial trees this dune is too sandy for paddy agriculture. However, its tree cover provides protection for the valley against the strong winds that sometimes come off the Indian Ocean. The top of the dune stands about 11 meters (36 feet) above the beach. On the valley side of the dune the land slopes gently down (1.1% slope) to an elevation of 1.5 meters (5 feet) in the middle of the valley. It appears that over time the dune has been built by storms from the Indian Ocean. Material from the dune has been pushed toward the center of the valley by large storms and/or earlier tsunamis forming the gentle slope.

Figure 2. 2004-2006 satellite images of Birek and Kareung and valley. (DigitalGlobe, QuickBird)

Behind the dune are paddy fields that continue inland to about 1.6 kilometers (1 mile). These fields define the valley floor. Paddy cropping patterns and seasonal production are mainly determined by irrigation and rainfall patterns. Based on the monsoon winds, two main growing seasons exist in a year. They are referred to as wet and dry seasons. The wet season generally starts in October and extends through March. It produces some 65% of the

annual rice crop and half of the vegetables and legumes (peanuts, soybeans, long beans). The harvesting period is from January to March. The dry season covers the period from April to August/September when the remainder of the annual crop is produced. Since this pre-tsunami image was recorded on April 12, the paddy fields had already been harvested from the wet period and were being prepared for the dry season. Of the 221 families residing in Birek and Kareung in 2003, 190 families (86%) produced food crops as their main source of income (Martin, 2006).

Near the west end of the valley, in the midst of the paddy fields, is a cluster of trees and small structures. This area is the adjacent villages of Birek and Kareung. Birek occupies the northern portion of the settlement and Kareung the southern portion. This settlement extends in a north-south orientation corresponding to the arrangement of the beach and dune. The bright, white structure on the east side of the settlements is the local mosque.

Starting at the east end of the valley the river, Krueng Kala, flows westward and then turns southward where it expands in width, forming a small estuary. Sand bars block sea water from entering the estuary and a narrow flow of freshwater cuts across the bars entering Lho' Biang Raya, a large open bay that eventually merges with the Indian Ocean. Brackish water fish ponds called *tambaks* are located on both sides of the estuary. Milkfish, intended for local consumption and bait for tuna long lining, and shrimp, destined for export markets, are the main fish harvested in the tambaks. Along with paddy agriculture and aquaculture, deep sea fishing provides outside income for the two villages, especially Kareung. A road starting in Kareung wraps around a hill area and leads to the Kareung fish landing on the Lho' Biang Raya Bay. It is from this landing that men would take their long, narrow boats out to sea. A processing house exists at the landing where women would prepare the fish to be transported by land to city markets.

In the northeast corner of the image a section of the West Coast highway can be seen coming across a hill. This highway meanders across the steep hill slope and is not easy to navigate. Through the middle of the valley is a narrow, dirt road that intersects with the highway. This road and highway provide the people of the valley with their only access to major market centers where they sell their food and fish products.

TSUNAMI – JANUARY 2, 2005

This entire landscape changed drastically on December 26, 2004 (Figure 2, middle, 2005). The earthquake occurred on a Sunday morning at 7:58 am local time. The first tsunami surge reached the coast 20 minutes later. On a normal Sunday morning some of the men from the villages would have been fishing on the open sea and would only have experienced a minor wave as the tsunami crossed underneath their boats. Women were either working the fields before the heat and humidity level of the day became overwhelming or waiting for their husbands at the Kareung fish landing. These women and their children encountered the full force of the tsunami. Before the tsunami Kareung's male/female ratio was 175/169 (51%/49%). This ratio changed to 62/32 (66%/34%), reflecting the open sea fishing economy of Kareung. Birek's male/female ratio was 199/219 (47%/53%). After the tsunami the ratio was 68/77 (47%/53%). The population decreased but the ratio (percent) of males and females remained the same. Birek has more of a crop production economy. Men prepare and harvest the fields and women maintain them. During the growth seasons men often find temporary jobs in cities. However, in late December many of the men would have returned to the village for the beginning of the harvest season, which accounts for Birek's after tsunami male/female ratio being more equally balanced in comparison to the Kareung's ratio. Seungko Mulat's population decreased from 420 to 325 and it's after tsunami male/female ratio was 166/159 (51%/49%). Like Birek its economy was based more on crop production than open sea fishing.

