www.rigeo.org ISSN: 2146-0353
RIGEO
Review of International Geographical Education Online

Review of International Geographical Education Online ©RIGEO 2017, **7** (2), Summer 2017

Research Article

To cite this article: Pesaresi, C.; Van Der Schee, J.; Pavia, D. (2017). 3D and 4D Simulations for Landscape Reconstruction and Damage Scenarios: GIS Pilot Applications, *RIGEO*, 7 (2), 131-153. Retrieved from http://www.rigeo.org/vol7no2 /Number2Summer/ RIGEO-V7-N2-1.pdf

Submitted: March 27, 2017 **Revised:** July 19, 2017 **Accepted:** August 19, 2017

3D and 4D Simulations for Landscape Reconstruction and Damage Scenarios: GIS Pilot Applications*

Cristiano PESARESI[1]
Sapienza University of Rome, Rome, Italy

Joop VAN DER SCHEE[2]
Vrije Universiteit, Amsterdam, The Netherlands

Davide PAVIA[3]
Sapienza University of Rome, Rome, Italy

Abstract

The project *3D and 4D Simulations for Landscape Reconstruction and Damage Scenarios: GIS Pilot Applications* has been devised with the intention to deal with the demand for research, innovation and applicative methodology on the part of the international programme, requiring concrete results to increase the capacity to know, anticipate and respond to a natural disaster. This project therefore sets out to develop an experimental methodology, a wide geodatabase, a connected performant GIS platform and multifunctional scenarios able to profitably relate the added values deriving from different geotechnologies, aimed at a series of crucial steps regarding landscape reconstruction, event simulation, damage evaluation, emergency management, multi-temporal analysis. The Vesuvius area has been chosen for the pilot application owing to such an impressive number of people and buildings

*C. Pesaresi has written paragraphs 1 (Introduction), 2 and 3, D. Pavia paragraph 4, Joop van der Schee paragraph 5. The Scientific responsible of this project is Cristiano Pesaresi. The Sapienza University research group is made up of: Edoardo Boria, Gino De Vecchis, Mario Di Traglia, Maria Rosaria Florinda Giuva, Riccardo Morri, Davide Pavia. Other Participants are: David K. Chester, Angus M. Duncan, Christopher Kilburn, Pierluigi Cara, Maurizio Fea, Lisetta Giacomelli, Roberto Scandone. Other Institutions involved are: ESRI Italia; The Geographic Research and Application Laboratory (GREAL), European University of Rome; The Italian Centre for Historical-Geographical Studies (CISGE); The Italian Association of Geography Teachers (AIIG). Joop van der Schee started to collaborate to the issues of the project during his permanence in Rome as Visiting Professor in September-October 2016.

[1]Corresponding author: Researcher, Scientific Responsible for the GeoCartographic Laboratory, Documentary, Linguistics, Philology and Geographic Sciences Department, Sapienza University of Rome, Rome, Italy, cristiano.pesaresi[at]uniroma1.it

[2]Emeritus Professor, Faculty Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands, j.a.vander.schee[at]vu.nl

[3]Research grants, Documentary, Linguistics, Philology and Geographic Sciences Department, Sapienza University of Rome, Rome, Italy, davide.pavia[at]uniroma1.it

subject to volcanic risk that one could speak in terms of a possible national disaster. The steps of the project move around the following core elements: creation of models that reproduce the territorial and anthropic structure of the past periods, and reconstruction of the urbanized area, with temporal distinctions; three-dimensional representation of the Vesuvius area in terms of infrastructural-residential aspects; GIS simulation of the expected event; first examination of the healthcare-epidemiological consequences; educational proposals. This paper represents a proactive contribution which describes the aims of the project, the steps which constitute a set of specific procedures for the methodology which we are experimenting, and some thoughts regarding the geodatabase useful to "package" illustrative elaborations. Since the involvement of the population and adequate hazard preparedness are very important aspects, some educational and communicational considerations are presented in connection with the use of geotechnologies to promote the knowledge of risk.

Keywords

3D and 4D Simulations; Communication and Education; Damage Scenarios; Geodatabase; GIS Platform; Landscape Reconstruction; Volcanic Hazard and Risk

GIS applications can provide remarkable added value in supporting strategic planning in areas exposed to natural disasters, i.e. integrating and refining geophysical and statistical models; producing digital elaborations and buffer zones aimed at defining priority orders of intervention and the possible extension of the areas which could be involved and destroyed; expressing vulnerability and hazard values; quantifying the social and demographic components subject to risk; re-elaborating data and images obtained by remote sensing in different periods for an updated and diachronic framework; interfacing with images captured by drones to monitor and follow the event etc. For example, for volcanic eruptions, some studies have also delivered elaborations of the physical and geomorphological aspects which can favour or hinder the direction of flows and phenomena, successively providing moving scenarios useful for the emergency phases (Esposti Ongaro et al., 2008), with the support of well tested procedures and algorithms (Neri et al., 2003) and corroborated by in-depth knowledge of the dynamics and local aspects (Neri et al., 2015). Instead, there is a clear shortage of research providing analytical 3D GIS representations of urbanized and artificial areas in highly exposed contexts, involving every type of buildings (houses, industrial and commercial activities, hospitals, schools etc.), in which the neuralgic elements are to be found to give a significant geographical framework of the damage scenarios connected to a natural disaster.

A rigorous 3D reconstruction of urban centres subject to high level risk can therefore represent a model with an important explicative effect in order to be able to visualize, understand and evaluate the amount of losses in the case of an event, and to support the successive phase of geographic screening. A series of tested steps are required to enhance the possibility of deploying natural disasters and crisis management assets, in the perspective of simulating scenarios, proposing damage estimates, improving aspects regarding the decision-making, the coordination of response actions and sense of awareness.

Thus, the project *3D and 4D Simulations for Landscape Reconstruction and Damage Scenarios: GIS Pilot Applications*, which represents the "natural" continuation of the

GIS4RISKS project (Pesaresi & Lombardi, 2014; Baiocchi & Pesaresi, 2015), has been thought to meet the requirement to draw up a harmonized set of activities aimed at promoting the geotechnical and procedural interoperability in the case of a pre-event crisis. Following similar perspectives, this project, recently financed by the Sapienza University of Rome, sets out to maximise the benefits to be obtained by using together, according to an experimental methodology, sophisticated applications to process, visualise and analyse geographical data in both connected and dialoguing 2D and 3D environments. It is then preparatory to the production of 4D animations with which to simulate an expected damage scenario on the basis of the propagation of the event and the territorial context of reference.

In this pilot application, the attention is focused on the Vesuvius area since the potential losses in the case of a volcanic event would represent a national disaster, owing to the impressive amount of people and buildings exposed, with an explosion in an urban sprawl phenomenon with the saturation of spaces and the merging together of municipalities (Pesaresi & Marta, 2014). In fact Vesuvius is considered the volcano of Europe characterised by the highest potential impact on the population and infrastructural-residential fabric (Spence, Gunesekara & Zuccaro, s.d.), to which must be added the huge impact on the stately historical and archaeological heritage, and any explosive activity would generate dramatically singular effects.

Therefore, first of all this paper provides a synthesis of the applicative steps and the basic core elements of the project. It then shows a planning picture of the various consequential phases which, in the present state, have been partly followed and which will be progressively realised following the organisation of a wide geodatabase – currently in the advanced stage of processing – with images and data coming from multiple sources specifically described herein. Moreover, this contribution provides a presentation of the procedures and tools which together contribute to defining the main foundation of the methodology which we are testing to support a broad and in-depth framework of the knowledge of the study area, both in geospatial and multi-temporal perspectives.

From an educational point of view, three-dimensional thinking and operating can acquire a strategic role: for the didactical dimension; for the communication of important aspects; and for the active population involvement and participation about relevant issues. Three-dimensional thinking and operating can strongly increase the capability to touch the individual and collective perception, stimulating young people to develop ad hoc competences and to work with GIS, also in the sharing direction and with the aim of a practical use.

In the Vesuvius area, many people living around the volcano denote an inadequate knowledge of the risk and related measures to adopt for a right behaviour in case of eruption. A similar situation highlights the necessity to promote and improve the risk perception and information (Carlino, Somma & Mayberry, 2008). At the same time, in the Italian schools there is a very weak knowledge of GIS and their potentialities are considerably underused (Pesaresi, 2005 and 2012). In fact, GIS do not seem to be part of geographical education while they could provide a notable add value for a modern and renewed geographical image.

So, new frontiers must be explored to reduce these problems and gaps and to make geographical education, supported by GIS applications, an efficient way for the awareness of the young people and for providing them rigorous interpretative keys and powerful tools.

