Supplementary Material

# S1a Table of Repeat or recurring evacuations in the period 1986-2015

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Eruption  Year | Warning trigger(a) | No. (peakb) | Activity  (VEImaxc) | Duration | Destruction(d) | Relocation | Compliance(e) | Pull | | | Push | | | Notes |
|  | **Kelut, Indonesia (DAC Classification =LMI, World Risk Index = HIGH)(f)** | | | | | | | | | | | | | |
| *1990(g)* | Monitor (seismic) | 60,000(1) | XP(4) | ~ 4 weeks | 500(1) |  | n/r |  |  | |  | |  |  |
|  |  | |  | |  |
| 2007 | Monitor  (seismic) | 38,170(2) | Dome(2) | 3 weeks | - | - | Low, 50% not at all, 75% early return (2) |  |  | |  | |  | Insanitary conditions and looting interpreted as rumoured(2) |
|  |  | |  | |  |
| 2014 | Monitor (seismic)(3)/surface(4) | 166,000(3) | XP(4) | 8 days | 11,093(4) | - | Good during emergency(3)but, farmers stay put & daytime return(4) |  | |  |  | |  | Rapid evacuation but strong pull to return from resource, tourism(5)by day 4 evacuees reduced by 17,000(4) |
|  | |  |  | |  |
|  | **Merapi, Indonesia (LMI, HIGH)** | | | | | | | | | | | | | |
| 1994 | Surface | 6,026(6) | Dome/pf(x) | ~5-6 weeks |  | 2700(7) | Low, 50% return within 1 month(8) |  | |  |  | | | Largely self-evacuation(8), continuation enforced(7,8) |
|  | |  |
| 2006 | Monitor/surfaces | 26,870(9) | Dome/pf | 1 month |  |  | Variable, 20-86% daily return after 1 week(7,10) |  | |  |  | | | Strong ownership of risk culture(7,10), complicated by regional earthquake |
|  | |  |
| *2010* | Monitor/ surface | 399,403(11) | XP/pf(4) | Majority 11 days;some 5 weeks | (13) | 2200(13) | High initial conformity (81%) but 50% return at some point(12) |  | |  |  |  | | Boredom and family separation(14) as well as protecting livelihoods(12,14) |
|  | |  |  |  | |
|  | **Sinabung, Indonesia (LMI, High)** | | | | | | | | | | | | | |
| 2010 | Surface | 26,137(15) | XP(2) | 1 month |  |  | Varied with activity(15) | uk | | |  |  | | Poor preparedness affected coping(3) |
|  |  | |
|  | **Mayon, Philippines (LMI, VERY HIGH)** | | | | | | | | | | | | | |
| *1993* | None | 57,000(16) | *XP*(2) | 2-4 months | 500(18) | 500 (17) | Enforced compliance |  | |  |  |  | | Daytime entry for farming permitted(17) |
|  | |  |  | |
| 2000 | Surface | 29440-68596 | XP(3) | ~6 weeks |  | 1480 |  |  | |  |  |  | | Daytime entry for farming permitted(17) |
|  | |  |  | |
| 2006 | Surface | 95926(17) | XP(1)/lahars | 6 weeks |  | 1160(17) |  |  | |  |  |  | | 3000 families still in centres 1 year later, system overwhelmed by volcano+ typhoon(17). Daytime entry for farming permitted(17) |
|  | |  |  |  | |
| 2009 | Surface | 47766(17) | XP |  |  | 2004 |  |  | |  |  |  | | Daytime entry for farming permitted(17) |
|  | |  |  |  | |
| 2014 | Surface/gas | 51625(18) | Dome(0) | 6weeks (70%)-3 months (30%) |  |  | Initially daily return to secure water etc(18) |  | |  |  |  | | Mandatory evacuation orders used, strategic change to preserve resource and pre-empt unofficial return |
|  | |  |  |  | |
|  | **Karthala, Comoros (LDC,HIGH)** | | | | | | | | | | | | | |
| 2005 | Surface | 10000 | XP(3)/lahars | 3days-1 week | (30) |  | Voluntary evacuation(19) |  | | |  |  | | No shelter, water and food security. Water supply issues across island. Lahars destroyed buildings(20) |
| 2006 | Surface | 2000 | Lava lake(0) | 2 weeks |  |  | Voluntary evacuation |  | | |  |  | | Concerns triggered by 2005 activity, felt EQ |
|  |  | |
| 2007 | Surface | - | Lava |  | 1 |  | Voluntary evacuation |  | | |  |  | | Concerns from felt EQ |
|  |  | |
|  | **Fogo, Cabo Verde (LMI, HIGH)** | | | | | | | | | | | | | |
| 1995 | Surface | 1498(21) | Lava/XP(2) | ~6 months | (village) |  | Some returning, 12.5% waited ‘until last minute’ (paroxysm)22 |  | |  |  |  | | Re-settlement unsuccessful(22) |
|  | |  |  |  | |
| 2014-5 | Surface | 1076(21) | Lava/XP(2) | ~ 6 months | 260 |  | Daily return/rebuilding |  | |  |  |  | | Some re-occupation immediately after eruption re-building within one year (22,23) |
|  | |  |  |  | |
|  | **Cerro Negro, Nicaragua (LMI, VERY HIGH)** | | | | | | | | | | | | | |
| 1992 | Surface | 9282 | XP(3) | 1 week |  | 450 | 75% compliance |  | |  |  |  | |  |
|  | |  |  |  | |
| 1995 | Surface | 6000 | XP(2)/lava | 2 weeks |  |  | 50% compliance |  | |  |  |  | |  |
|  | |  |  |  | |
| 1999 | Surface | 6,195 | XP(2) | nr |  |  | nr |  | |  |  |  | |  |
|  | |  |  |  | |
|  | **Popocatepetl, Mexico (UMI,MEDIUM)** | | | | | | | | | | | | | |
| 1994 | Surface | 25,000(24) | XP | ~ 1week |  |  | e.g. 38% in 1 town never evacuate(25) |  | |  |  |  | | Perceptions of shelter conditions important as well as livelihoods. |
|  | |  |  |  | |
| 1999 | monitored | 50,000 | XP | 4 days |  |  | e.g. 38%-50% in 1 town never evacuate(25) |  | |  |  |  | |  |
|  | |  |  |  | |

