SUITMA 13

5-9 October 2025
CNR Pisa, Italy

Technical Visit Program

CALCI
8 October 2025

PRATO
9 October 2025

Editors

Francesca Bretzel, Eliana L. Tassi, Francesca Vannucchi
CNR Research Institute on Terrestrial Ecosystems
(CNR IRET) Pisa Italy

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1. Urban Soil as a Living Canvas, Soil & Art Workshop

Gerd Wessolek, TU-Berlin, Germany

Abstract

These reflections and memories present insights from the Soil & Art workshop held as part of the Urban Soil Conference "SUITMA 13" in Pisa, Italy, 2025. It was the third Soil & Art workshop I gave after Berlin in 2006 and NYC in 2017. It brings together soil scientists, artists, and environmental thinkers to explore the intersections between urban soil science and artistic expression. Through hands-on artistic practice and reflective discussion, participants engage with urban soils as both ecological entities and cultural material. These reflections discuss the pedological and artistical outcomes of the SUITMA-seminar, offering perspectives on how artistic approaches can deepen public and scientific appreciation of urban soils.

Introduction

Urban soils are both witnesses and participants in the processes that shape cities. They store traces of human activity, pollution, and transformation, while also sustaining vegetation and regulating water and temperature. The rise of industrialized agriculture, coupled with a global demographic shift toward urbanization, has marginalized everyday connections between individuals and soils. This societal shift has led to a decline in the appreciation of and cultural identity with soils (Wessolek & Toland, 2024). Amid a broader movement aimed at fostering soil awareness and environmental action, artists and designers have been instrumental in bringing soils to the cultural mainstream, figuring their esthetic, social, political, and ecological dimensions (Toland et al., 2018). Yet, in the public imagination, soils are often perceived merely as dirt—an inert substrate beneath our feet (Feller et al., 2015). This Urban Soil Art workshop in Pisa, Italy aimed to challenge this perception by engaging SUITMA-participants in creative practices that reveal the vitality, history, and aesthetic dimensions of soils.

Concept and Methodology

The workshop took place outdoors in an historic environment of the of the Cittadella Galileiana, allowing direct interaction with the material and aesthetic qualities of urban soils. For motivating and encouraging participants of the SUITMA13, a short seminar guide has been prepared as a first announcement (Table 1). This guide helps soil scientists discover the artistic potential of urban soils, build the base of a cross-disciplinary dialogue, and create participatory artworks that raise awareness of urban soil's ecological, social, and historical dimensions.

Rather than focusing on soil scientific or technical data, the seminar emphasized perception, interpretation, and emotional connection to soils. This participatory approach merged scientific observation with artistic intuition, creating a shared space for dialogue between the natural and cultural dimensions of soil.

Table 1: Artistic guide for making Urban Soil visible

1. Start with Soil as Story

Select urban sites such as parks, construction zones, vacant lots - and collect soil samples. Note GPS coordinates, land use, and personal observations. Photograph soil in situ and in hand. Goal: Treat each soil as a narrative fragment of the city and history.

2. Transform Soil into Art Material by the Following Techniques:

- Use a binder to fix soil and artefacts on a canvas, combine it with colors.
- Soil Prints: Press and scratch moist soil onto paper or fabric.
- Soil Reliefs: Build textured maps with soil and natural glue.
- Using photographs for collage effects

Tip: Include scientific data (pH, color, texture) and comments within your artwork.

3. Explore the Urban Soil Biome

If available, use portable microscopes or camera to view soil life. Create:

- A 'Soil Life Gallery' with abstract and/or real sketches.
- Sound installations from soil interactions.
- own soil memories photos

4. Co-Create with the Community by

- Workshops: 'Bring Your Soil'
- Invite locals to share soils from their surroundings
- Compare and map colors/textures.
- Paint a collective mural or mandala

Purpose: Turn urban soils into a shared cultural and ecological archive.

5. Exhibit: Science Meets Art

Ideas for displaying your work:

- Outdoor pop-up exhibits.
- Paired displays: microscope imagery + abstract art.
- QR codes linking to soil data or stories.
- Use color and add poetry or reflections.

This kind of “out-door workshop” included the following working steps:

- Organization of canvas, adhesive, acrylic color, color spray, brushes, water, tables and seats
- A short welcome and introduction on Soil & Art to the participants
- Participants decide to paint, i.e., work either individually or in small groups up to 3-4 people together for about two hours
- At the end of the artistic field work, a presentation and discussion of all artworks started for about one hour
- The artworks were presented in the entrance of the SUITMA13 conference building to stimulate discussions

The whole procedure is documented by the following photographs. As mentioned, all participants were invited to sketch, draw, paint, picture, or write in response to the soil surfaces and surrounding landscape (Figure 1).

Figure 1: Working individually or in small groups

Figure 2: Artworks from the SUITMA 13 workshop in Pisa, Italy, 2025

After finishing field work, all artworks were individually presented, explained, and discussed within the SUITMA community as exemplarily shown in Figure 3.

Figure 3: Presenting artworks and explaining motivation and background

All artworks were presented in form of an exhibition during the whole SUITMA13 conference to stimulate discussions (Figure 4).

Figure 4: Exhibition of urban artworks in the entrance hall during the SUITMA13 conference

Discussion

The experiences and results of the urban Soil & Art workshop in Pisa demonstrate that artistic exploration could serve as a powerful tool for both soil awareness and education by engaging senses and emotions. Participants reported a heightened understanding of soil textures, colors, and structures linked with soil history, memories, and own soil science experiences. The act of creating art from and about soils helped foster new perspectives on soil stewardship and sustainability. Such transdisciplinary methods could complement conventional soil science by communicating complex environmental concepts in a more accessible and experiential way (Wessolek et al., 2016).

Conclusions

Urban soil art initiatives stand for a promising bridge between science, art, and society. The outdoor workshop with seminar character revealed that aesthetic engagement with soils can enrich both scientific inquiry and environmental communication. Future work may explore how these approaches could be integrated into urban planning, environmental education, and citizen science programs. And it was -like in Berlin and NYC- fascinating how the soil community was working together in a peaceful, creative, and quiet atmosphere. This creative format is not dividing us, it keeps us together.

Acknowledgment

Many thanks go to all participants of the Urban Soil Art Workshop for their interest and creative engagement, and to the whole SUITMA 13 crew for their support, prudence, and inspiration. Special thanks go to the IUSS for financing the workshop and to all colleagues who contributed their artistic and scientific perspectives, making this transdisciplinary encounter possible.

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2. Visit in Calci (Pisa) (8 October 2025)

2.1 The environmental characteristics of the Calci territory

Lorenzo Gardin, Romina Lorenzetti, CNR Institute of Bioeconomy (CNR-IBE), Sesto Fiorentino, Italy

Geology

The territory of Calci lies on the slopes of Monte Pisano, a small tectonically isolated massif in northwestern Tuscany, between Pisa and Lucca. From a geological perspective, Monte Pisano preserves exceptionally diversified lithostratigraphic layers, including basement rocks and Northern Apennine units. These include stratigraphic successions ranging from the Paleozoic to the Cenozoic, metamorphic and carbonate formations (notably the well-known marbles of Monte Pisano), portions of the Tuscan Nappe, and tectonic slices related to Ligurian and serpentinite units. This complex assemblage accounts for the massif's remarkable geodiversity and rich paleontological heritage.

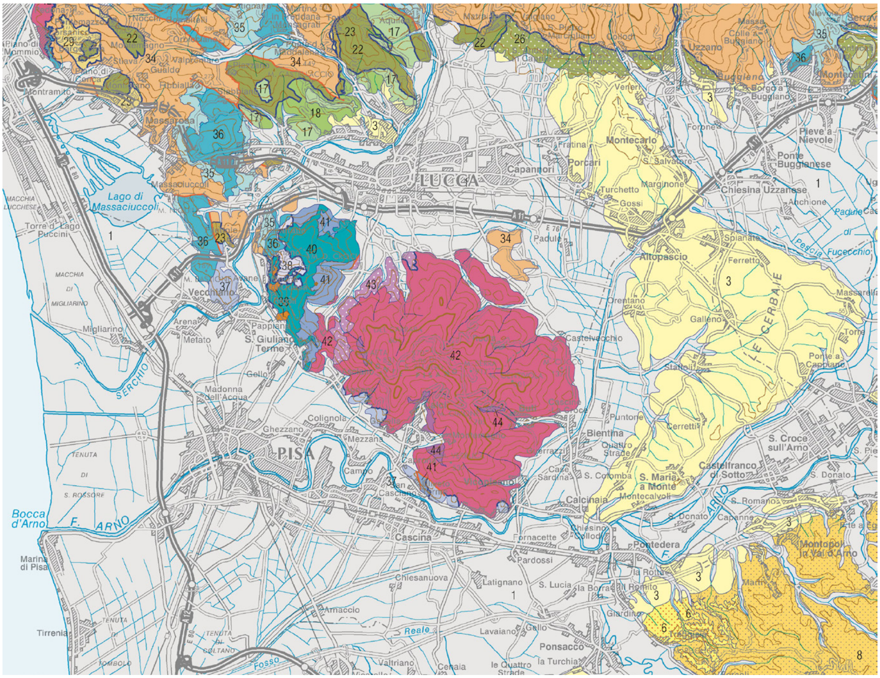

Figure 5 Geological setting of the Calci area within the Geological Map of Tuscany (Regione Toscana, 2004)

The Monte Pisano and the Monti d'Oltre Serchio form low mountain ranges (Monte Serra rises to just over 900 m a.s.l.) bordering the Pisa Plain to the northeast. Since Roman times, the Pisa Plain has been heavily modified by extensive reclamation works and hydraulic-agricultural schemes, which have made its drainage network almost entirely artificial. The plain is traversed by the lower courses of the Arno and Serchio rivers. From a geological perspective, the Pisa Plain lies within a large tectonic depression and represents a coastal plain developed through the accumulation of fluvio-lacustrine deposits from the Arno–Serchio system—currently hydrologically independent—together with aeolian and transitional shoreline deposits derived from coastal processes and dune progradation towards the open sea. The piedmont zone is characterized by flooding processes linked to multiple phases of glacio-isostatic uplift and eustatic sea-level fluctuations, with steep flanks alternating with sectors that merge gradually into the plain through extensive alluvial systems, including alluvial fans and fluvial terraces. The streams originating in the Monte Pisano are channelized in their lowland reaches and conveyed into the dense network of ditches and canals, which in the past served both as hydraulic power sources and as waterways. The drainage toward the sea is managed by two major artificial canals - the Arnaccio, draining the Bientina Plain, and the Scolmatore, draining the Fucecchio depression- as well as streams descending from the Pisan and Livorno hills.

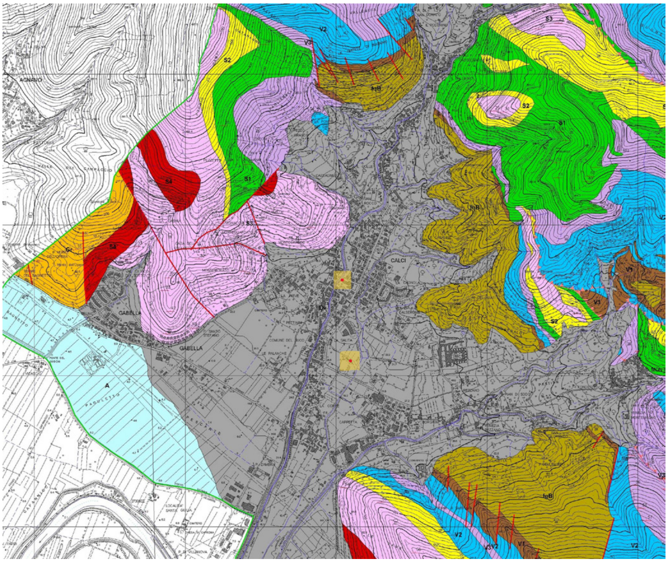

Figure 6 Geological map of Calci Municipality (Comune di Calci, 2023) and stop points.

