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SOILS OF URBAN, INDUSTRIAL, TRAFFIC, MINING AND MILITARY AREAS (SUITMA) FROM A ONE HEALTH PERSPECTIVE

Pisa (Italy), 5th-9th October 2025

Editors
Francesca Bretzel
Beatrice Pezzarossa
Francesca Vannucchi

BOOK OF ABSTRACTS

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ORGANIZERS

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Scientific Programme

6th October 2025

08:30	REGISTRATION	
09:00	WELCOME	
	Pisa Municipality Representative, IRET Director, President Area CNR	
09:20	OPENING	
	Edoardo Costantini, IUSS	SUITMAs and the new Challenges of the IUSS 2025-2034 Decade of Soil Sciences for Sustainable Development
TOPIC 1 SUITMAs as sinks and source of pollutants		
09:30	Paula Medejon Rodriguez, IRNAS-CSIC, Spain, Keynote speaker	Soil contamination by trace elements in the food chain: experiences in different mining and urban scenarios
10:00	ORAL SESSION	chairs: Grazia Masciandaro and Ali Boularbah
	Anna Paltseva	From Hotspots to Protocols: What St. Louis Urban Soils Reveal About Contamination and PXRF Reliability
	Tom Künnemann	Evaluation of innovative management practices for urban lawn and their impact on CO_2 and N_2O emissions
	Przemysław Charzyński	Prevalence of microplastic and metals contamination in Soils of the irrigated fields and peri-urban the Marrakech Region: An Emerging Environmental Challenge
	Liliane Jean-Soro	Effect of the origin of Pb (geogenic vs. anthropogenic) on its accumulation in tomato and butternut grown on moderately contaminated soil.
	Abdelaali Ait Saghir	Bioaccumulation of metals in the leaves of coffee (Coffea arabica) and enset (Ensete ventricosum) as affected by home garden agroforestry system in Gedeo Zone, Ethiopia
	Discussion	
11:00	COFFE BREAK	
11:20	ORAL SESSION	chairs: Meri Barbafieri and Salvatore Engel Di Mauro
	Laila Ait Mansour	Vertical distribution and source attribution of potentially toxic elements in agricultural soils of central morocco: a soil-type and profile-based assessment
	Medina Veliu	Circular Economy and Urban Gardens: Formulations of Local Inorganic and Organic Waste to Minimize Harmful Trace Elements Exposure and Pollution
	Andrey Dolgikh	Soil Diversity of Urban Green Infrastructure Sites in the Kola Arctic Region
	Salvatore Engel-Di Mauro	Soil and Vegetable Trace Element Contamination and Atmospheric Deposition in Urban Community Gardens of Kingston, New York (US)
	Michal Snehota	Multi-layer Constructed Technosol Systems: Impact of layering on water regime and heavy metals leaching
	Cécile Quantin	Soil Formation on Mining Residues: Impacts on Metal(oid) Dynamics and Consequences for Soil and Water Resources
	Tadeusz Magiera	Influence of environmental conditions on the ecological quality of Wood Biomass growing on different Soils and geological Background.

	Valérie Cappuyns	Bioaccessibility of Arsenic in Mining Waste and Mining-affected Soils
	Demba Diarra	Determining the long-term behavior of deconstruction concrete impacted by hydrocarbons in a circular economy context
	Discussion	
13:00	LUNCH BREAK	
14:00	POSTER SESSION TOPIC 1-2	
TOPIC 2 SUITMAs to conserve and improve soil quality and biodiversity		
14:30	José Luois Moreno Ortego, CEBAS-CSIC, Spain, Keynote speaker	Effects of climate change on soil biodiversity
15:00	ORAL SESSION	chairs: Silvia Traversari and Masayuki Kawahigashi
	Geoffroy Seré	Reclamation of moderately degraded urban soils: use of a cognitive model to link soil organisms' functional traits to soil processes & functions
	Tom Künnemann	Litter C:N Ratio and Soil Water Retention drive early CO_2 and N_2O Emissions from Recycled Litter on Urban Lawns
	Engracia Madejón	Enhancing Soil Health and Resilience in Mediterranean Organic Olive Orchards Through Cover Crops and Biocompost
	Nour Ismail	Tailoring Calcium Amendment Strategies for Alfalfa: Long-Term Yield Responses to Raw, Burned, and Sulfate-Based Inputs across Contrasting Soils and Stand Types
	Wolfgang Burghardt	Rooting underneath sealed Ground. Study of Tree Roots entering Sewers underneath Streets
	Discussion	
16:00	COFFE BREAK	
16:20	ORAL SESSION	chairs: Eleonora Peruzzi and Remigio Pardelo
	Korneykova Maria	Functions and Ecosystem Services of Microbial Community in Subarctic Urban Soils
	Alessandra Bonetti	Impacts of sustainable agronomic practices on Balsamita yield: from soil health to bioactive compounds quality
	Kozlova Ekaterina	From Tundra to Subtropics: Agrochemical and Microbiological Parameters of Soils in Landscape Analogs of Zaryadye Park — A Unique Green Roof in the Center of Moscow
	Simon Masson	Eff ect of a Constructed Technosol on the Microbial Functional Diversity in an Urban Aff orestation Site
	Lisa Le Moller	Soil desealing: just an illusion?
	Stéphanie Ouvrard	Pilot-scale in situ assessment of desealing Strategies under different pedo climatic Conditions
	Hermine Huot	Effect of the type and degree of compaction of urban soils on the growth and response to water deficit of herbaceous plants
	Hullot Olivier	Mine Soil Rehabilitation: Integrating Field-Based Approaches and Remote Sensing Tools
	Fadwa Khalfallah	Could invisible effects of land use and management on soil microbial communities durably impact carbon and nitrogen cycling in urban soils?
	Discussion	
18:00	DAY CLOSING	

POSTER SESSION TOPIC 1-2		
TOPIC	AUTHOR	TITLE
1	Sung-Chul Kim	Source Appointment of Heavy Metal Pollution in Agricultural Fields Surrounded by Industrial Complex in Korea
1	Zuzana Vankova	Remediation of contaminated Soils using novel Mn Oxide-Biochar Composites
1	Hicham El Khalil	Biological Properties of Alfalfa Rhizospheric Soil Under Natural and Anthropogenically Modified Conditions.
1	Btissam Mandri	Metallic Trace Elements Accumulation By Medicago sativa Grown on Reconstituted Soil Irrigated by Wastewater
1	Niluka Wickramasinghe	Functionalised Biochar Composites in Assisted Phytostabilisation of Contaminated Soil
1	David Ramier	Optim'EHAU : a new projet to understand impacts of professional urban agriculture on water ressources
1	Meri Barbafieri	Distribution of Trace Metals and Rare Earth Elements in Urban and Mining Soils and Their Uptake by Plant
1	Hugo López-Romano	Quantification And Monitoring of Trace Elements Trace Elements in Rooftop Crops in Madrid: Implications for Food Safety
1	Michele Di agosto	Phytoremediation-agrivoltaic systems for heavy metals soils decontamination: a review
1	Tadeusz Magiera	New chance for Polluted Lands: Recovery of agricultural soil function by non-food farming and adapted soil management at degraded sites.
1	Abdelaali Ait Saghir	Bioaccumulation of metals in the leaves of coffee (Coffea arabica) and enset (Ensete ventricosum) as affected by home garden agroforestry system in Gedeo Zone, Ethiopia
1	Yetao Tang	Source apportionment of mobile heavy metals from artisanal non-ferrous mining site assisted by metallurgical organic pollutants
1	Thomas Cummins	Data Sources and Screening for Sites with Potential Soil Contamination in Ireland, for forthcoming EU Soil Monitoring Law
2	Geoffroy Sere	Assessing Soil Health at Former Thermal Power Plant Sites
2	Sung Chul Kim	Effect of Manure-Based Biochar Application on Soil Chemical Properties and Crop Growth
2	Carolina dos Santos Batista Bonini	Soil Quality Enhancement through Crop-Livestock Integration: A Four-Year Study in Tropical Agroecosystems
2	Lenka Bobuľská	Unwelcome Guests, Unseen Consequences: The Microbial Impact of Plant Invasions
2	Alfredo Bonini Neto	Application of Artificial Neural Networks for the Classification of Different Categories of Agricultural Soils
2	Björn Kluge	ClApT - Climate adaptation tool for the district of Charlottenburg-Wilmersdorf of Berlin, Germany
2	Lenka Demková	Edible Mushrooms as Bioindicators of Soil Pollution: Environmental and Health Risk Assessment
2	Niluka Wickramasinghe	Soil Enzyme Responses to Sewage Sludge Amendments under Contrasting Metal(loid)s Concentrations
2	Ali Boularbah	Are Native Plants Survivors, or Silent Restorers? Insights from Rhizosphere Soils in Phosphate Mine Sites