1. Warning trigger relates to the dominant signal that initiated decision to call an evacuation. Surface indicates evacuation did not occur until activity was observable at surface. Monitor, evacuation caused by a change in some type of subsurface monitored data.
2. No of evacuees. Numbers are from Smithsonian GVP unless indicated otherwise
3. Dominant activity. Where a sequence was recorded they are named sequentially. VEImax refers to the maxmimum explosivity recorded for that eruptive episode by SI GVP. XP: explosive activity; Dome: dome building: pf: activity generating pyroclastic density currents other than explosions; lahars: significant lahar activity.
4. Filled box indicates there was permanent infrastructure destruction, where number is quoted (as buildings or homes) this is also shown . Similarly relocation indicates the number of households relocation in geographically distinct setting post eruption.
5. Filled box square are based on our push-pull characters as follows Top Left: crops and livestock, Top Right: place, Bottom left: tourism or other resource (mining) Bottom right: protecting assets. Pull Top left: disease/crowding Top Right: mental health and boredom Bottom left: hostilities Bottom right: lack of food, water.
6. World Risk Index refers to the rank assigned risk as a function of exposure to natural hazrds, susceptibiilty, coping capacity and adaptive capacity (Welle et al., 2015). DAC refers to the classification given by the OECD to the country based on Gross National Income per capita.: LDC is Least Developed Countries, LMI Lower Middle Income Countries and Territories, UMI Upper Middle Income Countries and Territories and H High Income Countries and Territories
7. Italicised eruptions also feature in the fatalities in Table 2.

