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# Soils of the Aversa plain (southern Italy)

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**ABSTRACT**

The Aversa plain is one of the most important agricultural areas of the Campania region, combining the presence of very fertile soils, sites of great archaeological interest and growing residential urbanization.

In this paper, the soil map (1:50,000 scale) of the Aversa plain is presented. Three main land systems (coastal, alluvial and foothill plains) characterized by different soil types (Andosols, Phaeozems, Cambisols, Vertisols, Arenosols, Histosols, Luvisols) have been identified. However, Andosols are the most widespread soil type (9768 ha) and, along with part of the Phaeozems and Cambisols, represent the most fertile soils of the Aversa plain (first and second classes of the land capability classification).

In order to evaluate recent intense soil sealing, its impact over land capability classes was assessed during the last 60 years. Results show that soil sealing in the Aversa plain affected mainly the most fertile first- and second-class soils.

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**KEYWORDS**
Andosols; soil sealing; agricultural areas; Campania region; urbanization; archaeological finds

## 1. Introduction

The Aversa plain is part of two larger Rural Territorial Systems of the Campania region (southern Italy), named Piana Flegrea and Piana del Volturno in the 6th census of agriculture by the regional administration of the Campania region, on the basis of the previous soil and forestry maps (Regione Campania, 2013). The Aversa plain is characterised by a variety of mainly arable crops (7506 ha); they are concentrated mainly in Villa Literno (2272 ha) and Casal di Principe (1774 ha). However, if we exclude the agricultural areas of these two cities, which occupy 44.2% of the total Utilized Agricultural Surface (UAS) of the Aversa plain, agrarian tree cultivation (mainly olive, citrus and fruit-bearing trees) represents 35.9% of the remaining UAS, with fruit-bearing trees covering 92.5%. In the Campania region, agrarian tree cultivation occupies 24.4% of the total regional UAS, producing high-quality products.

This study represents the first systematic contribution to the scientific knowledge of the soils of the Aversa plain on a semi-detailed scale (1:50,000), produced within the framework of the Unità Operative Territoriali (UOT) 'Soil Maps of the Campania Region' program.

The area involved in the study has very fertile soils combined with sites of great archaeological interest (e.g. protohistoric tombs, finds from agriculture plowing and villages). These testify the existence of the continued population in this area since protohistory and the intense urbanization in recent decades. It is important to emphasize here that the southern boundary of the Aversa plain is ca. 6 to 8 km from the Naples urban area, which represents 8.6% of the territory of the Campania region but hosts half of the region's population, with a density of 2635.5 inhabitants per $km^2$ (census at November 2016). Urban residential expansion has affected the areas north of Naples, including parts of the Aversa plain, in the last 30 years, mainly due to urban reconstruction after the disastrous 1980 earthquake and the increased value of land following recent deindustrialization of the city. Hence, the actual high human pressure is associated with the unique properties of Andosols (IUSS Working Group WRB, 2015) and andic soils, which occupy large areas of this territory. These soils are known from the literature for their excellent properties (Nanzyo, 2004; Shoji & Takahashi, 2003; Shoji, Nanzyo, & Dahlgren, 1993) that give high chemical and physical fertility to ecosystems (Maeda, Takenaka, & Warkentin, 1977; Quantin, 1990), both in volcanic districts and in non-volcanic mountain landscapes (Mileti, Langella, Prins,

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Vingiani, & Terribile, 2013; Vingiani, Scarciglia, Mileti, Donato, & Terribile, 2014). In spite of these positive properties, Andosols and andic soils have an inside 'fragility' to land degradation and pollution (Kabata-Pendias, 2001; Latrille, Denaix, & Lamy, 2003; Tanneberg, Jahn, Meijer, & Kleber, 2001; Vingiani, Mele, De Mascellis, Terribile, & Basile, 2015; Zhao, Maeda, Zhang, Zhu, & Ozaki, 2006) and this makes the Aversa plain a highly vulnerable territory, with consequences to be taken into account by the local community.

In the context of this scenario, the main aims of this paper are: (i) to present a Soil map of the Aversa plain, (ii) to describe the main features of the Aversa landscape and (iii) to address recent intense soil sealing (i.e. the covering of the ground by an impermeable material and associated land take leading to the loss of important soil functions) (COM, 2012; Scalenghe & Marsan, 2009) by evaluating its impact over land capability classes (Klingebiel & Montgomery, 1961) in the period between 1954 and 2015.

## 2. Methods

### 2.1. Environmental setting

The Aversa plain is part of the Rural Territorial Systems 12 and 04 – Piana Flegrea and Piana del Volturno – of the Campania Region (southern Italy) (Regione Campania, 2013). The investigated area is 20,000 hectares in size and includes 19 cities in the province of Caserta (Figure 1). Geomorphologically, it lies between Campi Flegrei volcanic hills and Volturno river plain, in the central portion of the Campania Plain, a Plio-Pleistocenic graben at the western edge of the Apennines (Vezzani, Festa, & Ghisetti, 2010 and references therein). Volcanic activity of the area intensified from the Middle Pleistocene, in connection with the above-mentioned tectonic structures, and led to the formation of the Roccamonfina, the Campi Flegrei caldera, the isles of Ischia and Procida and the Somma-Vesuvius. Because of its position, the Aversa plain was reached primarily by volcanic deposits from Campi Flegrei and the Vesuvius, with the most recognized tephra being the Campanian Ignimbrite (dated at 39.28 ± 0.11 ka by De Vivo et al., 2001), the Neapolitan Yellow Tuff (dated at 14.9 ± 0.4 ka by Deino, Orsi, de Vita, & Piochi, 2004) and the Pomici di Avellino (dated at 3550 ± 20 $^{14}$C yr BP by Passariello et al., 2009). Both these still active volcanoes strongly affected the recent soil formation processes of the study area (De Vita, Sansivero, Orsi, Marotta, & Piochi, 2010; Orsi, Di Vito, & Isaia, 2004; Santacroce et al., 2008). The Aversa plain was already known throughout the Roman Empire as *Campania Felix* due to the extreme fertility of its land. The discovery of numerous villages and cultivated fields dating back to the EBA (early bronze age) showed that the Campania region had been densely inhabited since the protohistoric age (Di Lorenzo et al., 2013). At that time, notably well-developed socio-economic communities of farmers and pastoralists belonging to the Palma Campania culture (Albore Livadie, 2007 and references therein) populated the Vesuvius plain and inner central Campania. Settlements of considerable extension have been found at Gricignano d'Aversa (6 ha), in the Aversa plain. The key factor in understanding the wide demographic distribution of the Palma Campania culture is in the chemical fertility of the lands (Vingiani, Minieri, Albore Livadie, Di Vito, & Terribile, 2018).

