

**Computational Earth System Sciences – From
Tipping Points to Earth Resilience**

1815 Tambora Today: Damage Assessment

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9. Februar 2026

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1 Introduction

Indonesia's population number is currently larger than 284 million (BPS, 2025). According to the ashfall extent, an equal or greater than 20 cm ash blanket would cover the provinces of Bali and Nusa Tenggara Barat, affecting over 10 million people (BPS, 2025). The area covered by 5 cm of Tambora ash is currently inhabited by more than 52 million people (provinces Java Timur and Bali and Nusa Tenggara Barat; BPS, 2025). Ash thicknesses of over 20 cm have the potential of severely limiting crop growth in agricultural areas and destroying rice paddies (Blong, 1984). Also, roof collapses were reported after the 1815 eruption with an ash load of 10 cm only (Blong, 1984), which would leave a large part of the 45 million people severely affected by the direct impacts of a Tambora-style eruption. Already in 1815 the eruption claimed at least 11,000 deaths by direct volcanic effects (ash fall and pyroclastic flows), and about 49,000 victims died due to consequent famine and epidemic diseases (Tanguy et al., 1998). The more accurate one can define the spatial extent of the ash distribution and volume estimates, the more precise the preparation of hazard and risk maps will become, leading to the ultimate goal of better forecasting the volcanic hazard for the affected population.

Introduction taken from (Kandlbauer, Sparks, 2014) and updated with the „Statistical Yearbook of Indonesia 2025“ (BPS, 2025).

2 Damage Classes

Here we present our estimation of different damage classes depending on the thickness of ashfall. The damages described are most likely to happen in given ranges of ashfall. Naturally, the severity of consequences increases proportionally to the ashfall thickness.

2.1 Ash fall below 1 cm

Little damage possible to livestock (possible irritation of skin & eyes and fluorosis may happen but unlikely), plants (acid damages, discolouration or abrasion during clean-up) and humans (possible irritation of skin & eyes). Nutrient rich ash fall may even have positive Impact on soil. Key quantities are soluble salt burden, particle size and abrasiveness.

2.2 Ash fall of 1 cm up to 10 cm

Damage to livestock is similar to less ash fall but generally more severe. Access to clean drinking water and food is likely impaired and nutrient supplements necessary. Ingestion of much ash likely leads to intestinal blockages and fluorosis is more likely. Plants and agriculture may suffer from the ashes weight and shading of the sun. Acidic seep likely damages fruit and foliage. The impact on agriculture potentially leads to food shortages for humans in surrounding areas. Key quantities are soluble salt burden and mechanical strength of the ash layer.

2.3 Ash fall of 10 cm up to 100 cm

Generally a stronger incapacitation of human society and appearance of more severe long term effects. Agriculture suffers severely from heavy loads of ash. Planted crops are lost and new ones cannot be sown due to the soil being buried below the thick layers of ash. Rehab of soil by human intervention is likely necessary. Therefore humans are bound to face food shortages. Trees are damaged by the load and shading from the sun. Key quantities are density, loading, particle size and thickness of the ash cover.

2.4 Ash fall Above 100 cm

Total burial of basically anything. Life in this region is hardly possible without MAJOR efforts to remove the ash cover and restoration of soil and environment.

3 Further Damage Assessments

Additional information on potential damages caused by a Tambora eruption today.

3.1 Economy Indonesia

The total export revenue of Indonesia in 2025 surmounts to nearly \$ 283B. Depending on the assessment the share of agricultural products is between 15 to 18 %.

Additionally, Indonesia with its more than 284 million people is the largest national economy in south-east Asia with a nominal GDP of near \$ 1.5T. Agriculture, forestation and the fishing industry contribute about 13.5 % to the GDP. This sector is the largest employment source for the people of Indonesia with about 28 % of the working population active in this field. Tourism corresponds to about 5 % of this GDP. The foreign exchange revenue for tourism to Indonesia total near \$ 19B. Bali accumulates near 50 % of the foreign exchange revenue. In the year 2025, approximately 15.4M people tourists visited Indonesia with approximately 46 % directly arriving in Bali. This led to \$ 9B foreign exchange revenue in Bali alone.