Figure 2 (middle, 2005), taken seven days after the tsunami, clearly illustrates the destruction of Birek and Kareung and the valley. The tsunami entered the valley from two different directions. The first direction was across the beach and dune. The large palm trees on the dune mixed with beach sand and debris from the ocean floor were washed down the valley at about 20 kilometers (12 miles) per hour (FAO, 2005). The second direction came up the estuary and the Krueng Kala River. This path brought debris from the sand bars blocking the estuary and from the bottom of the Lho' Biang Raya Bay. The water funneled through a gap created by steep hillsides on both sides of the river. The gap situation raised the water level before a surge entered the valley. Witnesses to the tsunami varied on the number of surges but by most accounts three major surges occurred (Subasinhe, 2005). Since the dune stands higher than the middle of the valley, most of the retreating water went back through the estuary and gap. As the water receded, sand, silt, fine clay, and various organic matters were deposited on the valley floor. The gap would have slowed down the speed of the retreating water, resulting in heavy, thick deposits on the valley floor.

The beach with its white sand was gone. Over 15 hectares (37 acres) of surface sand from the beach was washed inland and scattered throughout the valley floor (Baumann, 2008). The new coastline became the western edge of the dune that was formerly 85 meters (280 feet) away from the ocean. Except for a few individual trees the dune was completely denuded of vegetation and covered by debris. The tsunami surges went the full length of the

valley, a distance of about 1.9 kilometers (1.2 miles). Based on comparing topographic maps with the imagery the surges extended up the valley sides to approximately the 25 meter (82 foot) contour. The post tsunami imagery clearly shows that trees, pastures, and small coconut groves were wiped away from the valley sides below this contour.

The outlines of the paddy fields are still visible in Figure 2 (middle, 2005) but the fields are clearly covered with debris varying in color from light salmon pink to light gray. Only one building, the mosque, remains standing. Some concrete floor pads of homes still exist and a few large trees in the village remain. The freshwater estuary is now an open bay to the sea and the tambaks are inundated with saltwater (Phillips and Budhimon, 2005) Before the tsunami the former estuary, including the tambaks, covered about 11.13 hectares (27.5 acres) but now the new bay extends over 15 hectares (37 acres) (Baumann, 2008) Most of the dikes around the tambaks were washed away or covered by water, and the estuary spreads out over some of the former paddy fields. The sand bars at the mouth of the estuary no longer exist, opening up the entire area to the sea.

Major portions of the West Coast highway and nearly all of its bridges were destroyed, making access and rescue attempts to Birek and Kareung and the valley extremely difficult. In addition, over 90% of the government offices were destroyed and more than 40% of the government personnel were killed (FAO, 2005). Many official land tenure records and much of the communal memory were also destroyed. The loss of land records and communal history could create land ownership issues during recovery.

FIRST RECOVERY AND RELOCATION – MAY 16, 2006

Figure 2 (bottom, 2006), recorded one and one-half years after the tsunami, shows the beginning of the recovery process. The ocean is rebuilding the sandy beach especially along its northern edge where a small semi-bowl-shaped shoreline is developing. The dune is also recovering. In comparison to the period immediately following the tsunami when most of the vegetation was gone and only bare ground was showing, the area now has vegetation coverage of grasses and low growing plants. A few palm trees survived but unlike before the tsunami when a heavy tree cover existed, the area is now open, allowing severe weather from the ocean to move farther inland.

A comparison between the 2004 and 2006 images in Figure 2 shows a significant decrease in the amount of cultivated land. The bluish gray areas in the 2006 image are the restored paddy fields. The levees around the fields are well-defined and the fields appear to be clear of debris. Since this image shows conditions in May, the fields are being prepared and planted for dry season crops. These fields represent about forty-five percent of the acreage cultivated before the tsunami. The remaining fifty-five percent, shown in green, of the former cultivated land is covered with overgrowth and it is difficult, and in some areas impossible, to detect the outlines of the former paddy fields. The total amount of land used for crop production before the tsunami was approximately 56.5 hectares (140 acres); the amount of land being used now is about 25.7 hectares (63.4 acres), a 55% decrease in workable agricultural land (Baumann, 2008). The quality of the workable land is not known. If, as previously indicated, 190 families had food crop production as their main source of income, the amount of land now available for such production would only support 85 or 86 such families.

