



Selected works 2024

# BOOK OF EXCURSIONS

International Union of Soil Sciences



International Union of Soil Sciences





René Magritte - *The blank signature* (1965)

## Book of Excursions IUSS Centennial Congress and Celebration

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## Villa Lubin and soil treasures of the ancient Rome May 18, 2024

**Tour Leader:** Serena Giuliani PhD, Archaeologist and Vatican City and Patrons of-  
ficial guide

**By:** Claudia Fontana, Irene Fabbri, Cristina Giannetti

*To celebrate the Centennial of the IUSS, International Union of Soil Sciences, the day begins with the visit to Villa Lubin where the IUSS was established during the Fourth International Conference of Pedology in 1924.*

10:00	Guests welcoming Plenary Room “Marco Biagi”
10:15	Celebrations opening CNEL – National Council for Economics and Labour Dott. Alessandro Vaccari – Press Office Manager
10:25	Greetings Prof. Giuseppe Corti- President SISS and Head of the IUSS Secretariat Prof. Edoardo A.C. Costantini- Presidente IUSS
10:45	The establishment of the IUSS Prof. Edoardo A.C. Costantini- Presidente IUSS
11:00	Visit to the Villa Lubin
11:45	Final greetings
12:00	Soil treasures of the Ancient Rome tour
17:30	Arrival at CREA, where the IUSS Secretariat is hosted and managed.

**Welcome speech of the IUSS President, Edoardo A.C. Costantini**

***The establishment of the IUSS during the Fourth International Conference of Pedology.***

The opening ceremony of the Conference took place on the 12th of May 1924 in the presence of the king of Italy, Vittorio Emanuele III. In his welcome speech, Louis Dop, Vice-President of the International Institute of Agriculture, thanked the king for his presence and the High Patronage Granted to the Conference by the Head of the Italian Government, which indicates the strong interest that the Italian Government brought to the success of the conference. Afterwards, the floor was given to Gioacchino De Angelis D'Ossat, who made the inauguration speech. I quote:

*“As President of the Organizing Committee of the Fourth International Conference of Pedology, I have the honour to express my deep satisfaction in seeing such a large number of Scientists gathered in Rome, also coming from the most distant parts of the world, in order to continue, with intellect and love, the search for the laws that regulate the life of plants and transformations of*



*agricultural land, to increase their yields. The Italian pedologists are proud to welcome valiant foreigners and formulate the wish that the present Conference will exercise a beneficial and feracious influence on Italian soil research.*

*It is not long since the scientists ungratefully almost despised the study of that soil that gave them daily bread. In short, however, the isolated became cohort, and elected; and now about 2,000 scholars investigate the agricultural land, not so much for direct interest as for the attraction that it exercises the mystery of the life which it fecundates.*

*The theory of Kant and Laplace represents the origin of our planet. In the birth certificate of a rock the decree of death is written, and between this and that, passes existence. However, nothing is lost: the death of one rock marks the birth of another. The passage is represented by the detritus, the son of terrestrial dynamism.*

*Although to the detritus is geologically granted a transient life, nevertheless nature wanted the seed to find its seat and sustenance in it. The minerals and the rocks becoming detritus, that is agricultural soil, in-*

*crease their surface and pass to the colloidal state. Therefore, instead of the rocks, life was better suited to the detritus, because it splits up to the colloidal state. In the debris, suspended or flocculated in ionized water, with the energy given by the solar ray, life found the first cradle. As soon as the elemental organic substance got married to the detritus, life threw out its eager roots, developing its marvellous trunk, which, branching out through geological times, procreates the following floras and fauna.*

*Colleagues, the object of your research is very high and the task you propose to yourselves is essential to life and our very existence. You consciously impart a more accelerated rhythm to the biological cyclical elements and thus create a greater vital production....”*

**This was a part of the inauguration speech of Gioacchino De Angelis D'Ossat.**

*“The Conference had 463 adherents from 39 countries. The most attended delegation was that of Italy, followed by Germany and Czechoslovakia. The broad Italian participation in the event was testified by the numerous institutions represented in Rome. Among the overall 120 scientific Institutions, 39 were Italians. Besides IIA, there were representatives of the national academic and scientific societies related to agriculture and geology, the Royal Bureau of Geology, the faculties of Agriculture and Geology of several Universities, many Itinerant Chairs of Agriculture, and the agricultural experimental stations, Institutions that now belong to the CREA. There was also an important interest shown by the industrial sector. Among the 16 companies and factories present in Rome, 7 were from Italy, most of them related to the production and sale of fertilizers.*

*The 293 paying participants in the Congress paid 50 Italian Lira each as a registration fee, corresponding to about the current 47 euro. The low fee was available because of the sponsorships of the Italian Agronomic Society, the chemical factory “Società Montecatini”, and mostly the generous contribution of the Ministry of Economy, which donated 58,960.55 Lira, equivalent to about current 56,000 euro.*

*The discussion and approval of the Statute of the ISSS took place during the final general session of the Conference, on Monday morning, 19th of May. The rapporteur of the special commission responsible for drafting the statute, Oberst Girsberger from Switzerland, presented the Special Commission's report. The main points of the statute were introduced. During the discussion, significant attention was given to the name of the Society. It was proposed that the name should be “Soil Science” instead of “Pedology,” which had been used in previous conferences. The reason was that the literal translation of the latter did not accurately reflect the purpose of the society. The report and the statute were approved by acclamation.*

Jacob Lipman from the USA was elected as the first President, and David Hissink from the Netherlands was elected as the first General Secretary. The vice presidents, Gioacchino De Angelis D'Ossat from Italy and Benjamin Frosterus from Finland, the editor of the journal, Friedrich Schucht from Germany, and the librarian Guido Borghesani, from Italy, were also elected by acclamation.

The scientific sessions were animated by 280 communications, within 6 thematic sessions on:

- Mechanical and physical study of the soil, application of pedology to agricultural hydrology;
- Soil chemistry;
- Bacteriological and biochemical study of the soil
- Soil nomenclature and classification;
- Cartography;
- Study of plant physiology in relation to pedology.

The main scientific outcomes of the Conference can be summarized as follows:

- 1) Standardization of the methods of soil analysis;
- 2) Standardization of soil microbiological research;
- 3) Study program to establish a nomenclature and a definitive soil classification;
- 4) Development of an international agro-geological map of Europe;
- 5) Organization of soil studies in countries where they do not yet exist;
- 6) Introduction of the study of pedology in the curriculum of middle and higher schools;
- 7) Definitive constitution of the sixth Commission: Plant physiology in relation to soil;
- 8) Convening of the First International Congress of Soil Science in the USA.



The Proceedings of the Conference have been a major outcome of the Conference itself, producing three volumes and one annexe for a total of around 2,000 pages, now digitized and available on the website of the IUSS. The Conference of Rome had an outstanding success, both internationally as well as in Italy, where important research works and publications about soils were produced. Among them, Ugo Pratolongo published a book about agricultural Chemistry, Alvisé Comel a set of papers about the red and brown soils in Central Italy and his famous treaty "Elements of Climatic Pedology". Angelo Oliva published a treaty on soil and water con-

servation at the farm and field scale, and Paolo Principi published the famous book "The Soils of Italy", with a soil map of Italy.

Today, one hundred years later, following in the footsteps of the Masters allows us to tap into their wisdom, experiences, and discoveries to make progress in our current research endeavours.

To conclude, let me quote Isaac Newton: "We can only see further by standing on the shoulders of giants."

Let the lessons learned from the past guide our path towards a more sustainable and equitable future for all humanity!

Thank you for your attention and enjoy the visit!"

The morning carries over with the visit of the Villa Lubin, a magnificent building nestled in the very heart of the Villa Borghese gardens. Inaugurated in 1908, the Villa was a project of the architect Pompeo Passerini and his decorators: Adolfo Cozza, Adolfo Apolloni, Giuseppe Mazzoni, Lemmo Rossi-Scotti. Back in the days, they were involved in the construction of the monument to Vittorio Emanuele II, the Vittoriano. Adolfo Cozza painted the Parlamentino frescoes: "The Agriculture from the Barbarians to the Imperial Rome" and "The great navigators, the astronomers and naturalists from XII to XVIII sec." The yellow room, instead, is the masterpiece of Lemmo Rossi-Scotti with his fresco "The triumph of Cerere followed by the Nations cortege".

This Villa truly accomplished the idea of the Passerini to balance the neo-baroque architecture with the liberty influences, setting the building within one of the most beautiful roman gardens. After some pictures, the group carries on with the tour of the ancient Rome soil treasures. The attendees reach Piazza del Popolo, the famous square designed by Valadier, which lies in the Northern Gate of the Aurelian Walls, once the so-called Porta Flamina, leading to the most important route to the North of Italy. After admiring the obelisk of Seti I from Heliopolis which stands in the middle of the piazza, the groups heads to via di Ripetta towards the Augustus Mausoleum.

This is a large tomb build in 28 b.C. on the Campus Martius. The Mausoleum has a circular plan, made of several concentric bricks' rings with cypresses on the top tier, and was built to celebrate the Res Gestae of emperor Augustus.

Next steps, via della Scrofa and Piazza Navona, where the fountain of the Four Rivers by Bernini proudly stands. The piazza is built on the Stadium of Domitian, I century A.D. and follows its oval shape. The ancient Romans used to watch the agones (games) and, therefore, it was known as the Circus Agonalis. During the XVII Century, it became the hearth and soul of the Baroque design, with the Bernini fountain of Four Rivers standing just opposite the church of Santa Agnese in Agone, by

Borromini. The name of the church, “in agone”, means “in the site of the competitions” as the piazza was built on a stadium of a Greek model, with one flat end, and was used for footraces. The interior of the church is near-circular, a Greek cross design, and surrounded by Baroque marbles of Saints and Martyrs. After a lunch with typical roman delicacies, the group carries on along via Dei Fori Imperiali, the Imperial Fora, one the most beautiful archaeological sites in the world, and core of the Roman Empire. Built between 46 a. C and 113 A.D., its incredible route takes the attendees through the Forum of Trajan (with its market), the Forum of Augustus and the Forum on Nerva. Parts of these fora can be seen on both sides of the road.

The tour then heads towards the Colosseum, the largest amphitheatre ever built in human history. Its construction begun under the emperor Vespasian, and was completed in 80 A.D. The Colosseum is built with travertine, limestone, tuff (a volcanic rock), and brick-faced concrete. It can hold between 50,000 to 80,000 spectators, and was used for Gladiators fight, animal hunts and re-enactments of famous battles, and served these purposes until the Medieval times.

The name of the Colosseum is believed take after a colossal statue of the Emperor Nero modelled on the Colossus of Rhodes; the word colosseum being a Latin neutral noun formed by the adjective colosseus meaning gigantic or “colossean”. The tour then carries over to via Claudia and towards villa Celimontana, on the Celio hill where CREA, the Council for Agricultural Research and Economics, hosts and manages the IUSS Secretariat. The historical building stand over the monastery and hospital of the Trinitarian fathers, and dates to the XIII Century. Built on one of the most interesting Roman hills where the foreigners gathered and lived once arrived in Rome, it hosts the Basilica of Navicella, just opposite the aqueduct of Nero, and beside the Arch of Dolabella and Silano where St. Francis was hosted.

On the façade a magnificent mosaic shows Christ in the act of freeing two slaves, one of them being of African descendant and the very first men of colour in the history of religious art. The opera dates to 1200 and was carried out by the Cosmati brothers, the most famous mosaicists of their times.

A coffee breaks and some pictures bring the day to an end.

## Bibliography

- A Arnoldus, K Bowes, M MacKinnon, AM Mercuri et al. Agriculture and Land Use - Bowes 2021c, 2021 - degruyter.com
- Arnoldus-Huyzendveld, A., Gioia, P., Carboni, G., Boccuccia, P., & Remotti, E. (2007). La capanna di Casale del Cavaliere (Roma) ed alcune riflessioni sulle strategie di insediamento nel territorio di Roma durante il Neo-eneolitico. Atti della XL Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, 509-520.
- AA.VV. (2002) Villa Lubin CNEL Ed., Rome
- Costantini, E.A., Benedetti, A. (2024). The Italian Contribution to the Foundation of the International Society of Soil Science. In: Dazzi, C., Benedetti, A., Corti, G., Costantini, E.A.C. (eds) Soil Science in Italy. Springer, Cham. [https://link.springer.com/chapter/10.1007/978-3-031-52744-9\\_2](https://link.springer.com/chapter/10.1007/978-3-031-52744-9_2)
- Del Monte, M., Fredi, P., Pica, A., & Vergari, F. (2013). Geosites within Rome City center (Italy): a mixture of cultural and geomorphological heritage. Geografia Fisica e Dinamica Quaternaria, 36(2), 241-257.
- A cura di Gaudio C., I tesori del CREA, Edizioni Nuova Cultura, 2022. ISBN: 9788833654928
- Villedieu F., La vigna Barberini II, Domus, Palais Impèrial et Temples, Stratigraphie du secteur nord. est du Palatin, école française de Rome, Soprintendenza archeologica di Roma 2007

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The IUSS thank CREA – Council for Agricultural Research and Economics - for hosting its guests in the magnificent setting of the historical building in Via della Navicella.



Group picture in the Parlamentino (ph. Francesco Ambrosini)



David Lubin seat (ph. Irene Fabbri)



Villa Lubin – CNEL (ph. Irene Fabbri)



Group picture on CNEL terrace (ph. Francesco Ambrosini)

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# From Alpine Soils to Rice Paddies: an outlook into the soils and the services they provide

**Emanuele Pintaldi, Michele E. D'Amico, Silvia Stanchi, Andrea Benech, Sara Negri, Maria Martin, Daniel Said Pullicino, Michele Freppaz, Luisella Celi, Eleonora Bonifacio**

## Introduction

From May 22 to 25 2024, the field excursion in NW Italy took place, crossing three regions (Aosta Valley, Piedmont and Lombardy) and four ecosystems



Figure 1 Localization of the study sites.

The soil profiles were dug under Alpine forests, lowland oak formations and agricultural areas (paddy rice and maize). We observed some wonderful examples of very different soils developed in these areas, discussing the processes that shaped their development and their taxonomic classification (IUSS Working Group WRB, 2022).

## Stop 1: Alpine Soils

We spent the first two days in the Aosta Valley, which is the smallest region of Italy, completely located inside the NW Alps, between 321 and 4810 m a.s.l. It is surrounded by some of the highest and most iconic mountains in Europe, such as Mont Blanc (on the border with France), Matterhorn and Monte Rosa (on the border with Switzerland), and Gran Paradiso (on the border with Piemonte region), all reaching or passing 4000 m of elevation. More than 80% of the region lies above 1500 m a.s.l.

The extreme environmental diversity characterising the region is reflected in a high soil diversity (D'Amico et al., 2020), with the presence of soils typical of cold and humid biomes (e.g. Umbrisols, Podzols, Turbic Regosols) at close distance from soils normally found in hot and dry climates, such as Calcisols and Kastanozems. The balance between precipitation and evapotranspiration

is one of the most important environmental parameters, influencing leaching or base and carbonate accumulation.

We visited two different soil profiles: the first was a well-developed Podzol typical of subalpine Larch (*Larix decidua* M.) and Stone pine (*Pinus cembra* L.) forests, the second was a Kastanozem with petrocalcic horizon developed under open Scots pine (*Pinus sylvestris* L.) mixed with steppe grasslands and xerophilous shrubs on a dry southward slope.

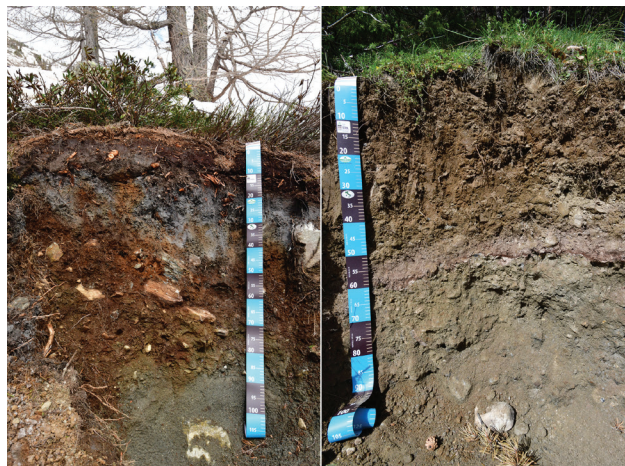


Figure 2 Left: profile AO5, a well-developed Podzol under a typical subalpine forest. Right: profile AO39, a well-developed Kastanozem under xerophilous Scots pine forest. Starting from c.a. 50 cm depth, the Bkm horizon sequences is well visible, composed of almost pure pedogenic  $\text{CaCO}_3$  (Bkkm horizons, according to Soil Survey Staff, 2022)

The first soil profile was located near Colle San Carlo (1950 m a.s.l.), which represents the watershed between the Valdigne (the highest part of the Aosta Valley, close to Monte Bianco Massif) and La Thuile Valley, at the border with France. The soil profile was located near the shore of the Lake Arpy (2066 m a.s.l.), under a subalpine forest with ericaceous shrubs as understory vegetation (e.g. *Vaccinium myrtillus* L., *Rhododendron ferrugineum* L., etc.). The parent material was local glacial till, composed of metamorphosed, silica-rich conglomerates, deposited during the Last Glacial Maximum. The climate is subcontinental (average yearly precipitation below 900 mm and a distinct summer rainfall minimum, average temperatures around 1-2°C). The soil was classified as Skeletic Albic Ortsteinic Podzol (Loamic, Endoarenic, Densic, Endoraptic), after an interesting discussion based on morphology, chemical properties and micromorphological features.

In this profile organic C (SOC) stock was ca. 5 kg/m<sup>2</sup>. Most of this carbon was stored in the deep B horizons, where it was bound to Fe and Al oxyhydroxides and fixed for long times. Quite large SOC were also stocked in the thick organic horizons (2.8 kg/m<sup>2</sup>).

Observing the thin sections under microscope magnification, it was possible to verify the main processes associated with the formation of this soil profile. In

particular, the AE horizon had a weak biological activity, showing only few dark organic pellets and a very loose blocky aggregation. The underlying E horizon showed well-developed platy aggregates, with silt accumulations on the plate surfaces (Fig. 3a), evidencing strong seasonal cryoturbation and no mixing by biological activity. The same silt accumulations appeared dark because of monomorphic (soluble) organic matter.

The Bhs horizon was very different, showing dark organic pellets created by biological activity, dark coatings on the upper part of the sand grains and some reddish, spodic accumulations sometimes associated as aggregates in pores. The underlying Bhsm was much richer in reddish brown spodic materials, which filled most of the pore spaces and connected the sand grains; very large pores were still abundant, allowing water percolation despite the strong cementation. Some Fe-Mn nodules could be detected inside cemented aggregates (Fig. 3b). The BCm(s) below was greyish in the field, and in thin section it was possible to observe only few spodic materials on pore walls, and a dense structure, with alignment of micas, in the surrounding aggregates (probable effect of ancient deep frost activity).

The second profile was located on the opposite, southward slope of Valdigne, near La Salle. An extremely dry microclimate characterises this slope, as most of the central part of the Aosta Valley (Ustic moisture regime, according to Soil Survey Staff 2022) which supports a stunted Scots pine (*Pinus sylvestris* L.) forest. *Juniperus Sabina* L. underlines the xericity of the site. The parent material was glacial till belonging to the lateral moraines of the Dora glacier, deposited during the Last Glacial Maximum.

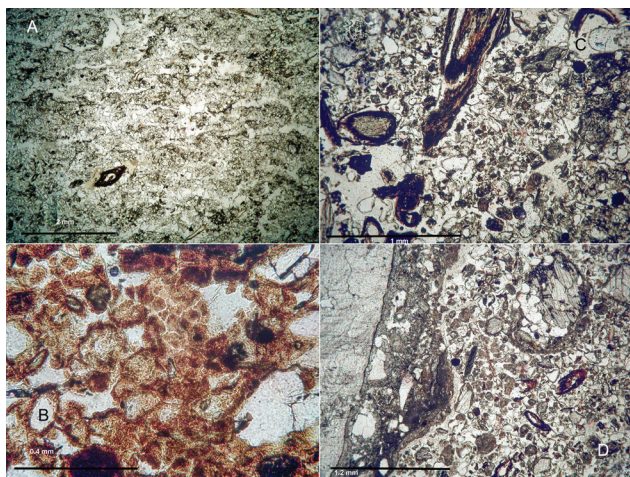


Figure 3 3a: E horizon: very well developed fine platy aggregation, with dark silty coatings on the top of the aggregates showing intense freeze-thaw processes. 3b: Bhsm horizon in the Podzol AO5: abundant large pores, few organic pellets and common dark coatings on sand grains, some reddish, “fluffy” accumulations of reddish brown spodic materials. 3c: A horizon in the Kastanozem: abundant roots and root fragments, rounded and fine, less regular organic pellets created by faunal activity. 3d: Ak horizon: abundant roots and root fragments, well rounded organic pellets of different dimensions and layered CaCO<sub>3</sub> cementations on the low lower side of stones, showing different generations of CaCO<sub>3</sub> accumulation.

The lithology of this material was mixed, with granitic

clasts derived from Mont Blanc, silic metamorphic rocks and calcschists from elsewhere. In this weakly productive forest, characterised by a dry, steppe microclimate, the C stock in soils was high, mainly thanks to the inorganic C fixation in pedogenic carbonates: more than 13.4 kg/m<sup>2</sup> of C was stored in pedogenic CaCO<sub>3</sub> (considering primary CaCO<sub>3</sub> as 15% in the parent material). 4.42 kg/m<sup>2</sup> of SOC were stored in the same horizons; organic layers stored less, but with high lateral variability according to the presence of trees.

In thin section, the pedogenic trends were verified: the A horizon showed many roots and abundant organic pellets created by soil fauna.

The Ak horizon was characterised by CaCO<sub>3</sub> coatings under the clasts and by a strong biological activity. The CaCO<sub>3</sub> cementation in the lower part of stones was layered, showing different phases of CaCO<sub>3</sub> accumulation, with finer or coarser crystals and darker or lighter colours. The Bkm1/Bkm2 horizons showed well-developed CaCO<sub>3</sub> layers characterized by differently crystallised materials (Bkm1) and complete infillings in soil pores (Bkm2) between mineral grains. The soil was classified as Skeletic Petrocalcic Kastanozem (Loamic).



Figure 4 Group photo of the participants at the Podzol site (Lake Arpy - Aosta Valley, 2066 m a.s.l.).

## Stop 2: Rice agro-ecosystems

On the third day we moved to the most extensive rice-growing area in Europe, within the Vercelli-Novara-Pavia district. Here, rice cultivation was introduced in the 16th century and extended further with the construction of the most important irrigation network in the 19th century that contributed to the creation of a unique artificial environment that changed the features and socio-economic relevance of the plains of the river Po plain in various ways. Rice paddies in NW Italy contribute to unique wetland ecosystems. The shallow water and seasonal flooding provide habitats for a wide range of species, including migratory birds, amphibians, and insects.

