# A Perfect Tsunami? El Nino, War and Resilience on Aceh, Sumatra

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**Abstract** The history of Aceh, Indonesia highlights societies' resilience and vulnerability in the face of natural and human-made disasters. A multi-scalar, qualitative and quantitative analysis of land use changes in nineteenth century Greater Aceh by using GIS analysis, highlights that processes may play out differently at the system and subsystem levels. At the system's meso and micro levels, the episodic and the structural violence of war, climate anomalies, and tsunamis wiped out entire communities and families of people, animals, and plants while at the macro scale Aceh society showed remarkable resilience. Greater Aceh's case also suggests that the impact of war through population displacement and the destruction of such environmental infrastructure as homes, villages, orchards, and irrigated fields while less immediately and directly destructive than such episodic events as the devastating 2004 tsunami, nevertheless may have a comparable impact because the events are more sustained and cumulative over a timeframe of years and decades.

**Keywords** War- environmental aspects · Global environmental change · Climate change and resilience/collapse · Human ecology · Natural and human-made disasters · Post-crisis reconstruction

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## Introduction

The history of Greater Aceh (modern Aceh) on the northern tip of Sumatra, Indonesia highlights societies' resilience and vulnerability in the face of natural and human-made disasters. A comparative perspective using a more recent, more data-rich case study provides detailed insights into the processes involved that may shed light on the dynamics involved in other cases discussed in the book for which the data are scarcer. The chapter offers a multi-scalar, qualitative *and* quantitative analysis of land use changes in nineteenth century Greater Aceh by using GIS analysis. It sheds light on key issues relating to spatial and temporal scales of analysis. What and who collapsed or proved resilient and to what extent are the qualifications of collapse and resilience dependent on the temporality of the analytical framework? What does a focus on the abstract level of "systems" reveal or hide? What is "the system:" a polity represented by a state elite and state infrastructure or an ecosystem or agro-ecological system? How do processes at the meso-level communities of people, animals, and plants factor? What about the microlevel of households and individuals? Indigenous Americans experienced genocide and ecocide, and demographic and societal collapse between 1492 and the 1880s. Yet, the Huron, Iroquois, Sioux and many other survived as tribes (Kreike 2021: 59–96, 137–172, 279–317). The history of Greater Aceh raises the same questions. Greater Aceh was the core of the Aceh Sultanate, which was a major political and economic power in Southeast Asia from the sixteenth century to the late nineteenth century. In 1873, the Dutch invaded the sultanate, triggering a war that dragged on for decades causing destruction, displacement, and massive loss of life (Van 't Veer 1969; Reid 1969; Stolwijk 2016; Hagen 2018: 438–480; Kreike 2021: 318–357). The humanitarian and economic costs of the war initiated a public debate in the Netherlands, with a former colonial officer accusing the Dutch government of genocide in Aceh (Wekker 1907; Kreike 2021: 318–320, 355–357). A century later, the Netherlands' colonial wars in Indonesia and elsewhere are once again under scrutiny because of the intense violence and destruction that accompanied them (Luttikhuis and Moses 2014; Enthoven et al. 2013).

## Monsoons and El Niño Southern Oscillation (ENSO)

Greater Aceh, located on the northwestern tip of Sumatra (Fig. 1), is subject to the monsoons, with a wet season in December-February and a dry season in June–August. Irrigated cultivation has marked the densely populated Aceh River Valley lowlands since the sixteenth century and many households also had dryland fields in the foothills and mountains surrounding the floodplain. In addition to the staple paddy rice crop, farmers cultivated such highly valuable export crops as pepper, betel nuts and betel leaves. Heavy rains that are exacerbated by wetter ENSO La Niña events cause flooding in Greater Aceh (Fig. 2) while onsets of El Niño are associated with droughts (Ilhamsyah et al. 2019). Flooding can severely damage buildings, fields,

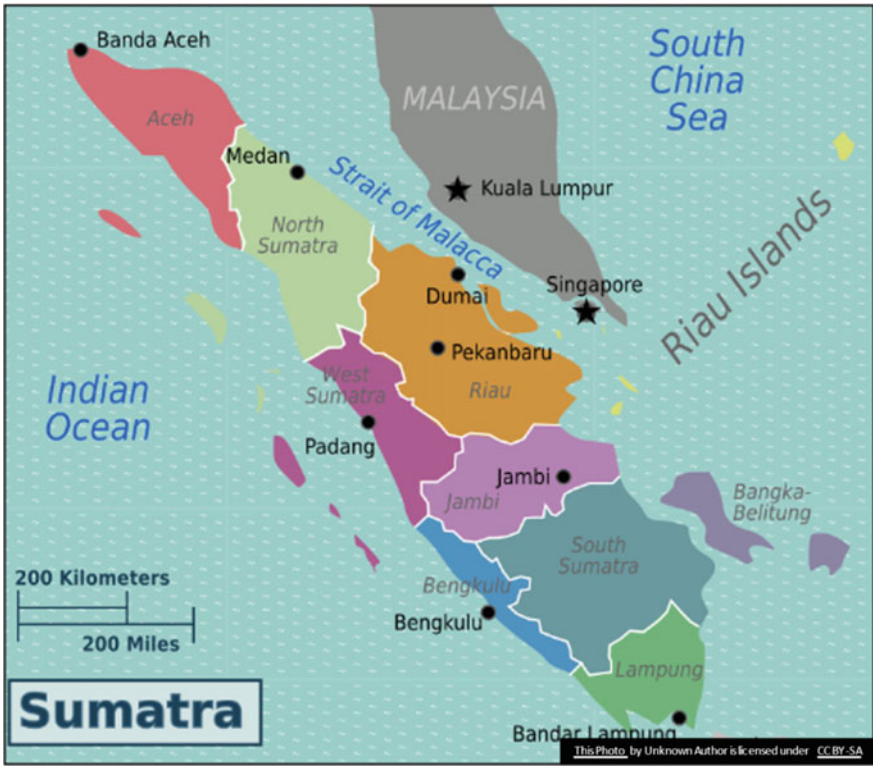


**Fig. 1** Sumatra with Aceh (*source* Wikimedia commons/creative commons)


**Fig. 2** The flooded village of Meulaboh south of Banda Aceh, the capital of Aceh in November 2014 (*source* Getty images/christian science monitor)

and crops not only in the low-lying floodplain of the Aceh River, but also in the upland valleys and mountainous slopes surrounding the floodplain (Azmeri and Isa 2018).

## Earthquakes and Tsunamis

Greater Aceh also lies in an earthquake zone that caused the terrible Christmas Tsunami in 2004 that killed over 100,000 people and displaced half a million with mortality rates in some of the coastal districts climbing to over 20% (Fig. 3).