Open sea fishing is a major source of income for the villages in the Lhoong Kecamatan. Before the tsunami two open sea fish landings existed. One was located at the village of Saney and the other at the village of Kareung. Both landings supported about 200 fishermen each. The two landings were totally destroyed. The Saney landing has been rebuilt and relocated about 650 m (2100 ft) from its former location. The Kareung landing was situated on the Lho' Biang Raya Bay coastline, a short distance from where the Krueng Kala River flowed into the bay. With the sand bars that protected the river's estuary being washed away and with saltwater entering the river's mouth making it into a small bay environment, the new fish landing has been relocated in the small bay near the destroyed tambaks. This location provides more protection from the open sea than the previous location (Martin, 2006). This location is also a shorter distance from Birek and Kareung, allowing the fishermen more direct and easier access to the landing. The old landing has been renamed Pantai Birek, (Birek Beach).

The biggest change relates to the rebuilding and relocating of Birek and Kareung. Immediately after this massive earthquake/tsunami occurred over one thousand relief and aid organizations throughout the World responded with support. One of these organizations was Caritas International, a confederation of 165 Catholic relief societies in over 200 countries and territories. The German and Austrian chapters of Caritas contacted the non-governmental organization in Indonesia named Mamamia (Masyarakat Makmur Mitra Adil or People's Welfare through Equitable Partnerships) for the purpose of having several hundred homes built in the Lhoong Kecamatan. Mamamia was established in Aceh in early 2003, before the tsunami, to promote the interests of poor people in the

Aceh, particularly in rural areas. Caritas Germany and Caritas Austria would provide the needed funds to build the houses and Mamamia would make the arrangements to have the houses constructed.

Mamamia's housing project was called the Lhoong House Rehabilitation Program (PRR-L). Between March 2005 (only three months after the tsunami) and the end of 2005, 1,057 houses were completed under PRR-L. Within a very short period people residing in temporary tent towns were able to have new permanent homes. PRR- L's major goal was to meet all the housing reconstruction needs of a village. To accomplish this goal Mamamia negotiated and consulted with villagers through village meetings. These meetings explained what Mamamia called a Grant Contract, the type of house to be built under the contract, the building materials being provided, the legal status of the land on which a house would be constructed, and the relocation issues outlined by the Government of Indonesia's "Blueprint for Reconstruction." A Grant Contract provided a beneficiary with the means to be the owner and builder of his/her own house. It covered the purchase of required tools, all the building materials and related costs, logistical matters, and needed technical assistance. If a villager was not able to build the house, he/she could hire a contractor. This approach allowed villagers to be involved directly in the building of their own homes and their village. It was part of Mamamia's empowerment policy. Caritas through Mamamia also acquired the land on which the houses would be constructed and covered the surveying and legal costs of subdividing the land into lots and providing each house owner a deed to his/her lot. Paved roads and other infrastructure throughout the new villages were also provided.

Three clusters of small white squares appear on Figure 2 (bottom, 2006). These squares identify the Mamamia houses and indicate the new locations of the villages. Figure 3 (upper left) is an example of a Mamamia house. Rather than rebuilding the villages in their former locations on the valley floor, they were relocated on the north side of the valley on some gentle slopes and at slightly higher elevations, supposedly protecting the new villages from future tsunamis. However, as Figure 2 (middle, 2005) shows the lower sections of the slopes were denuded of vegetation from the tsunami. These areas could be inundated by future tsunamis. Most of the new houses are high enough to endure a large tsunami. If the houses were placed farther up the hillside, the slopes would be too steep for development. As shown in Figure 2 (top, 2004) pasture-like fields existed at the lower slopes, above which heavy forest vegetation occurred indicating steep slopes. No Mamamia houses were constructed in the former locations of the two villages. The white squares appearing in the former locations are the previously mentioned exposed concrete floor pads of some of the destroyed structures.