More specifically, the Municipality of Calci lies in the southeastern sector of the Monte Pisano, within a complex stack of superimposed tectonic units. Most of the exposed lithologies belong to the Monte Serra Unit, which represents the structurally lowest element of the Monte Pisano and is affected by low-grade metamorphism. According to the geological map of the area (Figure 6), the following geological units are present, listed in chronostratigraphic order:

A	**Quaternary deposits:** Recent and Modern Alluvium (A);
Dv	Older and Terraced Alluvium, Slope and Fan Deposits (Dv)
Ft	**Tuscan Nappe Unit:** Limestones and Marls (Ft), Late Triassic–Early Jurassic (Rhaetian–Lias)
Gr	**Monte Serra Unit:** Grezzoni, dark-grey dolomites (Gr), Rhaetian
S4 S3 S2 S1	**Monte Serra Quartzite Formation:** quartzites and schists (S1–S4), Carnian
V3 V2 V1	**Verruca Formation:** “Anagenites” (low-grade metamorphic rocks of arenaceous–clayey origin, foliated) and violet schists (V1–V3), Ladinian
fqB	**Paleozoic formations:** phyllites and Buti quartzites (fqB)

Geomorfology

Figure 7 3D view of the study area from Google Earth, showing geomorphological elements (valleys, slopes, and plateaus)

From a geomorphological point of view, three main physiographic domains can be distinguished in the study area:
1 Mountainous–hilly sector. This sector culminates at 917 m a.s.l. on Monte Serra, with slopes averaging 15–20%, locally exceeding 25% and in places approaching vertical. The slopes are mantled by slope deposits derived from in-situ rock weathering and colluvial accumulations of variable thickness. On the reliefs of the Montagna Antica, particularly over the siliceous basement of the Monte Pisano, relict periglacial block streams, locally known as "Sassaie", are visible from great distances. These features, typical of such geological substrates, are unique within Tuscany.
2 Valley floors. These are dominated by alluvial fans of the tributary streams, with slopes ranging from 5–10% and locally up to 15%. The Zambra Torrent fan, where it merges with the Arno alluvial plain, is characterized by gentler gradients (<5%). The valley floors are filled with paleo-alluvial deposits that formed under paleoclimatic and geomorphic conditions distinct from the present, as indicated by their thickness, lateral extent, and the large size of transported clasts compared to the modest discharge of current streams. Climatic fluctuations led to successive phases of burial and re-incision, and in several stretches, streams are now entrenched into bedrock. The two main watercourses and their tributaries show incised channels; in their lower reaches, artificial embankments elevate the streams above the adjacent plain, creating perched channels.
3 Alluvial plain. This sector is underlain by recent alluvial deposits of the Arno River. Channel facies are dominated by loamy and silty sediments, while interchannel areas are characterized by clay-rich deposits. Slopes across the plain are consistently below 5%.

Climate

According to the Köppen climate classification, Calci falls into the Cs climate type, humid temperate with summer aridity, and specifically into the Csa subtype, Mediterranean, where the average temperature of the coldest month is between -3.0°C and 18.0°C, and that of the warmest month is above 22.0°C.

Summary data:

- Average annual temperature: 16.3°C
- Average annual precipitation: 929 mm
- Coldest month: January (8.0°C)
- Warmest month: July (25.4°C)

- Driest month: July (31 mm)
- Wettest month: November (134 mm)

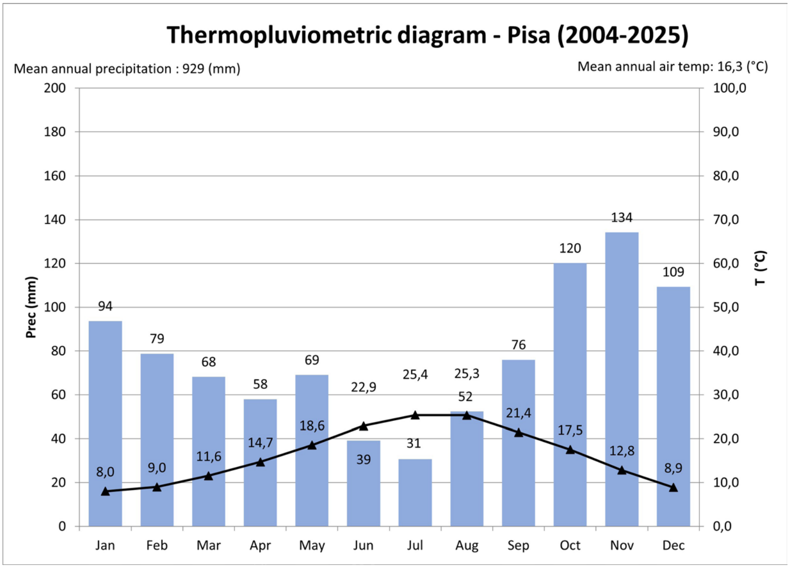

Figure 8 Thermo-pluviometric diagram; station of Pisa (2004-2025)

The climatic gradient of Monte Pisano is very pronounced given its high relief and proximity to the sea. Climatic calculations assign the summit of Monte Pisano an average annual temperature of 12°C and an average annual rainfall of 1,300 mm.

Soil Taxonomy soil moisture and thermic regime

The temperature difference between summer and winter in the study area is significant. The average summer temperature (June, July, and August) is around 24.5°C, while the winter temperature (December, January, and February) is approximately 8.6°C. This results in a seasonal variation of approximately 15.9°C, a value that clearly indicates a non-isothermic regime, i.e., a temperature difference between summer and winter of more than 5°C. The overall average annual temperature is around 16.3°C, confirming that the local climate follows a non-isothermic thermic regime.
Regarding soil moisture regime, the area has a Mediterranean climate characterized by rainy winters, hot, dry summers, and with at least four consecutive dry months, therefore, the soil falls into the xeric regime category, which is rather widespread in Tuscany. In

these soils, the dry summer period lasts more than 45 consecutive days, while in winter the soil remains moist for at least 90 consecutive days. This alternating moisture cycle strongly influences soil dynamics, soil biological activity, and land management.

Land Use and Vegetation

A distinctive feature of the Tuscan hilly agricultural landscape, particularly on the slopes of Monte Pisano, is the hydraulic system of terraced slopes. In Italy, terracing expanded significantly from around the year 1000, thanks to the implementation of advanced hydraulic techniques, increasingly adapted to local soil and landscape characteristics. This development followed the increase of agricultural activity after the post-Roman abandonment and renaturalization of the Italian landscape during the Early Middle Ages.

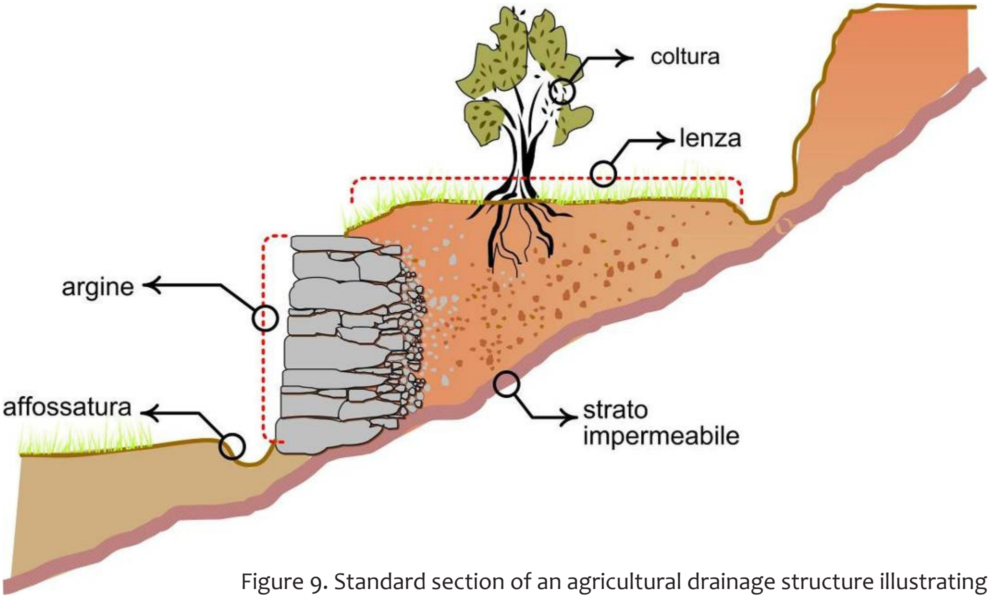

Figure 9. Standard section of an agricultural drainage structure illustrating the essential elements to identify different typology of terraces (coltura=crop; lenza = terrace; argine = retaining wall; affossatura=drainage; strato impermeabile= impermeable layer) (Rizzo D., 2009)

Terracing involves reshaping slopes into regular cultivable platforms, constructed with dry-stone retaining walls whose dimensions and form are adapted to local topography. These structures primarily function to retain soil, reduce surface runoff, and minimize landslide risk. In Tuscany and Monte Pisano, terraced areas are mainly concentrated in the foothills are largely employed for olive cultivation, the dominant crop. Areas near settlements and with gentler slopes were intensively cultivated and maintained. Other crops include herbaceous and arboreal species, with cereals and vines often intercropped with olives. Arable land is limited in extent and fragmented. Chestnut groves were historically significant in the forests, providing both food and raw materials for local traditional industries.

Currently, the area faces challenges related to land abandonment and the deterioration of hydraulic systems. Progressive abandonment has led to forest encroachment, erosion, and increased fire risk, which in turn contribute to hydrogeological instability, including flash floods and frequent landslides.

Regarding vegetation cover, acidophilic communities occur on the steep, wooded slopes not managed for agriculture. On Monte Pisano, deciduous forests are largely composed of chestnut groves between 50 and 900 meters above sea level, developing on acidic substrates. These groves are associated with species such as *Fraxinus ornus*, *Ilex aquifolium*, *Arbutus unedo*, and *Erica arborea*. The shrub layer is dominated by *Pteridium aquilinum*, with occasional *Cytisus scoparius*. Additionally, pine forests with *Fraxinus ornus* and black locust (*Robinia pseudacacia*) occur along northern slopes near Lucca, particularly in cooler valleys and transitional zones with hygrophilous formations (Bertacchi et al., 2006)

Monte Pisano hosts one of the largest concentrations of maritime pine (*Pinus pinaster Aiton*) in the Tuscan hills. These pine forests are mainly located in the southeastern sector, on siliceous substrates, between 100 and 500 meters, with sporadic occurrences above 600 meters on eastern-facing slopes. Recently, the maritime pine forests have suffered severe impacts from pathogens, in particular *Matsucoccus feytaudi*, as well as from wildfires, which have significantly compromised their extent and health in the area.

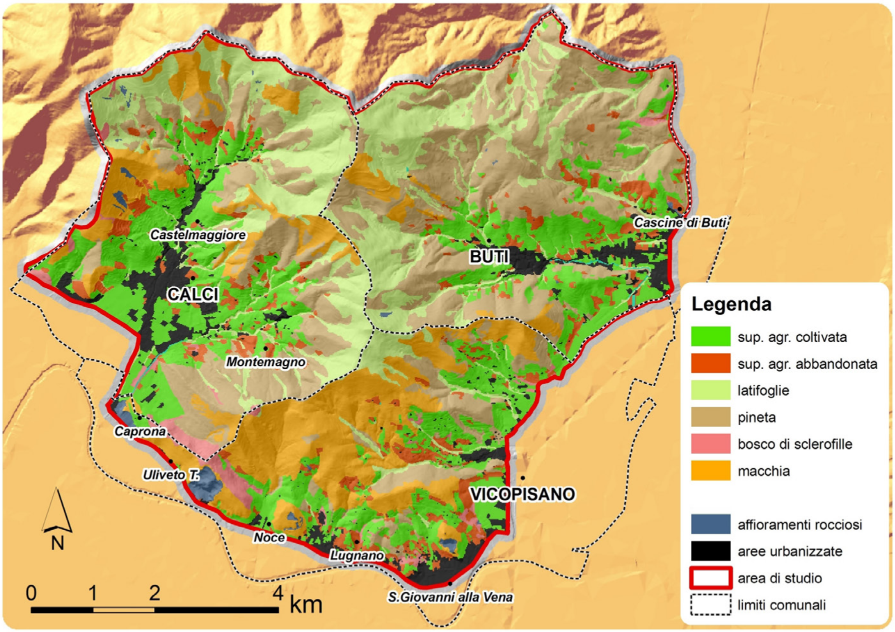

Figure 10 Landuse map of Calci, Vicopisano and Buti Municipalities (Rizzo D., 2009)

The Soils of Monte Pisano

The soil map of the Tuscany Region (Regione Toscana, 2017) shows that the soils of Monte Pisano have the following characteristics and geographic distribution:

Volpaio soils (VPO1), (Dystric Haplustepts loamy-skeletal, mixed, mesic), are located on steep, moderately eroded slopes. They are very common and predominantly covered by forest formations such as pure or mixed pine forests of indigenous species, chestnut groves, and mixed forests of deciduous broadleaf and coniferous trees. Are moderately deep, with an A-Bw-C profile, gravelly, with a loamy texture, highly acidic, sometimes excessively drained.