The sea waters inundated areas up to 4 km inland and permanently moved the shore of Aceh 1.5 km inland (Doocy et al. 2007; Borrero 2005). Archaeological evidence points to equally devastating tsunamis in 1394 and 1450 (Fig. 4). The 1394 tsunami wiped out the small settlements that existed in the coastal region where the modern city of Banda Aceh is located but left the thriving Lamri trade port unscathed because it was located on higher ground behind a tongue of land. During the 2004 tsunami, Lamri's location once again saved it from the impact of the wall of water.

In the 16th century, however, Lamri was replaced as a key node in the Silk Road by the new Aceh sultanate (Fig. 5) that arose in the area of modern Banda Aceh despite it having been hit twice by a tsunami in half a century. It appears that refugees from Samudra/Pasai further east on the Sumatra coast recolonized the area around the modern capital of Banda Aceh after the Portuguese occupied their town (Daly et al. 2019; Meltzner et al. 2004).

In 2004, massive aid from the Indonesian government and international emergency and development assistance sustained the survivors and allowed the region to

**Fig. 3** Flooding caused by 2004 Tsunami (*source* Wikimedia commons/US Navy)

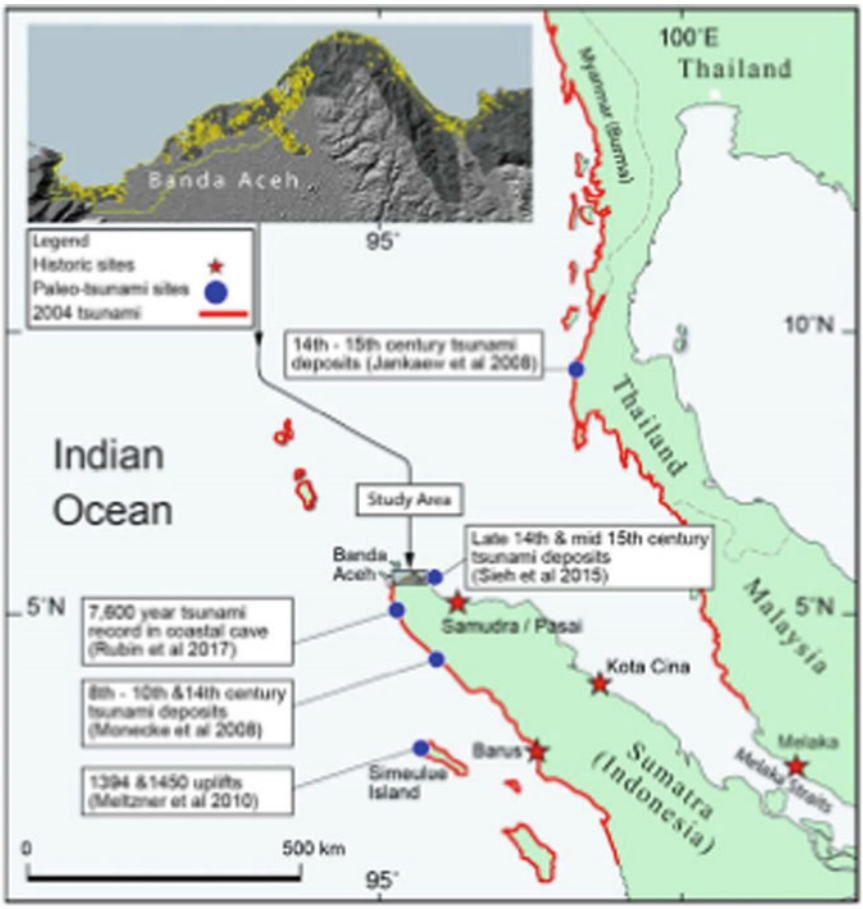


**Fig. 4** Map showing pre-historical and historical record tsunami impacts Aceh (*source* Daly et al. 2019)

be rebuild. Research on the post-2004 recovery suggests that restoring individual and family level livelihoods were at least as significant for recovery as the reconstruction of system-level physical and institutional (i.e., state) infrastructure. Restoring livelihoods (including shelter) was especially important to rebuilding resilience for those who were displaced from their homes by the disaster (Sina et al. 2019).

## Natural Disasters and War

Other contributors to this volume emphasize that the phenomena of collapse and resilience are multi-causal: the Horsemen of the Apocalypse seldom ride alone. The colonial war of conquest in the second half of the nineteenth century is the main focus.

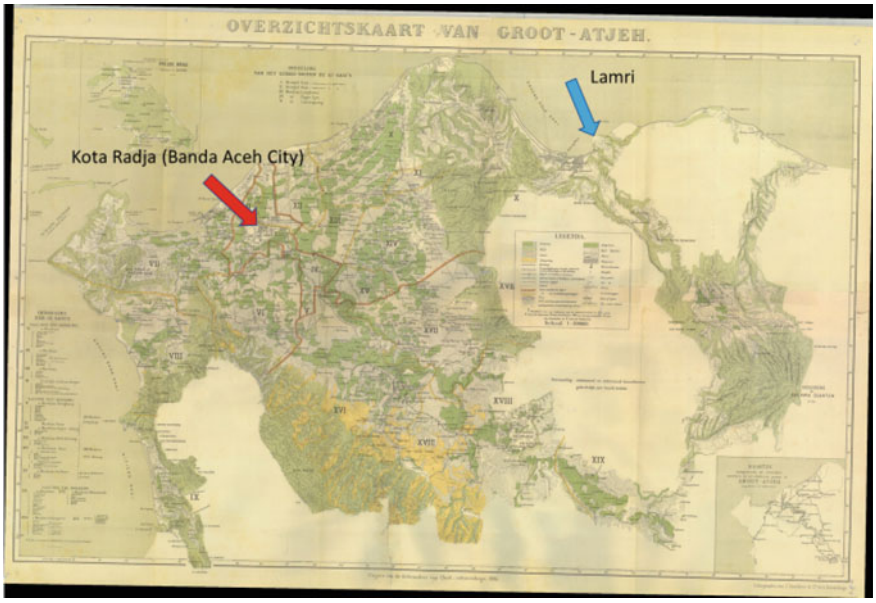


**Fig. 5** Dutch late-nineteenth century map of Aceh Sultanate with arrows indicating Lamri and Banda Aceh City (*source* base map E.B. Kielstra, Beschrijving van den Atjeh-Oorlog, 3 vols. (Den Haag: Van Cleef, 1883–1885))

It lasted well into the twentieth century, causing not only direct destruction through scorched earth but also by triggering massive population displacement, tearing people from villages, homes, granaries, water sources, seed supplies and other key environmental infrastructure and exposing people and animals to heat, cold, hunger, thirst, epidemic disease, and death. Seasonal and cyclical droughts and floods in the Aceh River Valley and the surrounding mountainous forests in the monsoon climate exacerbated the impact of war, disease, and famine. Tens of thousands were displaced and thousands perished (Hagen 2018: 479–480; Reid 1969:187–188).