Figure 3. Mamamia houses at different stages and a BRR house (Trummer, 2010a).

The new villages were organized in a more rectangular arrangement rather than the irregular pattern that existed before. Houses were generally 8.54 meters (28 feet) by 7.93 meters (26 feet) in size or 67.7 square meters (728 square feet). They were made of brick and timber or synthetic siding with corrugated zinc roofs. Electricity was installed in all houses and the houses were connected by piped water to a centralized water system. The owners painted the homes in different pastel colors and some enhanced the homes with verandahs and hanging flower pots, indicators of long term commitment to the homes. The houses had three rooms and indoor toilet facilities. Previous houses generally did not have toilet facilities. Kitchens were located adjacent to house to permit outdoor cooking.

SECOND RECOVERY AND RELOCATION – FEBRUARY 6, 2010

On April 16, 2005, Indonesia established the Agency for the Rehabilitation and Reconstruction (Badan Rehabilitasi dan Rekonstruksi, BRR) to coordinate and jointly implement a community-driven recovery program for the Special Territory Aceh and the island of Nias, part of the province of North Sumatra. BRR's mandate was to design policies, strategies and action plans, within an atmosphere of transparency and accountability, and to implement them through effective leadership and coordination of the combined domestic and international effort to rebuild Aceh and Nias (BRR, 2009). BRR faced the overwhelming task of trying to coordinate the efforts of over 1000 national and international organizations that spent more than $7.2 billion (U.S. dollars) in the recovery process. Some of these organizations such as Mamamia were already on the ground rebuilding Aceh and Nias (BRR, 2009). The survivors needed homes quickly and to have their lives returned to some degree of normalcy. The fact that it took the Indonesian Government four and one-half months to establish an agency such as BRR illustrated the slowness of the government bureaucracy to handle a natural disaster of this magnitude.

At the end of 2006 and the beginning of 2007 BRR approached the villagers of Birek and Kareung and offered them the possibility to have new houses to replace the Mamamia houses and have their new houses built in the original locations of the two villages, locations that were in the center of the tsunami's path. The villagers were not provided the opportunity to have the new houses built on the sites occupied by the Mamamia houses. Such an opportunity might have meant the removal of a Mamamia house or the merger of the houses. Community meetings were held by the villagers and all except seven families decided to accept the offer provided by BRR. The seven families elected to remain in their Mamamia houses (Trummer, 2010a).

Of the three clusters of the Mamamia houses spread across the north side of the valley, Figure 4 shows the changes that occurred in the middle cluster during the years 2006, 2010, and 2014. By the time that the 2006 image was recorded the Mamamia's PRR-L housing project was completed and the villages had not yet been approached by BRR. The middle cluster at this time had 70 houses and a large community type building. Vegetation was nicely cleared around the houses, suggesting that they were fully occupied. These houses were constructed for the survivors from the village of Birek. In 2010, four years later, the number of houses had decreased to 55 and the community building was gone. Twenty five houses had either been removed or destroyed. The remnants of the houses are easily detected on the 2010 imagery. The upper right photograph in Figure 3 provides a ground level view of the remnants of a house. Within another four years, in 2014, the number of remaining houses was down to 13. Based on the amount of surrounding vegetation some of these houses had been abandoned. Figure 3 (lower left) shows an abandoned Mamamia house. The western cluster of Mamamia houses experienced the same changes. In 2006 the cluster had 39 houses and a community type building. The number of houses dropped to 12 by 2014 and the community building was gone. This cluster was developed for the village of Kareung. No change occurred in the eastern cluster. The houses in this cluster were built for the villagers of Seungko Mulat. The BRR did not offer to provide new houses and relocate them on their original home sites for the people of Seungko Mulat.

