Risk Profile – Indonesia 1815 Volcanic Eruption Reanalysis

1. **The 1815 Tambora volcanic eruption on the island of Sumbawa, possibly along with the eruption of Mount Paektu (Baitoushan) around 950 AD, remains to date the largest on Earth since the Lake Taupo eruption in about 180 AD. Tambora produced more than 50 km^3 of volcanic deposits and caused global effects but also major damage, disease and famine in Indonesia.**
2. **A reanalysis of the event on today's exposures shows that over $9 billion in damage just from tephra loading on residential roofs could be expected.**

Why are we looking at Indonesia

- Indonesia has had very few risk studies done for the entire country, with largely differing estimates of built capital available via existing natural hazards scenarios and PDNAs.
- Indonesia is the fourth most populated country in the World and contains 150 active volcanoes, frequently suffering from violent eruptions.

Why is this useful to the TTL?

The Indonesian volcanic eruption scenario is useful to inform the GFDRR and TTLs of the potential reoccurrence of such an event as well as giving some background as to the potential losses in the residential sector in Indonesia. It also provides lessons as to the collection within a PDNA in a future disaster as well as a new background to the event of 1815 in the proximal area.

Why are we doing the disaster scenario?

The "Disaster Scenarios" Indonesia volcano model can be applied to a probabilistic or deterministic modelling effort in the future. The building of this model allows for future events to be quickly analysed and losses to be determined more easily in the residential sector. By reviewing the loss differences today vs. at the time of the event, a full suite of scientific studies, knowledge and expertise has been used, which benefits the production of exposure, hazard and vulnerability models for volcanic eruptions anywhere around the world.

Background and historic losses

The 1815 Tambora volcanic eruption affected most of the country particularly west of Sumbawa with ashfall, although loading heavy enough to cause roof collapse was seen in western and central Sumbawa and to lesser extent in Lombok and even less in Bali. The population of Sumbawa, Lombok and Bali is presently just over 9 million while at the time it was less than 750,000. Deaths have been estimated at more than 88,000 people as per Stothers (1984) quoting Petroeschevsky (1949), but more reliable those of Tanguy et al (1998) at 60,000 (11,000 direct & 49,000 indirect) or Oppenheimer (2003) at 71,000. Contemporary estimates likely underestimate the indirect deaths. In reality, the death toll will never be known, and an estimate of 100,000 has thus been included here.

Disaster Type	Volcano	**Deaths**	ca. 100,000
Magnitude and Location	VEI7 (Tambora)	**Homeless**	200,000
Date	10/04/1815	**Houses existing at time**	ca. 2,250,000
Country Population at Time	17,000,000	**People in dam./destr. houses**	1,000,000
Capital Stock at Time (Res.) - $USDmn (1990	2,456	**Houses destroyed**	ca. 25,000
Capital Stock at Time (Non-Res.) - $USDmn	n/a	**Houses damaged**	ca. 125,000

Commented [A1]: Deaths >88,000 as per Sothers (1984) quoting Petroeschevsky (1949), but more reliable those of Tanguy et al (1998) at 60k (11k direct & 49k indirect) or **Oppenheimer (2003) at 71k.** Homeless looks reasonable. Houses existing at time = **2,250,000** (ppd=7.55) feels more reasonable. Houses destroyed = **25,000**; Houses damaged = **125,000** feels more reasonable. I think all ashfall damage was restrained in Sumbawa, Lombok, Bali and eastern extremity of Java (ash>20cm)

How did we remodel the scenario?

Historic aftermath descriptions and tephra fall isopach maps were examined in order to gain the best possible reanalysis of the scenario. We adopted the isopach map of Blong et al. (2017) as this builds on latest findings by Kandlbauer et al. (2013) informed by Stothers (1984) containing fifteen distinct isopach zones as opposed to six zones in previous maps for the event (Self et al., 1984). In addition, original descriptions of the tephra heights and accounts from the Java Government Gazette have been examined in order to choose the preferred isopachs.