The Dutch invaded Aceh in 1873 (Fig. 6). The first invasion was a failure, with heavy casualties due to the fighting and disease and the Dutch withdrew before the full onset of the monsoon that made it impossible to effectively deploy their men and material.

A new invasion force sent from the Netherlands reached Aceh in December 1873 and occupied the palace of the Aceh Sultan in January 1874, in the middle of the rainy season. Dutch campaign reports on the war are replete with complaints of how flooded and swampy terrain handicapped their operations, with heavier losses due to disease than to actual combat (Van't Veer 1969: 49–81). The last three decades of the nineteenth century saw an unprecedented clustering of ENSO events that coincided with the Dutch conquest wars. El Niño events occurred in 1873 and 1874, 1876, 1877, 1878, 1881, 1887, 1888, 1889, 1891, 1895, 1896, and 1897. The hotter

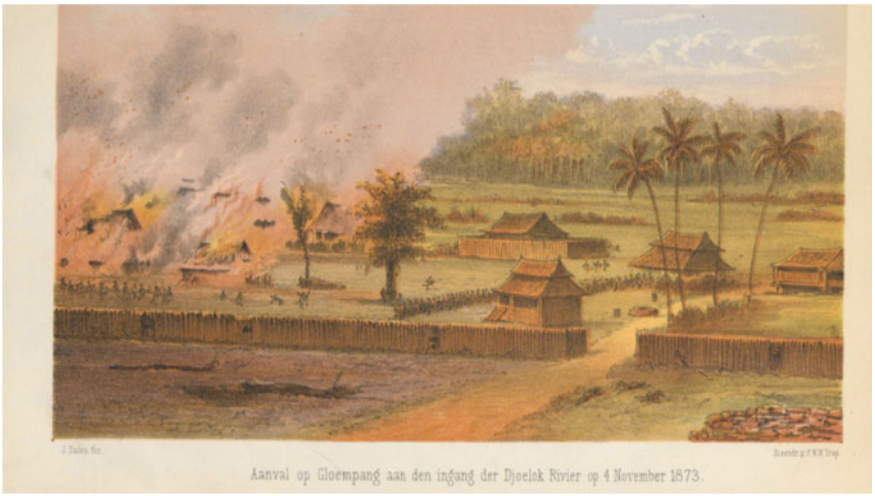


**Fig. 6** The village of Glumpang (Gloempang) burning while under Dutch attack in 1873 (*source* J.A. Kruijt. Atjeh en de Atjehers: Twee Jaren Blokkade (Leiden: Gualth. Kolff, 1877))

and drier conditions associated with El Niño years made the terrain more passable for men, horses, carts, and cannon. La Niña events associated with cooler and wetter conditions occurred in 1876, 1878, 1879, 1880, 1886, 1887, 1889, 1890, 1892, 1893, and 1894 and may have exacerbated inundations in Aceh. Analysis from early twenty-first century ENSO events suggests that western Sumatra and Greater Aceh may be less affected by ENSO effects than other parts of Indonesia and that anomalies cluster in the dry season months of June–August. An extreme double ENSO El Niño that occurred in 1877–1878 likely had a substantial impact. The relative temperature anomalies of the 1877–1878 event were comparable to the events in 1982–1983 and 1991, which caused heavy padi rice losses and severe bush fires across Indonesia. Moreover, high-temperature dry ENSO El Niño periods are usually followed by cooler and wetter years (Harger 1995; As-syakur et al. 2014; Davis 2001: 271, table 8.8; Giese and Ray 2011: C2, tables 1 and 2). In Aceh, the 1878–1879 El Niño may have favored Dutch operations, literally fanning the flames of scorched earth. The 1878–1879 El Niño may also have depressed irrigated and dryland rice production in regions that were not directly subject to the hostilities. The cooler and wetter years that followed may have intensified flooding and encouraged the invasion of *alang alang* grasses in the rice fields, and bamboo and brushwood in village gardens and dryland fields; these invasive species negatively impacted agricultural yields. ENSO events thus were likely to have been a significant factor during the late 1870s and the early 1880s, exacerbating the impact of the war and population displacement. The severest ENSO events of the late nineteenth century coincided with the peak of the Dutch scorched earth campaign and its immediate aftermath, when many villages lay abandoned, along with their gardens, plantations, orchards and irrigated rice fields (Fig. 7).

**Fig. 7** Damaged Aceh houses (*source* National Archive, The Hague, The Netherlands (henceforth NL-HaNA) 2.20.46_850_15)

## 1873–1880: Scorched Earth and Population Displacement

From 1878 to 1880, the Dutch invaders intensified their attempts to conquer the territory, advancing up the Aceh valley inland while relying heavily on scorched earth: any village that resisted or was found abandoned was burned to the ground. In many cases, the inhabitants narrowly escaped with the little they could carry and their cattle.

The Dutch colonial soldiers captured or destroyed the smallstock and the rice stores left behind. The Dutch timed their campaigns with the onset of the rice harvest season in March–May when the rains ended, and the irrigated rice fields were drained, making them passable for the soldiers and their heavy equipment. By 1880, the Aceh Valley had been subdued. But even the general who had led the second invasion in 1873 concluded that the price of Dutch success had been too heavy: 500 villages had been reduced to ashes and 30,000 Acehnese had perished in the fighting or had fallen victim to starvation or disease, including smallpox and cholera (Kreike, 2021: 318–342).

## 1880–1884 War, Resilience, and Recovery

Many villagers had fled the Aceh Valley and those who returned found themselves homeless and short of labor, food, seed, and water buffaloes (Fig. 8) to prepare the rice fields (Kreike 2021: 337–338, 341–342).

**Fig. 8** Waterbuffalo in rice field (*source* NL-HaNA 2.20.46_850_29)

The May–June 1880 padi-rice harvest was poor, many rice fields remained abandoned. Returned villagers only managed to clear, plant, and harvest the fields closest to their homes. Meanwhile, violence continued to hamper a return to normal life. Dutch patrols only had control over the countryside by day. By night, rebels extracted food and war taxes from the villagers at will and punished anyone suspected of collaborating with the Dutch invaders. Having temporarily abandoned their blanket scorched earth strategy for a policy of "exemplary punishment" during the early 1880s, Dutch security forces now limited themselves to the selective and occasional burning of single villages accused of actively supporting the rebels (Kreike 2021: 342–350).