A synthetic Eruptive and Anthropic Framework of the Vesuvius Area

The Somma-Vesuvius complex is an enclosure-type volcano structure, composed of the ancient volcanic apparatus of Somma and the more recent volcanic apparatus of Vesuvius. Its eruptive history has been characterized by many events "largely variable in magnitude, intensity and composition of the involved products" (Santacroce et al., 2008, p. 1) which have also required rigorous proposals for the classification of its explosive activity. It has been done on the basis of critical and detailed "revision of a large set of published and unpublished stratigraphic, compositional, and physical volcanology data on the products of the past 20,000 years of activity", in order to interpret its possible future eruptive behaviour (Cioni et al., 2008, p. 331).

Even if the eruptions recorded over time have been very numerous and often distinguished by specific aspects which have been expressly reconstructed (Scandone, Giacomelli & Gasparini, 1993; Scandone, Giacomelli & Fattori Speranza, 2006), the main events which cover a particular interest for this study are above all the following.

A.The 79 A.D. eruption which was the strongest in historic times (Volcanic Explosivity Index, VEI, =5-6), with a very high column, the propagation of destructive pyroclastic flows and the fall of an enormous amount of ash, pumice (before white and then grey) and other products towards South-South-East. It destroyed and buried Pompeii, Herculaneum, Oplonti and Stabiae showing the notable power which can derive form an eruption of Somma-Vesuvius. The main phases and temporal evolution of the activity, reconstructed on the basis of the geological deposits and the description of Pliny the Younger, have been synthesized in four major sequences. "1. The first phase, after minor phreatic explosions, is characterized by the development of an high, sustained column where the erupted mixture of juvenile gases and pyroclasts, mixing turbulently with atmospheric air, rises convectively into the stratosphere reaching an estimated maximum height of 32 km. 2. The second phase is characterized by the collapse of the eruptive column with the emplacement of pyroclastic flows and surges which destroyed every settlement within a radius of 10-15 km from the volcano. 3. Collapse of the magma chamber, ingression of water into the feeding system, magma water interaction and final phreato-magmatic activity. 4. Post eruption remobilization of ashes and pumice by rain water during the following years" (Giacomelli et al., 2003, p. 234).

B.The 1631 eruption which is often assumed as a reference event able to provide input for a possible future eruption and that consequently plays a fundamental role for the planning activities, also because it was "the most violent and destructive event in the recent history of Vesuvius" (Rosi, Principe & Vecci, 1993, p. 151)[4]. This eruption had a Volcanic Explosivity Index (VEI=4) lower than the event of 79 A.D. but also in this case overwhelming pyroclastic flows caused destruction in a wide radius, while the fall of ash, pumice and other products took place towards East-North-East. In the end the eruption, recorded in an already considerably anthropised context with respect to 79 A.D. and to the general level of other contemporary Italian areas, caused some thousands of victims and general panic, opened a new eruptive chapter and, thanks also to the numerous descriptions released, provided important data for future studies.

C.The 1944 eruption which was the last one to be recorded, now dating back to 73 years ago, and which closed the singular phase characterized by the cyclicality of the events that started after the 1631 eruption. Particularly, during the 1944 paroxysm, which ended the cycle starting in 1913, the activity was distinguished by lava flows and fountains and by a column with a maximum height of 6 Km, obviously much lower than the ones observed in the other two mentioned eruptions, from which little and limited pyroclastic flows were developed and above all a relevant amount of ash and other products collapsed towards East-South-East. The eruption, even if with a VEI=3, produced important damage to houses, places of worship, cultivated fields, economic activities and road infrastructures, both owing to the lava flows propagation and ash and other clasts relapsed, and caused 26 victims (Pesce, Rolandi, 1994), creating discouragement and fearful conditions once again. These aspects could and should have been a deterrent able to avoid a dissemination of housing in a solution of continuity, but on the contrary the memory of the event has had a brief duration and the population has exploded creating a surreal situation.

Since the census of 1951, the number of inhabitants of the Naples province[5], in general, and the Vesuvius area, in particular, has recorded an exorbitant increase and the coastal zone has become a unicum with the city of Naples for example, where it is impossible to distinguish the borders among municipalities which design a long and thick offshoot. The population of the Naples province was little more than 2,000,000 inhabitants in 1951 (2,081,119), rapidly almost reached the threshold of 3,000,000 inhabitants in 1981 (2,970,563) and the positive trend slowly continued until 2001 (3,059,196 inhabitants), while in 2011 first very slight decrease (3,054,956 inhabitants) was recorded. The population has shown an increase of 46.8% (973,837 inhabitants) between 1951 and 2011 and many municipalities have denoted a very remarkable growth which has strongly amplified the population density and the risk levels.

With respect to the other provinces of the Campania region, the Naples province, with a population density of 2,591 inhabitants/Km2 and the maximum value in Italy, seems a powerful "magnet" (Figure 1) where rarely do the municipalities have less than

[4]In the emergency plan of 1995, the concept of Maximum Awaited Event (EMA) in the case of Vesuvius activity in a short-medium period was introduced and for that scenario it was considered an activity similar, but obviously note equal (as far as concerns energy, volume of magma, eruptive phenomena), to 1631. In the recent documents an approach based on the probability of occurrence has been preferred and it has conducted to elaborate the "tree of events" which would let to think to an eruption with a minor Volcanic Explosivity Index (VEI=3) respect to the 1631 activity. Nevertheless, in terms of civil protection and safety margins the eruption of 1631 continues to be considered the reference scenario (Dipartimento della Protezione Civile, 30.04.2012, pp. 4, 13).

[5]With Law No. 56 of 7th April 2014, the Naples province became Metropolis city of Naples as of 1st January 2015.

1,000 inhabitants/Km2 and where some contexts also of the Vesuvius area (Portici, 12,110 inhabitants/Km2; San Giorgio a Cremano, 11,089; Torre Annunziata, 5,772) have more than 5,000 inhabitants/Km2. The result of this process has been a massive conurbation around the Naples city (8,082 inhabitants/Km2) and in proximity of the Somma-Vesuvius complex, which has been transformed into an urbanized and continuously changing mountain (D'Aponte, 2005) observing an almost entirely compacted coastal zone from a built-up point of view (Gasparini, 2005)[6]. Therefore, even if in the last census intervals a decrease in the population was recorded in several municipalities of the Vesuvius area, also in the application of some regional laws (No. 19 of 28 December 2009; No. 1 of 5 January 2011)[7], the general situation remains dramatic, both because there have been demographic reshuffles among municipalities and because the amount of inhabitants, houses, economic activities, historical and cultural estate has no comparisons in Europe. It requires a profound risk culture among people who, instead, show inadequate levels of awareness and preparedness (Davis, Ricci & Mitchell, 2005; Barberi et al., 2008), creating an amplification of the potential problems.

[6]The Vesuvius "red zone", subject to invasion of pyroclastic flows or collapse of the roof of the houses for accumulation of ash and other products, in addition to the "historic" municipalities (Boscoreale, Boscotrecase, Cercola, Ercolano, Massa di Somma, Ottaviano, Pollena Trocchia, Pompei, Portici, Sant'Anastasia, San Giorgio a Cremano, San Sebastiano al Vesuvio, San Giuseppe Vesuviano, Somma Vesuviana, Terzigno, Torre Annunziata, Torre del Greco, Trecase), has been recently expanded (Palma Campania, Poggiomarino, San Gennaro Vesuviano, a part of the district of Barra, Ponticelli and San Giovanni a Teduccio, in the municipality of Naples, a part of Nola and the enclave of Pomigliano d'Arco in the municipality of Sant'Anastasia, and Scafati, in the Salerno province). See http://www.protezionecivile.gov.it/resources/cms/documents/Direttiva_Vesuvio_14feb2014_def.pdf.

[7]These laws proposed "Provisions for the delocalisation of buildings from areas at very high hydrogeological risk and from the red zone at risk of eruption by Vesuvius".