Monte Vasone soils (MVA1), (Lithic Haplustepts, loamy-skeletal, mixed, mesic), thin to moderately deep, with an A-Bw-R profile, sometimes with a poorly expressed or absent cambic horizon, ranging from gravelly to very gravelly, loamy in texture, non-calcareous, moderately acidic to neutral, excessively drained, are generally found on steep to very steep, heavily eroded slopes, predominantly covered with degraded shrub or tree vegetation.

Tocchi soils (TCH1), (Ultic Haplustalfs, fine-silty, siliceous, mesic) are located on gently sloping slopes, subject to moderate erosion on more preserved colluvial forms with little rockiness and common surface stoniness. Land use is olive groves and forest formations; Soils are moderately deep to deep, with an Ap-Bt-C profile, slightly gravelly to heavily gravelly and pebbly, with a silty and loamy texture, moderately acidic, and well-drained.

Fabbri soils (FBR1) (Typic Haploxeralfs, fine, mixed, thermic) are located on alluvial fans and on gently sloping surfaces connecting the reliefs of the Monte Pisano and the alluvial plain of the Arno River. Land use consists of arable land, olive groves, and residential areas. Soils are deep, with a profile of Ap-2Bt-2Btg-2C, with limitations to root penetration due to the presence of abundant skeleton at depth, a loamy texture on the surface and silty clayey loam at depth, moderately acidic at the surface to weakly acidic and neutral at depth, very high base saturation, moderately well-drained.

The soils of regional database described above differ in pedoclimatic regime from the field trip profiles, as they refer to hilly and mountainous environments located at higher elevations. Consequently, the observed differences are primarily attributable to the altitudinal gradient and the related climatic variability.

2.2 Forest fire effects

Effects of the latest wildfire on the soils of Monte Pisano

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A massive forest fire profoundly transformed the landscape of the Monte Pisano in September 2018. It was the largest wildfire in Tuscany over the past 25 years. Fortunately, there were no human casualties or injuries among residents or workers. Remarkably, a fire that affected over a thousand hectares was brought under control within 48 hours.
The fire burned approximately 1,148 hectares, including about 1,000 hectares of forest—primarily maritime pine (Pinus pinaster), chestnut trees, and Mediterranean shrubland—and the rest agricultural land, including olive groves, vineyards, and other crops. Thousands of trees were destroyed, including centuries-old olive trees, chestnut groves, and vineyards (Figures 11 and 12).
The fire behaviour ranged from surface to crown fire due to the high biomass density, affecting large contiguous areas cultivated or covered with maritime pine and maquis.

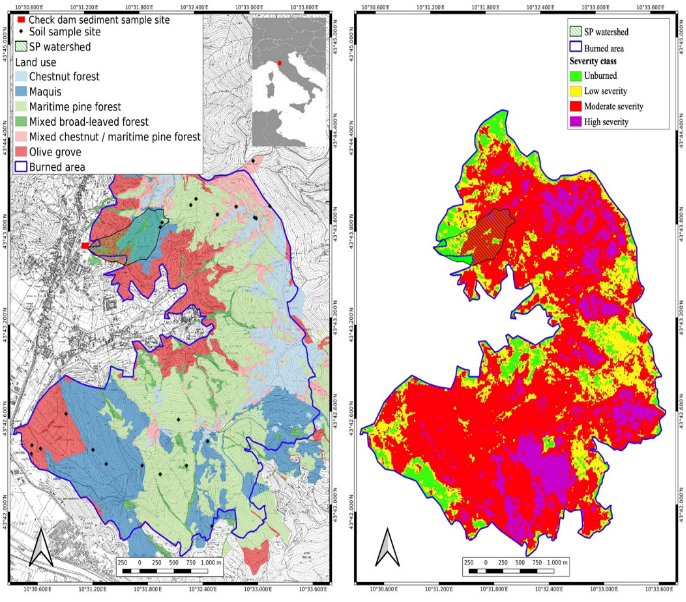


Figure 11. Left: Perimeter of the Monte Pisano, with land uses shown in the overlaid traced area; locations of the soil sampling sites from Mastrolonardo et al. (2024) are also indicated. Right: Fire severity map of the study area based on the relativized burn ratio index, highlighting the Santo Pietro (SP) watershed, where a check dam was built within the Calci city perimeter (Mastrolonardo et al. 2024).

Figure 12. Some examples of burned areas in Monte Pisano: (a) high burn severity in a pine stand; (b) high burn severity in maquis; (c) low burn severity in maquis; (d) moderate burn severity in a chestnut stand (Mastrolonardo et al., 2024).

The impact of fire extended beyond vegetation loss, affecting hydrological and pedological processes. These include increased surface runoff and erosion, reduced soil hydraulic conductivity, decreased stability of soil aggregates, loss of soil nutrients, alterations in physical and chemical soil properties, and changes in vegetation dynamics. In general, the soils of the Monte Pisano are shallow and rich in rock fragments. The median soil depth was 0.4 m, ranging from a minimum of 0.1 m to a maximum of over 1.2 m, the latter recorded only in a single sampling point out of the twenty analysed (Figure 11). Following the wildfire, the first autumn rains—typically the most erosive post-fire events in the Mediterranean basin—produced an estimated erosion rate of 7.85 t ha^{-1} within just a couple of months, as measured in the Santo Pietro watershed (Calci municipality). Although notable, this value is relatively low compared with others reported in the literature and lower than expected given the steep slopes of the Monte Pisano and the severity of the fire. A likely explanation is that the shallow, stone-rich soils provided only a limited supply of fine erodible material, while previously eroded areas had a soil surface relatively enriched in stones, which altogether constituted a sort of protective pavement. Rock fragments probably also favoured water infiltration and limited the formation of a continuous fire-induced hydrophobic layer.

It is important to note, however, that a relatively moderate soil loss does not necessarily correspond to a moderate ecological impact. Since organic matter and nutrients are concentrated in the topsoil, even limited erosion can severely affect soil fertility and water quality, particularly in already degraded systems such as the one studied. Moreover, the proposed Soil Monitoring and Resilience Law (EC, 2024) defines healthy soils as those with erosion rates not exceeding 2 t ha^{-1} yr^{-1}.

Overall, the fire severely compromised soil fertility and hydrogeological function, enhanced erosion and landslide susceptibility, and caused significant biodiversity loss.

Soil Indicators for postfire recovery

Francesca Vannucchi, Francesca Bretzel, Eliana L. Tassi, CNR Research Institute on Terrestrial Ecosystems (CNR-IRET), Pisa, Italy

Wildfires threaten soil health with consequences on its properties and functionality. Depending on fire intensity and severity, texture, pH, organic matter, nutrients availability, aggregate stability, water infiltration may be affected. Soil texture experiences deep changes, as soil particles (clay, silt and sand) modify at specific temperature thresholds, with consequences for soil sorption capacity. Combustion modifies the soil organic matter (SOM) amount and composition, accelerating mineralization and volatilization processes, and alters the microbial community structure, affecting the soil enzyme activities. Moreover, combustion affects the availability of nutrients, and their assessment allows to establish a degree of soil degradation. The case study refers to the severe fire occurred on Monte Pisano (Pisa, Italy) in 2018, with the destruction of 1150 ha of forest. The study considered the soil of two forest types (pine and chestnut) and monitored over time by remote sensing and in situ. In each forest type, burned and unburned sites were compared in terms of soil properties, mycorrhizal abundance, stable isotopes, and enzyme activities after two (2020) and five (2023) years from the fire event. The satellite data, Normalized Difference Vegetation Index (NDVI) and the Normalized Burn Ratio (NBR) index, together with soil texture, indicated a higher fire impact and a slower vegetation recovery in pine forest compared to chestnut forest. The soil stable isotope composition and enzyme activities showed a degradation of soil organic matter and nutrient cycling, especially in pine forest soil. Moreover, mycorrhizal colonization under chestnut was higher than under the pine forest. The application of remote sensing tools and the validation of the data in situ enabled the selection of suitable soil indicators which contributed to quantifying the soil degradation and assessing the ecosystem recovery. Post-fire soil indicators as texture, soil enzymes and mycorrhizal colonization, coupled with remote sensing, can help adopt strategies for postfire forest recovery. (Vannucchi et al. 2026).

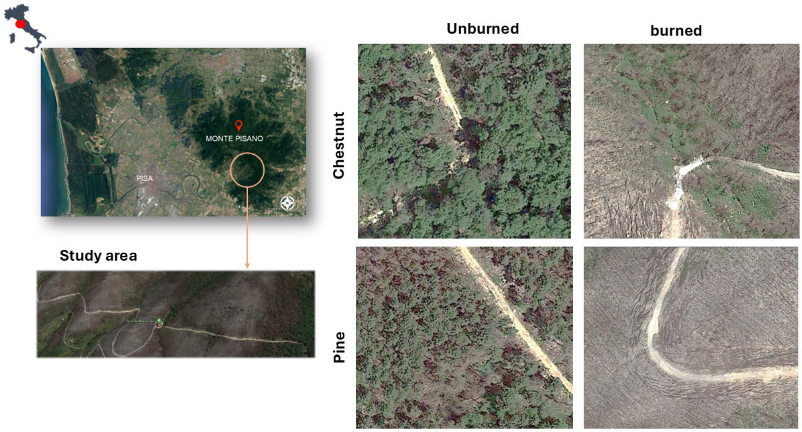


Figure 13. The Monte Pisano study area (source: Vannucchi et al. 2026).

Figure 14. Chestnut and pine forests one year after the fire

2.3 Profile description

Lorenzo Gardin, Romina Lorenzetti, Institute of Bioeconomy (CNR-IBE), Sesto Fiorentino, Italy

Edoardo A.C. Costantini, Institute of Bioeconomy (CNR-IBE), Sesto Fiorentino, Italy; IUSS Past President and Chair of the Research Forum

Station data

Location (Municipality and Province): Calci (PI)

Substrate lithology: siliceous alluvial deposits of gravel and pebbles (quartzite, phyllite, schists);

Morphology: fluvial incision in an ancient alluvial fan; anthropogenic microfeatures: excavation and filling

Land use: urban area (school garden)

Slope: flat (<0.2%)

Aspect: --

Drainage: sometimes excessively drained

Soil Taxonomy Classification (ed. 2022):

coarse-loamy, mixed, active, thermic Typic Haploxerept

WRB Classification (ed. 2022):

Calcaric Cambisol (Loamic, Humic, Prototechnic)

Horizons

The horizon designations used in this profile follow the definitions and guidelines of the USDA Soil Taxonomy (Keys to Soil Taxonomy, 2022, 12th edition).

Au 0–10 cm: dry; very dark grayish brown (10YR 3/2); medium and large granular structure, moderate; slightly hard (dry) consistence; sandy loam; common medium gravel (20 mm), angular, siliceous (~10%); common artifacts (3–5%, bricks, plastic, metal); many medium tubular pores (~2 mm); common very fine roots (<1 mm), vertical; moderate effervescence with dilute HCl; abrupt smooth boundary.

ABu 10–40 cm: dry; dark yellowish brown (10YR 3/4); large subangular blocky structure, moderate; very hard (dry) consistence; sandy loam, gravelly and cobbly; common coarse gravel (50 mm, ~15%) and common cobbles (80 mm, ~15%), angular, siliceous; common artifacts (3–5%, bricks, plastic); few very fine tubular pores (~0.5 mm); few fine roots, subhorizontal; moderate effervescence with dilute HCl; gradual, wavy boundary.

Bwu 40–70 cm: dry; dark yellowish brown (10YR 4/4); large subangular blocky structure, moderate; very hard (dry) consistence; sandy loam, cobbly; common coarse gravel (50 mm, ~10%) and frequent cobbles (80 mm, ~20%), angular, siliceous; common artifacts (3–5%, bricks, plastic); few very fine tubular pores (~0.5 mm); few fine roots, subhorizontal; moderate effervescence with dilute HCl; abrupt, irregular boundary.

2Bw/Aub 70–100 cm:

2Bw: dry; strong brown (7.5YR 4/6); large angular blocky structure, strong, tending to prismatic; hard (dry) consistence; sandy loam; common coarse gravel (75 mm, ~10%) and few cobbles (100 mm, ~5%), rounded, mixed siliceous lithology; no artifacts; soft iron-oxide concentrations present; few very fine tubular pores (~0.5 mm); few fine roots, subhorizontal; no effervescence with dilute HCl; clear, irregular boundary.

