IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 2, Issue 6 Ver. II (Nov-Dec. 2014), PP 40-45
www.iosrjournals.org

GIS Application To Map Volcanic Risk In Vesuvian Area

Oscar Rosario Belfiore, Pamela D'Allestro, Claudio Parente
(Department of Sciences and Technologies, University of Naples "Parthenope". Italy)

Abstract: *The aim of this paper is to demonstrate the versatility of GIS (Geographic Information System) tools to map volcanic risk. The work was conducted within the Course of Thematic Mapping at University of Naples "Parthenope" and referred to one of the most significant volcanic area in Italy that is around the Vesuvius. Formula of UNESCO was used to map Risk: Map Algebra functions were applied to vector files concerning Hazard and Value, while Vulnerability, because of didactic simplification, was considered equal to a constant (value=1) for the whole geographic area. Georeferencing and vectorizing processes were carried out on the original raster map of Vesuvius Hazard while population data by ISTAT (the Italian National Institute of Statistics) were jointed to the shape file of the Campania Municipalities to build the Value layer. To consider more realistic distribution of people also CORINE Land Cover (CLC) layer was introduced taking into account the first level of its categories (Artificial, Agricultural, Natural areas). Considering different sources of information (ISTAT data, CLC data, integration of ISTAT and CLC data) for Value layer definition, three different volcanic risk maps were obtained and compared.*
Keywords: *GIS, volcanic risk, Vesuvius, Map Algebra, vector map.*

I. Introduction

The volcanic activity is a threat to the community; this phenomenon can cause a high number of lost human lives and huge damage to the goods. The first step to limit these effects is the production of risk maps to be used for planning the development of an area subject to volcanic events as well as organizing first aids in occurrence of eruption. GIS (Geographic Information System) supplies powerful tools to facilitate risk mapping: different layers in raster as well as vector format can be overlapped, analyzed and elaborated so to obtain new information [1]. Particularly Map Algebra tools [2] permit to manipulate geographic data using mathematical operators and functions that perform computations within and among layers. To demonstrate the considerable role that GIS can be assumed for volcanic risk mapping, the Vesuvian area (Figg. 1-2) was considered because of its relevance as well as proximity to our University: the most part of the elaborations was carried out on vector files and three different maps were produced to remark the role of the input dataset for accuracy of the results.

Figure 1: Satellite image of Vesuvius (Source: Digital Globe, 2014, http://www.digitalglobeblog.com)

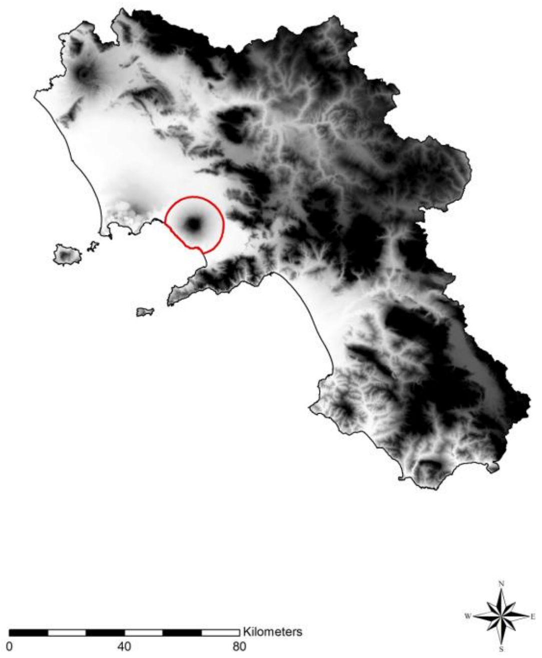

Figure 2: Vesuvian area and its location in Campania Region (Italy)

This paper is organized as follows. In Section II main characteristics of Vesuvius Volcano are summarized and a brief history of its activities is provided. In Section III the attention is focalized on data and methods. In Section IV results are shown and discussed. Section V concludes the paper with general considerations.