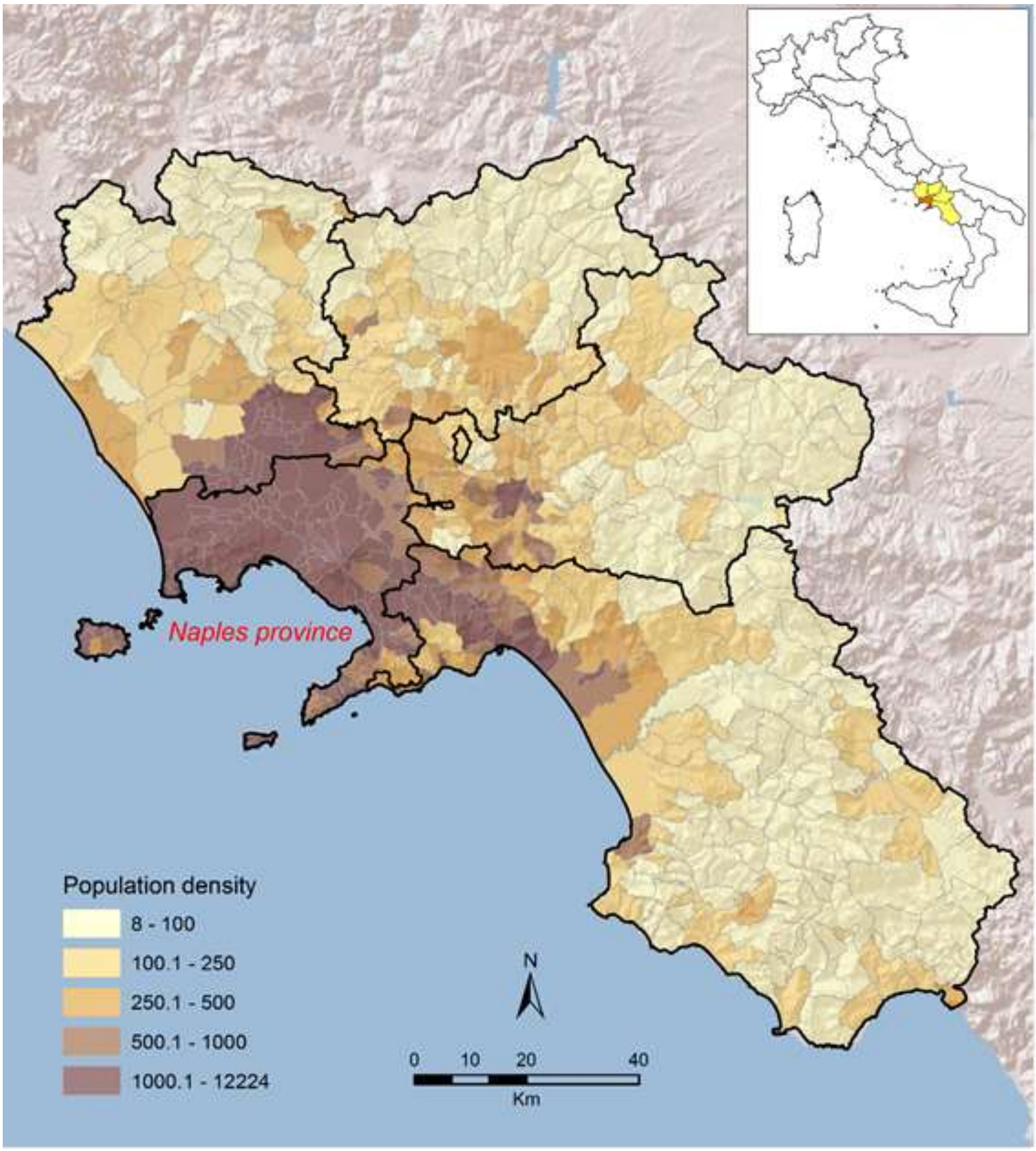

Figure 1. Population density (inhabitants/Km^2) in all the municipalities of the Campania region in 2011. Elaboration on ISTAT data, 2011 and ESRI's ArcGIS Online (World Shaded Relief).

The Main Aims and Steps of the Research

The various applicative steps of this project move around a number of basic core elements that, after the organisation of a powerful geodatabase, can be summarised as follows:

1. Creation of models that in their main characteristics reproduce the territorial structure and anthropic fabric of the past, with reference to the eruption periods that can give precious elements as expected events. Similar information, also reconstructed by cartographic modelling based on different sources in GIS environment, are also very

useful to once again run through the different phases which have led to the present impressive level of urbanization and to visualize the directions of expansion with consequent space saturation. Therefore, it is possible to study the interaction between volcanism and human activity in historic times and to consider the aspects related to the increase of volcanic risk. By combining the documental value of the historical cartography, satellite images, pictures and other documentation with the elaboration potential of Geographical Information Systems, through georeferencing, interpolation, data processing and the creation of simulated environments, it is possible to give a general framework aimed at supporting interdisciplinary analysis whereby to highlight the impact differences between an eruption that took place centuries ago and a potential present day eruption, since the anthropic-infrastructural context of reference has undergone a significant change;

2.Three-dimensional reconstruction of the Vesuvius area, to raise the structures actually present and thus set out a reference project system that will make it possible to go from the 2 dimensions on the map to 3 dimensions in models that geolocalise and reproduce what is there, so as to get different information in orthogonal and perspective shots. By using specific GIS applications and extensions and re-elaboration of detailed cartography, Digital Terrain Model (DTM)[8], Digital Surface Model (DSM) obtained by LIDAR[9] (that capture and record height parameters for the built-up areas), images captured by drones and light vehicles equipped with ad hoc software, an integrating digital model – whose production can be considered the “nucleus” of the research – can be created able to raise the anthropic structures according to the actual parameters, as well as the physical-morphological features. A similar model is fundamental in order to give a real picture of the areas and elements exposed to the risk of destruction and, thanks to its whole processing, it is possible to summarize the scenic effect with the rigour of geographic representation and analysis, and to combine a quantitative and qualitative approach in a mixture aimed at social utility (Figures 2-3);

3. Moving simulation of a possible expected event, on the basis of geophysical parameters and of what happened in the past, thus passing to 4D, which can then make it possible to interface and be integrated with the three-dimensional scenario of the urbanization. This should be done in such a way as to generate an overall simulation, in which the phenomenologies will have an impact on the built-up area, so as to be able to reach the definition of a damage scenario on the infrastructural-residential patrimony and an estimate of the possible social and economic impact, in a context where the urbanistic-settlement continuum has exploded above all from the 1950s on, creating situations with a disproportionate degree of crowding. The purpose of this step – from a geographic point of view and towards an interdisciplinary convergence of competences – is “to translate” the simulation of explosive eruption dynamics on Vesuvius (e.g. Neri et al., 2007) in a harmonic GIS environment where geophysical and anthropic

[8]We use – for the examples here presented – the DTM of the dataset TINITALY/01 (National Institute of Geophysics and Volcanology) which is explained by Tarquini et al., 2007 and 2012.

[9]We use the DSM obtained by LIDAR with the flight 2009-2012 whose download – as kindly indicated by Giuseppe Vilardo (National Institute of Geophysics and Volcanology, Vesuvius Observatory) – is possible at http://sit.cittametropolitana.na.it/lidar.html.

components can be filleted in an animation from which to obtain a series of useful information in terms of civil protection, damage hypothesis and costs of the disaster. Therefore, this is also aimed at realising a bridging platform between the 3D of the anthropic-settlement fabric and the 4D of the expected event and at producing a final elaboration model to be put in a video animation, which can permit its exportation into a file format that is compatible with most multimedia reproduction software;