Aub: dry; dark brown (7.5YR 3/2); fine granular structure, very weak, nearly single grain; loose consistence; sandy loam; common fine gravel (~10%), rounded, siliceous; common artifacts (3–5%, bricks, plastic); few coarse roots, subhorizontal; moderate effervescence with dilute HCl; clear, irregular boundary.

2C 100–150+ cm: dark yellowish brown (10YR 4/4); single grain; loose consistence; sand; abundant medium and coarse gravel (~40%), frequent cobbles and stones (~30%), rounded, mixed siliceous lithology; no artifacts; common medium roots, subhorizontal; few coarse roots, subhorizontal; no effervescence with dilute HCl; boundary not observed.

Horizon	Depth (cm)	Sand (2000 - 50µm) %	Clay (<2 µm) %	Texture	$CaCO_3$ %	pH (H_2O)	EC (mS/cm)	CEC (meq/ 100g)	SOC %	TC%	TN %	C/N
Au	0-10	60.6	4.6	sandy loam	16.9	8.0	0.70	3.16	5.48	7.51	0.48	11.3
ABu	10 -40	42.9	8.2	loam	7.4	8.5	0.32	2.06	0.93	1.82	0.10	9.6
Bwu	40-70			loam								
2Bw	70-100	35.6	7.9	loam	0	8.0	0.08	2.26	0.25	0.18	0.03	8.5
Aub	70-100	60.1	4.3	sandy loam	11.7	8.2	0.38	2.73	2.95	4.35	0.34	8.6
2C	100-150+											

Figure 15. Soil Profile in Calci and discussion time

Comments for discussion

Introduction

A soil profile is presented to highlight its origin and composition, as well as to identify the main changes caused by human activities, such as fill deposits and the presence of artifacts. This exploratory investigation aims to provide a knowledge base for assessing the current conditions of urban soils, identifying potential critical issues, and evaluating their suitability for future sustainable land uses. Building on previous soil scientists' study and the approaches already adopted by local administration of some Italian regions, this soil characterization also offer the opportunity to evaluate soil ecosystem services (Calzolari et al., 2020). This approach enables the classification of soils based on an estimation of the functions they provide, including support for biodiversity, water purification, carbon storage, agricultural productivity, and water regulation. This analysis offers quantitative indicators to guide sustainable land use planning and identify opportunities for alternative urban soil applications.

Origin and Composition

This soil profile is located in a fluvial incision of the ancient alluvial fan; the river flows approximately 20 m from the site, and the fluvial deposits represent the substratum of the soil, clearly recognizable in the deeper horizons of the profile. In the 1970s, the soil was deeply disturbed by mechanical excavation during the construction of a school: the surface was levelled, and the upper layers were mixed with bricks and other artifacts derived from construction activities (Figure 15).

According to the definitions of the Soil Taxonomy (Keys, 12th ed., 2022), the observed landform corresponds to an anthropogenic microfeature, since it does not have the areal extent required to be classified as an anthropogenic landform. No constructional forms are evident; the profile lies at the same level as the surface hosting some old olive trees, which are already visible in aerial photographs taken before the construction of the school. This form represents a destructional form filled with the same original soil material and with discrete artifacts. Therefore, down to a depth of 70–100 cm, the soil consists of Human Altered Material (HAM), developed within a destructional anthropogenic microfeature. According to the Soil Survey Manual (2017): "where the excavations have been partially or totally filled with the original soil material, the material is considered HAM."

As background information, it should be noted that the surrounding soils, described both from the regional soil database and from field observations, are moderately acidic and derived from siliceous parent materials (deposits of quartzites, schists, and phyllites). Immediately next to the olive trees, soil is unaffected by excavation and backfilling, and it shows a moderately acidic reaction.

The surface horizon Au (0–10 cm) has a high organic matter content, due to a natural accumulation process that occurred in the decades following the anthropogenic disturbance (the soil has not been tilled since the 1970s). The presence of artifacts and carbonates indicates human-altered material.

Horizons ABu and Bwu (10–70 cm) show weak structural development resulting from physical reorganization processes that occurred in situ after the anthropogenic disturbance but affecting material that had already undergone pedogenesis. The occurrence of artifacts and carbonates further confirms the nature of human-altered material.

Horizon 2Bw/Aub (70–100 cm) is composite, i.e., a transitional horizon.

The 2Bw portion is a cambic horizon, well developed in structure and color; it represents an in-situ horizon formed from the alteration of underlying fluvial deposits. A lithologic discontinuity marks the sharp separation between the overlying HAM and the soil formed from natural deposits in place. Furthermore, in this horizon, the coarse fragments consist mainly of rounded river gravels and pebbles, while the overlying terrain is dominated by angular gravels derived from alluvial fan deposits.

The Aub portion of the same horizon (70–100 cm) represents a surface horizon displaced downward by mechanical operations, without being mixed. It consists of HAM and is very similar to the surface horizon in texture, organic carbon content, carbonate occurrence, and presence of artifacts.

Finally, the 2C horizon consists of a substratum of loose, siliceous, gravelly and cobbly alluvium.

Soil Taxonomy classification

For classification according to Soil Taxonomy, we considered:

- the presence of Human Altered Material;
- the presence of an Anthropic epipedon (formed in HAM, with artifacts, and at least 25 cm thick);
- the presence of a Cambic horizon within 100 cm.

The use of HAHT Material Classes was also evaluated, but the requirements are not met in this case:

- Pauciartifactic (requires artifacts >15% and <35%);
- Araric (requires ≥3% by volume of mechanically detached and re-oriented fragments of diagnostic horizons or properties).

WRB classification

We have excluded the possibility that the Au–ABu–Bwu horizons could be classified as a Terric horizon, as this is more closely related to anthropogenic interventions aimed at improving the agricultural fertility of soils rather than to urban-related modifications.

The ABu–Bwu horizons, although formed in Human-Altered Material (HAM), are classified as Cambic horizons, considering that the material was displaced more than 50 years ago and shows both color development and structural aggregation. The 2Bw horizon is also a Cambic horizon.

Principal qualifiers: Calcaric

Supplementary qualifiers: Loamic; Humic (having ≥ 1% soil organic carbon as a weighted average to a depth of 50 cm from the mineral soil surface); Prototechnic (artifacts ≥ 5%) within 100 cm of the soil (considering also the Ab horizon).

Post-field trip note

The description and interpretation of the soil horizons presented above refer only to the right-hand side of the profile (Fig. 16).

The left-hand side of the profile was in fact widened a few days before the field excursion to facilitate access for participants. However, this portion shows noteworthy differences from the described section and was discussed during the field trip. In the horizons of the left-hand side, the amount of anthropogenic artifacts is much lower: they consist only of fragments of older bricks, while plastic, metal, and cement artifacts are absent. Moreover, the surface horizons are non-calcareous, and there is no evidence of buried horizons.

Discussions with the participants suggested that, although the left-hand side of the profile also has an anthropogenic origin, it represents a soil that developed earlier, likely during the construction of the traditional terraced systems that are widespread in the Calci area and contemporary with the olive trees still present on the surface. This portion

of the profile does not appear to have been affected by the more recent excavation and backfilling works carried out during the construction of the school.
According to the WRB classification, only the left-hand side of the profile changes its classification and is identified as Eutric Cambisol (Loamic, Humic).

Historical landuse

Historical land use at the profile site was also analysed: it was an olive grove in 1954, a school garden in 1978, and no significant changes were observed between 2007 and 2023.

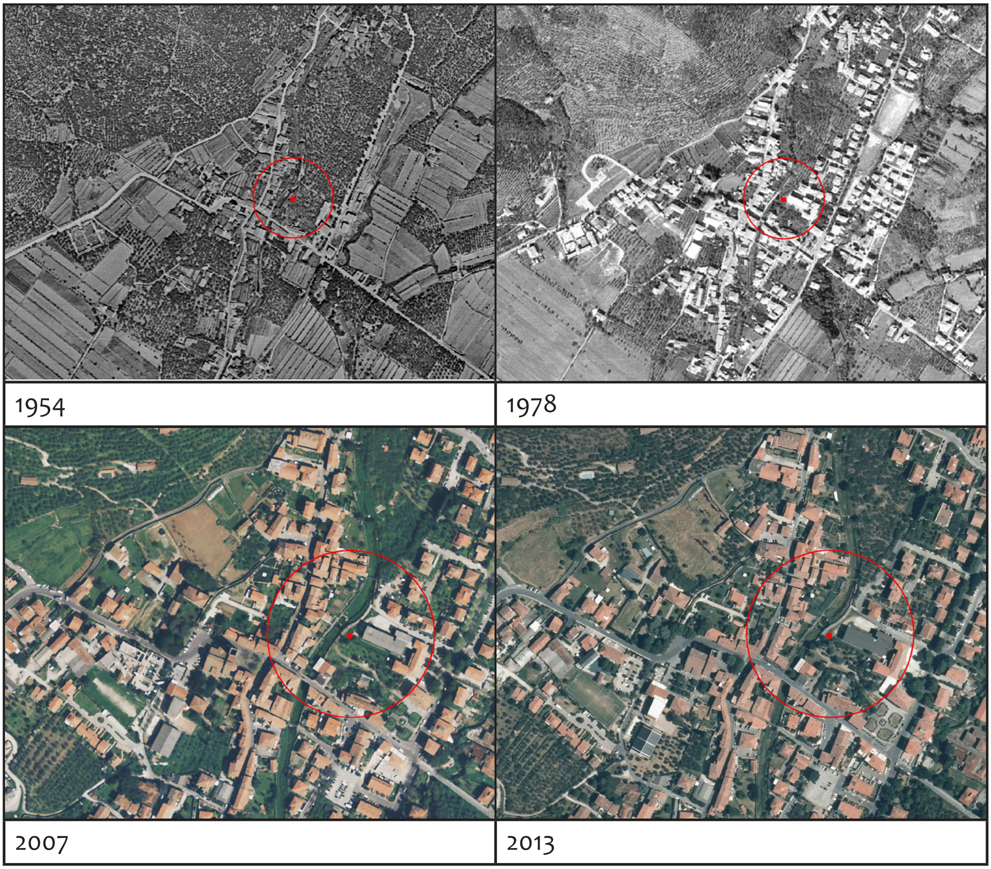


Figure 16. Land-use change analysis of the study area based on aerial photographs from 1954 onwards (Regione Toscana, 2024).

2.4 ReCROP project

Eliana Tassi, Francesca Bretzel, Research Institute on Terrestrial Ecosystems (CNR-IRET), Pisa, Italy

Visit to the 'Fattoria San Vito', wine and olive oil producer and partner of the RECROP project (Bioinocula and CROPping systems: an integrated biotechnological approach for improving crop yield, biodiversity and REsilience of Mediterranean agro-ecosystems) funded by PRIMA program coordinated by Portugal. IRET units of Pisa and Florence carried out the trials on the vineyard. The project focuses on the agroecology approach that considers the use of sustainable practices in cultivated territories with the aim, among others, of strengthening resilience, reducing the use of mineral fertilizers and intensive agriculture techniques. Soil treatments with commercial quality compost and bioinoculum (alone or in combination) were applied on established organic vineyard for three consecutive years (2022-2024).

The results from the two-year study (2022 and 2023) indicate that the combination of inoculum and compost positively influenced grape nutrition. While the differences in grape production were not statistically significant, a noticeable trend toward higher yields was observed in both the bioinoculant and the bioinoculant + compost treatments. In the 0-10 cm soil layer, enhancements in the availability of P, Mg, Mn, and Cu were noted across all treatments in both 2023 and 2024. For the 10-20 cm layer, P, Mg, and Mn availability was greater across all treatments, with bioinoculation also influencing Cu levels at both soil depths. There were no statistically significant differences in the amount of soil carbon sequestered among the treatments. However, treatment with the inoculum resulted in a larger presence of stable aggregates with a larger average diameter.