II. Origins And Activities Of Vesuvius Volcano: A Brief History

Vesuvius is one of the most famous volcanoes on Earth above all for having produced in 79 AD the first eruption of which very notable remains are preserved. Its activity ranging from Hawaiian-style emission of very liquid lava to violently explosive events that produce pyroclastic flows and surges [3]. At present, it is quiescent after 300 years of almost continuous volcanism, which ended with the 1944 eruption [4]. It is part of the Campanian volcanic arc that includes Campi Flegrei (a large caldera a few kilometers to the north west), Mount Epomeo (on the island of Ischia 20 kilometers to the west), and several undersea volcanoes (to the south).

Vesuvius was originated because the collision of two tectonic plates, the African and the Eurasian. Volcanic activity was present in this area since 400,000 years ago, but the mountain started forming 25,000 years ago as the product of the Codola Plinian eruption. Then a series of lava flows interspersed by smaller explosive eruptions contributed to its construction. Since 19,000 years ago the manifestations of volcanic activities changed and a sequence of large explosive plinian eruptions occurred.

Since 79 AD Vesuvius has erupted many times, such as in 203, 472, 512, 685, 787, 968, 991, 999, 1007, 1037, 1139; probably it erupted again in 1270, 1347 and 1500 [5]. New eruptions occurred in 1631, in the 18th century (six times), in the 19th century (eight times), and in 1906, 1929, and 1944. Eruptive activity of Vesuvius occurred in cycles that lasted several centuries and alternated with repose periods lasting several centuries as well; each of these repose periods ended with a major (Plinian) eruption, thus initiating an active cycle; the most recent one persisted from 1631 until 1944 [6]. Current activity consists of earthquakes and fumarolic emissions principally located in the crater area [7]. The surveillance of the Vesuvius as well as of the entire Neapolitan volcanic area represents the principal activity of the Osservatorio Vesuviano [8].

III. Data And Methods

In literature there are different definitions of risk. In this paper the well know formula introduced by UNESCO [9] was assumed as a start point considering its adaptation for volcanic risk [10]. Particularly:

$$\text{Risk} = \text{Value} \times \text{Vulnerability} \times \text{Hazard} \tag{1}$$

Where Value is the number of lives or the monetary value of goods at risk in a volcanic area; Vulnerability is the percentage of lives or goods that would be lost because of a given volcanic event; and Hazard is the probability that a certain area would be affected by a certain volcanic phenomenon [11].

In this case Value was estimated considering the population density: dataset (.csv) of the Italian National Institute of Statistics (ISTAT) [12] updated at 2008 was jointed in GIS environment to administrative boundaries (.shp) of the Municipalities of Campania that are included in the Vesuvian Area.

Vulnerability could be evaluated taking into account historical series of volcanic phenomena and assuming as reference values the mortality estimations due to volcanic activity. Because the aim of this paper was not to achieve the exact map of volcanic risk in the Vesuvian area rather than to demonstrate the possibility to use GIS to facilitate mapping operations, Vulnerability was considered as a constant value in the entire zone and assumed equal 1.

The evaluation of Hazard was obtained by the map of the Italian Ministero dell'Ambiente [13] that distinguished the Vesuvian area in three different zones: Pyroclastic fall, Lava flows and Craters (Fig. 3). This map was georeferenced in the cartographic system UTM-WGS84, Zone 33 N using Polynomial Functions – 1th order [14]. Then vectorization of three different Hazard zones was performed giving to the above mentioned zones different coefficients, respectively equal to 1, 2 or 3 (Tab.1). The resulted Map of the Hazard zones with relative coefficients (H) is reported in Fig. 4.