2	Graziela Moraes de Cesare Barbosa	Runoff-induced losses of water, soil, and nutrients under no-till agricultural hillslope in southern Brazil
2	Pardo Sheila Daniela	Application of biochar amendments for enhancing the quality of agricultural soils contaminated with heavy metals.
2	Pardo Sheila Daniela	Connecting Adsorption Mechanisms with Heavy Metal Immobilization in Biochar-Amended Contaminated Soils
2	Thomas Lerch	Urbanization Effects on Soil Microbial Communities and Organic Matter Quality in Paris Region
2	Margherita Nardelli	Evaluating soil quality and carbon storage in remediated site in Castenaso (Emilia-Romagna, Italy)

7th October 2025

08:30	REGISTRATION	
TOPIC 3 SUITMA improvers and ecosystem services		
09:00	Christina Siebe, UNAM, Mexico, Keynote speaker	Waste Materials as Resources for Soil Recarbonization: is it a sustainable solution?
09:30	ORAL SESSION	chairs: Cristina Macci and Michal Sneota
	Marcin Switoniak	Aggerosols - Technosols or natural soils?
	Zhihong Xu	Is the Nitrogen cycle still coupled with the Carbon cycle in global forests under climate change?
	Julia Oblin	How can functional soils be constructed ?
	John Kim	The Transplantation of a giant Tree using Peat-based growing Substrates - A Case Study
	Luke Beesley	A geochemical, physical and agronomic evaluation of technosols made from construction and demolition fines mixed with green waste compost.
	Discussion	
10:30	COFFE BREAK	
10:50	ORAL SESSION	chairs: Eliana Tassi and Luke Beesley
	Remigio Paradelo	Soil Health in Urban Areas: Use of Compost for Protection and Improvement
	Francesca Vannucchi	Indicators of soil health for evaluating the efficiency of Nature-based Solutions and restoration actions in degraded environments
	Masayuki Kawahigashi	Positive feedback effect to growth planting black pines on the artificial planting bases
	Mascetti Gaia	Impactsof Recycled Concrete and Asphalt Aggregates onSoilMicrobial Functions and PhysicochemicalProperties: an Indoor-Mesocosm Experiment
	Sepken A. Kaptanoğlu	Assessment of Long-Term Effects of Soil Amendments on CO_2 Efflux in a Reclaimed Magnesite Site (Preliminary Results)
	Elio Padoan	From urban waste to natural soil preservation: newly constructed technosols evaluation for sustainable urban greening.

	Irina Mikajlo	From Waste to Soil: Constructing Fertile Technosols with Excavated Mineral Materials, Milled Asphalt and Compost
	Giuseppe Picca	Turning Waste into Substrates Enhance Rooftop Tomato Production through Microbial Mediation
	Kabira M'barki	Microbiological and Enzymatic Responses in Waste-based Reconstructed Soil Profiles
	Gianni Mastrolonardo	Use of waste materials as feasible strategy for urban de-sealed soil reclamation: evidence from a restoration case study in Prato, Italy
	Khan Muneeb Rehman	Development of good practices of managing urban "green" to achieve climate change adaptation and mitigation
	Boyer Cyprien	Effect of Soil Fauna Inoculation on constructed Technosol
	Discussion	
13:00	LUNCH BREAK	
14:00	POSTER SESSION TOPIC 3-4	
TOPIC 4 SUITMA challenges for the future		
14:30	Giacomo Certini, DAGRI UniFi, Italy, Keynote speaker	The shocking impact of warfare on the soil
15:00	ORAL SESSION	chairs: Francesca Vannucchi and Bijorn Kluge
	Cécile Le Guern	A typology of multifunctional soils for spatial planning: example from Rennes Metropolis (France)
	Christophe Schwartz	From research to practice: the genesis of a guide to help reduce urban soils sealing
	Thomas Nehls	Quantifying ecosystem services of green roof substrates - coupled hydraulic-thermic properties from sample preparation to performance assessment
	Gebru Zinabu Marsie	Ski Slope Management and Its Ecological Impacts on Mountain Grasslands: Soil and Biodiversity Perspectives
	Viacheslav Vasenev	University Campuses as Living Labs to study Carbon Stocks and Fluxes in Urban Green Infrastructure?
	Discussion	
16:00	COFFE BREAK	
16:20	ORAL SESSION	chairs: Serena Doni and Thomas Nehels
	Margaux Clesse	Temporal dynamics of urban soil health
	Arnaud Herbreteau	Reactivity of Road Asphalt buried in Soils after desealing Operations
	Sara Acevedo	Prioritizing urban soil sampling for climate change mitigation based on greenspace management intensity and urban heat analysis
	Björn Kluge	Climate adaptation by de-sealing public street spaces in Berlin: Blue-Green Perspectives
	Silvia Frezzi	Exploring the Link between Land Take and Soil Sealing in European Cities
	Hicham El Khalil	Development of an Interactive Platform for Processing Soil Characterization Data Using Artificial Intelligence.
	Silke Cram Heydrich	To walk, observe and interpret urban Soils

	Carlotta Kollmann	Carbon Storage and Age of Sealed Urban Soils: A Case Study from Berlin's Oldest Marketplace
	Andrzej Greinert	Construction and Demolition Waste as parent material of Constructosols
	Discussion	
18:00	Conference CLOSING	