Figure 17. Treatments at the vineyard for the ReCrop project and results' presentation during the visit

3. Visit in Prato

3.1 The environmental characteristics of the Prato territory

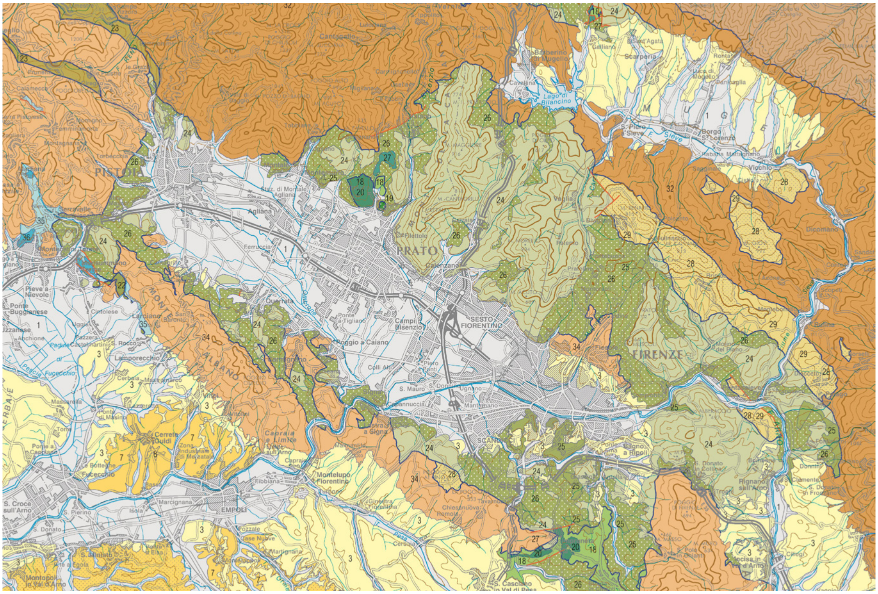
Lorenzo Gardin and Romina Lorenzetti CNR Institute of Bioeconomy (CNR-IBE), Sesto Fiorentino, Italy

Geology

The study area is part of the extensive Florence–Prato–Pistoia plain, which, with a NW–SE orientation, forms a broad alluvial depression approximately 45 km wide and 100 km long. This plain originated from a Villafranchian lacustrine depression, subsequently filled with fluvio-lacustrine and alluvial deposits overlying the older geological units.

The Florence–Prato–Pistoia plain is bordered by mountain ranges with an elevation difference of about 1,000 meters. These ranges are composed of several geological formations widespread throughout Tuscany, such as the Macigno del Chianti sandstones; the calcareous marls and marly limestones of the Alberese (the Calvana ridge is characterized by rounded morphologies, with surface karst features such as dolines, uvalas, and karren, as well as caves, especially in the southern part); and the chaotic claystones, extensively cultivated with olive groves and vineyards. These formations occur both along the NW–SE ridge and to the south, where Monte Albano closes the plain.

These rocks provided the building stones of the Florentine Renaissance palaces (Pietraforte, Pietra Serena, and the Green Prato Marble from Monte Ferrato–Monte Lavello), within a landscape dominated by ophiolitic reliefs.



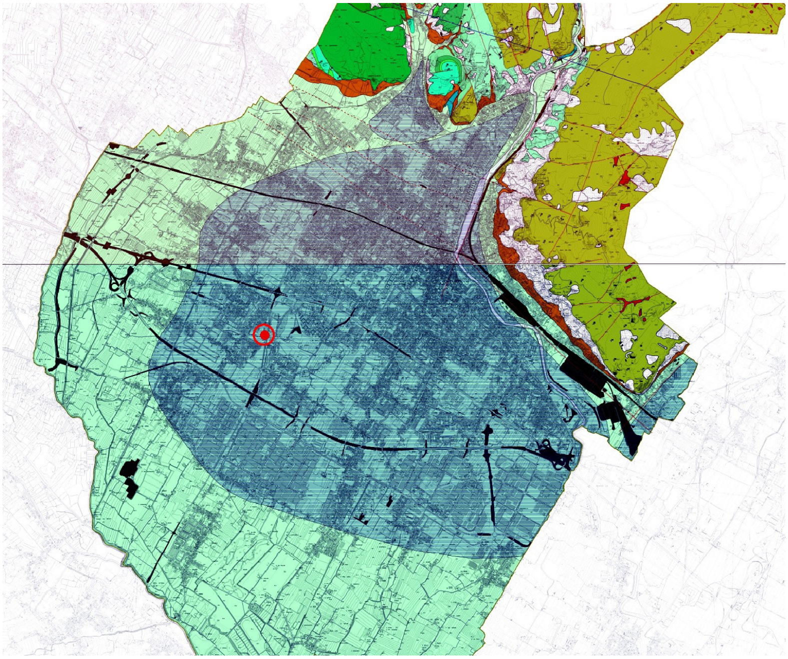
	1 - Alluvial deposits
	20 - Ofiolites: peridotites, gabbros, basalts
	21 - Flysch: marls, limestones and sandstones
	24 – Shales, sandstones, conglomerates
	30 - Flysch: sandstones, siltstone, shales and marls

Figure 18 Geological setting of the Prato area within the Geological Map of Tuscany (Regione Toscana, 2004)

During the Lower Pleistocene (between 1.7 and 1.0 million years ago), after the sea had already retreated from the area, the post-paroxysmal extensional phase of the Apennine orogeny took place. This phase led to the formation of large basins such as the Mugello, the Upper Valdarno, and—of particular relevance here—the Florence–Prato–Pistoia basin. As a consequence of these tectonic processes, the hydrographic network of the area was modified: rivers such as the Ema, Greve, and Mugnone, instead of flowing toward the retreating ancient sea, began to channel their sediment-laden waters into this large basin.

Within the Florence–Prato–Pistoia plain, a vast lake developed, confined between the Monte Albano and Signa reliefs to the west, Monte Giovi to the north, and the foothills of Chianti to the south.
The progressive subsidence of the basin floor was counterbalanced by the substantial sediment input delivered by watercourses, particularly those draining the Apennines, which were experiencing rapid uplift and, consequently, intense erosion.
As the waters receded, the plain—located at approximately 50 meters above sea level—was characterized by numerous ponds and marshes. These features, particularly in the areas of Campi Bisenzio, Signa, and Bagno a Ripoli, persisted over the centuries despite repeated land reclamation efforts.
In more recent times (Holocene to Present), rivers progressively crossed the plain, with some sectors retaining lacustrine and marshy conditions. These environments were gradually reclaimed, notably through river straightening and canalization works, which reduced sediment deposition.

Geomorfology



	Recent alluvial deposits (bna)
	Alluvial fan deposits (ca)
	Colluvium (b7)
	Serpentinized peridotites with gabbroic and basaltic dikes (PRN)
	Cherts (DSA)
	Limestones and marls (MLL)

Figure 19. Geological map of Prato Municipality (Comune di Prato, 2023)

According to the municipal geolithological map, the soil profile is located within an inactive alluvial fan, slightly elevated above the surrounding floodplain. The fan-delta deposits are composed of coarse clastic sediments—pebbles and gravels, locally of considerable size—embedded in a silty-sandy matrix. In contrast, the recent floodplain deposits mainly consist of sandy silts, associated with overbank fluvial deposition during flood events.

It is noteworthy that, during recent floods that severely affected the plain (nov 2023), the inundated areas did not include the alluvial fan sectors.

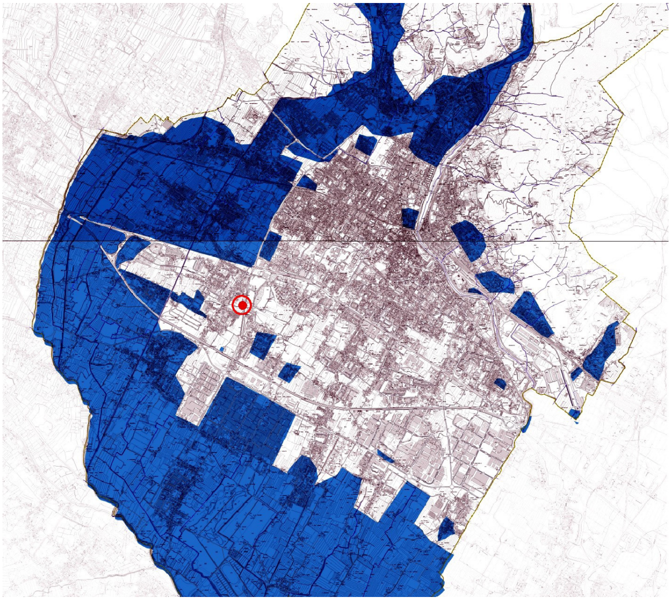


Figure 20. Map of the areas flooded (in blue) after the events of November 2, 2023 (Comune di Prato, 2023).

Climate

According to the Köppen climate classification, the Florence-Prato-Pistoia plain falls into the Cs climate type (humid temperate with dry summers), and specifically into the Csa (Mediterranean) subtype, where the average temperature of the coldest month is between -3.0°C and 18.0°C, and that of the warmest month is above 22.0°C.

Summary data:

- Average annual temperature: 16.3°C
- Average annual precipitation: 905 mm
- Coldest month: January (7.3°C)
- Warmest month: August (26.1°C)
- Driest month: July (28 mm)
- Wettest month: November (124 mm)

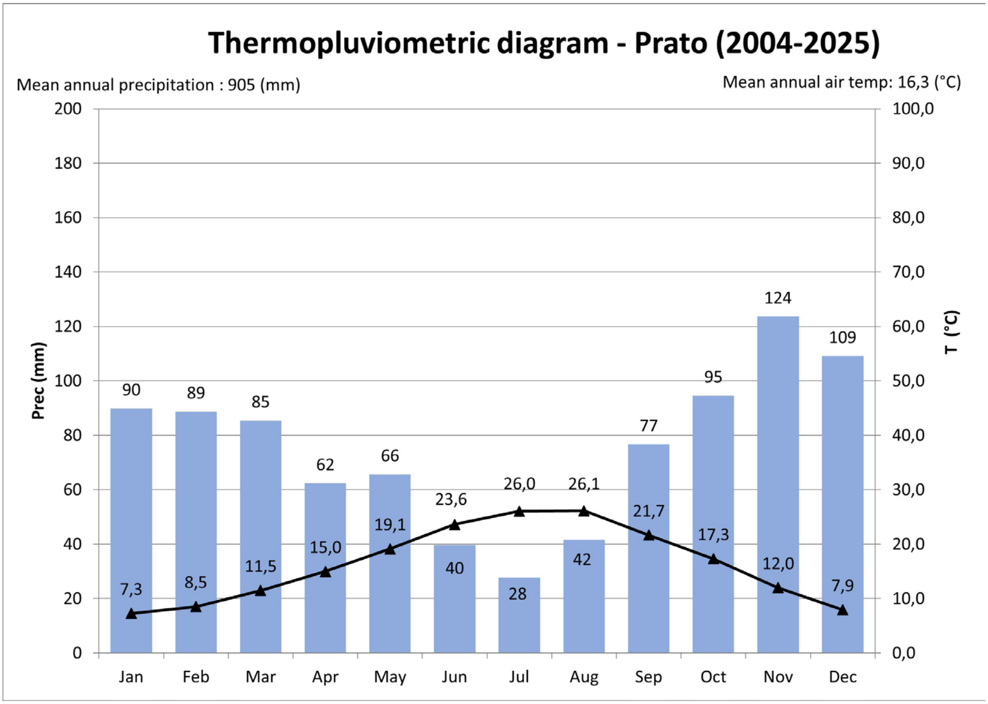


Figure 21.Thermo-pluviometric diagram; station of Prato (2004-2025)

The climate of the plains is characterized by high summers, with frequent heat waves exacerbated by the "heat island" effect of cities. Winters are cold and humid, with possible temperature inversions, especially on clear, windless days.

Soil Taxonomy soil moisture and thermic regime

The temperature difference between summer and winter in the study area is significant. The average summer temperature, calculated for the months of June, July, and August, is around 25.3°C, while the winter temperature, calculated for December, January, and February, is approximately 7.9°C. This results in a seasonal variation of approximately 17.4°C, a value that clearly indicates a non-isothermic regime, i.e., a temperature difference between summer and winter of more than 5°C. The overall average annual temperature is around 16.3°C, confirming that the local climate follows a non-isothermic thermic regime.

Regarding soil water regime, based on the area's Mediterranean latitude and the presence of at least four consecutive dry months, the soil falls into the xeric regime category, although there may be short periods of temporary groundwater saturation in the control section.

The xeric regime is typical of Mediterranean climates and widespread in Tuscany, characterized by hot, dry summers and rainy winters. In these soils, the dry summer period lasts more than 45 consecutive days, while in winter the soil remains moist for at least 90 consecutive days. This alternating moisture cycle strongly influences soil dynamics, soil biological activity, and land management.