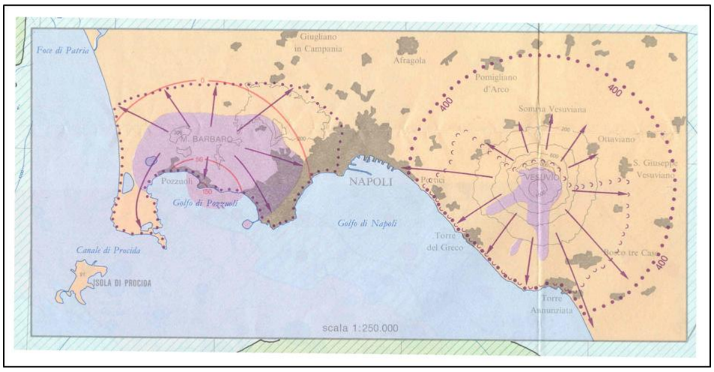

Figure 3: Original raster map of the Italian Ministero dell'Ambiente used for Hazard zones definition

Table 1: Coefficients (H) of the Hazard zones

Hazard zones	Hazard coefficients (H)
Pyroclastic fall	1
Lava flows	2
Craters	3

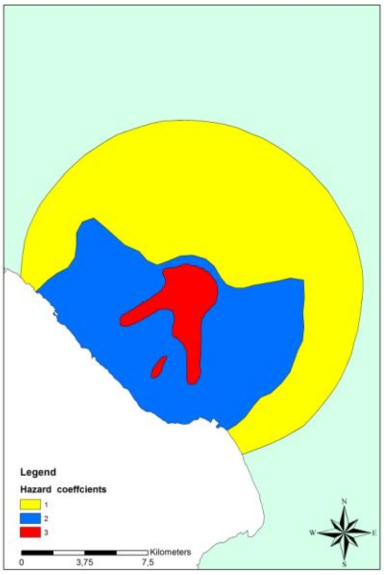

Figure 4: Map of the Hazard zones and relative coefficients (H)

The distribution of density values (people per hectare) was clustered, in ascending order, in 4 classes (Fig. 3) using Natural Breaks method performed by the classification algorithm of Jenks [15, 16]. Thresholds and coefficients are reported in Table 2. The resulted Map of the Population density zones with relative coefficients (D) is reported in Fig. 5.

Table 2: Thresholds of population density and coefficients (D)

Intervals of population density (people per hectare)	Density coefficients (D)
7.2341 – 20.7323	1
20.7324 – 45.3536	2
45.3537 – 81.5983	3
81.5984 – 120.1233	4

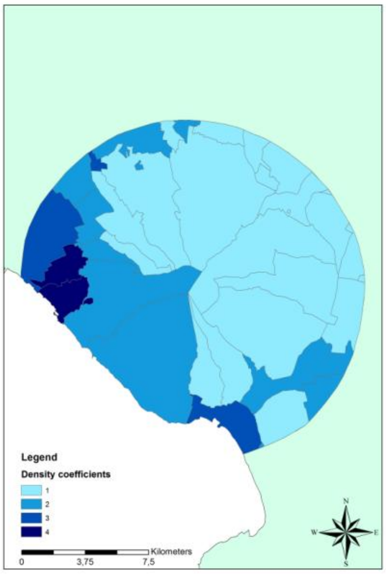

Figure 5: Map of the Population density zones and relative coefficients (D)

To obtain a more realistic distribution of people (that obviously was not constant within each municipality, but changed in consideration of the different land uses), the layer of the first level of the CORINE Land Cover (CLC) of the year 2000 [17] was introduced. To each category of the CLC data one coefficient (C) (Table 3) was assigned considering that the population density was higher in urban areas than in the agricultural or natural ones. The resulted Map of the CLC categories with relative coefficients (C) is reported in Fig. 5.

Table 3: CLC categories (Level 1) and coefficients (C)

CLC Categories Level 1	CLC coefficients (C)
1. Artificial surfaces	50
2. Agricultural areas	10
3. Forest and semi-natural areas	1

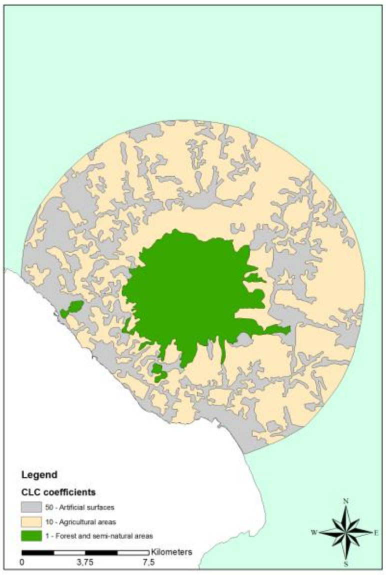

Figure 6: Map of the CLC categories and relative coefficients (C)