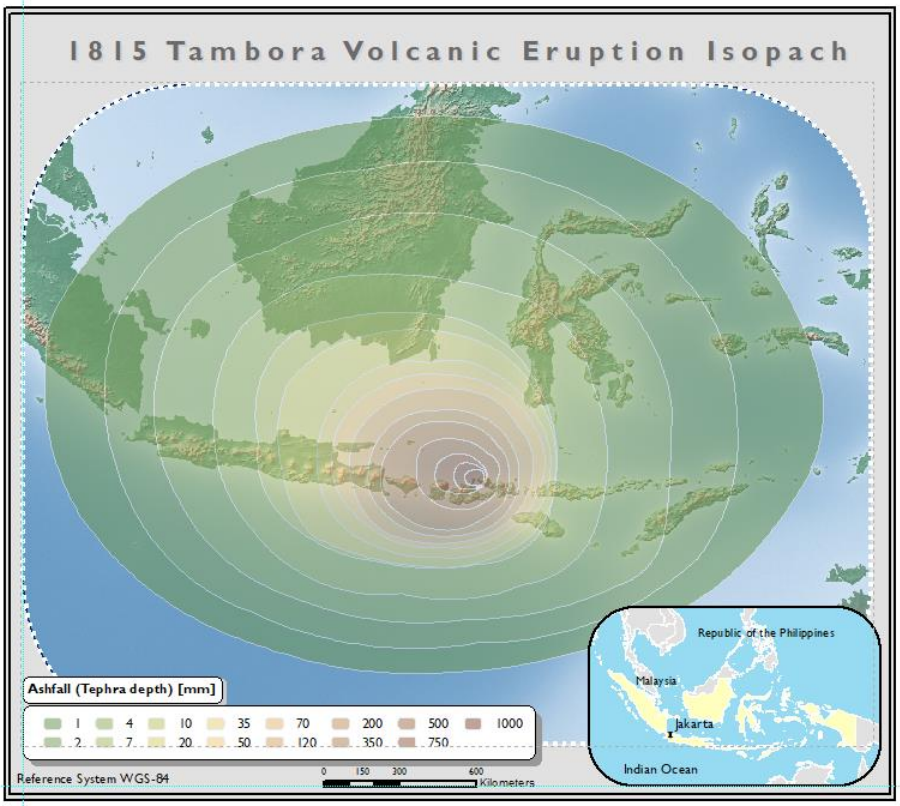

Figure 1: 1815 Tambora reanalysis isopach with tephra depth measured in mm

The assessment of the Indonesia residential buildings exposure was developed for the analysis of the great 1815 Mount Tambora volcanic eruption. The exposure is for the residential buildings only, calculated at province level (34 provinces) using the 2015 intercensal survey (SUPAS) and considered valid for prices and population at mid-2015. Each province is split into urban and rural part (except Jakarta that is 100% urban). Thus we have 67 homogeneous inventory regions to describe the structural inventory of Indonesian housing. In Indonesia the Housing Census and the SUPAS survey give information on dwelling size; outer wall, ceiling, roof cover and floor type. Emphasis was given to propose a vulnerability schema that is adequate for tephra loading vulnerability during large volcanic eruptions using both the roof and the wall types. The proposed Indonesian housing schema consists of eight distinct classes derived from combination of outer wall and roof cover types. Dwelling sizes for each vulnerability class in urban and rural areas of each province were also proposed. Poverty rates in Indonesia are quite high (41.7% of the population living on less than 3 USD per day in 2012). We have taken this into account when assigning costs of construction (UCC) to the vulnerability classes. The UCCs in the urban part range from 400 USD/m^2 to 12.5 USD/m^2 while in the rural parts they are about 20% lower. The mean urban UCC is 224 USD/m^2 while the mean rural UCC is 129 USD/m^2. The total residential exposure was estimated at 860939 million USD (Fig. 7) and was in line with the estimated Gross Capital Stock of Indonesia in 2015 and equivalent to the 2015 Indonesia GDP. In Fig. 8 the province-level per capita residential exposure is shown. It ranges between 735 and 6328 USD as it is influenced by the house typologies, dwelling sizes, unit cost of construction and the mean size of the households in each district.