## The Concentrated Line

In 1884, due to the continued high military and economic costs of the occupation of Aceh and the failure of its civilian-led pacification campaign, the Dutch government radically changed its policies. Instead of trying to control the entire territory, it retreated to the far west of Greater Aceh. The so-called "Concentrated Line" consisted of a 5–6 km deep territory that extended from the coast inland, basically the lower

Aceh River Delta, and included the capital Kota Radja (modern Banda Aceh) and the Oleh Leh Port. All territory beyond the concentrated line was abandoned by the Dutch military and administration. The line consisted of a number of larger and smaller forts connected to one another and to Kota Radja and Oleh Leh by all-weather roads and a narrow-gauge railroad. The roads and the railroad were elevated to ensure that they were above the monsoon flood levels of the Aceh River. Despite having placed drains where the elevated roads and railroad track crossed smaller and larger rivers, the roads and railroads effectively functioned as dikes, increasing the incidence of flooding upstream and causing water shortages downstream.

Dutch soldiers and laborers also created and maintained a one-kilometer free fire zone beyond the line of forts that faced inland along the entire length of the defensive line. Forced laborers razed homes, trees, graves and entire villages to create free fields of fire for the Dutch artillery installed in the forts. The defensive line, the free fire zone and the areas directly beyond transformed into a deserted no man's land. Dutch patrols had standing orders to shoot to kill anyone crossing the defensive line without permission. The Dutch also responded to shots fired from beyond the territory under their control, and indeed, anything seen as a provocation by shelling villages beyond the defensive line in retaliation. In 1891, a mere six years after the completion of the defensive line in 1885, a broad swath of territory beyond the one-km-wide free fire zone lay entirely abandoned as villagers and farmers fled their homes and fields.

The red line on the 1891 Dutch military map (Fig. 9) highlights the defensive line with the railroad connecting the forts. The green color indicates abandoned villages and the blue color marks abandoned and inundated rice fields. Population flight led to a decline in the repair and maintenance of the infrastructure of dikes, dams, drains, and sluices in the padi-rice fields, turning them into swamps or weed deserts. Clustered ENSO events increased the incidence of flooding and water shortages and the Dutch road and railroad dikes reshaped and impeded pre-existing drainage and irrigation patterns in the delta (Kreike 2021: 350-355). Not all flooding was incidental. Hostile villagers closed dams, sluices and drains to flood the rice fields during the off-season in order to hinder the Dutch advance. The flooding forced the Dutch soldiers to advance very cautiously over the warren of narrow slippery dikes and rickety bridges towards the villages (Fig. 10) that were surrounded by bamboo stakes and fences and palisades (Kreike 2021: 328, 331). It is somewhat ironic that the Dutch reports increasingly portrayed the conflict as being fought in swamps and jungle, that is, as wilderness warfare, although the swamps and the jungle-like flora they encountered in the Aceh Valley were actually the outcome of their own destructive war tactics.

## Measuring Resilience at the Systemic Scale Through GIS

Dutch military surveyors accompanied the troops during the fighting and used trees and mosques as markers to draw maps that contain detailed information about villages, vegetation, and land use. An 1885 map and an 1891 update were separately georeferenced in GIS using up to 100 points to tie features on each map to the same features identified on the modern satellite image (Fig. 11).

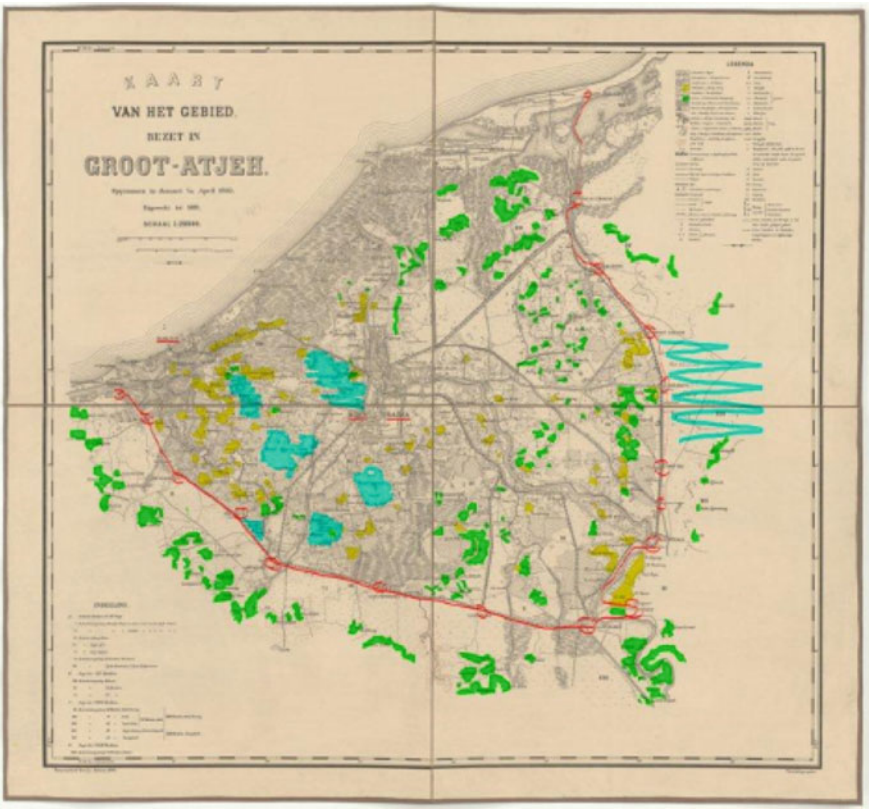


**Fig. 9** 1891 Dutch military map of Aceh with color mark up in Paint software (*source* base map: NL-HaNA, 4. Ministerie van Kolonien (henceforth MIKO), 1414, 1891)

Next, villages, padi rice fields, and other land use features on the georeferenced maps were marked with polygons. The polygons allowed the surface totals for each feature to be calculated and facilitated assessing the land use changes between 1885 and 1891.

Many villages and rice fields already had been abandoned before 1885 because of the fighting since 1873. The polygons in the georeferenced 1885 map (Fig. 12) mark different types of land use or abandonment, including previously abandoned village lands (coded as *Previouslyabandoned* in the legenda and marked by the blue-lined transparent polygons); actively cultivated ricefields (*Ricefield*: red filled polygons); partially cultivated ricefields (*Ricefieldpartiallycultivated* in dark pink); uncultivated ricefields (*Ricefielduncultivated* in light pink); and inhabited villages (*Village* in dark green).

