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Multiphase procedure for landscape reconstruction and their evolution analysis. GIS modelling for areas exposed to high volcanic risk

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Abstract

This paper – focussed on the province of Naples, where many municipalities with a huge demographic and building density are subject to high volcanic risk owing to the presence of the Campi Flegrei (Phlegrean Fields) caldera and the Somma-Vesuvius complex – highlights the methodological-applicative steps leading to the setting up of a multiphase procedure for landscape reconstruction and their evolution analysis. From the operational point of view, the research led to the: (1) digitalisation, georeferencing and comparison of cartographies of different periods of time and recent satellite images; (2) elaboration and publication of a multilayer Story Map; (3) accurate vectorisation of the data of the buildings, for each period of time considered, and the use of kernel density in 2D and 3D; (4) application of the extrusion techniques to the physical aspects and anthropic structures; (5) production of 4D animations and film clips for each period of time considered. A procedure is thus tested made up of preparatory sequences, leading to a GIS modelling aimed at highlighting and quantifying significant problem areas and high exposure situations and at reconstructing the phases which in time have brought about an intense and widespread growth process of the artificial surfaces, considerably altering the features of the landscape and noticeably showing up the risk values. In a context characterised by land use conflicts and anomalous conditions of anthropic congestion, a diagnostic approach through images in 2D, 3D and 4D is used, with the aim to support the prevention and planning of emergencies, process damage scenarios and identify the main intervention orders, raise awareness and educate to risk, making an impact on the collective imagination through the enhancement of specific geotechnological functionalities of great didactic interest.

Keywords: 4D Animations, Building Density, Georeferencing, GIS Modelling, Kernel Density, Multilayer Story Map, Multiphase Procedure, Naples Province, Three-dimensional Representations, Volcanic Risk

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1. Aims of the research and features of the study area

This work, focussed on the province of Naples – from 1st January 2015 Metropolitan city of Naples, as set down by Act No. 56 of 7th April 2014 – pursues a number of aims which can be summarised in the points below[1].

- Identify reference periods and highly explanatory cartographic sources to produce, by means of accurate georeferencing, elaborations that make it possible to reconstruct the main physical-morphological and anthropic aspects of different periods of time.
- Highlight, with special effects and the overlay of layers, the dynamics leading to the present urban-settlement structure, stressing the risk values and possible losses.
- Create a multilayer analysis environment aimed at territorial screening with an interdisciplinary approach, for both provincial and sub-provincial scale analysis whereby to recognise macroaggregates blended together in a one off with no empty spaces, and studies on a local scale to emphasise dynamics and specific cases of singular atypicalness.
- Share and circulate the results obtained with web applications and Story Maps that make it possible to reach a vast and mixed range of users and which can be easily consulted, drawing from this for interesting inputs in didactic-educational terms too.
- Quantify the differences, with functionalities of spatial and temporal analysis, and recognise the phases of greatest demographic and building growth, returning significant representations of these.
- Produce a GIS modelling which by extrusion makes it possible to three-dimensionally represent the contexts in question and to define suitable damage scenarios on the basis of buildings' end use, the values of the area and volume and economic parameters.
- Apply specific functionalities and overlay of layers to the two-dimensional and three-dimensional models to maximise the level of deductible information for rational emergency planning and management.
- Produce 4D animations and film clips that make it possible to match the accuracy of the research with a strong aesthetic-figurative impact, also with the purpose of creating a strong active involvement by the population and institutions and to move towards a widespread communication of and awareness to risk.

These aims were drawn up in consideration of the specific features of the study area from a number of perspectives regarding for example the following aspects[2].

1. The presence of two volcanic systems, two "fires" that grip the city of Naples and expose the population of many municipalities to high risk and potential dramatic consequences should any eruptive activity begin. This refers to: the Campi Flegrei caldera, generated following highly explosive eruptions and characterised by a series of monogenic cones situated in a context of deep collapses; and the Somma-Vesuvius complex, distinguished by the compresence of Monte Somma – older and broken up for the most part – and Vesuvius, conical in shape and partially surrounded by the remains of Monte Somma, giving the peculiar fence aspect.

   In particular, the Campi Flegrei were the protagonists in two terrifying eruptions, the *Campanian Ignimbrite* (about 39,000 years ago; VEI=7) and the *Neapolitan Yellow Tuff* (about 15,000 years ago; VEI=6), both responsible for far-reaching land upheavals (Lirer, Luongo and Scandone, 1987; Orsi and Zollo, 2013). In the last 10,000 years, other explosive eruptions from different cones have been recorded, while the last eruption – the only one widely documented in the historical period[3] – occurred in 1538 and was a moder-

[1] This work is the result of the activities conducted and the elaborations produced in the context of the Projects "*GIS4RISKS. Synergic use of GIS applications for analysing volcanic and seismic risks in the pre and post event*" and "*3D and 4D Simulations for Landscape Reconstruction and Damage Scenarios. GIS Pilot Applications*", both funded by the Sapienza University of Rome and of which Cristiano Pesaresi is the Scientific Responsible.

[2] For an in-depth examination of these aspects, see Pesaresi and Pavia, 2017a.

[3] The event at the Solfatara in 1198 could be added, which has been defined "at most a minor phreatic explo-

ate event which led to the formation of Monte Nuovo and marked the beginning of a long phase of quiescence (Bianchi et al., 1987; Del Gaudio et al., 2010; Scandone and Giacomelli, 2013). Since this last eruption, some relevant vertical ground movements have been recorded and the most worrying uplift episodes occurred in 1970-1972 and 1982-1985, provoking also tangible and questionable building construction works (Gasparini, 2013; Luongo, 2013), always in zones highly exposed to eruptive phenomenologies.

The Somma-Vesuvius history has been marked by events considerably different in intensity, heights of the generated columns and typology of emitted products, and in the historical period a large number of eruptions and peculiar cycles occurred (Santacroce et al., 2008; Pesaresi, van der Schee and Pavia, 2017). While the eruption of 79 A.D. has been the strongest of the last 2,000 years (VEI=5-6), the eruption of 1631 (VEI=4) is very important for the interpretation of possible precursory phenomena (Rosi, Principe and Vecci, 1993; Rolandi, Barrella and Borrelli, 1993) also because it is considered the reference scenario in terms of civil protection and organization of possible emergency and evacuation operations. In short, infrequent explosive events happened during the period from 79 A.D. to 1631, which represents the last sub-Plinian event, while from 1631 to 1944, when the last eruption was recorded, Vesuvius was characterised by persistent and peculiar activity with a series of short and mild explosive and longer effusive eruptions (Scandone, Giacomelli and Gasparini, 1993; Scandone, Giacomelli and Fattori Speranza, 2008).

2. The fragility and atypicalness of the settlement condition, owing to the explosive values of demographic density and the impressive and anomalous amount of artificial surfaces. Furthermore, if compared to the other provinces of the Campania region, the Naples province (with a population density of 2,591 inhabitants/Km^2 and the highest value in Italy) appears as a peerless "magnet" and along the coastal zone and the hinterland a unique huge offshoot which has its origin in Naples city has developed towards all directions (Pesaresi, van der Schee and Pavia, 2017, pp. 135-136). Above all in the last two decades, signs of demographic re-dimensioning have been seen in some municipalities exposed to high risk in the Vesuvius area, but this has instead not happened in the municipalities more subject to risk in the Phlegrean area. Moreover, this has often just consisted in a phenomenon of redistributing the population towards other nearby municipalities, which have thus been subject to increased exposure values (Pesaresi and Scandone, 2013). Furthermore, the artificial surfaces and building density continue to generally increase, creating situations of exacerbated overcrowding and compression of spaces (Pesaresi and Marta, 2014), significantly altered, damaged and characterised by incumbent environmental issues and inadequate usage and management (Pollice, 2009). Endless rows of buildings, the encroaching of one municipality onto another, astonishing growth of the overall settlement fabric thus connote a context that is increasingly more saturated and chaotic (D'Aponte, 2005; Gasparini, 2005; La Foresta, 2005; Leone, 2013). All this becomes more evident in a province than can boast a first-order historical-cultural-artistic heritage, where the archaeological areas of Pompeii and Herculaneum stand out, where it is possible to dive into the daily life of two millennia ago, which was suddenly interrupted and at the same time preserved by the flows and deposits of the eruption of Vesuvius in 79 A.D. This increases the levels of risk even more so with respect to the possible losses and leads one to reflect on the imbalances, the conflicts regarding the land use, the frequent situations of neglect that have come about in time and often appear to be unequivocal.

3. The different pieces of research which were carried out to evaluate the exposure and the level of hazard and risk in the area surrounding Vesuvius and the Phlegrean Fields, using various functionalities, numerical simulations and by producing accurate GIS applications, in order to consider the various parameters

sion" (Scandone, D'Amato and Giacomelli, 2010, p. 202).

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and to study the territory in its diversified interrelated components. For example, for the Naples province, GIS have been used to assess the volcanic risk integrating the hazard maps with the urbanization maps (Alberico et al., 2002) or with the exposure maps based on the economic value of structures possibly exposed (Alberico, Petrosino and Lirer, 2011), and events with different volcanic explosivity index were considered. GIS have been also used to evaluate the "social risk" due to volcanic eruptions obtained combining the demographic risk per number of inhabitants, the demographic risk per population density, and the infrastructural risk per number of houses (Pesaresi et al., 2008). Moreover, GIS have been used to simulate, in case of eruption, the seismic damage scenario and the buildings collapsed, the damage distribution due to ash fall, the pyroclastic flows impact and the cumulative damage distribution after the pyroclastic flows (Zuccaro et al., 2008). And then GIS models have been defined for volcanic hazard prediction (Renschler, 2005) while numerical simulations – using a 3D flow model based – were applied to represent a possible eruptive column collapse and a consequent pyroclastic density current scenario (Esposti Ongaro et al., 2008) and to provide the 4D dynamics of explosive events and their distribution and evolution (Neri et al., 2007). Other methodological and applicative contributions have used GIS as founding elements to propose interdisciplinary models, in order to harmonize the technical-physics approach with the anthropic-social one in integrated research, and to conduct synoptic and diachronic screening useful for risk management and awareness, for emergency planning and the detection of specific problems (Pesaresi and Lombardi, 2014; Pesaresi, van der Schee and Pavia, 2017).

2. The methodological-applicative steps of the research

The methodological-applicative steps of the research led to the definition of a multiphase procedure, from the geotechnological viewpoint conducted with ArcGIS Desktop, and relative extensions (among which first of all ArcGIS 3D Analyst and ArcGIS Spatial Analyst), and ArcGIS Pro. During the different phases, a powerful and integrated geodatabase built as the pivotal part of the system was continuously expanded, updated and integrated. Data and information – quantitative, qualitative, spatial, from geoportals, cartographic, satellite and technical works, Digital Terrain Model (DTM), Digital Surface Model (DSM) etc. – flowed into the geodatabase coming from numerous sources and linked with the same reference systems and geographic coordinates to produce a waterfall of digital elaborations at various geographical scales, in 2D, 3D and 4D, where moreover historical cartography, recent satellite images and ad hoc functionalities hook up together to give back distribution patterns and evolutive trends. The consequentially defined set of steps has made it possible to work with a GIS modelling, making it possible to move as if carrying out territorial diagnostics by images, functionally to the applied research of a geographical-interdisciplinary nature.