### 2.2. Climate

Meteorological data were obtained for 14 rainfall (1951–1999) and 7 thermometric stations (1970–1999) (data from ISPRA – SINTAI: Progetto Annali, Banca dati, available at: http://www.acq.isprambiente.it/annalipdf/). In the study area for this period mean monthly temperatures range from minima of 1.9°C in January at Ischitella station to maxima of 30.5°C in August at Napoli-Fisica Terrestre station, with mean annual values around 16°C, while the mean annual rainfall varies from 785 mm at Licola to 1009 mm at Grazzanise. The present-day pedoclimate, calculated by the use of the Newhall simulation model (Van Wambeke, 2000), is defined as a thermic soil temperature regime, associated with a ustic soil moisture regime.

### 2.3. Soil survey and mapping

Soil survey and mapping procedures followed a purposive sampling method, including analysis of the existing geological (Geological Map of Italy 1:100,000, Napoli, Foglio 183–184, and 1:50,000, Napoli, Foglio 446–447) (ISPRA, 1960, 2015), topographic (IGM and CTR topographic maps) (IGM, 1907–1957; Regione Campania, 1998) and land use maps (CUAS, 2009), aerial photo interpretation (G.A.I. fly, 1954–1955) at 1:33,000 scale, soil-landscape unit map definition, land soil survey at 1:25,000 scale by means of hand drilling and dug profiles, soil description (ISSDS, 1995), chemical and physical soil analyses (SSS, 1996) and soil classification (IUSS Working Group WRB, 2015). The main outputs were (i) the drawing of the Aversa plain soil map at 1:50,000 scale, by the use of GIS systems, and (ii) the land capability classification of the soil-land units, following the USDA method by the Soil Conservation Service of the USA Department of Agriculture (Klingebiel & Montgomery, 1961). Evaluation and mapping of the soil sealing affecting the Aversa plain was performed over three selected periods (1954, 1998 and 2015) and urban areas were derived by remotely sensed images: (1) G.A.I. 1954–55, (2) I.G.M.-1998, and (3) satellite images 2015 (derived by ISPRA, 2016a).

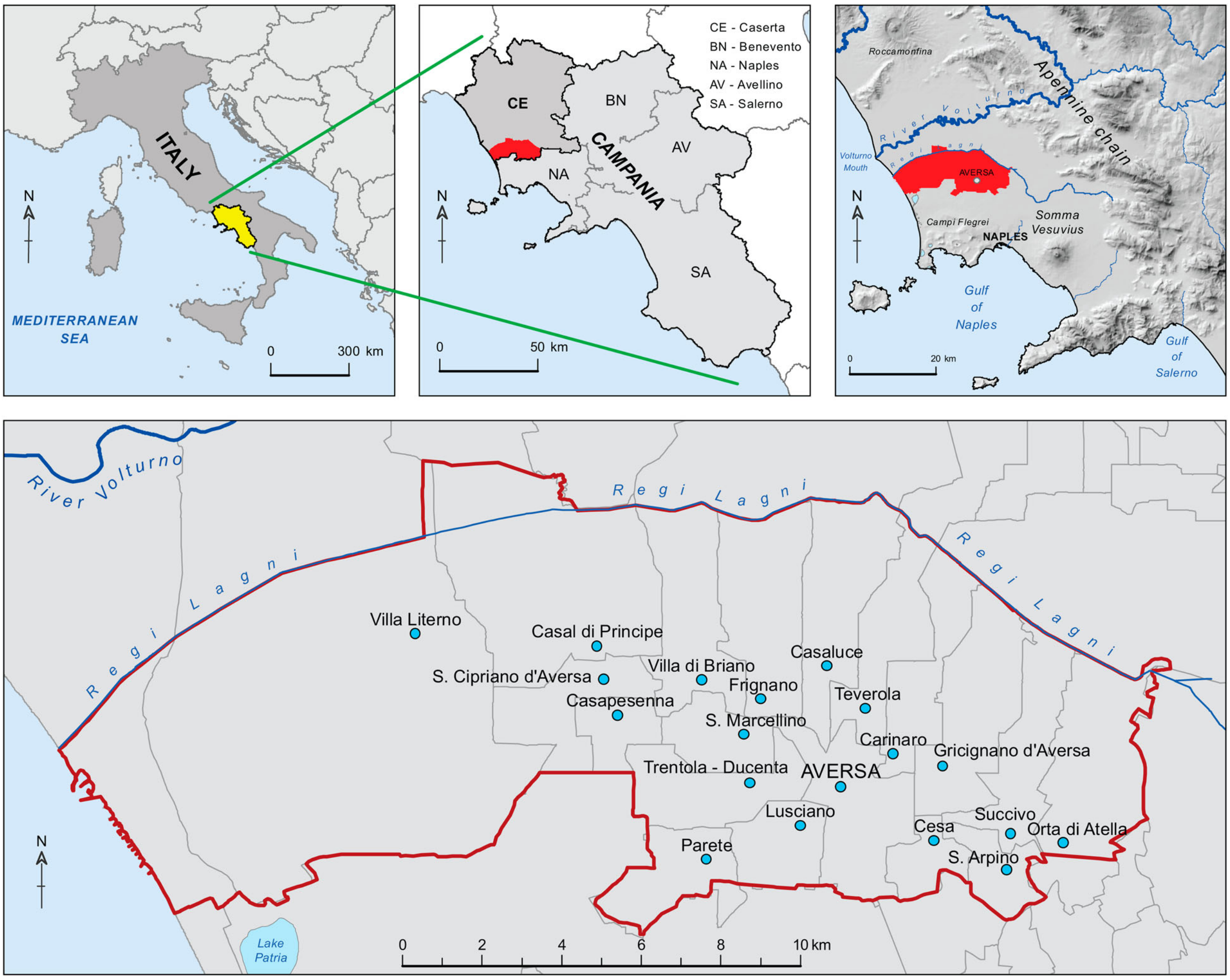


**Figure 1.** Location of the Aversa plain.

## 3. Results

### 3.1. The Aversa plain soil map

Three main land systems were identified in the area: (i) the coastal plain (PCO), (ii) the foothill plain (PPM) and (iii) the alluvial plain (PAL) (see Figure 2 and Main Map). The main characteristics of land systems and land units are described in Table 1, whereas the field morphology and the chemical and physical properties of soils representative of the land units are reported in Supplementary materials (Annex 1).