Land use and vegetation

The Florence-Prato-Pistoia alluvial plain is one of the most critical areas in Tuscany for processes of artificialization, urbanization, and land consumption. These dynamics, linked to the loss and/or fragmentation of wetlands, agroecosystems, and lowland forests, are accompanied by complementary processes of renaturalization and the loss of agricultural and pastoral environments in the surrounding high hills and mountains.

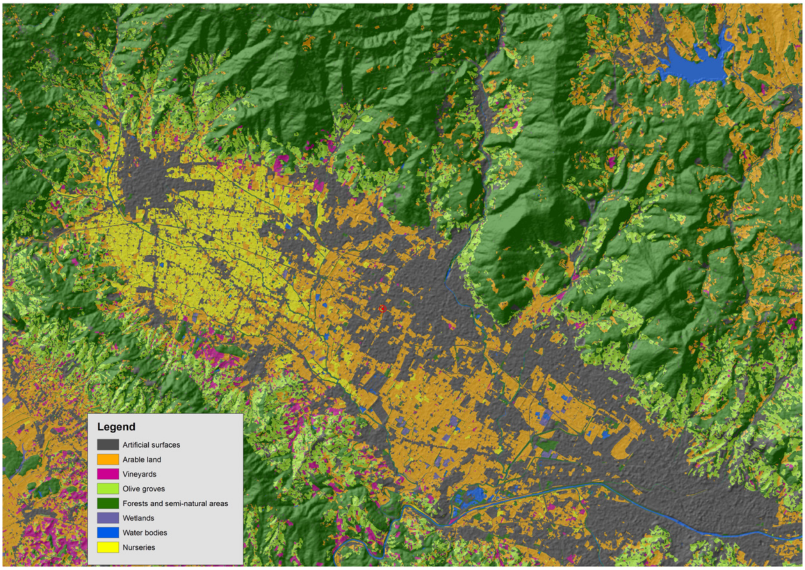


Figure 22. Land cover map of Florence-Prato-Pistoia alluvial plain (Regione Toscana, 2024)

The alluvial plain, together with the Florence–Prato–Pistoia metropolitan system, is characterized by extensive urban development, including large urban centers and suburban areas, scattered residential settlements, extensive commercial and industrial zones, a dense network of linear infrastructure (motorways, expressways, and railways) and energy facilities (power lines), as well as a well-developed nursery industry concentrated in the Pistoia plain and expanding toward the Prato plain.

The plain is highly vulnerable to groundwater pollution due to the nature of its deposits, which provide limited protection for the aquifers. This vulnerability is particularly pronounced in the Upper Plain and Margin areas, where permeable soils and deposits coexist with a relatively shallow water table, reducing the time required for pollutants to reach the surface. Dense urbanization on alluvial fans further alters natural groundwater flow, replacing it with surface runoff, which increases the hydraulic management burden and introduces additional pollutants, effectively transforming a natural resource into a cost.

Watercourses across the plain transport pollutants from urban and industrial wastewater, as well as from agricultural lands and nurseries. Given the entirely human-modified

nature of these territories and the extent of settlement, the plains require continuous maintenance and updating of hydraulic infrastructure, particularly in light of growing uncertainties regarding the stability of historical flood return periods.
In terms of land use, simplified lowland arable fields dominate the Florence and Prato plains, whereas the Pistoia plain is almost entirely dedicated to horticultural cultivation, resulting in a highly artificialized landscape. In the most densely urbanized areas, particularly around Florence and Prato, residual rural spaces are closely interwoven with the built environment, reduced to enclosed agricultural plots primarily consisting of arable land and permanent meadows, and, more rarely, small plots representing remnants of historical landscape organization. These residual rural areas can play a strategic role within the urban fabric, contributing to its morphological, environmental, and functional redevelopment (Regione Toscana, 2015).

The Soils of Prato plain

The soils of the plain (Regione Toscana, 2017) are all of alluvial origin, recent, and poorly developed. The plain can be divided into two main sectors. West of Prato, the fluvial alluvium consists predominantly of sand and sandy silt derived from the erosion of arenaceous-siltitic flysch, resulting in soils that are non-calcareous and primarily silty and sandy in texture. In contrast, starting from the Bisenzio alluvial fan, where we are located, the sediments originate from feeder basins composed of calcareous marl, marly limestone, and clay shale, producing soils with a finer texture and marked alkalinity.
The Ombrone alluvial soils are all non-calcareous, acidic to neutral, and differ in particle size and in the depth of the water table within 150 cm. They belong to the following soil typological units:
Lupori soils (LUP1), Aquic Haploxerepts, coarse-silty, mixed, thermic;
Baldi soils (BLD1), Fluventic Haploxerepts, coarse-silty, mixed, thermic;
Verciano soils (VRC1), Fluvaquentic Dystroxerepts, fine-silty, mixed, thermic.
The soils derived from calcareous and finer deposits up to Florence belong to:
Santa Croce soils (SCR1), Vertic Haploxerepts, fine, mixed, thermic, occurring in backswamp deposits;
Cortenuova soils (CRN1), Fluventic Haploxerepts, fine-loamy, mixed, thermic, occurring in levee deposits.

The Soils of the Prato alluvial fan

The soil map of the Tuscany Region shows that the soils of the natural areas within the Prato alluvial fan have the following characteristics: very deep, with an Ap–Bw–Cg profile, sparsely gravelly, and a loamy to silty texture. They are slightly calcareous in the surface horizon and slightly to moderately calcareous at depth, slightly alkaline at the surface and moderately alkaline at depth, and are moderately well-drained.

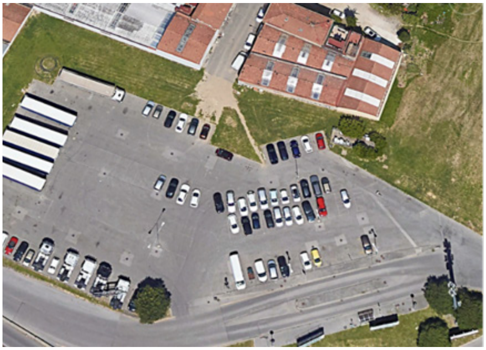
They belong to Sant'Ippolito soils (SIP1), classified as Fluventic Haploxerepts, fine-loamy, mixed, thermic.

3.2 Cost-effective solutions in Urban Soil Management

Giovanni Mastrolonardo, Bianca Rompato, Beatrice Fiore, Giacomo Certini, University of Firenze Dipartimento di Scienze e Tecnologie Agrarie, Alimentari, Ambientali e Forestali (DAGRI), Università degli Studi di Firenze. Firenze, Italy.

Antonella Perretta, Prato City Council

Thanks to the 2020 Toscana Carbon Neutral regional call for proposals, which promoted tree planting to mitigate climate-altering emissions in urban areas, three different areas were created with distinct landscape and agronomic approaches: the first near the entrance to the Pecci Museum of Contemporary Art, the second consisting of linear forestation along Via Rimini, and the third forming a dense woodland that extends from a previously uncultivated area to a park-and-ride facility. Part of the parking lot was converted into a small camper parking zone, while another portion was de-sealed (as shown in the image on the right below). For the de-sealed section, after the removal of approximately 10 cm of asphalt, the area was backfilled with about 40 cm of relocated soil material sourced from other construction works carried out in the city, where the excavated soil had been scraped and preserved. The new parking spaces utilize semi-draining materials, while the driving lanes retain a bituminous surface. The intervention was completed with the planting of 215 trees from 16 different species and nearly 400 shrubs and climbing plants.



The area before the de-sealing intervention (2022)

The area after the de-sealing intervention (2024)

Within the de-sealed area, the soil science team led by Prof. Giacomo Certini (Department of Agriculture, Food, Environment, and Forestry, University of Florence)

obtained permission to carry out an experimental study funded by National Recovery and Resilience Plan (NRRP) through the National Biodiversity Future Center (Mission 4, Component 2, Investment 1.4). A dedicated sub-area within the study site was selected, fenced, and equipped for long-term monitoring.
The aim of the experiment was to reduce the environmental and economic costs usually associated with de-sealing by testing the performance of a Technosol produced from in situ soil materials and the asphalt removed during de-sealing. Typically, de-sealing generates inert waste (dismantled asphalt) and requires exogenous topsoil as backfill material, either alone or mixed with organic or mineral amendments. This topsoil is often sourced from agricultural land or collected from other urban sites, a practice that entails significant environmental and economic costs due to soil depletion and transportation.
As a first step, the quality of the sealed soil materials was assessed. In December 2022, a soil trench was excavated to a depth of about 1 m. Although a detailed pedological study was not among the study's objectives, the soil profile was described and classified according to the IUSS Working Group WRB (2022) classification.

Profile Description

Station data
Location (Municipality and Province) Prato (PO)
Land use: Parking lot
Slope: Flat

WRB Classification (ed. 2022):
Gleyic Ekranic Technosol (Siltic, Carbonic, Ochric) (IUSS Working Group WRB, 2022)
Reference Soil Group: Technosol (soils containing significant amounts of artefacts)

Principal qualifiers Gleyic (gleyic properties, reducing conditions), Ekranic (having technic hard material starting ≤ 5 cm from the soil surface)
Supplementary qualifiers: Siltic (having a texture class of silt or silt loam), Carbonic (having a layer with ≥ 5% organic carbon that belongs to artefacts), Ochric (having ≥ 0.2% soil organic carbon in the upper 10 cm of the mineral soil).

Horizons (according to WRB)

U1	(0-9 cm)	Continuous layer of bituminous conglomerate, black road wear surface, fine grain size, waterproof.
U2	(9-12 cm)	Binder layer made of larger-grained bituminous conglomerate, bituminous binder.
U3	(12-17 cm)	Compacted calcareous gravel, with little fine earth (10-20%). Unstructured and non-pedogenized. Very strong effervescence with 10% HCl on both clasts and fines.
U4	(17-35 cm)	Limestone rock fragments and bricks (the latter prevalent, maximum 10 cm in size) not cemented together but compacted, less than 10% of interstitial fine earth.
U5	(35-52 cm)	Predominantly calcareous rock fragments (maximum 10 cm in size, no bricks), mixed with fine earth (20-30% of the total), apparently and at least partly belonging to the underlying horizon.
Crρδτ	(52-70 cm)	5G 4/1 "dark greenish gray" (dry), stone-free, clay. Massive, very hard, plastic, slightly sticky. No roots, very low porosity, very fine, vesicular. pH 6-7. Sharp and linear lower boundary.
2Crb	(70-90+)	10YR 5/2 "greyish brown" (dry), stone-free, clay. Massive, very hard, plastic, slightly sticky. No living roots, low porosity, very fine, vesicular and tubular (the latter with root remnants). pH 6-7.

Horizon/ layer	c Sand (>500 µm) %	m Sand (500-250 µm) %	f Sand (250-50 µm) %	c Silt (50-20) µm %	f Silt (20-2) µm %	Clay	Texture class
U1-U2	-	-	-	-		-	
U4-U5	34	15	30	3	15	2	Loamy sand
Crρδτ	1	4	34	15	36	10	Silt loam
2Crb	1	5	32	5	45	12	loam

Horizon/ layer	pH	Carbonates	f Sand (250-50 μm) %	c Silt (50-20) μm %	f Silt (20-2) μm %	Clay
U1-U2	7.8	22.3	8.8	-	-	-
U4-U5	7.8	46.6	2.1	-	-	2
Crρδτ	6.9	0	3.5	9.21	1.8	10
2Crb	7.5	0	3.3	11.49	-	12

Analysis of land use changes over time (Figure 24) suggests that the study site was converted from agricultural land into a parking lot as a result of a series of interventions associated with the construction of the main road, the roundabout, and the adjacent buildings. The soil was probably disturbed multiple times by mechanical operations.