The same categories and colors were used for the analysis of the 1891 map (Fig. 13). One complication is that the land use information provided on the two maps was not always consistent between the two maps, making the comparison challenging. Not all village spaces and rice fields indicated on the 1885 map were

**Fig. 10** Dutch officers on a narrow dike with a bridge in the background (*source* NL-HaNA 2.20.46_850_17)


**Fig. 11** Dutch 19th-century military map of Aceh superimposed on satellite image for georeferencing (*source* map: NL-HaNA, 4 MIKO, 1414, 1891)

marked in the same way as on the 1891 map. For example, some of the abandoned village sites on the 1885 map were identified as bush vegetation on the 1891 map. Similarly, the locations of abandoned padi-rice fields on the 1885 map appeared as swamps or grasslands on the 1891 map, without any reference to their previous

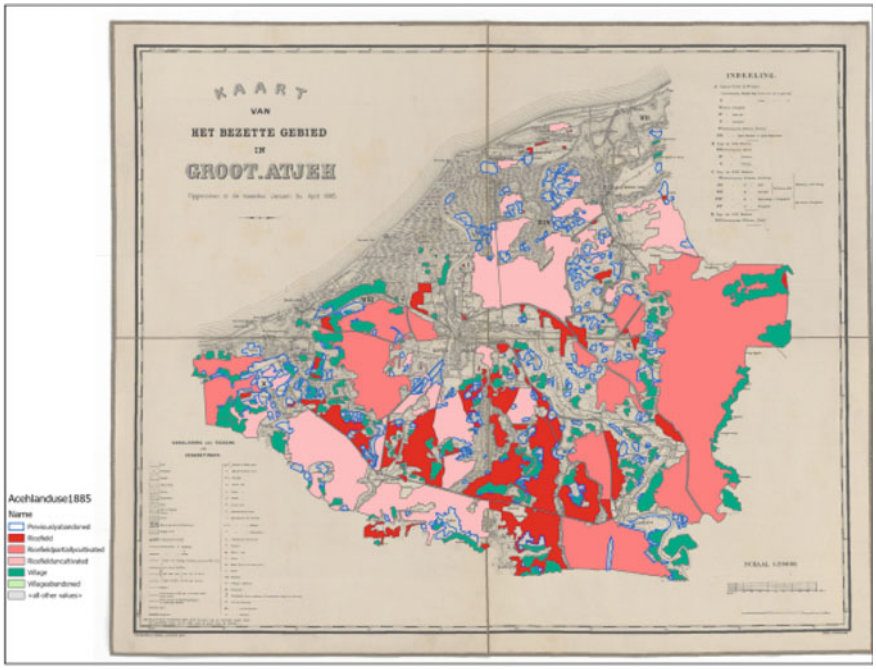


**Fig. 12** Georeferenced map: Aceh land use 1885 (*source* base map: NL-HaNA, 4 MIKO, 1239, 1885)

classification on the 1885 map. To measure the total size of the village surfaces abandoned between 1885 and 1891, for example, I marked the village surfaces that were marked as abandoned *before* 1885 with blue-lined transparent polygons in the 1885 map to highlight that they are different from the villages on the 1891 map that could be identified as having been newly abandoned between 1885 and 1891 (coded as *Villageabandoned* and marked in light green).

To better visualize the land use changes, I separated the changes in the size of village spaces from the changes in the sizes of irrigated rice fields in the following images and displayed the changes in each category on a single map. The first image (Fig. 14) shows the occupied and inhabited village spaces in 1885 (in dark blue), with the village spaces still inhabited in 1891 (in orange superimposed on the blue 1885 polygons) within the Dutch-occupied Concentrated Line. The image indicates that most of the villages were entirely or partially abandoned. The total surface of inhabited village space shrunk from 880 ha in 1885 to 267 ha in 1891, a loss of 520 ha of village lands (homes, gardens, orchards) that constituted a 60 percent reduction in 6 years. The abandoned village lands transformed into dense thickets and bush. Indeed, on the 1891 map, many areas that had been identified as abandoned village lands on the 1885 maps were now relabeled as forest and wilderness.

The next image of the 1891 map (Fig. 15) includes the category of abandoned villages (coded *Villageabandoned1891* in yellow) and adds two new sets of data: the

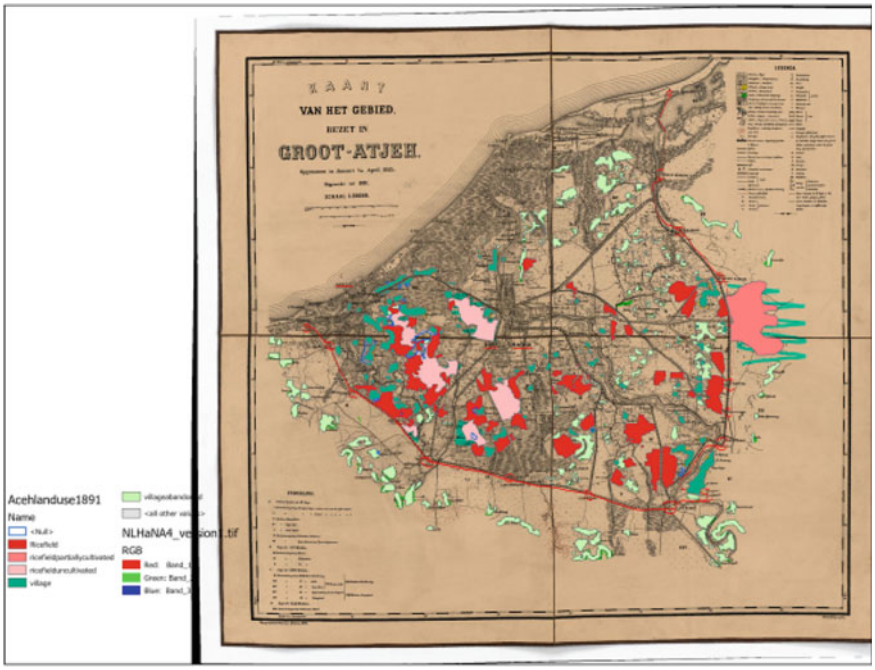


**Fig. 13** Georeferenced map: Aceh land use 1891 (*source* base map: NL-HaNA, 4 MIKO, 1414, 1891)

extent of the abandonment of 1885 village sites by 1891 (in orange); and projected village spaces that appear to have been abandoned before 1885 (in blue).

The next image (Fig. 16) compares cultivated irrigated rice fields in 1885 and 1891. The image shows that the surface area of irrigated padi rice fields shrunk from 984 ha in 1885 (*Ricefield1885* in light green) to 572 ha in 1891 (coded *Ricefield1891* in dark green), a reduction of 45%. On the maps, abandoned padi rice fields often are marked either as overgrown by *alang alang* grass (*Imperata cylindrica*) or as wild sugar cane (*Sacharum spontaneum*) infested swamplands. In particular, *alang alang* is known for its invasive properties. *Alang alang* invasion in irrigated rice fields is a major problem especially if fields are cleared too late in the season to plant the rice. Two-and-half years after the 2004 Tsunami and despite a massive influx of aid and machine-assisted clearing of the rice fields, rice production had not resumed because of *alang alang* invasion, flooded fields and saltwater intrusion. (Thorburn 2009).