These ecosystems serve as vital feeding grounds for birds along the migratory routes, particularly during the spring and autumn months. These particular hydrolog-

ical conditions have also heavily influenced the soils of these regions and the ecosystem services they provide. The study site was located in Zeme (Province of Pavia, Lombardy), situated in the low section of the Po plain between the Sesia and Agogna rivers, which includes the distal part of the glaciofluvial Würmian flat and was characterised by the presence of local Holocene fluvial dynamics and levelling due to the recent agricultural processes. The study area has a temperate climate, with a mean annual temperature of 12.5 °C and mean annual precipitation of 830 mm.

Soils developed on alluvial sediment with a maximum elevation of 105 m a.s.l., characterised by a high groundwater level during spring, up to 30–50 cm below surface, particularly when paddy fields are submerged. Two adjacent plots were identified for this excursion, one under maize (*Zea mays*) monocropping and another under paddy rice (*Oryza sativa*) monocropping established about 50 years ago. Comparison between these two cropping systems allowed for the evaluation of agricultural management-induced effects on soil formation and functioning. Whereas maize is an upland crop, rice is cultivated in flooded paddies with water management involving continuous flooding for most of the growing season from seeding till ripening stages, except for one or two short mid-season drainage periods. The comparison of two soil profiles without (Profile 1) and with (Profile 2) paddy management evidenced extremely strong and fast processes, which are driven by paddy rice cropping.

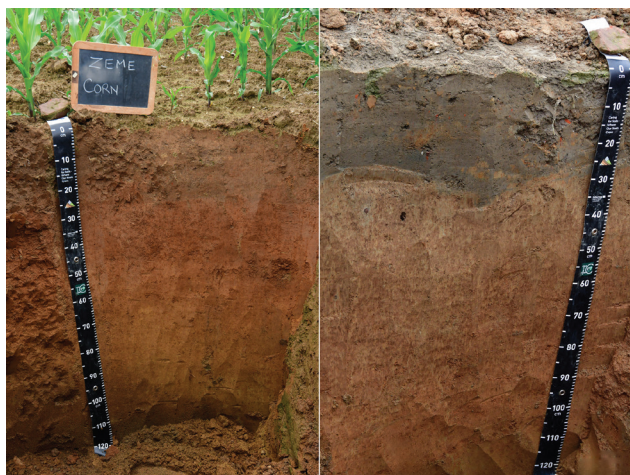


Figure 5 Soil profiles under non-paddy (left) and paddy management (right).

Non-paddy soils (Haplic Luvisol (Loamic, Aric, Cutanic, Epidystric, Ochric, Endoraptic) had few mottles, which increased at depth thanks to high seasonal water table; mottles became common only below 70 cm, in the CBg horizon. The Bt horizon had very well-developed, strong brown clay coatings. They demonstrate a rather long-lasting pedogenesis in an undisturbed pedo-environment. Pedogenic Fe oxyhydroxides showed a maximum in the Bt horizon (noticeable from dithionite-extractable Fe), but the difference with the overlying horizons was not particularly evident, evidencing weak

reduction in surface horizons.

The paddy soil (Luvic Anthraquic Stagnosol (Loamic, Aric) had extremely different morphological characteristics, caused by intense artificial waterlogging, particularly in the surface horizons (Anthraquic conditions).

The tillage layer (Arp horizons) is thus characterised by intense waterlogging and reduction, which causes substantial Fe and an almost complete Mn loss. In particular, oxalate-extractable Fe was reduced by ca. 70%, while dithionite extractable Fe by 75–80%. As a result of this Fe loss in the topsoil, Fe was more concentrated in the subsoil horizons of the paddy soil. Fe-Mn nodules were observed at the upper limit of the B horizon below the plough layer. Short-range-ordered (SRO) metal oxides were also concentrated in the Btg1 horizon, evidenced by the large value of the ratio between oxalate and dithionite-extractable Fe. Rice, like most wetland plants, transports oxygen via aerenchyma from the atmosphere to the roots and O<sub>2</sub> release into the rhizosphere results in the presence of roots channels covered by oxidised Fe coatings.

This was particularly visible in the Apr horizon, where distinct zones can be distinguished around root channels as shown by the different colours. Micro-scale spatial element distribution along transects from the root channels into the rhizospheric soil matrix evaluated by nano-scale secondary ion mass spectrometry (NanoSIMS) and image analysis have allowed to distinguish three distinctive zones extending from single rice roots: (i) an inner zone composed of oxide-encrusted residues of root cells and their fragments; (ii) a thin intermediate zone comprising precipitated Fe (hydr) oxides and organic matter, but also rhizodeposits with Al compounds retained therein; and (iii) a silicate-dominated outer zone, which reflects the transition from the rhizosphere to the bulk soil (Kölbl et al., 2017).

During the excursion participants had the opportunity to discuss several ecosystem functions related to these soils including the production of elevated yields of high quality rice and potential of these soils to store substantial amounts of organic carbon (in the order of around 8 kg m<sup>-2</sup> up to a depth of 1 m; Said-Pullicino et al., 2021) compared to upland cropping systems, not only in the topsoil but also in the subsoil due to the important percolation fluxes of dissolved and colloidal organic matter during the cropping season (up to 50 g C m<sup>-2</sup> over a cropping season; Said-Pullicino et al., 2016). Several challenges related to the sustainability of agricultural management and their effects on soil processes were also discussed, including the contribution of these soils to methane emissions (on average between 400–500 kg CH<sub>4</sub> ha<sup>-1</sup> yr<sup>-1</sup>; Bertora et al., 2018) and effective mitigation strategies. Nutrient management options for improving nitrogen and phosphorus use efficiency by the crops, and challenges related to the cycling and plant uptake of contaminants in these

soils, namely arsenic and cadmium, as a function of alternating soil redox conditions were also presented.

### Stop 3: La Mandria Regional Park (Venaria Reale - TO): Fragic Luvisol

We spent the last day at La Mandria Regional Park in Piedmont region. This park represents one of the few patches of forests close to the metropolitan city of Turin. It has served as a hunting reserve since the 16th century for the Savoia family, and it was later acquired by Regione Piemonte. It comprises public and private land and represents a valuable example of biodiversity conservation. Still, it suffers from the presence of allochthonous tree species such as: red oak (*Q. rubra* L.). We observed how the invasiveness of this species has affected the development of soils in the area, altering humus forms and the biogeochemical cycles. The study area (45°08'58.4"N 7°35'39.5"E) inside the Regional Park is on the SW side of the Stura di Lanzo (SL) alluvial fan, located in Turin Metropolitan area. This terraced glaciofluvial and alluvial fan stretches over 300 km<sup>2</sup> at an elevation between 210 and 550 m.a.s.l.



Figure 6 The soil profile on the Lanzo Pleistocene glaciofluvial terraces, located in La Mandria Regional Park (TO).

The glaciofluvial and alluvial materials are derived from the Stura di Lanzo and the Ceronda rivers, dominated by serpentinites and peridotites inherited from the Lanzo Ultramafic Complex, with smaller quantities of silic components coming from the Stura di Lanzo alpine basin. A few loess layers lie on top of the glaciofluvial and alluvial materials, deposited in different periods during the Pleistocene, starting around 730 ka, although precise datings of the loess deposits is still missing. The Lanzo alluvial fan is now mostly covered by crops. The native hardwood forests with predominance of English oak (*Quercus robur* L.) and European hornbeam (*Carpinus betulus* L.) are preserved only in small and marginal portions of the area, or in protected sites such as the La Mandria Regional Park.

The study area has a temperate climate, with a mean annual temperature (1971-2000) of 12 °C and mean annual precipitation of 980 mm, with equinoctial distribution and winter minima. The oldest soils in the Lanzo

terraced glacio-fluvial fan are strongly developed, characterized by the widespread presence of fragipan layers and Bt horizons, and by a limited drainage. They are usually classified as Fragicudalf (from the 1:50.000 Regional Soil Map). The observed soil profile (Tab. 1, Fig. 6) is a typical and rather complete profile developed on Pleistocene glaciofluvial terraces (Raimondo et al., 2019; Negri et al., 2021; Stanchi et al., 2021), characterized by a shallow surface layer (A, E and Bw horizons) developed in recent (LGM or Late Glacial) loess. The biological activity in the topsoil is poor, because of the red oak litter, which is rich in tannins and other polyphenols (Bonifacio et al., 2015).

As a consequence, litter accumulated in the uppermost part of the A horizon, increasing the OM contents, and inducing the formation of discontinuous OH horizons that are not visible under English oak. The low biological activity was also evidenced by the platy structure of both A and E horizons. Below 50/65 cm, the consistency abruptly changes, and the first, weakly developed, fragipan horizon (2Bx) limits water percolation and root development. The abrupt but wavy upper boundary of this horizon is marked by a thin sub-horizon enriched in Fe-Mn soft nodules and mottles. A strong reduction characterizes this horizon, with abundant grey glossae and mottles. At 90 cm the fragipan properties become stronger, the grey glossae and reticulated mottles become more expressed. These more expressed properties might be interpreted as an older loess layer (3Btx), even if the colour of the matrix is the same as in the horizon above.

Another discontinuity is observed at ca. 128 cm, below which the consistency becomes harder, the structure from prismatic becomes platy and the fragipan properties more expressed (4Btx2). More clay coatings also appear in the pores and on the aggregate faces. Another pedogenic discontinuity can be recognized below. Here, the structure changes again, becoming blocky, and the colour is less red; mottling is even more expressed (5Btx3). The few coarse fragments in this bottom horizon are extremely weathered and originated from serpentinite.

After productive discussions on genetic, morphological, mineralogical and chemical properties, the observed soil profile was classified as Stagnic Fragic Luvisol (Siltic, Cutanic, Ochric, Bathymanganiferic).

**Description of the representative soil profile on the Lanzo Pleistocene glaciofluvial terraces, located in the La Mandria Park (TO).**

Profile description		
Horizon	Boundaries (cm)	Description
OL	5-2	Unaltered organic horizon composed of fresh leaves and twigs.
OF	2-1	Hemi-altered organic horizon with evidence of fungi mycelia.
OH	1-0	Discontinuous, in relation to ungluate disturbances. Moist colour very dark yellowish brown (10YR 2.5/2) and abundant roots and fungal mycelia.
A	0-1.5	Moist colour olive brown (2.5Y 4/3); laminar structure, like the E below to which it is associated; no stone fragments; common fine to very coarse roots; abrupt wavy lower boundary.
E	1.5-9	Moist colour light yellowish brown (2.5Y 6/4); massive sub-laminar aggregates with poor internal porosity, no stone fragments; scarce fine to very coarse roots; gradual wavy lower boundary.
Bw	9-60	Very wet; moist colour brownish yellow (10YR 6/6), sub-angular blocky structure with aggregates (ca. 5 cm) of soft consistency, granular secondary structure; common roots, and evident root activity within the aggregates; abrupt wavy lower boundary.
2Bx	60-90	Very wet; moist colour dark yellowish brown (10YR 4/6), with evident redoximorphic features in the form of few Fe-Mn soft nodules and greyish glossae; friable when humid, quite hard when dry; moderately developed coarse prismatic structure, secondarily medium, platy; scarce roots; abrupt wavy lower boundary.

3Btx	90-128	Wet; moist colour brownish yellow (10YR 6/8); no coarse fragments; coarse prismatic structure, massive; abundant Fe-Mn nodules, particularly at the lower boundary and network of mottling, more distinct than in the overlying horizon; well visible clay coatings on the aggregate surfaces; abrupt wavy lower boundary.
4Btx	128-170	Moist colour strong brown (7.5YR 5/6), with grayish (10YR 6/2) and strong brown (7.5YR 4/6) mottles; no coarse fragments; strong laminar structure, secondarily fine platy, weakly developed; abundant streaks and nodules, especially in correspondence of the lower boundary; well visible clay coatings on the aggregate surfaces; clear wavy lower boundary.
5Btx	170/185+	Dry; humid colour brownish yellow (10YR 6/6) with abundant reddish, black and grey mottles; hard consistency; the structure is less laminar than above, more blocky; much more abundant clay coatings; presence of scarce, strongly weathered serpentinitic coarse fragments.

**References**

- Bertora C., Cucu M.A., Lerda C., Peyron M., Bardi L., Gorra R., Sacco D., Celi L., Said-Pullicino D. (2018) Dissolved organic carbon cycling, methane emissions and related microbial populations in temperate rice paddies with contrasting straw and water management. *Agriculture, Ecosystems & Environment* 265:292-306. DOI: <https://doi.org/10.1016/j.agee.2018.06.004>.
- Bonifacio E., Petrillo M., Petrella F., Tambone F., Celi L., 2015. Alien red oak affects soil organic matter cycling and nutrient availability in low fertility well-developed soils. *Plant Soil* 395, 215-229.
- D'Amico, M. E., Pintaldi, E., Sapino, E., Colombo, N., Quaglino, E., Stanchi, S., ... & Freppaz, M. (2020). Soil types of Aosta Valley (NW-Italy). *Journal of Maps*, 16(2), 755-765.
- IUSS Working Group WRB. 2022. World Reference Base for Soil Resources. International soil classification system for naming soils and creating legends for soil maps. 4th edition. International Union of Soil Sciences (IUSS), Vienna, Austria.
- Kölbl A., Schweizer S.A., Mueller C.W., Höschel C., Said-Pullicino D., Romani M., Lugmeier J., Schlüter S., Kögel-Knabner I. (2017) Legacy of rice roots as encoded in distinctive microsites of oxides, silicates, and organic matter. *Soil Systems* 1:2. DOI: <https://doi.org/10.3390/soils1010002>.
- Negri, S., Raimondo, E., D'Amico, M.E., Stanchi, S., Basile, A., Bonifacio, E., 2021. Loess-derived polygenetic soils of North-Western Italy: a deep characterization of particle size, shape and color to draw insights about the pas. *Catena* 196, 104892.
- Raimondo, E., Falsone, G., D'Amico, M.E., Stanchi, S., Celi, L., Bonifacio, E., 2019. Characteristics of fragipan B horizons developed on different parent material in North-Western Italy. *Arch. Agron. Soil. Sci.* 65, 308-321.
- Said-Pullicino D., Giannetta B., Demeglio B., Missonig A., Gottselig N., Romani M., Bol R., Klumpp E., Celi L. (2021) Redox-driven changes in water-dispersible colloids and their role in carbon cycling in hydromorphic soils. *Geoderma* 385:114894. DOI: <https://doi.org/10.1016/j.geoderma.2020.114894>.
- Said-Pullicino D., Miniotti E.F., Sodano M., Bertora C., Lerda C., Chiaradia E.A., Romani M., Cesari de Maria S., Sacco D., Celi L. (2016) Linking dissolved organic carbon cycling to organic carbon fluxes in rice paddies under different water management practices. *Plant and Soil* 401:273-290. DOI: <https://doi.org/10.1007/s11104-015-2751-7>.
- Soil Survey Staff. 2022. Keys to Soil Taxonomy, 13th ed. USDA-Natural Resources Conservation Service.
- Stanchi, S., Negri, S., D'Amico, M.E., Raimondo, E., Bonifacio, E., 2021. Atterberg limits fail in recognizing fragipan horizons. *Catena* 202, 105282.

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## Soil and art: a scientific trip in Palazzo Vecchio

**Organizer: Costanza Calzolari with the collaboration of Maria Adele Signorini, Università di Firenze and Valentina Zucchi, MUSE**

The excursion on soil and art was held in Palazzo Vecchio, Florence, on May the 22nd. The event was organised by CNR IBE, Costanza Calzolari, with the collaboration of Maria Adele Signorini, botanist, University of Florence and Valentina Zucchi, art historian, Associazione Mus.E, museums of the city of Florence.

Actually, the excursion is based on a research commonly conducted by a group of naturalists (botanists, zoologists, pedologists) in 2016- 2018 and coordinated by Mus.E. and University of Florence.

The results edited by Signorini and Zucchi were published in 2018. A copy of the book was released to the participants.

Some 25 participants from 13 different countries participated at the excursion aimed at understanding the linkages between art and natural sciences in the XVI century Florence. Palazzo Vecchio offers a good opportunity to explore the issue. Built in 1299, it became the residence of the Medici family in 1540. To this aim, it was completely restored and decorated under the direct supervision of Giorgio Vasari (1511- 1574) a famous Tuscan architect and artist.

Visiting Palazzo Vecchio allows perceiving the profound relationship that linked Cosimo I first and his son Francesco I later with the natural world. The ducal apartments and the government rooms can be read as a manifesto of celebration of political power and at the same time of love for nature.

Cosimo and then Francesco played an essential role in what has been defined as the 'Renaissance' of botany, thanks to the work of scientists who orbited around Florence and the Medici court. Among these in particular Luca Ghini, founder of the first botanical garden in the world (Pisa, 1543-44) and probable 'inventor' of the technique of preserving dried plants in herbariums; but also, Andrea Cesalpino, Ulisse Aldrovandi and others. The establishment of the Gardens of Pisa and then of Florence (1545) and the preparation of the first herbals (the one by Cesalpino is today in the Botanical Section of the University Museum of Natural History) laid the foundations of botany as an experimental discipline.

The artists who decorated the Palace in the mid-sixteenth century were able to perfectly capture this love for nature, managing to translate it into the fascinating works object of our tour.

### First stop: Piazza della Signoria, The "lily" of Florence

In a crowded and windy Piazza della Signoria, the botanist Mariele Signorini talked about the main symbol of Florence, the "lily" (Fig. 1, top left). We call it 'lily', but it is not the well-known white fragrant flower (*Lilium candidum*), which in fact it does not resemble at all.

The lateral petals facing downwards and the central upright one rather reproduce, albeit in a stylized manner, the profile of an iris flower maybe inspired by the white iris (*Iris florentina*, today considered a form of *Iris germanica*; Fig 1, top right), a flower which already bears in its name the imprint of the city around which it seems to have once been widespread. Originally the coat of arms had a white flower (as it is in nature), on a red background; after the conflict between Guelphs and Ghibellines (XIII century), the latter appropriated the city symbol and the Guelphs took the inverted colour version as their emblem, which was then adopted as the city's coat of arms after the expulsion of the Ghibellines (1266).

The story is recalled by Dante in the *Divina Commedia*, who makes his ancestor Cacciaguida regret the good times of prosperity and healthy customs, when "the lily / was never placed backwards / nor made vermilion by division". Evidence of the original version with the white lily on a red background can also be seen in the Palace. Worth to be noted that the cultivation of iris is still pres-



ent in Tuscany and in the Chianti region.  
Figure 1 From top left and clockwise: the group in Piazza della Signoria (Valentina Zucchi Ph); the "lily" of Florence (web free access image); iris cultivation in Tuscan hills (web free access image).

### Second stop: Salone dei 500, Vasari and Tuscan landscapes

The evolution of the hall along the Florentine history was explained by Valentina Zucca, art historian (Fig. 5). Within the complex iconographic project of the Salone dei Cinquecento, which aimed to celebrate Cosimo as the cornerstone of the new Medici political geography, gives us a series of views of Tuscany. It is known that

Vasari based himself on sketches painted from life by his collaborators sent on site and that his paintings describe the different landscapes - as he himself writes - 'through a natural view': from the Chianti to the Casentino, from the Apennines to Valdarno.

The frescoes on the right wall of the hall narrate three crucial episodes of the war with Siena: The downfall of the Fort near the Porta Camollia of Siena, which marked the beginning of the war (26 January 1554); the Battle of Marciano in Val di Chiana, decisive for the Medici victory (2 August 1554); and the conquest of Porto Ercole, one of the last Sienese bastions (21 April 1555).

In the evocative fresco of the assault on Porta Camollia (Fig. 2), the ducal army attacks Siena from the gate facing Florence. This side of the walls, considered the most vulnerable, had been strengthened on the outside in 1206 with a second gate, the so-called 'antiporto'; and it is from here that the ducal army entered under the cover of darkness.

However, Porta Camollia, visible on the right of the fresco, remained inviolate, forcing the Medici forces to subject Siena to a long and painful siege. In the fresco the landscape, illuminated by the moon, is typical of the Sienese countryside: gentle hills with undulating slopes as far as the eye can see.

The city of Siena rests on marine sediments from the Pliocene era (about 3 million years ago), as the large quantity of fossils found there reminds us. Siena stands on sandy (in Siena called 'tuffs') and gravelly deposits, which ensure a certain morphological stability and allow the infiltration of water. This then rises again upon



contact with the underlying clayey sediments, giving rise to the famous springs that dot the city.

Figure 2 Giorgio Vasari, Giovanni Battista Naldini and Giovanni Stradano, 1567- 1571: The storming of the fortress near Porta Camollia in Siena. Source: *Catalogo generale dei Beni Culturali* (<https://catalogo.beniculturali.it/>)

What is striking about Vasari's landscapes is the lack of woodland, which was certainly subjected to severe cutting at the time, and the absence of agricultural activities in the fields. Even in the Allegory of Chianti the centres of Castellina, Radda and Brolio are recognised, but the vines are not represented (Fig. 3).



Figure3 Giorgio Vasari and Giovanni Stradano, 1563 – 1565, Allegory of Chianti. Source: *Catalogo generale dei Beni Culturali* (<https://catalogo.beniculturali.it/>)

An exception regarding the forests is the panel with the Defeat of the Venetians in Casentino, which describes an episode of the war against Pisa (1498). Vasari intends here to portray "the site of the Vernia stone in its natural state" (Fig. 4). And in fact, the particular tabular shape of Mount Penna, where the Verna hermitage stands, is well recognizable in the painting; it is a relief made up of limestone rocks, which stand out compared to the sandstones of the adjacent Monte Fumaiolo formation. In the snowy and barren landscape painted by Vasari, the Verna cliff is covered, then as now, by a dense forest of beech and fir trees. Currently the centuries-old forests connected to the monasteries present in the place - in addition to La Verna, also Camaldoli and Val-



lombrosa - are part of the National Park of Casentinesi Forests, Monte Falterona and Campigna.

Figure 4 Giorgio Vasari and Giovanni Stradano, 1563–1564, Defeat of Venetians in Casentino. Source: Catalogo generale dei Beni Culturali (<https://catalogo.beniculturali.it/>)



Figure 5 The group in Salone dei 500. Source: Valentina Zucchi Ph.

**Third stop: lo studiolo di Francesco, a collection of natural wonders**

The Studiolo of Francesco I de' Medici is a small room that opens onto the Salone dei Cinquecento. The small room, which originally had no direct connection with the Salone was built between 1570 and 1575. It is a private and secret place as Vasari writes, “where no one ever enters and rarely secretaries”, and more precisely of a “wardrobe of rare and precious things both for value and for art, that is to say jewels, medals, carved stones, worked crystals and vases, wits and similar things, not too large, placed in their own cabinets, each in its own kind” (Fig. 6). The paintings of the lower register in fact hide a series of wardrobes and the iconography alludes to the goods that would have been contained inside,



«conforming to the material and quality of the things that are stored there... indeed it serves in part as a sign and almost inventory to find things”.