2.1 First step: digitalisation, georeferencing and comparison of cartographies of different periods of time and recent satellite images

The first step consisted in a series of operations of digitalisation and georeferencing of cartographies of different periods of time and recent satellite images, in visible light and false colours, to then be able to carry out a rigorous overlapping and comparison of the layers. As reference cartographies, the following were selected: the "*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.*" (updated to the early 1860s)[4] and the "Tavolette" of the *Istituto Geografico Militare* (IGM) dating back to the mid-1950s. With regard to the recent satellite images, reference was made to the or-

[4] Owing to its aesthetic importance and accuracy, such work can in fact be considered a cartographic support of fundamental importance in the research regarding the Bourbon Kingdom during the nineteenth century (Valerio, 1995; Conti, 2005).

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thorectified images of the *Geoportale Nazionale* in visible light, along with the ArcGIS basemaps, and images in false colours of the "Sentinel 2". In this way three ages of reference were identified (nineteenth century, mid-1950s, up until today) supported by cartographies of a high level of quality, contents and geographical information and by high resolution satellite images.

The comparative analysis of the layers (Figure 1), in terms of macroaggregates, made it possible to identify four main areas of uncontrolled building development, made up of (1) the coastal zone, (2) the Phlegrean area, (3) the municipalities surrounding the northern side of Monte Somma and (4) the municipalities developed to the north of Naples. In these cases, the levels of building density has exploded like wildfire, creating evident situations of coalescence and connection among neighbouring municipalities. In order to facilitate the combined visualisation of georeferenced materials, the *swipe* effect was used, applied north-southwards and west-eastwards on different associations of layers, so as to observe the changes that have taken place in a progressive and detailed way.

Focussing the attention in particular on the coastal zone facing Vesuvius and on the Phlegrean area, since they are vitally important in terms of hazard and volcanic risk, it was possible to recognise specific dynamics and local peculiarities for each single municipality and the level of detail of the reconstruction of the dynamics has increased thus corroborating the information to be gleaned from the layers with the demographic census data (starting from the first data collection, going back to 1861). Therefore, for each municipality four sets of elaborations were produced with the same scale and the same technical features and graphic layout, operating with the interpretation of images and analysis of statistical data (Figure 2).

Moreover, the integrated use of cartography and satellite images in a GIS environment makes it possible to develop a powerful synergy among different sources since, for example by using transparency effects, the satellite images are enriched with the symbols and placenames deriving from the cartography and thus become more communicative and easy to interpret. In this way, the information referred to the cartography is automatically transmitted to the satellite images, considerably increasing their explanatory power and it is possible to move towards a very efficient language of images, which are gathered in a geo-informatics dialoguing system.

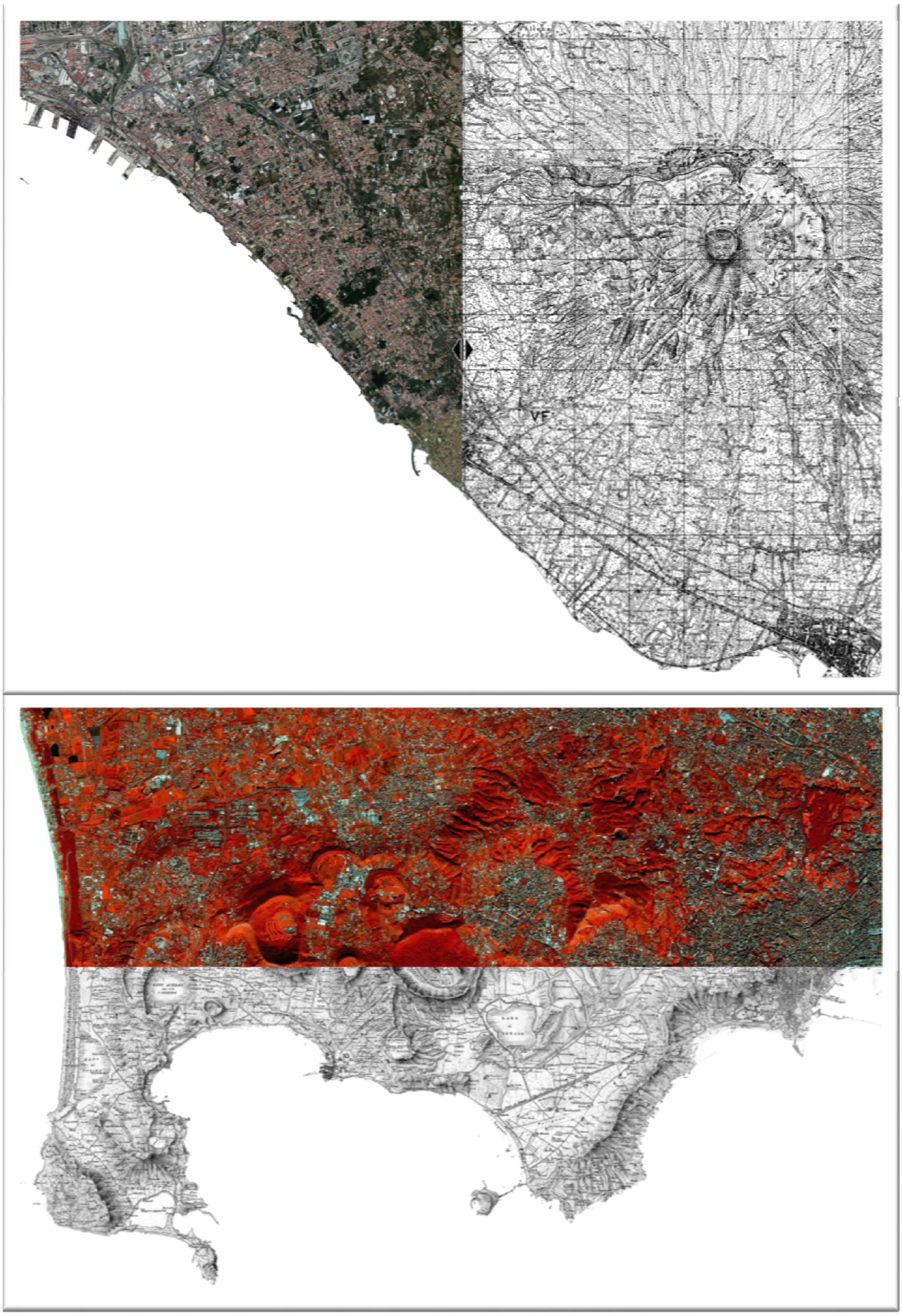

Figure 1. Application of the *swipe* effect onto the coastal zone facing Vesuvius: between the recent satellite images in visible light and the IGM "Tavolette" (above). Application of the *swipe* effect onto the Phlegrean area: between the recent satellite images in false colours and the "*Carta Topografica ed Idrografica dei contorni di Napoli…*" (below). Source: Authors' elaboration.

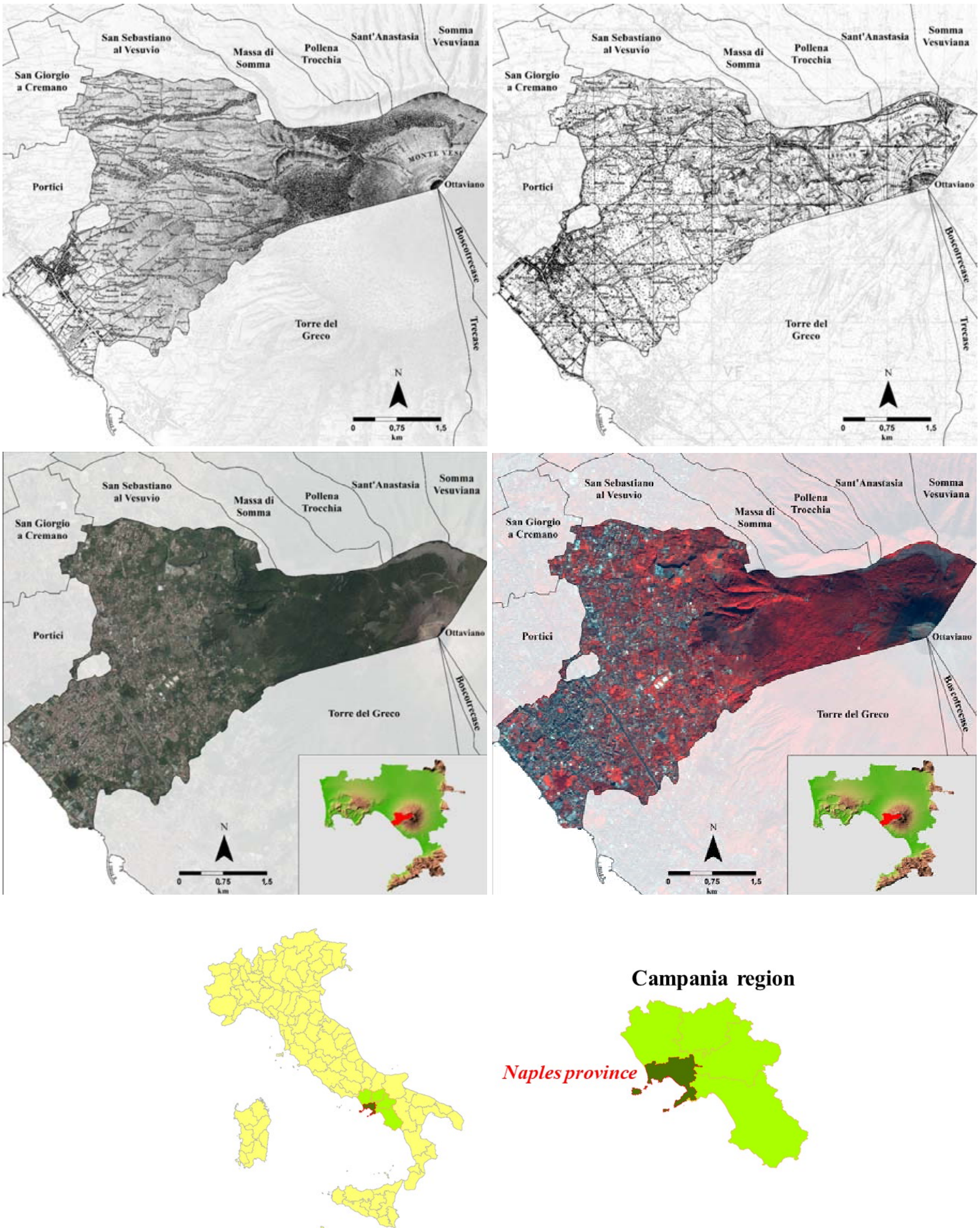

Figure 2. The municipality of Ercolano (Resina until 1969) in the XIX century (above left), in the mid-1950s (above right), to its present state in the satellite images in visible light (below left) and in the satellite images in false colours (below right). Source: Authors' elaboration.

