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Recognizing the Importance of an Urban Soil in an Open-Air City Museum: An Opportunity in the City of Madrid, Spain

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Abstract: This article examines the presence of urban soil buried under anthropogenic debris in an air-museum park in the Madrid city center (Spain), and highlights the particularities of this singular urbanized setting to indicate ecological evaluation options for soils. The study of a soil profile (with a thickness of about 2.30 m), classified as Urbic Technosols, allowed us to devise that it is formed by a series of filled-in amounts of artifacts (construction debris and other anthropogenic waste) of about 10–30%, plus organic and mineral materials. These soils' composition and morphology depend on the natural conditions of the territory and also on anthropogenic activities. The soil properties (analyzed by conventional techniques) are moderate in acidity reaction and have relatively higher organic matter content. The Pb, Cu and Zn concentrations in anthropogenic horizons do not exceed the approximate permissible concentrations by 1.5–10-fold. Over the course of time, the soil profile has been transformed as a result of the impact of pedogenetic processes developing under the Mediterranean climate and man's hand. Although urban environments present a certain complexity, at least the role of soil should be recognized regarding flood mitigation, recycling of wastes and toxins, filtering of nutrients or carbon storage and GHG regulation. The analysis of our results concludes the need to better perceive this soil profile and its green space to improve the urban ecosystem and to ensure better citizen well-being.

Keywords: urban soils; cultural soil; pedogenesis; ecological engineering; urbic technosols; artifacts; soil transformation; urban environment

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1. Introduction

Urban soils are defined as soils severely influenced by several human activities, except for those performed for cultivation purposes. Like natural soils, urban soils provide a wide range of ecosystem services [1] and are particularly significant given their increasing relevance in green cities. However, according to Puskas and Farsang [2], urban soils differ from natural ones insofar as they are more strongly influenced by anthropogenic activities. This means that the essential role that soil plays in urban landscapes is often underestimated because the soil is often covered by buildings and houses, asphalted streets, cement benches, underground transport systems and other man-made structures.

Soil is a key resource to not only produce food but also to maintain water and ecosystem health by helping to maintain biodiversity and important cultural functions in parks and gardens. Urban soils are generally characterized only from their view of geotechnical properties, or more recently, contamination levels. In fact, urban planners do not consider urban soils to be potentially living resources or to form part of an urban ecosystem that is capable of performing highly diversified functions and providing ecosystem services. Conversely, the reality lies in their potential contribution to urban planning not always being well appreciated and they should be taken into account by city managers when dealing with major urban environmental issues. In other words, policymakers and planning operators rarely consider soils to be living resources capable of performing and fulfilling essential functions.

Urban soils are a vital element of the city environment [3], whose ecological use is missed by the population. Residents perceive public green spaces in different ways. The United Nations' Agenda 2030 defines 17 Sustainable Development Goals (SDG) to be fulfilled in the present decade [4]. Particularly, SDG 11, "Sustainable Cities and Communities", is closely connected with universal access to public green spaces. In an urban context with a growing global urban population, public parks and gardens can provide spaces for recreation, coming into contact with nature, and fulfilling different social and cultural needs [5]. The importance of urban green spaces for improving resilience and adaptation to new challenges (i.e., climate change, urban growth, social inclusion) was recognized by several authors, such as Colding and Barthel [6], Ferreira et al. [7], and Meerow and Newell [8]. Moreover, these spaces provide many ecological, psychological and social benefits [9,10].

Ecosystem services are defined as the benefits that human populations obtain directly or indirectly from an ecosystem (e.g., climate regulation, food production, energy supply) [11–13]. This ecosystem concept was recently transferred to urban environments [14]. It refers to specific aspects such as carbon storage in cities and global climate regulation [15], urban heat island regulation [16] and green infrastructures [17].

Soil quality is important to determine ecosystem services and soil quality is assessed using several indicators (e.g., soil texture, pH, organic matter content, available nutrients) that are aggregated into the main indices (e.g., structural stability, chemical fertility) [18,19].

Soil studies related to urban areas began in the 1970s and 1980s. In fact, interest in urban soils is relatively recent [20–31] and the focus is placed primarily on geotechnical or soil pollution. Many urban soils are no longer similar to the original or natural soils in an area or region, their functionality is expected to depend on their quality and they are naturally bound by soil properties.