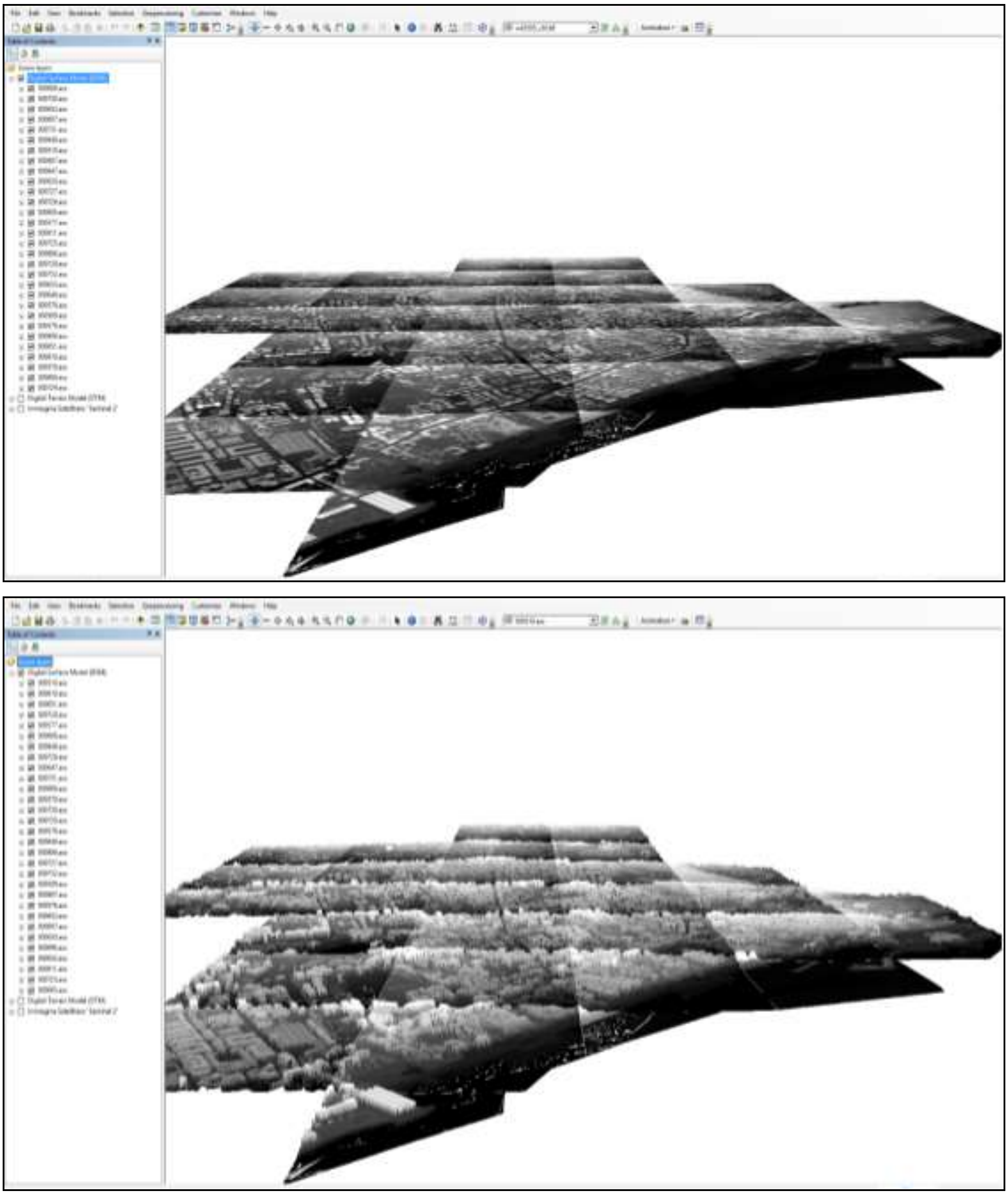

Figure 2. An example of Digital Surface Model (DSM) concerning all the tiles of the municipality of Portici in 2D, above, and 3D, below. Elaboration by D. Pavia & C. Pesaresi

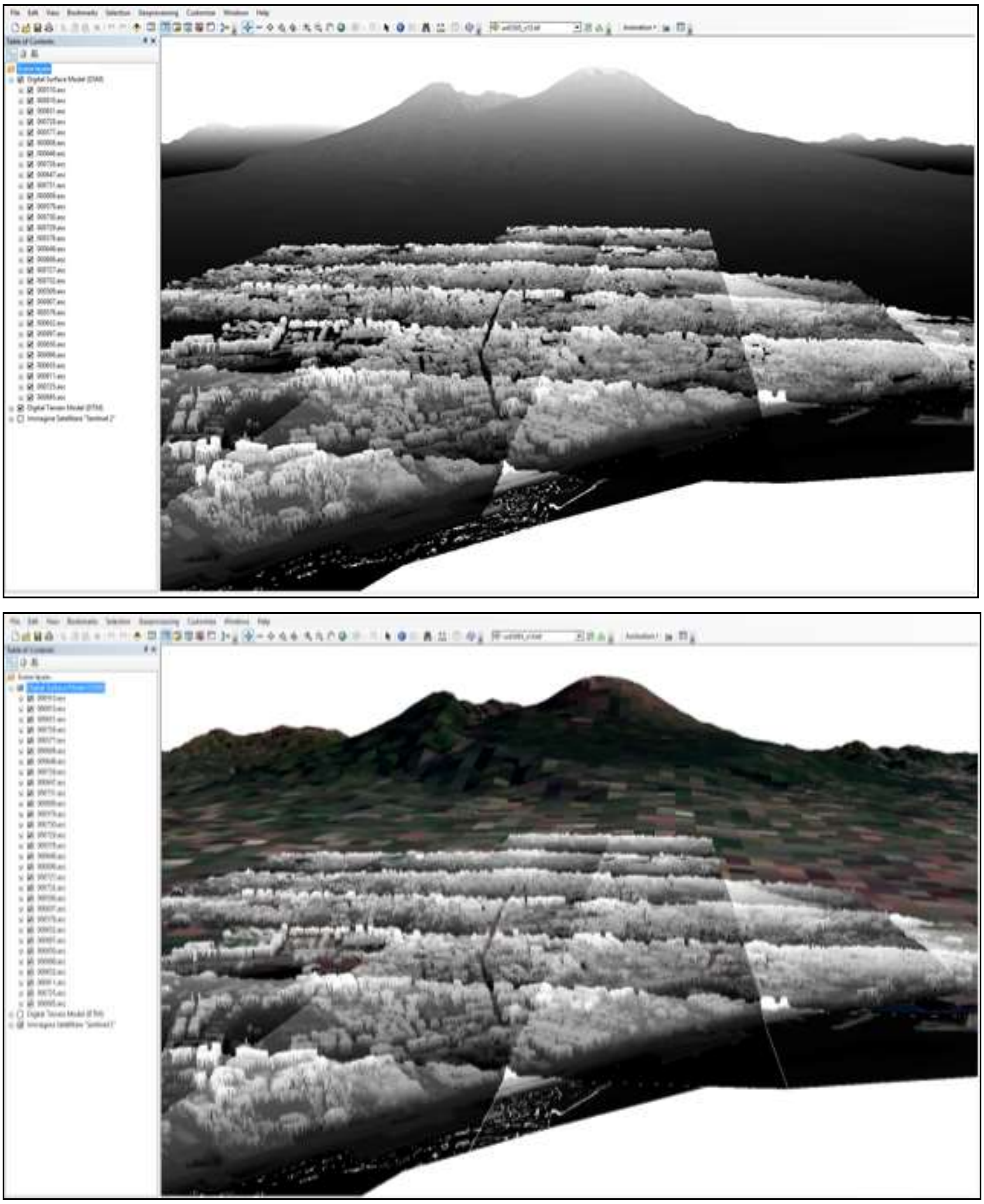

Figure 3. An example of Digital Surface Model (DSM) concerning all the tiles of the municipality of Portici with the overlay of a Digital Terrain Model (DTM) which shows the morphology of the Somma-Vesuvius complex, above, or with a specific overlay of a satellite image ("Sentinel 2") which provide further elements in terms of visualization, below. Elaboration by D. Pavia & C. Pesaresi.

4. Estimation of the related damage scenario and the effects of the eruption on the infrastructural-residential patrimony and examination of the healthcare-epidemiological

consequences, in an area marked by notable land use conflicts and frequent environmental hazards for solid urban waste disposal. It can give an assessment of the impact that could arise owing to the destruction-damaging of residential buildings, industrial facilities and activities, tips and toxic waste, hospitals with chemical and special waste, in a somewhat already fragile and sensitive area. So, relevant inputs can be also given in the context of medical geography evaluating the healthcare impact of a geodynamic event, by means of geostatistical simulation models starting by the considerations which identified different hazard classes for human safety and health from explosive volcanic activity (Bernstein, Baxter & Buist, 1986, p. 4), that it is to say: *direct and immediate*; *direct and delayed*; *indirect and immediate*; *indirect and delayed*. In fact – in addition to the *direct* consequences[10] – among *indirect and immediate* plausible effects there are: "Health hazards from epidemic outbreaks of endemic diseases due to disruption of routine environmental, public health, and medical services"; while among *indirect and delayed* there are: "Health hazards from increases in the pathogenic potential of infectious and toxic pulmonary pathogens due to the irritant and toxic effects of volcanic gases and ash on the lung's defence mechanisms";

5. Definition of didactical and educational proposals which can make it possible to directly involve a great number of the population starting from students at school, also using the added values of the considerable power and ability of geotechnologies to charm. It is worthy of note that: "The history of the major eruptions of 79 AD and 1631 has shown that many people living around the volcano were able to escape even without any knowledge of volcanic phenomena and without knowing that Vesuvius was a volcano. […]. So, even in the case of the failure of all prevention measures, could it be possible to avoid large losses of people by the simple knowledge of elementary rules of behavior that should be taught at school. Primary school should provide the elementary information regarding volcanic phenomena and emergency drills. Specific ad hoc projects in junior schools may embrace [first of all geography,] science, history, and Latin language, supplemented with visits to the excavations and volcanic outcrops to better appreciate the nature of eruptive phenomena and their effect on the environment" (Scandone & Giacomelli, 2014, p. 41). Further projects also carried out in a team-based system, using GIS, Story Maps with different templates, geobrowsers, web applications and GPS, can provide important inputs, in a proactive and enthusiastic atmosphere, aimed at increasing the singular and overall knowledge regarding risk and hazard. In this way, by pursuing the directions of cooperative and problem-based learning in a constructivist approach, geospatial technologies and geography can profitably converge to know and share common issues which cover outstanding social relevance, giving the possibility to develop critical capabilities of analysis and the desire to explain and broaden one's own knowledge (Pesaresi, 2016, pp. 115-116). On the other hand: "The

[10]Examples of *direct* consequences are (Bernstein, Baxter & Buist, 1986, p. 4): "Health hazards from inhalation exposure to intense airborne concentrations of ash and gases […] or from ingestion of water contaminated with toxic amounts of volcanic minerals" (*immediate*) and "New onset, exacerbation, or acceleration of non-communicable respiratory diseases from frequent, intense, or prolonged exposures to toxic gases and/or respirable-size ash" (*delayed*).

central pillar for every educational system in modern, multicultural societies around the world is school. […]. Cooperative and experiential learning form the core of innovative and ground breaking teaching approaches. […]. The combination of Cartography and Geographical Information Systems (GIS) leads to a faster creation of new, digital, dynamic and interactive maps" which let students "acquire values and abilities that will help them become cognitively aware and develop their […] competences" also useful for decision-making and critical knowledge of problems (Rizou & Klonari, 2016, pp. 254-255). Therefore, GIS and geotechnologies can be neuralgic tools for opening the mind and reinforcing young people's spatial thinking attitudes and competency (Oda, 2016, p. 177) along a process which must at the same time provide – in addition to technical abilities – learning enthusiasm, cognition of concrete issues, individual and then collective feeling of self-efficacy in the case of a possible emergency.