2.2 Second step: elaboration and publication of a multilayer Story Map

The second step consisted in developing and publishing a multilayer Story Map (https://geosapienza.maps.arcgis.com/apps/StorytellingSwipe/index.html?appid=267e4b2118d34a16978fc03d6578ea53; *translated in English at* https://geosapienza.maps.arcgis.com/apps/StorytellingSwipe/index.html?appid=e0598d2af3664414a8853e3c042fb55a), able to highlight the results obtained and to enhance, in an integrated way, the huge quantity of cartographic and satellite materials used and georeferenced. The Story Maps – constructed according to appropriate modalities, objectives and contents – in fact make it possible to share some themes and results of the research on the web and to attract the attention of a great number of people, above all young people who are otherwise difficult to reach, thus making inroads into their collective imagination by using means and systems congenial to them. As the basic template, *spyglass* was chosen for this purpose, which makes it possible to move a lens, above the recent satellite images in visible light, that shows the other layer zone by zone, represented by the mosaic of the IGM "Tavolette", so as to facilitate the temporal comparison and an accurate analysis of the changes and main lines of development over the almost sixty year period intervening (Figure 3A). A link was associated to this main elaboration – which represents the matrix of the multilayer application produced – leading to a second possibility of visualisation. In this case, the *swipe* effect was used to be able to consult the IGM "Tavolette" superimposing them onto the satellite images in false colours, where the cold shades of the blue and grey emphasise the built-up areas (Figure 3B). In this way integrative information can be gathered in preparation for the territorial screening, to be conducted in a distributive and evolutive way. Moreover, in order to embrace the entire time span and add additional pieces, another link was associated with the main elaboration which leads to a third possibility of consultation. The *spyglass* was then used once more, this time between the recent satellite images in visible light and the "*Carta Topografica ed Idrografica dei contorni di Napoli…*" (Figure 3C). So, it is possible to observe and evaluate the radical transformations recorded in physical-morphological (considering that Vesuvius was very active) and urbanistic-settlement terms in the long period.

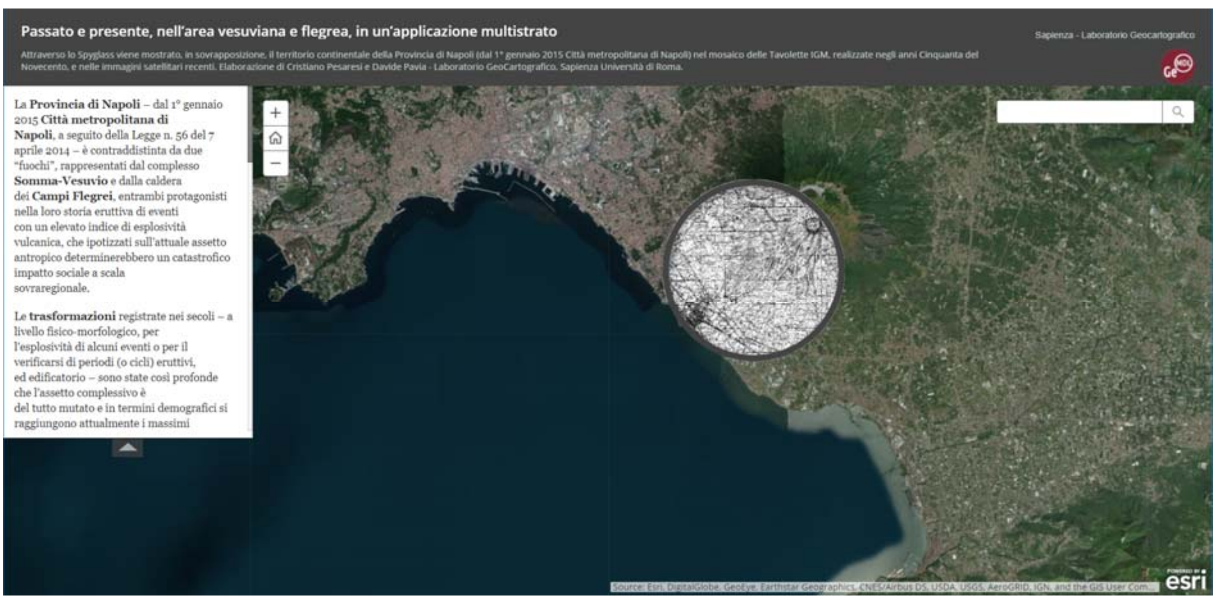

Figure 3. The multilayer Story Map. Here (A), the *spyglass* makes it possible to move a lens, above the recent satellite images in visible light, that shows the other layer represented by the mosaic of the IGM "Tavolette".
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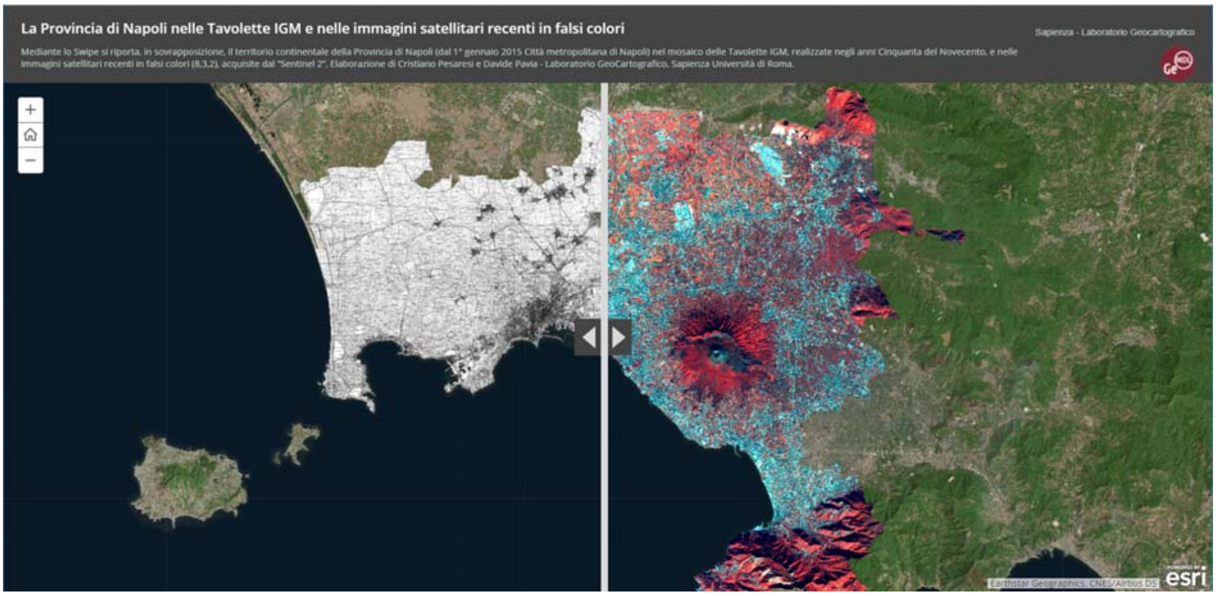

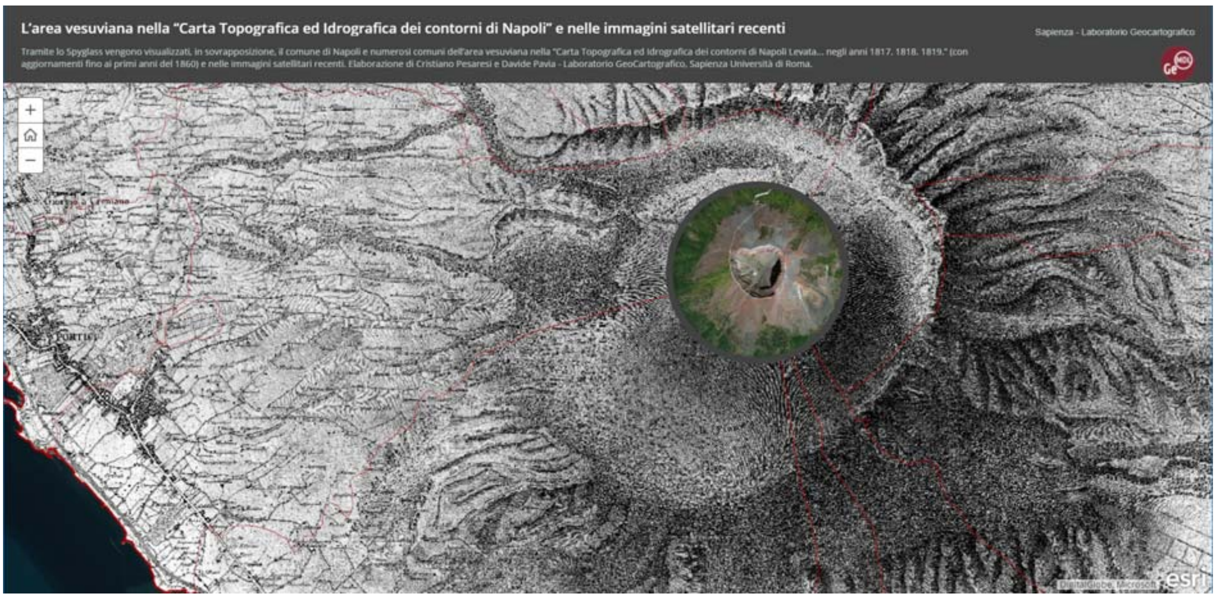

[*continued from the previous page*]

Above (B), the *swipe* effect makes it possible to consult the IGM "Tavolette" superimposing them onto the satellite images in false colours. Below (C), the *spyglass* makes it possible to move a lens, above the "*Carta Topografica ed Idrografica dei contorni di Napoli…*", showing the other layer represented by the recent satellite images in visible light. Source: Authors' elaboration.