In many regions of the world, urban soils support plant growth and biogeochemical cycles and they maintain urban green spaces by promoting ecosystem functions and services. Therefore, knowledge about urban soil properties is essential for improving urban ecosystem services and management, and even for detecting pollution.

Normally urban soils are severely degraded by the enormous anthropic activities that take place in their locations and surroundings. This results in them being morphologically degraded and contaminated, especially by heavy metals and polycyclic aromatic hydrocarbons. Characterizing these potentially degraded and contaminated soils is, therefore, necessary to identify a city's environmental health.

As in other cities, the inhabitants of the city of Madrid benefit from soil structure and functions because they act via a number of ecosystem goods and services, such as garden areas, sports areas, water and temperature regulation, etc., which all contribute to quality living. Therefore, accepting soil as a natural resource, which is fundamental for the valuable goods and services that it provides society with, involves recognizing the importance of soil requirements.

Although there is a soil map of the Community of Madrid [32] and this community works to help promoters and entrepreneurs through the so-called Land Portal 4.0 (https://www.comunidad.madrid/inversion/inicia-desarrolla-tu-empresa/portal-suelo-40 accessed on 14 April 2022), the truth is that hardly any studies into soil profiles in the city of Madrid are available.

The Castellana Open-Air Sculpture Museum, located in the Paseo de la Castellana (which forms part of the north–south axis that runs through Madrid), covers just over 4000 m^2, most of which is under the deck of a bridge with landscaped areas on either side. In these landscapes, the presence of a genuine and representative edaphic profile of the urban soils of the city of Madrid has recently been evidenced when making an improvement to the physical place where this museum is located.

According to Burghardt et al. [33], there is a marked need to explore soil profiles to gain an idea of what can be expected in urban areas. In this context, the present study aims to: (i) contextualize and emphasize the original features of a soil profile in the urban ecosystem of a big city such as Madrid; (ii) determine the share of natural and anthropogenic features in the studied soil; (iii) analyze a list of ecosystem services that can be provided by urban soils such as those herein studied; and (iv) analyze an urban soil quality assessment to formulate propositions to improve future urban planning. It is expected that the results of this study may be valuable for the authorities to issue guidelines for better management of urban soils, underlining the environmental role that soils play. It should also help to reflect on whether an urban land profile can be exhibited as one more piece in the context of an open-air museum.

2. Material and Methods

2.1. The Study Area

The city of Madrid lies in the center of the Iberian Peninsula and the Central Plateau (40°25′00″ and 3°42′00″) and covers an area that is slightly larger (Figure 1) than 600 km^2. It has a resident population of around 4,500,000 inhabitants (Pérez-González et al., 2022). In topographical terms, it occupies a flat-to-undulating surface (with low hills and elongated troughs) in the "Campiña" countryside, a transition area between the Sierra de Guadarrama and the Madrid Basin on tertiary Neogene materials of a detrital nature in the study area [34].

Figure 1. Location of the studied soil profile.

The Madrid region forms part of the structural geographic unit commonly called the Central Plateau. In this territory, a series of large physiographical units are distinguished, namely, the Sierra, Piedemonte, Rampa, Campiña, Vegas and Páramos [35], which contribute to form a notable diversity of territorial spaces, landscapes and soils [32,36,37]. Soil diversity is manifested by the presence of Entisols, Inceptisols, Alfisols and Mollisols (following Soil Taxonomy criteria). It is also worth noting the presence of Histosols and Ultisols in certain mountain areas.

The nature of the material that originates from the soils of Madrid and its immediate surroundings are fundamentally Miocene arkose deposits. Obviously, the anthropic incidence in the vicinity of Madrid is increasing, and in such a way that most of the ramp's surface is occupied by urban settlements, which have determined the disappearance or deterioration of soil.

From a climate point of view, it is Mediterranean with a continental hue. During the 1981–2010 period, the mean annual temperature was 14.5–15 °C with 371–428 mm annual rainfall. Summer droughts take place from June to September with equinoctial maximums. October, November, December and May are the wettest months (41–60 mm/month). From a vegetation point of view, pine (*Pinus pinnea* and *Pinus halepensis*, 34.3%) and holm oak (*Quercus ilex*, almost 17%) clearly predominate, to which *Cupressus arizonica*, *Platanus hybrida*, *Ulmus pumila* and *Sophora japonica* (16.2%) are added [38].