IV. Results And Discussion

Using equation (1), three different volcanic risk maps were produced. The first one (Fig. 7) was the result of the interaction between layers H and D: the intersection of the Municipalities boundaries with Hazard zones produced new geometries that derived attributes of both the native layers. A new column was introduced in the table of the new file to implement in it the equation (1). The resulting different values were grouped in 4 classes by Jenks algorithm: low, medium-low, medium-high and high risk level.

The second risk map (Fig. 8) was obtained with the same procedure of the first one considering layer C instead of layer D: in this way the areas were differenced taking into account the land uses, but no consideration was introduced about the variability of density population among the municipalities.

The third risk map resulted in the respect of both land use as well as administrative realities: interactions were operated with all layers (H, C and D) (Fig. 9) and the equation (1) was applied considering Value as the product of the coefficients of CLC categories and population density.

The comparison of the three risk maps remarks the different levels of detail that can be achieved integrating two or more georeferenced layers.

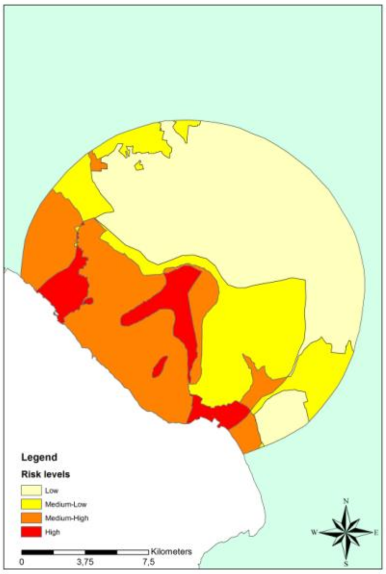

Figure 7: Volcanic risk map considering Population Density and Hazard layers

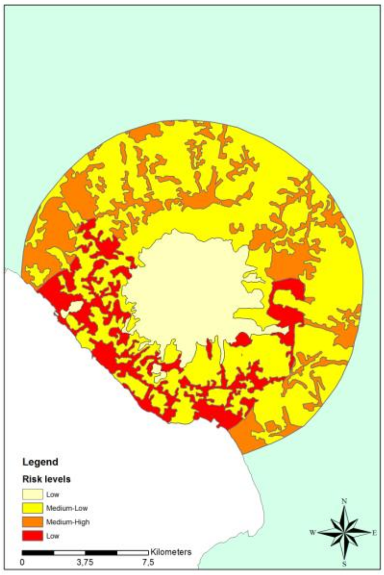

Figure 8: Volcanic risk map considering CLC categories and Hazard layers

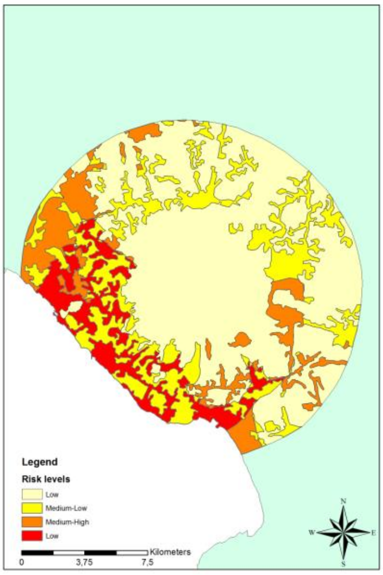

Figure 9: Volcanic risk map considering Population Density, CLC categories and Hazard layers

V. Conclusion

This application shows the validity of GIS tools to support volcanic risk mapping: Map Algebra functions and operators permit to integrate different layers and implement several routines, so also UNESCO formula can be easily applied. In this way valid instruments are obtained for planning human activities: availability of maps that distinguish zones with different level of risk permits not only to manage first aids in case of eruption, but also to support screening of areas for the realization or modification of the infrastructures as well as urban, industrial and agricultural systems.