Figure 6 The Studiolo of Francesco I de' Medici. Source: Museo di Palazzo Vecchio website (<https://cultura.comune.fi.it/node/140>)

The entire decoration of the Studiolo responds to a rigorous iconographic program that starts from the centre of the vault: Mother Nature is intent on nourishing with her four udders all species of living beings while offering a rough stone where emerald crystals are recognisable to the hero Prometheus, who will be able to transform it into a carved jewel. The painting therefore shows the fruitful encounter between Nature and Art, summarizing the character of Francesco’s interests and his collection, “considering that similar things are not all of nature nor all of art, but they both have a part in it, helping each other the other one”. Is worth to be noted that no plants are depicted in the fresco.

Indeed, the nature celebrated in the Studiolo, the one Francesco I was passionate about, is a nature investigated, collected and manipulated by man; man places himself at the centre of natural objects and makes himself their master, discovering the laws that regulate them, finding materials to forge to meet his own needs and satisfying the thirst for knowledge that is the characteristic trait of the era.

An example of this is given by the “Banquet of Antonio and Cleopatra (Alessandro Allori, 1570-1575). In the crowded banquet (Fig. 7) where Cleopatra shows off her wealth by dissolving a pearl earring in vinegar as narrated by Plinio the Elder, even the precious cutlery and the abundance of fruit underline the opulence of the queen: in the sixteenth century fruit was in fact a status symbol that characterised the tables of wealthy



people. On the table and in the trays handled by the servants you can recognize melon, grapes, pears, plums, peaches, apples, apricots.

Figure 7 Alessandro Allori., *Banquet of Antonio and Cleopatra*, 1570-1571. Source: *Catalogo generale dei Beni Culturali* (<https://catalogo.beniculturali.it/>)

The landscapes depicted in paintings are usually not realistic. Rather they may be fantastic as in the “search for diamonds” (Maso da San Friano, 1570-1575; Fig. 8). The painting offers an admittedly fantastic and exotic vision of what the painter imagined a diamond mine could be. If diamonds had been known since ancient times, Maso da San Friano could not have an idea of what diamond mines looked like, since those known at the time were in the distant Indies. Thus, imagination makes up for the lack of direct knowledge.

The three diamond-bearing cliffs could be inspired by an idealization of the Apuan Alps, the harshest and most crystalline landscape available nearby, to which the painter could therefore be referring. Many of the theories and legends regarding diamonds are evoked in the painting: the harsh rocks from which the slaves extracted the gems are covered in ice, with reference to Plinio’s theory on the formation of crystals - related in his opinion to the diamond - in the environment frozen in the Alps; ropes are used to extract the stones, as Pliny himself reports; the exotic appearance of the man with the turban to whom the slave hands the dia-



mond recalls India, where most of the precious stones came from until the 19th century. All slaves working in the mine have their left arms tied behind their backs, to prevent them from stealing or escaping.

Figure 8 Maso da San Friano “Search for diamonds”, 1570-1571. Source: *Catalogo generale dei Beni Culturali* (<https://catalogo.beniculturali.it/>)

Leaving the Studiolo and the Salone dei 500, the staircase leading to the second floor (Fig. 9) presents a lively and precious decorative apparatus on a naturalistic profile, born from the creativity of Giorgio Vasari, Giovanni Stradano (Italian name for the Flemish artist Jan Van der Straet, 1523- 1605) and Marco Marchetti da Faenza (1528- 1588).

On the ceiling of the first landing, the artists created the illusion of a bright sky that can be glimpsed between the wooden trellis with flowering plants. Among the plants we can recognize the roses: here the double red flowers suggest that *Rosa gallica* is depicted, cultivated since ancient times and already portrayed in some Pompeian frescoes (1st century AD). The climber plant with white flowers and leaves divided into leaflets is a jasmine. The presence, among ornamental climbers, of a vine with bunches of black grapes is surprising, and even more so that of a plant with lobed leaves and small pear-shaped fruits, almost certainly referable to



a type of pumpkin (*Cucurbita pepo*) which arrived from America. It is possible that at the time this small-fruited variety was actually used in Europe more as an ornament than as a vegetable.

Figure 9 The group on the Monumental Staircases. Source: Valentina Zucchi Ph.

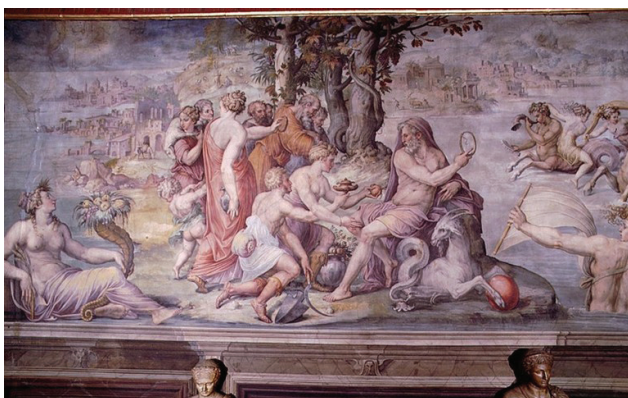
**Forth stop: Quarter of elements, Elements Hall: Mother earth, the first fruits from earth offered to Saturn (Giorgio Vasari, 1555-1558).**

In the Hall of the Elements, on the ceiling is the Air, with the Sky and its creatures; then Water, with the birth of

Venus celebrated by all the marine deities; Fire, with the god Vulcan intent on forging lightning for Jupiter with the help of the Cyclopes but also arrows for Cupid. The fourth element is then 'the mother earth' (Fig. 10), identified with Sicily due to 'its abundance'. At the centre of the scene is Saturn, god of seeding, of life cycles and therefore of time. The myth tells that Saturn, born from Gea - the earth - and from Uranus - the sky - had evirated his father with a sickle; this, falling on Sicilian land, had given the island its shape. In the painting there are references to Sicily, the city of Trapani Mount Etna and Lipari which 'burn' in the background. The symbol of the sickle is double here: on the one hand, a weapon, which in the fresco is seen falling from the sky in the top left corner; and on the other the symbol of agriculture, painted at the feet of Saturn next to a spade.

The fruits of the earth are due to Saturn: oil, milk, honey, first fruits, a lamb; just as the fruits of the people's labour are due to Cosimo. It is no coincidence that the Capricorn, the Duke's emblem animal, is depicted next to the god. On the left sits Mother Earth, the florid forms of the goddess, the large wheat ears in her hand, the cornucopia full of cereals and fruit refer to the abundance and generosity of the products of the earth.

It is no coincidence that this painting which celebrates the products of the fields is one of the few, if not the only one, in the palace where scenes from the agricultural world are depicted: in most of the works the landscapes are in fact the backdrop to war scenes or representations of cities, and agriculture is not at the



centre of the artists' interest. Here instead, countryside activities are carefully described: farmers work the land with the plough and hoe and are sowing; the grain is brought to the mill and the shepherds watch over the sheep, while a woodcutter cuts the trees in the woods.

Figure 10 Giorgio Vasari, *Saturn receives early fruits from earth*, 1555-1558. Source: *Catalogo generale dei Beni Culturali* (<https://catalogo.beniculturali.it/>)

On the ceiling of the hall, the most original plant decoration found in Palazzo Vecchio can be seen: on a base of oak and laurel branches, common elements are harmoniously arranged together with other less usual ones. Lemons, sorbs, melons, plums, grapes, quinces, pears, figs, pomegranates, peaches, watermelons are accompanied by chestnuts still enclosed in their

spiny cupule (bur), pine nut cones and what seem to be spruce (*Picea abies*) cones. White roses with double and simple flowers (*Rosa alba*, *Rosa moschata*) are combined with red and white carnations, marigolds, jasmine; but also, wildflowers such as broom, honeysuckle, privets, elderberries. And vegetables are also well represented: artichokes, cucumbers, onions, garlic, black radish, turnips, pumpkins, broad beans and a nice cabbage. The composition is completed by ears of cereals and other herbs.

The same attention to the depiction of fruits and vegetable is found in other rooms of the residential part of the palace. In the apartment of Eleonora da Toledo, wife of Cosimo I, the so-called green room fully expresses the Medici's love and interest in nature (Fig. 11).

The room ceiling was painted by Ridolfo del Ghirlandaio (son of Domenico, 1483 – 1561). Flowering branches of roses (perhaps *Rosa damascena*) soften the heads of sheep or rams which seem to hang from imaginary architraves; colourful specimens of macaws, parrots from tropical America, are resting on pumpkin shoots with small pear-shaped fruits, which also recently arrived from the new continent. Around the head of an African gazelle and that of a bear (at the time still present in the forests of the nearby Apennines) with its jaws wide open to show its large and characteristic canine teeth, branches of ivy and laurel perhaps recall their symbolic meanings, respectively of everlasting fame and victory. Lemons and other citrus fruits depicted with great naturalism are hung on threads with a trompe-l'oeil



effect, while a profusion of fruits and other vegetables portrayed in a rougher way emerge from festoons and cornucopias: pomegranates, pine cones, grapes, citrus fruits, medlars, hazelnuts, acorns, cucumbers, wheat, roses and others.

Figure 11 Ridolfo del Ghirlandaio, *Grottesques (particular)*, 1540-1542. Source: *Catalogo generale dei Beni Culturali* (<https://catalogo.beniculturali.it/>)

The Audience Hall, decorated by Francesco Salviati (1510- 1563) was intended to surprise the guests of the Medici court, with the magnificent decorations and with lush vegetal festoons (Fig. 12). As if wanting to

show off his skill, the painter Francesco Salviati depicts ‘fake’ monochrome festoons, as if they were sculpted, but also ‘real’ and coloured festoons, overflowing with fruits and vegetables that almost anticipate the forms of baroque still-lives. The hundreds of specimens that make up the decorations of the room can be read as a sort of catalogue of the variety of plant products that could have been present on the ducal table. Along with roses, convolvulus and anonymous little flowers, we observe cabbages, peas, cucumbers, artichokes, bottle gourds or lagenarias and the uncommon (at the time) aubergine, in forms with white skin and purple skin. Root vegetables are also depicted, that are considered ‘less noble’ and therefore especially suitable for the diet of the poor classes: garlic, onions, leeks, turnips, twigs, chicory and the other various roots used as food before the great success of carrots starting from the seventeenth century. Although wheat and barley seem absent, there are other cereals, such as panicle, millet and sorghum, widely used for porridge and polenta before the spread of corn. And above all there is a triumph of fruit: apples, pears, lemons, oranges, citruses, quinces, medlars, cherries, pomegranates, melons, grapes, figs, pine nut cones, chestnuts. Nor is there any lack of



new vegetable products recently arrived from America: pumpkins of numerous species and varieties, corn cobs, chili peppers. The ‘exotic’ atmosphere is accentuated by two parrots on the door of the chapel: a Moluccan cockatoo and an African grey parrot.

Figure 12 Francesco Salviati, Audience Chamber, 1543- 1545. Source: Museo di Palazzo Vecchio website (<https://cultura.comune.fi.it/node/141>)

### Fifth stop: the hall of the geographical maps

Our last stop was in the hall of geographical maps. The room contains 53 maps (30 by Egnazio Danti, 23 by Stefano Bonsignori) representing the continents known so far.

Within the different regions and areas we observe descriptions of wooded areas, stylized drawings of known cities, orographic and hydrographic indications: mountains and ranges are highlighted with simple drawings, while lakes, large rivers and their tributaries appear as blue grids, similarly to what happens in current cartog-

raphy. Outside the emerged lands seas and oceans are identified by their names.

In the maps of the African continent, the internal borders are indicated approximately with the simple wording of the geographical areas, or the denominations of kingdom or populi. Perhaps not by chance, the lands have shades that tend towards orange and red, which is the dominant colour of the soils of tropical Africa. Although the chromatic shade of the land in Africa is very variable, the alteration of rocks and sediments rich in iron generates soils with a vivid red and yellow colour, especially in tropical and subtropical areas. At the time, the geography of sub-Saharan Africa was known through the merchants of Tombutto (today’s Timbuktu in Mali), in whose stories descriptions of the colours of the earth may also have found place.

The geographical representation of the Niger River is interesting (Fig. 13), as it originates in Guinea and flows into the ocean after a 4,160 km journey that passes through Mali, Niger, Benin and Nigeria. In Bonsignori’s map, the river, which will only be systematically explored starting from the 18th century, rises from a large



lake (Borno lacus) roughly corresponding to Lake Chad, from which other large African rivers were believed to originate, including the Nile. To the west appears Lake Guber, actually an internal Niger delta today known as Lake Debo.

Figure 13 Stefano Bonsignori, Niger, Nigeria and Cameroon, 1580. Source: Wikimedia commons ([https://commons.wikimedia.org/wiki/File:Stefano\\_Bonsignori\\_-\\_Niger,\\_Nigeria\\_and\\_Cameroon\\_-\\_Google\\_Art\\_Project.jpg](https://commons.wikimedia.org/wiki/File:Stefano_Bonsignori_-_Niger,_Nigeria_and_Cameroon_-_Google_Art_Project.jpg))



Figure 14 The group in Palazzo Vecchio. Valentina Zucchi Ph.

### Reference

Calzolari et al., 2018. Nature Depicted. Plants, flowers and animals portrayed at Palazzo Vecchio in Florence. Maria Adele Signorini and Valentina Zucchi Eds., Aboca, IGR Grafiche, 143 pp.

### Acknowledgments

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# Paleosols in the Vulsini Volcanic District, Central Italy: pedological evidences of climatic and geomorphological evolution in the middle Pleistocene

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2024, May 22nd - 23rd

A group of 25 soil scientists from various parts of the world took part in a fieldtrip in the Tuscia area (Latium and Tuscany regions, Central Italy) to know recent studies carried out on two paleosol sequences, one near Sermugnano (Latium, Viterbo) and the other near Canino and Pitigliano (Tuscany, Grosseto) villages. The two paleosol sequences are characterized by different ages and features in a context of widespread volcanic and volcanic-sedimentary successions of the Vulsini Volcanic District (middle Pleistocene), which developed from the deposits of 5 major volcanic complexes (or lithosomes), partially overlapping in space and time: Paleovulsini, Vulsini Fields, Bolsena-Orvieto, Montefiascone, Latera (Figure 1).

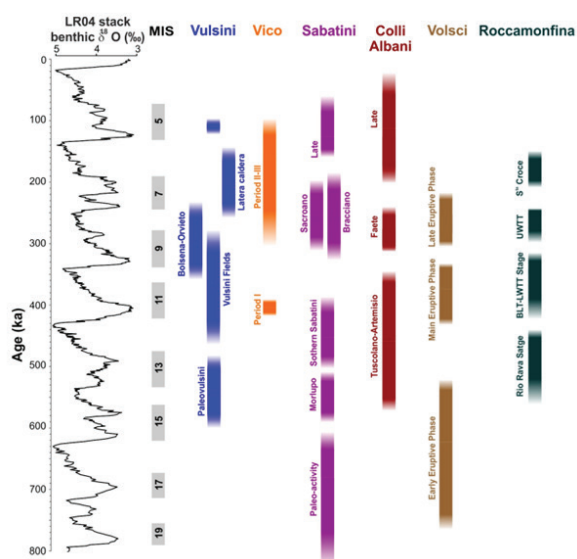


Figure 1 Temporal distribution of the Middle Pleistocene volcanic activity from the peri-Tyrrhenian potassic volcanic systems, plotted against the LR04 benthic stack record (Lisiecki and Raymo, 2005). Data source: Vulsini: Palladino et al. (2010), Marra et al. (2020a,b); Vico: Perini et al. (2004), Pereira et al. (2020); Sabatini: Sottili et al.

(2010), Marra et al. (2014, 2020b); Colli Albani: Marra et al. (2009); Volsci: Boari et al. (2009a), Centamore et al. (2010), Marra et al. (2021); Roccamonfina: Giannetti (1996a, 1996b), Giannetti and De Casa (2000), Rouchon et al. (2008), Scaillet et al. (2008) (Branca et al., 2023).

The Vulsini volcanic activity spanned the ~590-111 ka time interval, with a broad spectrum of eruptive styles, intensities and magnitudes, ranging from small-scale explosive (Strombolian and hydromagmatic) and effusive eruptions from monogenetic centres up to Plinian and pyroclastic flow, caldera-forming, events.

The 2-paleosols-sequence exposed at Sermugnano, here called SER1-SER2, developed on multiple Plinian fall deposits from the early Paleovulsini phase of activity, in a 65 ka time span (from 589±1 ka to 570±1 ka) which encompasses two cold periods corresponding to MIS 14 and MIS 13.2, separating the full MIS 13.3 and the early MIS 13.1 interstadials (Figure 2).



Figure 2 Sermugnano paleosols sequence

Therefore, repeated climate fluctuations between cold-arid and warm-humid conditions have influenced the soil development and evolution. The Sermugnano paleosols sequence was sealed by the emplacement of the “Nenfri” hot pyroclastic-flow at 505±1 Ka, whose deposits show at its base some remains of tree logs.

The Sermugnano sequence represents a polycyclic paleosol probably developed by an initial Stagnic Cambisol, which was sealed by a pyroclastic deposition that mixed with the previous organo-mineral horizon of the buried soil (SER1). This deposition occurred in a water saturated environment and the soil formed by the more recent pyroclastic deposition (SER2) was undergone to weathering in stagnic conditions in which smectite clay minerals formed. as inferred by the redoximorphic features found in. Presence of fossil diatoms, Fe-Mn concretions, redoximorphic features as well as the presence of pyrite support the hypothesis of oxygen-poor redox condition in the SER1 soil. Then, a first arrival of thermal water enriched of soluble salts, sulphates and chlorides, involved the soil, and water solutions enriched of Na caused clay deflocculation with subsequent clay migration and illuviation towards the underlying horizons.

The formation of a natric horizon produced obliteration of the previous Ab horizon. Subsequent arrivals of hypersaturated saline-sodic thermal waters reduced and stopped the illuviation process. The SER2 pedogenetic phase was interrupted by the pyroclastic flow deposition of the Nenfri eruption, a high temperature pyroclastic flow that very likely produced strong evaporation of the saline-sodic water in the soil and caused the precipitation of the less soluble salts, including calcium sulphates (like gypsum) at the top of SER2, while the more soluble ones (chlorides) percolated through the depth. In the meantime, it was assumed that the surface soil of SER2 had undergone truncation by erosion during the setting in place of the Nenfri event. However, the origin of the soil enrichment of soluble salts might be explained according to three different hypotheses: (i) chlorides were present in the paleosol at the time of burial due to sea water occurrence for the closeness to the coastline; in fact, the paleoclimate is that of the MIS 13.1 high-stand, and there is evidence in this region of a sedimentation affected by sea-level fluctuations; (ii) chlorides derived from interaction with hydrothermal waters; in this region travertines are in association with, or close to, mineralized groundwaters with slightly acidic pH, low thermalism and enrichment in sulphates or sodium chloride, and several thermal and cold mineral springs are scattered across the valley and along the boundaries of the limestones and volcanic formations (Capelli et al. 2012); (iii) syn-depositional chlorides from the Nenfri eruption cannot be excluded.



Figure 3 Pitigliano (A) - Canino (B) paleosols sequence

The other paleosols sequence is located near Canino (CAN1-CAN2) and Pitigliano (PIT3) (Figure 3). They are interbedded with pyroclastic deposits of the Latera volcanic activity, and they are well constrained in age to the 253-226 ka interval, allowing their correlation with the MIS 8 - 7.4 interval. The development of CAN1, CAN2 and PIT3 occurred in different time intervals

(13.4, 5 and 9 ka, respectively) from various pumice fall deposits of the Latera volcano. A lower pedogenic development of CAN2 has been observed with respect to CAN1 and PIT 3. However, CAN 1 and CAN2 do not meet the criteria for Andosols classification since neither andic nor vitric properties were observed. In the more recent paleosol (PIT3), an extensive biological activity has been observed, high content of organic carbon and large amount of phytoliths were found as residues of root decomposition in surface horizons. Only two horizons of PIT3 showed andic index exceeding 0.4%, phosphate retention >25%,  $\geq 5\%$  (by grain count) of volcanic glass, glassy aggregates, other glass-coated primary minerals in the fraction between  $> 0.02$  and  $\leq 2$  mm, therefore only these horizons of PIT3 fulfil the requirements of the vitric properties.

The pedogenesis of the three paleosols seems well correlated with timing and climatic phases (Figure 3). From the top to the bottom of the sequence, PIT3 developed for a fairly long period within the maximum glacial. This is consistent with the poorly developed andic properties, needing humid weathering conditions to take place. In the Sovana flow (the volcanic event sealing the PIT3), no evidence of tree holes has been found, therefore PIT3 very likely developed under herbaceous vegetation, shrub or temperate forest. However, the moderate to high content of soil organic carbon of PIT3, the huge amount of amorphous silica, the very dark colour of the A horizons and the incipient vitric properties suggest that this paleosol undergone the conditions for non-allophanic (aluandic in WRB classification) Andosols formation. Non-allophanic soils are dominated by Al-humus complexes, form in pedogenic environments dominated by organic acid weathering and have pH values of 5 or less (Shoji, 1985; Shoji and Ono, 1978). Nevertheless, since PIT3 developed in a period of progressively colder climate, towards the maximum glacial phase, the development of andic properties was completely inhibited. The following CAN2 paleosol developed in a shorter period than PIT3 and CAN1 paleosols, from the maximum interglacial until the beginning of the climatic deterioration. So never in conditions of intense cold, but first warm-humid and then temperate. According to previous investigations conducted in this region, several evidence of huge tree holes (diameter  $>1$  m) were found in the pyroclastic flow of the Farnese eruption covering the CAN2 paleosol, which might be developed under a sort of boreal forest. It is supposed that if andic properties were developed in CAN2, a further transformation of short-range order allophane and imogolite in more crystalline minerals occurred. Finally, CAN1 developed over a longer period compared with CAN2 and PIT3, from a maximum glacial to a maximum interglacial. It therefore undergone extreme and opposite climates: first extremely cold and then very hot-humid. CAN1 showed the lowest content of organic matter and the highest mineral weathering probably because of the longer period of pedogenesis under hot-humid climatic condition before burial. No

evidence of andic properties was found, due to the high weathering conditions that likely inhibited allophane formation in strong leached environment.

The structural-morphological, socio-cultural and archaeological attractions of the Vulcini area were also shown during the excursion through the visit at the Bolsena caldera, at the “via cava” and San Giuseppe Etruscan Necropolis near Pitigliano, and at the enchanted village of Civita di Bagnoregio (Latium, Viterbo).

Bolsena caldera constitutes the central, most evident and distinctive morphological feature of the Vulcini Volcanic District. It is markedly asymmetrical in shape, with a gradual increase in subsidence from south to north where an intensively faulted caldera rim highlights the area of highest subsidence (about 1.1 km). The western margin of the caldera is not evident, due to interference with the Latera volcanic complex, where its products (280-140 ka) and its caldera development obliterated the Bolsena caldera structure. During the excursion, the site of the so called “thrown stones” at the foot of the inner eastern slope of the caldera was visited. The site represents a lava dyke connected to a bordering fault of the caldera with a peculiar and amazing prismatic fracturing of the rock (a tephritic phonolite with leucite) (Figure 4).