2.2. Profile Site Description: The Anthropogenic Soil Profile

Research was carried out in the Castellana Open-Air Sculpture Museum (Figure 1) located in Madrid under the Enrique de la Mata Gorostizaga bridge, which connects Juan Bravo street with that of Eduardo Dato on "Paseo de la Castellana". Its coordinates are 40°25′59″ N 3°41′15″ W. This museum, which was created in 1972, contains an excellent collection of 17 abstract sculptures by Spanish artists. It was one of the first of its kind in Europe during the wake of other similar venues, such as the Vigeland Park in Oslo or Middelheim in Antwerp.

This zone forms part of the so-called "Ensanche de Madrid" (the Madrid Enlargement), which was a later urban plan by Carlos María de Castro or an urban response to an increasing population based on the construction of an orthogonal N/S network of streets of different sizes built by means of squares.

Figure 2 shows how soil profile patterns (including the garden soil at the top) are not spatially uniform, which is probably due to the different urban planning periods during which the square was remodeled. As is normal in urban soils, the profile shows temporo-spatial heterogeneity [24,39] because exogenous (anthropogenic) materials were mixed and added, which lead to wide spatial variability. Along the almost 4 m that the profile measures, artifacts such as loose fine rubble, tar masses, ash and bricks, slag and waste, sewer ditches filled with sand, and likely mixtures from sludge, are visible (Figure 2). Stony and compacted materials partially hinder vegetation growth.

Figure 2. Garden soil profile formed of an artificial mixture of several internal and external artifacts. Samples 1 to 10 correspond to the analyzed soil samples. Sample 2 depicts the bricks, rubble and debris substrate mediums embedded in horizon Bwp; Samples 4, 6, 7 correspond to humic topsoil above mixtures of arkose material, ash and bricks, and probably sludge; Samples 9, 10 are horizons on slightly sealing-consolidated and not segregated substrate, partly crushed and massive. At the bottom, a sewer ditch filled with sand and other cement materials.

A series of degradation processes of the soil profile is distinguished and is closely linked with the stages followed to build and develop the square. Topsoils are moved, mixed and compacted by garden and construction activities. Truncation processes are clearly noted because it was observed how the surface horizon was removed from the soil profile, which was buried by added material, especially debris deriving from excavation and construction activities.

Samples 1, 2 and 3 correspond to the most recent soil. The oldest buried soil is formed of Samples 4 and 8. Sample 8 represents the most natural parent material of the entire profile and can be considered the starting point (specifically as regards the elemental contents as a true geochemical background). Samples 1, 5, 9 and 10 are the recent anthropic horizons, which extend to the profile's top surface width. What differentiates Samples 9 and 10 from Samples 1 and 5 is that they are apparently more contaminated. Samples 4, 6 and 7 represent the spatial dimension of the buried soil's surface horizon. Table 1 provides the most significant features of the profile's horizons.

Table 1. Important features of the profile's horizons.

Sample Number	Horizon/Depth (cm)	Color Munsell	Artefacts (%)	Structure	Others
1	Ap 0–24	10YR8/2	20	Moderate subangular blocky medium to fine	Abundant roots
2	Bwp 24–73	10YR5/6	25	Very strong in very thick angular blocks	Hardened (artifacts)
3	C1p 73–148	10YR7/4	5	Very strong in very thick angular blocks	-
4	Apb 148–168	10YR5/4	5	Moderate subangular blocky fine	Buried Ah
5	Ap 0–26	10YR5/2	25	Strong in very thick angular blocks	-
6	Apb 176–202	10YR5/2	25	Strong in very thick angular blocks	Buried Ah
7	Apb 170–198	10YR5/3	5	Moderate subangular blocky medium to fine	Buried Ah
8	C2 >230	10YR7/6	0	Simple, weak, particular	Arkose. No roots. Parent material
9	Ap 0–19	10YR4/3	10	Moderate subangular blocky fine	Frequent roots. Possible contamination
10	Ap2 30–62	7.5YR7/4 and 5Y6/2	30	Strong in medium-thick angular blocks	No roots. Possible contamination

2.3. Analytical Methods

Particle size distribution, pH, organic matter and electrical conductivity were determined by standard procedures for soil research purposes. Particle size distribution was established by the hydrometer method [40]. pH was determined in H_2O solution, 1:5 soil/solution ratios (potentiometric method); organic matter was established by calcination at 1000 °C; electrical conductivity was measured by conductometry.