POSTER SESSION TOPIC 3-4		
TOPIC	AUTHOR	TITLE
3	Anna Świercz	Evaluation of the content of potentially toxic metals in environmental samples of the Belnianka River (southern Poland) in the light of geochemical indicators.
3	Anna Świercz	The use of bypass dust from cement plants and fruit and vegetable processing waste for the production of mineral-carbon material in the reclamation of acidified soils.
3	Geoffroy Sere	A Formulation Support Tool for the Design of Functional Constructed Technosols
3	Ludwika Poręba	Mitigating Effect of Green Infrastructure on the Impact of Urbanisation on Ecosystem Services of Urban Soils
3	Lobzenko Ilya Pavlovich	Urbic Technosoils of the Imeretinskaya Lowland (Russia) - Soils of the Olympic Construction Site
3	John Kim	The Transplantation of giant Trees using Peat-based growing Substrates - Success Stories
3	Razbar Azad Wahab	Hybrid Green Roof System combining Constructed Wetland and Semi-intensive Green Roof with Recycled Crushed Brick Substrate: experimental and numerical study
3	Olga Romzaykina	Soil Constructions of Nature-based Solutions (NBS) for moderate Climate: Monitoring and Modelling
3	Chengcheng Feng	What drives Ecosystem Services' Delivery by constructed Urban Soils in Wageningen: the first Outcomes of the social Survey and Field Experiment
3	Lauren Porter	Synergies between urban Ecosystem Services of biochar-amended circular, engineered Soils are soil-texture dependent and diminish with intensified Stormwater Events
3	Serena Doni	GreenLife4Seas project: a new LIFE for sediments and shells recovery and reuse
3	Samantha Spinoso-Sosa	What's Beneath the Surface? - How Surface Management Shapes Soil Function in Urban Green Spaces
3	Silvia Traversari	Sustainable nitrogen fertilization to optimize chili pepper production in organic agriculture
3	Rugana Imbaná	Constructed Technosol-based reclamation following the 2019 Brumadinho tailings dam collapse (Minas Gerais, Brazil)
4	Andrea Salvucci	Surface Sealing Characteristics Shape Soil Properties in Urban and Peri-Urban Areas: Case Evidence from the REUSES Project
4	Cécile Le Guern	Towards a webtool helping spatial planners and designers to better integrate soil in their process and practice
4	Remigio Paradelo	Urban Soil Threats in the European Union, a Systematic Review

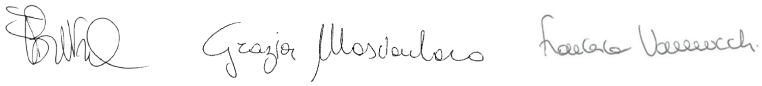
4	Rossella Moscarelli	Road Infrastructures and the direct and induced Impacts on Soil Sealing. An Analysis on the Highway A35, in Italy
4	Takuya Takahashi	Soil Formation Processes promote Spatial Dependence of Physicochemical Properties in Anthropogenic Soils
4	Wolfgang Burghardt	Podosol: Soil of unfortified walkways, squares and roads
4	Nicolas Mangin	Impacts of the first world war on the properties and functioning of forest soils in the Champagne region (France)
4	Dvornukow Yuri	Soil type and content of macro-elements determine hotspots of Cu and Ni accumulation in soils of subarctic industrial barren: inference from a cascade machine learning?
4	Pierferdinando Lamberti	Soilless Substrates from Buffalo Livestock Waste and Zeolite-rich Tuffs
4	Andrzej Greinert	Lignite as a Source of modern manufactured Soil organic Improvers
4	Kolja Thestorf	Distribution and Mobility of Ammunition-derived heavy Metals in historic Shooting Range Soils in the Berlin Metropolitan Area
4	Eleonora Peruzzi	Efficiency of Nature-based Solutions in Urban Areas: Identifying Soil-Plant-Atmosphere Indicators

Introduction

Soil is a key component of the water and nutrient cycle, and a major contributor to global carbon sequestration. Soil also provides habitats for nearly all land plants, as well as a large proportion of terrestrial fauna. Despite its global importance, it is estimated that one third of global soil is degraded. In anthropized areas, soils undergo many forms of disturbance: manipulation, compaction, and pollution which impact their quality. However, even degraded soils have the potential to alleviate environmental problems and play a vital role in supporting vegetation. Degraded soils of urban areas and other anthropogenic lands merit scientific and professional attention in order to enhance their ecosystem services and to support nature- based solutions, to tackle the urgent challenges of climate change, and for the health of all organisms and ecosystems.

The co-chairs of the conference

Francesca Bretzel Grazia Masciandaro Francesca Vannucchi



Urban soils and the new challenges of the IUSS 2025-2034 decade of soil sciences for sustainable development

Edoardo A.C. Costantini

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

***Corresponding author:** edoardo.costantini@ibe.cnr.it*

Keywords: IUSS, DSSSD, SDGs, NBS, sensors, DSM, DSS, urban soils

The International Union of Soil Sciences (IUSS) states that healthy soils underpin healthy societies: healthy soils are the foundation of social, ecological, and economic sustainability. This means maintaining or enhancing soil health and protecting it from destruction, pollution, and exploitation in all social activities, including extensive urban development. Without addressing the impact of human activities on soil health, achieving most of the targets set by the United Nations Sustainable Development Goals (SDGs) is unfeasible. One contributing factor is the lack of sufficient focus on sustainable soil management and protecting areas from sealing and other forms of destruction.

In consideration of the need to prioritize production, dissemination and use of actionable scientific knowledge to achieve the targets of the SDGs, the IUSS has launched the 2025-2034 Decade of Soil Sciences for Sustainable Development (DSSSD) which aims to prioritize the production, dissemination, and use of actionable scientific knowledge and promote solutions to support the achievement of the SDGs. The DSSSD is a strategic initiative highlighting soil's critical role in achieving sustainable global development. By fostering scientific collaboration, advancing research, and engaging with policymakers and the broader society, the IUSS aims to ensure that soil management remains a top priority in global sustainability efforts. DSSSD will contribute to a future where healthy soils support resilient ecosystems, food security, and sustainable development worldwide through structured activities, knowledge dissemination, and international cooperation.

The World Bank estimates that over half of the world's population currently lives in urban areas, and this proportion is expected to rise to 68% by 2050. In 2018, 55% of the global population—about 4.2 billion people—resided in cities. This trend is driven by both rural-

to-urban migration and natural population growth within urban centres.

Urban soils, if managed through Nature-based Solutions (NbS), can significantly enhance their ecosystem services and contribute to the achievement of the SDGs. For example, in relation to SDG 13 (Climate Action), estimates for 54 European cities suggest that NbS could reduce total carbon emissions by an average of 17.4%, including reductions of 8.1% in the residential sector, 14.0% in the industrial sector, and 9.6% in the transport sector. However, the effective selection and planning of NbS in urban areas require detailed and accurate knowledge of urban soils. In this context, tools developed for precision agriculture, such as proximal and remote sensing technologies and digital soil mapping, which can inform specific decision support systems, are increasingly envisioned for application in urban environments.

SUITMAs
as sinks and source of pollutants

INVITED TALK

Soil contamination by trace elements in the food chain: experiences in different mining and urban scenarios

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Topic: SUITMAs as sinks and source of pollutants
Keywords: metals, soil pollution, ecological risk, health risks, bioaccumulation, edible crops

A major concern associated with the presence of trace elements in soil is their potential transfer into the food chain. While many of these elements are essential for both plant and human health, elevated concentrations can pose significant risks to animals and humans—even when they are not toxic to plants.

This transfer of trace elements from soil to the food chain is explored across several contaminated areas. The first scenario focuses on the Guadiamar Green Corridor—a restored area affected by a toxic spill of sludge rich in trace elements. Despite restoration efforts soils remain contaminated prompting an assessment of how these elements move through various levels of the food chain and the risks they pose to wildlife and human populations. Three key case studies are examined in detail: the potential toxic effects on horses grazing in the area, and the accumulation of trace elements in snails and mushrooms—two types of wild foods that may be foraged locally and consumed by nearby residents.