Figure 4 The “thrown stones” at the foot of the inner eastern slope of the Bolsena caldera

The “vie cave” are ancient routes, deeply dug into the tuff deposits along the margin of the Vulcini area, used to have an easier and quicker connection between the valley floors around the so called “tuff towns” and the surrounding high volcanic plateaus. The “vie cave” were initially excavated by the Etruscans and were later enlarged and deepened during the Roman, medieval, Renaissance and modern times (Figure 5).



Figure 5 The “vie cave” (A) and the Etruscan necropolis (B)

The little town of Civita di Bagnoregio is placed at the top of a high tuff spur exposed to a fast erosion, where the land planning and management are continually challenged by intense slope dynamics (Figure 6): many landslides through time have sculpted this enchanting and unique place, leading to the gradual narrowing of the village, which has probably Etruscan origin and presents sure remnants of the Roman presence. Moreover, Civita di Bagnoregio is the birthplace of Saint Bonaventure (13th century), who was a religious philosopher, theologian and the most important biographer of St. Francis of Assisi



Figure 6 The little town of Civita di Bagnoregio at the top of a high tuff spur exposed to a fast erosion

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We wish to thank for their contribution to the analytical and interpretative framework of the paleosols in the Vulsini Volcanic District the pedologists Eleonora Bonifacio, Gilmo Vianello, Gloria Falsone, Alberto Agnelli, Claudio Colombo, Erika di Iorio, Alessandro Buscaroli, Simone Priori, the agricultural chemists Maria Cristina Moscatelli and Rosita Marabottini, as well as the geologists Giovanni Maria Di Buduo, Mario Gaeta, Danilo Palladino and Fabrizio Marra.

**Bibliography**

- Boari E., Avanzinelli R., Melluso L., Giordano G., Mattei M., De Benedetti A., Morra V., Conticelli S. (2009a) - Isotope geochemistry (Sr-Nd-Pb) and petrogenesis of leucite-bearing volcanic rocks from "Colli Albani" volcano, Roman Magmatic Province, Central Italy: inferences on volcano evolution and magma genesis. *Bull. Volcanol.*, 71, 977-1005.
- Branca S., Cinquegrani A., Cioni R., Conte A.M., Conticelli S., De Astis G., de Vita S., De Rosa R., Di Vito M.A., Donato P., Forni F., Francalanci L., Gaeta M., Giaccio B., Giordano G., Giuffrida M., Isaia R., Lucchi F., Marra F., Massaro S., Nicotra E., Palladino D.M., Perinelli C., Petrosino P., Pistolesi M., Sepulveda-Birke J.P., Sottili S., Romagnoli C., Rotolo S., Sulpizio R., Tranne C.A., Viccaro M. (2023) - The Italian Quaternary Volcanism. *Alp. Mediterr. Quat.*, 36 (2): 221-284.
- Centamore E., Dramis F., Di Manna P., Fumanti F., Milli S., Rossi D., Palombo M.R., Palladino D.M., Trigila R., Zanon V., Chiocchini M., Didaskalou P., Potetti M., Nisio S. (2010) - Note illustrative del Foglio 402 Ceccano. *Carta Geologica d'Italia 1:50.000*. Servizio Geologico d'Italia, Rome
- Giannetti B. (1996a) - The geology of the Yellow Trachytic Tuff, Roccamonfina Volcano. *J. Volcanol. Geotherm. Res.*, 71 (1), 53-72.
- Giannetti B. (1996b) - Volcanology of trachytic and associated basaltic pyroclastic deposits at Roccamonfina volcano, Roman Region. Italy. *J. Volcanol. Geotherm. Res.*, 71 (2-4), 229-248.
- Giannetti B., De Casa G. (2000) - Stratigraphy, chronology, and sedimentology of ignimbrites from the white trachytic tuff, Roccamonfina Volcano, Italy. *J. Volcanol. Geotherm. Res.*, 96(3-4), 243-295.
- Marra F., Jicha B., Palladino D.M., Gaeta M., Costantini L., Di Buduo G.M. (2020a) - 40Ar-39Ar single crystal dates from pyroclastic deposits provide a detailed record of the 590-240 ka eruptive period at the Vulsini Volcanic District (central Italy). *J. Volcanol. Geotherm. Res.*, 398, 106904.
- Marra F., Castellano C., Cucci L., Florindo F., Gaeta M., Jicha B.R., Palladino D.M., Sottili G., Tertulliani A., Tolomei C. (2020b) - Monti Sabatini and Colli Albani: the dormant twin volcanoes at the gates of Rome. *Sci. Rep.*, 10, 8666.
- Marra F., Sottili G., Gaeta M., Giaccio B., Jicha B., Massotta M., Palladino D.M., Deocampo D.M. (2014) - Major explosive activity in the Sabatini Volcanic District (central Italy) over the 800-390 ka interval: geochronological - geochemical overview and tephrostratigraphic implications. *Quat. Sci. Rev.*, 94, 74-101.
- Marra F., Castellano C., Cucci L., Florindo F., Gaeta M., Jicha B.R., Palladino D.M., Sottili G., Tertulliani A., Tolomei C. (2020b) - Monti Sabatini and Colli Albani: the dormant twin volcanoes at the gates of Rome. *Sci. Rep.*, 10, 8666.
- Marra F., Karner D.B., Freda C., Gaeta M., Renne P.R. (2009) - Large mafic eruptions at the Alban Hills Volcanic District (Central Italy): chronostratigraphy, petrography and eruptive behavior. *J. Volcanol. Geotherm. Res.*, 179, 217-232.
- Marra F., Cardello G.L., Gaeta M., Jicha B.R., Montone P., Niespolo E.M., Nomade S., Palladino D.M., Pereira A., De Luca G., Florindo F., Frepoli A., Renne P.R., Sottili G. (2021) - The Volsci Volcanic Field (central Italy): eruptive history, magma system and implications on continental subduction processes. *Int. J. Earth. Sci.*, 110, 689-718.
- Palladino D.M., Simej S., Sottili G., Trigila R. (2010) - Integrated approach for the reconstruction of stratigraphy and geology of Quaternary volcanic terrains: an application to the Vulsini Volcanoes (central Italy). In: GropPELLI G., Viereck L. (Eds.), "Stratigraphy and geology in volcanic areas", *Geol. Soc. Am., Spec. Pap.*, 464, 66-84.
- Pereira A., Monaco L., Marra F., Nomade S., Gaeta M., Leicher N., Palladino D.M., Sottili G., Guillou H., Scao V., Giaccio B. (2020) - Tephrochronology of the central Mediterranean MIS 11c interglacial (425-395 ka): New constraints from the Vico volcano and Tiber delta, central Italy. *Quat. Sci. Rev.*, 243, 106470.
- Perini G., Francalanci L., Davidson J.P., Conticelli S. (2004) - Evolution and Genesis of Magmas from Vico Volcano, Central Italy: Multiple Differentiation Pathways and Variable Parental Magmas. *J. Petrol.*, 45(1), 139-182.
- Rouchon V., Gillot P.Y., Quidelleur X., Chiesa S., Floris B. (2008) - Temporal evolution of the Roccamonfina volcanic complex (Pleistocene), Central Italy. *J. Volcanol. Geotherm. Res.*, 177, 500-514.
- Scaillet S., Vita-Scaillet G., Guillou H. (2008) - Oldest human footprints dated by Ar/Ar. *Earth Planet. Sci. Lett.*, 275, 320-325.
- Sottili G., Palladino D.M., Marra F., Jicha B., Karner D.B., Renne P. (2010) - Geochronology of the most recent activity in the Sabatini Volcanic District, Roman Province, central Italy. *J. Volcanol. Geotherm. Res.*, 196, 20-30.

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# Soils and viticultural terroir of Central Italy

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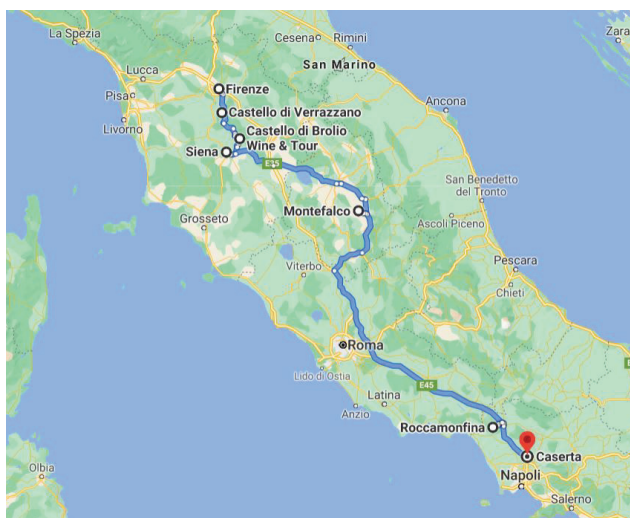
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**22-25 May 2024**

## Excursion Guide



## PROGRAM:

### Wednesday 22/5/2024

8:00: Leaving from Florence (Piazzale Montelungo)

9:00-10:00: Arrival to Verrazzano Castle, Greve in Chianti. Greetings and history of the castle and the winery. Visiting to the ancient cellar.

10:00-11:30: Coffee break in the terrace with vineyards view. Description of the research activities to plan and project the new vineyards. Visiting to vineyards and a

soil profile.

12.30-13.00: Arrival to Barone Ricasoli winery, greetings in the reception room.

13:30-14.30: Lunch and wine tasting at "Osteria del Castello", Castello di Brolio.

14.30-17.30: Visiting two areas with different terroirs, description research activities carried out in this farm for viticultural zoning, description of two soil profiles

18.00-18.30: Arrival to Siena, Hotel Moderno.

20:00: Dinner in the Siena city centre "Ristorante Spadaforte, Piazza del Campo".

### Thursday 23/5/2024

8:00: Leaving from Siena, Hotel Moderno

10:00-12:30: Arrival to Arnaldo Caprai Winery, Montefalco, Perugia. Greetings and information of the winery. Technical visit of vineyards and soil profiles

12:30-13:30: Light lunch

14:00-16:15: Arrival to Di Filippo organic winery, Cannara, Perugia. Greetings and information of the winery. Description of research activities and soils. Leaving to Frascati, Rome.

19:00: Arrival to Frascati, Hotel Villa Vecchia.

20.00-22.00: Dinner and wine tasting of Castelli Romani wines to the winery "Cantine Santa Benedetta".

### Friday 24/5/2024

8:30: Leaving from Frascati, Hotel Villa Vecchia

10:00-12:30: Arrival to "Porto di Mola winery", Galluccio, Caserta. Greetings and information of the winery. Technical visit of vineyards and soil profiles

12:30-13:30: Lunch at Porto di Mola winery

15:00-17:30: Arrival to "La Guardiense winery", Santa Lucia, Benevento. Technical visit of vineyards and soil profiles

18.30: Arrival at Novotel Caserta sud hotel

20:00-22:00: Dinner at the restaurant "Mastrangelo" situated inside an historical mansion in the old Caserta village

### Saturday 25/5/2024

8:00: Leaving from Novotel Caserta hotel

8:30-8.45: Stop at Afragola-Napoli train station on request (to catch high-velocity trains to Rome or Naples)

14:30: Arrival to Florence, Piazzale Montelungo

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“The role of soil in the expression of terroir effect”

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Climate and topography

Geological and pedological setting

“An example of organic viticulture”

DAY 3: Wines of volcanic region of Campania

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Geology and Pedological Setting: The Foundation of Terroir Excellence

“Soil science applied to precision viticulture”

“Climate change and terroir”

“Terroirs and wine cooperative”

Introduction

Numbers of the global viticultural sector

kha	2018	2019	2020	2021 Prev.	2022 Prel.
Spain	972	966	961	963	955
France	792	794	799	805	812
China	779	781	783	785	785
Italy	705	714	719	718	718
Türkiye	448	436	431	419	410
USA	408	407	402	393	390

Table 1 The countries with the larger surface dedicated to vineyards, in thousands of hectares (source OIV)

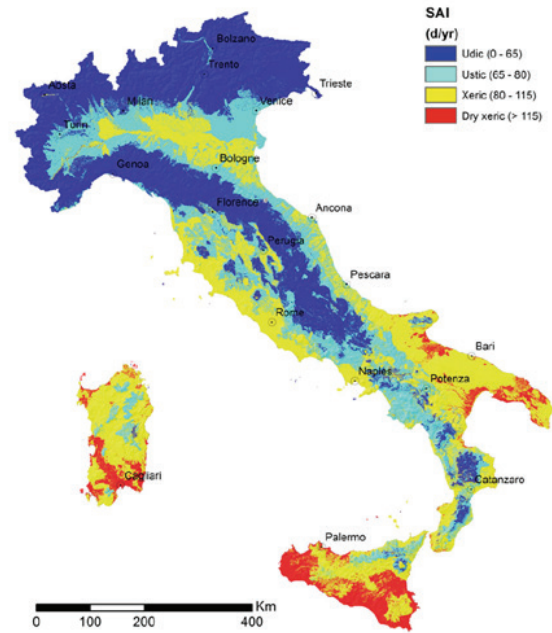
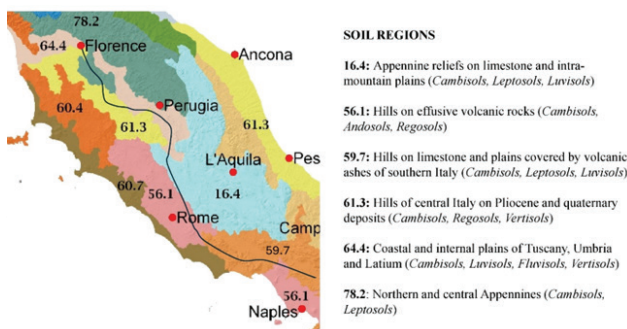
mhl	2018	2019	2020	2021 Prev.	2022 Prel.
Italy	54.8	47.5	49.1	50.2	49.8
France	49.2	42.2	46.7	37.6	45.6
Spain	44.9	33.7	40.9	35.5	35.7
USA	26.1	25.6	22.8	24.1	22.4
Australia	12.7	12.0	10.9	14.8	12.7
Chile	12.9	11.9	10.3	13.4	12.4
Argentina	14.5	13.0	10.8	12.5	11.5
South Africa	9.5	9.7	10.4	10.8	10.2
Germany	10.3	8.2	8.4	8.4	8.9

Table 2 The countries with the highest wine production, in millions of hectoliters (source OIV)

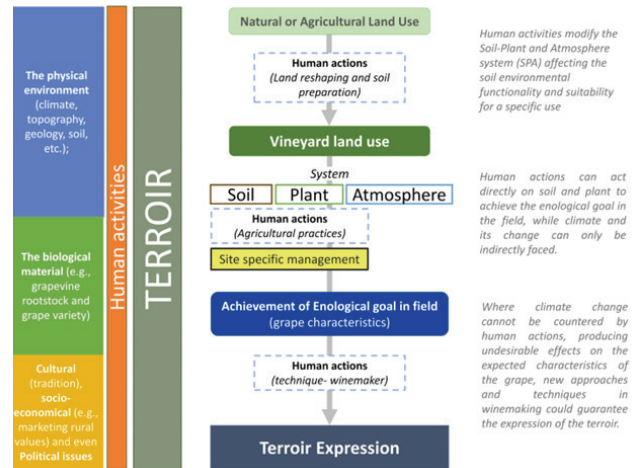
	Volume (mhl)		Value (mEUR)	
	2021	2022	2021	2022
Italy	22.0	21.9	7 116	7 834
	variation of -0.6%		variation of 10.1%	
Spain	23.6	21.2	2 895	2 984
	variation of -10.2%		variation of 3.1%	
France	14.6	14.0	11 074	12 279
	variation of -4.5%		variation of 10.9%	
Chile	8.7	8.3	1 664	1 818
	variation of -4.0%		variation of 9.3%	

Table 3: Main wine exporters, in millions of hectoliters and values in millions of euro (source OIV)

Soil Regions and climate



Terroir concept

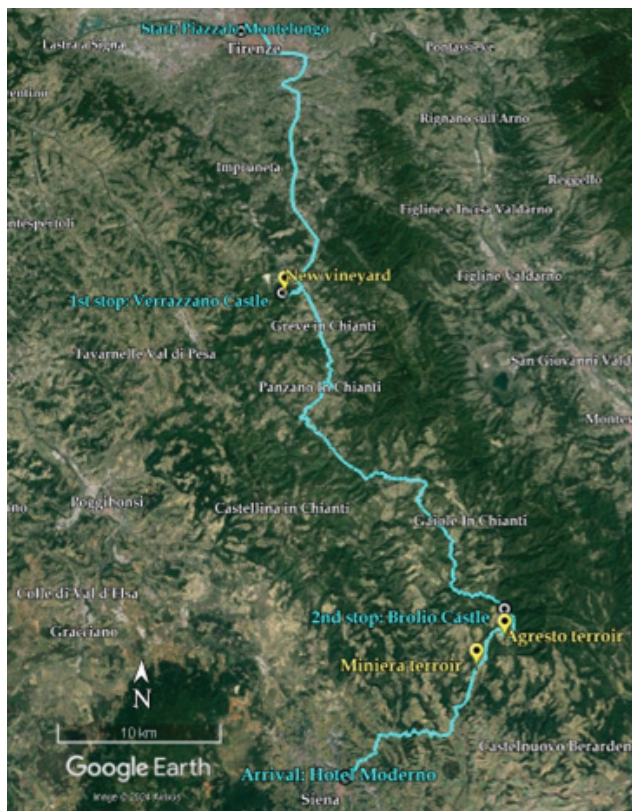


Scheme of Terroir concept (from Bonfante and Brillante, 2022)

For overviews on Terroir concept:

- Bonfante A., Brillante L. (2022). Terroir analysis and its complexity. *Oeno One*, 56 (2).
- Vaudour E., Costantini E.A.C., Jones G. V., Mocali S. (2015) An overview of the recent approaches to terroir functional modelling, footprinting and zoning. *SOIL*, 1, 287–312.
- Brillante, L., Bonfante, A., Bramley, R. G., Tardaguila, J., & Priori, S. (2020). Unbiased Scientific Approaches to the Study of Terroir Are Needed!. *Frontiers in Earth Science*, 8,

**DAY 1: Chianti Classico wine district**



**Landscape, history and culture**



The Etruscans people (about 2,700 years B.P.) were the ones who first shaped the Chianti landscape. They abandoned pastoral for agricultural life, introducing the cultivation of grapevines. Probably, the name “Chianti” derived from the Etruscan family “Clante”. The Romans came next, and with them the beginnings of olive tree cultivation. The earliest documentation of a “Chianti wine” dates back to the 14th century, when viticulture was known to flourish in the “Chianti Mountains” around Florence. A military league called Lega del Chianti (League of Chianti) was formed in this century between the townships of Castellina, Gaiole and Radda, which would lead to the wine from this area taking on a similar name. In 1716, the Tuscany Duke Cosimo III delineate the

boundaries of Chianti wine production territory. The modern history of Chianti Classico can be attributed to the efforts of Baron Bettino Ricasoli, a visionary winemaker who, in the 19th century, conducted extensive research to define the optimal grape varieties and winemaking techniques for this region. In 1872, Ricasoli formulated the “recipe” for Chianti wine, which included a blend of Sangiovese, Canaiolo, and Malvasia grapes, laying the foundation for the style of Chianti that would become internationally renowned.

In 1924, the Chianti Classico Consortium was established (first in Italy), aiming to safeguard the authenticity and quality of wines produced within the Chianti Classico territory. The consortium introduced regulations to delineate the geographical boundaries of the Chianti Classico wine region and define the specific grape varieties (> 80% Sangiovese grape) and winemaking practices allowed, thus formalizing Chianti Classico as a distinct and prestigious appellation. The symbol was the “black rooster” (Gallo Nero in Italian), derived from the symbol of League of Chianti.

Currently, the Chianti Classico consortium (fig.1) counts 480 wineries for a total vineyard surface of about 10.000 hectares, usually not exceeding the 700 m a.s.l. Average annual output is around 35 million bottles, exported to more than 100 countries.

The average annual temperature is 13-14°C, with cold winters and hot summers and maximum temperatures often above 35°C. The daily fluctuations are quite pronounced, especially at higher elevations.

**1.2 Geological and pedological setting**

The hills are part of the broader Apennine Mountain range, which stretches across much of Italy. The specific geological history of the Chianti hills can be traced back to the Alpine and Apennines tectonics. During the Mesozoic era, the area that would become the Chianti hills was submerged under the sea. Over time, layers of sediment accumulated on the seabed, consisting of marine organisms, sand, and clay. Around 65 million years ago, during the late Cretaceous period, tectonic forces caused the uplift of the Apennine Mountain range, including the Chianti hills. This uplift was accompanied by intense folding and faulting of the Earth’s crust, leading to the creation of the characteristic undulating landscape seen in the Chianti region today.

The main lithologies and soilscapes can be summarized as follows (Fig.2 and 3):

- Neogene and Quaternary deposits (Cong, PLIOs, PLIOc, MIO\_L): marine, delta and fluvio-lacustrine deposits characterized by different texture and coarse fragments content. Such deposits characterize the lower hills of the western and southern part of the territory. The soils showed very different texture, according to the nature of the deposits, clayey or loamy-clay soils on PLIOc and MIO\_L deposits, sandy-loam or loamy-sands in PLIOc. All these soils have generally

from moderate to high content of total calcium carbonate and sub-alkaline pH.

- Sandstone (MAC, Macigno formation): Feldspathic sandstone with siltstone layers, generally non-calcareous. This formation characterizes the higher altitude of the hills, mainly in the eastern part of the territory and generally covered by forests. The soils are generally sandy loam or loamy sand in texture, rich in coarse fragments and with shallow depths. The calcium carbonate is generally absent, and pH is neutral or slightly sub-acid.

- Calcareous flysches (MML, Monte Morello formation and similar): flysch formation characterized by a sequence of thick layers of white limestones and shales. This formation characterizes the central part of the Chianti area, and it is probably where the vineyards are more frequent. The soils have clayey, loamy-clay or silty-clay loam texture, with elevated content of coarse fragments of limestone. The total calcium carbonate is usually high (from 20 to 50%).

- Marls and siltstone flysches (SIL, Sillano formation and similar): flysch formation characterized by sequences of marls, siltstone, shales and thin layers of limestone. The soils are like the previous ones, but less calcareous, sometimes with no presence of limestone. The texture has generally higher content of silt than the previous one.

- Sandstones cemented by limestone (PIE, Pietraforte formation): sandstones and rudites cemented by limestone. The soils are generally sandy loam or loamy sand, sometimes loamy, with moderate content of calcium carbonate and subalkaline pH.