Samples were air-dried, gently crushed and sieved at 2 mm. A portion of each sample was further ground at 0.15 mm. Although contaminants can be both inorganic (eg, Pb, Cu, Zn) and organic (e.g., polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins), only the former is herein addressed. A bulk elemental analysis was carried out by aqua regia digestion (HCl/HNO_3, 3:1 solution) and measured by inductively coupled plasma-mass spectrometry (Perkin-Elmer Sciex Elan 6000 equipped with an AS 91 autosampler).

Samples' mineralogical composition was determined by powder X-ray diffraction (Malvern Panalytical, Madrid, Spain) using a PANalytical X'Pert PRO X-ray diffractometer equipped with a Cu anode. Its operating conditions were 40 mA, 45 kV, 0.5° divergence slit, and 0.5 mm slit reception. Samples were scanned with a step size of 0.0167° (2θ) and 150 ms per step. Samples characterization was carried out by the random power method, operating from 5° to 80° (2θ) [41]. The measured patterns were qualitatively and quantitatively analyzed using Match v.3 and the Fullprof software for the Rietveld analysis, respectively, software with the Inorganic Crystal Structure Database (ICSD) and the Open Crystallography Database [42].

3. Results

The studied profile containing various artifacts (consisting mainly of remains of buildings constructed with wood, stones, bricks, or other materials) was affected by pedogenic processes. Thus it is simultaneously soil, sediment and a cultural layer. It is very stony, has a neutral reaction, and is enriched by organic matter (Table 2 and Figure 3) and several "typically named" urban elements [43]: Pb, Cu, Zn and As (Table 2 and Figure 4). The following heavy metal contents (in mg/kg) were recorded in the soil profile: Pb 68.5–17.9, Cu 21.3–3.74, Zn 65.2–13.1, As 7.9–1.3, Cr 13.5–1.7 and Cd 0.03–0.8 (Table 2). The origin of these elements can be associated with the natural parent material and pipes, cables, foundations and paints, which are typical urban soil components. The high Pb concentrations are most likely related to transport and roadway sources. The mean concentrations of the urban elements in this soil are similar or slightly lower than the data reported by De Miguel et al. [44] and Izquierdo et al. [45] for urban soils in Madrid.

Table 2. Summary statistics of the analytical results.

Parameter	Mean	Standard Deviation	Maximum Value	Minimum Values
Na_2O (%)	1.4	0.2	2.1	0.8
MgO (%)	0.1	0.0	0.2	0.0
Al_2O_3 (%)	22.3	1.9	30.6	13.8
K_2O (%)	0.8	0.1	1.6	0.4
CaO (%)	0.5	0.0	0.8	0.3
TiO_2 (%)	0.1	0.0	0.2	0.0
MnO (%)	0.0	0.0	0.1	0.0
Fe_2O_3 (%)	1.9	0.3	4.1	0.9
SiO_2 (%)	72.9	2.4	83.3	60.6
pH	6.9	0.3	8.2	4.9
EC (dS/m)	0.145	0.05	0.63	0.024
Organic matter (%)	2.9	1.17	9.6	0.1
Pb (mg kg^{-1})	44.3	5.4	68.5	17.9
Cu (mg kg^{-1})	12.1	2.1	21.3	3.74
Zn (mg kg^{-1})	40.1	6.1	65.2	13.1
As (mg kg^{-1})	2.8	0.5	7.9	1.3
Cr (mg kg^{-1})	7.4	1.5	13.5	1.7
Cd (mg kg^{-1})	0.2	0.07	0.8	0.03