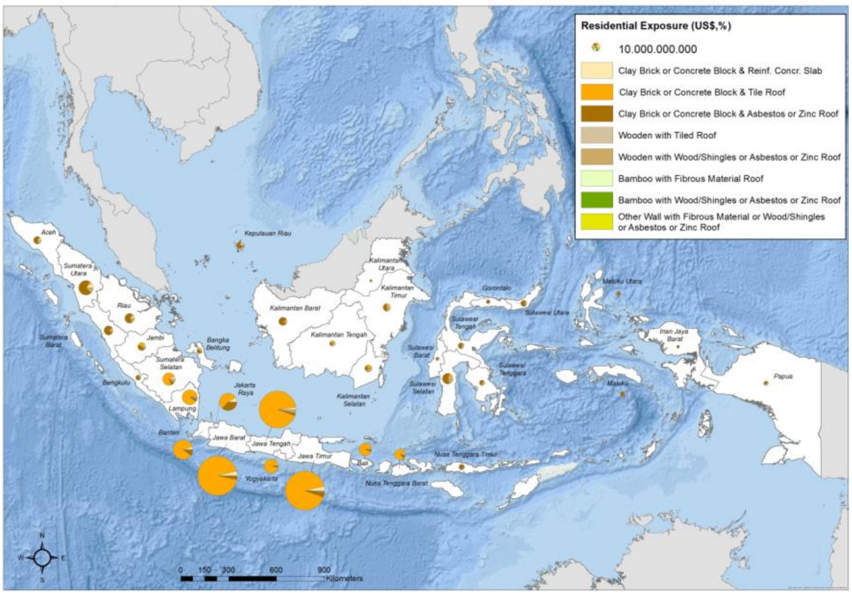

Figure 2: Residential exposure in Indonesia. The map shows the size of the exposure in USD (scaled pie charts) and its breakdown into eight vulnerability classes for each of the 34 provinces.

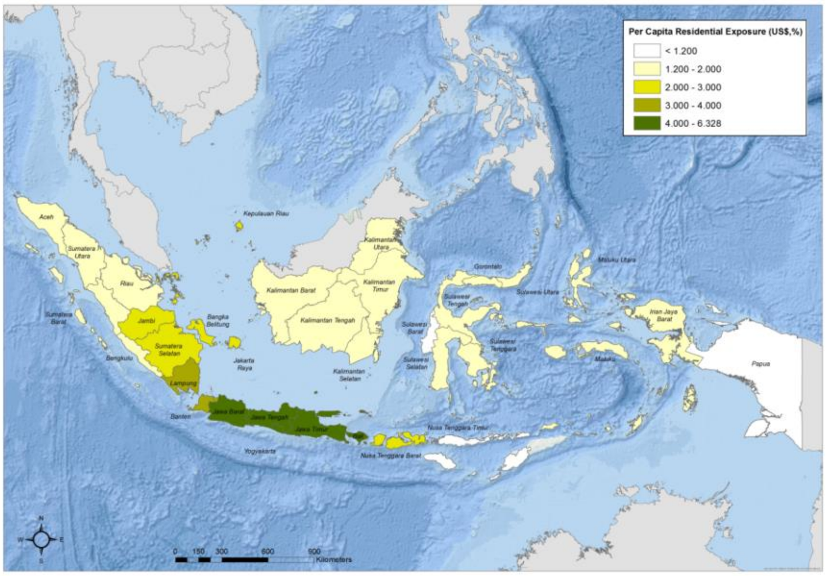

Figure 3: Per capita residential exposure in Indonesia (in USD) at province level.

It is important to note that Bali derives much of its $13 billion GDP via tourism, and this would also be significantly affected let alone the capital losses. West Lesser Sunda Islands are the 2nd poorest province by GDP per capita in Indonesia with it being around 2.5 times less than the Indonesian average.The vulnerability of the buildings has been informed by a large study of volcanic tephra loading functions globally. This included reviewing MIA-VITA; Blong (2017), Jenkins et al. (2014) through the GVM (2014), Milazzo (2013a, 2013b), Spence (2005), Blong (2003), Pomonis (1990), Pomonis et al. (1999) and others. A set of vulnerability curves for the different building typologies indicated above have been made.

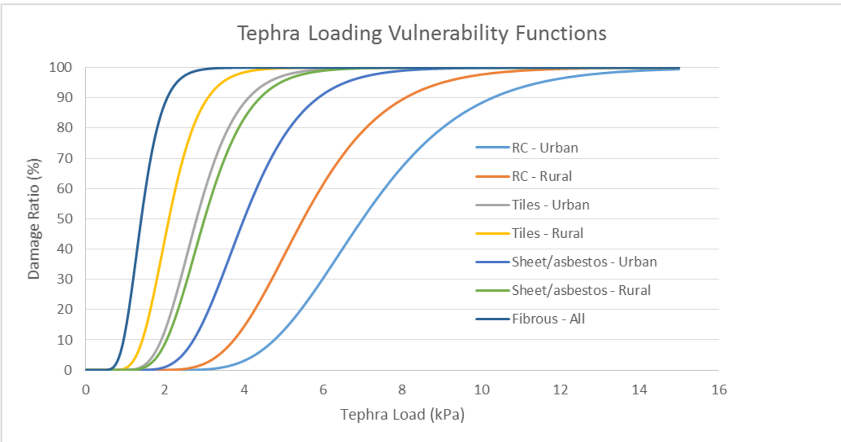

Figure 4: Vulnerability functions used for the analysis

What are the potential losses due to the reanalysis?