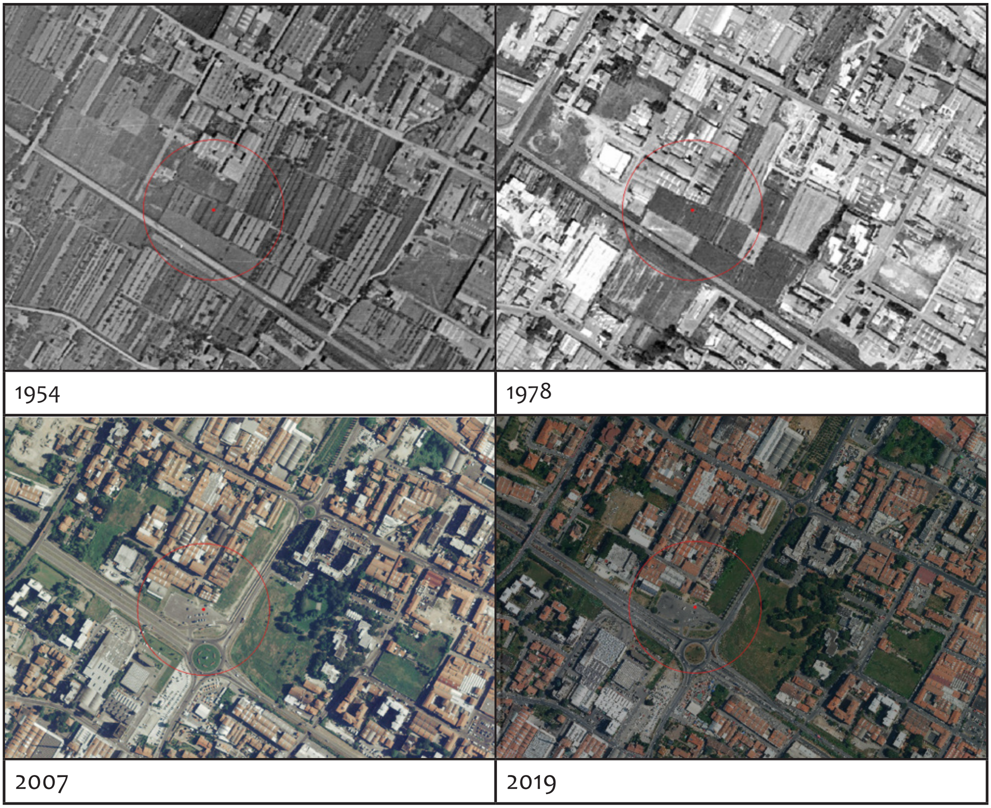


Figure 24. Land-use change analysis of the study area based on aerial photographs from 1954 onwards (photos from Regione Toscana, 2024).

In any case, the soil horizon underlying the artificial impermeable layer—which would have been the main source material for our constructed Technosol—was a greyish, highly reduced, massive, and very hard plastic Crρδτ horizon, and was therefore poorly suited to support prompt and healthy vegetation growth.

For this reason, we chose to use the same relocated soil material applied throughout the rest of the parking area for our experimental site, while focusing on repurposing the removed asphalt within de-sealed urban soils. Rather than disposing of this material as costly landfill waste, its reuse in urban soil de-sealing provides a dual benefit: reducing both the environmental and economic costs of such interventions, while at the same time expanding green and permeable surfaces in cities, yielding direct advantages for both citizens and the environment.

The reuse of milled asphalt (not as a soil additive) is a well-established and sustainable practice in urban areas, regulated by specific provisions that define when the material ceases to be classified as waste and can possibly be regarded as a resource. In Italy, bituminous conglomerate obtained from road milling may attain "End of Waste" status if it meets prescribed chemical and physical requirements and is employed for compatible purposes, such as the production of new hot or cold bituminous mixtures (Ministerial Decree 28 March 2018, No. 69). Under these conditions, asphalt milling is no longer treated as special waste but as a reusable by-product.

The safety of incorporating milled asphalt into soil — considering its effect on grass growth, heavy metal content, and PAH concentrations in both soil and leachates — has also been assessed in two separate pot experiments, with results already published or in preparation (Rompato et al., 2025; Rompato et al., in preparation). In brief, these studies indicate that adding asphalt to constructed soils, even at relatively high proportions, does not pose significant risks to plant growth or the environment, as concentrations of both heavy metals and PAHs remained well below the limits established by Italian legislation for urban green areas.

The experimental area (145 m^2) was divided into three blocks of 5 × 5 m. Every block was further subdivided into four plots (2 × 2 m, 40 cm deep). The plots were excavated and refilled in two layers: the lower 20 cm with relocated soil material originally used to fill the rest of the parking lot, and the upper 20 cm with the same soil material amended with urban waste compost and sieved (<2 cm) milled asphalt. This mixture was prepared to create four treatments with different mass proportions of asphalt (0%, 10%, 25%, and 50% w/w). Compost produced by a composting facility was incorporated into all treatments at a rate of 5% (w/w) to stimulate microbial activity and enhance plant biomass production. The following treatments were established:

- Treatment 0: Urban soil + 5% compost;
- Treatment 10: Urban soil + 5% compost + 10% milled asphalt;
- Treatment 25: Urban soil + 5% compost + 25% milled asphalt;
- Treatment 50: Urban soil + 5% compost + 50% milled asphalt.

To ensure homogeneity and proper integration of the asphalt and compost, all materials were carefully weighed and mechanically mixed prior to application. In March 2024, two months after the materials were placed, a grass seed mixture consisting of *Lolium perenne* L. (two varieties), *Festuca rubra* L. (two varieties), and *Poa pratensis* L. was sown. Irrigation was manually applied only as an emergency measure during the summer of 2024.

Figure 25. Set-up of the experimental site. The parking lot was de-sealed, and the plots were prepared and filled with a mixture of relocated soil, milled asphalt, and urban compost. After a few months, vegetation had successfully colonized the entire area.

Over the past year, the experimental area has been monitored for a range of physical, chemical, and biological soil properties, along with assessments of herbaceous plant growth and diversity. Monitoring will continue in the coming years.

Basic soil physicochemical properties were either unaffected or positively influenced by the addition of asphalt at all rates, both immediately after incorporation and after one year. Some of the added asphalt particles were <2 mm and thus fell within the fine earth fraction, influencing several soil properties. Texture was particularly affected, as many fine asphalt particles had dimensions corresponding to coarse and medium sand (>250 µm), thereby increasing the soil's sand fraction. Despite the asphalt consisting of a binder (bitumen) and carbonate-containing mineral aggregates, the initial sub-alkaline pH of the soils remained unchanged. Bitumen is composed of hydrocarbons that are partially or fully oxidized during both dry combustion and Walkley–Black analyses. As a result, the measured organic carbon (OC) content tended to increase with rising asphalt content, as did the C/N ratio, although this carbon is not biologically available.

Bulk density (BD) was also affected by asphalt addition, showing a decreasing trend with increasing asphalt content. Vegetation growth further contributed to improving soil structure by reducing BD and increasing pore space.

Time	Treatment	BD g/cm	pH	Conductivity mS/m	SOC %	TN %	C/N	Sand %	Silt %	Clay %
0 month	0	1.50±0.09	8.23±0.06	309±21	0.83±0.16	0.12±0.00	7.1	43	44	13
	10	1.44±0.07	8.35±0.07	264±33	1.29±0.16	0.12±0.01	10.4	46	43	11
	25	1.38±0.10	8.27±0.19	305±15	1.60±0.36	0.12±0.01	13.5	47	41	12
	50	1.36±0.12	8.20±0.23	299±75	2.38±0.16	0.12±0.01	19.4	60	30	10
12 months	0	1.35±0.15	8.02±0.12	293±20	1.16±0.17	0.13±0.01	8.6	41±2	53±3	6±2
	10	1.35±0.08	8.08±0.04	285±10	1.37±0.02	0.14±0.01	10.1	42±7	52±6	6±1
	25	1.21±0.18	8.14±0.01	269±15	1.83±0.20	0.14±0.01	12.9	47±3	48±5	5±1
	50	1.16±0.12	8.06±0.06	299±2	2.21±0.10	0.15±0.01	15.2	50±4	44±6	6±1

During the first year of monitoring, the addition of asphalt did not affect topsoil temperature. Although high asphalt concentrations altered the albedo of the soil surface, this effect became negligible once vegetation was established. In contrast, asphalt incorporation reduced topsoil moisture, potentially creating constraints for sustaining vegetation growth and soil biota (Figure 26).

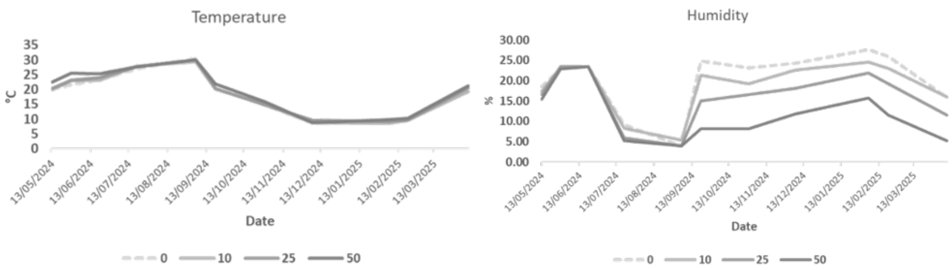


Figure 26. Temporal dynamics of soil temperature and moisture in the top 5 cm during the first year of monitoring.

Nonetheless, the most recent vegetation monitoring activity, carried out in May 2025, did not show any negative effect of asphalt on grass growth. We recorded vegetation cover (%), species richness, the Shannon diversity index, and evenness. The following table reports the mean values ± standard deviation for these variables:

Treatment	Cover %	Species Richness	Shannon diversity (H')	Evenness (J)
0	98±1	13±3	1.167±0.289	0.482±0.045
10	98±2	15±3	1.233±0.289	0.463±0.106
25	98±3	13±0	1.233±0.153	0.480±0.044
50	93±10	16±2	1.700±0.436	0.603±0.133

In total, we identified 43 grass species across the plots. Vegetation cover showed a decreasing trend with increasing asphalt content, although the differences were not statistically significant. Species richness reflects the total number of species present in a community, without accounting for their relative abundances. The Shannon Index (H′) combines species richness and relative abundances into a single measure of diversity, with higher values indicating greater diversity. Evenness (J′) describes how uniformly individuals are distributed among species, ranging from 0 to 1, with values closer to 1 representing a more balanced community. All three indices displayed no statistically significant differences across treatments.

The use of a soil biological quality index, the QBS-ar (Soil Biological Quality based on arthropods), further indicated that asphalt addition did not substantially impair soil health. The QBS-ar is based on the presence and degree of adaptation of soil microarthropods and reflects the soil's capacity to support a diverse and specialized arthropod community. In our experimental plots, annual average values ranged from 60 (treatment 50) to 95 (treatment 25), corresponding to soils of moderate to poor quality. These results suggest a slight deterioration in soil conditions at the highest asphalt addition, although the differences were not statistically significant.

Soil microbial activity was not impaired by asphalt addition, as well. Monitoring of selected soil enzymatic activities showed that the highest asphalt doses did not result in values significantly lower than the control without asphalt, whereas low asphalt additions (10%) had a slightly positive effect.

Time	Treatment	Soil Respiration *mg C-CO_2 g soil^{-1}*	Betaglucosidase *µg pNP g soil^{-1}*	Acid Phosphomonoesterase *µg pNP g soil^{-1}*	Alcaline Phosphomonoesterase *µg pNP g soil^{-1}*
0 month	0	95±32	1070±265	1170±360	1600±650
	10	105±20	900±325	1200±175	1650±300
	25	70±15	680±175	1100±200	1600±350
	50	65±7	900±300	1180±400	1500±375
6 months	0	115±22	630±175	1680±550	2650±300
	10	107±20	1120±500	2200±350	2450±475
	25	115±20	730±375	1900±550	2000±250
	50	62±11	1300±500	1930±400	2900±425
12 months	0	60±30	1100±175	1500±350	2200±350
	10	92±12	1650±550	1300±150	2750±150
	25	45±15	780±250	1250±175	1800±150
	50	48±12	1020±175	1380±225	2650±250

Overall, our results indicate that reusing asphalt milling for soil de-sealing can represent a sustainable, replicable, and strategically valuable approach to urban redevelopment. This practice serves multiple objectives: it enhances ecosystem services, improves environmental quality and soil permeability, and helps mitigate risks linked to extreme weather events. In doing so, it strengthens urban resilience, i.e., the capacity of cities to adapt to climate change and environmental pressures. At the same time, incorporating removed asphalt into new soil mixtures provides a concrete example of the circular economy: a material that would otherwise be treated as waste is reintegrated into productive cycles with added value. This approach not only reduces the economic and environmental costs of construction waste disposal but also valorizes resources already available.