2.3 Third step: accurate vectorisation of the data of the buildings, for each period of time considered, and the use of kernel density in 2D and 3D

The third step consisted in the accurate vectorisation of the data of the buildings in the three periods of reference and in the application of the kernel density function to translate the visual information into specific data and quantify the transformations. In this way it was possible to pass from a phase of detailed analysis and visual interpretation to a phase of "generation" of numerical data aimed at measuring the entity of the changes. It was calculated that: from the mid-1950s onwards the province of Naples more than doubled its building density, while from the period of the "*Carta Topografica ed Idrografica dei contorni di Napoli…*" to the realisation of the *Carta Tecnica Regionale* (1998)[5] – used to obtain the vectoral data of the buildings – such increase was about six-fold. Furthermore, the cartographic result obtained gave significant images which even on a provincial scale make it possible to immediately see the areas of strong concentration and high building density, on the basis of a specific division into classes. These classes were in fact maintained homogenous for each elaboration produced (for the nineteenth century, the mid-1950s, and for the present situation according to the *Carta Tecnica Regionale*) as far as concerns the number of classes, their extent and relative colours. This step makes it possible to "extrapolate" additional information and quantitative data from the traditional cartography which is turn can be represented in another modality, able to return a highly explicative integrative image, both in contents and aesthetic performance. From a comparative point of view on a temporal scale, significant information can be gathered with this step which would otherwise remain "hidden" and unusable, and furthermore very detailed spatial and temporal analyses can be conducted.

Being able to count on a harmonious and interconnected GIS environment, the kernel density function was applied directly above the image from which it is derived[6] and then such elaborations (produced with ArcGIS Desktop) were imported in ArcGIS Pro, so as to be able to use a dual possibility of 2D and 3D visualisation (Figure 4). This considerably increases the quantity of information that can be gathered and the three-dimensional scenario combines a remarkable figurative effect with the accuracy of the research. In environments exposed to high risk, a three-dimensional representation of the physical-morphological features gives a significant added value to better understand the dynamic of the past eruptions and with a view to pre-event simulations allows the identification of those elements that could facilitate or hinder the spread of flow phenomena.

2.4 Fourth step: application of the extrusion techniques to the physical aspects and anthropic structures for a three-dimensional modelling

The fourth step consisted in applying extrusion techniques and modalities first of all to the physical aspects of the ground and then to the anthropic structures, so as to unite the three-dimensionality of the morphological features to the three-dimensionality of the buildings (residential, commercial, industrial etc.) actually existing. This phase required the synergy of a number of blended sources to reach, as the product of outputs, a synthetic reconstruction of the building modelled on topographic and orographic features. These elaborations are highly communicative and contain a patrimony of data and information, since for each building it is possible to know the end use and, by means of appropriate queries, the volume, area and perimeter.

[5] At the time of the analysis, the 1998 CTR was the most recent available in vectoral format.

[6] For the image referring to the present situation the kernel density function derived from the *Carta Tecnica Regionale* was applied above the recent satellite images in visible light to further increase the aesthetic effect and its communication capacity.

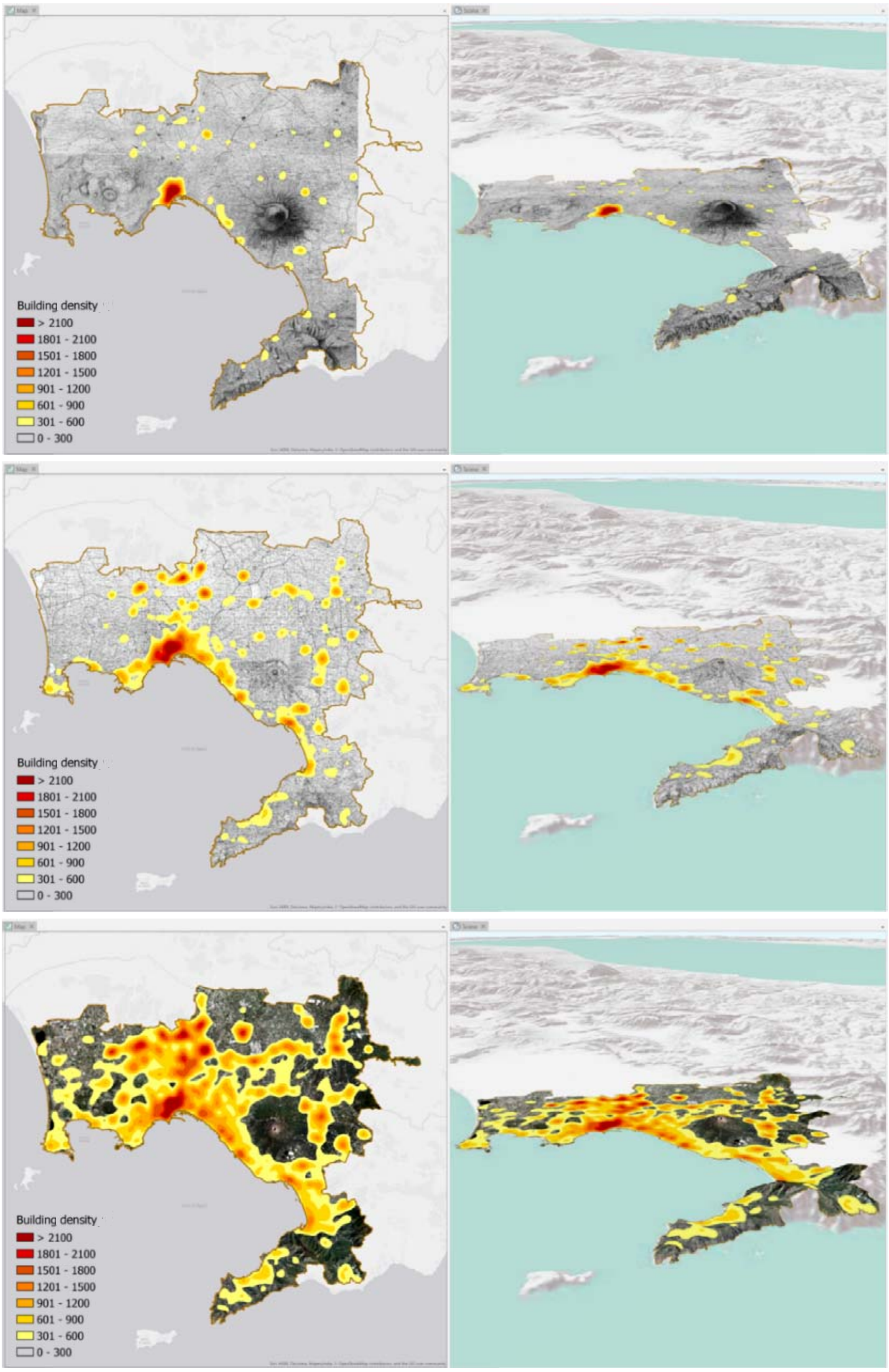

Figure 4. Application of the kernel density function – to represent the building density – superimposed onto the "*Carta Topografica ed Idrografica dei contorni di Napoli…*" (above), the IGM "Tavolette" (centre) and the recent satellite images in visible light (below). Source: Authors' elaboration.

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A three-dimensional modelling is thus achieved for the analysis of the buildings and the socio-economic damage scenarios, which can be loaded onto a basemap that confers further levels of information concerning for example the contour lines (isoipsas), the road practicability and the connections to be used in the case of preventive evacuation, for a summary representation supporting the relational investigations among the numerous components and the different areas (Figure 5). A similar modelling has an important role also from the point of view of the health-epidemiological scenarios, as the involvement and explosion of certain facilities, such as industries with polluting substances, petrol stations, hospitals with dangerous or highly infectious waste, tips etc. could trigger the release of very harmful substances into the atmosphere there and then or in the long term. These elaborations, of great scenographic impact (above all when realised with ArcGIS Pro which increases the aesthetic effect), thus carry out high level functions also in terms of territorial planning, prevention and the management of possible emergencies, and support experimental analyses of interdisciplinary interest and social usefulness.

2.5 Fifth step: production of 4D animations and film clips for each period of time considered

The fifth step led to the production of animations and film clips for each period considered, giving a privileged bird's eye view over the province of Naples. In particular, these 4D animations were set (with the same shrewdness) on the three-dimensional elaborations produced in the third step after importing them in ArcGIS Pro and thus concern: the "*Carta Topografica ed Idrografica dei contorni di Napoli…*" (Bourbon cartography) with the relative kernel density elaboration superimposed (Figure 6); the IGM "Tavolette" with the relative kernel density elaboration superimposed (Figure 7); the recent satellite images in visible light with the kernel density elaboration superimposed, derived from the *Carta Tecnica Regionale* (Figure 8). This makes it possible – during the flight – to focus the attention on the areas characterised by a greater building density, and by repeating the flight for each period of time it is possible to observe the notable transformations recorded in time, recognise the main trajectories and areas of building density and see important details at physical-morphological and settlement level, on the basis of a dynamic and engaging modality. The final result is a meticulous reconstruction of the landscapes and the reproduction of a virtual journey in time, made by means of applications that faithfully retrace everything to be found on the territory. In areas exposed to high volcanic risk similar animations and footage can play a very important role at the level of scientific research, strategic planning and analysis of the critical issues and active didactics, focussed on representation modalities with high educational contents that catch the attention and arouse interest in geotechnological applications and the problems affecting specific contexts.

3. The five steps from a technical point of view

The following paragraphs give a brief synthesis of the single operations carried out by this research, examining the tools, the technical aspects and procedures used for every step. The research workflow was designed according to the input availability, its properties and features, along with the accessibility of the application licenses and extensions. Owing to the huge dimension of the study area surface (more than 1.000 Km^2), the following geoprocessings were executed in batches with Python scripts.

3.1 First step: digitalisation, georeferencing and comparison of cartographies of different periods of time and recent satellite images

Due to the size of the sheets, the historical cartography was scanned with a roller scanner[7] at a resolution of 300 dpi, suitable for finding the control points at larger scales in the following georeferencing phase.

Depending on the historical cartography characteristics, a different georeferencing method was applied for every period. Thanks to the presence of the vertex coordinates, the IGM's "Tavolette" were georeferenced by typing the first four control points values: thus, the image shifted to its closely real position, easing the research of the remaining control points on the underlying satellite basemap; every image was georeferenced with 10 control points with a 2nd order polynomial transformation that scaled, rotated and curved the raster dataset.

On the contrary, georeferencing the "*Carta Topografica ed Idrografica dei contorni di Napoli…*" posed several problems: while a sheet of the mid-1950s cartography represents an average surface of 96 Km^2, the Bourbon one displays three times as much (about 315 Km^2); moreover, the landscape changes that occurred over almost two hundred years are so important that the recognition of the control points between the historical and contemporary layer is barely possible. To honour the georeferencing standard of maximum distribution of the control points around the study area, a 30-cell fishnet was thus superimposed on every image in order to focus the research on a smaller area; in some of these cells, the research was concentrated on the few categories that still remain untouched today, such as the noble properties, the ancient hamlets and the churches[8]. Except for the cells that overlaid natural areas (i.e. sea, woods, mountains, orchards etc.), a control point was placed in the other areas, enough to transform the image with the "Spline" algorithm, which transforms the source control points exactly to target control points.

Before saving the georeferencing results, the control point links were saved in a text file to memorize their position and root mean square error. Once the images were georeferenced, a mosaic dataset was created for the two historical cartographies, of which the images were clipped to the province of Naples and balanced in brightness and colours.