The residential damage is expected to be in the order of $9.7 billion from tephra loading alone. This does not occur other effects, and assumes also some degree of cleaning off roofs further afield.

	Historic	Modelled
Residential Damage (mn USD)	?	9708
Residential Stock (mn USD)	171.5	915846
Res. Stock exposed to 10mm or more		361431
Residential Loss Ratio		1.06%

The damage to buildings as a result of tephra loading is limited to within around 300km radius of the volcano. This can be seen in the following diagrams showing the absolute and relative losses on a geocell and administrative level 1 division and totals around $9.7 billion or around 1% of Indonesian residential capital stock.

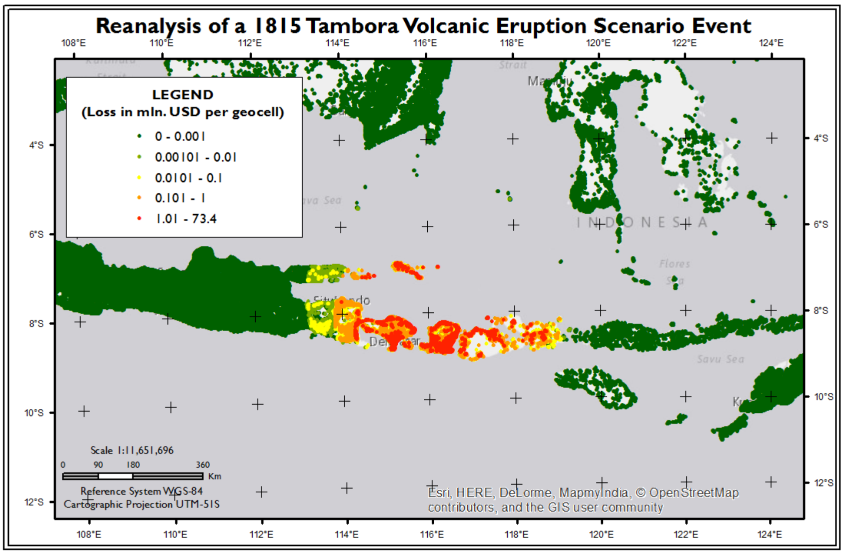

Figure 5: Absolute Losses in million USD per geocell showing the direct losses due to tephra loading.

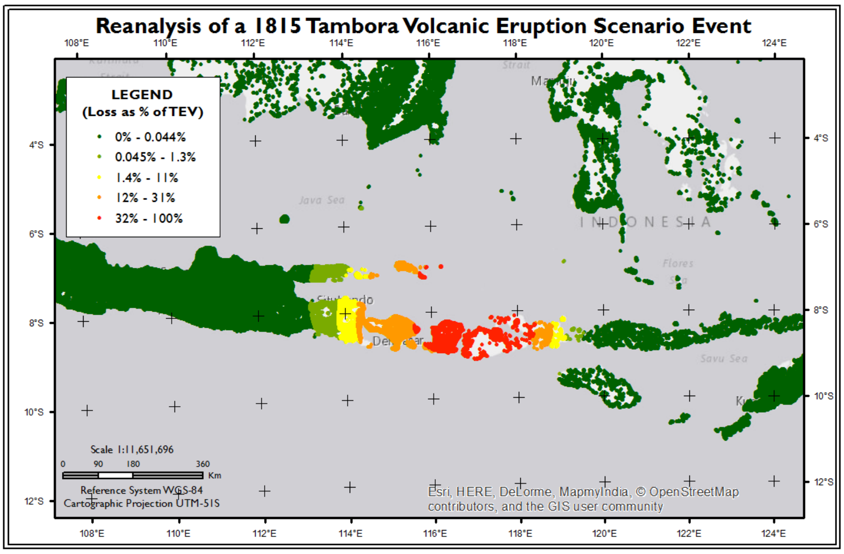

Figure 6: Relative losses per geocell as a percentage of total exposed value showing the direct losses due to tephra loading

Table: Top 3 Provinces in terms of relative losses and exposure

Province	Res. Loss (USDm)	Res. Exposure (USDm)	Loss Ratio
Nusa Tenggara Barat	6177.0	14421.2	42.83%
Bali	2557.1	20206.0	12.66%
Jawa Timur	974.4	197350.7	0.49%