- Schists, shales and siltites intercalated by thin layers of limestone and marls (GAL "Galestro" rock): "Galestro" is an informal name of a group of rocks characterized by strong exfoliating character. The soils are generally shallow and characterized by clay or clay-loam texture, and great amount of platy coarse fragments (schists). In some cases, these schists have red-purple color, that make the color of the landscape quite unusual. The calcium carbonate is generally low or moderate, and pH is subalkaline. Such soils are strongly valued for viticulture, because they show scarce fertility, but the strong fracturing of these rocks allows a very good and deep grapevine rooting.

MML: Monte Morello Formation, limestone and shale flysches (Cretaceous-Paleocene); SIL: marls and shale flysches (Cretaceous-Paleocene); PIE: Pietraforte formation, sandstone cemented by calcium carbonate (Cretaceous); GAL: "Galestro" type rocks, shales and marls (Cretaceous).

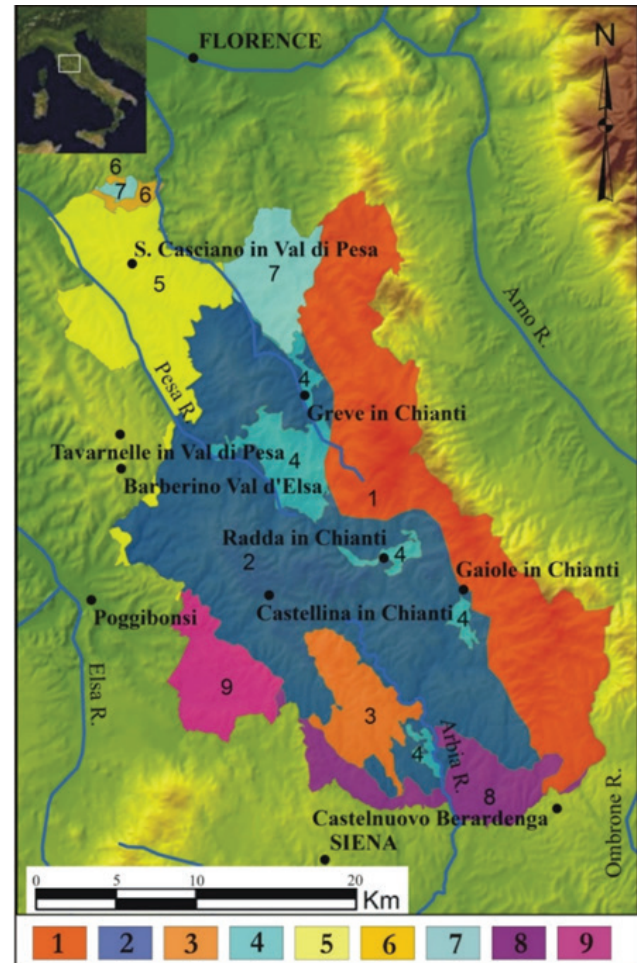


Figure 3 – Landscape unit map of the Chianti Classico area. 1. Low mountain and high hills with medium and high gradient on sandstone (Macigno del Chianti Formation); 2. Low mountain and high hills with medium and high gradient on limestone and marly limestone, sandstone and shale (Montemorello Formation); 3. High hills with medium gradient on sandstone (Macigno del Chianti Formation) and slope of the Flysch of the Chianti Formation; 4. High hills with medium gradient on predominantly marly clay and shale; 5. Low and medium hills with medium gradient on mostly calcareous conglomerates and gravels, with sand and clayey sandy; 6. Low and medium hills with medium gradient on sandstone; 7. Low and medium hills with medium gradient on marly clay and shale; 8. Low and medium hills with medium gradient on marine sand sediments; 9. Low and medium hills with medium gradient on marine clay sediments.

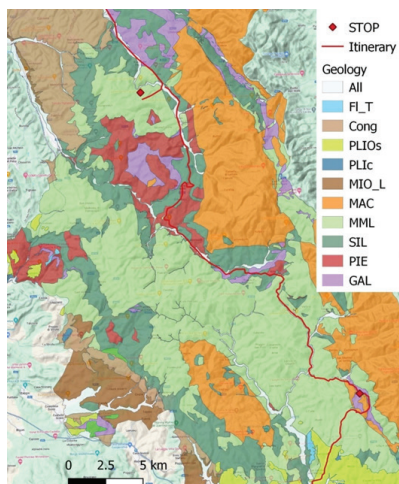


Figure 2: Geological map of Chianti Classico area. All: recent alluvial deposits; FT: fluvial terraces; Cong: Delta and fluvial conglomerates (Quaternary-Pliocene); PLIOs: Marine sands and conglomerates (Pliocene); PLIOc: Marine clays and silt (Pliocene); MIO\_L: Lacustrine deposits (Miocene); MAC: Macigno formation, feldspathic sandstone, non-calcareous (Oligocene);

**“Viticulture 4.0: the soil knowledge to plan and project the plantation of new sustainable vineyards”**

**STOP 1: The Castello di Verrazzano, Greve in Chianti**

The Castello di Verrazzano farm (lat: 43.601, long: 11.287), 6 ha, 320 m. a.s.l., is characterized by Cambisols and Regosols, steep slopes, on marly limestone flysch, organically cultivated with Sangiovese grape variety.

The original 2019 project for the new vineyard, just below the castle, provided two ditch level roads, characterized by the roadway made against the slope, to reduce erosion along the row of the vines. The study of the slope suggested making 3 ditch roads following

contour lines and changing the orientation of the rows. Thanks to a constant exchange of ideas with CREA, the farm decided even to terrace with greened embankments, where the slope was steepest.

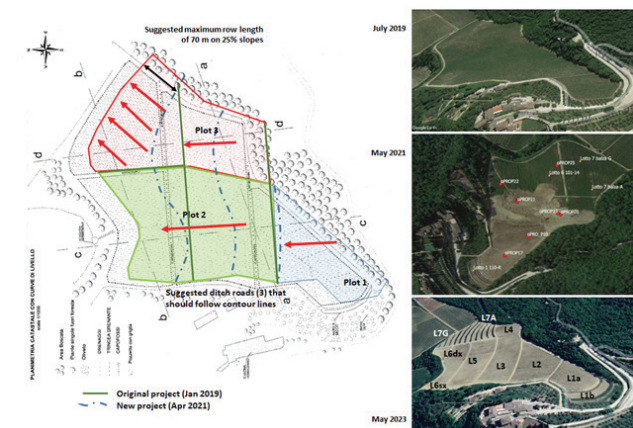


Figure 4 ditch level roads proposed in the old and new plant project. Google earth picture before, during and after implementation with location of profiles (oPRO#) and soil analysis (lotto#), and then final lots (L) identification

Then there were (i) soil excavation, (ii) stripping (removal of surface soil rich in organic matter and its redistribution once the soil has been leveled) (figure 4), (iii) drainage, (iv) leveling, (v) basal fertilization (the pre-planting fertilization), (vi) sowing of green manure before the plantation of the grafted rootstocks, and (vii) soil preparation and planting of the grafted rootstocks. In total 7 soil profiles (oPROP# in figure 3, oPRO22 in figure 4) 4 soil samples (lotto # in figure 3) with auger (0-30 and 30-75 cm deep), and proximal gamma ray assessment was performed.

SOC losses measured in the Verrazzano field (average about -40% after earthmoving works) were higher if compared with Costantini et al. (2015) and Cerdà et al. (2017), ranging from -6.4% in a flat valley until -33% within the area with slope, and this can be explained by the intense and long-lasting earthmoving works, that exposed a deep layer of soil to oxidation for a long time, and the steep slope of the field that favored erosion when the soil was bare (from March 2021 until April 2022, except for a short period of cover crops grown on 1/4 of the land). Barbetti et al., (2024) by a geographical decision support system reports 100 m grid estimation of (a) overall carbon footprint including SOC losses, (b) potential erosion and maximum vine row length compatible with tolerable erosion, (c) potential water stress, (d) risk of runoff/waterlogging, (e) identification of suitable rootstocks, and (f) nutritional needs before planting.

As an example, the results are here reported of an original model to exclude rootstocks considered unsuitable because of the pedoclimatic characteristics of the site, concerning fertility class, total limestone, salinity, acidity, risk of water stress, and waterlogging was carried out an applied to this new plant. The soil assessments inherent in the chemical and physical soil properties refer to the whole rootable volume. The model output

was discussed with farmers that decided to follow indication in 7 out of 10 (table 1) (Andrenelli et al., 2022).


Lotto	N°	Portinnesti	Scelta Aziendale
1b	5	420A 41B Fercal M1 M4	110R
1a	5	420A 41B Fercal M1 M4	420A
2	12	K5BB SO4 420A 1103P 110R 140Ru 41B Fercal M1 M2 M3 M4	110R
3	9	420A 1103P 110R 140Ru 41B Fercal M1 M2 M4	110R
4	9	420A 1103P 110R 140Ru 41B Fercal M1 M2 M4	420A
5	12	K5BB SO4 420A 1103P 110R 140Ru 41B Fercal M1 M2 M3 M4	110R
6sx	12	K5BB SO4 420A 1103P 110R 140Ru 41B Fercal M1 M2 M3 M5	110R
6dx	12	K5BB SO4 420A 1103P 110R 140Ru 41B Fercal M1 M2 M3 M6	101.14
7G	9	420A 1103P 110R 140Ru 41B Fercal M1 M2 M4	101.14
7A	9	420A 1103P 110R 140Ru 41B Fercal M1 M2 M5	110R


Table 1 suitable rootstock for Verrazzano new vineyard. Lot numbers are the same (L#) reported in figure 3. In red rootstocks selected by the farm for commercial reason





Figure 5 Soil profile dug after land preparation for vineyard plantation. The topsoil (0-30 cm) was removed, then the subsoil was deep ploughed (30-90 cm) and mixed by excavator and then land levelled. After all, the topsoil was replaced.

**FOR FURTHER DETAILS:**

 Barbetti, R., Criscuoli, I., Valboa, G., Vignozzi, N., Pellegrini, S., Andrenelli, M. C., ... & D'Avino, L. (2024). A Regional 100 m Soil Grid-Based Geographic Decision Support System to Support the Planning of New Sustainable Vineyards. *Agronomy*, 14(3), 596.

 Costantini, E. A., Castaldini, M., Diago, M. P., Giffard, B., ... & Zombardo, A. (2018). Effects of soil erosion on agro-ecosystem services and soil functions: A multi-disciplinary study in nineteen organically farmed European and Turkish vineyards. *Journal of environmental management*, 223, 614-624.

 Costantini, E. A. C., Agnelli, A. E., Fabiani, A., Gagnarli, E., Mocali, S., Priori, S., ... & Valboa, G. (2015). Short-term recovery of soil physical, chemical, micro-and mesobiological functions in a new vineyard under organic farming. *Soil*, 1(1), 443-457.

 Costantini E.A.C., D'Avino L., Priori S. 2021 Interrow organic management to restore soil functionality of vineyards (pp 286-295) In: FAO and ITPS. 2021. Recarbonizing Global Soils – A technical manual of recommended sustainable soil management. Volume 4: Cropland, grassland, integrated systems and farming approaches – Case studies. Rome. ISBN 978-92-5-134897-0



Costantini E. A.C., Pellegrini S., Bucelli P., Barbetti R., Campagnolo S., Storchi P., Magini S., Perria R. (2010) Mapping suitability for Sangiovese wine by means of  $\delta^{13}\text{C}$  and geophysical sensors in soils with moderate salinity. *Europ. J. Agronomy* 33; 208–217.



Andrenelli M.C., Pellegrini S., L'Abate G., Becagli C., Barbetti R., Valboa G., Orlandini A., Perria R, Vignozzi N. 2022 Pedoclimatic characteristics and adaptability of vine rootstocks: an application to facilitate its choice (p.68) and Valboa G., Andrenelli M.C, Orlandini A., Vignozzi N., Pellegrini S., L'Abate G., Barbetti, R., Criscuoli I., D'Avino L. A model-based approach for managing soil chemical fertility in vineyards (p.118) 2022 in *Atti del 43° Congresso Nazionale della Società Italiana della Scienza del Suolo – Roma, 5-7 ottobre 2022*



Project website: [www.goprosit.it](http://www.goprosit.it)



Project website: [Resolve Core-Organic plus](#)

SOIL BEFORE LAND PREPARATION

SOIL SITE oPRO P 10

**UTS - STS:** **Correlation:** **Survey date:** 6/19/2020  
**Soil region:** 78.2 **Surveyer:** #Errore  
**Land system:** **Coordinates:** **N:** **E:** **LAT:** 43.60 **LO:** 11.25  
**Land subsystem:** 26252 **Site:** Verrazzano, Vigneto del Rosi, Intermedio  
**Land Unit:** SOM1\_ **Municipality:** Greve in Chianti  
**Elevation:** 321 m s.l.m. **Province:** Firenze  
**Slope:** 10 % **Aspect:** 340 ° **Stones:** small frequent (4-15%)  
**Rocks:** medium few (0.4-1%)  
**Land use:** non-irrigated arable land cereals legumes fodder crops root large absent  
**Land form hm:** level ground, reshaped slope



**Land element dm:** back slope convexity: linear-concave  
**Substratum:** marly limestone; silty or loamy very gravelly  
**Parent material:** saprolite; silty or loamy extremely stony  
**Characters and qualities:** erosion: water: sheet erosion moderate, internal drainage: well drained, rooting depth: moderately deep 50-100 cm; root restriction: critic quantity of coarse fragments and concentrations

**Class. USDA:**  
**Class. WRB:** 3° ed. (2014)Calcaric Cambisols (Loamic),  
**Notes:** Codice archivio: AOF00197; AOF00198

HORIZONS

**Ap** 40 cm moist color: 2,5Y 4/3 dry color: 2,5Y 4/4 Olive Brown, on lithochromic mottles; coarse fragments: common (5-15%) type: coarse gravel (20-76 mm), shape: angular, marly limestone, weathering: very slight and scarce (<5%) type: boulders (>600 mm), shape: angular, marly limestone, weathering: very slight; structure: angular blocky coarse, moderate; secondary structure: angular blocky medium, moderate; adhesive; very plastic; hydraulic conductivity: moderately low; pores: fine (0.5-1 mm) common (0.5-2%) and fine (0.5-1 mm) few (0.1-0.5%); roots: fine (1-2 mm) few (1-10) and medium (3-5 mm) abundant (>200); boundary: clear wavy  
**Bw** 100 cm moist color: 2,5Y 5/4 Light Olive Brown; coarse fragments: common (5-15%) type: coarse gravel (20-76 mm), shape: angular, marly limestone, weathering: very slight and common (5-15%) type: cobbles (76-250 mm), shape: angular, marly limestone, weathering: very slight; structure: angular blocky coarse, moderate; secondary structure: angular blocky medium, moderate; adhesive; very plastic; hydraulic conductivity: moderately low; pores: fine (0.5-1 mm) common (0.5-2%) and fine (0.5-1 mm) few (0.1-0.5%); roots: fine (1-2 mm) few (1-10) and fine (1-2 mm) few (1-10); boundary: unknown

CHEMICAL AND PHYSICAL ANALYSIS

Horiz.	Depth cm	Sand g/kg					Silt g/kg			Clay g/kg	F.C. (cm/m)	W.P. mm/m	AWC g/cm3	B.D. g/cm3	COLE	Text	Gran
		v. coarse	coarse	med.	fine	v. fine	total	coarse	fine								
Ap	-1 40						400			310						CL	FPI
Bw	40 100						420			300						CL	FPI

Horiz.	Depth cm	Exchange complex cmol(+)/kg								BS %	ESP %	P ass mg/kg	K mg/kg	N tot g/kg	CaCO3 g/kg		O.C. g/kg	pH			E.C. dS/m	C/N	
		Ca	Mg	Ca+Mg	Na	K	H	Al	CEC						total	active		H2O	CaCl2	KCl			NaF
Ap	-1 40	17.0	0.7		0.3	0.6				18.6	100	5.0	0.12	434	76	11	8.1					0.23	
Bw	40 100	11.5	0.7		0.3	0.5				13.0	100	4.0	0.08	440	80	7	8.2					0.18	

Horiz.	Sample	cm	Extractable Fe g/kg			Extractable Al g/kg			Si g/kg	SAR	CaSO4 %	Fe mg/kg	Mn mg/kg	Cu mg/kg	Zn mg/kg	P tot g/kg	P ads %	pH	Alpi/ Alos	Alos+0.5Feos
			ossal.	ditiou.	pirof. totale	ossal.	ditiou.	pirof. totale												
Ap	-1	40									12.80	29.8	19.60	2.6						
Bw	40	100									10.80	14.80	2.6	2.8						



**“The role of soil in the expression of terroir effect”****STOP 2: Barone Ricasoli farm, Castello di Brolio****The farm**

The Barone Ricasoli winery, situated in the Castello di Brolio, is one of the largest and most important wineries of the “Chianti Classico” wine district. The wine making “formula” of the Chianti wine was born from the study and the experiments in this farm made by Baron Bettino Ricasoli in the XIXth century. The Baron, businessman and agronomist, was the first in the region to introduce experimental vineyards, to train the workers for the correct management of the vines, and for wine production. From the soils and the vines more vocated for his land, he developed a blend of cultivar Sangiovese (about 80%) and Canaiolo (about 20%) grapes, which after an aging of 2 years in wood barriques became “Chianti Classico” wine.

At present, the farm has a total extension of about 1,200 hectares, 250 of which with vineyards, 30 with olive tree groves and the rest mainly covered by deciduous forest. The vineyards are mainly placed on slopes, spanning in altitude from 180 to 490 m a.s.l., often with South or South-West aspect. The main vine cultivar of the farm is Sangiovese, although some vineyards are dedicated to Canaiolo, Cabernet Sauvignon, Merlot, white grapes, as Chardonnay and Malvasia, are present.



Planting densities are high, between 5,500 and 6,500 vines per hectare. The vines trained to vertical trellises and pruned to the spurred cordon technique at a height of 50 cm, and leaf canopies about 1.1 m high. There are 8 buds per vine, and bunch thinning results in an average yield of 1-2 kg of grapes per vine.

The primary varietal is Sangiovese, in large part from internal clonal selections made in the estate’s older vineyards. The vines are grafted onto rootstocks that confer moderate vigor, for example the 420 A, and in less fertile areas the 110 Richter. There are also white and red international varietals that are used to make specific wines.

Vineyard management is integrated. There is natural grass cover between the rows, which is alternated with mechanical tillage during the periods of greatest summer dryness. Fertilization is generally carried out through the application of organic matter from compost or manure, while in recent years pest control treatments have been carried out with low-impact products

used in organic farming.

The first project of viticultural zoning at farm scale During 2008–2009 a soil survey of the vineyards and olive groves was carried out. Later, some specific vineyards cultivated with Sangiovese cultivar, were mapped, and monitored in more detail to study the relationships between soils and grape quality.

The main macro-Terroir of the farm are strictly related to geology and can be summarized as follow:

- 1) Soils on sandstone (SAND): Eutric Arenosols, Skeletic Eutric Cambisols situated on regular slope or high-plains of the hills between 430 and 470m a.s.l.; with sandy loam or loamy sand texture, from common to abundant coarse fragments of sandstone, non-calcareous, pH 6.5-7.5.
- 2) Soils on calcareous flysch (CALC): Skeletic Calcaric Cambisols, Skeletic Calcisols, and Calcaric Regosols situated in slopes between 400 and 450 m a.s.l.; with clay loam, loamy or silty clay loam texture, from common to abundant coarse fragments of limestone, elevated content of calcium carbonate, pH 8.2-8.4.
- 3) Soils on marine deposits, mainly sandy (MAR): Calcaric Arenosols, Calcaric Cambisols, and, in few stable surfaces also Cutanic Luvisols, situated on marine sands and gravelly-sands of early Pliocene period, in slopes around 300–350 m a.s.l. The texture is variable between sandy-loam to clay-loam, with variable content of rounded cobbles, and the calcium carbonate content is usually medium (around 15%).
- 4) Soils on ancient fluvial terraces (FLUV): Calcaric Cambisols, Eutric Cambisols, and Cutanic Luvisols at lower elevation than the others (250–320 m a.s.l.), developed on ancient fluvial deposits (Pliocene-Quaternary). The texture is loam or clay-loam, with variable coarse fragments, and the calcium carbonate content is between 8 to 19%, pH 8.1-8.4.

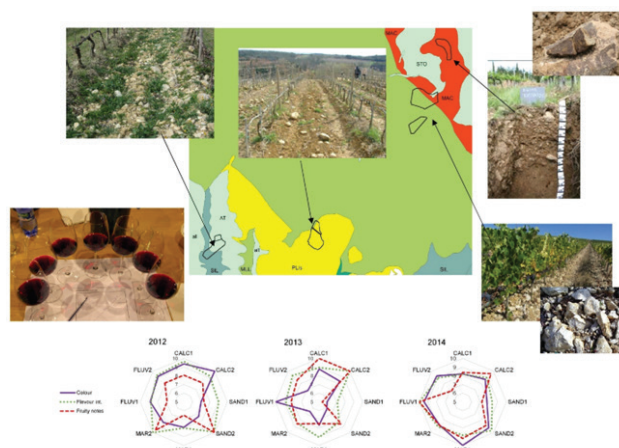


Figure 6: Summary of the zoning study of Barone Ricasoli winery (Pirori et al., 2019; Geoderma).

From 2018, the farm decided to produce 3 premium wines or CRU\* (100% Sangiovese cultivar) in 3 of this macro-terroir, with the only exception of SAND. In particular, “Colli di là” wine is completely made by grapes of CALC, “Roncicone” wine from grapes of MAR, and

“Ceni Primo” from grapes of FLUV.

\*CRU is a French term meaning “growth.” More precisely, it references a great or superior growing site or vineyard, where a premium wine is produced.

**STOP 2a (“Colli di là” CRU vineyards):**



Coordinates WGS84 32N: 4808196N – 699016E  
 Elevation: 435 m s.l.m.  
 Slope: 7%      A s - pect: SSE (135°)  
 Geology: Monte Morello Flysch (Limestone and shales)  
 Internal drainage: Well drained  
 Rooting depth: elevated (>100 cm)  
 Classificazione WRB (2022): Cambic Skeletic Calcisols (Loamic)

**Horizons:**

- Ap (0-15 cm): color 10YR 4/4; coarse fragments of limestone common (5-15% gravels, 20-60 mm and 5-15% stones, 6-20 cm), silty loam texture; structure subangular blocky fine, strongly developed; HCl reaction: extremely strong; clear wavy limit.

- Bk1 (15-70 cm): color 10YR 5/4; coarse fragments of limestone frequent (15-35% gravel, 20-60 mm and 5-15% stones, 6-20 cm); silty clay loamy texture; structure subangular blocky medium, moderately developed; CaCO3 nodules (2%, <5 mm); HCl reaction: extremely strong; clear wavy limit.

- Bk2 (70-120 cm): color 10YR 5/4; coarse fragments of limestone frequent (15-35% gravel, 20-60 mm and stones, 6-20 cm); clay loamy texture; structure subangular blocky medium, moderately developed; CaCO3 nodules (2%, <5 mm); HCl reaction: extremely strong; clear wavy limit.