The land use data suggest that more than half of the villages and almost half of the irrigated rice fields in Banda Aceh were abandoned between 1885 and 1891, while many, if not most, villages and ricefields already had been abandoned before 1885. Yet, as a political, societal, and environmental system and measured at a time scale of give or take 20 years (from the Dutch invasion of 1873 to1891), Aceh seemed to be surprisingly resilient. Despite the use of total war and scorched earth, the Dutch retreated within the Concentrated Line in 1885, leaving the Aceh Sultan and the rebels

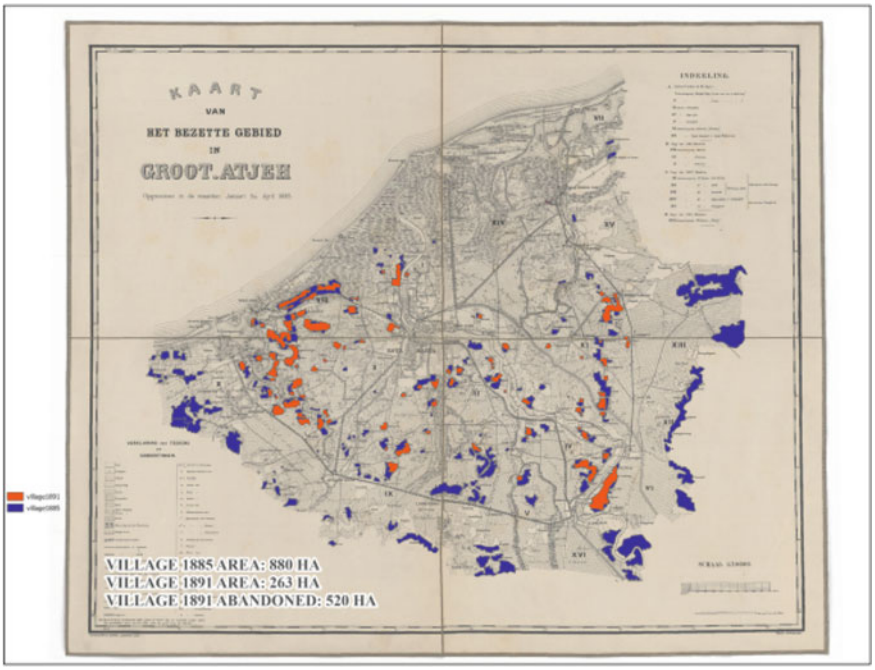


**Fig. 14** Abandoned villages 1891: 520 hectares of village lands abandoned (*source* base map: NL-HaNA, 4 MIKO, 1414, 1891)

in control of the remainder of the territory. Although dramatically reduced in size, the preserved villages and rice fields continued to sustain the remaining population. If, however, the year 1880 is selected to assess Aceh at the system level (using a time scale of less than a decade: 1873–1880), collapse seems the more appropriate description with the sultanate defeated, over 500 villages burned, and the population exposed to the monsoons, drought, famine, and disease.

## Sub-Systemic Resilience and Collapse: A Village View in Lamara

Data on the village of Lamara (Fig. 17) allow for a sub-systemic assessment of resilience and collapse, providing insights into the dynamics at a village meso-level that also point to differentiation at the micro-level of households. The violence and the displacement prevented clearing, cultivating, and weeding fields, gardens, orchards, and plantations at the village level. Unchecked weed growth and denser undergrowth during the wetter La Niña years resulted in an increased availability of fuel and consequently tinderbox conditions during the dry season. The extra heat that marked

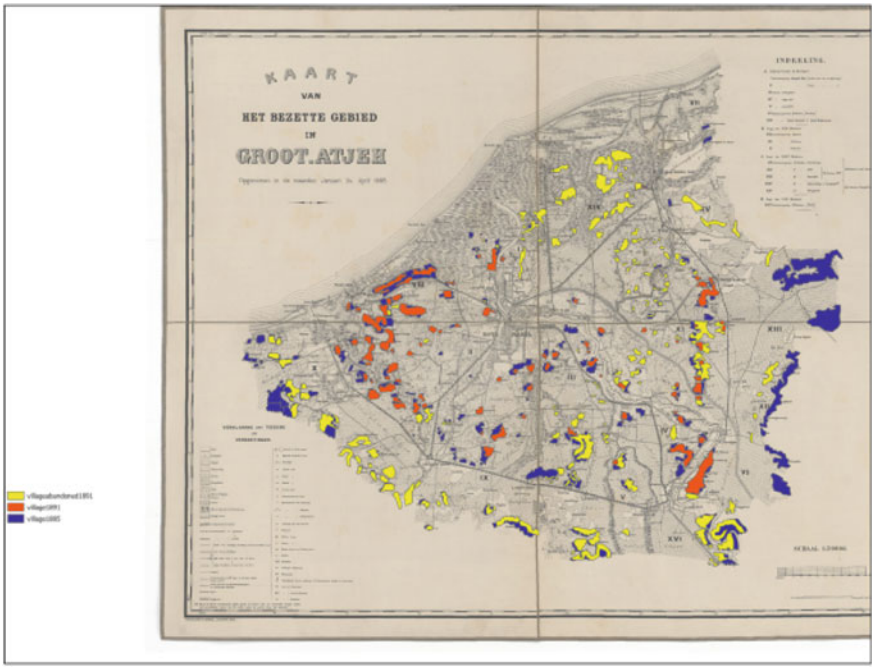


**Fig. 15** Villageabandoned1891 (*source* base map: NL-HaNA, 4 MIKO, 1414, 1891)

El Niño events rendered scorched earth and fires more destructive. In the dry season month of June 1880, an accident with a cooking fire caused a blaze in Lamara that destroyed most of the 30 newly rebuilt houses.

Fortunately, the fire occurred during the day, when the villagers were engaged in the rice fields and most livestock was in the pastures. One man, a cow, and a water buffalo suffered burns and six goats perished. The ease with which the fire spread may have been related to an abundance of weedy undergrowth in the village that only recently had been resettled in what was a La Niña year. Seven months earlier, in 1879, Dutch soldiers had burned Lamara to the ground after they found the population had abandoned it. Returning refugees had rebuilt part of the village and a new mosque. The house frames consisted of betel nut palm poles (*Areca catechu* or *pinang*), with bamboo sides, and a roof covered with mangrove palm leaves (*Nypa fruticans* or *atap*), all locally available resources. Only seven homes and the mosque survived the June 1880 fire. In November of the same year, with irrigated rice cultivation under way, the Lamara men organized themselves in shifts of 25 individuals, taking turns to work in the fields and in the village to rebuild their homes once again (Kreike 2021: 338, 340). The mosque is indicated by a symbol indicated by the yellow arrow on the Dutch map (Fig. 18).