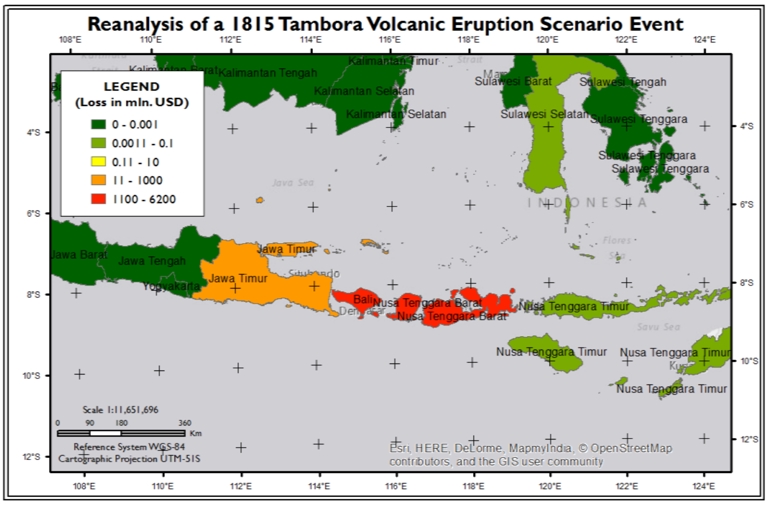

Figure 7: Absolute losses aggregated to a province level for the event in million USD. It can be seen that Jawa Timur, Bali and Nusa Tenggara Berat are worst affected.

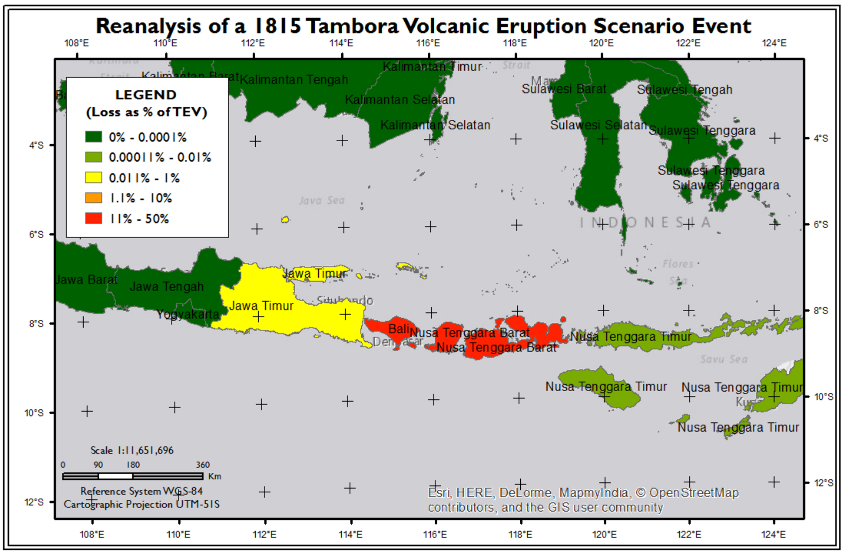

Figure 8: Absolute losses aggregated to a province level for the event in million USD. It can be seen that Jawa Timur, Bali and Nusa Tenggara Barat are worst affected.

What is the return period of such an event?

It is difficult to place this on an EP curve given the uncertainties in volcanic eruptions for each volcano in Indonesia. A VEI7-style eruption is expected globally on the order of 300-500 years. But for Indonesia, such an eruption would be in the order of 2000 years.

Why was it important to collate the data?

The 1815 volcanic eruption in Tambora is one of the most recent major eruptions to affect the globe, and is not out of the realms of being possible. Indonesia has many volcanic eruptions, one of the most recent being the Merapi Volcanic eruption, which also caused tephra loading failures. By characterising the possible vulnerability and exposure of the Indonesian stock, smaller eruption losses than a Tambora style event can also be calculated.

References to be added after review or online in archive rather than in the 4 pagers?

Kandlbauer J, Carey SN, Sparks RSJ. The 1815 Tambora ash fall: implications for transport and deposition of distal ash on land and in the deep sea. Bull Volcanol. 2013;75(4):1–11.

Self S, Rampino MR, Newton MS, Wolff JA. Volcanological study of the great Tambora eruption of 1815. Geology. 1984;12:659–63