|  |
| --- |
|  |
|  |

# S1b One off or continuous recurring evacuations in the period 1986-2015(a)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Volcano/ Year(s)** | **Activity style** | **Evacuation patterns** | **No. and trigger (peak)** | **Compliance** | **Pull** | | **Push** | | **Notes** |
| **Sinabung, Indonesia, ( DAC Classification = LMI, World Risk Index = HIGH)** | | | | | | | | | |
| *2013-2015* | XP | Staged, long term then relocation | 22000 (3) (surface) | Initially good, becoming less good with daily drift after few weeks |  |  |  |  | Early self evacuation, issues with long term use of shelters meant for other purpose encourages driftback (18). Issues with finance release and legislative ‘disaster’ affected long term solutions (18) |
|  |  |  |  |
| **Pinatubo, Philippines (LMI, HIGH)** | | | | | | | | | |
| *1991-1993* | Dome/XP | Staged evacuations until the eruption peak, from circular zones centred on the volcano.  Permanent destruction of many settlements. Long term evacuation and resettlement post-eruption, due to lahars. | > 60.000 by June 15, 1991. (surface) | In early stages of activity, 80% of a sample of those ordered to evacuate took precautionary measures; 46% evacuated immediately26  Later on, pattern of living in new settlements but working lands on volcano flanks |  |  |  |  | Indigenous Aeta were most affected pre-eruption, and permanently excluded from settlements within 10 km of the volcano27. Following eruption, there were considerable displacements for over a decade, due to the long-term hazards from lahars(28). |
|  |  |  |  |
| **Unzen, Japan,(HIGH, VERY HIGH)** | | | | | | | | | |
| *1991-1995* | Dome/XP | Staged evacuations, following first debris flow/lahar (May 15), first pyroclastic flow (May 24) and continued escalation in activity. | Ca. 11,000 by early June 1991(29). Surface. |  |  |  |  |  | In late May 1991, there were multiple returns to the evacuated zone both by farmers, but also by journalists and mass media, eager to capture images of the growing dome. The fatal eruption of June 3rd, 1991, led to multiple deaths inside the evacuated zone(30). |
|  |  |  |  |
| **Manam, Papua New Guinea (LMI, VERY HIGH)** | | | | | | | | | |
| *2004-2015(b)* | XP | ‘Permanent and total’ | 9000(31) (surface) | Initially good, but now 2,500 are back on island with daily movement(31) |  |  |  |  | Many evacuees spent more than a decade in ‘care centres’ on mainland, creating profound issues with wellbeing, livelihoods and local hostility (31,32). Some now relocated. Better use of local knowledge would have improved situation (31,32,33) |
|  |  |  |  |
| **Rabaul, Papua New Guinea (LMI, VERY HIGH)** | | | | | | | | | |
| 1994-95*(c)* | XP(4) | 4-6 months, destruction of villages | 70000 (felt/monitored seismicity34,35) | Some self evacuation, 15,000 homes lost(35) |  |  |  |  | Geographically distinct responses to eruption, due to difference in felt EQ(35). Militarised control of destroyed zone (looting(36).) Rebuilding on top of some destroyed areas, others re-settled. |
|  |  |  |  |
| **Mt Cameroon, Cameroon (LDC, VERY HIGH)** | | | | | | | | | |
| 1999 | Lava/XP(2) | 6 weeks | ~600-1000(37) (surface activity) | 86% compliance in most affected village(37) |  |  |  |  | Younger males tended to return in daytime, and not evacuate (farming). Theft of livestock reported but not verified. Poor conditions in camp. (38) |
|  |  |  |  |
| **Nyiragongo, Democratic Republic of the Congo (LDC, not determined)** | | | | | | | | | |
| *2002* | Lava | Few days | 500,000 (surface activity39) | Village self-evacuation on flanks and in Goma. Rapid re-occupation but many homes destroyed |  |  |  |  | Crisis involved cross-border evacuation, prompting some re-occupation within two days (before lava cooled(40). Issues of food supply for 15,000 remaining in camps after 4-5 days. |
|  |  |  |  |
| **Tungurahua, Ecuador (UMI, HIGH)** | | | | | | | | | |
| 1999-2014 | XP | Enforced total (3 months) then periodic short evacuation (days), staged to activity. | 26,000 (surface activity42) | Variable through eruption, improved by ‘vigias’(41) |  |  |  |  | Initially forced evacuation prompted conflict and re-occupation. Some re-settlement sites built, variably occupied. Collaborative monitoring network(42,43) |
|  |  |  |  |
| **SHV, Montserrat (UMI, not determined)** | | | | | | | | | |
| 1995-2010 | Dome/XP | Staged | 7,500 (surface) | Poor shelter conditions drove return in 1997(44) |  |  |  |  | Significant migration in response to eruption (>50%) population. Some (most vulnerable, (45)) remained in temporary shelters for years. Poor conditions in shelters, loss of infrastructure significant in driving zoning decision. |
|  |  |  |  |
| **Chaiten, Chile (HIGH, VERY HIGH)** | | | | | | | | | |
| 2008 | XP(4) | Total, return spatially determined relative to river (lahars) | 8119 | Drift back to ‘permanent exclusion zone’ by some(46) |  |  |  |  | Re-settlement site abandoned. Legislative issues around long term solutions. Some early return to retrieve belongings were unofficial |
|  |  |  |
| **Eyjafjallajökull,Iceland (HIGH,VERY HIGH)** | | | | | | | | | |
| 2010 | Lava/XP(3) | Initial 24 hours then 4-5 days | 700 | Large compliance but some daily return and non-evac(47) |  |  |  |  | First evacuation, compliance affected by warning time. Daily return driven by livestock concerns (48). |
|  |  |  |  |