Approximately 700 soil observations with sample collection were carried out in the area; this enabled us to identify highly fertile Andosols as the main soil type present, having formed by the weathering of pyroclastic materials which erupted from the still active volcanoes of the region (Campi Flegrei and Vesuvius). In addition, Phaeozems, Cambisols, Vertisols, Arenosols, Histosols, Luvisols (in order of abundance) are also present.

#### 3.1.1. The coastal plain (PCO)

The PCO is an area including gentle morphology surfaces, with altitudes ranging from –0.2 to 4 m asl. This is a coastal dune environment, with sets of sand dunes running parallel to the shoreline, directly inland from the beach. Starting from the coast line, 7 land units were identified. Closest to the sea is the beach and mobile dune area (D), which is the pioneer zone extending landward from the debris line at the top of the beach in the fore dune or frontal dune. Only specialised pioneer plants can colonise this area exposed to salt spray, sand blast, strong winds and flooding by the sea. The D area is small and occupies only the extreme southern and northern part of the unit, separated by urbanization and the presence of the Pinetamare harbour. Soils are poorly developed and were classified as *Tidalic Arenosols*. In areas protected from windy and salty conditions, behind the frontal dunes, recent stabilised dunes (MAC) are colonized by Mediterranean vegetation, anthropogenic pinewood (*Pinus pinea*) and oak forest (*Quercus ilex*). Less than a third of the MAC unit is urbanised. Soils show very deep and poorly differentiated profiles, excessively drained, sandy and calcareous, with a thin surface horizon darkened by humified organic matter. Soils were classified as *Calcaric Arenosols (Alcalic, Ochric)*. An area of ancient dunes (SMA), generally parallel to the coast line and partially following the *Regi Lagni*

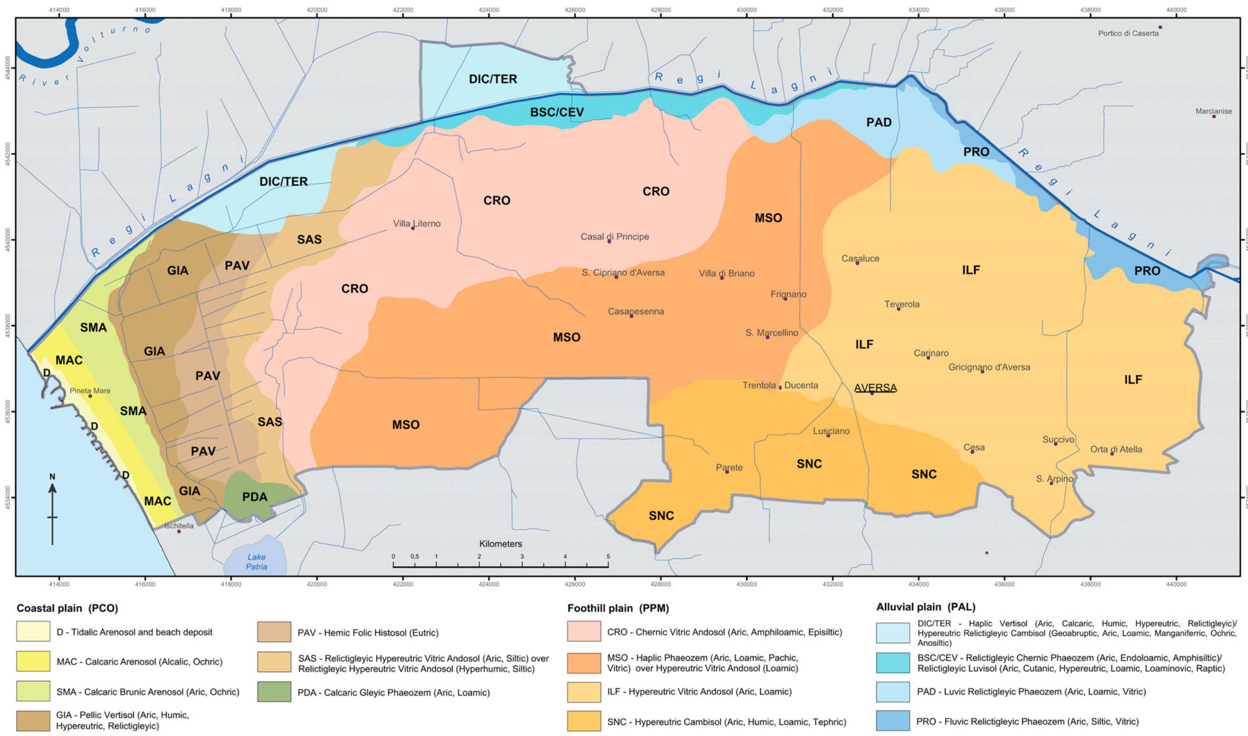


**Figure 2.** Soil map of the Aversa plain (southern Italy). Scale 1:50 000.

channel, was identified at the boundary with MAC. SMA is very much modified by anthropic levelling and urbanization; however agricultural soils are used for vegetable crops. Soils were classified as *Calcaric Brunic Arenosols (Aric, Ochric)* (Figure 3, profile a). Inland of SMA, low plain surfaces (altitude between –0.2 and –1.8 m asl) of GIA unit show shallow groundwater (within 1 m of depth) with high salinity. The area has lost the morphology of marsh and swamp after reclamations dating back to the eighteenth and twentieth centuries. Soils were classified as *Pellic Vertisols (Aric, Humic, Hypereutric, Relictigleyic)* (Figure 3, profile b) and their use is mainly for forage crops and pasture. Other low surfaces (PAV unit)