3.2 Second step: elaboration and publication of a multilayer Story Map

Furthermore, so as to share the contents of the research with a wider audience (population, people from other places, local institutions etc.), the datasets were published and embedded in some ESRI Story Maps (parts of a same multilayer Story Map), a server-side application that embeds the client contents in a ready-made layout.

The main Story Map represents, in a *spyglass* layout, the IGM "Tavolette" mosaic dataset and the natural colour satellite basemap; for this and all the other related Story Maps, the mosaic datasets were published as a tile layer service to the ArcGIS Online server, caching the data from a display scale of 1:577.790 to one of 1:2.256: these values represent the 10th and the 18th levels of the ArcGIS Online / Bing Maps / Google Maps tiling scheme, which leads the client content to perform a faster overlay with online basemaps. The published service was then added to a new web map, superimposing a natural colour satellite basemap.

The *swipe* Story Map collects three different web maps: the natural colour satellite basemap and the IGM "Tavolette" mosaic ones, together with the one representing the province of Naples with the false colours satellite image, composed of the combination of three "Sentinel 2" bands (8,3,2), resulting in a new multiband raster dataset.

[7] Scanner A0 Colorscan Smart Xpress, property of the GeoCartographic Laboratory (Department of Document studies, Linguistics, Philology and Geography), Sapienza University of Rome.

[8] To focus on the topic georeferencing, see i.e. Dainelli et al., 2008, pp. 31-37; Favretto, 2000, pp. 97-101; Fantozzi, 2013; Pesaresi, 2017, pp. 31-32 and 195-234.

The last of the three Story Maps represents, in a *spyglass* layout, many municipalities[9] of the Somma-Vesuvius area in: the "*Carta Topografica ed Idrografica dei contorni di Napoli…*" mosaic dataset; the administrative boundaries layer (symbolized in dark red); the natural colour satellite basemap. Before the publishing of the service, the Bourbon cartography mosaic dataset was clipped to the study area with a mask created from the dissolving of the municipalities' polygons together.

Once the web maps were created, the Story Maps were then prepared by adding them as layers in the *swipe* and *spyglass* layouts, along with the text (description, tile and summary), logos and custom extents.

3.3 Third step: accurate vectorisation of the data of the buildings, for each period of time considered, and the use of kernel density in 2D and 3D

To go beyond the simple visual screening of the study area, one objective of the research was the production of a series of kernel density maps to achieve an arithmetic calculation of the artificial surface growth process: according to the length of the search radius, the kernel algorithm generates a virtual circumference around each inputs, assigning a value of 1 to its centre which decreases to 0 at the edge; the output cell value is given by the sum of the surface values beneath it[10].

With regard to the kernel tool input type, a fishnet made of 225 sq. m. cells was thus created on the entire province of Naples, with a point created at the centre of each fishnet cell: assuming that a point would represent the space occupied by a single building, the points were thus intersected by three different layers of polygons, representing the building's base; to guarantee the whole representation of the buildings, a point was then created at the centroid of the polygons that were too small to be intersected.

According to the period, a different method was used to create the buildings' polygons: for the recent layer, a 1998 vector-based cartography of the Naples province was provided by the Vesuvius Observatory of the National Institute of Geophysics and Volcanology (INGV), consisting of 402 .dwg files representing natural and human territorial assets, including the buildings. In order to compare the three layers, a Python script was executed to query the attributes and to select the buildings that were mapped all over the three different periods (i.e. churches, residential buildings etc.). The output was then merged and dissolved to be used before the next intersection with the punctual dataset.

The process was more complicated for the two historical layers: initially the mosaic datasets were vectorised by the conversion of each cell into a polygon, reporting the value of the red band of the electromagnetic spectrum as an attribute of the new table. Considering that constructions are mapped in black in both the historical cartographies, a range in an 8-bit scale (from 0 to 255) of values was established to select only the polygons that closely represented the dark colours used in the cartographies. The selected polygons were then dissolved in a series of single-part features, carefully supervised to exclude other unwanted objects such as toponyms or natural elements like brushes, orchards etc., all mapped by the same dark colour of the buildings.

For every punctual dataset, a 30 meter raster was created to display the density of point features, measuring their magnitude per square kilometre. To enhance the image readability, the outputs were thus symbolized by quantities using eight classes and a red-scale colour, which represents a way to show the concentration and dispersion of a certain phenomenon, highlighting their relationships and enhancing their visual comparison.

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[9] Boscotrecase, Ercolano, Massa di Somma, Naples, Ottaviano, Pollena Trocchia, Portici, San Giorgio a Cremano, San Giuseppe Vesuviano, San Sebastiano al Vesuvio, Sant'Anastasia, Somma Vesuviana, Terzigno, Torre Annunziata, Torre del Greco, Trecase.

[10] A series of case studies of the kernel density application are discussed in Graci et al., 2008, p. 247; Longley et al., 2011, pp. 371-373.

The 2D maps were then superimposed onto a hillshade of the area, created from a surface raster of 10 meter resolution[11], while the 3D maps were made in ArcGIS Pro by superimposing the density rasters onto a topographic basemap in a scene.

3.4 Fourth step: application of the extrusion techniques to the physical aspects and anthropic structures for a three-dimensional modelling

The three-dimensional modelling of the Naples province offered a different view of the study area, useful to reveal some aspects that could be ignored from a cartographic perspective[12]. To reconstruct the ground morphology, a single raster dataset was thus created by merging the single surface tiles into a new one, successively clipped to the province boundary and used as the base height of the natural colour satellite image from "Sentinel 2". The anthropic structure modelling combined the values of both a DTM and a DSM raster dataset: to extrude the buildings polygons by their heights, the cells of both these rasters were converted into points, thus obtaining the values of the building bases and their eaves. To assign these values to the polygons, a spatial join was used between the two different shapes, using a containment criterion where the polygons would have retained the bases and eaves values from the points contained in their perimeter[13]. The height was then measured by subtracting the base value from the one of the eaves. Finally, the buildings were symbolized by their function by clustering the 1998 vector-based cartography attributes into four new classes (commercial, industrial, residential, other). For example, by classifying the polygons of the Torre Annunziata municipality into three major classes with the addition of a fourth mixed class, in order to provide a first representative evaluation, the most diffused class was "residential" (77.9%), followed by the "industrial" (12.9%) and "commercial" (2.4%) ones, with a remaining 6.8% classified as "other" (mixed class). A similar estimate, extended to all the municipalities both in absolute and percentage values, makes it possible to define a general framework of the main use destinations according to the building classification defined.

3.5 Fifth step: production of 4D animations and film clips for each period of time considered

Using the ArcGIS Pro animation tools, a clip was made for every research period filming a flight through the three-dimensional scenario. The scene was made by setting the topographic basemap as the base height for the three different mosaic datasets, two representing the historical cartographies, one the natural colour satellite image, all three superimposed by the kernel density maps. The animation was created by setting a series of key-frames located in a position chosen to display the study area in its entirety. The clips were then recorded and exported as new movie clips.

Instead of the traditional 3D application of ArcGIS for Desktop (ArcScene), ArcGIS Pro works with 64-bit technology, which makes the 3D scene visualization faster and more responsive. Moreover, the 2D and 3D frames are now embedded in a single software, allowing a faster switching from the cartographic to the scene prospective.

[11] 10 meters DTM from INGV (Tarquini et al., 2007, 2012).
[12] An example of representative three-dimensional elaboration with a specific building classification is offered by Longley et al., 2011, pp. 340-344.
[13] About the characteristics of the spatial join, see i.e. Price, 2016.

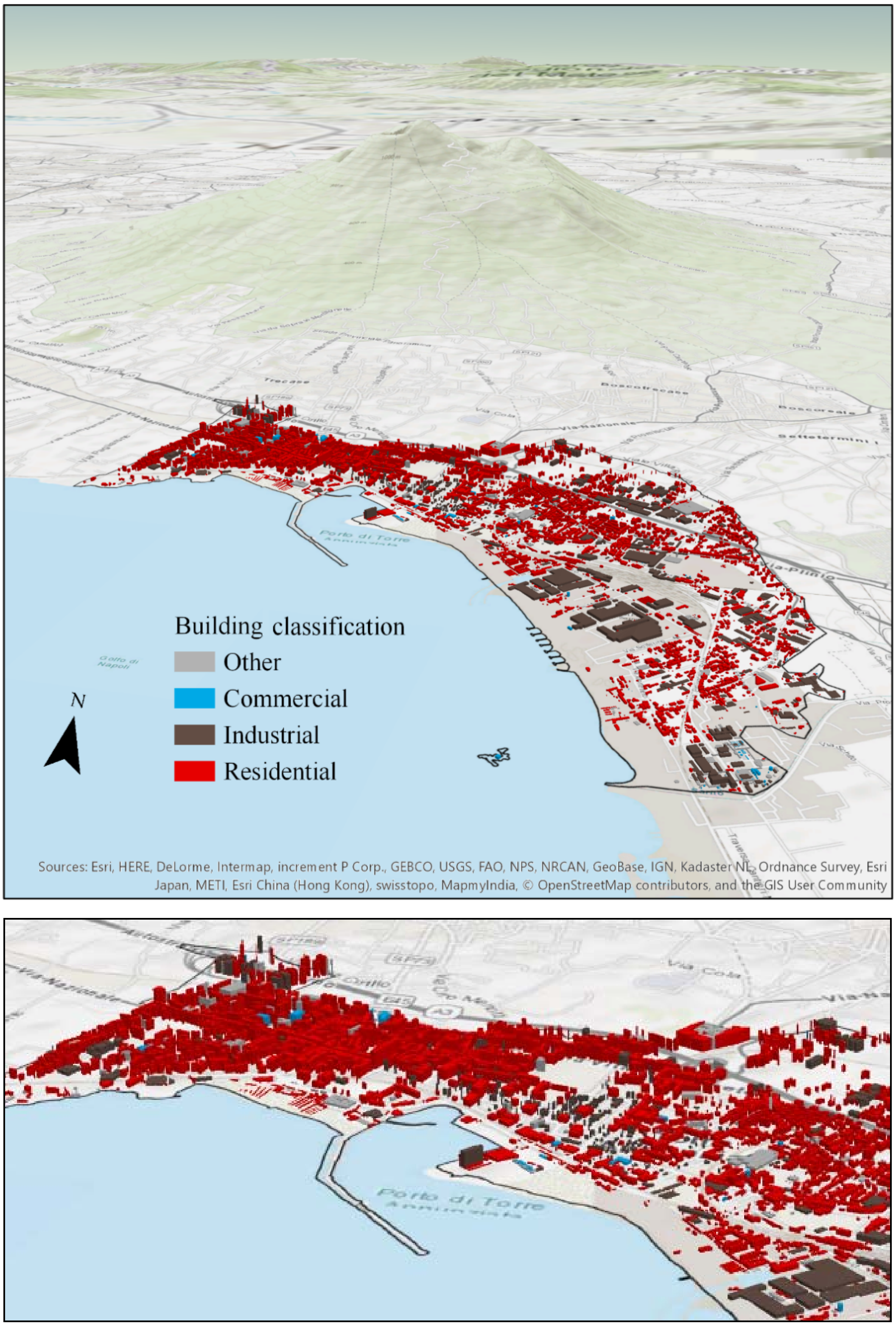

Figure 5. Above, three-dimensional representation of the buildings, according to a specific classification, in the municipality of Torre Annunziata and three-dimensional representation of the physical and morphological aspects, where the Somma-Vesuvius complex stands out. Below, a zoom on an area characterised by high building density. Source: Authors' elaboration.

