Journal of Volcanology and Geothermal Research 266 (2013) 1–15

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

journal homepage: www.elsevier.com/locate/jvolgeores

Economic impact of explosive volcanic eruptions: A simulation-based assessment model applied to Campania region volcanoes

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ARTICLE INFO

Article history:
Received 6 May 2013
Accepted 8 September 2013
Available online 21 September 2013

Keywords:
Volcanic hazard
Economic assessment
Emergency management
Planning management

ABSTRACT

PLINIVS Study Centre of University of Naples Federico II has developed a methodology that aims to estimate, in probabilistic terms, the direct and the indirect economic impacts of a Sub-Plinian I or Strombolian type eruption of Vesuvius. The economic model has been implemented as a complementary tool of the Volcanic Impact Simulation Model, a tool developed at PLINIVS Center available to the Italian Civil Protection Department (DPC) decision makers to quantify the potential losses consequent to a possible eruption of Vesuvius or Campi Flegrei. Along the expected time history of the eruptive event all the possible "direct costs" and the "factors" (indirect costs) impacting the economic growth in the event area have been identified. Each cost factor is built up through a specific algorithm that is fed by various providers, in order to run software that will estimate the global amount of economic damage from a volcanic event. The model does not include the economic evaluation of intangibles (e.g. human casualties), while the evaluation of damage to the local cultural heritage (historical buildings, archeological sites, monuments, etc.), is linked to the economic impact on tourism, estimated into indirect costs. The architecture of the model is based on a simulation logic, which allows an evaluation of different economic impact scenarios through input changes, allowing the model to be used as a tool to support the decision making process.

1. Introduction

The effects of a volcanic eruption on the built environment have been investigated in the last 15 years, defining a comprehensive framework of studies, surveys and simulations that include all the different eruptive phenomena and their possible impacts on existing buildings and infrastructure. Nevertheless, in order to define a methodology for the assessment of the economic impact of a volcanic eruption in densely populated areas – such as the Campania Region – a broader approach is possibly needed (Spence et al., 2010). The cumulative effects given by a complex eruptive scenario (such as a Sub-Plinian or Plinian eruption) produce extremely variable impacts on buildings, transport infrastructures (roads, railways, etc.), service networks (gas, electricity, etc.) and business activities. The effects depend on the specific time history of the event (Magill et al., 2006; Neri et al., 2008), on the building typologies and on their grade of vulnerability (Johnston et al., 1997; Zuccaro et al., 2008), on strategic choices connected to emergency management procedures and on the specific local characteristics of business activities.

This approach has been recently formalized in order to evaluate the impact of a Sub-Plinian eruption in the Vesuvius and Campi Flegrei areas (Baxter et al., 2008; Zuccaro, 2010; Zuccaro and Cacace, 2010; Zuccaro and Leone, 2012), through the development of a simulation model for the definition of impact scenarios. A dynamic model able to evaluate the cumulative damage distribution in time and space has been developed within several national and international projects such as Exploris (explosive eruption risk and decision support for EU populations threatened by volcanoes, EU-FP6 — proj. ref. EVR1-CT-2002-40026) and SPeeD (hazard and damage scenarios at Vesuvius and Campi Flegrei, 2007–2009).

The basic assumption is that the damage due to a volcanic eruption depends on several disastrous events, whose effects are cumulated in the final scenario. The damage level along the eruptive history is strictly linked to the number of the events, the range of the intensity of the events and the distribution in time and space (Zuccaro et al., 2008). The PLINIVS Volcanic Impact Simulation Model is a tool available to the Italian Civil Protection Department (DPC) decision makers to quantify the potential losses consequent to a possible eruption of Vesuvius or Campi Flegrei (Fig. 1). It has to be considered that the results are strongly dependent on the hypothesis assumed and on the parameters used as inputs. Therefore the "single-shot" output scenarios (i.e. scenarios developed through a single run of the model, from a single array of hazard inputs) have to be taken into account with great caution, given the considerable range of uncertainty in play (Zuccaro and Cacace, 2010). Nevertheless, considering the reliability of each single scenario, once the input data have been defined, a comprehensive overview of

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http://dx.doi.org/10.1016/j.jvolgeores.2013.09.002