**Table 1.** Main characteristics of land systems and land units of the Aversa plain.

| Land systems | Land units | Landforms | Soil types following IUSS Working Group WRB, 2015 | Areas km$^2$ |
|---|---|---|---|---|
| *Coastal plain (PCO)* | D | Beach and mobile dune area | Tidalic Arenosol and beach deposit | 1.12 |
| | MAC | Recent stabilised dunes | Calcaric Arenosol (Alcalic, Ochric) | 2.78 |
| | SMA | Ancient dunes | Calcaric Brunic Arenosol (Aric, Ochric) | 4.19 |
| | GIA | Low plain surfaces | Pellic Vertisol (Aric, Humic, Hypereutric, Relictigleyic) | 8.87 |
| | PAV | Low plain surfaces | Hemic Folic Histosol (Eutric) | 6.72 |
| | PDA | Low plain surfaces close to Patria Lake | Calcaric Gleyic Phaeozem (Aric, Loamic) | 1.27 |
| | SAS | Plain surfaces between the coastal and the foothill plain | Relictigleyic Hypereutric Vitric Andosol (Aric, Siltic) over Relictigleyic Hypereutric Vitric Andosol (Hyperhumic, Siltic) | 7.44 |
| *Foothill plain (PPM)* | CRO | Distal lands of the foothill plain with slope gradients from 0.1% to 0.5% | Chernic Vitric Andosol (Aric, Amphiloamic, Episiltic) | 38.62 |
| | MSO | Surfaces of the foothill plain with slope gradients from 0.5% to 1% | Haplic Phaeozem (Aric, Loamic, Pachic, Vitric) over Hypereutric Vitric Andosol (Loamic) | 44.46 |
| | ILF | Surfaces of the foothill plain, with slope gradients from 0.5% to 1%, where a hard cineritic horizon is found between 90 and 120 cm of depth | Hypereutric Vitric Andosol (Aric, Loamic) | 51.62 |
| | SNC | Surfaces of the foothill plain, with slope gradients from 1% to 2%, where a hard cineritic horizon is found between 90 and 120 cm of depth | Hypereutric Cambisol (Aric, Humic, Loamic, Tephric) | 18.89 |
| *Alluvial plain (PAL)* | DIC/TER | Recent alluvial plain area, near to the lower course of the Regi Lagi river | Haplic Vertisol (Aric, Calcaric, Humic, Hypereutric, Relictigleyic)/ Hypereutric Relictigleyic Cambisol (Geoabruptic, Aric, Loamic, Manganiferric, Ochric, Anosiltic) | 9.08 |
| | BSC/CEV | Recent alluvial plain area, near to the medium course of the Regi Lagi river | Relictigleyic Chernic Phaeozem (Aric, Endoloamic, Amphisiltic)/ Relictigleyic Luvisol (Aric, Cutanic, Hypereutric, Loamic, Loaminovic, Raptic) | 4.33 |
| | PAD | Recent alluvial plain area, near to the medium-high course of the Regi Lagi river | Luvic Relictigleyic Phaeozem (Aric, Loamic, Vitric) | 5.15 |
| | PRO | Recent alluvial plain area, near to the high course of the Regi Lagi river | Fluvic Relictigleyic Phaeozem (Aric, Siltic, Vitric) | 3.31 |

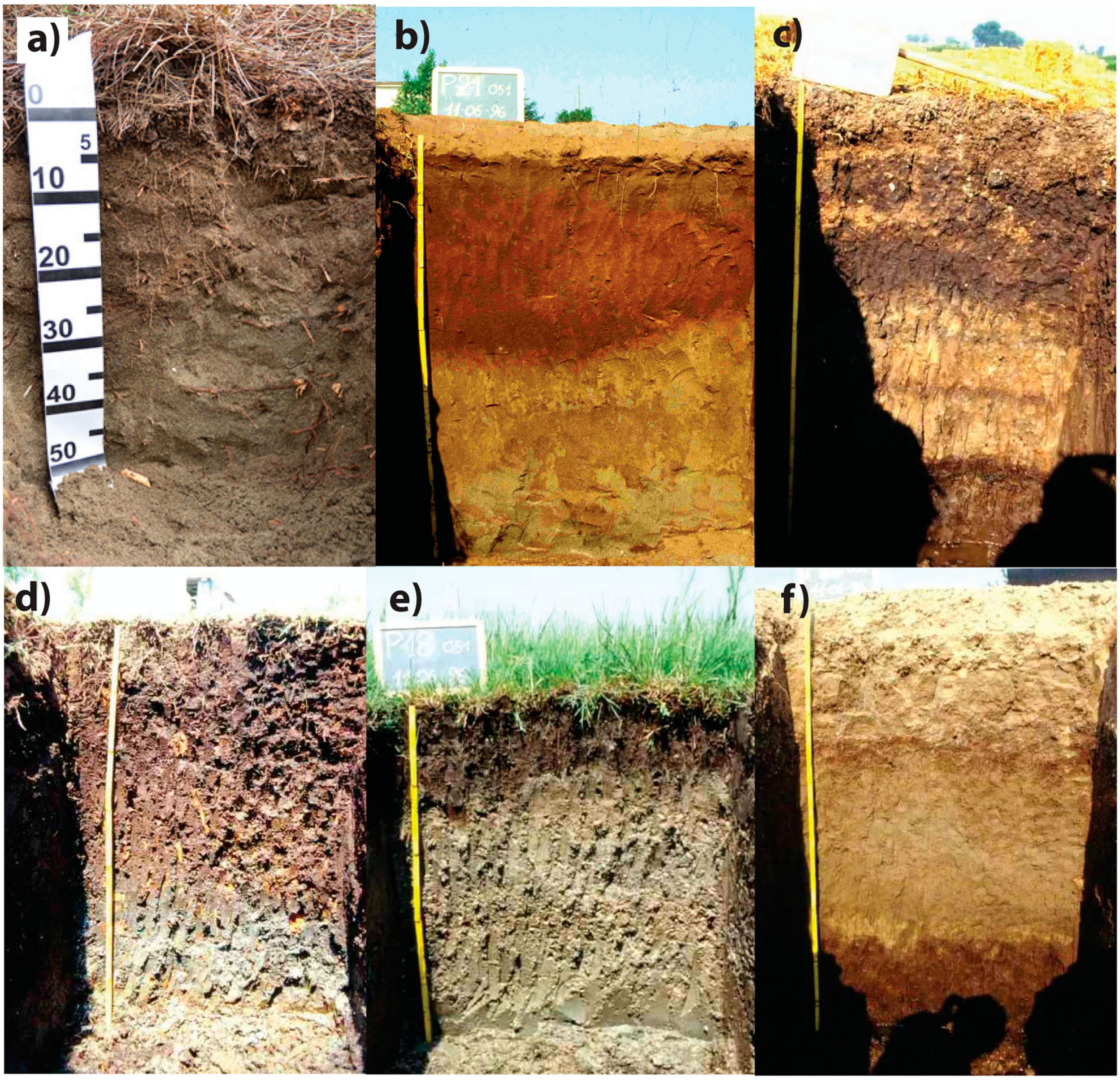


**Figure 3.** Coastal plain (PCO) land system. Representative soil profiles of the land units: (a) MAC, (b) SMA, (c) GIA, (d) PAV, (e) PDA and (f) SAS.