1. Main notes and annotations as for Table S1a
2. There were discrete events in our timeframe in 1992 and 1996, In 1996 around 2,500 from one side of the island were temporarily but this established land and access ties utilised in 2004 (Connel and Lutkehaus, 2015).
3. Further eruptions and evacuations in 2006 and 2014 but these have not been documented in peer-reviewed literature as yet.

## SUPPLEMENTARY REFERENCES

## 1. Global Volcanism Program, Report on Kelut (Indonesia), in Bulletin of the Global Volcanism Program. 1992.

## 2. De Bélizal, É., et al., The 2007 eruption of Kelut volcano (East Java, Indonesia): Phenomenology, crisis management and social response. Geomorphology, 2012. 136(1): p. 165-175.

## 3. Andreastuti, S., et al., Character of community response to volcanic crises at Sinabung and Kelud volcanoes. Journal of Volcanology and Geothermal Research, 2017. In press.

## 4. Blake, D.M., et al., The 2014 eruption of Kelud volcano, Indonesia : impacts on infrastructure, utilities, agriculture and health. 2015.

## 5. Wardhani, P.I., J. Sartohadi, and S. Sunarto, Dynamic Land Resources Management at the Mount Kelud, Indonesia. 2017, 2017. 31(1): p. 13.

## 6. Mei, E.T.W. and F. Lavigne, Influence of the institutional and socio-economic context for responding to disasters: case study of the 1994 and 2006 eruptions of the Merapi Volcano, Indonesia. 2012. 361(1): p. 171-186.

## 7. Dove, M.R. and B. Hudayana, The view from the volcano: an appreciation of the work of Piers Blaikie. Geoforum, 2008. 39(2): p. 736-746.

## 8. Global Volcanism Network, Report on Merapi (Indonesia), B.o.t.G.V. Network, Editor. 2006.

## 9. Lavigne, F., et al., People's behaviour in the face of volcanic hazards: Perspectives from Javanese communities, Indonesia. Journal of Volcanology and Geothermal Research, 2008. 172(3): p. 273-287.

## 10. Wilson, T.K., G.; Stewart, C.; and Cole, J., Impacts of the 2006 eruption of Merapi volcano, Indonesia on agriculture and infrastructure in GNS Science Report. 2007. p. 69.

## 11. Mei, E.T.W., et al., Lessons learned from the 2010 evacuations at Merapi volcano. Journal of Volcanology and Geothermal Research, 2013. 261: p. 348-365.

## 12. Jenkins, S., et al., The Merapi 2010 eruption: An interdisciplinary impact assessment methodology for studying pyroclastic density current dynamics. Journal of Volcanology and Geothermal Research, 2013. 261: p. 316-329.