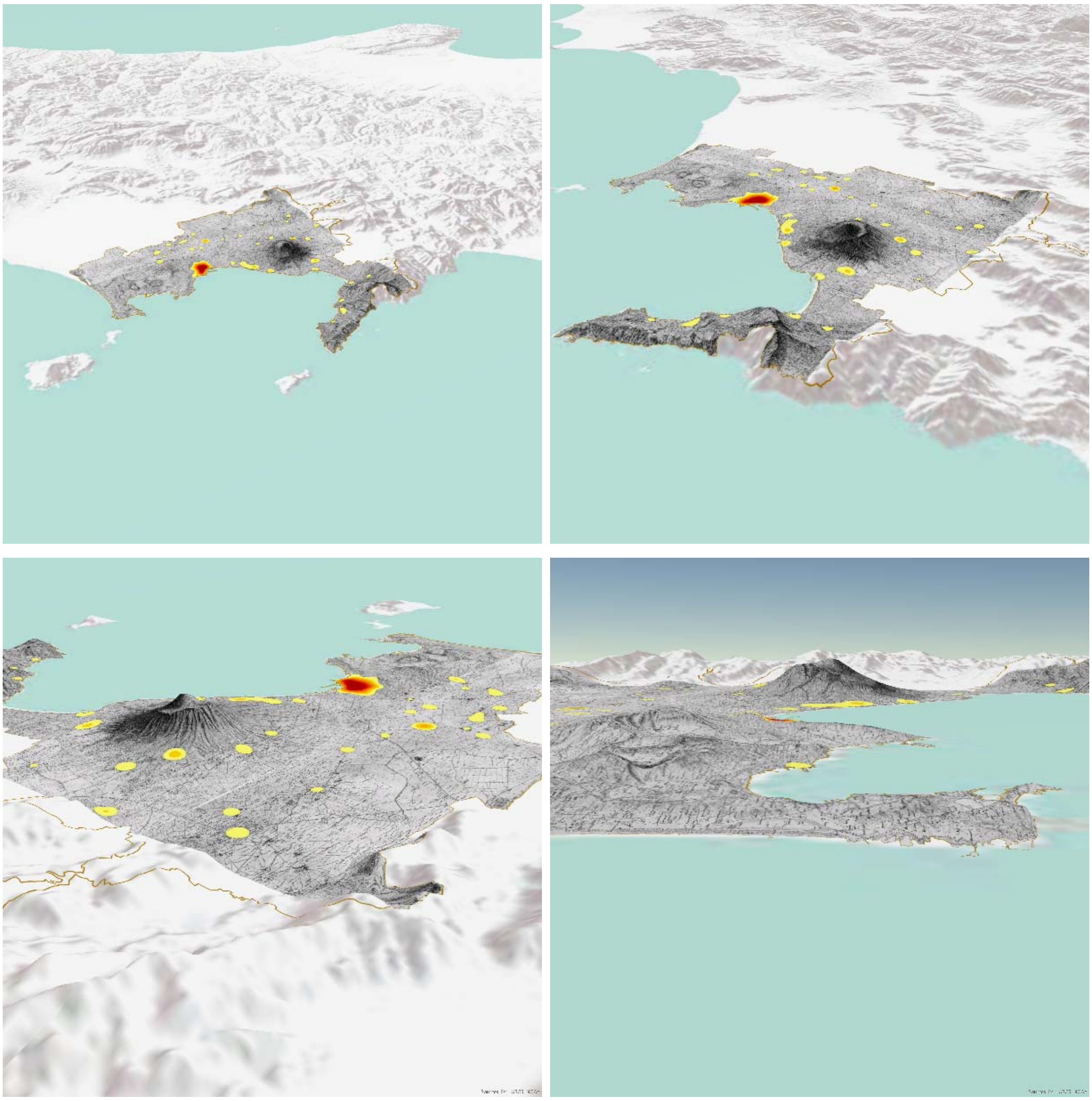

Figure 6. Screenshots of the 4D animation produced for the "*Carta Topografica ed Idrografica dei contorni di Napoli…*" with the relative kernel density elaboration superimposed. Source: Authors' elaboration.

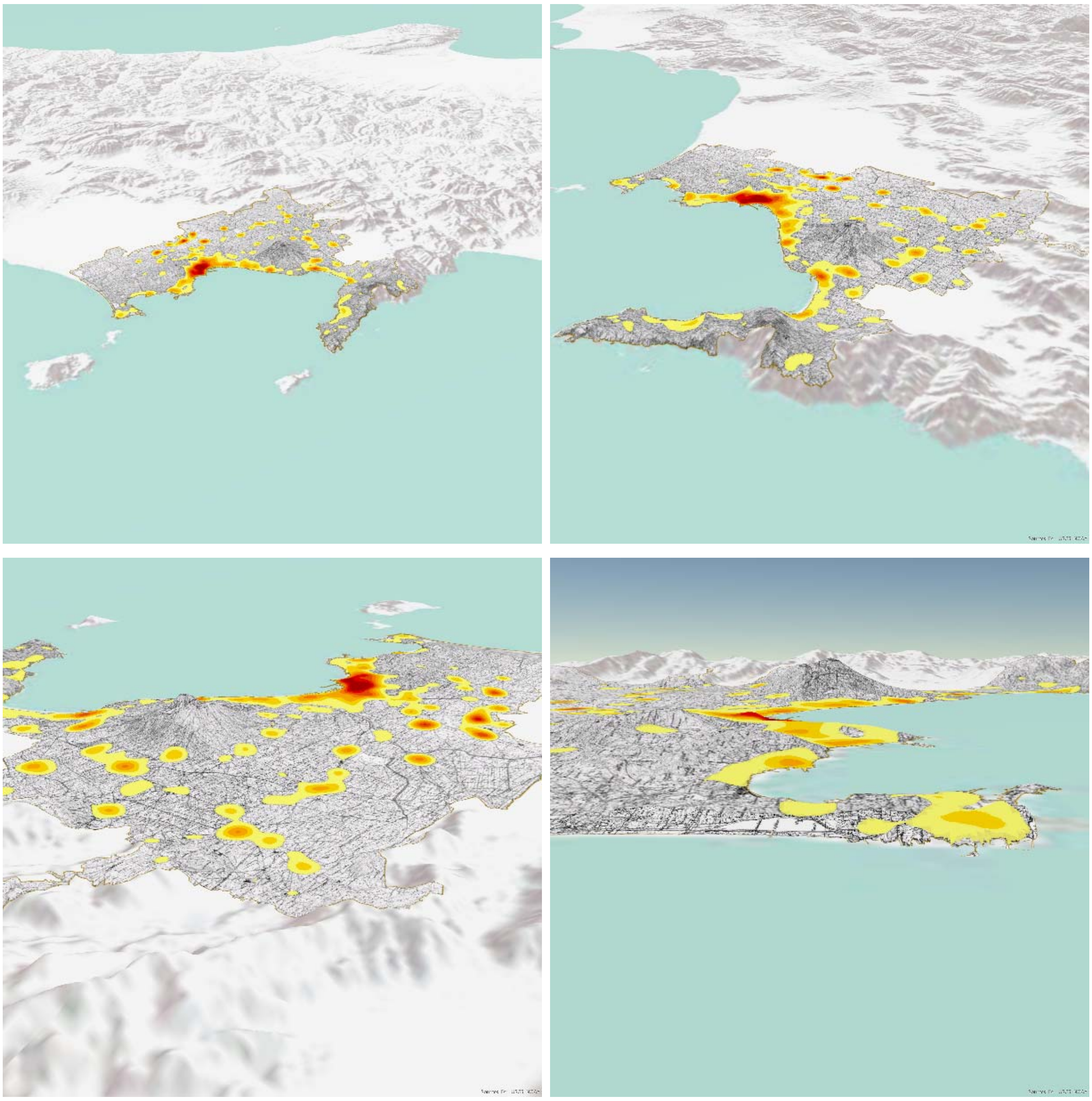

Figure 7. Screenshots of the 4D animation produced for the IGM "Tavolette" with the relative kernel density elaboration superimposed. Source: Authors' elaboration.