were identified in a different range of altitude (between –0.2 and 0.2 m asl), in the inner strip of land. Peats and silty sediments constitute the soil parent material. Soils of PAV were classified as *Hemic Folic Histosols (Eutric)* (Figure 3, profile c) and their main use is forage crops and pasture. Low areas were also observed close to the Patria lake (PDA unit), the largest coastal lake of the Campania region, where lacustrine silty clay deposits make up the soil parent material. Soils were classified as *Calcaric Gleyic Phaeozems (Aric, Loamic)* (Figure 3, profile d) and their use is mainly forage crops and pasture. A transition area (SAS unit), made by plain surfaces at 0–4 m asl, was identified between the coastal plain (PCO) and the foothill plain (PPM) systems, where stratified pyroclastic deposits occur and the groundwater lies between 1.5 and 1.8 m deep. Soils have very pronounced andic properties and were classified as *Relictigleyic Hypereutric Vitric Andosols (Aric, Siltic) over Relictigleyic Hypereutric Vitric Andosols (Hyperhumic, Siltic)* (Figure 3, profile e). Their main use is for vegetable crops.

### 3.1.2. The foothill plain (PPM)

The PPM system includes the volcanic plain, with a gradient ranging from 0.1% to 2% and altitudes from 5 to 60 m asl, located on the northern side of the Campi Flegrei. Pyroclastic falls and flows from the local eruptive centres (Campi Flegrei and Vesuvius) were deposited on the plain over the millennia and represent the primary soil parent material. PPM is bordered by PCO on the western and PAL on the northern side. Soils that formed in this area are generally very deep, well drained and show slightly to moderately developed andic properties. A soil benchmark

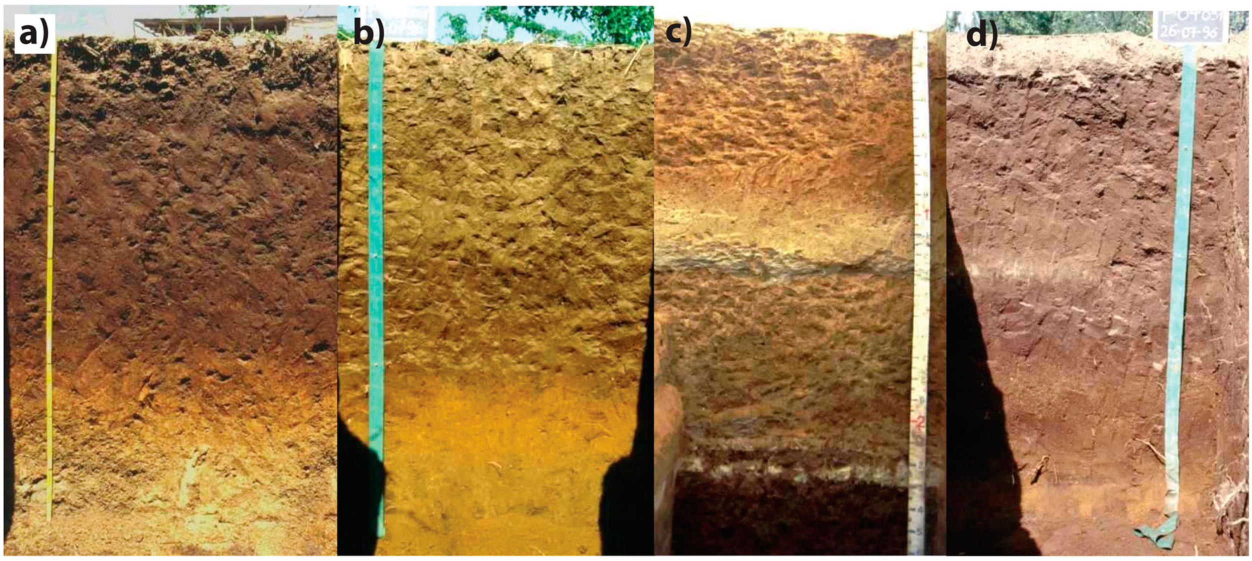


**Figure 4.** Foothill plain (PPM) land system. Representative soil profiles of the land units: (a) CRO, (b) MSO, (c) ILF and (d) SNC.

was identified at different depths throughout the land system and has been taken as the reference level for the general soil distribution in the landscape, in terms of age and degree of development. The considered benchmark is an ancient soil, dark in colour and rich in organic matter, showing pronounced andic properties (*sensu* IUSS Working Group WRB, 2015). Due to these properties, the soil benchmark very likely formed by the weathering of the Neapolitan Yellow Tuff (which has been frequently identified at the bottom of the benchmark soil), in a moisture regime much more humid than the present. This hypothesis is consistent with several findings in the Campania plain of a very similar soil (Marzocchella, 2000; Vingiani et al., 2018) formed before the Agnano-Mt. Spina eruption (4130 ± 50 $^{14}$C yr B.P.), in a period falling entirely in the Holocene climatic optimum (ranging between 8 and 4 ka BP). The Holocene climatic optimum represented an important phase in terms of soil development because of increased environmental moisture and temperatures, arboreal vegetation spread (temperate deciduous forest) (Russo Ermolli & Di Pasquale, 2002) and morphoclimatic stability as a consequence of volcanic quiescence. This period corresponds to the Neolithic and Eneolithic ages in the Campania region. The closer the lands are to volcanos, the deeper the ancient soil benchmark underground, as a consequence of the pyroclastic material deposition. Therefore, in the eastern and southern areas of the Aversa plain, the thickest (from 2 to 4 m) soils and pyroclasts/tephra cover are found over the benchmark as soil cover showing weakly developed andic properties, due to its recent deposition (younger than 10,000 years BP). At the boundary with the PCO system, the CRO unit includes distal lands of the foothill plain at altitudes ranging from 1 to 18 m asl and slope gradients from 0.1% to 0.5%. Within the PPM system, CRO is the furthest unit from the Vesuvius volcanic edifice and includes the most developed soils of the system. These soils, which showed moderately developed andic properties, were classified as *Chernic Vitric Andosols (Aric, Amphiloamic, Episiltic)* (Figure 4, profile a) and their use is mainly arable and vegetable crops. On the south-eastern side of CRO, there is MSO unit, whose lands slope towards the coast and the *Regi Lagni* channel, with altitudes ranging from 6 to 40 m asl and gradients between 0.5% and 1%. Soils were classified as *Haplic Phaeozems (Aric, Loamic, Pachic, Vitric) over Hypereutric Vitric Andosols (Loamic)* (Figure 4, profile b) and their use is arable crops and fruit-bearing trees. Then, on the eastern side of MSO is ILF unit, whose lands slope towards the *Regi Lagni* channel, with altitudes ranging from 40 to 16 m asl and gradients between 0.5% and 1%. In this unit, both volcanological and archaeological stratigraphic reconstructions (mainly from the Gricignano US Navy excavations) enable the dating of ancient soils, by means of huts and tombs, of both the Eneolithic period and the Early Bronze Age, the last falling below the Pomici di Avellino eruption about 3.9 ka (Albore Livadie, 2007). The ILF soils were classified as *Hypereutric Vitric Andosols (Aric, Loamic)* (Figure 4, profile c) and their use is fruit-bearing trees and arable crops. Lastly, SNC is the southernmost unit of the PPM system and its lands have slope gradients between 1 and 2% and altitudes between 40 and 60 m asl. Soils were classified as *Hypereutric Cambisols (Aric, Humic, Loamic, Tephric)* (Figure 4, profile d) and their use is fruit-bearing trees, arable crops and vineyards. Soils of both SNC and ILF are characterised by the presence of a hard ash layer (*pyroclastic surge*) belonging to the Pomici di Avellino eruption, at depths ranging from 90 to 120 cm.