By means of a methodology punctuated by a series of preparatory sequential steps, the applicative goal is to produce a series of highly explicative digital elaborations filleted in a calibrated GIS environment, streamlined with geophysical-statistical, geographic-humanistic and cartographic-satellite components organised in an ad hoc geodatabase. From a concrete point of view, it is possible to operate in a coordinated and integrated system among different scientific disciplinary sectors for the support of activities related to risk management and awareness, emergency preparedness and planning, civil protection operations. Thus, the present project sets out to work towards processes for the optimisation and finalisation of geotechnological interoperability on real case studies and the construction of a performant GIS platform that is preparatory for the promotion of a powerful cartographic and digital modelling for the Vesuvius area which can be also taken as reference for other volcanic areas. In fact, there is a strong need for methodologies and models for volcanic hazard and risk assessment and interpretation, that can be widely and consistently applied (Auker et al., 2015, p. 349), supported by the functionalities of geotechnologies. One of the directions that we are going to follow is the development of a high tech GIS environment, functional to the application research, which will be able to interface and integrate itself with other platforms and system architectures used by scientists, public institutions and policy makers. In this way, specifically harmonized quantitative and qualitative procedures and techniques can interact and support the elaboration of analytic and highly communicative digital representations of the territorial distributions, the study and highlighting of critical local aspects, the reconstruction and forecasting of evolutionary dynamics (Longley & Batty, 1996, p. 1), and the simulation of scenarios in contexts that are greatly exposed to volcanic risk (Scandone, Arganese & Galdi, 1993; Pesaresi et al., 2008).

Working with the ArcGIS Geodatabase

As the core of the entire data storage, the architecture of the geodatabase has a key role in the project, since the huge amount of geographic data that it stores can be easily combined to produce a series of elaborations useful to support the geographical analysis. As an archive created and meticulously organised to manage the quantitative and qualitative data, some of the elements of the ArcGIS geodatabase are used to combine inputs from various spatial references under a common coordinates system, setting the working environment to create a multi-layer map that combines information from different times and themes, valuable for the management of data referred to areas subject to continuous and remarkable changes, and for completely modified territorial assets.

Building the geodatabase involved the research, organisation, georeferencing, integration and processing of several cartographic documents from different periods and formats, such as LIDAR images (DSM, DTM), the shapefile of administrative areas, scanned historical cartographies, census data etc. Mostly, these data were converted in the form of ArcGIS geodatabase items such as Feature Class, Feature Dataset, Mosaic Dataset and Raster Image, and used as the data source of the layers of the project map document. As far as concerns the structure and contents of the geodatabase, all the project data were collected in a file system directory named “Project” which contains a series of directories and the ArcGIS file geodatabase of the project.

At base level (Figure 4), a first division of the content was provided by four folders: “Data”, where all the project data were stored; “Documentation”, dedicated to the documents, such as worksheet, text documents and images used to write notes, reports, comments regarding elaborations, models and functionalities used etc. useful in terms of the progress of the project; and finally “Mxd” and “Sxd”, both containing the map and scene documents of the project.

In the “Data” folder, where the ArcGIS geodatabase is stored, the following items were then created: the “Backup” folder, to periodically save the results of the project, and the “Raster” and “Vector” folders (Tables 1-2), where the concrete data were stored according to their format; as part of the raster collection, the Digital Elevation Model and the satellite images, together with the use of web map services from the Italian National Geoportal and the ArcGIS Basemaps, provided a contemporary vision of the territorial assets, while the ancient cartography, scanned from the paper map collection of the Geographic Unit (Documentary, Linguistics, Philology and Geographic Sciences Department), Sapienza University of Rome, and georeferenced to the more recent layers, was used to compare the differences between the last centuries. The shapefiles collected in the vector data folder were referred to administrative boundaries, transportation network and land use from which to derive the labels and cartographic symbols used to customize the map for sharing purposes.

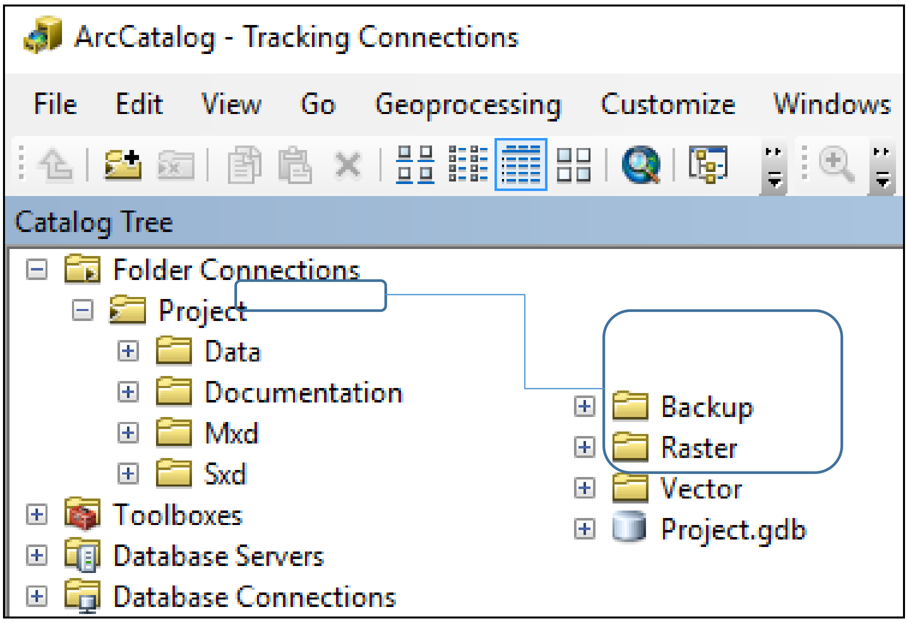

Figure 4. The Project and the Data's directories tree view seen from ArcCatalog.

A subset of the data, limited to the study area, was exported in the form of the items of the geodatabase: different Feature Classes were created in a series of Feature Datasets according to the category of the contents, while the Mosaic Datasets were used to represent and customize a portion of the raster images.

Therefore, the geodatabase structure, together with its clear interface, provides a working environment suitable for the integration of different layers together, from which to generate outputs, multi-layers maps, models, 3D elaborations, geostatistics evaluations to promote the analysis of the spatial transformations of the project area.

The Figures 5-7 represent a portion of the project area (the Somma-Vesuvius complex and a segment of the coast from the eastern part of Naples, upper left corner, to the town of Torre Annunziata, lower right corner) from the nineteenth to the twenty-first century, mapped by combining both vector and raster layers: the vector ones – the sea and the municipality boundaries – describes the territory's departments and focuses the attention on the mainland, where each Mosaic Dataset represents a different epoch according to the data that it contains. Figure 8 shows the same territory from a satellite "Sentinel 2" multiband image, which intensifies the urbanization extent view by representing the near infrared in the red channel.