- BC/R (120-130+ cm) color 10YR 5/5, coarse fragments of limestone frequent (15-35% stones, 6-20 cm and 15-35% boulder, 20-60 cm)

Horizon	Sand	Silt	Clay	Text.	CaCO <sub>3tot</sub>	SOC	TN	C/N	pH	EC
	dag/kg		Class		dag/kg		g/kg			mS/cm
Ap	20.9	38.0	42.2	SiL	18.5	0.95	1.11	8.6	8.4	0.21
Bk1	16.6	37.7	33	SiCL	31.7	0.65	0.93	7.0	8.2	0.20
Bk2	23.0	25.7	29.8	CL	37.4	0.58	0.91	6.4	8.3	0.19

	Base exchange							
	Ca	Mg	K	Na	CSC	TBS	P <sub>ass</sub>	K <sub>ass</sub>
	cmol(+)/kg				%	mg/kg		
Ap	25.7	0.7	0.42	0.1	26.9	100	8.69	165
Bw	22.1	0.4	0.31	0.06	22.8	100	0.51	121
BC/R	23.6	0.4	0.27	0.05	24.3	100	0.47	104

**STOP 2b (“Roncicone” CRU vineyards):**

Some selected vineyards were mapped at high detail by the use of three proximal soil sensors: i) Veris 2000xa, measuring apparent electrical conductivity (ECa) at a depth of about 0-45 cm (Fig.7); ii) the electromagnetic

induction sensor Geonics EM38-Mk2, measuring ECa at 0-75 and 0-150 cm (Fig.7); iii) “the Mole” gamma-ray spectrometer, measuring gamma-ray total counts (TC) and the major radionuclides 40K, 232Th and 238U of the topsoil (about 0-30 cm, Fig. 8) (Priori et al., 2014). The aims of this proximal survey and mapping were mainly two: i) obtaining covariates to interpolate soil parameters analyzed in specific sites within the whole area; ii) using such maps to perform a clustering to map homogeneous zones of soil (HZs) (Priori et al., 2019). The vineyard, where “Roncicone” wine is produced, was also mapped by these proximal sensors and several points of observations, collected and analyzed in laboratory. Relationships and predictive models between gamma-ray spectroscopy and clay, sand, and gravel content were found (Priori et al., 2014). K-means clustering of the proximal sensing maps delineated two homogeneous zones (HZs), called Leccio1 and Leccio2 (Fig.9)

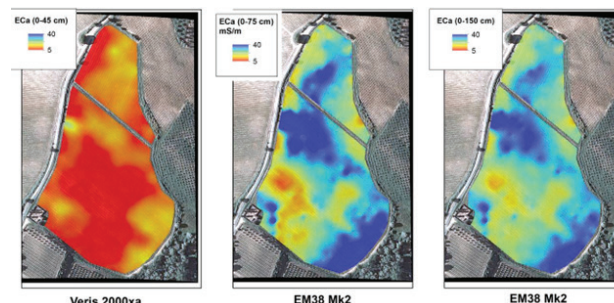


Figure 7: Maps of ECa at three pseudo-depths namely 0-45, by Veris 2000Xa, 0-75 and 0-150, by EM38-Mk2.

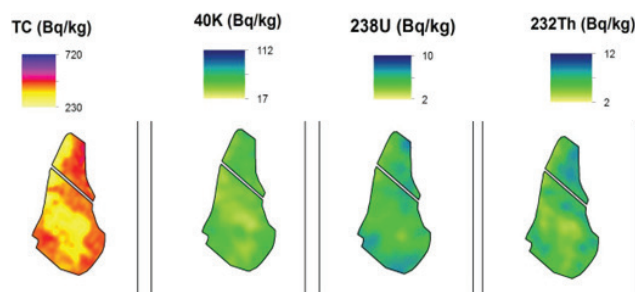


Figure 8 Maps of TC and radionuclides, performed by the survey with gamma-ray spectroscopy (Priori et al., 2014)

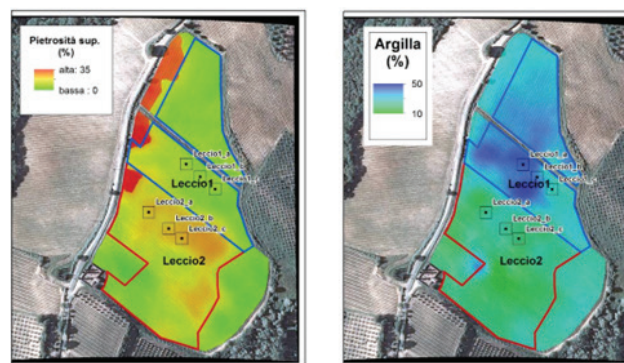


Figure 9: Predicted stoniness (left side) and clay (right side) of the topsoil (0-30 cm). The maps also show the boundaries of the two HZs “Leccio1” and “Leccio2”, delineated by k-means clustering of the maps obtained by the proximal soil sensing. Some little areas outside the boundaries were excluded because characterized by different lithology, moderate waterlogging or marine clay deposits in the subsurface horizons.

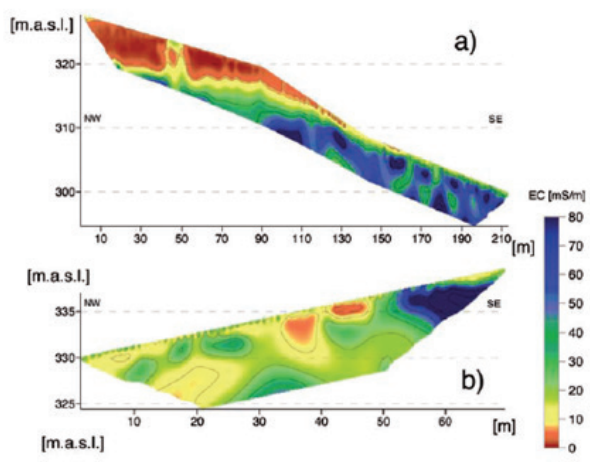


Figure 10: Inverted ERT (Electrical Resistivity Tomography) section. The blue (high conductivity) part represents the marine clays, whereas the red (low conductivity) part represents the marine sands and conglomerates. At 310 m a.s.l., where the boundary between sands and clays is very shallow, little ephemeral springs and higher moisture can be observable (Martini et al., 2013).



**LECCIO 1**  
**C**oordinates  
 WGS84 32N: 4806325N – 697385E  
 Elevation: 318 m s.l.m.  
 Slope: 5%  
 Aspect: SE (135°)  
 Geology: Marine sandy-gravelly deposits (Pliocene)  
 Internal drainage: Well drained  
 Rooting depth: deep (140 cm)  
 Classificazione WRB (2022):

Eutric Cambisols (Solimovic, Loamic)

**ORIZZONTI:**

- Ap (0-10 cm): color 10YR 4/3; coarse fragments, rounded, common (5-15% gravels, 20-60 mm), moderately or strongly weathered; clay loam texture; structure granular large, moderately developed; HCl reaction: visible effervescence; clear wavy limit.
- Bw1 (10-45 cm): color 10YR 4/3; coarse fragments, rounded, common (5-15 gravel, 20-60 mm), moderately or strongly weathered; clay loam texture; structure subangular blocky medium, moderately developed; HCl reaction: visible effervescence; gradual wavy limit.
- Bw2 (45-110 cm): color 10YR 4/4; coarse fragments, rounded, frequent (15-35% gravel, 20-60 mm and 5-15% cobbles, 6-20 cm), moderately or strongly weathered; clay loam texture; structure subangular blocky medium, moderately developed; HCl reaction: visible effervescence; clear wavy limit.
- Bw3 (110-140 cm): color 10YR 4/5; coarse frag-

ments, rounded, common (5-15% gravels, 20-60 mm), moderately or strongly weathered; clay loam texture; structure subangular blocky medium, slightly developed; HCl reaction: visible effervescence; abrupt linear limit.

- BCu (140 cm+): color 10YR 4/5; coarse fragments, probably artefacts, angular, frequent (45-60% stones 6-20 cm), moderately or strongly weathered; clay loamy texture; structure subangular blocky medium, moderately developed; HCl reaction: visible effervescence; unknown limit.

**LECCIO 2**

Horizon	Sand	Silt	Clay	Text. Class	CaCO <sub>3</sub> <sup>tot</sup>	SOC	TN	C/N	pH	EC
	dag/kg					dag/kg	g/kg			mS/cm
Ap	31.4	33.7	34.9	CL	3.6	1.29	1.24	10.4	8.3	0.27
Bw1	30.9	34.1	35.0	CL	2.9	0.75	0.79	9.5	8.3	0.25
Bw2	36.6	32.1	31.3	CL	3.5	0.60	0.70	8.6	8.3	0.25
<b>Base exchange</b>										
	Ca	Mg	K	Na	CSC	TBS	P <sub>tot</sub>	K <sub>tot</sub>		
	cmol(+)/kg					%	mg/kg			
Ap	16.2	1.2	0.6	0.1	18.1	100	13.3	242		
Bw1	15.9	0.8	0.4	0.1	17.2	100	4.0	147		



**Coordinates** WGS84 32N: 4806261N – 697235E  
 Elevation: 322 m s.l.m.  
 Slope: 8%  
 Aspect: SE (135°)  
 Geology: Marine sandy-gravelly deposits (Pliocene)  
 Internal drainage: Well drained  
 Rooting depth: elevated (> 100 cm)  
 Classificazione WRB (2022):  
 Calcaric Cambisols (Loamic)

**ORIZZONTI:**

- Ap (0-12 cm): color 10YR 4/4; coarse fragments, rounded, common (5-15% gravels and stones, 20-200 mm), moderately or strongly weathered; sandy loam texture; structure granular large, moderately developed; HCl reaction: strong; clear wavy limit.
- Bw1 (12-50 cm): color 10YR 5/5; coarse fragments, rounded, frequent (15-35% gravel, 20-60 mm and 5-15% stones, 6-20 cm), moderately or strongly weathered; loamy texture; structure subangular blocky medium, moderately developed; HCl reaction: strong; clear wavy limit.
- Bw2 (50-80 cm): color 10YR 5/6; coarse fragments, rounded, frequent (15-35% gravel, 20-60 mm and 5-15% stones, 6-20 cm), moderately or strongly weathered; loamy texture; structure subangular blocky medium, moderately developed; HCl reaction: strong;

clear wavy limit.

- BC1 (80-100 cm): color 10YR 5/6; coarse fragments, rounded, scarce (<5% gravel, 20-60 mm), moderately weathered; loamy texture; structure subangular blocky coarse, slightly developed; HCl reaction: strong; gradual linear limit.

- BC2 (100-130+ cm): color 10YR 5/6; coarse fragments, rounded, frequent (15-35% gravel, 20-60 mm and 5-15% stones, 6-20 cm), moderately or strongly weathered; loamy texture; structure subangular blocky medium, moderately developed; HCl reaction: strong;

Horizon	Sand	Silt	Clay	Text. Class	CaCO <sub>3</sub> <sup>1</sup>	SOC	TN	C/N	pH	EC
	dag/kg				dag/kg		g/kg			mS/cm
Ap	57.3	28.1	14.6	SaL	16.9	0.700	0.79	8.9	8.40	0.258
Bw1	50.0	28.9	21.1	L	16.0	0.335	0.54	6.2	8.29	0.178
Bw2	46.9	31.9	21.2	L	15.0	0.289	0.42	6.9	8.26	0.222
BC1	50.0	33.3	16.7	L	9.5	0.699	0.74	6.9	8.15	0.180
BC2	45.9	30.0	24.1	L	9.4	0.700	0.79	9.4	8.23	0.229

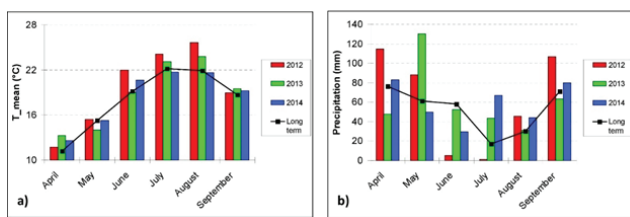
  

Base exchange								
	Ca	Mg	K	Na	CSC	TBS	P <sub>acc</sub>	K <sub>acc</sub>
	cmol(+)/kg				%		mg/kg	
Ap	10.1	0.41	0.26	0.04	10.8	100	4.8	102
Bw1	10.6	0.24	0.21	0.03	11.1	100	1.5	84
Bw2	11.2	0.17	0.23	0.04	11.7	100	0.4	91
BC1	10.0	0.28	0.20	0.04	10.5	100	1.2	80

unknown limit.

UTB	Clay	Sand	CaCO <sub>3</sub> <sup>1</sup>	Stoniness	TOC <sup>2</sup>	Ntot <sup>3</sup>	K <sup>4</sup>	AWC <sup>5</sup>	Ksat <sup>6</sup>
	(g·100 g <sup>-1</sup> )			(m <sup>2</sup> ·m <sup>-2</sup> )	(g·kg <sup>-1</sup> )		(mg·kg <sup>-1</sup> )	(mm·m <sup>-1</sup> )	(mm·h <sup>-1</sup> )
CALC1	36.0 ± 3.9	16.5 ± 2.7	38.7 ± 9.1	30.8 ± 10.9	6.6 ± 0.1	0.7 ± 0.1	132 ± 12	114 ± 27	2.1 ± 0.4
CALC2	33.6 ± 5.8	21.6 ± 1.2	57.0 ± 1.7	36.2 ± 10.5	5.4 ± 0.1	0.8 ± 0.1	107 ± 7	94 ± 10	2.3 ± 1.0
SAND1	9.8 ± 3.5	59.8 ± 5.5	1.7 ± 0.6	19.2 ± 2.7	4.4 ± 0.6	0.4 ± 0.1	74 ± 4	113 ± 27	19.7 ± 5.9
SAND2	10.0 ± 2.7	61.0 ± 5.2	2.6 ± 0.6	36.5 ± 6.6	3.9 ± 1.2	0.3 ± 0.1	170 ± 23	64 ± 11	22.8 ± 14.7
MAR1	35.3 ± 5.9	33.5 ± 6.8	13.3 ± 3.2	8.1 ± 3.7	8.4 ± 1.1	0.9 ± 0.1	149 ± 67	139 ± 3	7.5 ± 7.7
MAR2	19.2 ± 4.3	51.3 ± 5.8	26.7 ± 2.1	21.8 ± 10.6	5.8 ± 2.1	0.6 ± 0.2	86 ± 30	103 ± 21	11.6 ± 2.6
FLUV1	31.5 ± 3.8	31.4 ± 5.1	12.3 ± 6.4	7.0 ± 3.4	3.3 ± 1.1	0.4 ± 0.1	126 ± 28	79 ± 8	2.5 ± 0.6
FLUV2	25.5 ± 7.9	39.8 ± 6.0	28.3 ± 8.4	27.2 ± 10.2	6.1 ± 1.9	0.7 ± 0.2	100 ± 36	67 ± 19	9.1 ± 1.3

Table 2 Summary of the soil features of the main HZs of the Barone Ricasoli farm. MAR1 and MAR2 correspond to Leccio1 and Leccio2, whereas CALC1 and CALC2 correspond to “Colle di là” CRU. In bold, the values significantly different (p<0.05) for T-test between the two UTS within each macroterroir.



Cenological results

Figure 11 Temperature and precipitation of the three vintages of the study

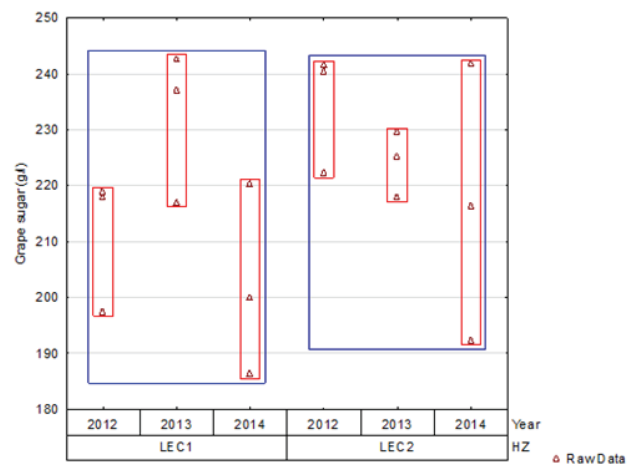


Figure 12 Variance of total sugar in grape must in the two HZ and the 3 years. LEC2 have significant higher sugar only in the optimal and drier summer (2012). LEC1 showed very low sugar content in the wettest vintage (2014).

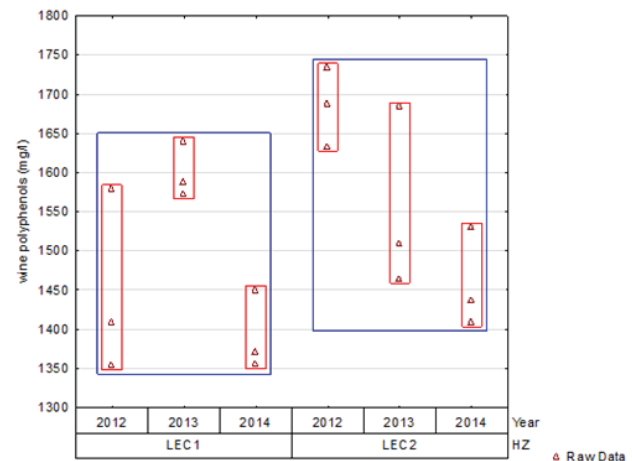


Figure 13: Variance of total polyphenols in wine in the two HZ and the 3 years. LEC2 have significant higher polyphenols in the optimal and drier summer (2012).

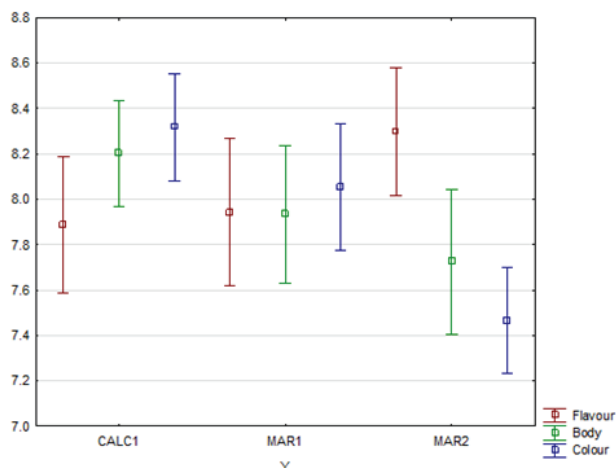


Figure 14 Analysis of the tasting scores (means of 10 wine tasters, for all the three vintages). CALC1 showed the higher scores regarding “Colour” and “Body” (structure) of the wine. MAR2 showed the highest scores regarding “Flavour”, but the lowest scores of “Colour” and “Body”.

#### FOR FURTHER DETAILS:

Mocali, S., Kuramae, E. E., Kowalchuk, G. A., Fornasier, F., & Priori, S. (2020). Microbial functional diversity in vineyard soils: sulfur metabolism and links with grapevine plants and wine quality. *Frontiers in Environmental Science*.



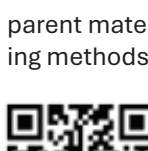
Priori, S., Pellegrini, S., Perria, R., Puccioni, S., Storchi, P., Valboa, G., & Costantini, E. A. (2019). Scale effect of terroir under three contrasting vintages in the Chianti Classico area (Tuscany, Italy). *Geoderma*, 334, 99-112.



Braschi, E., Marchionni, S., Priori, S., ..... Conticelli, S. (2018). Tracing the  $^{87}\text{Sr}/^{86}\text{Sr}$  from rocks and soils to vine and wine: An experimental study on geologic and pedologic characterisation of vineyards using radiogenic isotope of heavy elements. *Sci. of the Total Environment*, 628–629, 1317–1327.



Priori, S., Bianconi, N., & Costantini, E. A. (2014). Can  $\gamma$ -radiometrics predict soil textural data and stoniness in different parent materials? A comparison of two machine-learning methods. *Geoderma*, 226, 354-364.



Costantini, E. A. C., Agnelli, A., Bucelli, P., Ciambotti, A., Dell’Oro, V., Natarelli, L., Pellegrini S., Perria R., Priori S., Storchi P., Tsolakis, C., Vignozzi N. (2013). Unexpected relationships between  $\delta^{13}\text{C}$  and wine grape performance in organic farming. *OENO One*, 47(4), 269-285



Priori S., Barbetti R., L’Abate G., Bucelli P., Storchi P., Costantini E.A.C. (2014). Natural terroir units, Siena province, Tuscany. *Journal of Maps*, 10(3), 466-477



Priori S., Martini E., Andrenelli M.C., Magini S., Agnelli A.E., Bucelli P., Biagi M., Pellegrini S., Costantini E.A.C. (2013). Improving wine quality through harvest zoning and combined use of remote and soil proximal sensing. *Soil Science Society of American Journal*, 77(4), 1338-1348.



Martini E., Comina C., Priori S., Costantini E.A.C. (2013). A combined geophysical-pedological approach for precision viticulture in the Chianti hills. *Bollettino di Geofisica Teorica e Applicata*, 54(2), 165-181.



## DAY 2: Sagrantino di Montefalco wine district

### History and culture

The cultivation of vines in Montefalco dates back to Roman times. Plinio the Elder tells in his book *Natural History* (77 A.D.) of a particularly fine wine made from the “Itriola” grape grown in this area. Moreover, the cultivation of vines and the production of wine in the district of Montefalco are attested by many documents dated between the 11th and 15th centuries where it is possible to find clues (sales, donations, sharecropping contracts, etc.) about the relevance of vineyard cultivation in this area. Even as early as the 1400s, were promulgated laws (statutes) which described in every detail the activity of growing vines, the time of harvest, the sale and processing of grapes, and the sale of wine. Other documents point out that during the 1500s the wine trade in Montefalco was a fine art (“exercere et traficare in arte vini”) and that this product was much sought after and object of gifts to famous people, such as cardinals and even the Pope.

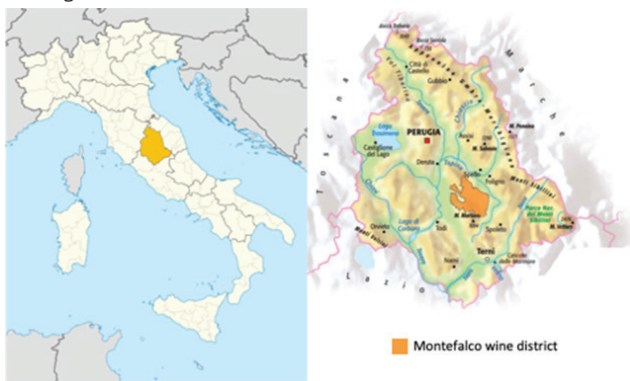
The Montefalco district is characterized by wine production of the highest quality. The most representative wine is Sagrantino, which is made from an indigenous grape that is very rich in polyphenols and tannins, which give it great structure, extraordinary longevity and an original bouquet. However, before being consumed, Montefalco Sagrantino requires a long period of aging, 37 months, including 12 months in wooden barrels and then 25 months in the bottle.