The second scenario examines agricultural plots situated near a sulfidic waste dump. This study evaluates the elemental composition of several edible crops cultivated in soils heavily contaminated with metals and metalloids, under traditional smallholder farming practices.

The third scenario focuses on ecologically managed urban and peri-urban community gardens in Spain, aiming to identify the key factors contributing to trace metal contamination in soils and cultivated vegetables, as well as the associated health risks for consumers.

From hotspots to protocols: what St. Louis urban soils reveal about contamination and PXRF reliability

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Topic: SUITMAs as sinks and source of pollutants
Keywords: trace elements, soil survey, land use, XRF, soil analysis, urban landscapes

St. Louis, Missouri—once a hub of industrial activity and a historic transportation gateway—bears a complex legacy of environmental pollution embedded in its soils. The city's urban soils are formed from loess-derived parent material and shaped by a mosaic of landforms, including floodplain terraces, upland disturbed sites, wind-blown deposits, and anthropogenic topsoils. These layered histories make St. Louis a critical case study for understanding contamination patterns in urban landscapes. As part of the first USDA urban soil survey conducted in the city, we analyzed heavy metal concentrations across a range of land uses and soil profiles. This presentation will focus on understanding the distribution of heavy metals in different landscapes and depths impacted by anthropogenic activities. For example, Pb shows strong surface enrichment, averaging 181 mg/kg in the 0–10 cm layer, with extreme hotspots above 1200 mg/kg. Concentrations drop sharply with depth, falling below 50 mg/kg past 50 cm—indicative of surface-based legacy pollution. Arsenic displays a more uniform profile, with topsoil concentrations averaging 16.5 mg/kg and gradually decreasing to 12.9 mg/kg at 100–200 cm. A second goal of the project involved evaluating the consistency of portable X-ray fluorescence (PXRF) measurements across labs. Preliminary comparisons show that dried samples analyzed in controlled lab conditions yield more reliable results than in situ field-moist readings, which produced inconsistencies. These findings support the need for harmonized PXRF protocols in urban soil surveys to ensure data accuracy and cross-site comparability. Together, our findings underscore the dual importance of addressing shallow contamination in urban soils and establishing standardized methodologies for

urban soil assessment. The St. Louis case highlights how soil science, technology, and land use history converge in the pursuit of healthier, more sustainable cities.

Evaluation of innovative management practices for urban lawn and their impact on CO2 and N2O emissions

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Topic: SUITMAs as sinks and source of pollutants
Keywords: greenhouse gases, soil mineral nitrogen, temperature, WFPS, mowing, fertilization

In 2019, the European Commission adopted a series of proposals aimed at adapting the EU's climate, energy, transport and taxation policies with a view to reducing net GHG emissions by at least 55% by 2030 compared with 1990 levels (Green Deal). Therefore, local and regional authorities have a major role to play in the fight against climate change through their mitigation and adaptation actions.

Among the possible levers, the greening of cities represents a major challenge in offsetting GHG emissions. Urban green spaces (UGS) are diverse (urban forests, flowered areas, parks, lawns, allotments, etc.). In particular, lawns, which designate a grassed surface composed mainly of *graminae*, are the most representative type of UGS and account for 50 to 70% of the surface area of UGS worldwide. Fertilisation and irrigation stimulate particularly N_2O emissions through nitrification and/or denitrification. However, other forms of management could reduce GHG emissions by encouraging soil C storage. Reducing the frequency of mowing, leaving grass clippings on site, or leaving tree litter are all innovative practices that may be considered 'aesthetically dirty' by residents, but which could increase C stocks in the soil through the decomposition of plant residues.

The main objective of this study is to assess the impact of management methods for grassed areas on CO_2 and N_2O flows. To this end, a 9-month experiment was carried out in 2024 using several management methods for grassed areas, where CO_2 and N_2O flows were measured and correlated with climatic variables (temperature, soil moisture) and

the soil mineral nitrogen content (NO_3^-, NH_4^+). These measurements were taken over three seasons: spring, summer and autumn, in order to assess the relevance of practices according to the seasons.

The main conclusions of the study are that fertilization should be avoided, or organic fertilizers should be preferred to mineral ones, and the first fertilization in spring should be delayed to avoid nitrogen lixiviation risks. Leaving tree litter in place and reducing mowing frequency reduce GHG emissions. Green space managers are very sensitive to these changes and are reluctant to leave litter in place for aesthetic reasons and because of the possible reduction in plant biodiversity.

Prevalence of microplastic and metals contamination in soils of the irrigated fields and peri-urban the Marrakech region: an emerging environmental challenge

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Topic: SUITMAs as sinks and source of pollutants
Keywords: microplastics (MPs), soil contamination, wastewater irrigation, polymer identification, Morocco, food security

Soil microplastic (MP) contamination poses a growing threat to agroecosystem health. This study investigated sources, distribution, and risks of MPs in peri-urban soils of Marrakech, characterized by xeric moisture regimes, where plastic waste accumulation is exacerbated by drip irrigation (plasticulture) and urban development. Thirty composite soil samples were collected from 0–10 cm and 10–20 cm depths across three land-use systems: wastewater-irrigated cropland (P1), well-water-irrigated olive orchard (P2), and non-cultivated areas (P3). MPs were extracted via density separation, characterized by stereomicroscopy and FTIR spectroscopy. Electrical conductivity (EC) and heavy metals (Pb, Zn, Cu, Cd, Co, Cr, Ni) were concurrently analysed.

Polyethylene (PE), polypropylene (PP), and polyvinyl chloride (PVC) dominated MP profiles, primarily sourced from plasticulture, wastewater reuse, and urban waste. EC reached 2.66 dS/m, indicating significant salinity stress. Heavy metal concentrations revealed Zn up to 170.1 mg/kg (approaching or exceeding thresholds of 150–200 mg/kg), Ni up to 45.1 mg/kg (surpassing China's 40 mg/kg limit and nearing other frameworks), and Cu up to 28.8 mg/kg (within typical limits of <50 mg/kg). While Pb, Cd, Cr, and Co generally remained below critical regulatory values, spatial patterns indicated localized

accumulation linked to anthropogenic pressure. Elevated metal concentrations and EC co-occurred near agricultural infrastructure and waste pathways.

A normalized pollution index integrating metal and EC data confirmed contamination hotspots aligned with intense human activity. These results underscore the multi-pollutant nature of soil degradation near Marrakech, driven by MPs, salinity, and metals. Addressing MP contamination alongside chemical stressors is crucial for preserving soil health, sustaining agricultural productivity, and ensuring food security in semi-arid ecosystems. Targeted land management strategies are essential.

Effect of the origin of Pb (geogenic vs. anthropogenic) on its accumulation in tomato and butternut grown on moderately contaminated soil

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Topic: SUITMAs as sinks and source of pollutants
Keywords: urban allotment garden, food production, contaminated soil, lead

Urban gardens are in high demand in urban areas, and their number is increasing. However, urban soils are often contaminated due to their history. The contamination can be anthropogenic due to current or past industrial or artisanal activities. The contamination can also have a natural origin (geochemical background). Vegetables growing on these soils can be contaminated and pose health risk due to the ingestion of these crops.

The aim of this study was to estimate whether the origin of lead contamination could influence the lead (Pb) accumulation in the vegetables. In addition, the issue of growing vegetables that are safe to eat has been assessed.