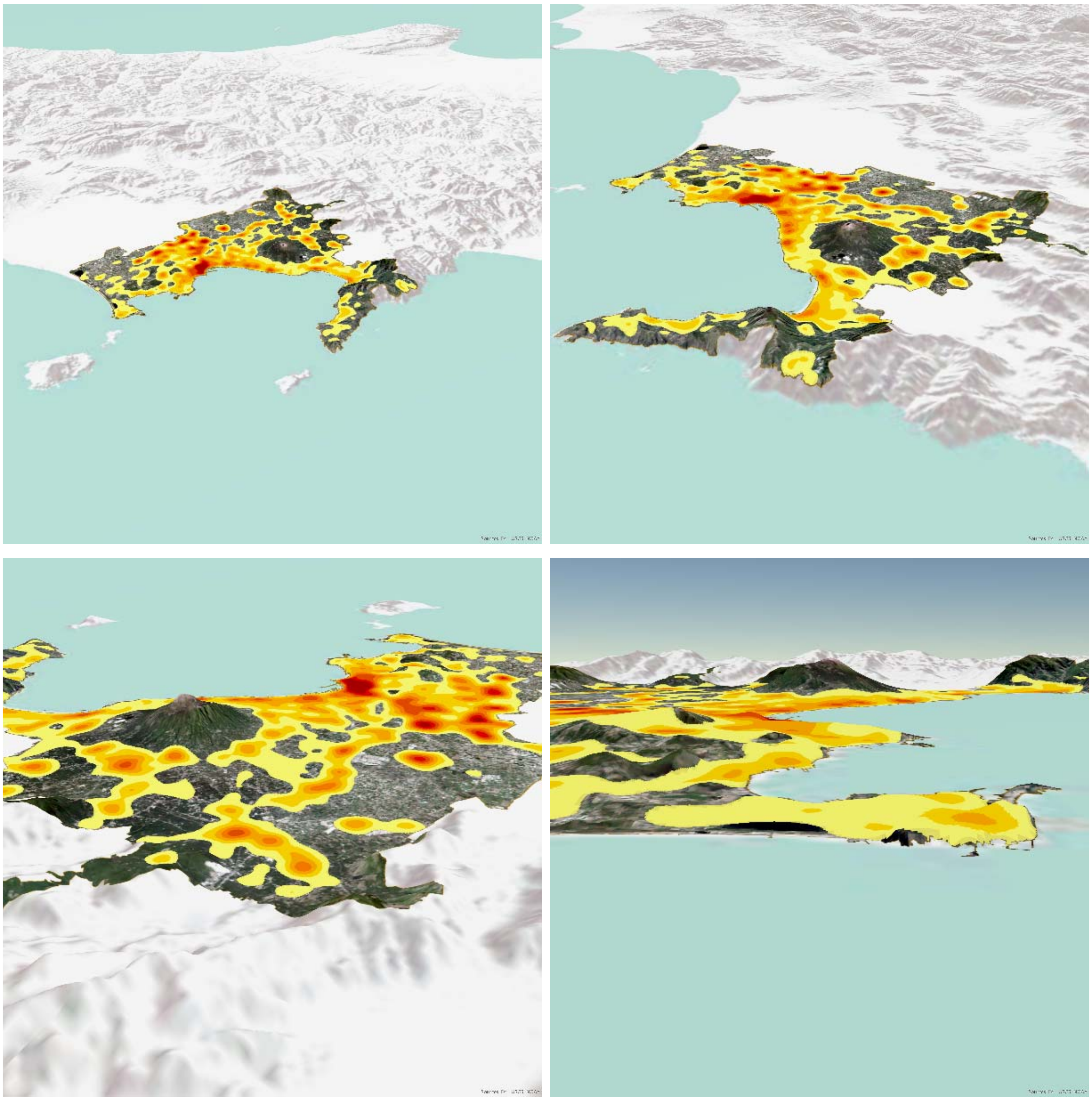

Figure 8. Screenshots of the 4D animation produced for the recent satellite images in visible light with the kernel density elaboration superimposed, derived from the *Carta Tecnica Regionale*. Source: Authors' elaboration.

4. The five steps from an educational point of view

As far as the first step is concerned, it is evident how georeferencing can represent a didactic operation of great importance giving significant results. In fact, during the search for the control points one has the possibility to carry out a preliminary analysis of the study area, or rather a first fact-finding investigation. The meticulous search for control points, conducted according to appropriate guidelines, leads one to being catapulted into the past and then to propel oneself into the present reality to find the same elements with which to anchor the two images to be connected together. Once the georeferencing has finished, the comparison of the layers and the use of special effects effectively shows the modifications that have taken place in time and transmits a great sense of personal gratification when the work has been carried out accurately, permitting an overall and detailed analysis opening up to a multitude of interdisciplinary perspectives, especially in areas exposed to geodynamic risks.

It thus becomes possible "to create a product with high quality historical-geographical contents and significant aesthetic appeal, which arouses interest and stimulates the production of original works whereby to combine the statistical-quantitative dimension with the visual-qualitative one. By marrying the documentary value of historical cartography with the elaborative potential of Geographical Information Systems, by means of georeferencing, interpolation, data processing and the creation of simulated environments, it is possible to obtain virtual models, which 'bring to light' the landscapes of decades and centuries ago, in their peculiar features" (Pesaresi, 2017, p. 32).

Working on a very large study area, such as the province of Naples, is a complex operation, above all going back far back in time, since a high number of control points is required, their widespread and as far as possible homogenous distribution and the precise work of recognition of the elements to be selected. A thorough georeferencing thus requires solid bases from the methodological and technical point of view and in terms of didactics high-quality skills, well defined objectives and a strong motivation are needed to pursue them.

The second step, aimed at the elaboration and publication of a (multilayer) Story Map like the one designed for this research, is strictly linked to the first step and the greatest operative difficulties are in fact connected to the previous phase of georeferencing. The creation of a Story Map is in itself quite simple and didactically can represent an excellent means to immediately capture students' imagination and be used in any school environment, of any type or level, arousing the interest and attention of children and teachers alike. The Story Maps based on *swipe* and *spyglass* templates are the most complex to create because, by and large, they require preventive work of georeferencing, but there are many other templates available that one can get the hang of it with the creation of a Story Map much more simply and rapidly. On the contrary, one of the negative aspects is the one linked to the fact that the Story Maps, intuitive in their arrangement and online publication, are often produced to speak about facts and events that have little or nothing to do with geography, going on to fuel a mindless sharing of empty representations from the contents point of view. It is therefore essential to plan Story Maps with a certain criterion, following a guiding principle aimed at enhancing processes and contents, images and findings, also because such an elaboration arouses emotive involvement and fills those working on them, either singly or in groups, with satisfaction.

"Today, educators and their students have a wide variety of resources with which to enter the world of web mapping". Important aspects are defining some crucial aspects and seeking "to model for the instructor *how* to teach with dynamic web maps. It should be noted that the web maps alone do not transform education from rote memorization to grappling with problems and issues. It is the instructors who are dedicated to inquiry-driven and constructivist methods who accomplish that, modeling lifelong learning for their students. But the web maps are key tools to enable critical and spatial thinking". For example "Using historical and current maps and imagery, students could answer such questions as the following: What has changed in my community or in other communities, and why has it changed? Were the changes because of natural forces or human-caused forces, or a combination? What will this area look like in 10 years? What will it look like in 100 years? What did the landscape look like when my parents or grandparents were secondary school students? Is the area changing more quickly or more slowly than other parts of my community, or other parts of my country or elsewhere in the world? Why? What is the land use like in my neighborhood? How does it compare to land use elsewhere in the world? What influence does population, climate, proximity to coastlines, or other phenomena have on land use?" (Kerski, 2013, pp. 14, 19-20).

The third step – for the accurate vectorisation of the data of the buildings and the use of kernel density in 2D and 3D – and the fourth step – for the application of the extrusion techniques to the physical aspects and anthropic structures – require high level skills, both in terms of the significance of the operations to be undertaken and the functions to adopt, and at the methodological-operative knowledge level.

This brings us back in time, to the early 1990s, when it had been pointed out that: without adequately trained people involved in an organic educational project little will be achieved and although the importance of similar planning and initiatives has been put in evidence much must be done to reduce and alleviate the general skill shortage (Maguire, 1991, p. 16). In this case one must reason from the viewpoint of a highly professionalising didactics, which might satisfy the needs that are much in demand in research and institutional contexts[14].

After all, the need is increasingly felt to experiment innovative and diversified solutions, able to convey specific competences according to ad hoc projects and modalities, aimed at enriching the background and set of skills of those involved (Pesaresi and Pavia, 2017b, p. 111). Working in the three-dimensional perspective, and easily passing from 2D to 3D, then become increasingly important requirements to represent physical and anthropic components, express relational aspects, evaluate the cause and effect links, conduct simulations and envisage scenarios.

Three-dimensional representations are very effective to reveal contextual aspects and information, to highlight the presence of areas with high urban density (also according to specific building classification) or with mixed land use, to virtually walk along the streets, to evaluate difficulties in terms of the availability of escape routes, to suppose and understand the effects of different phenomena and processes also in relation to the topographic conditions, and users able to enhance the interaction between 2D and 3D have got strategical application keys (Longley et al., 2015, p. 282).

Furthermore, by translating some of the geotechnological results of one's work into 4D, it is possible to draw the population closer, starting with the young, to issues of great contingency and present day importance by enhancing specific GIS functions that let to propose interactive methods and modalities from a geographical-educational angle, that are requested and widespread but little used in a meticulous didactic approach, where a compelling scenic rendering and research accuracy blend together. The fifth step, which leads to the production of animations and film clips, represents from the applicative-didactic point of view the crowning of the previous work, the dynamic summary of a long series of sequential developments and acts as a concrete example of 4D that can be produced on the basis of a multiplicity of data, functions, cartographic documents, satellite images of different types, basemaps and other sources used and collected on a performing platform.

The GIS modellings in areas subject to high volcanic risk can thus play an important role in highlighting critical situations and in evaluating their dimension. Moreover, they give a valid support in reconstructing the main phases that have led to disjointed phenomena which in time have spread like wildfire, creating imbalances and alarming conditions, radically transforming the features and physiognomy of the landscape. They offer the possibility of critical reflection for decision-making aimed at interrupting dy-

[14] Applying well planned directions and strategies "can lead to a significant reduction of the gap between the technical field of GIS and the academic field of geography: teaching GIS can become the means to form a new generation of [Geographers-] GIScientists, not simply of GIS technicians" (Bertazzon, 2013, p. 72).

namics that are harmful for the long term and to identify, by means of scenarios and simulations, the steps to take for a responsible and shared planning, to recognise the areas that are more exposed and to draw up the most important intervention orders.

In this way, GIS output often becomes "the pinnacle" of high innovative projects, where layers and information, important for many scientific fields and for an overall perspective, converge in integrated elaborations, which can be used to explore, synthesise, analyse and present/represent spatial and temporal data in order to promote thinking, awareness and knowledge construction (Longley et al., 2011, pp. 298, 326-327).

Furthermore, in this way, it is possible to promote "cartography/map-making, spatial modelling, geocomputation and database development" together with "geonarratives, qualitative/mixed methods, storytelling and synthesis" in order to "explore new areas of enquiry with greater sensitivities to the social and political dimensions of GIS application" (Sui, 2015, p. 1).