The origins of the Sagrantino vine are still debated. One hypothesis links it to the “itriola” vine mentioned by Plinio the Elder, one theory considers it to have originated in Greece and been imported in the Middle Ages by Byzantine monks. According to others, the grape was brought around 1400 by Franciscan monks returning from Asia Minor, and used to make a raisin wine (passito) that was destined for religious rituals, hence the name Sagrantino.

The Sagrantino di Montefalco, which received DOC (Controlled Denomination of Origin) and DCG (Con-

trolled and Guaranteed Denomination of Origin) recognitions in 1979 and 1992, respectively, is perfect in pairing with Umbrian gastronomy, from salumi to roasts, first courses and dessert. The area also produces another excellent red wine, Rosso di Montefalco, made from 60-70 % Sangiovese grapes, 10-15 % Sagrantino grapes and other nonaromatic red grapes, and a white wine (Grechetto) that is particularly popular as an aperitif.

Figure 15 Montefalco wine district, located in the middle of the Umbria region.



### **Climature and topography**

The town of Montefalco, surrounded by vineyards and olive groves, is situated atop a hill overlooking the plain of the Topino and Clitunno rivers. Because of this favorable panoramic position, on clear days it is possible to admire a 360-degree panorama that ranges across the entire valley between Perugia and Spoleto, from the sub-Apennine chain to the Martani Mountains. The geographical area of Sagrantino di Montefalco falls in the province of Perugia, in the center of Umbria, and embraces the entire municipality of Montefalco and part of the municipalities of Bevagna, Giano dell'Umbria, Gualdo Cattaneo and Castel Ritaldi. It is a very small area (approx. 600 ha), with land that slopes gently along the contours of the hills and with altitudes ranging from 220 m to 472 m above sea level. The slope and general exposure of the vineyards is variable, so that a wide range of microclimates and growing conditions are possible.

The average temperature in Montefalco district is 18°C, with January the coldest month (+3.8°C) and July the warmest month (+23.5°C). Average annual precipitation is around 700 mm, distributed over about 90 days, with a relative minimum in summer and a peak in autumn. Snow is not uncommon, and sometimes accumulations are also quite substantial. On average there are 40 days a year when temperatures go below zero.

### **Geological and pedological setting**

The Umbra Valley is a wide alluvial plain that extends in a N-NW to S-SE direction from Perugia to Spoleto, and is bounded on the east by the Apennine chain and on the west by the Martani Mountains. In ancient times, the Umbra valley was occupied by the Tiberine lake, a saltwater lake up to 1,000 m deep, which formed

during the Pliocene, reached its maximum extent about 1,500,000 years ago, and disappeared about 400,000 years ago. The actual Trasimeno lake (northwest of Perugia) was, at the time, a part of Tiberine lake. Given the large size of Tiberine lake (120 km in length and a maximum width of 30 km) and its evolution over time, sediment deposits are variable in both thickness and particle size characteristics. In particular, the area of Montefalco district, which occupies the southernmost part of the valley, is characterized by different types of fluvio-lacustrine sediments: conglomerates, clays and sands, alluvium, and marls.

The soils that develop on these substrates are generally Inceptisols and Entisols or Cambisols and Regosols for the Soil Taxonomy and WRB, respectively.

### **STOP 1: Arnaldo Caprai winery (Montefalco, PG) "In the heart of the Sagrantino di Montefalco terroir"**



Figure 16: Soil profile in a vineyard at the Arnaldo Caprai winery.

Position: 42°55'15" N, 12°38'20" E  
 Exposure N, Slope 15, Elevation: 252 m a.s.l.  
 Parent material: fluvial-lacustrine sediments (Plio-Pleistocene)  
 Soil: fine silty, mixed, mesic, Typic Haplustept (Soil Survey Staff, 2014) / eutric calcare Cambisol (loamic) (IUSS Working Group WRB, 2022)  
 Wine grape variety: Sangiovese

Horizon	Depth (cm)	Colour <sup>a</sup>	Structure <sup>b</sup>	Consistence <sup>c</sup>	Roots <sup>d</sup>	Skeleton <sup>e</sup>	Boundaries <sup>f</sup>	Thickness (cm)	Notes
Ap1	0-11	2.5Y5/4	2f abk	(m)fr, (w)so, p	(h)3v f, f	<1% f	CW	8-11	It may have been produced by surface tillage
Ap2	11-20	2.5Y6/4	2f abk	(m)fr, (w)so, ps	(h)2f, m	<1% f	AW	4-9	
Ap3	20-31	2.5Y6/2	2m abk	(m)fr, (w)so, ps	(v)1f, m	<1% f	CW	7-11	It could be the lower limit of the deep tillage Roots concentrate along the lines of discontinuity between peds
Bw1	31-44	2.5Y6/4	1m abk	(m)fr, (w)ss, p	(v)2v f, f, m	<1% f	CS	-	
Bw2	44-70	2.5Y5/4	1-2m abk	(m)fr, (w)ss, vp	(v)2f, m, co m	<1% f	CS	-	Roots concentrate along the lines of discontinuity between peds
BC	70-93+	2.5Y5/2	1-2m abk	(m)fr, (w)so, ps	(v)2f, m, co m	<1% f	-	-	

Table 3. Morphological descriptions of the vineyard soil from Caprai Farm, Montefalco (PG). Codes according to Schoeneberger et al. (2012).

a According to the Munsell Soil Color Chart; b 1=weak, 2=moderate, f=fine, m=medium, abk=angular blocky; c m=moist, fi=firm, fr=friable, w=wet, so=nonsticky, ss=slightly sticky, ps=slightly plastic, p=mod. plastic, vp=very plastic; d h=herbaceous, v=vine, 1=few, 2=common, 3=many, vf=very fine, f=fine, m=medium, co=coarse; e Abundance estimated by sight, vf=very fine gravels, f=fine gravels, m=medium gravels, c=coarse gravels; f C=clear, S=smooth, W=wavy, A=abrupt.

Table 3. Particle size distribution, textural class, content of CaCO<sub>3</sub> and pH of the vineyard soil from Caprai Farm, Montefalco (PG).

Horizon	Sand <sup>a</sup>			Silt <sup>b</sup>		Clay	Textural class <sup>c</sup>	CaCO <sub>3</sub>	pH
	coarse	medium	fine	coarse	fine				
Ap1	1.7	1.7	14.3	7.8	43.5	31.0	SICL	22.5	7.9
Ap2	1.1	0.8	10.6	18.1	36.7	32.6	SICL	23.0	8.1
Ap3	0.8	0.6	9.1	3.6	51.4	34.5	SICL	24.8	8.1
Bw1	0.8	0.4	3.2	11.1	50.6	33.9	SICL	27.1	8.3
Bw2	0.1	0.1	0.7	2.6	39.0	57.5	SIC	23.8	8.4
BC	0.4	0.2	1.6	3.4	46.7	47.6	SIC	27.0	8.4

<sup>a</sup> coarse sand 2-0.5 mm, medium sand: 0.5-0.25 mm, fine sand 0.25-0.05 mm; <sup>b</sup> coarse silt: 0.05-0.02 mm, fine silt: 0.02-0.002 mm; <sup>c</sup> SICL=silty clay loam, SIC=silty clay

Table 4. Chemical properties of the vineyard soil from Caprai Farm, Montefalco (PG).

Horizon	Organic C	Total N	Available P	Exchangeable cations				
				K	Na	Ca	Mg	Σ
	g kg <sup>-1</sup>	g kg <sup>-1</sup>	mg kg <sup>-1</sup>	cmol(+) kg <sup>-1</sup>				
Ap1	13.9	1.4	32.1	0.5	0.3	14.1	2.4	17.4
Ap2	4.5	0.8	33.0	0.3	0.4	12.8	2.5	15.9
Ap3	3.6	0.8	49.8	0.2	0.3	9.8	2.6	13.0
Bw1	4.1	0.8	2.7	0.3	0.4	18.9	1.8	21.4
Bw2	2.0	0.7	0.6	0.4	0.6	13.3	7.5	21.9
BC	1.7	0.6	9.3	0.3	0.9	10.6	6.6	18.4

Table 5. Mineralogical composition of the vineyard soil from Caprai Farm, Montefalco (PG). Semiquantitative estimation.

	C	D	Q	Pl	Kao	M	Z
Ap1	++++	+	+(+)	+	tr	(+)	+
Ap2	+++(+)	(+)	+	+	tr	+	++
Ap3	+++	(+)	(+)	++++	tr	(+)	+(+)
Bw1	++++	+	+	+	(+)	+	+(+)
Bw2	++++	+	+	(-)	(-)	(-)	+(+)
BC	+++(+)	+	+	+	(+)	+	++

C=calcite, D=dolomite, Q=quartz, Pl=plagioclases, Kao=kaolinite, M=micas, Z=Zn minerals  
 += about 10%, (+)=about 5%, tr=traces

**“An example of organic viticulture”  
 STOP 2: Di Filippo winery (Cannara, PG)**



Figure 17: Soil profile in a vineyard at the Di Filippo winery.

Position: 42°59'19" N, 12°32'49" E  
 Exposure SE, Slope 7%, Elevation: 269 m a.s.l.  
 Parent material: fluvial-lacustrine sediments (Plio-Pleistocene)  
 Soil: fine silty, mixed, mesic, Typic Haplustept (Soil Survey Staff, 2014) / eutric calcare Cambisol (loamic) (IUSS Working Group WRB, 2022)  
 Wine grape variety: Grechetto

Table 5. Morphological descriptions of the vineyard soil from Di Filippo farm, Cannara (PG). Codes according to Schoeneberger et al. (2012).

Horizon	Depth (cm)	Colour <sup>a</sup>	Structure <sup>b</sup>	Consistence <sup>c</sup>	Roots <sup>d</sup>	Skeleton	Boundary <sup>f</sup>	Thickness
(cm)	Notes							
Ap1	0-8	2.5Y6/4	2f, vf sbk	(m)fr, (w)so, p	(h)3vf, f <1% f	CS	-	Biological activity (ants)
Ap2	8-25	2.5Y5/4	2m sbk	(m)fi, (w)so, p	(h)2vf, f <1% f	CS	-	
Bw	25-37	2.5Y5/4	2m sbk	(m)fi, (w)so, ps	(v)1f, m 1-2% f	CW	9-13	7.5YR5/6 mottles (5%) and few carbonate concretions
BC1	37-57	2.5Y5/4	1m sbk	(m)fi, (w)so, ps	(v)2f, 1m 5% f	CS	-	10YR6/6 mottles (5%); carbonate concretions (10%)
BC2	57-72	2.5Y5/3	2m sbk	(m)vfi, (w)so, ps	(v)1f, m 2% f. m	CS	-	10YR6/6 mottles (5%) and carbonate concretions (10%); root residues among peds
Ck	72-85+	2.5Y6/3	1m sbk	(m)vfi, (w)so, ps	(v)1f 5% f. m	-	-	10YR6/6 mottles (8%) and carbonate concretions (15%); root residues among peds

a According to the Munsell Soil Color Chart, b 1=weak, 2=moderate, vf= very fine, f=fine, m=medium, sbk=angular blocky, abk= angular blocky; c m=moist, fr= friable, fi=firm, vfi= very firm, w=wet, so=nonsticky, ps= slightly plastic, p=mod. plastic; d h= herbaceous, v=vine, 1=few, 2=common, 3=many, vf=very fine, f=fine, m= medium; e Abundance estimated by sight, f=fine gravels, m=medium gravels; f C=clear, S=smooth, W=wavy.

Table 6. Particle size distribution, textural class, content of CaCO<sub>3</sub> and pH of the vineyard soil from Di Filippo farm, Cannara (PG).

Horizon	Sand <sup>a</sup>		Silt %	Clay	Textural class <sup>b</sup>	CaCO <sub>3</sub> %	pH
	coarse	fine					
Ap1	2.2	16.4	54.9	26.5	SIL	14.0	8.0
Ap2	1.6	15.2	52.5	30.7	SICL	19.0	8.2
Bw	1.6	12.6	46.8	39.0	SICL	17.5	8.3
BC1	3.7	15.9	44.0	36.4	SICL	17.4	8.3
BC2	5.6	15.0	42.5	36.9	CL	15.5	8.3
Ck	2.5	12.0	47.6	37.9	SICL	22.0	8.4

<sup>a</sup> coarse sand 2-0.25 mm, fine sand 0.25-0.05 mm;

<sup>b</sup> SIL=silt loam, SICL=silty clay loam, CL= clay loam

Table 7. Chemical properties of the vineyard soil from Di Filippo farm, Cannara (PG).

Horizon	Organic C	Total N	Exchangeable cations*					Plant available micronutrients**			
			K	Na	Ca	Mg	Σ	Fe	Mn	Cu	Zn
	g kg <sup>-1</sup>	g kg <sup>-1</sup>	cmol(+) kg <sup>-1</sup>					mg kg <sup>-1</sup>			
Ap1	12.1	1.5	0.5	0.9	14.2	3.4	19.0	5.4	7.3	7.5	0.5
Ap2	6.2	1.0	0.4	1.0	15.4	4.5	21.3	5.1	7.1	3.4	2.0
Bw	4.2	0.8	0.4	0.9	10.2	5.2	16.7	10.8	8.2	4.2	0.8
BC1	3.6	0.6	0.3	1.1	12.1	8.9	22.4	6.0	5.0	1.3	0.9
BC2	3.7	0.7	0.5	0.9	17.3	8.0	26.7	5.3	4.0	0.9	0.7
Ck	2.5	0.7	0.4	0.6	12.6	6.0	19.6	6.8	4.5	0.7	0.7

\*Extracted by NH<sub>4</sub> acetate

\*\*Extracted by DTPA

**Table 8.** Mineralogical composition of the vineyard soil from Di Filippo Farm, Cannara (PG). Semi-quantitative estimation.

	C	Q	PL	ILL	SME	VER	INT. ILL/SME	+2:1 INT
Ap1	+++	+++	+	(+)	+	(+)	(+)	(+)
Ap2	+++	+++	+	(+)	(+)	+	(+)	(+)
Bw	+++(+)	++	+	(+)	+(+)	(+)	(+)	(+)
BC1	+++(+)	++	(+)	(+)	+(+)	(+)	+	(+)
BC2	++++	++	(+)	(+)	+	(+)	+	(+)
Ck	++++	++	(+)	(+)	+	(+)	+	(+)

C=calcite, Q=quartz, PL=plagioclases, ILL=illite, SME=smectite, VER=vermiculite, INT ILL/SME=interstratified illite/smectite, +2:1 INT = other 2:1 interstratified minerals  
+ = about 10%, (+) = about 5%

**FOR FURTHER DETAILS:**

Massaccesi, L., Cartoni Mancinelli, A., Mattioli, S., De Feudis, M., Castellini, C., Dal Bosco, A., ... & Agnelli, A. (2019). Geese reared in vineyard: soil, grass and animals interaction. *Animals*, 9(4), 179.

**DAY 3: Wines of volcanic region of Campania****History and Culture**

The Campania region preserves ancient and valuable vines, which are the basis of a highly typical oenology and are increasingly appreciated worldwide. The regional territory is one of the oldest vine settlement centers, and even today, in the context of international viticulture, it is characterized by the presence of centenary strains in many vineyards. The wines praised in ancient times by Cicero, Pliny, Martial, and Virgil, such as *Vitis Hellenica*, *Vitis Apiana*, *Vinum Album Phalanginum*, and *Aminea Gemina*, just to name a few, are none other than the progenitors of Aglianico, Fiano, Falanghina, and Greco.

The union between vine and territory is also demonstrated by the precious archaeological finds that document the excellent quality of the local wines, not surprisingly known in ancient times as the “wines of the emperors.” The frescoes of the ancient villas of the excavations of Pompeii and Herculaneum and the deposits of amphorae illustrate how wine was already stored in cellars and even labeled, offering tangible proof of the centuries-old tradition of the “cult of wine” in Campania.

Regional enology is currently characterized by the enormous varietal richness of the vines grown in the area. In fact, in Campania there are over 100 native vines: a number that has no equal in any of the wine-growing areas of the world. The originality of the regional wines, with highly recognizable aromatic profiles, is due precisely to the thoughtful choice by the local actors to protect and encourage the local vines over time. Over

the past twenty years, while all the wine-growing regions of the world were focusing their attention on “international” vines, Campania has discouraged, and in some cases prohibited, the planting of vineyards with international vines, focusing instead on indigenous varieties.

Its most important variety is arguably Aglianico, the grape behind the region’s two most famous and respected red wines: Taurasi and Aglianico del Taburno. Aglianico was introduced to the area by the Greeks and later cultivated by the Romans.

Also vital to Campania’s vineyards are the white-wine varieties Fiano and Greco, which are championed by the region’s most respected white wines, Fiano di Avellino and Greco di Tufo. Fiano has been used here for more than 2000 years. Its original name was *Vitis apiana* (Latin for “vine of the bees”) but this has become shortened almost beyond recognition over the intervening centuries. Greco’s name is a little more obvious and indicates its Greek origins.

Another light-skinned grape of interest here is Falanghina, which forms the backbone of Falerno del Massico and Galluccio wines. The honeyed sweetness of Falanghina wines gained the variety of praise from the ancient writer and philosopher Pliny the Elder, who is credited by some as being the creator of the phrase “in vino veritas” (there is truth in wine).

Alongside the more important varieties mentioned above are a host of little-known gems. These include Biancolella and Forastera, which together form the backbone of the white wines of Ischia. Suppezza, Sabato, and Sciascinoso (locally called Olivella because of their olive-shaped grapes and used in blends to bring a hint of color and acidity to wine) also play their part, particularly in wines from the Sorrento Peninsula.

Along the Amalfi coast, the aromatic and orange blossom-infused Ravello and Furore wines are distinctive for the inclusion of interesting local Fenile, Ripolo, Peppella and Ginestra grapes. In the Aversa plains, the Asprinio variety, producing a dry white or zesty sparkling wine, gives the DOC Asprinio di Aversa its name. Finally,

the Coda di Volpe vine, named for its resemblance to a fox's tail due to the way the grapes grow in long bunches, also plays a role alongside Verdeca, Greco di Bianca, and Falanghina in the Lacryma Christi del Vesuvio whites.

Campania's success owes much to the varied climates and terroir. Viticulture is in its element thanks to an abundance of sunshine, dry, hot summers, mild winters, a long growing season, and volcanic soil (the latter ensured phylloxera was kept at bay). The coastal Mediterranean breezes blow in from the Tyrrhenian Sea and across the Apennine Mountains to temper the heat, encouraging a bright acidity in the fruit.

Campania is well-suited to the production of high-quality wine. Its abundant sunshine, dry and hot summers (with coastal Mediterranean breezes tempering the heat), mild winters, mountainous areas (allows planting at higher elevations), volcanic soil, and lengthy growing season add up to a growing environment that is a winemakers dream.

Currently, the region hosts around 100,000 acres (46,800 ha) of vines distributed inside a quartet of DOCGs: Aglianico del Taburno and Taurasi for red wines, plus Fiano di Avellino and Greco di Tufo for whites. There are also 15 DOCs and 10 IGPs, including the region-wide designation (Fig. 18).

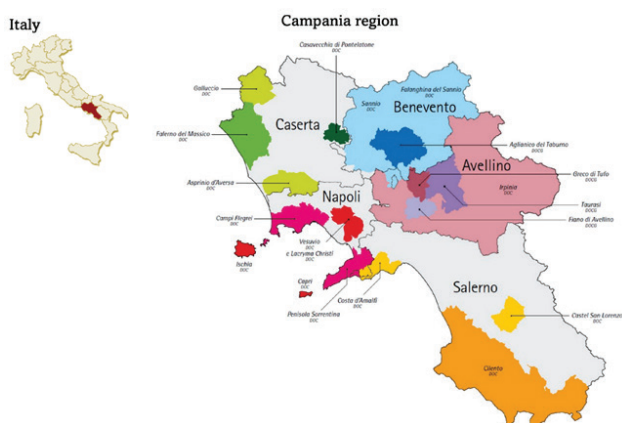


Figure 18. Map of the distribution of the DOCG and DOC wine-growing areas in Campania region.

### **Galluccio Wine District**

Nestled amidst the verdant hills of the Caserta province, bordering Lazio, the Galluccio wine district proudly unveils a rich tapestry of viticultural heritage, its roots deeply embedded in the annals of ancient Rome. Renowned for its exquisite production of red, white, and rosé wines, Galluccio rightfully earned its DOC designation in 1997, a testament to its exceptional terroir and the unwavering dedication of its passionate winemakers. The district's viticultural prowess extends across the municipalities of Conca della Campania, Galluccio, Mignano Monte Lungo, Rocca d'Evandro, and Tora e Piccilli, all cradled within the embrace of the Caserta province. Vineyards gracefully adorn the gentle slopes and undulating hillocks, basking in the radiant Mediterranean sunshine and drawing sustenance from the fertile volcanic soils that define the landscape. The

Galluccio wine district stands as a microcosm of Campania's viticultural tapestry, where time-honored traditions seamlessly intertwine with innovative viticultural practices, giving rise to wines that are both expressive of their terroir and captivating to the palate.

### **Climate and Topography**

The Galluccio wine district basks in the embrace of a Mediterranean climate, characterized by warm, sun-kissed summers that give way to mild, gentle winters. This climatic pattern, in harmonious concert with the influence of the nearby Tyrrhenian Sea, orchestrates an ideal environment for the meticulous ripening of grapes. The diurnal temperature variation, the captivating interplay between daytime warmth and nighttime coolness, plays a pivotal role in the development of the grapes' intricate flavors and captivating aromas. The district's topography further enhances its viticultural allure, with vineyards strategically positioned between 200 and 400 meters above sea level. These elevations bestow the land with exceptional drainage, effectively preventing waterlogging and promoting optimal vine health. The gentle slopes and undulating hillocks further favor excellent air circulation, minimizing the risk of vine-afflicting diseases and ensuring even grape ripening across the vineyards.