This study was conducted in Nantes (France) on two moderately Pb-contaminated soils with an anthropogenic vs. a natural origin. The soil with anthropogenic contamination comes from a former military camp. Pb concentrations range from 181 to 263 $mg.kg^{-1}$ of dry matter. The soil with geogenic contamination comes from an urban allotment garden with Pb contamination ranging from 311 to 463 mg.kg-1 in the topsoil of several plots. Two vegetables were chosen, i.e., tomato (*Solanum lycopersicum*) among the most widely cultivated vegetable in France and Butternut squash (*Cucurbita pepo*), suggested by the gardeners of the above-mentioned site. On the same site, reconstructed plots using these two soils were divided into two groups of 12 sub-plots (120x120 cm): one group with the soil from the allotment garden, and the other with the soil from the military camp. Two cropping systems were tested: phytoextraction (i.e., only tomatoes whose shoots were previously shown to accumulate Pb but not fruits), association (i.e.,

tomato and squash) and a control (squash). Pb contents in vegetables were determined by ICP-MS-MS and isotopic analyses were used to evaluate the influence of the Pb origin on its accumulation in vegetables. The results revealed that Pb amounts for tomato and squash are below the European regulatory thresholds (EEC no. 1881/2006). Moreover, Pb accumulation depends more on the cropping system than on the soil. This study reinforces the idea that it is possible to produce safely on contaminated soil but in specific conditions.

Bioaccumulation of metals in the leaves of coffee (*Coffea arabica*) and enset (*Ensete ventricosum*) as affected by home garden agroforestry system in Gedeo Zone, Ethiopia

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Topic: SUITMAs as sinks and source of pollutants
Keywords: home garden agroforestry, Gedeo Zone, Coffea arabica, Ensete ventricosum, heavy metals

This study evaluates metal bioaccumulation in the leaves of coffee (*Coffea arabica*) and enset (*Ensete ventricosum*) plants cultivated in home garden agroforestry systems in the Gedeo Zone, Ethiopia. Soil and leaf samples from 46 agroforestry plots across three predominant soil types—Cambisols, Luvisols, and Nitisols—were analysed for potentially toxic elements (PTEs), including As, Ba, Cd, Cu, Mn, Pb, Sr, Ti, and Zn. Coffee and enset were selected due to their significance in local agroforestry systems and their different physiological responses to metal uptake. Globally, concentrations of these trace elements in soils varied notably, ranging from 0.01 to 1,548 mg/kg. Results indicated moderate uptake of essential metals such as Cu (11.8–19.9 mg/kg in coffee; 6.1–18.4 mg/kg in enset), Mn (43.1–52.2 mg/kg in coffee; 95.8–801 mg/kg in enset), and Zn (9.5–77 mg/kg in coffee; 22.5–37.7 mg/kg in enset), while toxic elements such as Cd (0.08 mg/kg mean in coffee; 0.07 mg/kg mean in enset), Pb (up to 9.6 mg/kg in coffee), and As (undetectable) remained generally low. Nevertheless, the detection of trace Cd and Pb in coffee leaves underscores the necessity for continuous environmental monitoring to prevent potential long-term risks. Enset exhibited resilience and selective metal uptake across varying soil conditions, highlighting species-specific strategies in metal management. This comparative analysis emphasizes the importance of leaf tissues as sensitive bioindicators, providing early detection of environmental quality changes prior

to contamination of consumable plant parts. The findings demonstrate how interactions among soil type, organic matter management, and agroforestry practices collectively stabilize metal bioavailability, contributing to soil fertility and food safety. Nonetheless, ongoing vigilance and integrated soil-plant management practices are essential to safeguard long-term environmental and agricultural sustainability.

Vertical distribution and source attribution of potentially toxic elements in agricultural soils of central Morocco: a soil-type and profile-based assessment

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Topic: SUITMAs as sinks and source of pollutants
Keywords: Potentially Toxic Elements (PTEs), soil profiles, soil contamination, anthropogenic and geogenic sources, XRD analysis, agricultural soils

Heavy metal contamination in agricultural soils represents a major environmental concern, posing significant threats to ecosystems and human health. This paper investigates the spatial and vertical distribution of heavy metals in soils from key agricultural regions in midland Morocco, focusing on their sources, ecological risks, and implications for public health. We assessed concentrations of As, Cd, Cu, Mn, Pb, and Zn across five soil profiles representing different soil types, including Calcisols, Vertisols, Luvisols, and Phaeozems, analyzing their availability using DTPA and $CaCl_2$ extraction methods, analyzing their availability using DTPA and $CaCl_2$ extraction methods. Additionally, mineralogical analyses were performed using X-ray diffraction (XRD) to further characterize the soil composition and metal association. Our findings demonstrate elevated levels of As, Cd, Pb, and Mn, highlighting significant anthropogenic influences from agricultural inputs, notably fertilizers and pesticides. Moreover, the combined use of statistical analysis and XRD revealed that while some metals such as Cd and Pb are mainly anthropogenic, others like Mn and Zn are predominantly geogenic in origin. Additionally, distinct vertical variations in metal concentrations reflect their different mobility and accumulation behavior in response to soil characteristics and anthropogenic activities. This work provides a comprehensive assessment of both vertical and spatial distribution of heavy metals by examining full soil profiles across different soil types, an approach not previously applied in this context, integrating advanced statistical tools and ecological and health risk evaluations. The identification of critical contamination pathways

through the soil profile provides essential insights for mitigating risks associated with heavy metal pollution in agricultural systems.

Circular economy and urban gardens: formulations of local inorganic and organic waste to minimize harmful trace elements exposure and pollution

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Topic: SUITMAs as sinks and source of pollutants
Keywords: urban agriculture, peat replacement, urban waste, circular economy, trace elements pollution, human exposure

The global expansion of urban agriculture practices, and the scarcity of available, fertile, and non-polluted urban soils increased the demand for soilless cultivation systems and growing substrates. The most common growing substrates are primarily composed of peat, but peatlands are vulnerable environments, and their drainage and exploitation are primary greenhouse gas emission source. In response, some governments are implementing policies to end peat extraction (LULUCF Regulation, EU), pushing for alternatives for growing media while avoiding unsustainable extraction of non-renewable raw materials. For this purpose, the use of locally available organic and inorganic wastes to produce sustainable growing substrates could support an urban-based circular economy. Construction waste (CW) is a significant fraction of the public sector residues, and national French laws mandate their valorization up to 70% in mass1. Nevertheless, the potential pollution of secondary raw materials should be carefully managed to ensure their safe use by the public.

This study investigated the pollution of trace elements (TEs) and their pathways from alternative cultivation substrates prepared with locally sourced inorganic and organic residues. We combined CW provided by a local waste management company with community compost (CC) and a commercial peat-based medium (PE). Tested formulations were prepared by progressively increasing the proportion of CW while replacing that of PE, maintaining CC constant. Substrates were then tested for tomato

plant cultivation (Solanum lycopersicum, Marmande variety) for one summer season. The experiment was conducted in the open air in the peri-urban area of Nantes, employing terracotta pots (5 replicates for each formulation) placed in raised structures. During the cultivation period, we recovered pot leachates with glass bottles placed under the pots (3 replicates). With this setting, TEs pathways were studied, from the tested substrates to edible fruits. The investigation included both edible and non-edible plant tissues, as well as the TEs content in leached water, considering both dissolved and particulate fractions.