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References

1. Alberico I., Lirer L., Petrosino P. and Scandone R., "A methodology for the evaluation of long-term volcanic risk from pyroclastic flows in Campi Flegrei (Italy)", *Journal of Volcanology and Geothermal Research*, 116, 2002, pp. 63-78.
2. Alberico I., Petrosino P. and Lirer L., "Volcanic hazard and risk assessment in a multi-source volcanic area: the example of Napoli city (Southern Italy)", *Natural Hazards and Earth System Sciences*, 11, 2011, pp. 1057-1070.
3. Bertazzon S., "Rethinking GIS teaching to bridge the gap between technical skills and geographic knowledge", *Journal of Research and Didactics in Geography (J-READING)*, 1, 2, 2013, pp. 67-72.
4. Bianchi R., Coradini A., Federico C., Giberti G., Lanciano P., Pozzi J.P., Sartoris G. and Scandone R., "Modeling of Surface Deformation in Volcanic Areas. The 1970-1972 and 1982-1984 Crises of Campi Flegrei, Italy", *Journal of Geophysical Research*, 92, B13, 1987, pp. 14.139-14.150.
5. Boffi M., *Scienza dell'informazione geografica. Introduzione ai GIS*, Bologna, Zanichelli, 2004.
6. Carafa P. and D'Alessio M.T., "Pompei: stratigrafia, ricostruzioni e storia della città", in Ferrandes A.F. and Pardini G. (Eds.), *Le regole del gioco. Tracce Archeologi Racconti*, Rome, Quasar, 2016, pp. 215-225.
7. Conti Si., "Il fenomeno vulcanico in alcuni scrittori, cartografi e vedutisti dei secoli XVII-XIX", in D'Aponte T. (Ed.), *Terre di vulcani. Miti, linguaggi, paure, rischi*, *Proceedings of International Congress of Italian and French studies*, vol. 2, Rome, Aracne, 2005, pp. 43-61.
8. Dainelli N., Bonechi F., Spagnolo M. and Canessa A., *Cartografia numerica. Manuale pratico per l'utilizzo dei GIS*, Palermo, Dario Flaccovio, 2008.
9. Dai Prà E. (Ed.), *La Cartografia storica da bene patrimoniale a strumento progettuale*, *Semestrale di Studi e Ricerche di Geografia*, 2, 2010.
10. D'Aponte T., "Il 'rischio vulcanico' tra approccio scientifico e suggestione artistica", in D'Aponte T. (Ed.), *Terre di vulcani. Miti, linguaggi, paure, rischi*, *Proceedings of International Congress of Italian and French studies*, vol. 2, Rome, Aracne, 2005, pp. 11-19.
11. Del Gaudio C., Aquino I., Ricciardi G.P., Ricco C. and Scandone R., "Unrest episodes at Campi Flegrei: A reconstruction of vertical ground movements during 1905–2009", *Journal of Volcanology and Geothermal Research*, 195, 2010, pp. 48-56.

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

13. Fantozzi P.L., *Georeferenziare i dati geografici con ArcGIS. Problemi cartografici e metodi di soluzione tramite l'uso di ArcGIS 10.1*, Palermo, Dario Flaccovio, 2013.

14. Favretto A., *Nuovi strumenti per l'analisi geografica: i G.I.S.*, Bologna, Pàtron, 2000.

15. Gasparini M.L., *Dinamiche demografiche e tendenze insediative nell'area vesuviana*, in D'Aponte T. (Ed.), *Terre di vulcani. Miti, linguaggi, paure, rischi*, *Proceedings of International Congress of Italian and French studies*, vol. 2, Rome, Aracne, 2005, pp. 217-229.

16. Gasparini P., "Il bradisismo del 1970", *Ambiente Rischio Comunicazione*, 5, 2013, pp. 31-35.

17. Giacomelli L. and Scandone R., *Vulcani d'Italia*, Naples, Liguori, 2006.

18. Gorr W.L., Kurland K.S., *GIS Tutorial 1 for ArcGIS Pro. A Platform Workbook*, Redlands, Esri Press, 2017.

19. Graci G., Pileri P. and Sedazzari M., *GIS e ambiente. Guida all'uso di ArcGIS per l'analisi del territorio e la valutazione ambientale*, Palermo, Dario Flaccovio, 2008.

20. Kerski J.J., "Understanding Our Changing World through WebMapping Based Investigations", *Journal of Research and Didactics in Geography (J-READING)*, 2, 2, 2013, pp. 11-26.

21. La Foresta D., "La 'montagna urbana di fuoco': vulnerabilità, pianificazione e gestione del rischio", in D'Aponte T. (Ed.), *Terre di vulcani. Miti, linguaggi, paure, rischi*, *Proceedings of International Congress of Italian and French studies*, vol. 2, Rome, Aracne, 2005, pp. 231-258.

22. Leone U., "Mutamenti del paesaggio e politiche dell'ambiente in Campania: i parchi naturali", *Bollettino della Società Geografica Italiana*, 3, 2001, pp. 457-465.

23. Leone U., "Editoriale", *Ambiente Rischio Comunicazione*, 5, 2013, pp. 4-6.

24. Lirer L., Luongo G. and Scandone R., "On the Volcanological Evolution of Campi Flegrei", *Eos*, 68, 16, 1987, pp. 226-234.

25. Longley P.A., Goodchild M.F., Maguire D.J. and Rhind D.W., *Geographic Information Systems & Science*, Hoboken, John Wiley & Sons, 2011.

26. Longley P.A., Goodchild M.F., Maguire D.J. and Rhind D.W., *Geographic Information Science and Systems*, Hoboken, John Wiley & Sons, 2015.

27. Luongo G., "Il bradisismo degli anni Ottanta", *Ambiente Rischio Comunicazione*, 5, 2013, pp. 36-45.

28. Maguire D.J., "An Overview and Definition of GIS", in Maguire D.J., Goodchild M.F. and Rhind D.W. (Eds.), *Geographical Information Systems*, vol. 1 (Principles), Harlow, Longman Scientific and Technical, Longman Group UK, 1991, pp. 9-20.

29. Maiuri A., *Pompei ed Ercolano fra case e abitanti*, Florence, Giunti, 1998.

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

31. Orsi G., Di Vito M.A. and Isaia R., "Volcanic hazard assessment at the restless Campi Flegrei caldera", *Bulletin of Volcanology*, 66, 2004, pp. 514-530.

32. Orsi G. and Zollo A., "Struttura e storia dei Campi Flegrei", *Ambiente Rischio Comunicazione*, 5, 2013, pp. 18-24.

33. Pesaresi C., *Applicazioni GIS. Principi metodologici e linee di ricerca. Esercitazioni ed esemplificazioni guida*, Novara, UTET – De Agostini, 2017.

34. Pesaresi C. and Lombardi M., "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, 2014, pp. 9-32.

35. Pesaresi C. and Marta M., "Applicazioni GIS per l'analisi dell'urbanizzazione nella provincia di Napoli. Un'analisi multitempo-

rale in aree esposte a elevato rischio vulcanico", *Bollettino dell'Associazione Italiana di Cartografia*, 150/2014, pp. 34-51.

36. Pesaresi C., Marta M., Palagiano C. and Scandone R., "The evaluation of 'social risk' due to volcanic eruptions of Vesuvius", *Natural Hazards*, 47, 2008, pp. 229-243.
37. Pesaresi C. and Pavia D., *Tra Vesuvio e Campi Flegrei, dal XIX secolo a oggi. Modellizzazione cartografica in ambiente GIS*, Rome, Nuova Cultura, 2017a.
38. Pesaresi C. and Pavia D., "Progettualità mirate e corsi GIS: per un approccio geografico coinvolgente e professionalizzante", in Pasquinelli d'Allegra D., Pavia D. and Pesaresi C. (Eds.), *Geografia per l'inclusione. Partecipazione attiva contro le disuguaglianze*, Milan, Franco Angeli, 2017b, pp. 110-124.
39. Pesaresi C. and Scandone R., "Nuovi scenari di rischio nell'area vesuviana", in Paratore E. and Morri R. (Eds.), *Studi in onore di Cosimo Palagiano*, *Semestrale di Studi e Ricerche di Geografia*, 1, 2013, pp. 225-241.
40. Pesaresi C., van der Schee J. and Pavia D., "3D and 4D Simulations for Landscape Reconstruction and Damage Scenarios: GIS Pilot Applications", *Review of International Geographical Education Online (RIGEO)*, 2, 7, 2017, pp. 131-153.
41. Pesce A. and Rolandi G., *Vesuvio 1944. L'ultima eruzione*, S. Sebastiano al Vesuvio, 1994.
42. Petrosino P., Alberico I., Caiazzo S., Dal Piaz A., Lirer L. and Scandone R., "Volcanic risk and evolution of the territorial system in the volcanic areas of Campania", *Acta Vulcanologica*, 16, 1-2, 2004, pp. 163-178.
43. Pollice F., "Sotto la cenere. Su alcune tendenze evolutive del tessuto industriale nell'area vesuviana", in Faccioli M. (Ed.), *Processi territoriali e nuove filiere urbane*, Milan, Franco Angeli, 2009, pp. 205-219.
44. Price M.H., *Mastering ArcGIS*, New York, Mc Graw Hill Education, 2016.
45. Renschler C.S., "Scales and uncertainties in volcano hazard prediction-optimizing the use of GIS and models", *Journal of Volcanology and Geothermal Research*, 139, 1-2, 2005, pp. 73-87.
46. Rolandi G., Barrella A.M. and Borrelli A., "The 1631 eruption of Vesuvius", *Journal of Volcanology and Geothermal Research*, 58, 1993, pp. 183-201.
47. Rosi M., Principe C. and Vecci R., "The 1631 Vesuvius eruption. A reconstruction based on historical and stratigraphical data", *Journal of Volcanology and Geothermal Research*, 58, 1993, pp. 151-182.
48. Santacroce R., Cioni R., Marianelli P., Sbrana A., Sulpizio R., Zanchetta G., Donahue D.J. and Joron J.L., "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, 2008, pp. 1-18.
49. Scandone R., Bartolini S. and Martí J., "A scale for ranking volcanoes by risk", *Bulletin of Volcanology*, 78, 2, 2016, pp. 8.
50. Scandone R., D'Amato J. and Giacomelli L., "The relevance of the 1198 eruption of Solfatara in the Phlegraean Fields (Campi Flegrei) as revealed by medieval manuscripts and historical sources", *Journal of Volcanology and Geothermal Research*, 189, 2010, pp. 202-206.
51. Scandone R. and Giacomelli L., *Vulcanologia. Principi fisici e metodi d'indagine*, Naples, Liguori, 2004.
52. Scandone R. and Giacomelli L., "Cronache di un'eruzione: la nascita di Monte Nuovo nel 1538", *Ambiente Rischio Comunicazione*, 5, 2013, pp. 25-30.
53. Scandone R., Giacomelli L. and Fattori Speranza F., "Persistent activity and violent strombolian eruptions at Vesuvius between 1631 and 1944", *Journal of Volcanology and Geothermal Research*, 170, 3-4, 2008, pp. 167-180.
54. Scandone R., Giacomelli L. and Gasparini P., "Mount Vesuvius: 2000 years of volcanological observations", *Journal of Volcanology and Geothermal Research*, 58, 1993, pp. 5-25.
55. Sui D., "Emerging GIS themes and the six senses of the new mind: is GIS becoming a liberation technology?", *Annals of GIS*, 21, 1, 2015, pp. 1-13.

56. Tarquini S., Isola I., Favalli M., Mazzarini F., Bisson M., Pareschi M.T. and Boschi E., "TINITALY/01: a new Triangular Irregular Network of Italy", *Annals of Geophysics*, 50, 2007, pp. 407-425.
57. Tarquini S., Vinci S., Favalli M., Doumaz F., Fornaciai A. and Nannipieri L., "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, 2012, pp. 168-170.
58. Valerio V., "Il Vesuvio immagini e misurazioni", *L'Universo*, 2, 1995, pp. 239-252.
59. Zuccaro G., Cacace F., Spence R.J.S. and Baxter P.J., "Impact of explosive eruption scenarios at Vesuvius", *Journal of Volcanology and Geothermal Research*, 178, 2008, pp. 416-453.

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