## 13. Mei, E.T.W., et al., Resettlement Following the 2010 Merapi Volcano Eruption. Procedia - Social and Behavioral Sciences, 2016. 227: p. 361-369.

## 14. Christia, M., Experiences of people affected Merapi Eruption in 2010: a qualitative study conducted in Ktinjing village, Indonesia. 2012, University of Oslo. p. 99.

## 15. Reliefweb, Indonesia: Mt Sinabung Volcano - Aug 2010, Reliefweb, Editor. 2010: https://reliefweb.int/disaster/vo-2010-000170-idn. p. https://reliefweb.int/disaster/vo-2010-000170-idn.

## 16. Global Volcanism Network, Report on Mayon (Phillipines), in Bulletin of the Global Volcanism Network. 1993: Smithsonian Institution.

## 17. Usamah, M. and K. Haynes, An examination of the resettlement program at Mayon Volcano: what can we learn for sustainable volcanic risk reduction? Bulletin of Volcanology, 2012. 74(4): p. 839-859.

## 18. Enia, J., Rules versus discretion: Comparing disaster declaration institutions in the Philippines and Indonesia. International Journal of Disaster Risk Reduction, 2016. 16: p. 158-166.

## 19. United Nations World Food Program, Comoros: comprehensive food security and vulnerability analysis, V.A.a.M. Branch, Editor. 2006, United Nations World Food Program. p. 62.

## 20. Morin, J. and F. Lavigne, Institutional and Social Responses to Hazards related to Karthala Volcano, Comoros. Part 2 : Deep-seated root causes of Comorian vulnerabilities. Vol. 3. 2009. 54-71.

## 21. Savoia, E., et al., Engaging the Diaspora in Response to the 2014 Fogo Volcano Eruption in Cape Verde. Disaster Medicine and Public Health Preparedness, 2016. 10(2): p. 185-186.

## 22. Jenkins, S.F., et al., Damage from lava flows: insights from the 2014–2015 eruption of Fogo, Cape Verde. Journal of Applied Volcanology, 2017. 6(1): p. 6.

## 23. de Castro, F.V. and B. Martins, The 2014 volcanic eruption in Fogo and the reterritorialization process: from risk to geographic resilience. Singapore Journal of Tropical Geography, 2018. 39(1): p. 149-168.

## 24. De la Cruz-Reyna, S. and R.I. Tilling, Scientific and public responses to the ongoing volcanic crisis at Popocatépetl Volcano, Mexico: Importance of an effective hazards-warning system. Journal of Volcanology and Geothermal Research, 2008. 170(1): p. 121-134.

## 25. Tobin, G.A., Whiteford, L., Jones,E.C. and Murphy, A.D., Chronic hazard: weighing risk against against the effects of emergency evacuation from Popocatepetl volcano, Mexico, in Evolving Approaches to Understanding Natural Hazards, G.A.a.M. Tobin, B.E., Editor. 2015, Cambridge Scholars: Newcastle-Upon-Tyne. p. 515.

## 26. Tayag, J.C. and R.S. Punongbayan, Volcanic Disaster Mitigation in the Philippines - Experience from Mt- Pinatubo. Disasters, 1994. 18(1): p. 1-15.

## 27. Gaillard, J.C. and V. Le Masson, Traditional societies' response to volcanic hazards in the Philippines - Implications for community-based disaster recovery. Mountain Research and Development, 2007. 27(4): p. 313-317.

## 28. Leone, F. and J.-C. Gaillard, Analysis of the institutional and social responses to the eruption and the lahars of Mount Pinatubo volcano from 1991 to 1998 (Central Luzon, Philippines). GeoJournal, 1999. 49(2): p. 223-238.

## 29. Unzen Fugendake Eruption Disaster Study Group, Unzen Fugendake Eruption 1990-1995 2007.

## 30. Nakada, S., H. Shimizu, and K. Ohta, Overview of the 1990–1995 eruption at Unzen Volcano. Journal of Volcanology and Geothermal Research, 1999. 89(1): p. 1-22.