Our findings can help to understand the feasibility of incorporating locally sourced inorganic and organic residues into cultivation substrate formulations as an alternative to peat, with the aim of minimizing human exposure and environmental pollution from harmful TEs.

Soil diversity of urban green infrastructure sites in the Kola Arctic Region

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Topic: SUITMAs as sinks and source of pollutants
Keywords: urban soils, technosols, podzols, histosols, cryosols, arctic

Urbanization is a global trend that leads to irreversible changes in vegetation and soil around the world. The environmental consequences of urbanization are especially apparent in polar regions, where low temperatures and nutrient-poor soil hinder the restoration and development of ecosystems. Creating a sustainable green ecological framework in new areas and maintaining urban green infrastructure in the residential and recreational areas of Arctic cities is important. In the European Arctic, many cities are located outside the cryolithozone, where there is no permafrost. Alternatively, the area of permafrost has decreased, while the thickness of the active layer has increased. At the same time, the frost-free period often lasts less than six months, and stable snow cover lasts up to six months. We studied the morphological structures, chemical properties, and diversity of soils in long-term frozen natural soils (Albic/Entic Podzols and Histosols) and artificial constructed soils (Urbic Technosols) in recreational and residential zones of cities, as well as operating and abandoned settlements in the Kola Arctic Region (Apatity, Monchegorsk, Murmansk, Vaiga-Guba, and Teriberka). These settlements are located outside the permafrost zone. We also used materials from studies in Vorkuta and Naryan-Mar (in the Eastern European Arctic), Barentsburg and Pyramiden (in the Svalbard archipelago), and the Tikhaya Bay polar station (in the Franz Josef Land archipelago).

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Soil and vegetable trace element contamination and atmospheric deposition in urban community gardens of Kingston, New York (US)

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Topic: SUITMAs as sinks and source of pollutants
Keywords: atmospheric deposition, soil contamination, trace element contamination, urban vegetable gardens, and vegetable contamination

The relative contribution of atmospheric deposition to the contamination of vegetables and soils was studied in three urban community gardens located in Kingston, New York (US). Two-tiered soil sampling was carried out along a transect covering the extent of the town's administrative limits (11 sites) and within gardens (20 points each) at 0-5 and 15-20 cm (or where feasible). Monthly atmospheric bulk deposition samples were gathered over one year. Experimental raised beds were built in each garden, consisting of imported soil within and outside root pouches. Kale (*Brassica oleracea var. acephala*) was grown in root pouches under three treatments (imported soil only and imported soil straw mulch with/without row cover). Leaves were harvested and sampled after 110 d at each garden (n = 114, of which 64 were analysed), as well as purchased and sampled from local supermarkets (n = 10). Root pouch soil was sampled at two-tiered depths (0-1 cm and 15-20 cm). Irrigation water, straw mulch, and imported soil (prior to raised bed construction) were sampled. Leaf trace element content was very low, while legacy soil contamination tended to be higher than recommended safe levels for New York State. Dust deposition and gardening inputs had small to negligible trace element concentrations, with the exception of straw and imported soil (especially Hg, Pb). Dust trace element content coincided with degree of raised bed trace element concentrations in surface soil, straw mulch, and harvested leaves. As a result, bulk deposition sampler height standards may require further study. There was inconsistency in the effectiveness of straw mulch and/or hoop cover treatments in reducing trace element input. This brings into the question commonly practised measures for exposure reduction. In the

area of investigation this is particularly important as local redeposition processes within gardens are likely a primary source of contamination over the long term.

Multi-layer constructed technosol systems: impact of layering on water regime and heavy metals leaching

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Topic: SUITMAs as sinks and source of pollutants
Keywords: Technosols, green roofs, water retention, evapotranspiration, X-ray tomography, stable isotopes

This study investigates the influence of layering in multi-layer constructed Technosol systems on hydraulic behavior and heavy metal retention, essential aspects for intensive green roofs within blue-green infrastructure. We hypothesize that distinct interfaces and varying substrate properties introduced through layering significantly affect evapotranspiration, infiltration, heavy metal retention, leaching processes, and root growth dynamics compared to single-layered systems.

To elucidate these complex interactions, we conducted a controlled modified rhizobox experiment, comparing six Technosol configurations with one, two, and four layers in three replicates, each planted with *Allium schoenoprasum* and *Thymus vulgaris*. The substrates combined intensive green roof material and coarse-grained expanded clay aggregates. Experiments were performed over a complete vegetation season on a raised-bed, open-air rooftop setup assisted by an automated FarmBot CNC gardening system used for irrigation and regular photography monitoring of plants. Rhizoboxes received both natural precipitation and supplemental irrigation, allowing systematic monitoring of water balance components, stable isotopes ($\delta^{2}H$ and $\delta^{18}O$), and heavy metal leaching.

Our results demonstrate that multi-layered systems (two and four layers) showed greater variability among replicates and lower overall water retention compared to single-layer configurations. The four-layer systems exhibited evidence of bypass flow. Stable isotope

analysis revealed elevated evaporation rates in rooftop conditions relative to typical ground-based scenarios, attributed to the extreme microclimate conditions typical of exposed roofs. X-ray tomography conducted on in situ samples encased in removable cylinders identified the root growth and showed small structural changes.

Heavy metals analysis of input precipitation, irrigation water, and effluents identified Cu, Zn, and Ni as dominant metals. Leaching behavior varied among different layering configurations and replicates.

In conclusion, this complex study provides valuable insights for optimizing intensive green roof design using multi-layer Technosol systems, emphasizing the critical role of material selection and layer arrangement to enhance environmental performance and ecosystem services.

Soil formation on mining residues: impacts on metal(oid) dynamics and consequences for soil and water resources

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Topic: SUITMAs as sinks and source of pollutants
Keywords: Potentially toxic elements mobility, metal(oid) bearing-phase, soil and water pollution

The Allier department, located on the eastern edge of the Massif Central (France), is one of many regions with a rich mining history. Among the ore deposits, one was exploited until 1914 for antimony (Sb), and another until 1962 for tungsten (W), tin (Sn), and associated metals and metalloids (As, Zn, Sb). This mining activity generated over 335,000 m³ of residual materials, tailings, or waste from ore processing phases, whose chemical and mineralogical stability evolves depending on changes in the physicochemical conditions of the environment.

Part of this waste was used to backfill extraction galleries. At the same time, the surplus was stored on the surface without any specific protection, making it vulnerable to biotic and abiotic weathering processes. Under these conditions, potentially toxic elements (PTE) present in these residues can change speciation during the weathering of their bearing phases. Therefore, they may be dispersed with varying efficiency and at various distances from the source areas, either in dissolved or particulate forms.

In the case of the more recent residues from the sites of interest, exposure to supergene conditions for at least sixty years has led to the development of Technosol (WRB, 2022). Therefore, the processes involved need to be identified and understood to quantify PTE mobility and assess the associated risks.