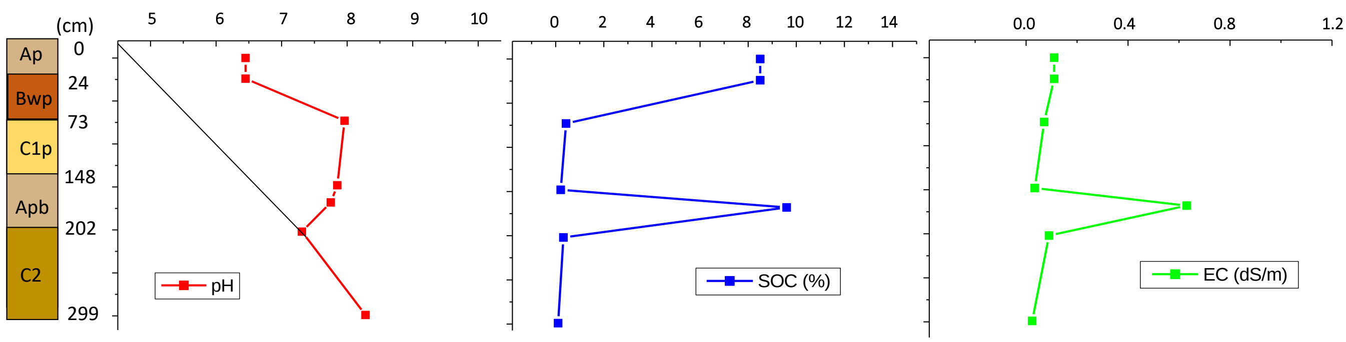

Figure 3. Values of pH, soil organic carbon (%) and electric conductivity (dS/m) in the studied soil profile.

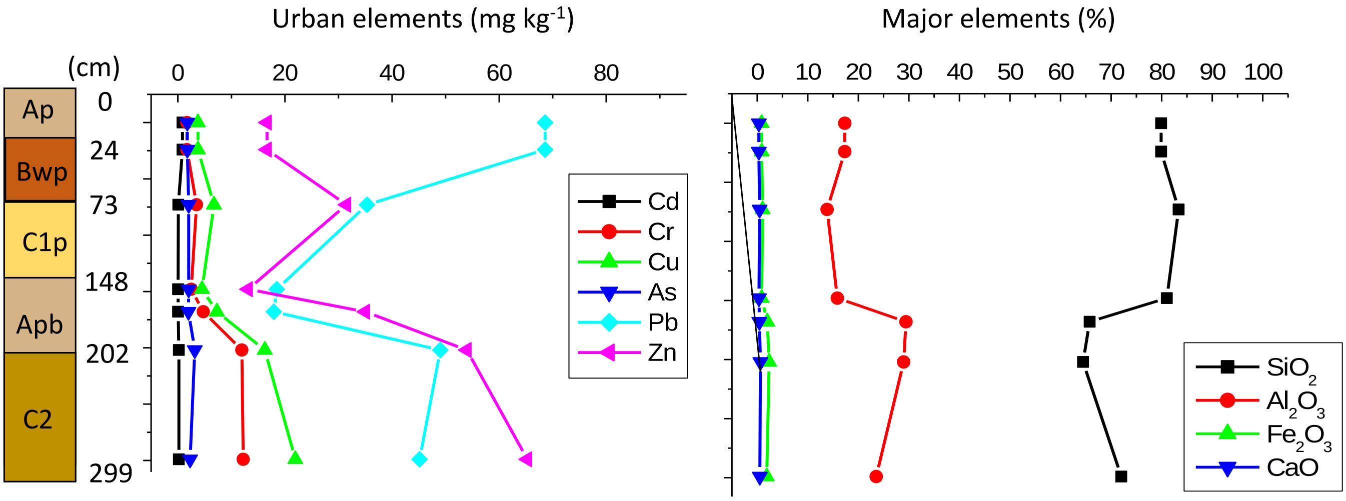

Figure 4. Values of typically urban elements (mg kg^{-1}) and the main major elements (%) of the studied soil profile.

In the soil profile, a section (top) comprising three horizons (fully anthropic) is distinguished, while the bottom section consists of two horizons of seminatural soil. The reaction is slightly acid or neutral because pH values range from 4.9 to 8.2 (Figure 3). The rise or fall in pH values is partially due to the production of acids during organic matter decomposition. Electrical conductivity oscillates between 0.024 and 0.630 (dS/m) and organic matter contents vary from 0.1 to 9.6 (%) (Figure 4). Regarding texture, sand content oscillates between 11 and 74 (%), while clay content varies from 5 to 62 (%) (Figure 5). All these values show the origin of the materials making up the soil profile in light of what was pointed out by Greinert [46] about the heterogeneity of urban soils.