Table 1
The raster data collection of the project

RASTER		
Name	*Source*	*Brief Description*
Digital Elevation Model	National Institute of	10 meter spatial resolution

	Geophysics and Volcanology (INGV)	Digital Elevation Model presented in 2007
Digital Surface Model	Metropolis city of Naples Territorial Information System	15 cm spatial resolution Digital Surface Model of 2009-2012
“Sentinel 2” Images	United States Geological Survey (USGS)	10 meter spatial resolution multispectral images of the present time
IGM cartography	Italian Geographic Military Institute (IGM)	Topographic cartography of the 1950s, scale 1:25,000
“Carta Topografica ed Idrografica dei contorni di Napoli Levata per ordine di S.M. Ferdinando I: Re del Regno delle due Sicilie dagli uffiziali dello Stato Maggiore e dagl’ ingegneri topografi negli anni 1817. 1818. 1819.”	Kingdom of Naples Topographic Office	Topographic cartography of XIX century (*and others in progress*)

Table 2
The vector data collection of the project

VECTOR		
Name	*Source*	*Brief Description*
Administrative areas	National Institute for Statistics (ISTAT)	Polygon shapefile of Italian administrative areas (and census data)
Corine Land Cover	European Environment Agency	Polygon shapefile of European Land Cover
Campania’s region technical cartography	Campania region	CAD file of 1998 region technical cartography (*and others in progress*)
Transportation network	The Italian Ministry for the Environment Land and Sea	Polyline shapefile of Italian transportation network

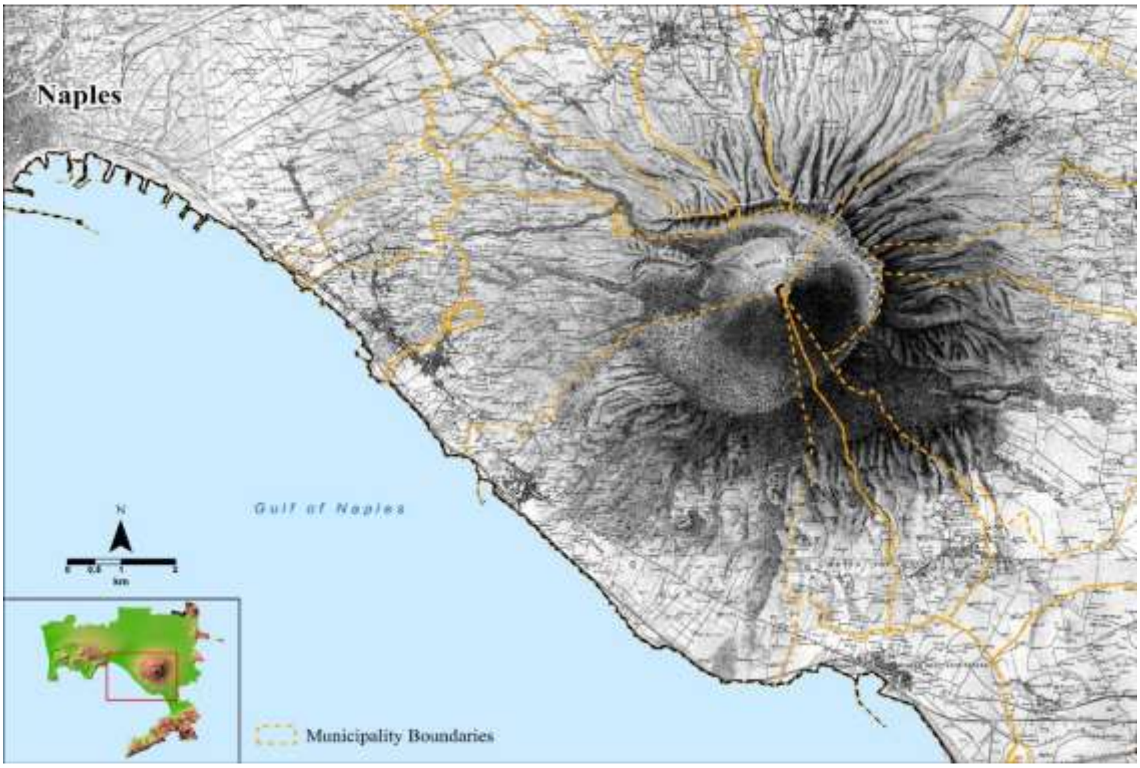

Figure 5. Portion of the Kingdom of Naples map Mosaic Dataset, representing the area around the Somma-Vesuvius complex in the XIX century. Elaboration by D. Pavia & C. Pesaresi.

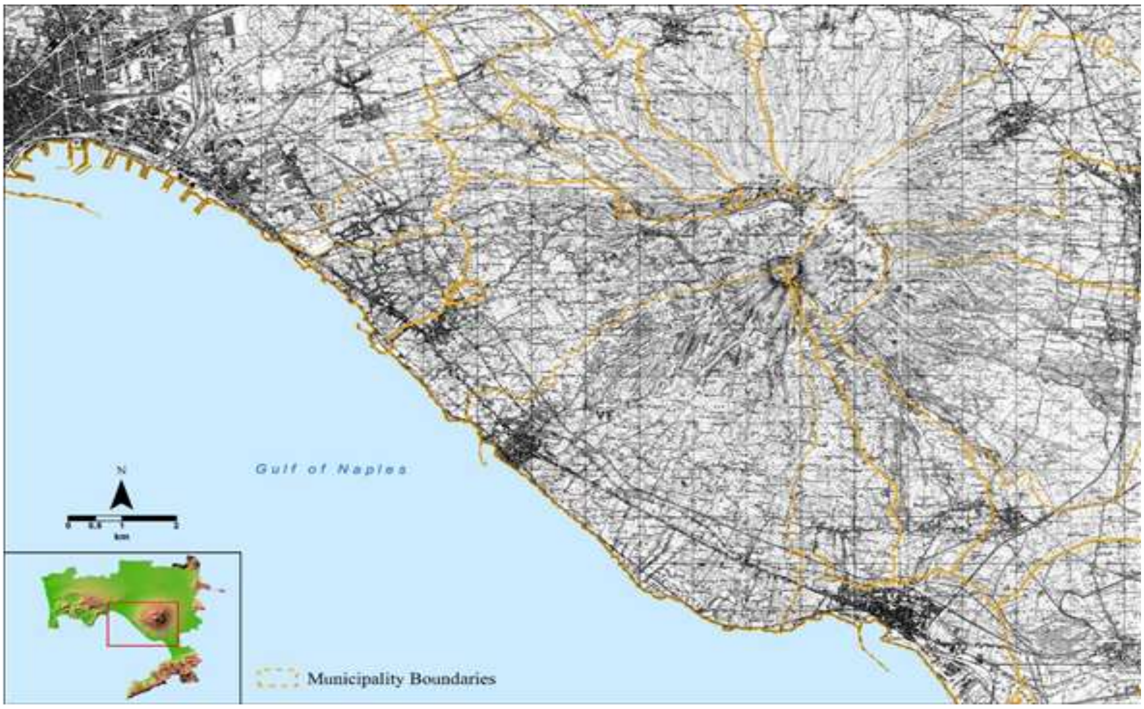

Figure 6. Portion of the IGM's maps Mosaic Dataset, representing the area around the Somma-Vesuvius complex in the XX century. Elaboration by D. Pavia & C. Pesaresi.

Figure 7. Portion of the 2012 Imagery Collection Web Map Service from The Italian Ministry for the Environment Land and Sea collection, representing the area around the Somma-Vesuvius complex in the XXI century. Elaboration by D. Pavia & C. Pesaresi.

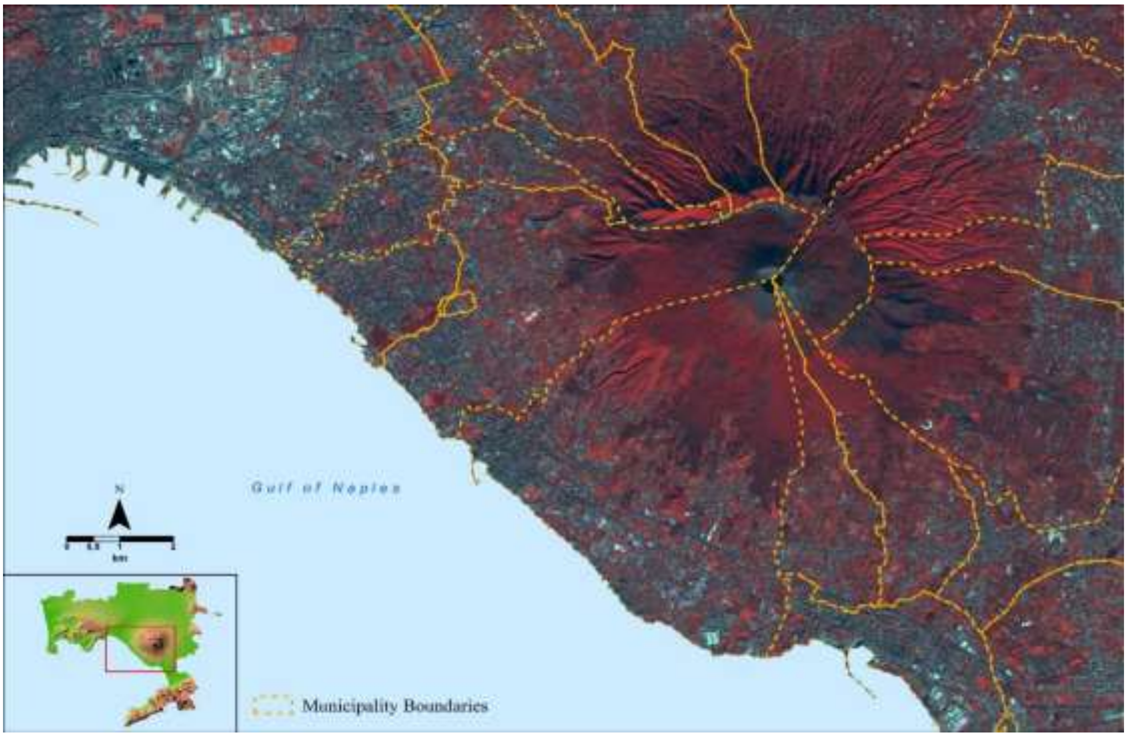

Figure 8. Portion of a “Sentinel 2” multiband imagery, representing the area around the Somma-Vesuvius complex in the XXI century by coloring the vegetation in red. Elaboration by D. Pavia & C. Pesaresi.