To this end, samples from several soil profiles developed on or near mining residues were characterized using various physico-chemical methods (particle size analysis, mineralogical analysis by XRD and SEM-EDS of solids, elemental composition) in order to quantify and determine the bearing phases of the PTE. Surface waters draining the impacted areas were also collected and analyzed for their PTE content. Leaching experiments and selective extractions provide information on the PTE mobility under environmentally relevant pH conditions and solid:solution ratios. Better understanding PTE dynamics helps anticipate and manage the environmental risks associated with PTEs in post-mining management

Influence of environmental conditions on the ecological quality of wood biomass growing on different soils and geological background

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Topic: SUITMAs as sinks and source of pollutants
Keywords: wood biomass, soil pollution, potentially toxic elements, Technosol

In some cases, energy crops are used for the biological reclamation of mining and metallurgical waste dumps or in ecologically contaminated areas where food production is impossible or unprofitable due to environmental reasons. Undoubtedly, plants growing on such substrates accumulate some pollutants in their biomass tissues. From an ecological point of view, it is also important to determine whether the biomass obtained from such areas has a statistically significant impact on the increased emission of potentially toxic elements into the environment during combustion. In our study, we investigated various tree species (pine, larch, spruce, birch, oak, poplar, and aspen) growing under different environmental conditions and on different soil types: Technosol developed on forested, old metallurgical and mining dumps; Rendzina developed on ore-bearing dolomite; Ranker developed on basic igneous or metamorphic rocks; highly polluted Podzolic soils. Samples of small twigs, bark, and wood biomass were collected separately, and the biomass was chipped before combustion. The samples were combusted in the laboratory using a muffle furnace. Each ash sample was analysed for major components three times using an Avio 200 ICP-OES spectrometer. Trace elements (Co, Cd, Ni, Pb, Ba, Cu, Zn, Mo, Sb, Sn, Cr, W) were determined using ICP-MS. The highest Pb content was observed in all tree species growing on Technosol developed on old Pb-Zn metallurgical wastes (up to 4 wt% in birch wood ash). In the same location, the highest concentrations of Cd (up to 300 mg/kg in pine wood ash), as well as Sb and Sn (up to 70 and 30 mg/kg respectively in ash from larch twigs and needles), were also recorded. Cd contents above 200 mg/kg were also detected in poplar wood and bark ash from the same site, as well as in pine wood grown on ore-bearing dolomites. A very high concentration of Zn (>1 wt%) was observed in birch (wood, twigs, and bark), regardless of

location—even in a relatively clean reference area in northern Poland on sandy podzolic soil. This suggests that birch is a zinc hyperaccumulator.

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Bioaccessibility of arsenic in mining waste and mining-affected soils

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Topic: SUITMAs as sinks and source of pollutants
Keywords: arsenic, bioaccessibility, health risk assessment, mineralogy

In vitro bioaccessibility tests are being used to evaluate the release of trace elements upon ingestion of soil, dust, and other fine-grained materials. In most cases, it considers fine-grained materials with varying chemical, physical and mineralogical properties, but it is not always clear how these properties influence the bioaccessibility of elements. The present study focusses on the bioaccessibility of arsenic (As) in mining waste and mining-affected soils. First, the results of a detailed study of the mobility (leaching tests), solid-phase speciation (SEM-EDS, XRD, LA-ICP-MS), and in vitro bioaccessibility of As in different types of mining waste and mining-affected soils are presented. Additionally, from the literature, data on the bioaccessibility of As in soil and mining waste samples were used to investigate the relation between chemical (element composition, pH, organic carbon content) , physical (grainsize distribution) and mineralogical properties of the samples and the gastric and intestinal bioaccesibility of As. Stepwise multiple linear regression was performed to assess the relationship between bioaccessibility as a dependent variable, and (physico)chemical and/or mineralogical sample properties as independent variables

The detailed characterization of the mine waste and soil samples showed that the mineralogical composition, specifically the content of Fe(hydr)oxides and arsenopyrite, played a significant role in determining As bioaccessibility. Overall, As displayed a low bio-accessible fraction, below 10% of its total content. Human health risk assessments, using bioaccessible As concentrations, indicated low carcinogenic or non-carcinogenic risks in case of (accidental) ingestion of soil or dust particles.

From the literature data, total As concentrations and pH were the most significant predictors of As bioaccessibility. Surprisingly, in only 7 of the 18 papers, information on

the mineralogical composition of the samples was provided, and only 3 of the 18 papers provided quantitative mineralogical information. It was therefore difficult to explain bioaccessible As concentrations reported in literature using mineralogical sample composition. It is strongly recommended, in the context of bioavailability testing, to quantify the mineralogical composition of materials for which this is relevant and to share data in a more transparent manner.

Determining the long-term behaviour of deconstruction concrete impacted by hydrocarbons in a circular economy context

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Topic: SUITMAs as sinks and source of pollutants
Keywords: deconstruction concrete, circular economy, backfills, environmental impact assessment, total hydrocarbon (TPH) C_{10}-C_{40}, chemical fingerprints

The deconstruction of numerous thermal power plants by The French National Electricity company (EDF) produce thousands of tons of waste, including large quantities of concrete containing hydrocarbons. As a circular economy approach, EDF aims to reuse materials on site to meet the backfill needs and limit the consumption of non-renewable resources. Current regulatory approach differentiates the management of waste such as crushed concrete impacted by hydrocarbons and soils considered to be polluted. Thus, the threshold value defined for hydrocarbons content in deconstruction waste limits the reusability of impacted concrete as alternative backfills even on industrial sites where soils, managed according to the French methodology on polluted sites, may present higher concentrations of hydrocarbons.

This research project aims to evaluate the long-term behaviour of deconstruction concrete impacted by hydrocarbons in backfill conditions. The objective is to better characterize the nature and quantity of the organic substances mobilized by rainwater infiltration and to evaluate their consequences on the environment. To answer these questions, a multi-scale experimental approach was implemented (batch leaching, percolation in laboratory columns, *in situ* experiments in large lysimetric columns) combined with ecotoxicological tests on aquatic organisms. Various samples of crushed concrete impacted by hydrocarbons, from coal and fuel oil power plants are studied. The total hydrocarbon concentration (TPH C_{10}-C_{40}) of samples indicates high values (750–50,170

mg.kg^{-1}) and different chemical fingerprints depending on the suspected substances (heavy fuel / heating oil, maintenance oil). Batch leaching tests (EN 12457-2) on concrete showed the absence of hydrocarbons in the leachates. At the same time, the first results on large lysimetric columns survey reveal contrasting percolate characteristics (pH value and dissolved organic carbon content. However, even if the liquid-to-solid ratio is lower for lysimeter experiments compared to batch tests, no hydrocarbons (TPH C_{10}-C_{40}) were detected into the percolate.

These preliminary results reveal that leaching tests should be used in conjunction with TPH content measurements on the solid for a more realistic assessment of the risks associated with concrete impacted by hydrocarbons. These results could support ongoing standardization work at European level on adapting existing leaching protocols to include organic substances.

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Source appointment of heavy metal pollution in agricultural fields surrounded by industrial complex in Korea

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Topic: SUITMAs as sinks and source of pollutants
Keywords: heavy metal, pollution, source track, positive matrix factorization, pollution index

Heavy metal pollution in agricultural soils can pose a critical risk in terms of food security, environmental sustainability, and human health. This study i) examines the concentrations of heavy metals in soils, ii) identifies the sources of heavy metal pollution, and iii) calculates ecological risks in a representative agricultural area influenced by surrounding industrial complexes. A total of 100 surface soil samples were collected across 13 industrial zones and analyzed for arsenic (As), chromium (Cr), cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), and nickel (Ni). Contamination and ecological risk levels were assessed using the Pollution Index (PI), Pollution Load Index (PLI), and Ecological Risk Index (ERI). Positive Matrix Factorization (PMF) modeling was applied to identify and quantify potential pollution sources. The results revealed moderate to high contamination levels, varying by metal type, with As showing the highest concentrations (1.56–571.71 mg/kg), followed by Ni (2.15–102.36 mg/kg). Calculated PI, PLI, and ERI values ranged from 0.40–13.43, 0.32–2.92, and 27.7–911.3, respectively, indicating significant pollution in the study area. PMF analysis identified three main source categories: agricultural inputs, industrial discharges, and mining activities. Of the 13 industrial complexes, six were predominantly impacted by agricultural practices, two by industrial emissions, and one by mining-related sources. This integrated methodology offers a comprehensive framework for assessing contamination and informing targeted soil pollution mitigation strategies.