In 1882, some of Lamara's inhabitants left the village to heed the mosque Iman's advice to construct a new village called Manga in the mountains surrounding the Aceh Valley. Colonial workers had destroyed a section of the village's irrigation

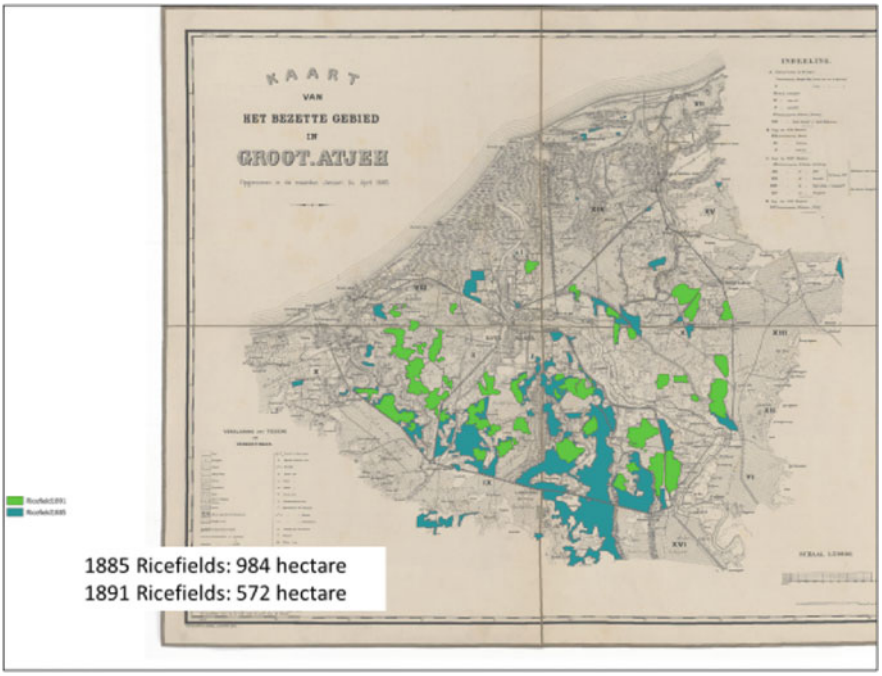


**Fig. 16** Rice fields 1885 and 1891 compared (*source* base map: NL-HaNA, 4 MIKO, 1414, 1891)

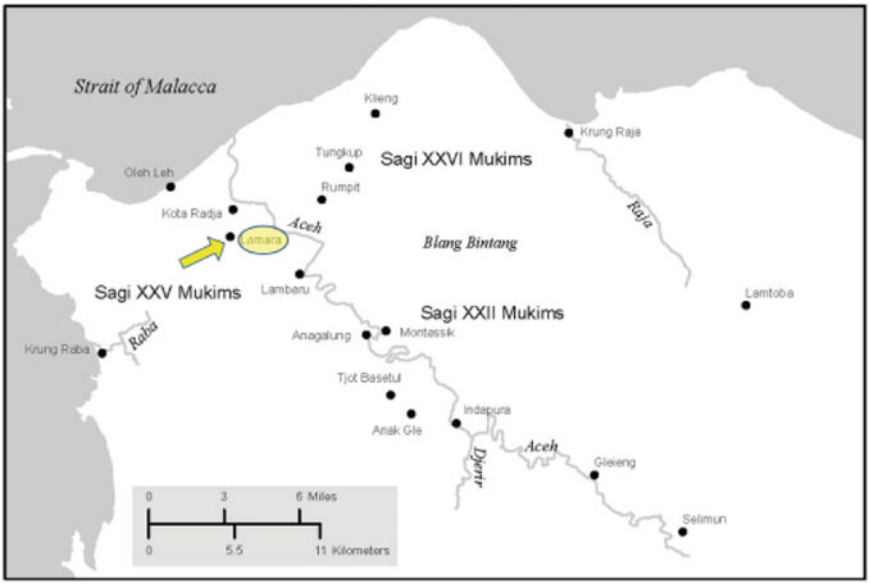


**Fig. 17** Greater Aceh with Lamara

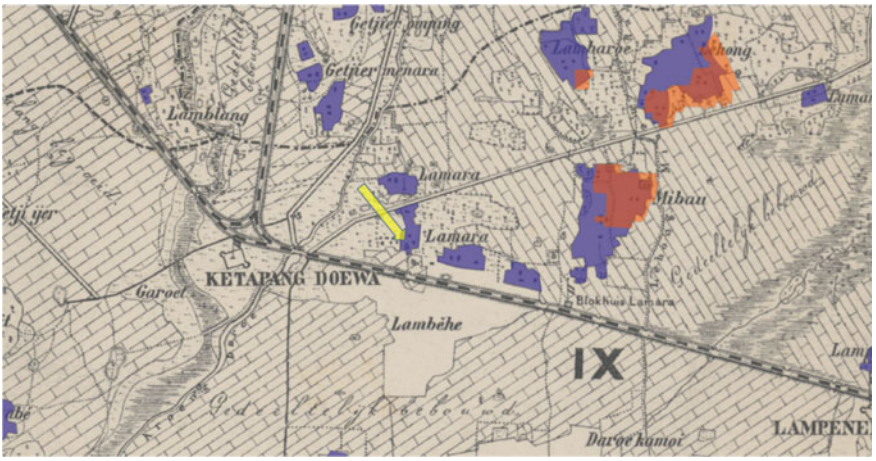


**Fig. 18** Dutch map with Lamara mosque indicated by yellow arrow, identified on the 1885 map as in use. (*source* base map: NL-HaNA, 4 MIKO, 1239, 1885)

infrastructure when they removed a large quantity of gravel from the local river to construct a new elevated all-weather road nearby. As a result, the river water could no longer reach the ditches to irrigate the Lamara rice fields leading its owners to migrate (Kreike 2021: 342). On the 1885 map, the mosque is still in use and parts of the village are still inhabited (marked in purple). Extensive cultivated rice fields (the hatched areas) extend around the village on all sides. On the 1891 map (Fig. 19), however, most of the rice fields are uncultivated (the transparent bluegreen unhatched

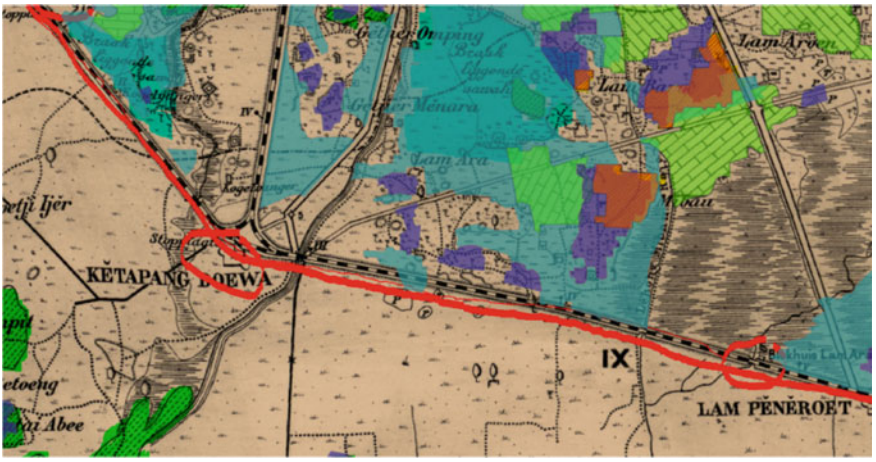


**Fig. 19** 1891 Lamara with abandoned ricefields (*source* base map: NL-HaNA, 4 MIKO, 1414, 1891)

areas) and only greatly reduced patches to the North remain (the transparent light green hatched areas).