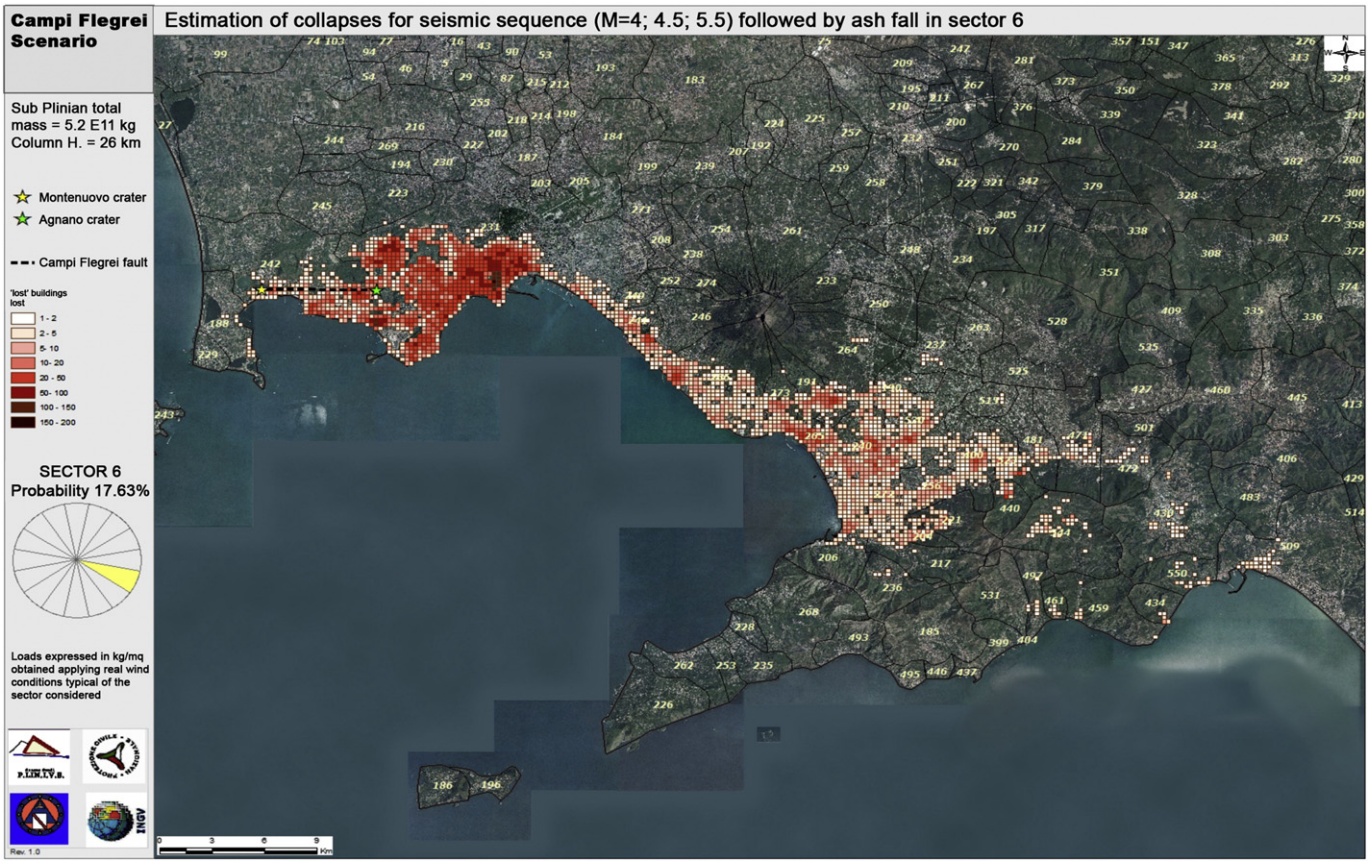

Fig. 1. Possible impact scenario of Sub Plinian I eruption at Campi Flegrei Caldera developed through PLINIVS Volcanic Impact Simulation Model.

the possible different situations likely to occur, with different ranges of probability, represents an important reference for emergency management and decision makers. In fact it allows a proper assessment of the resources needed to improve the arrangement of measures needed to face the event, as well as the implementation of feasible and effective mitigation measures on buildings and infrastructures to reduce the expected damage.

The definition of alternative impact scenarios (characterized by different probabilities of occurrence) and the consequent physical damages expected on buildings and infrastructures, as well as the population potentially affected, is the precondition for the definition of the economic impact of a volcanic eruption. The formalization of the methodology for the evaluation of direct and indirect economic damages and the implementation of the Economic Evaluation Model represent one of the key advancements produced within SPeeD research project.

The paper, starting from the definition of potential economic losses associated with volcanic eruptions (Section 2), focusing especially on the aspects connected to rehabilitation and reconstruction of buildings and infrastructures (Sections 3 and 4), describes the logic and the architecture of the model (developed in its prototypal phase), highlighting the first key results obtained through a simulation for a Sub-Plinian eruptive scenarios at Vesuvius (Section 5).

2. Economic losses associated with volcanic eruption

Economic losses associated with volcanic crises cannot be easily defined, since they range from the cost of emergency operations, evacuation and temporary housing for the affected population to the costs related to the physical destruction of infrastructures and subsequent disruption of business activity. Business activity decline may also result from increased depopulation and business uncertainty, and such uncertainty may persist for a considerable period of time (Baxter et al., 2008). One of the worst-case scenarios for government, individuals and businesses occurs if an eruption crisis remains in the unrest phase, never evolving into eruption. The ongoing global economic crisis has made it clear that one of the critical factors for economic growth and sustainability is the confidence in the outlook for future economic activity. A prolonged unrest phase prior to eruption may also produce large economic losses.

The magnitude of expected economic losses for local business during the unrest phase may depend upon: the anticipated magnitude, intensity and duration of the eruption threat; the amount and quality of information available to local businesses, investors and consumers; the type of business, e.g. the recreational and tourism industry is very sensitive to such a threat, whereas the demand could easily met elsewhere; the pre-existing economic health and trends; the scale of economic activity (i.e. large local economies are most at risk); the interconnection with other economies or industries; the 'flexibility' of the local business sector, e.g. their ability to diversify.

Mandatory evacuations entail significant economic costs to both governments and individuals. Residents without the financial resources necessary to evacuate, may require government funding to provide certain key resources such as transportation, shelter equipped with sufficient food, water, health and security personnel. Additional evacuation costs for governments, individuals and business include overtime pay to police and emergency officials, medical personnel and services, transport costs for converting highways into one-way evacuation routes, suspending toll collection for more-efficient evacuation and addressing traffic accidents, loss of time at work, increased petrol expenditure and lodging for evacuees, danger to temporarily abandoned property as well as final "back home costs". It is also clear that costs associated with the eruption crisis cannot be calculated in strictly monetary terms: for