The results depend on the data as well as their integration: in the considered case three different maps were achieved because the same component that compares in the UNESCO formula, the Value, was obtained in three different ways. However to define Value not only population density but also goods distribution could be considered, so other risk maps would be produced.

Acknowledgements

This paper synthesizes results of works performed within the project PRIN 2010-11 financed by MIUR (Ministero dell'Istruzione, dell'Università e della Ricerca) - Italy and developed at University of Naples "Parthenope" (Coordinator: Prof. Raffaele Santamaria).

References

[1]. C. Parente, A. Pugliano, and R. Santamaria, Rappresentazione dei rischi georiferibili mediante tecniche di cartografia numerica in ambiente GIS, Atti della III Conferenza Nazionale ASITA, Napoli, 1999, 1053-1058.

[2]. D. Tomlin, A Map Algebra, Proceedings of the 1983 Harvard Computer Graphics Conference, Cambridge, MA, 1983, 127-150.

[3]. SRV (Sistema Rischio Vulcanico) - Vesuvius volcano, Campania. http://srv1.rm.ingv.it/srv1/srv/study-sites/vesuvius/vesuvius-volcano-campania. Latest access 12/04/2014.

[4]. M. A. Di Vito, M. Piochi, A. Mormone and A. Tramelli, Somma Vesuvius: the Volcano and the Observatory, Officine grafiche Francesco Giannini, Napoli, 2011.

[5]. G. Delibrias, G. M. Di Paola, M. Rosi, and R. Santacroce, La storia eruttiva del complesso Somma-Vesuvio ricostruita dalle successioni piroclastiche del monte Somma, Rendiconti Società Italiana di Mineralogia e Petrologia, 35(1), 1979, 411-438.

[6]. Vesuvio Decade Volcano, Italy, http://www.geo.mtu.edu/volcanoes

[7]. G. Chiodini, L. Marini, and M. Russo, Geochemical evidence for the existence of high-temperature hydrothermal brines at Vesuvio volcano, Italy, Geochim. Cosmochim. Acta, 65, 2001, 2129-2147.

[8]. V. Achilli, O. Al-Bayari, G. Artese, S. Borgstrom, M. Capone, C. Del Gaudio, S. Gandolfi, N. Macchiavelli, G. P. Ricciardi, C. Ricco, V. Sepe, and A. Vettore, GPS measurements in the Neapolitan Volcanic Area, Physics and Chemistry of the Earth, Part A: Solid Earth and Geodesy, Vol. 25, 9-11, 2000, 705-711.

[9]. UNESCO, Report of consultative meeting of experts on the statistical study of natural hazards and their consequences, Document SC/WS/500, 1972, 11.

[10]. E.M. Fournier d'Albe, Objectives of volcanic monitoring and prediction, Journal of the Geological Society, 136(3), 1979, 321-326.

[11]. R. Scandone, G. Arganese, and F. Galdi, The evaluation of volcanic risk in the Vesuvian area, Journal of Volcanology and Geothermal Research, 58(1), 1993, 263-271.

[12]. ISTAT (Istituto Nazionale di Statistica), http://www.istat.it/it/

[13]. Ministero, dell'Ambiente, Relazione sullo stato dell'ambiente, 1992.

[14]. O. R. Belfiore, and C. Parente, Comparison of different methods to rectify IKONOS imagery without use of sensor viewing geometry, American Journal of Remote Sensing, 2(3), 2014, 15-19.

[15]. M. A. North, A method for implementing a statistically significant number of data classes in the Jenks algorithm, Fuzzy Systems and Knowledge Discovery, 2009, FSKD'09 - Sixth International Conference on, Vol. 1, IEEE, 2009.

[16]. Alberico, P. Petrosino, and L. Lirer, Volcanic hazard and risk assessment in a multi-source volcanic area: the example of Napoli city (Southern Italy), Natural Hazards and Earth System Science, 11(4), 2011, 1057-1070.

[17]. CORINE Land Cover a key database for European integrated environmental assessment. http://www.euromines.org/sites/default/files/publications/corine-land-cover-key-database....pdf. Latest access 12/04/2014