Communication and Education

Volcanic eruptions, earthquakes, tsunami, hurricanes, floods and other natural disasters often have huge impact on societies, but during the last decennia there is progression in hazard management. The digital revolution offers opportunities for research and action in the field of hazard management as huge amounts of data can be handled and presented quick and in an interactive way. Computers and the internet really have changed the world. Today more and more scientists, businessmen and policy makers are using the powerful tools of geospatial measurement for data collection, data management, geospatial analysis, and geospatial visualization. Geospatial technology can help to create more sustainable actions throughout the world (Dangermond, 2009). Geospatial technology has many applications but is also very useful to collect, analyse and present data to start measures to prevent disasters in the near future.

However, it is very important that not only policy makers but also citizens are aware of risks and what to do in the case of natural disaster. So a crucial question is how we can use geospatial technology to help people to be better informed about hazard management? How can formal and informal education contribute to inform inhabitants living in an area at risk? The use of geospatial technology in communication and education about hazard management is growing. Though this process goes often slowly as software and trained educators are lacking. Sometimes even the political will to inform people better seems to be missing.

Nevertheless, geospatial technology can help to make a big leap forward. In formal and informal education the growth of free software is a perspective rich development. The maps of Figure 1, 7 and 8 of the Vesuvius area can be part of a free and simple web atlas available for all. This web atlas can be integrated in an app "Is my house safe?". A comparable app "Am I flooded?" was recently developed in the Netherlands by the Ministry of Infrastructure & Environment (see www.overstroomik.nl). This app is very successful in and outside schools and got a lot of attention in the media. A comparable app can be developed for the threat of the Vesuvius with information about the dangerous zones in the area and what to do in case of a volcanic eruption. This should be accessible by every mobile phone and computer at any moment. It should contain digital maps of the expected flows of eruptions of the Vesuvius, maps of relief, roads, dangerous and safe areas, lists of things to do and how to be prepared. A team of policy makers, scientists, and IT and communication experts can develop such an app in an efficient and effective way.

In primary and secondary schools geography lessons environmental projects can help students to study hazard management in their local area. Teachers should train students in system thinking. The threat of a volcanic eruption can be seen as a chain of successive events that take place prior to and during the eruption. Bosschaart (2015, p. 101) states that in formal education a variety of learning activities is needed that facilitates experiential (experiences and feelings) as well as analytical information processing. Bosschaart used blended learning in his study about improving flood-risk perception of 15-year-old students in the Netherlands. Apart from a serious game, a 2-D simulation, a societal discourse, fieldwork and a problem-oriented group assignment were part of his project. Compared with a control group the intervention program showed a significant increase with respect to the perception of flood exposure (Bosschaart, 2015, p. 104). This blended learning approach seems can also be useful for studying hazard management in the area of Naples and elsewhere.

Apart from smart apps with digital maps for all and blended learning education packages in primary and secondary education there is a third and more important element of successful learning about geographical and environmental issues like hazard management. This third component consists of thinking skills and systematic disciplinary knowledge. It is important to train pupils to think about what they see and do, to learn them how things in our world are related, and also that in many situations there is not one solution or correct answer (Leat, 1998). Pupils have to realize that in many cases there are different options. Leat introduced “The great Kanto earthquake, Tokyo, 1923” as a thinking through geography strategy in a unit of lessons on the structure of natural hazards, once the students had a good idea of plate tectonics, volcanoes and the cause and effects of volcanic eruptions. To study the human response to natural disasters students were given a collaborative group work exercise to classify 32 pieces of information. Figure 9 shows 5 examples out of the set of 32. The students where asked to explain a) why earthquakes happen at plate boundaries; b) why the effects of the earthquake in 1923 in Tokyo were so bad; c) what the human response to the earthquake was, and d) which are the most effective strategies in saving lives and why? (Leat, 1998, p. 121). A similar classification exercise can easily be developed for “The Vesuvius eruption, Naples, 1944” or “The great hypothetical Vesuvius earthquake, Naples, 2023”. This can even be done with digital maps and other modern information tools in combination with statements on pieces of paper. An alternative is to ask students to do the Kanto earthquake exercise and then to develop the materials for the Vesuvius eruption exercise. Anyway, most important is the debriefing in which students should report what they have learnt from the exercise and what strategies seem to be most effective in saving lives. Exploring connections to other contexts is also a good way to stimulate thinking skills and extending geographical understanding.

1. Many people died when their feet got stuck in melting tarmac.
2. The harbour was flooded by a tsunami.
3. Every September 1st is Japan’s “Disaster Day” and people practice earthquake drills.
4. Many modern buildings have shock-absorbers built into them.
5. Japan lies on the boundary of the Eurasian Plate and stresses build up.

Figure 9. Examples from resource sheet 2 from “The great Kanto Earthquake, Tokyo, 1923”. Elaboration on Leat, 1998, pp. 119-120.

All education is for the future (Pauw, 2015) and there are probable, possible and preferable futures (Bell, 2009). That is also true for the area near the Vesuvius. The question is how to be prepared well for what might happen? Although school knowledge is not always focused on the future, new ways of thinking and modern technology make it possible to be informed about threats and options. Formal and informal education both can play an essential role to improve the eruption-risk perception of all inhabitants of the area near the Vesuvius. If policy makers are slow in improving risk perception, modern tools can help people to work bottom-up. Nowadays young people are becoming increasingly more familiar with engaging with geographic information in informal settings. Public Participatory GIS (PPGIS) is an approach where local community issues drive the use of technology and where there is a stronger emphasis on community involvement with GIS (Fargher, 2013, p. 209).

References

Auker, M.R., Sparks, R.S.J., Jenkins, S.F., Aspinall, W., Brown, S.K., Deligne, N.I., Jolly, G., Loughlin, S.C., Marzocchi, W., Newhall, C.G. & Palma, J.L. (2015). Development of a new global Volcanic Hazard Index (VHI). In Loughlin, S., Sparks, S., Brown, S., Jenkins, S. & Vye-Brown, C. (eds.), *Global Volcanic Hazards and Risk* (pp. 349-357). Cambridge University Press.

Baiocchi, V. & Pesaresi, C. (2015). GIS4RISKS: Geographic Information System for Risk Image – Safety Key. A methodological contribution to optimise the first geodynamic post-event phases and to face emergencies. *Journal of Research and Didactics in Geography (J-READING)*, *2* (4), 25-37.

Barberi, F., Davis, M.S., Isaia, R., Nave, R. & Ricci, T. (2008). Volcanic risk perception in the Vesuvius population. *Journal of Volcanology and Geothermal Research*, *172*, 244-258.

Bell, W. (2009). Foundations of futures studies, volume I: History, purposes and knowledge. New Brunswick: Transaction.

Bernstein, R.S., Baxter, P.J. & Buist, A.S. (1986). Introduction to the Epidemiological Aspects of Explosive Volcanism. *American Journal of Public Health*, *76* (Supplement), 3-9.

Bosschaart, A. (2015). Dry feet in the polder? Improving flood-risk perception of 15-year-old students in the Netherlands. Amsterdam: Ipskamp.

Carlino, S., Somma, R. & Mayberry, G.C. (2008). Volcanic risk perception of young people in the urban areas of Vesuvius: Comparisons with other volcanic areas and implications for emergency management. *Journal of Volcanology and Geothermal Research*, *172*, 229-243.

Cioni, R., Bertagnini, A., Santacroce, R. & Andronico, D. (2008). Explosive activity and eruption scenarios at Somma-Vesuvius (Italy): Towards a new classification scheme. *Journal of Volcanology and Geothermal Research*, *178*, 331-346.