#### 3.1.3. The alluvial plain (PAL)

The PAL system is on the northern boundary of the study area and includes the alluvial plain of the ancient *Clanis* river (modern *Regi Lagni* channel). The reclamation of the river *Clanis* wetlands was started in the XVII century by the viceroy Pedro Fernández de Castro to solve the problem of frequent flooding events of the cultivated lands. A main channel, named *Regi Lagni*, along with several tributary channels, was built in place of the river *Clanis*, with the aim to improve the agricultural productivity of the area. Currently, the *Regi Lagni* channel no longer performs the function of a drainage canal, but has been gradually transformed into a sewer, following the input of black water from all municipalities of the catchment area, and today it represents one of the major existing sewage collectors nationwide. The ancient alluvial deposits were distributed on both sides of the *Clanis* river course and showed different particle size, according to the river water energy and the local morphology.

In the PAL system, four main land units were identified, according to the distance from the mouth of the *Regi Lagni* channel and altitude above sea level. These units differ in terms of soil texture, with the areas closer to the coast (i.e. the lower river course) having fine textured calcareous soils whereas the area of the middle and high course have coarser textured non-calcareous soils. On the whole, the soils have moderate andic properties and are developed on pyroclastic deposits, both primary and redeposited. The DIC/TER unit is in the lower part of the river course, at altitudes between 1 and 8 m asl. Here silty-clay soils have typical morphological and functional characteristics (such as vertic properties) due to shrinking and swelling processes, whereas the deep horizons preserve traces of alluvial deposition processes (such as layers and/or sedimentary laminations). Soils were classified as *Haplic Vertisols (Aric, Calcaric, Humic, Hypereutric, Relictigleyic)* (DIC unit) and *Hypereutric Relictigleyic Cambisols (Geoabruptic, Aric, Loamic, Manganiferric, Ochric, Anosiltic)* (TER unit) (Figure 5, profiles a and b). The main land use is vegetable crops. The plain areas of the middle river course (BSC/CEV), which extends at altitudes between 8 and 14 m asl, show a generally silty loam – clay loam texture on the surface and a clayey texture with depth; carbonates are absent on the surface, but can be present in depth; locally, soils can show vitric properties. Soils were classified as *Relictigleyic Chernic Phaeozems (Aric, Endoloamic, Amphisiltic)* (BSC) and *Relictigleyic Luvisols (Aric, Cutanic, Hypereutric, Loamic, Loaminovic, Raptic)* (CEV) (Figure 5, profiles c and d) and their main use is vegetable crops and fruit-bearing trees (pome). PAD and PRO units are in the middle-high and highest part of the *Regi Lagni* channel, relative to the Aversa plain, and occupy altitudes between14 and 18 m asl. Soils show a loamy – silty loam texture on the surface that becomes coarser with depth, but generally, no carbonates are found. The land use is generally vegetable crops and fruit-bearing trees. PAD and PRO soils were classified as *Luvic Relictigleyic Phaeozems (Aric, Loamic, Vitric)* and *Fluvic Relictigleyic Phaeozems (Aric, Siltic, Vitric)*, respectively (Figure 4, profiles e and f).

### 3.2. Soil sealing

Data from the last ISPRA (2016b) report on the situation of soil sealing in Italy in 2015 showed a critical problem in the Campania region (third region of Italy for soil sealing), with soil sealing exceeding 10% (ca. 1.3 km$^2$) of the regional surface. Caserta, which comprises the Aversa plain, is the third province of the Campania region in terms of soil sealing (26,168 ha) after Salerno and Napoli. By land capability classification (see the map), the soils of the Aversa plain belong mainly to first and second classes (9898 and 7050 ha in first and second class, respectively) (Table 2). However, their high value and fertility are consistent with the long history of civilization of these areas. Three snapshots of selected crucial periods of the Italian landscape were analyzed: the urbanization of the Aversa plain in 1954 (in the period of reconstruction after the Second World War), 1998 (just before the end of the century) and 2015 (the current situation). In Table 2 data on soil sealing (in ha) are

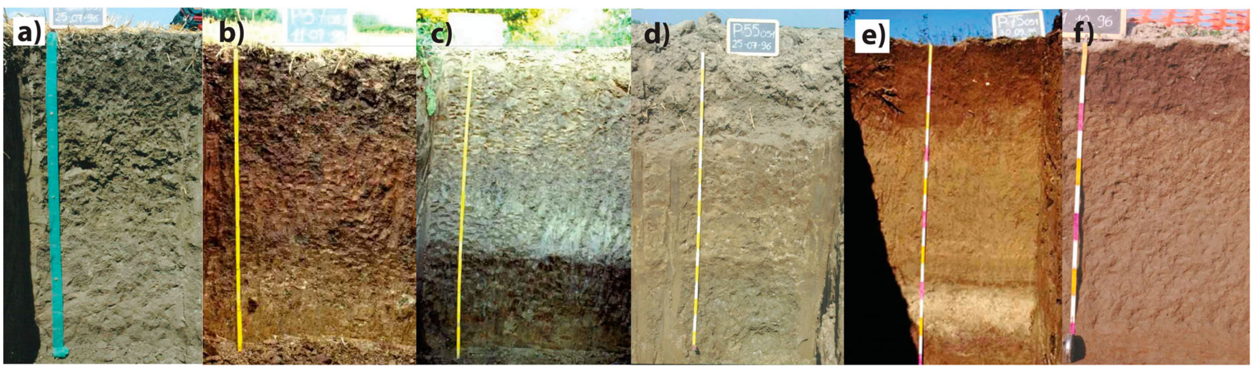


**Figure 5.** Alluvial plain (PAL) land system. Representative soil profiles of the land units: (a) DIC, (b) TER, (c) BSC, (d) CEV, (e) PAD and (f) PRO.