### **Geology and Pedological Setting: The Foundation of Terroir Excellence**

The geological history of the Galluccio wine district has indelibly shaped its terroir, imbuing it with a unique character that resonates in every sip. The area lies between the Campania Volcanic area and the Roman Magmatic Province being very close to the Roccamonfina volcano, a region that has witnessed intense volcanic activity over eons. This volcanic legacy has resulted in the deposition of rich tufaceous and pumiceous soils, renowned for their exceptional fertility and remarkable water retention capacity. These well-drained soils, meticulously crafted by nature's hand, are underlain by a bedrock of limestone, providing an unwavering support system for the flourishing grapevines. The tufa and pumice generously release essential nutrients, while the limestone imparts a distinctive minerality and refreshing finesse to the wines. The pedological setting of the Galluccio wine district, therefore, plays a paramount role in shaping the distinctive character and elegance that are the hallmarks of Galluccio wines. To fully appreciate the influence of geology and pedology on the Galluccio terroir, it is essential to delve deeper into the intricate composition of the soils. The tufaceous soils, derived from volcanic ash, are particularly rich in pumice, a lightweight rock characterized by its porous, sponge-like structure. This unique structure promotes excellent drainage, preventing waterlogging and ensuring optimal aeration for the vine roots. Furthermore, the tufaceous soils are enriched with a plethora of minerals, including potassium, magnesium, and iron, all essential for the healthy development of grapevines. These minerals contribute to the wines' complexity and

balance, imparting a symphony of flavors and aromas that are distinctly Galluccio. The underlying limestone bedrock, a sedimentary rock composed primarily of calcium carbonate, plays a crucial role in shaping the wines and their freshness. Limestone's alkaline nature buffers the soil's acidity, creating an environment conducive to the expression of the grapes' varietal character. Moreover, limestone imparts a distinct minerality to the wines, adding a refreshing edge that lingers on the palate. The harmonious interplay between these geological and pedological elements has given rise to a terroir that is uniquely suited for the cultivation of a diverse range of grape varieties, including Aglianico and Falanghina of Sannio. These grapes thrive in this environment, producing elegant and expressive wines, epitomizing the essence of Galluccio's viticultural heritage. The Galluccio DOC area extends north of the Roccamonfina volcano for an area of approximately 17,300 ha (approximately 400 ha under vines). The principal land systems where viticulture develops are the high and mid slopes of the Roccamonfina volcano caldera (F1) and the Roccamonfina foothill plain (G2) (Fig.2). The main soils are Andosols (Vitric Andosols, Molli-Vitric Andosols, Vitric Andosols (Endoleptic)), Luvisols (Ferri-Andic Luvisols, Cutanic Luvisols), and Cambisols (Calcaric Cambisols, Calcari-Vertic Cambisols, Haplic Cambisols). In the "Galluccio" controlled designation of origin area, the following wine is realized: "Galluccio White," "Galluccio red and red reserve," and "Galluccio rosé."

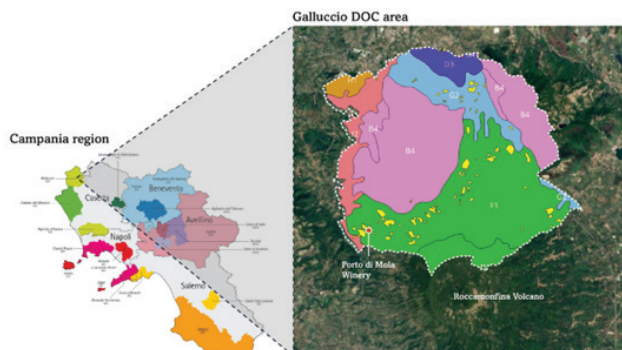
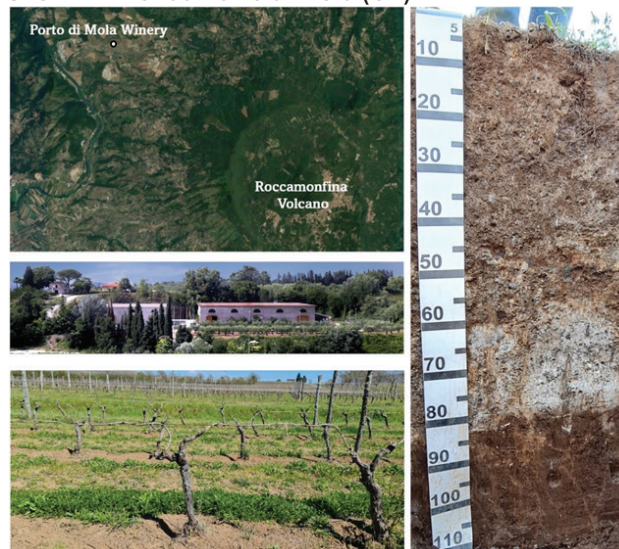


Figure 19. Galluccio landscape sub-systems: F1 = High slopes and caldera of the Roccamonfina volcano / Middle and lower slopes of the Roccamonfina volcano; G2 = Roccamonfina foothill plain; B4 = Central-northern pre-Apennine reliefs, moderate energy, with pyroclastic covers; H1 = Alluvial terraces of the upper and middle course of the Volturno River and the Apennine rivers; I2 = Valley floor and alluvial plain of the Garigliano river; D3 = Low energy relief limestone hill; B4 = Low slopes of the pre-Apennine mountains on gray tuff from Campania and slope deposits. (Di Gennaro, 2002).

**"Soil science applied to precision viticulture"**

**STOP 1: Azienda Porto di Mola (CE)**



Position: 41°19'58.52" N, 13°54'02.66" E  
 Exposure S-E, Slope 0, Elevation: 160 m a.s.l.  
 Parent material: volcanic falling ash  
 Soil: Vitric Andosols (IUSS Working Group WRB, 2022)  
 Wine grape variety: Aglianico, Cabernet sauvignon

Horizon	Depth (cm)	Colour <sup>a</sup>	Structure <sup>b</sup>	Consistence <sup>c</sup>	Roots <sup>d</sup>	Gravel <sup>f</sup>	Boundary <sup>e</sup>	Notes
Ap	0-50	7.5 YR 4/3	3m sbk	(m)vf, (w)ms, p	(h,v) 3vf, fm	7% m,c	SGS	
CB	50-80	10 YR 8/1	1fm ma/sbk	(m) f, (w)ss, ps	(v)1 f, m	15% m,c	SCA	presence of shards of anthropic artifacts
Ab	80- 110+	5YR 4/4	2m abk	(m) f, (w)ms, p	(v)1f, m	<1% f	-	presence of nodules and concretions of Fe-Aln

Table 1. Morphological descriptions of the vineyard soil Porto di Mola (CE). Codes according to Schoeneberger et al. (2012).

a According to the Munsell Soil Color Chart; b 1=weak, 2=moderate, 3=strong f=fine, m=medium, abk=angular blocky, sbk= sub angular blocky; ma= massive; c m=moist, vf=very firm, fi= firm, fr= friable, w=wet, so=nonsticky, ss= slightly sticky, ms=moderately sticky, ps= slightly plastic, p=mod. plastic; d h= herbaceous, v=vine, 1=few, 2=common, 3=many, vf=very fine gravels, f=fine gravels, m= medium gravels, c=coarse gravels; f C=clear, S=smooth, G= Gradual, A=abrupt.

Table 2. Soil characteristics

Soil horizon and thickness (cm)	Particle size fraction			Textural class	OM	N Tot.	Limestone Tot.	C/N	pH (H2O)	pH (KCl)	pH (NaF)	CEC	ECe	
	Clay	Silty	Sand											
Ap	0-50	22.5	21.1	56.4	SCL	1.1	0.08	0.17	8.3	7.0	4.8	8.7	16.9	0.05
CB	50-80	35.6	21.2	43.2	CL	0.1	0.01	-	4.6	7.4	4.9	8.7	15.6	0.04
Ab	80-110+	47.3	23.4	29.3	C	0.4	0.03	0.303	7.4	6.7	5.3	8.9	21.8	0.05

SCL=Sandy Clay Loam; CL=Clay Loam; C= Clay.

**“Climate change and terroir”****STOP 2: Valle Telesina wine district**

Valle Telesina wine district (Sannio DOC)

The province of Benevento is distinguished by the vast area of Sannio, home to those Samnites who have given the Romans a hard time. The area of Benevento is famous for the production of Sannio Doc, a designation of origin including red, white, and rosé wines that use the varieties traditionally grown in the area, such as Aglianico, Coda di Volpe, Falanghina, Fiano, Greco, Moscato Bianco, Piediroso and Sciascinoso. Another important denomination in the area is Aglianico del Taburno Docg, the pride of the Sannio hills.

The Valle Telesina area, about 20,000 ha (about 7000 ha under vines, Fig.3), is part of the Benevento province traditionally suited to the production of high-quality wine and olive oil (Bonfante et al., 2011; Terribile et al., 2017) in the hilly areas, while beech and chestnut forests are present in the mountain system, where there is a natural park.

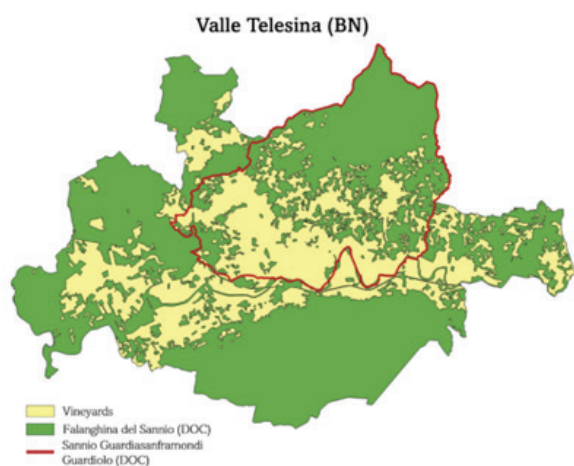


Figure 20 Spatial distribution of vineyards within the Valle Telesina and the two principal DOC areas (Falanghina del Sannio and Guardicelo).

**Climate and topography**

The Valle Telesina includes the portion of the middle valley of the Calore River delimited to the south by the Taburno-Camposauo massif and to the north-east and north-west respectively by the minor mountain ranges Mt. Croce-Mt. Ciesco and Colle Sella.

It falls within the municipalities of Amorosi, Teleso, S.Salvatore, S.Lorenzello, Guardia Sanframondi, Solopaca, S.Lorenzo Maggiore, S.Lupo, Ponte, Paupisi and, in part, Vitulano.

The minimum elevations are located in correspondence with the beds of the main watercourses; in particular, the Calore River flows at an altitude of 35 m above sea level. In the area where it flows into the Volturno and reaches 95 m above sea level. In Ponte. The lower energy mountain ranges have maximum altitudes distributed as follows: 807 m above sea level Monte Croce, 893 m above sea level in Monte Ciesco, 957 m above sea level in Colle Sella; the dominant relief in the area is the Camposauo massif which rises up to an altitude

of 1390 m above sea level.

The climatic conditions of the Telesina Valley are similar to the temperate-warm climate typical of the Mediterranean regions. Rainfall is distributed more in the autumn-winter period (approximately 2/3); the month of July until the first ten days of August is characterized by an almost total absence of precipitation. On average, there is an annual rainfall of about 1100 mm.

Morning fogs are frequent in spring and autumn, especially in the areas located near the Volturno and Calore rivers. The average annual temperature is 16.4°C; the hottest month is July, with an average of 26.3°C, and the coldest is January (7°C).

In recent years, the effects of changes have modified seasonal trends, increasing intra-annual variability and the presence of extreme thermal and rainfall events. According to a study conducted by Bonfante et al. in 2018, the impact of climate change on viticulture in Valle Telesina has resulted in a temperature increase of approximately one to two degrees Celsius every 30 years from the present day to the year 2100. This increase is observed in the RCP 4.5 and 8.5 scenarios. Regarding the extreme temperature events during the growing season, the probability of temperatures below -2.5°C increases by 2% for RCP 4.5 and 1% for RCP8.5. The increase of extreme events with temperature exceeding 35°C will be 2% and 5% in the RCP 4.5 and 8.5, respectively. In both future scenarios, most of the extreme events (65%) related to high temperature, occurring mostly in the 2070-2100 time period.

The vine growing season will experience an increase in intensive rainfall events, leading to a higher risk of phytopathological attacks or hailstorms compared to the reference period.

The thermal suitability for vine cultivation in the Valle Telesina has been evaluated in recent years using the Amerine and Winkler index through the study of the temperature data detected by the meteorological stations present in the Valle Telesina (Fig. 21) and through the study of the scenarios of IPCC climate change RCP 4.5 and 8.5, compared to the reference climate -RC (Fig. 22, 23).

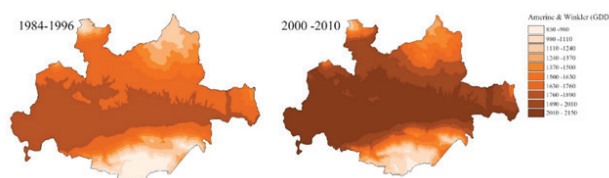


Figure 21 Spatial distribution of the average Amerine and Winkler index (GDD) for the periods of 1984-1996 and 2000-2010 within Valle Telesina.

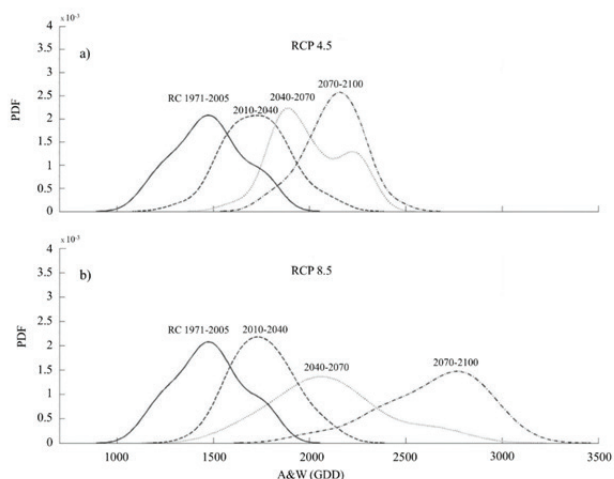


Figure 22 Probability Density Function (PDF) of the A&W index in the analyzed climate scenarios RC (1971-2005), RCP 4.5 (a) and 8.5 (b) and their time periods (2010-2040, 2040-2070, 2070-2100).

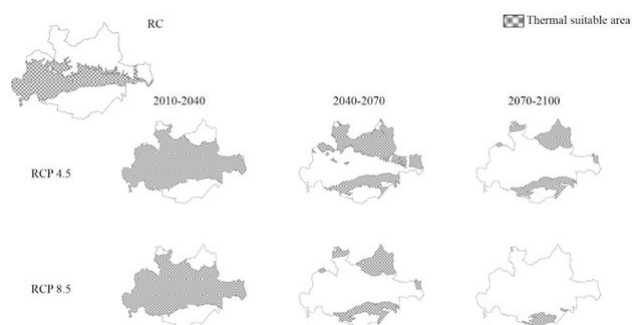


Figure 23 Maps of the suitable thermal area of Valle Telesina as expected for the reference climate (RC) and the two climate scenarios analysed, RCP 4.5 and 8.5, and the three time periods (2010-2040, 2040-2070 and 2070-2100).

**Geological and pedological setting**

Valle Telesina is an area of about 20,000 ha and encompasses 13 municipalities, with a very complex landscape with high soil spatial variability. It has a composite geomorphology and an elongated east-west graben where the Calore River lies. Five different landscape systems are present (Fig. 24, 25): (i) limestone mountains, with volcanic ash deposits at the surface; (ii) hills, comprised of marl arenaceous flysch; (iii) a pediment plain, comprised of colluvium material from the slope fan of the limestone reliefs; (iv) ancient alluvial terraces; and (v) the actual alluvial plain. Such complexity is echoed in the 60 STUs, the main soil types include Silandic, Melanic, Mollic, Eutrosilic, Vitric Andosols, Haplic and Vertic Calcisols, Vertic Lepitic Cambisol, Haplic Regosol, Vitric Phaeozem, Vitric Luvisol, Calcic Kastanozem, Vitric Kastanozem, Fluvisol Cambisol. Soil Types are spatially aggregated into 47 soil mapping units (Terribile et al., 2015)

Figure 24. Map of Valle Telesina landscape systems.

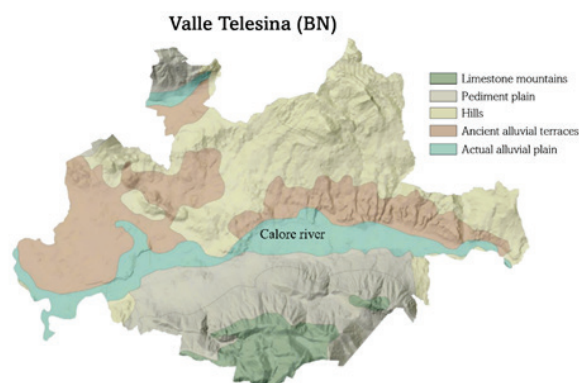


Figure 25. Map of Valle Telesina landscape sub-systems: I1= Alluvial valley floors of the Volturno river and the Apennine rivers; H1 = Alluvial terraces of the upper and middle course of the Volturno river and the Apennine rivers; A1 = Karst plateaus of the high limestone mountains with ash fall deposits/ Summits and slopes of the high limestone mountain with deposits from ashfall; B1 = Internal limestone reliefs with deposits from ashfall/ Low slopes of internal limestone reliefs with deposits from ashfall; D3 = Low energy relief limestone hill/ Marly-limestone and marly-arenaceous hill of Irpina and Sannio with strips of pyroclastic covers at various degrees of continuity/ Low energy relief sandstone hill; D1 = Clayey hill of upper Sannio and upper Irpinia, with soils with strong vertical properties; C1 = Marly-limestone mountain reliefs of the upper Tammaro-Tirerno.

Five main terroir systems have been identified in the Valle Telesina (Table 1 from Bonfante et al., 2011), where the resilience to climate change of the terroir concept was analyzed in 2018 by Bonfante et al. through a hybrid land evaluation approach based on the use of the SWAP agro-hydrological model (Kroes et al., 2008).

110 A. Bonfante et al. / Geoderma 167-168 (2011) 103-117

**Table 1**  
The main environmental features of the five terroir systems of "Valle Telesina". Abbr.: PTU: preliminary terroir unit; O.M.: organic matter.

Terroir systems	PTU (no. of units)	Surface (%)	Elevation* (m a.s.l.)	Slope* (%)	Main parent material	Main soil types <sup>b</sup>	Texture classes	CaCO <sub>3</sub> tot. (%)	pH <sup>a</sup>	O.M. <sup>a</sup> (%)	CEC <sup>a</sup> (cmol kg <sup>-1</sup> )	AWC (mm)
Mountains	mol/met (2)	27.62	(791 ± 202)	(23 ± 11)	Marl arenaceous flysch, volcanic ash	Silandic Andosol, Melanic Andosol	Loamy clay, loamy sandy	(9 ± 0)	(6 ± 1)	(5 ± 3)	(21 ± 3)	(161 ± 26)
Hills	mar/ter (10)	21.32	(242 ± 94)	(10 ± 6)	Marl arenaceous flysch, volcanic ash, alluvial and colluvial deposits, calcareous deposits	Haplic Calcisol, Vertic Lepitic Cambisol, Haplic Regosol, Vitric Phaeozem	Clay, loamy clay, loamy, loamy silty	(16 ± 10)	(8 ± 1)	(1 ± 1)	(21 ± 10)	(113 ± 53)
Pediment plain	ped (4)	12.32	(163 ± 80)	(10 ± 6)	Alluvial and colluvial deposits and volcanic ash	Vitric Andosol, Vitric Andosol (Clayic), Vitric Luvisol	Loamy sandy, sandy loamy	(5 ± 5)	(7 ± 1)	(2 ± 1)	(23 ± 2)	(120 ± 23)
Ancient fluvial terraces	ter/bec/ter (14)	29.8	(110 ± 46)	(5 ± 5)	Ancient alluvial deposits, gnambrine, marl arenaceous flysch	Mollic Vitric Andosol, Vertic Andosol, Calcic Kastanozem, Vitric Kastanozem, Vertic Calcisol	Clay, loamy clay, loamy	(7 ± 11)	(7 ± 1)	(2 ± 1)	(18 ± 6)	(112 ± 42)
Alluvial plain	pal (2)	8.94	(60 ± 33)	(2 ± 2)	Alluvial deposits	Fluvisol Cambisol	Loamy	(13 ± 7)	(8 ± 0)	(1 ± 1)	(14 ± 5)	(159 ± 20)

<sup>a</sup> Mean value ± standard deviation.  
<sup>b</sup> World Reference Base (WRB, 2006).

**For further information about the Valle Telesina:**



Bonfante A., Basile A., Langella G., Manna P., Terribile F., 2011. A physically oriented approach to analysis and mapping of terroirs. Geoderma Vol. 167-168, November 2011, Pages 103-117. <https://doi.org/10.1016/j.geoderma.2011.08.004>



Bonfante, A., Monaco, E., Langella, G., Mercogliano, P., Bucchignani, E., Manna, P., Terribile, F., 2018. A dynamic viticultural zoning to explore the resilience of terroir concept under climate change. Sci. Total Environ. 624. <https://www.sciencedirect.com/science/article/pii/S004896971733454X>



Prezi presentation of Bonfante et al., 2018

Visit the web site of LANDSUPPORT projet to explore the Valle Telesina through a web-DSS [HYPERLINK http://www.landsupport.eu](http://www.landsupport.eu)

### “Terroirs and wine cooperative”

#### STOP 3: Azienda La Guardiense (BN)

La Guardiense, in the town of Guardia Sanframonde in



the province of Benevento, is a wine cooperative and among the most famous wines we find the splendid Piediroso Janare , the excellent Falanghina Senete , the Greco Janere, the Aglianico Riserva Cantari and , best of all, the Aglianico I Mille for L'Aglianico.



### La Guardiense's History and Philosophy

Large cooperatives often become the subject of some suspicion, which, in the worst case scenario, turns into the belief that their size and nature as a cooperative indicates, or even ensures, that their sole objective is to produce large volumes of wine and that quality is not to be found in their work. This sort of prejudice is particularly strong in the case of southern Italy, and the La Guardiense cooperative in the town of Guardia Sanframondi , in the province of Benevento, has suffered, unjustly, for years from the consequences. Interesting grapes grow in these higher soils, among which there are the Aglianico and the Piediroso for the reds, the Falanghina (here unsurpassed as a source), the Greek , and the Coda di Volpe for whites.

### The wines of La Guardiense

An activity of this size obviously has a large number of members, about 1000, and thanks to the almost 1500 hectares of vineyards it produces lines of different quality levels. But the selections compete very well with, and sometimes surpass, the best wines of the entire region. The three production lines are: Janare, that is selections focused on the preservation of native vines, Fremondo and Classico, to which are added sparkling wines made with the Charmat method and the Classic method. Of great interest are the splendid Piediroso Janare, the excellent Falanghina Senete, the Greco Janere, and the Aglianico Riserva Cantari. And best of all, the Aglianico I Mille for L'Aglianico , very simply a great wine. A tribute to the passion of the growers, to the competence of the technical staff, from the consultant Riccardo Cotarella to the ambition and commitment of the directors. All for one, one for all.

### Janare project

According to legend, they are witches who weave the secrets of the earth with silver moonbeams and dance in the shadow of a walnut tree, united by the enchantment of life. Their mysterious footsteps and bewitching laughter still resound among the vines: they are the Janare, creatures of the wind and bearers of an inborn wisdom. In reality, they are the women of Sannio, untamed to the point of becoming witches for the sake of legend. We have dedicated our wines to the Janare in order to pass on an ancient culture in a contemporary taste while keeping their magical aura alive. The Janare wines are an invitation to discover an authentic Samnite tradition. We feel like its children, but above all its guardians.

Website: [www.laguardiense.it](http://www.laguardiense.it)