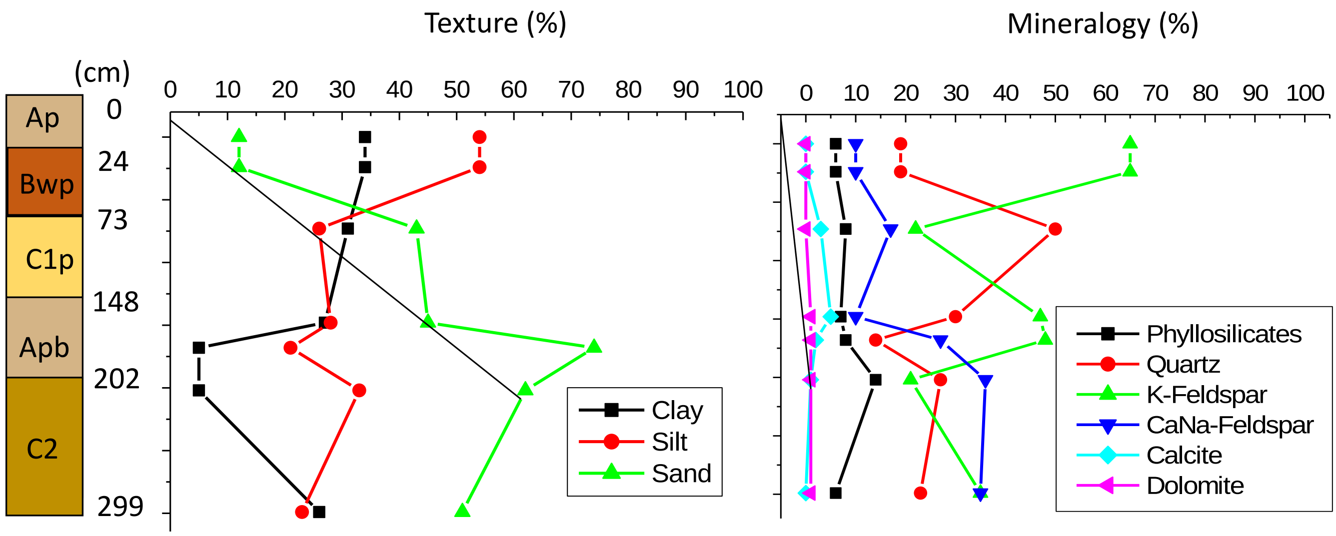

Figure 5. Texture and mineralogical composition of the studied soil profile.

In mineralogical terms, feldspars predominate, of which K ones are the majority (between 7% and 65% compared to calcosodic ones, which vary from 10% to 55%). It is followed by quartz (from 14% to 52%) and, to a lesser extent, by phyllosilicates (from 6% to 14%) (Figure 5). Of phyllosilicates, illite abounds, followed by smectite. Only in two samples does some kaolinite appear. This whole set of minerals is native to the soils on the arkose deposits in the Madrid region, as shown by Jimenez-Ballesta et al. [36,37] and Vigil et al. [47].

Calcite and dolomite are present (Figure 5). Different authors, such as Renforth et al. [48] and Washbourne et al. [49], have observed the formation of pedogenic carbonates in relation to the precipitation phenomena of soil solution in urban soils. However, this is not the case in our profile.

Our findings indicate that soil properties considerably change along the soil profile, which is consistent with our hypothesis. The soil profile showed a certain resemblance to other natural soils in the region (except for the high organic matter content in some horizons): moderate acidity, sandy or loamy sandy textures and the electrical conductivity values are low. Construction activities impact existing soils, which, therefore, possibly invokes the aforementioned effect [21,24] on urban areas, namely anthropogenic lithogenesis.

4. Discussion

The factors that have influenced the formation of the studied soil (substrate or original material, climate, topography, biota, time) are essentially the same as those that impact the formation of natural soils in the environment. However, the anthropic factor plays a fundamental role. According to Morel et al. [39], the human factor means that transformation cycles are very fast compared to those of natural conditions.

In their initial stage, the parent materials that have built the studied soil profile are medium and coarse sands (arkose) of Miocene origin. These materials have joined the technogenic parent materials of soils of anthropogenic origin, which are a characteristic feature of urban areas. These compositionally very diverse materials display wide spatial variability. Over time, these urbo-sediment deposits have been transformed due to the impact of pedogenetic processes [50] that have taken place on urban soil. Obviously, miscellaneous materials present several properties, which entail a potential impact that can modify morphology, soil properties and soil evolution. Although soils become very compacted during their deposition and will develop a perched water table, given the slope on which soil is located and its texture, no gleyc soil properties are observed.

