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Assessment of thephra-fall effects and physical vulnerability of roofs in the city of Arequipa, Perú

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Tephra fallout is considered the most common hazard from volcanic activity. Tephra fallout has rarely caused human life loss, but the high mobility of small particles is responsible for health problems and has economic impacts in cities around active volcanoes. The major impacts of tephra fallout include building roof collapse, damage on aircraft, disruption of lifelines, and environmental effects.

Arequipa, second economic center in Peru, is a city located 17 kilometers SW of El Misti volcano vent. Amongst ca. 1,000,000 people living in Arequipa at least 200,000 live in areas likely to be affected by PDCs, lahars and tephra fallout. Holocene and historical Misti's activity has encompassed a range of eruptions, including Vulcanian and Plinian events. Two of the principal eruptions, i.e. the 1440-1470 CE Vulcanian event and the ca. 2070 yr BP Plinian eruption have been taken as working references for probable scenarios. Ashfall deposits at least 10 cm thick was emplaced by the XVth Century event while 2070 yr BP pumice-fall deposits exceeding 50 cm have been observed across the city area. Tephra fallout towards the city depends principally on the eruptive style, column height, and on patterns of wind directions and velocities in south Peru. Probability hazard maps of tephra fallout were developed in earlier studies based on geological and historical data using elicitation and Bayesian Event Tree methods. Derived maps show the probability range of expected tephra loads of 100 and 250 kg/m2 according to two, dry and rainy, seasons and 10 km-, 20 km-high columns.

To assess risk of roof collapse and environmental damage, we have addressed the susceptibility of buildings and infrastructure to be affected by future tephra fallout. The vulnerability assessment deals with potential impacts of tephra falls on buildings, infrastructure (bridges), and road and water networks across two exposed areas in Arequipa. We have surveyed and ranked the structural performance and vulnerability of >2,000 roofs in case of probable tephra loads of 100 and 250 kg/m2. First, each building was classified based on the quality of the construction material, usage, and surface area, corresponding to structural ranking. The classification, mapped in the GRASS GIS software, used a dataset based on field visits, Google Street view and aerial Bing maps. Nine roof classes also include sport areas, churches, administration facilities and schools. Structural classes have been converted in four types of vulnerability in case of 100 and 250 kg/m2 loads used as hazard metrics and according to roof mechanical resistance. A particular attention was delivered to light and heterogeneous roofs, ranked as 'hybrid' roofs, which can be affected by minor tephra loads < 100 kg/m2. Finally, to obtain the probable effects of tephra fallout across the city, we correlate the dataset of vulnerable roofs with maps of probabilities of tephra fall, with two hazard metrics, two seasons, and two eruption columns. Probabilities of roof collapse in case of eruption may enable decision makers to undertake retrofitting projects and improve risk management in urban planning.