## 31. Connell, J. and N. Lutkehaus, Escaping Zaria's fire? The volcano resettlement problem of Manam Island, Papua New Guinea. 2017. 58(1): p. 14-26.

## 32. Connell, J. and N. Lutkehaus, Another Manam? The forced migration of the population of Manam Island, Papua New Guinea, due to volcanic eruptions 2004-2005. 2016, International Organisation for Migration. p. 88.

## 33. Mercer, J. and I. Kelman, Living alongside a volcano in Baliau, Papua New Guinea. 2010. 19(4): p. 412-422.

## 34. Blong, R., The Rabaul Eruption, 1994. Australian Geographer, 1994. 25(2): p. 186-190.

## 35. McKee, C., I. Itikarai, and H. Davies, Instrumental Volcano Surveillance and Community Awareness in the Lead-Up to the 1994 Eruptions at Rabaul, Papua New Guinea, in Observing the Volcano World: Volcano Crisis Communication, C.J. Fearnley, et al., Editors. 2018, Springer International Publishing: Cham. p. 205-233.

## 36. Johnson, R.W., Fire mountains of the islands : a history of volcanic eruptions and disaster management in Papua New Guinea and the Solomon Islands. 2013, Canberra, ACT, Australia: ANU E Press. xxiv, 391 pages.

## 37. Wantim, M.N., et al., Forensic assessment of the 1999 Mount Cameroon eruption, West-Central Africa. Journal of Volcanology and Geothermal Research, 2018. 358: p. 13-30.

## 38. Njome, M.S., et al., Volcanic risk perception in rural communities along the slopes of mount Cameroon, West-Central Africa. Journal of African Earth Sciences, 2010. 58(4): p. 608-622.

## 39. Komorowski, J.C. and K. Karume, Nyiragongo (Democratic Republic of Congo), January 2002: a major eruption in the midst of a complex humanitarian emergency, in Global Volcanic Hazards and Risk, C. Vye-Brown, et al., Editors. 2015, Cambridge University Press: Cambridge. p. 273-280.

## 40. Baxter, P.J., A. Ancia, and W.H. Organization, Human health and vulnerability in the Nyiragongo volcano crisis, Democratic Republic of Congo, 2002: final report to the World Health Organisation. 2002, World Health Organisation: Geneva.

## 41. Tobin, G.A. and L.M. Whiteford, Community resilience and volcano hazard: the eruption of Tungurahua and evacuation of the faldas in Ecuador. Disasters, 2002. 26(1): p. 28-48.

## 42. Mothes, P.A., et al., The scientific–community interface over the fifteen-year eruptive episode of Tungurahua Volcano, Ecuador. Journal of Applied Volcanology, 2015. 4(1): p. 9.

## 43. Armijos, M.T., et al., Adapting to changes in volcanic behaviour: Formal and informal interactions for enhanced risk management at Tungurahua Volcano, Ecuador. Global Environmental Change, 2017. 45: p. 217-226.

## 44. Loughlin, S.C., et al., Eyewitness accounts of the 25 June 1997 pyroclastic flows and surges at Soufrière Hills Volcano, Montserrat, and implications for disaster mitigation. Geological Society, London, Memoirs, 2002. 21(1): p. 211.

## 45. Hicks, A. and R. Few, Trajectories of social vulnerability during the Soufrière Hills volcanic crisis. Journal of Applied Volcanology, 2015. 4(1): p. 10.

## 46. Sandoval, V., C. Gonzalez-Muzzio, and C. Albornoz, Resilience and Environmental Justice: Potential Linkages. Procedia Economics and Finance, 2014. 18: p. 416-424.

## 47. Bird, D.K. and G. Gísladóttir, Residents' attitudes and behaviour before and after the 2010 Eyjafjallajökull eruptions—a case study from southern Iceland. Bulletin of Volcanology, 2012. 74(6): p. 1263-1279.

## 48. Bird, D.K., et al., Crisis Coordination and Communication During the 2010 Eyjafjallajökull Eruption, in Observing the Volcano World: Volcano Crisis Communication, C.J. Fearnley, et al., Editors. 2018, Springer International Publishing: Cham. p. 271-288.

****