Figure 5 demonstrates the changes that occurred in the villages of Birek and Kareung before the tsunami and ten years after. In April 2004 the structures in the two villages were randomly distributed and packed closely together. Mature trees covered large sections of the villages. By 2006 all of the structures except the mosque and most of the trees were gone. In 2014, the villages were rebuilt with BRR houses. The structures are tightly grouped and some tree covered areas appear around the edges of the villages. Figure 3 (bottom, right) shows the type BRR houses found in the villages. These houses are constructed of brick and concrete and slightly larger than the Mamamia houses. Some of the Mamamia houses from the hillside clusters were dismantled and reassembled as kitchen annexes to the BRR houses in the villages.

Caritas International hired an external consultant to perform an evaluation of its post-tsunami and earthquake housing reconstruction programs in Aceh and Nias (Trummer, 2010). Caritas was especially interested in determining what occurred in the villages of Birek and Kareung. The external consultant conducted an evaluation procedure that included a detailed household survey, village focus group discussions, and on-going observations and discussions with members of Mamamia and an interpreter.

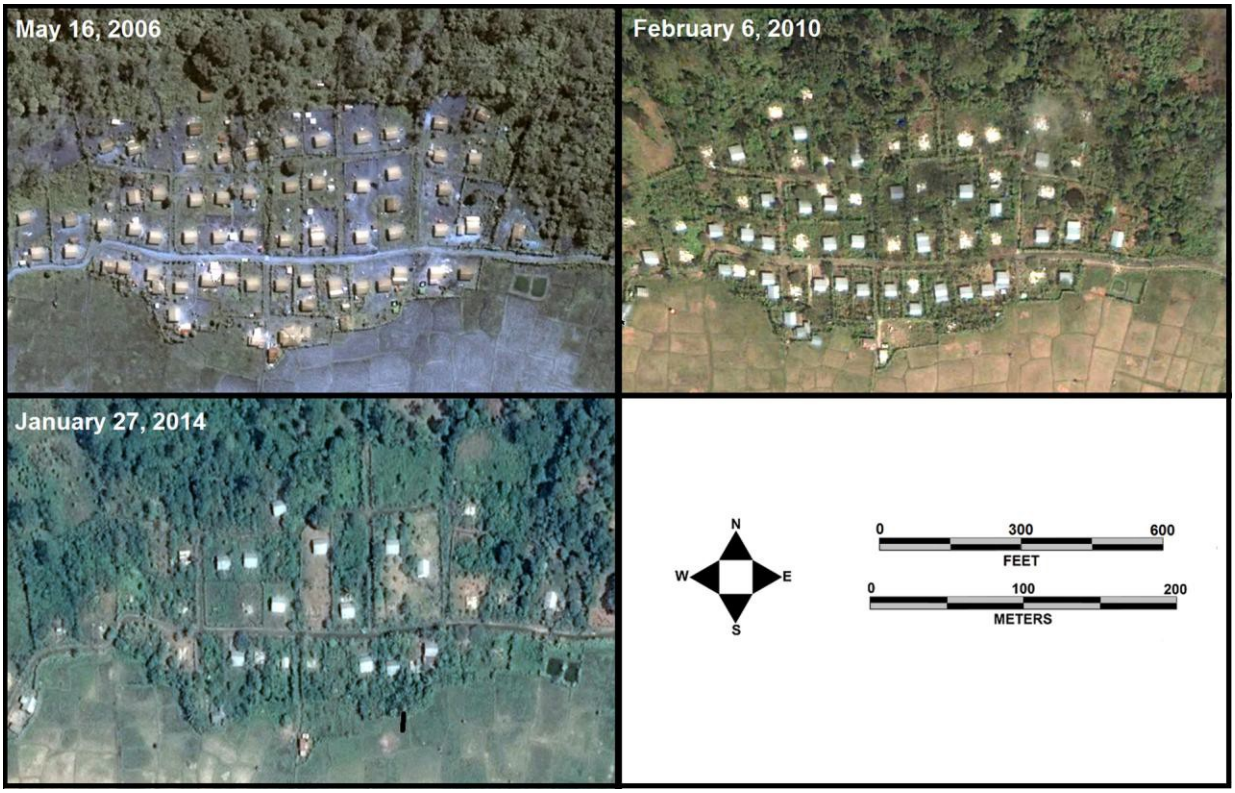

Figure 4. Hillside location of Birek, between 2006 and 2014 (DigitalGlobe, QuickBird; CNES-Astrium's Pléades).