**Table 2.** Areas (in ha) affected by soil sealing in the selected years (1954, 1998, 2015).

| | Soil sealing (ha) in the years | | |
|---|---|---|---|
| Land capability classes | 1954 | 1998 | 2015 |
| I | 269 | 1718 | 2010 |
| II | 655 | 2788 | 3395 |
| III | | 24 | 33 |
| IV | | 569 | 640 |

reported for the selected periods and grouped by class of land capability. In 1954, 269 ha of first and 655 ha of second-class land were sealed, with the second class higher than the first. After approximately 40 years (from 1954 to 1998), the situation had changed considerably: (1) first-class sealed soils were more than 6 times the soils that were sealed in the 1954; (2) second-class sealed soils were more than 4 times the soils that were sealed in the 1954; (3) third and fourth classes soils, previously not affected by soil sealing in 1954, have been urbanized on 24 and 569 ha, respectively. In the following 20 years up to 2015, soil sealing had a minor impact on the Aversa plain, nevertheless a further 292 ha of first-class soils and 607 ha of second-class soils were consumed until the year 2015, along with a total of 80 ha in the third and fourth classes.

## 4. Conclusions

The Aversa plain consists of three main land systems, the coastal, the alluvial and the foothill plains, where different geomorphological processes shape the landscape. Different soil types have been identified (Andosols, Phaeozems, Cambisols, Vertisols, Arenosols, Histosols, Luvisols), but the most widespread type is Andosols. As shown by the land capability classification, the soils of the Aversa plain mainly belong to first and second classes, which is consistent with the high fertility landscape well known to farmers and pastoralists since protohistoric times. The analysis showed that urbanization increased in the Italian landscape in three crucial periods, with the greatest modifications occurring from 1954 to 1998 at the expense of the most fertile soils. First and second-class lands were the most affected, with the second-class lands more affected by sealing compared to the first. These results are considered to be connected to the position of the Aversa plain close to and north of the Naples urban area, the main city of the Campania region. Because of the very high population density of Naples, migration towards city outskirts is one of the major causes of Aversa soil sealing, along with the urban reconstruction following the destructive 1980 earthquake and increased land value consequent to the recent deindustrialization of the city. We consider that the high fertility of these lands must be considered in urban planning in order to preserve these 'highly precious non-renewable' soil resources from sealing.

## Software

The information used to carry out this work was integrated into ESRI ArcGIS (v. 9.2) from which analysis of the data and derived spatial coverages were obtained. The final design of the cartography we have presented here was also made using ArcGIS.


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## Disclosure statement

No potential conflict of interest was reported by the authors.

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## References


Albore Livadie, C. (2007). *L'età del Bronzo antico e medio nella Campania nord–occidentale*. Atti della "XL Riunione Scientifica", Istituto Italiano di Preistoria e Protostoria, Strategie di insediamento fra Lazio e Campania in età preistorica e protostorica, Firenze (Vol. II, pp. 179–203).

COM. (2012). *European Commission. Report from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions. The implementation of the Soil Thematic Strategy and ongoing activities*. Brussels, 13.2.2012, 46 final.

CUAS (Carta dell'Utilizzazione Agricola del Suolo). (2009). *Tavola A.4. Programma di Sviluppo Rurale 2007–2013. Regione Campania. Ufficio dell'Autorità Ambientale*. Retrieved from http://www.agricoltura.regione.campania.it/PSR_2007_2013/cartografie/A04_cuas.pdf

De Vita, S., Sansivero, F., Orsi, G., Marotta, E., & Piochi, M. (2010). Volcanological and structural evolution of the ischia resurgent caldera (Italy) over the past 10 ka. In G. Groppelli & L. Viereck (Eds.), *Stratigraphy and geology in volcanic areas: Geological society of America book series, special paper 464* (pp. 193–239). doi:10.1130/2010.2464(10).

De Vivo, B., Rolandi, G., Gans, P. B., Calvert, A., Bohrson, W. A., Spera, F. J., … Belkin, H. E. (2001). New constraints on the pyroclastic eruptive history of the Campanian volcanic plain (Italy). *Mineralogy and Petrology*, *73*, 47–65. doi:10.1007/s007100170010

Deino, A. L., Orsi, G., de Vita, S., & Piochi, M. (2004). The age of the Neapolitan Yellow Tuff caldera-forming eruption (Campi Flegrei caldera – Italy) assessed by 40Ar/39Ar dating method. *Journal of Volcanology and Geothermal Research*, *133*(1–4), 157–170. doi:10.1016/S0377-0273(03)00396-2

Di Lorenzo, H., Di Vito, M. A., Talamo, P., Bishop, J., Castaldo, N., de Vita, S., … Marco Pacciarelli. (2013). The impact of the Pomici di Avellino Plinian eruption of Vesuvius on early and middle Bronze age human settlement in Campania (Southern Italy). In Proceedings of the 4th Archaeological Conference of Central Germany: 1600-Cultural change in the shadow of the Thera eruption? International Conference in Halle (Saale), October, 2011. *Tagungen des Landes museums für Vorgeschichte e Halle*, Band 9, 253–266.

G.A.I. fly. (1954–1955). *Aerial photos at 1:33.000 scale. IGM (Istituto Geografico Militare)*. Italy.

IGM (Istituto Geografico Militare). (1907–1957). *Carta Topografica d'Italia in scala 1:25.000*. Retrieved from http://intelspeedcontest2006.tiscali.it/prodotti/cartografia/carte_topografiche/serie_25.php

ISPRA. (1960). *SERVIZIO GEOLOGICO D'ITALIA Carta Geologica d'Italia, Napoli, Foglio 183–184 alla scala 1:100.000*.

ISPRA. (2015). *SERVIZIO GEOLOGICO D'ITALIA Carta Geologica d'Italia, Napoli, Foglio 446–447. Scala 1:50.000*.

ISPRA. (2016a). *Dati Nazionali, Regionali, Provinciali e Comunali. Il consumo di suolo in Italia*. Retrieved from http://www.sinanet.isprambiente.it/it/sia-ispra/download-mais/consumo-di-suolo/archivio

ISPRA. (2016b). *Consumo di suolo, dinamiche territoriali e servizi ecosistemici – Rapporto 2016. ISPRA, Rapporti 248/2016; ISBN 978-88-448-0776-4*.