Dangermond, J. (2009). Foreword. In Scholten, J., Velde, R. van de & Manen, N. van (eds.), *Geospatial Technology and the Role of Location in Science.* Dordrecht: Springer.

D'Aponte, T. (2005). Il "rischio vulcanico" tra approccio scientifico e suggestione artistica. In D'Aponte, T. (ed.), *Terre di vulcani. Miti, linguaggi, paure, rischi* (pp. 11-19), vol. 2. Rome: Aracne.

Davis, M.S., Ricci, T. & Mitchell, L.M. (2005). Perceptions of Risk for Volcanic Hazards at Vesuvio and Etna, Italy. *The Australasian Journal of Disaster and Trauma Studies, 1*

Dipartimento della Protezione Civile – Commissione Nazionale Incaricata di Provvedere all'aggiornamento dei Piani di Emergenza dell'area Vesuviana e Flegrea per il Rischio Vulcanico 2010 (30.04.2012). Scenari Eruttivi e Livelli di Allerta per il Vesuvio, prot. n. 0029251.

Esposti Ongaro, T., Neri, A., Menconi, G., de' Michieli Vitturi, M., Marianelli, P., Cavazzoni, C., Erbacci, G. & Baxter, P.J. (2008). Transient 3D numerical simulations of column collapse and pyroclastic density current scenarios at Vesuvius. *Journal of Volcanology and Geothermal Research, 178*, 378-396.

Fargher, M. (2013). Geographic Information (GI) – how could it be used? In Lambert, D. & Jones, M. (eds.), *Debates in Geography Education* (pp. 206-218). London: Routledge.

Gasparini, M.L. (2005). Dinamiche demografiche e tendenze insediative nell'area vesuviana. In D'Aponte, T. (ed.), *Terre di vulcani. Miti, linguaggi, paure, rischi* (pp. 217-229), vol. 2. Rome: Aracne.

Giacomelli, L., Perrotta, A., Scandone, R. & Scarpati, C. (2003). The eruption of Vesuvius of 79 AD and its impact on human environment in Pompei. *Episodes*, *26* (3), 234-237.

ISTAT (years 1951-2011), *Censimento generale della popolazione e delle abitazioni*. Rome.

Leat, D. (1998). *Thinking Through Geography*. Cambridge: Chris Kington Publishing.

Longley, P. & Batty, M. (1996). Analysis, modelling, forecasting, and GIS technology. In Longley, P. & Batty, M. (eds.), *Spatial Analysis: Modelling in a GIS Environment* (pp. 1-16). New York: John Wiley & Sons.

Neri, A., Esposti Ongaro, T., Macedonio, G. & Gidaspow, D. (2003). Multiparticle simulation of collapsing volcanic columns and pyroclastic flow. *Journal of Geophysical Research, 108* (B4), pp. 24.

Neri, A., Esposti Ongaro, T., Menconi, G., de' Michieli Vitturi, M., Cavazzoni, C., Erbacci, G. & Baxter, P.J. (2007). 4D simulation of explosive eruption dynamics at Vesuvius. *Geophysical Research Letters, 34*, pp. 7.

Neri, A., Esposti Ongaro, T., Voight, B. & Widiwijayanti, C. (2015). Pyroclastic Density Current Hazards and Risk. In Papale, P. (ed.), *Volcanic Hazards, Risks, and Disasters* (pp. 109-140). Amsterdam: Elsevier.

Oda, K. (2016). Concept Maps as a Tool to Analyse College Students' Knowledge of Geospatial Concepts. *Review of International Geographical Education Online (RIGEO), 6* (2), 176-198.

Pauw, I. (2015). Educating for the future: the position of school geography. *International Research in Geographical and Environmental Education*, *24* (4), 307-324.

Pesaresi, C. (2005). La geografia e i sistemi informativi geografici: l'esperienza in una scuola di Roma. In Bertoncin, M., Faggi, P., Gamberoni, E. & Pase, A. (eds.), *Cinquantenario dell'AIIG 1954-2004. "La grande trasformazione". Il Veneto fra tradizione e innovazione* (pp. 193-202). Padua: Università di Padova.

Pesaresi, C. (2012). Le potenzialità dei GIS percepite in alcune scuole della provincia di Salerno. In Bozzato, S. & Reali, R. (eds.), *GIS e Territorio. Laboratori sperimentali per una nuova didattica della Geografia* (pp. 11-25). Rome: Società Geografica Italiana, Collana Studi e Ricerche, *23*.

Pesaresi, C. (2016). Le geotecnologie per una didattica costruttivista-interdisciplinare e per un approccio cooperativo. In De Vecchis, G., *Insegnare geografia. Teoria, metodi e pratiche* (pp. 113-133). Novara: UTET Università, De Agostini.

Pesaresi, C. & Lombardi, M. (2014). GIS4RISKS project. Synergic use of GIS applications for analysing volcanic and seismic risks in the pre and post event. *Journal of Research and Didactics in Geography (J-READING)*, *2* (3), 9-32.

Pesaresi, C. & Marta, M. (2014). Applicazioni GIS per l'analisi dell'urbanizzazione nella provincia di Napoli. Un'analisi multitemporale in aree esposte a elevato rischio vulcanico. *Bollettino dell'Associazione Italiana di Cartografia*, *150*, 34-51.

Pesaresi, C., Marta, M., Palagiano, C. & Scandone, R. (2008). The evaluation of "social risk" due to volcanic eruptions of Vesuvius. *Natural Hazards*, *47*, 229-243.

Pesce, A. & Rolandi, G. (1994). *Vesuvio 1944. L'ultima eruzione*. S. Sebastiano al Vesuvio.

Rizou, O. & Klonari, A. (2016). Introducing 3D Visualization of Statistical Data in Education Using the i-Use Platform: Examples from Greece. *Review of International Geographical Education Online (RIGEO)*, *6* (3), 253-270.

Rosi, M., Principe, C. & Vecci, R. (1993). The 1631 Vesuvius eruption. A reconstruction based on historical and stratigraphical data. *Journal of Volcanology and Geothermal Research Volume*, *58* (1-4), 151-182.

Santacroce, R., Cioni, R., Marianelli, P., Sbrana, A., Sulpizio, R., Zanchetta, G., Donahue, D.J. & Joron, J.L. (2008). Age and whole rock–glass compositions of proximal pyroclastics from the major explosive eruptions of Somma-Vesuvius: A review as a tool for distal tephrostratigraphy. *Journal of Volcanology and Geothermal Research*, *177*, 1-18.

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

Scandone, R. & Giacomelli, L. (2014). Vesuvius, Pompei, Herculaneum: a lesson in natural history. *Journal of Research and Didactics in Geography (J-READING)*, *2* (3), 33-41.

Scandone, R., Giacomelli, L. & Fattori Speranza, F. (2006). The volcanological history of the volcanoes of Naples: a review. In De Vivo, B. (ed.), *Volcanism in the Campania Plain: Vesuvius, Campi Flegrei and Ignimbrites* (pp. 1-26). Amsterdam: Elsevier.

Scandone, R., Giacomelli, L. & Gasparini, P. (1993). Mount Vesuvius: 2000 years of volcanological observations. *Journal of Volcanology and Geothermal Research*, *58*, 5-25.

Spence, R., Gunesekara, R. & Zuccaro, G. (s.d.). *Insurance risks from volcanic eruptions in Europe*. Willis Research Network, pp. 1-26.

Tarquini, S., Isola, I., Favalli, M., Mazzarini, F., Bisson, M., Pareschi, M.T. & Boschi, E. (2007). TINITALY/01: a new Triangular Irregular Network of Italy. *Annals of Geophysics*, *50*, 407-425.

Tarquini, S., Vinci, S., Favalli, M., Doumaz, F., Fornaciai, A. & Nannipieri, L. (2012). Release of a 10-m-resolution DEM for the Italian territory: Comparison with global-coverage DEMs and anaglyph-mode exploration via the web. *Computers & Geosciences*, *38*, 168-170.

Biographical statements

Cristiano PESARESI is Researcher in Geography at Sapienza University of Rome, where he is Scientific Responsible for the GeoCartographic Laboratory of Documentary, Linguistics, Philology and Geographic Sciences Department and where he is President of the degree Course in Geographic science for environment and health. His research often focuses on the geographical analysis of volcanic risk with the support of GIS.

Joop VAN DER SCHEE is Emeritus Professor at Faculty Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, and he has been Co-chair of the International Geographical Union (IGU) – Commission on Geographical Education. He is professor for geography education appointed by the Royal Duch Geography Society. His research focuses on (digital) map skills and thinking through geography.

Davide PAVIA is research grants at Documentary, Linguistics, Philology and Geographic Sciences Department, Sapienza University of Rome, and he is Consultant in ESRI Italia. His research focuses on the geographical use of geotechnologies.