With respect to the building of the BRR houses in Birek and Kareung and the relocation of the villages back to their original sites, the external consultant's findings and conclusions centered on the focus group discussions and a meeting with Mamamia members that included some communication documents between Caritas and Mamamia (Trummer, 2010a). During the focus group discussions the villagers expressed that Mamamia complied with Indonesian law prohibiting post-tsunami construction of housing along beaches prone to future flooding and that BRR approached the villagers about building new homes on their pre-tsunami sites. The villagers did not express anything about why BRR made its offer of new houses or how the offer related to the Indonesian law restricting construction in certain areas. The villagers conveyed gratitude to Mamamia for providing shelter so quickly after the tsunami. They also indicated that the BRR houses were selected over the Mamamia houses because the new structures were built of brick and concrete, and thereby, more stable and durable. The terms "stable" and "durable" suggest that the houses could withstand future environmental hazards. Another reason the villagers communicated as why they elected the BRR houses was that they had emotional ties to the original sites of the villages. Also, they stated that their original plots of land were larger permitting them to have livestock and grow crops. In comparing the 2004 image in Figure 5 to the 2006 image in Figure 4, the density of structures in the villages in 2004 is much higher than in 2006 allowing less space for other activities. The density of structures in the 2014 image as shown in Figure 5 equals the density in the pre-tsunami 2004 images. Thus, the facts do the not support the villagers' statements about original plots of land being larger than the lots in the Mamamia sites. Most of the land situated immediately outside the villages that was previously used for crop production is no longer being utilized for agricultural purposes. Finally, some villagers stated that access to ground water was easier at the original village sites than on the hillsides where they had to walk up and down slopes. Figure 4 (upper right, 2010) shows that most of the initially dismantled houses were situated the farthest uphill from the valley floor (Trummer, 2010a). No questions were asked about the old site's proximity to the mosque.

The external consultant found that Mamamia tried several times to learn directly from BRR and the villagers who specifically initiated the construction of BRR houses and who decided to locate the houses back on the original sites of the villages that had been destroyed by the tsunami. In spite of Mamamia's efforts no clear reasons

materialized. BRR denied knowledge of the issue. For all of the houses constructed at other villages under the Mamamia's PRR-L that subsequently were relocated to new sites, the detailed survey administered by the consultant found that 58% of the people who had been relocated preferred the new locations of their homes over their old locations and only 8% felt that the location was worse (Trummer, 2010). Apparently, Mamamia had done a good job at relocating other villages within a short time period. Mamamia and Caritas view the houses and properties given to the villagers of Birek and Kareung as belonging to the villagers. Thus, if anything happens in the future, the beneficiaries are responsible (Trummer, 2010a).