Nonetheless, Java corresponds to near 17 % of the GDP alone due to hosting the country's industry.

3.1.1 Consequences

An 1815 Tambora eruption today would not only kill potentially millions of today's Indonesians but also majorly weaken the strongest national economy of south-east Asia. Without exceptionally strong precautionary measures not only the direct impact of an eruption would cost many lives but even more so the longer-lasting effects of an eruption. Coverage of landmass with ash and other products of the volcano eruption would lead to an unprecedented famine. Furthermore, due to its position in certain markets this damage also influences the corresponding world markets badly with scarcity and major price hikes.

3.2 World Palm Oil Market

Indonesia is the world's leader in market revenue share for palm oil. Its market revenue share is roughly 31.1 %. This corresponds approximately to \$ 24B. The country is the largest producer and exporter of palm oil, supported by extensive plantations and an ideal tropical climate. Efficient, high-yield cultivation practices and advanced processing

infrastructure ensure a reliable supply for both domestic consumption and global markets. Strong international demand, combined with supportive government policies and strategic investments in sustainable practices and value-added derivatives, solidifies its leadership in the region.

3.2.1 Consequences

With Indonesia's prime position in palm oil breaking away the world market experiences major shortages and consequential monumental price hikes. With the industry using palm oil for one being foods and beverages ultra-processed foods, which we typically consume in societies like ours, the consumer will be confronted with a spike in price. Other industries facing issues are personal care & cosmetics, biofuel & energy and pharmaceuticals.

3.3 World Rubber (TSNR) Market

Indonesia is one of the world's leading rubber exporters. In 2024, Indonesia exported \$ 3.14B of rubber, making it the 2nd largest exporter of rubber in the world. This corresponds to about 20 % market revenue share. TSNR is „Technically Specified Natural Rubber“ and holds a ~ 41 % share of Indonesia's export market.

3.3.1 Consequences

With Indonesia's capacities in rubber exports mostly cut short due to an eruption the world market of rubber faces extreme scarcity. Thus, leading to price hikes not only for rubber itself but also for products from the industry (Automotive; Construction; Industrial; Healthcare; Consumer goods; Packaging) utilizing the rubber. Ultimately, the end consumer faces the price-shock.

3.4 World Coffee & Cocoa Market

Indonesia is one of the most diverse coffee origins in the world, producing both arabica and robusta coffee, and contributing 5 % of the world's coffee exports with over \$ 1.5B in export revenues.

Regarding Cocoa Indonesia is the third-largest producer in the world. The cocoa bean export market of Indonesia is valued at about \$ 130M. This is a small number compared to the aforementioned but its position as a supplier to the world market is of higher importance here.

Additionally, Indonesia is also the 5th largest importer of cocoa beans with spendings totalling about \$ 1.24B, driven by the demand for raw materials for the countries processing industries. In consequence processed goods like cocoa butter are exported again with export revenue reaching more than \$ 2.6B.

3.4.1 Consequences

With Indonesia as a middle sized hub for coffee and cocoa breaking partly away from the world market cocoa products and the two most produced coffees arabica and robusta face some shortage. Especially the volatile cocoa market will show a shock. Consumer prices will rise for affected products.

3.4.2 For Coffee Connoisseurs

Coffee supports 1.77 million people and contributes over \$ 1.5B to export revenues, yet remains secondary to commodities like palm oil and cereals in economic contribution and public R&D investment. While much of Indonesia's arabica is regarded as speciality quality, commanding premium prices and protected by geographical indications (e.g., Sumatra, Gayo), average yields for both arabica and robusta remain low compared to global averages. Coffee cultivation is dominated by smallholders farming less than one hectare and robusta makes up 80 % of national production. Major challenges include coffee leaf rust, declining access to improved genetic material, and fragmented extension services, all limiting smallholder farmers' ability to adopt better-performing varieties. Nearly 70 % of Indonesia's coffee area is in need of renovation or rehabilitation due to aging trees and outdated varieties.