## The Village Was Entirely Abandoned in 1891

For comparison, the purple polygons marking the 1885 inhabited village patches are superimposed on the 1891 map. The close-up of the 1891 map (Fig. 20) highlights the symbol for Lamara's mosque which was rebuilt in 1880 (indicated by the yellow arrow) and in ruins 11 years later.

The 1891 map marks the padi fields north of the railroad (the interrupted black line) as uncultivated and the fields to the south of the railroad are labeled as *alang alang* grasslands. Thus, the Lamara community, which in 1880 had proved resilient by having constructed 30 new homes and a mosque only seven months after the Dutch had torched their village, had once again abandoned its home by 1891. The prospect of peace after the end of the 1879 Dutch scorched earth campaign had enticed part of Lamara's population to return from their places of refuge and to rebuild homes and their mosque. Neither the 1880 accidental blaze nor the damage to their irrigation system by Dutch roadbuilders in 1882 had broken their spirit. The 1885 map shows that the village continued to be partly inhabited and that its adjacent rice fields were under cultivation.

By 1891, however, the village community and its environmental infrastructure had collapsed. The village grounds were overgrown by bush and trees, the mosque in ruins, and the padi ricefields suffocated by invasive grasses. Lamara was located just inside the Dutch Concentrated Line that had been constructed in 1884 and 1885.


**Fig. 20** Detail of Fig. 19 highlighting abandoned mosque, indicated still as a structure on 1891 map but not identified as active. (*source* base map: NL-HaNA, 4 MIKO, 1414, 1891)

The dike for the narrow-gauge railroad line cut through its fields just south of the village. The railroad is visible right next to the red marker line that indicates the Dutch defenses; the red marker circles highlight the position of two nearby Dutch forts. Because the 1885 map depicts the village as partially inhabited, the mosque in operation, and the rice fields as under cultivation, it seems that Lamara's returnees did not immediately give up. But the continued violence along the border made lives and livelihoods very precarious. The 1880s damage inflicted upon the village's hydraulic infrastructure was compounded by the construction of the railroad on the southern edge of the village and a new road to the west of Lamara. Both the railroad and the road, which ran across new dikes that rose above the estimated highest flood levels, crossed and inhibited the drainage lines that the irrigated padi cultivation depended on. The levees for the road and the railroad likely led to the removal of even larger quantities of gravel from the local river, which lowered its water level below the level of the padi rice fields, and thereby incapacitating the gravity-forced irrigation system. Significantly, in other villages, the railroad and roads functioned as dikes, transforming rice fields into swamps because they interfered with drainage. The maps show Lamara's rice fields as *alang alang* drylands and deprived of water. Thus, although Lamara's society and environment demonstrated remarkable resilience during the early 1880s, when the village literally rose from the ashes after a decade of war, population displacement, scorched earth, epidemic disease, famine, continued insecurity, and the construction of Dutch defenses that affected local land use, proved fatal and by the 1890s led to the total collapse of the village's society and environment.

## *Conclusion*

Violence in Greater Aceh continued until the Second World War, when it was occupied by Japan until the end of the war. When Indonesia's nationalist leaders demanded independence, the Netherlands dispatched a large army, but the Dutch failed to reoccupy Greater Aceh. After a bloody war from 1945 to 1949, the Dutch government accepted Indonesia's independence. War returned to Greater Aceh in the 1970s as Aceh guerillas resisted Indonesian rule in another drawn out insurgency that displaced tens of thousands. Peace returned only after the deadly 2004 tsunami.

Plagued by a long history of devastating and deadly tsunamis, climate anomalies, and wars, Greater Aceh's society and the environmental infrastructure that it shaped and depended on demonstrated both its vulnerability to collapse and its remarkable resilience. Paradoxically, the region at times simultaneously revealed its vulnerability and resilience, as recurred during the 1879–1891 Dutch invasion of the territory. A detailed analysis deploying ARC-GIS methodology to analyze Dutch contemporary military maps in conjunction with Dutch documentary records facilitates identifying the impact of natural and human-made disasters at different temporal and spatial scales, highlighting that processes may play out differently at the system and subsystem levels. Moreover, these processes may not be synchronized, with different

outcomes at different spatial and temporal scales. At the meso-level of the village, Lamara's society and environmental infrastructure proved highly resilient by the early 1880s, despite the violence of war and scorched earth, the impact of a cluster of ENSO effects that rendered the village a tinderbox, and the destruction wrought upon its irrigation system by the construction of colonial military infrastructure. Yet barely a decade later, the population of Lamara had entirely abandoned the area and the village's environmental infrastructure was overgrown by weeds and bush. At a macro systems level, however, Aceh's society and environmental infrastructure in more ways than one displayed remarkable resilience from the sixteenth century to the present, despite a series of episodic and structural natural and human-made challenges that, moreover, reinforced one another. How meaningful then, is it to speak of the resilience of such an abstract system as "Greater Aceh" or the "Aceh Sultanate" if much of the population is displaced or killed as occurred during the 1871–1900 Dutch war of conquest or the 2004 tsunami, and the environmental infrastructure that the society created and that sustained it is destroyed? At the system's meso and micro levels, the episodic and the structural violence of war, climate anomalies, and tsunamis wiped out entire communities and families of people, animals, and plants. Moreover, to what extent does the use of the term "collapse" negate the strength and creativity of the survivors of war and tsunamis who managed to rebuild workable societies and environments, with or without aid from the outside?

The Greater Aceh case also suggests that the impact of war and insecurity, with the attendant population displacement and the destruction and deterioration of such environmental infrastructure as homes, villages, orchards, and irrigated fields while less immediately and directly destructive than the 1394 and 2004 tsunamis, nevertheless may have a comparable impact because the events are more sustained and cumulative over a timeframe of years and decades. In addition, war and population displacement may intensify and in turn be exacerbated by climate anomalies or changes, such as the clustered ENSO events that coincided with the late nineteenth century Dutch invasion. Although the war and ENSO events dominated for two decades to bring about what the 1394 and 2004 tsunamis accomplished in mere hours, for many the outcome was the same: death, devastation, displacement of the traumatic survivors, exposing them to hunger, disease, and more death.

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