Lahar Risk Assessment: the Case Study of Vulcano Island, Italy

Alessandro Gattuso (✉ alessandro.gattuso@ingv.it)

INGV: Istituto Nazionale di Geofisica e Vulcanologia <https://orcid.org/0000-0003-1815-0421>

Costanza Bonadonna

University of Geneva Faculty of Science: Universite de Geneve Faculte des Sciences

Corine Frischknecht

University of Geneva Institute of Environmental Sciences: Universite de Geneve Institut des Sciences de l'Environnement

Sabatino Cuomo

University of Salerno: Universita degli Studi di Salerno

Valerie Baumann

University of Lausanne: Universite de Lausanne

Marco Pistolesi

University of Pisa: Universita degli Studi di Pisa

Sebastian Biass

earth observatory of singapore

Ramon Arrowsmith

Arizona State University - Tempe Campus: Arizona State University

Mariagiovanna Moscariello

University of Salerno: Universita degli Studi di Salerno

Mauro Rosi

University of Pisa: Universita degli Studi di Pisa

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Abstract

Lahars are rapid flows composed of water and volcaniclastic sediments, which have the potential to impact residential buildings and critical infrastructure as well as to disrupt critical services, especially in absence of a hazard-based land-use planning. Their destructive power is mostly associated with their velocity (related to flow rheology and surrounding topography) and to their ability to bury buildings and structures (related to the deposit thickness). The distance reached by lahars depends on their volume, on sediments/water ratio, as well as on the overall characteristics of the path where they propagate. Here we present a novel strategy for the assessment of risk associated with lahar inundation related both to flow velocity and deposit thickness using Vulcano island (Italy) as a case study. First, a range of hazard scenarios has been identified that are related to the mobilization by intense rain events of tephra fallout deposited on the slopes of the La Fossa cone by a future Vulcanian eruption. Second, a numerical model has been used to identify the potential lahar impact areas on the northern sector of Vulcano, where both residential and touristic facilities are present. In this specific case we have used the Smoothed Particle Hydrodynamic (SPH) model that provides information on both flow velocity and deposit thickness. Finally, exposure and vulnerability surveys were carried out in order to compile risk maps for both lahar-flow velocity and final lahar-deposit thickness. Our analyses show the importance of carrying out accurate and detailed risk assessments exploring a variety of initial conditions in order to best quantify the potential damage and identify suitable mitigation strategies.

Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the latest manuscript can be downloaded and [accessed as a PDF](#).

Figures

Figure 1

Vulcano Island map showing critical facilities and infrastructures. The largest settlements are indicated. The inset shows the geographic location. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

Mitigation measures for floods, debris flows and lahars at Vulcano porto area. A-B) Drainage grids at the base of the Pietre Cotte Lava Flow; C) Drainage Tunnels at Levante Harbour. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 3

Tephra-fallout deposit on the northern sector of the La Fossa cone that could be remobilised by a syn-eruptive lahar as simulated with TRIGRS by Baumann et al. (2019) (i.e., equivalent to 18 months of Vulcanian eruption; see main text for details). Deposit thickness is indicated with different colours. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 4

Lahar hazard maps based on flow velocity classes (according to the strategy of Wilson et al. (2014 modified); Table 4) for the V3 scenario at 20 sec (a), 25 sec (b), 30 sec (c) and 35 sec (d) of the SPH simulation. The dashed lines show the maximum runout for V3 scenario; the main critical infrastructures are also showed (i.e. telecommunication and electrical power plant). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 5

Lahar hazard maps based on flow velocity classes (according to the strategy of Wilson et al. (2014 modified); Table 4) for the V3 scenario at 20 sec (a), 25 sec (b), 30 sec (c) and 35 sec (d) of the SPH simulation. The dashed lines show the maximum runout for V3 scenario; the main critical infrastructures are also showed (i.e. telecommunication and electrical power plant). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 6

Lahar hazard maps based on flow velocity classes (according to the strategy of Wilson et al. (2014 modified); Table 4) for the V6 Scenario at 15 sec (a), 20 sec (b), 25 sec (c) and 30 sec (d) of the SPH simulation. The dashed lines show the maximum runout for V6 scenario; the main critical infrastructures are also showed (i.e. telecommunication and electrical power plant). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 7

Final lahar deposit thickness at the end of simulations (60 seconds) for a) V3 scenario and b) V6 Scenario. The dashed lines show the maximum runout for V3 and V6 scenarios; the main critical infrastructures are also shown (i.e. telecommunication and electrical power plant). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country,

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Figure 8

Exposure map showing both buildings and infrastructures that are located in the lahar inundation areas for the three selected scenarios. The vulnerability of buildings was assessed either in situ (light violet) or remotely (with Google Earth; dark violet). The dashed lines show the maximum runouts for V1, V3 and V6 scenarios. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 9

Vulnerability index associated with the buildings located in the lahar inundation area for the V3 and V6 scenarios Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 10

Lahar risk map for the Vulcano Porto area based on impact velocities (m/s) for the V3 (a) and V6 (b) scenarios. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 11

Percentage of buildings buried by the final lahar deposit for the V3 and V6 Scenario (i.e. building height / lahar deposit thickness $\times$ 100). Low-risk class: portion of affected buildings $< 25\%$; medium-risk class: portion of affected buildings $25\text{--}50\%$; high-risk class: portion of affected buildings $> 50\%$. The thickness of deposit is also indicated with colour points. The dashed lines show the maximum runout for V3 and V6 scenarios; the main critical infrastructures in this area are also showed (i.e. telecommunication and

electrical power plant). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.