ISPRA – *SINTAI: Progetto Annali, Banca dati*. Retrieved from http://www.acq.isprambiente.it/annalipdf/

ISSDS (Istituto Sperimentale per lo studio e la difesa del suolo). (1995). *Guida al rilevamento dei suoli*. Progetto U.O.T. (versione 2), 64 pp.

IUSS Working Group WRB. (2015). *World Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps* (World Soil Resources Reports No. 106). Rome: FAO.

Kabata-Pendias, A. (2001). *Trace elements in soils and plants*. Boca Raton, FL: CRC Press.

Klingebiel, A. A., & Montgomery, P. H. (1961). *Land capability classification*. USDA Agricultural Handbook 210, Washington, DC: US Government Printing Office. 21 pp.

Latrille, C., Denaix, L., & Lamy, I. (2003). Interaction of copper and zinc with allophane and organic matter in the B horizon of an Andosol. *European Journal of Soil Science*, *54* (2), 357–364. doi:10.1046/j.1365-2389.2003.00530.x

Maeda, T., Takenaka, H., & Warkentin, B. P. (1977). Physical properties of allophane soils. *Advances Agronomy*, *29*, 229–264. doi:10.1016/S0065-2113(08)60220-5

Marzocchella, A. (2000). Storie di contadini alle falde del Vesuvio. *Archeo*, *182*, 36–45.

Mileti, F. A., Langella, G., Prins, M. A., Vingiani, S., & Terribile, F. (2013). The hidden nature of parent material in soils of Italian mountain ecosystems. *Geoderma*, *207–208*, 291–309. doi:10.1016/j.geoderma.2013.05.006

Nanzyo, M. (2004). Unique properties of volcanic ash soils. *Global Environmental Research* 6 (2). Association of International Research Initiatives for Environmental Studies (Airies), Japan.

Orsi, G., Di Vito, M. A., & Isaia, R. (2004). Volcanic hazard assessment at the restless Campi Flegrei caldera. *Bulletin of Volcanology*, *66*, 514–530.

Passariello, I., Albore Livadie, C., Talamo, P., Lubritto, C., D'Onofrio, A., & Terrasi, F. (2009). $^{14}$C chronology of Avellino pumices eruption and timing of human reoccupation of the devastated region. *Radiocarbon*, *51*(2), 803–816.

Quantin, P. (1990). *Specificity of the halloysite rich tropical or subtropical soils*. In: Transactions 14th International Congress of Soil Science (pp. 16–21), Kyoto, Japan.

Regione Campania. (1998). *Carta Tecnica Numerica Regionale in scala 1:5000*. Retrieved from https://sit2.regione.campania.it/alfresco/webdav/Siti/sit-regione-campania/CTR/CTR%20Edizione%201998/Caserta?rootFO=/Siti/sit-regione-campania/CTR

Regione Campania. (2013). *Il territorio rurale della Campania. Un viaggio nei sistemi agroforestali della regione attraverso i dati del 6° Censimento Generale dell'Agricoltura*. Direzione Generale Politiche Agricole Alimentari e Forestali. IMAGO editrice. ISBN: 978-88-95230-24-5.

Russo Ermolli, E., & Di Pasquale, G. (2002). Vegetation dynamics of south-western Italy in the last 28 kyr inferred from pollen analysis of a Tyrrhenian Sea core. *Vegetation History and Archaeobotany*, *11*(3), 211–220. doi:10.1007/s003340200024

Santacroce, R., Cioni, R., Marianelli, P., Sbrana, A., Sulpizio, R., Zanchetta, G., … 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. doi:10.1016/j.jvolgeores.2008.06.009

Scalenghe, R., & Marsan, F. A. (2009). The anthropogenic sealing of soils in urban areas. *Landscape and Urban Planning*, *90*(1), 1–10. doi:10.1016/j.landurbplan.2008.10.011

Shoji, S., Nanzyo, M., & Dahlgren, R. A. (1993). *Volcanic ash soils: Genesis, properties and utilization*. Amsterdam: Elsevier.

Shoji, S., & Takahashi, T. (2003). Environmental and agricultural significance of volcanic ash soils. *Global Environmental Research*, *6*, 113–135.

SSS (Soil Survey Laboratory Staff). (1996). *Soil survey laboratory methods manual. Version 3.0. National Soil Survey Center. Soil Survey Investigations Report No. 42*. U.S. Department of Agriculture, Lincoln.

Tanneberg, H., Jahn, R., Meijer, E. L., & Kleber, M. (2001, October 3–7). *Sorption (kinetic and capacity) and desorption of trace elements in volcanic soils of Italy and the Azores*. In: Cost Action 622, Soil Resources of European Volcanic Systems. Volcanic Soils: Properties, Processes and Land Use, International Workshop, Abstracts, Ponta Delgada (San Miguel), Azores (Portugal), pp. 58–59.

Van Wambeke, A. R. (2000). *The newhall simulation model for estimating soil moisture & temperature regimes. Department of crop and soli sciences*. Ithaca, NY: Cornell University.

Vezzani, V., Festa, A., & Ghisetti, F. C. (2010). *Geology and tectonic evolution of the Central-Southern Apennines, Italy*. Geological Society of America Special Paper,Vol. 469, 58 pp.

Vingiani, S., Mele, G., De Mascellis, R., Terribile, F., & Basile, A. (2015). Volcanic soils and landslides: A case study of the island of Ischia (Southern Italy) and its relationship with other Campania events. *Solid Earth*, *6*(2), 783–797. doi:10.5194/se-6-783-2015

Vingiani, S., Minieri, L., Albore Livadie, C., Di Vito, M., & Terribile, F. (2018). Pedological investigation of an early bronze age site in southern Italy (2017). *Geoarchaeology*, *33*, 193–217. doi:10.1002/gea.21625

Vingiani, S., Scarciglia, F., Mileti, F. A., Donato, P., & Terribile, F. (2014). Occurrence and origin of soils with andic properties in Calabria (southern Italy). *Geoderma*, *232–234*, 500–516. doi:10.1016/j.geoderma.2014.06.001

Zhao, B. Z., Maeda, M., Zhang, J. B., Zhu, A. N., & Ozaki, Y. (2006). Accumulation and chemical fractionation of heavy metals in Andisols after a different, 6-year fertilization management. *Environmental Science and Pollution Research*, *13* (2), 90–97.