3.3 Bosco delle Neofite

Antonella Perretta Prato City Council

Bosco delle Neofite, (Neophytes' wood) is a project completed in 2024. "Art, oxygen for the mind, plants, oxygen for the body" is the idea behind the forestation project supported by "Associazione Arte Continua," commissioned by Stefano Mancuso and PNAT in collaboration with the Municipality of Prato. Thanks to funds raised in 2022 through a solidarity auction of contemporary artworks, donated to the initiative by more than 15 international artists, the Association supported the creation of a green space with 150 trees and over 400 shrubs.

An olive tree from the Gardens of the Pontifical Villas of Castel Gandolfo, donated by the Vatican's Laudato Si' Center for Advanced Studies, was also planted. During the project's implementation, the Administration encouraged further initiatives in the surrounding areas, including those by private individuals, resulting in a park spanning over two hectares and boasting 250 trees.

A soil profile is presented to highlight the main pedological characteristics, in order to assess soil quality and its capacity to support vegetation and recreational activities. The analysis also considers alterations and limitations caused by fill materials, aiming to identify potential soil improvement practices and ensure environmental sustainability between the soil, existing vegetation, and public uses of the park.

3.4 Profile description

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Station data

Location (Municipality and Province) Prato (PO)

Substrate lithology: alluvial fan deposits, loamy, calcareous;

Morphology: Alluvial fan

Land use: Urban green area

Slope: Flat (<0.2%)

Aspect: --

Drainage: Moderately well-drained

Soil Taxonomy Classification (ed. 2022):

coarse-loamy, spolic, mixed, active, thermic Aquic Xerorthent

WRB Classification (ed. 2022):

Calcaric Transportic Protostagnic Regosols (Loamic, Humic, Prototechnic)

Horizons

The horizon designations used in this profile follow the definitions and guidelines of the USDA Soil Taxonomy (Keys to Soil Taxonomy, 2022, 12th edition).

^Au (0–15 cm): Dry; brown (10YR 4/3); medium granular structure, moderate; slightly hard, friable; loam; common medium angular gravel (20 mm, 10%), mixed lithology, unweathered; redoximorphic features absent; few very fine pores (0.5 mm, 1%); common very fine roots (<1 mm, 15%), vertical; artifacts absent; no effervescence with HCl; clear, smooth boundary.

^2Cu1 (15–60 cm): Dry; brown (10YR 4/3); massive, structureless; very hard, firm; silty loam, gravelly (artifactual); frequent coarse angular gravel (70 mm, 25%), calcareous; common fine angular gravel (25 mm, 10%); artifacts 3–5% (brick, asphalt, plastic); redoximorphic features: few small distinct Fe-enriched masses (10YR 5/6, brownish yellow) and few small distinct Fe-depleted masses (10YR 5/1, gray); very few very fine pores (0.5 mm, 0.1%); few very fine roots (<1 mm), subhorizontal; strong effervescence with HCl; gradual, smooth boundary.

^2Cu2 (60–100 cm): Dry; dark yellowish brown (10YR 4/4); massive, structureless; hard, firm; silty loam, gravelly (artifactual); common coarse angular gravel (70 mm, 10%), calcareous; common fine angular gravel (20 mm, 10%), calcareous; artifacts 3–5% (brick, asphalt, plastic); redoximorphic features: common small distinct Fe-enriched masses (7.5YR 4/6, strong brown) and common small distinct Fe-depleted masses (2.5Y 4/2, dark grayish brown); soft carbonate masses present; very few very fine pores (0.5 mm, 0.1%); roots absent; strong effervescence with HCl; clear, smooth boundary.

^2Cu3 (100–145 cm): Moist; brown (10YR 4/3); massive, structureless; hard, firm; silty loam, gravelly and cobbly (artifactual); frequent angular cobbles (150 mm, 17%), calcareous; frequent angular coarse gravel (70 mm, 17%), calcareous; artifacts present (brick, asphalt, plastic); redoximorphic features: few small distinct Fe-enriched masses (7.5YR 4/6, strong brown) and few small distinct Fe-depleted masses (10YR 6/1, gray); very few very fine pores (0.5 mm, 0.1%); roots absent; strong effervescence with HCl; clear, smooth boundary.

^2Bwu (145–160+ cm): Moist; brown (10YR 4/3); subangular blocky structure, medium to large, moderate; firm, slightly hard; silty loam; common coarse angular gravel (50 mm, 10%), calcareous; few artifacts (brick, asphalt, plastic); lithochromic features rare, dark greenish gray (5G 3/1); few very fine pores (0.6 mm, 0.5%); roots absent; strong effervescence with HCl; lower boundary not observed.

Horizon	Depth (cm)	Sand (0.05-2mm) %	Silt (0.002–0.05mm) %	Clay (<0.002 mm) %	Texture	$CaCO_3$ %	pH (H_2O)	EC (mS/cm)	CEC (meq/100g)	SOC %
^Au	0 - 10	42.70	46.8	10.5	Loam	0.69	6.6	0.65	8.87	2.51
^2Cu1	10 - 60	27.5	55.8	16.7	Silty loam	5.36	7.8	0.65	6.93	2.23
^2Cu2	60 -100	22.2	62.9	14.9	Silty loam	8.45	7.9	0.91	4.27	2.02
^2Cu3										
^2Bwu	145 - 160+	26.2	58.8	15.0	Silty loam	6.20	8.0	0.79	3.64	2.44

Figure 27, Soil profile at Bosco delle Neofite and SUITMA13 partecipants.

Comments for discussion

This soil profile is located on the alluvial fan of Prato, within a recently created public park.

Over the years, multiple interventions have modified the soil surface (Figure 17). The soil was deeply disturbed by mechanical operations during the construction of roads, a roundabout, and large adjacent commercial buildings. These activities involved extensive earth movements and the relocation of soil material.

According to the definitions of the Soil Taxonomy (Keys, 12th ed., 2022), the observed landform corresponds to an anthropogenic landform, as it is sufficiently extensive to be mapped and it appears as a constructional form, a raised land. The presence of artifacts (asphalt, concrete, plastic, and bricks) allows the identification of Human Transported Material (HTM).

As previously reported, soils of the Prato alluvial fan are described as calcareous gravelly loamy soils, whereas soils from the alluvium west of Prato are loamy soils, non-gravelly and non-calcareous.
In the present profile, the ^Au horizon, based on its chemical and textural properties, consists of transported material derived from soils other than those of the alluvial fan. The ^2Cu1 horizon also shows features of transported material, as it is part of the observed landform and contains artifacts; however, its chemical and particle-size characteristics indicate a lithologic discontinuity relative to the overlying horizon. The ^2Cu1 and the underlying ^2Cu2 and ^2Cu3 horizons share a similar genesis and are the result of recent anthropogenic modification: although composed of previously pedogenized material, they are structureless, even weakly, and strongly compacted, likely due to the machinery used during transport and relocation. Evidence of localized waterlogging and soft calcium carbonate accumulations (particularly in ^2Cu2) indicate low hydraulic conductivity, suggesting that these horizons may periodically reach saturation, potentially causing oxygen deficiency for plant roots.
The ^2Bwu horizon exhibits a moderate structure, not destroyed by the compaction of machinery as is evident in the overlying horizons; the similarity, in terms of physical and chemical properties, with the overlying horizons is clear.

Classification according to Soil Taxonomy

The following features were considered: the presence of Human Transported Material (HTM), an Anthropic epipedon (formed in HTM, containing artifacts, ≥ 25 cm thick), the absence of a Cambic horizon, and the occurrence of Aquic conditions within 100 cm.
Among the subgroups of Xerorthents, the Anthraltic subgroup was excluded, as the anthropogenic material is considered transported (HTM).
For Human Altered and Human Transported Material Classes, the Spolic class can be applied.

Classification according to WRB

Horizons ^Au, ^2Cu1, and ^2Cu2 were not interpreted as Terric horizons, which are more typical of anthropogenic interventions aimed at improving soil fertility rather than urban modifications.
Horizons ^2Cu1, ^2Cu2 and ^2Cu3 were not recognized as Cambic horizons due to the absence of structure, color development, and carbonate removal.

Reference Soil Group: Regosols
Principal qualifiers: Stagnic, Transportic, Calcaric
Supplementary qualifiers: Loamic, Humic (≥ 1% soil organic carbon as a weighted average to 50 cm from the mineral soil surface), Prototechnic (artifacts ≥ 5% within 100 cm of soil depth)
Stagnic properties and reducing conditions are present within 100 cm.
The filling appears to date back to the construction of the roundabout (1978-2007). Subsequent leveling and fill additions (horizon A) may have occurred in 2019 during surface remodelling.

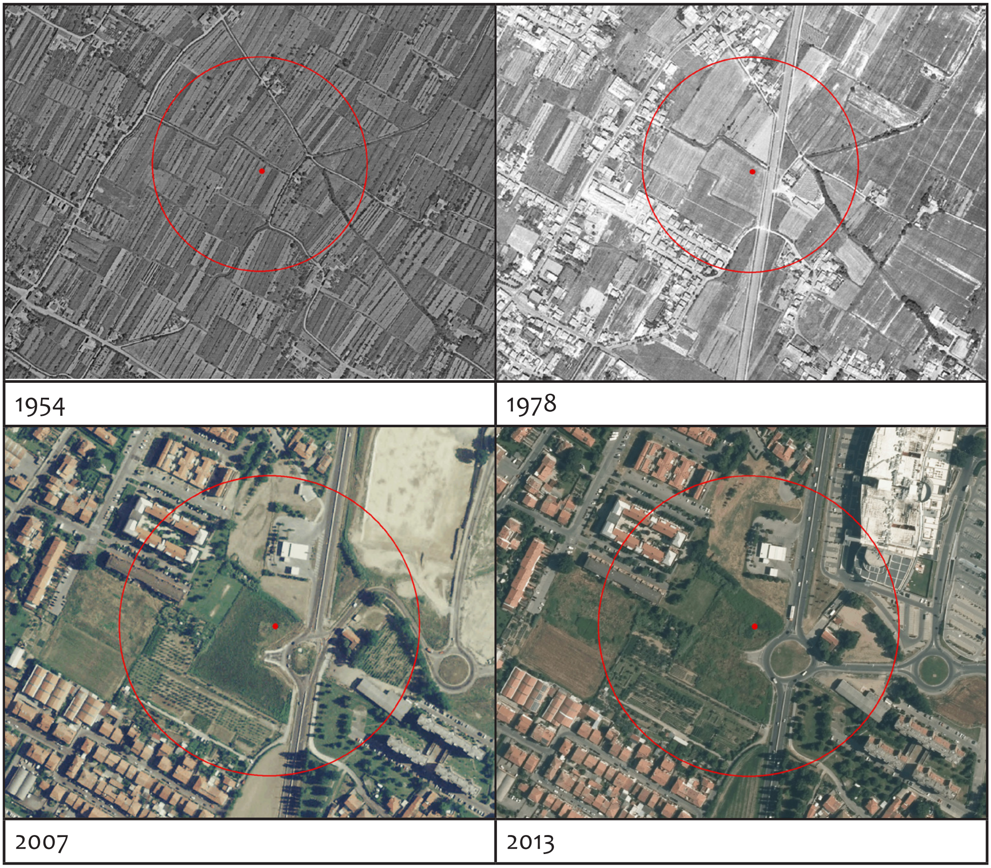

Figure 28. Land-use change analysis of the study area based on aerial photographs from 1954 onwards (photos from Regione Toscana, 2024)

3.5 Public housing greening intervention

Antonella Perretta, Luca Piantini Prato City Council

Project co-financed by the European Regional Development Fund (ERDF) through the Urban Innovative Actions program in 2019 and concluded in 2023, with the goal of transforming urban marginal areas in green well-being zones. The actions included four pilot sites and the production of two guidelines for interventions at the urban scale and for the building and its appurtenances (https://www.pratourbanjungle.it/it/pagina1943.html).

Figure 29. The buildings in via Turchia before the interventions

The Via Turchia complex, completed in 1994, contains a total of 102 public housing units. The project, designed by Stefano Boeri Architetti, included the removal of the approximately 1,600 m2 parking area for transforming in semi-draining paving, the planting of vertical greenery to mitigate the temperature of the houses, the construction of a large green pergola at the entrance, and the creation of social spaces in the shared garden. Furthermore, by using rainwater wherever possible, intercepted and collected in a system of underground cisterns, water consumption is reduced. One of the most interesting aspects of the project is the relationship with the residents, who, initially hostile, have taken care of the plantings two years after the project's completion.

Figure 30. Project by Boeri Studio (Delibera della Giunta Comunale 132/2021).

Figure 31. Public housing complex after the greening intervention and the participants to the SUITMA13 visit.

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SUITMA13