Guilland et al. [51] recently discussed the definition of urban soils. However, a general agreement was reached that urban soils are frequently characterized by strong horizontal and vertical heterogeneity. Many authors emphasize the strong heterogeneity of urban soils [46,52]. Indeed, along the vertical profile, it is possible to observe changes that consist of the partial truncation of the soil profile and the replacement of removed horizons with new, albeit not very different, materials: sand, clay, gravel and organic matter for construction purposes or for developing green areas. Schematically, the formation of the studied soil would obey a process that begins with an A-Bw-C morphology. A soil decapitation process (deprivation of humic and organic horizons) would then take place, while a mixture of rubble and other waste, land and leveling would be added to culminate in a new plant covering. Despite Park et al. [53] noting that soil chemical properties vary with urban age, this would not appear to be the case in our study. As a result, abrupt and clear boundaries of layers and horizons prevail in the soil profile. Thus organic urbo-soil has formed over time, which has transformed into soil as a result of low-intensity pedogenetic processes.

Many scientific studies have revealed the significance of anthropogenic urban soils in both ecological soil management and land-use planning. The spectrum of both internally and externally introduced substrates in urbanized areas results in a high diversity of urban land properties in small areas [22] (Bullock and Gregory, 1991).

Current and predicted trends indicate that an increasing proportion of the world's population is living in urban and suburban places [54]. More specifically, [55–57] stated that, at present, approximately 52% of the world's population and 73% of the European population are urban dwellers. Therefore, the soils they walk on or in which their plants live must have, as far as possible, a certain environmental quality. Pedologists or soil scientists have generally interpreted that urban soils are often regarded as off-topic, and in such a way that one cartographically speaks of "nonsoils". Fortunately, today, this trend has changed.

Inorganic carbon occurs much more frequently in urban soils than in rural areas, which explains why the profile contains a slightly higher carbon content than surrounding natural soils because carbon can occur as either organic carbon from decaying plants and animals or inorganic carbon from ashes and soot.

4.1. Geochemistry: Diversity of Heavy Metal Content

Urbanization and industrialization have generally affected trace elements in soils of large cities such as New York [58,59]. As some heavy metals slowly and gradually accumulate in the soil, soil can act as both a sink and a source of these pollutants. Although many trace elements are present in the original material from which soils have developed, numerous anthropogenic activities tend to increase trace element contents in urban soils [60,61]. Management without adequately understanding soil quality can actually worsen human health [62], and it usually focuses on eight heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb and Zn).

Of all potentially toxic elements, Cu, Pb and Zn are commonly found in European urban parks and were recognized for having a particular urban signature [63–65].

Despite the bulk composition of the studied urban soil largely reflecting natural sources, the soil is significantly enriched in some trace elements, apparently from anthropogenic sources. Therefore, although the burning of fossil fuels and traffic are the main sources of some trace elements [64,66], the results indicate that the cumulative processes of only some elements are observed.

The results unexpectedly show that the quality of the soil in each sampled horizon is medium-to-high. For example, the total lead concentrations do not exceed the USEPA [67] limit of 400 mg kg^{-1} for children's play areas on bare soil.

The role of organic matter in urban soils is important for the retention of the so-called urban metals (Cu, Pb and Zn). Except for Pb, it cannot be stated that levels rich in organic matter constitute layers that favor the retention of the aforementioned contaminants.

4.2. Soil Classificacion

Technosols as soils from manufactured materials are already included in the World Reference Base for Soil Resources [68]. Materials of technogenic origin, such as construction debris, slag, dust, rock material, lignite, coal, municipal waste and sludge, are currently considered parent materials for Technosols. Specifically in the study profile, artifacts such as bricks, pottery, glass, crushed or dressed stone, industrial waste, garbage, and processed oil products appear.