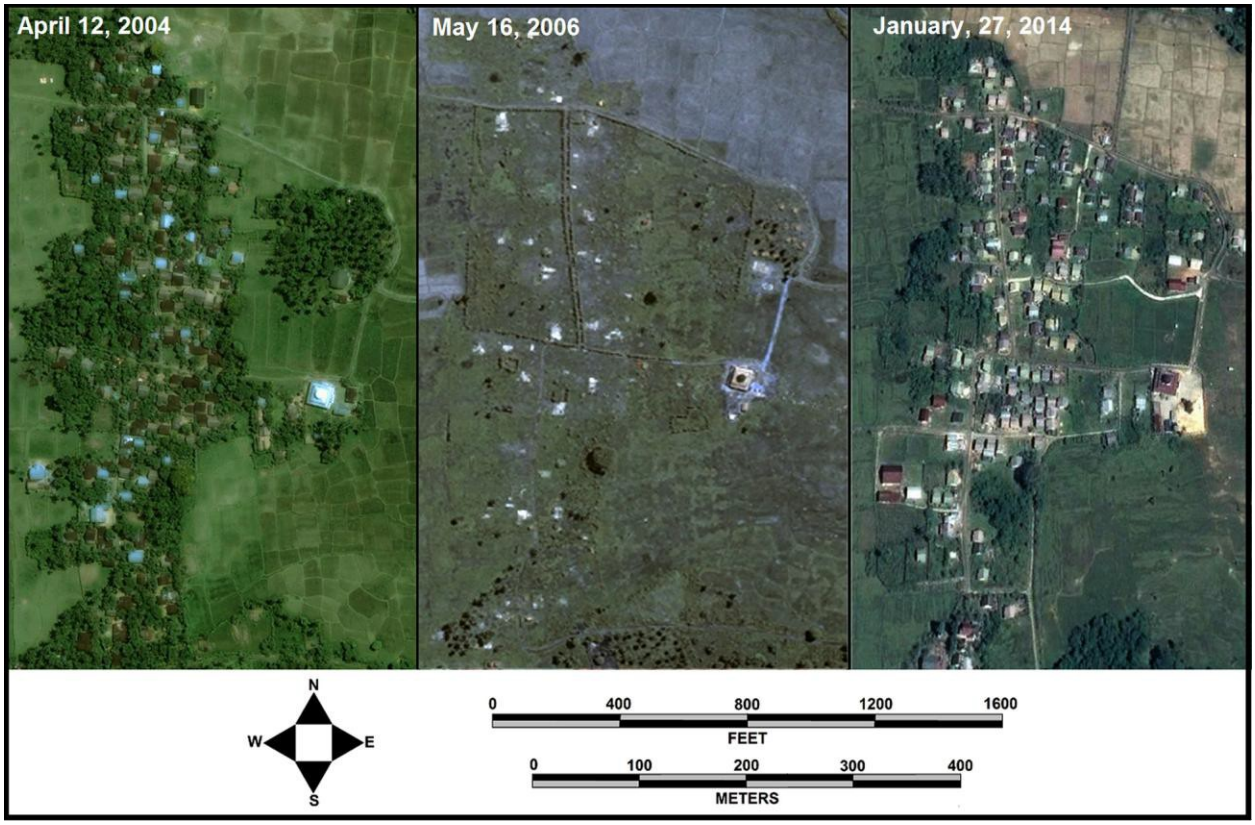

Figure 5. Changes in Birek and Kareung - 2004 and 2014 (DigitalGlobe, QuickBird; CNES-Astrium's Pléades

SUMMARY AND COMMENT

This case study examined the physical impact of a mega-tsunami on two small, rural villages and how these villages dealt with their recovery and relocation. The almost total devastation of the villages and environs was clearly documented by high resolution satellite imagery. The imagery also showed that the villages were relocated to areas better protected from future tsunamis. New homes, paved roads and centralized water systems were provided by non-government organizations. Villagers moved into these facilities as their new permanent homes. Then, a new Indonesian government agency, formed specifically to handle the post tsunami recovery process, gave the villagers the option to return to their original home sites. The vast majority of the villagers elected to abandon, and in some cases, dismantle/destroy their new homes and move back to where their original villages were located. They were provided with new homes by the government. The rationale for allowing and assisting the villagers to return to sites that were demolished by the tsunami has not been provided by the government.

Of the seventeen largest earthquakes in the World since 1900, three have occurred along the northwest coast of Sumatra. This number does not include the earthquake that produced the 2004 tsunami. The Banda Sea quake took place in 1938 with an 8.5 magnitude; the North Sumatra quake in 2005 at an 8.6 magnitude; and the West Coast of Northern Sumatra quake in 2012 at an 8.6 magnitude (USGS, 2015). On October 25, 2010 a 7.7 magnitude earthquake struck the west coast of Sumatra along the same fault line that produced the 2004 earthquake. It created a tsunami with 9 foot waves that destroyed many of the villages on the Mentawai Islands, located on the west coast of Sumatra, south of Aceh Besar. It displaced more than 20,000 people and reportedly killed 435. Thus, the

probability of other major earthquakes with ensuing mega-tsunamis is quite high throughout the northwest coast of Sumatra. Birek and Kareung sit again in the potential path of another tsunami.

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