Certainly, in the successive versions of the modern World Reference Base for Soil Resources, a new soil group Technosol was created; soils have been considerably modified by human activities and contain a high proportion of technogenic objects or materials (concrete, bricks or plastic). As per Rodríguez-Espinosa et al. [69], Technosols are soils designed with the intention to provide equal ecosystem services to those offered by natural soils. Scientifically, they match the so-called Anthropocene very well. Therefore, the soil under study can be classified as Urbic Technosol (Eutric, Transportic) over Urbic Technosol (Loamic, mollic terric) because it is generally understood that Technosols are soils that include all kinds of man-made materials, and are exposed to or transported by human activity that would otherwise not occur under natural conditions in a specific location on the Earth's surface.

4.3. Benefits of this Small Urban Green Space: Ecosystem Services

In the report of EEA [55], the notion that lies behind urban soil is that it is explored as an integral part of ecosystems by focusing on the flows of the valuable goods and services that can derive from it. Therefore, it is not surprising that soils in urban areas are included in the so-called "Thematic Strategy for Soil Protection" of the European Commission.

Many benefits and dangers of urban soils are recognized [24,39]. Burghardt [26] and Adhikari and Hartemink [70] point out that urban soils play a major role in stormwater infiltration (groundwater renewal), climate regulation and heat mitigation, and also in carbon sequestration. However, these functions differ according to the diverse types and ages of urban land use. Urban soils are studied primarily for their role in creating a sustainable environment, and they are also important for health [71]. According to Cheng et al. [72], urban soils are a critical resource that can play a key role in the long-term sustainability and resilience of cities. Therefore, a more careful urban soil policy is necessary for large cities.

Soil used in an urban context requires it to be suitable; that is, it should possess the appropriate characteristics for its use in question. In the study case, given its characteristics, especially structure and porosity, our studied soil has the capacity to regulate water and temperature, and also air quality, in a certain way.

Considering soil sealing versus soil maintenance in the green infrastructure, it is evident that, and as pointed out by Burghardt et al. [71], soil sealing interrupts any contact between edaphic and atmospheric environments and, therefore, changes gas, water and material fluxes.

Despite the scarce territorial space that the studied soil occupies, it improves the thermal comfort of the city's inhabitants, an effect that is more evident at peak summer times. Indeed the Castellana Open-Air Sculpture Museum stages a public park but also a critical environmental compartment. At this point, it is worth highlighting the role played by soil because this square suffers (exacerbated by soil sealing) from heat islands. Therefore, in this sense, soils such as those herein studied imply clear environmental well-being.

In general, anything that is usually carried by urban rainwater (e.g., particles, nutrients, metals, organic matter, oils and fats) tends to remain in the soil. Coinciding with the generation of storms (a typical process of the Mediterranean regime), certain rain peaks occur and large volumes of stormwater runoff are generated, which exceed sewer capacity. The result is localized flooding. In this situation, soil acts as a bioretention system and provides a "green infrastructure" that helps to manage stormwater runoff.

Finally, although it is true that soils are a scarce resource in the city to the extent that scientists, architects and engineers have started regarding soil construction, this possibility is still a long way off. Let us not forget that, according to Aleksandrovskaya et al.'s [73] ideas, the studied soil profile can also be considered a cultural layer. Consequently, its conservation means environmental improvement, urban planners and policymakers must take this into account when developing urban transformations and renovation plans such as those recently carried out in the Castellana Open-Air Sculpture Museum in Madrid, Spain.

5. Conclusions

The morphology, composition and physico-chemical properties of the soil urban horizons in a functional zone of Madrid were studied. The results obtained from this research underline the hypothesis of the need to make green spaces available. The urban soil in the Castellana Open-Air Sculpture Museum is characterized by horizontal and vertical heterogeneity. The studied profile represents a Technosol example of a pedolithogenic system because it includes buried soil, and the urban sediment and surface soil that develop from it are formed during the impact of interrelated pedogenesis and technogenesis processes (anthropogenic factor diagenesis). The presence of technogenic materials is a key factor that differentiates urban soils from the natural environment. Pedegenetic traits are somewhat poorly developed because the soil formation time was limited and interrupted by urban anthropization phases. Therefore, the studied soil can be considered a pedolithogenic system. There are no definite regularities in the distribution of the major and trace elements in the anthropogenic soil horizons. The studied urban soil plays a role in creating a sustainable environment. As a corollary, the need to educate citizens, architects, urban planners and legislators to manage, care for and improve urban soils to provide the required ecosystem functioning is evident. Finally, the results of this study should be taken into account by the authorities to issue better management guidelines for the urban soil landscape.

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