Remediation of contaminated soils using novel Mn oxide-biochar composites

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Topic: SUITMAs as sinks and source of pollutants
Keywords: biochar, contamination, remediation, immobilization, metals, metalloids

Biochar, a carbon-rich material derived from the pyrolysis of various organic waste substances, has gained increasing interest over the last 15 years. This versatile material is being explored across multiple sectors, including agriculture, forestry, environmental remediation, carbon sequestration, climate change mitigation, animal nutrition, construction, and even electrochemical applications. Within agricultural systems, biochar is particularly valued for its capacity to sequester carbon, thereby increasing the content of stable organic matter in soils. It is also known to enhance soil nutrient levels, boost water retention, lower fertilizer requirements, and improve overall crop productivity. Regarding the remediation of contaminated soils, biochar is able to immobilize potentially toxic metals and metalloids and also support the degradation of various organic contaminants. To further promote its remediation potential, biochar can be functionalised using various materials, e.g., Mn oxides (MnOx).

In our study, two novel MnOx-biochar composites were prepared. Cost-effective raw materials, such as waste woody biomass biochar, waste molasses, and white sugar, were used for the composites synthesis. The aim of the synthesis was to increase the immobilization capacity towards targeted contaminating metal(loid)s, while decreasing the risk of Mn leaching and reductive dissolution of soil organic matter. The new MnOx-biochar composites synthesized using molasses (BCM) and sucrose (BCS) were tested in three different contaminated soils with different physico-chemical properties and contaminant contents. The tested amendments were added to soils at a ratio of 0.5%, 1% and 2% (w/w), and incubated for a period of up to 6 months. Soil pore water samples were

collected after 1 week, 1 month, 3 months and 6 months of incubation and analyzed for their physico-chemical characteristics and content of metal(loid)s. In addition, the impact of added MnOx-biochar composites on the content of polyaromatic hydrocarbons (PAH) in the studied soils was investigated. Overall, the BCS composite demonstrated better performance in both immobilizing metal(loid)s, and degrading PAHs compared to BCM, effectively targeting As, Cd, Pb, and Zn, while generally exhibiting reduced Mn leaching. Conversely, composites were found to be less effective for Cu immobilization, particularly under acidic conditions, where greater mobilization of both Mn and Cu occurred.

Biological properties of Alfalfa rhizospheric soil under natural and anthropogenically modified conditions

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Topic: SUITMAs as sinks and source of pollutants
Keywords: soil remediation, soil biology, bioindicators of soil quality and functionality, genomics

In urban environments, soils are frequently subjected to intense anthropogenic pressures, including construction activities, pollution, and irregular land use. These disturbances significantly modify the physical, chemical, and biological properties of the soil, compromising its natural structure and ecological functions, particularly its role in supporting vegetation. The rhizospheric soil is especially sensitive to such changes, as it is directly influenced by both the quality of the substrate and the physiological behavior of plants under stress conditions. This study aims to assess the biological characteristics of the rhizospheric soil associated with Medicago sativa (alfalfa), a plant known for its resilience and bioaccumulation potential, when cultivated on both natural and anthropogenically altered soils. Particular attention was given to the influence of metallic trace element (MTE) contamination, resulting from the use of wastewater for irrigation. Alfalfa plants were grown in soils subjected to different types of irrigation: clean water (control), urban wastewater, and industrial wastewater. The biological activity of the rhizospheric soil was evaluated through an analysis of its mesofauna, which serves as a sensitive indicator of soil health. The abundance, diversity, and dominant groups of soil fauna were recorded. The results revealed a clear variation in mesofauna communities

depending on the type of soil and irrigation. Rhizospheric soils irrigated with wastewater, particularly industrial, exhibited the highest mesofauna abundance. These communities were mainly composed of insects and arachnids, suggesting that certain invertebrate groups may tolerate or even thrive in contaminated conditions. Chemical analyses showed that rhizospheric soils exposed to wastewater had significantly higher concentrations of cadmium (Cd), copper (Cu), and other trace metals compared to those irrigated with clean water. These elevated metal concentrations appear to directly influence the composition and structure of the soil fauna. In conclusion, the biological characteristics of rhizospheric soil are strongly affected by land use and irrigation practices. Wastewater irrigation alters the ecological balance of the soil, with both enriching and potentially toxic effects. These findings highlight the importance of monitoring soil biodiversity and metal contamination to better understand and manage the ecological impact of urban and industrial activities.

Metallic trace elements accumulation by *Medicago sativa* grown on reconstituted soil irrigated with wastewater

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Topic: SUITMAs as sinks and source of pollutants
Keywords: Alfalfa, reconstituted soil, Cd and Cu accumulation, wastewater irrigation

Wastewater irrigation is a common practice in developing countries. It can be exploited in a sustainable development strategy. However, the use of wastewater in agriculture can have a serious impact on the environment. The work presented aims to assess the capacity of Alfalfa to accumulate Cadmium and Copper on a reconstituted soil irrigated by wastewater. Alfalfa plants were grown on a reconstituted soil with peat and earthy materials. The Alfalfa plants were irrigated with two types of wastewaters collected from an urban effluent and an industrial effluent of the city of Safi (Morocco). The results show that the wastewater used in our studies contains considerable contents of Cd and Cu. The Cd and Cu contents measured in the reconstituted soil show a remarkable enrichment due to irrigation with urban and industrial wastewater. Alfalfa plants accumulated varying concentrations of Cd and Cu. The highest levels were observed in the aerial parts of Alfalfa plants irrigated by industrial wastewater. Alfalfa plants, cultivated on the reconstituted soil and irrigated with urban and industrial wastewater, showed remarkable performances of Cd and Cu accumulation. These findings support the proposal of further studies on using this plant in a system for the remediation of soils contaminated by metallic trace elements and/or for rehabilitation of degraded areas.

Functionalised biochar composites in assisted phytostabilisation of contaminated soil

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Topic: SUITMAs as sinks and source of pollutants
Keywords: biochar, Mn oxides, remediation, immobilisation, metals, metalloids

Biochar is a popular, versatile material currently used in many fields, such as agriculture, animal nutrition, forestry, and environmental remediation. Due to its alkaline nature and sorption properties, it can be used for immobilisation of contaminating metals and metalloids in contaminated soils, while its other benefits, such as increase of soil nutritious status, increase of soil organic matter content, resistance against drought, or increase of soil microbial activity, may further enhance plant growth. In addition, coupling biochar with other materials, e.g., Mn oxides (MnOx) in the case of the given study, may also increase the binding effectiveness towards targeted contaminants and make it a good candidate for use in assisted phytostabilisation. In the current study, two MnOx-biochar composites were synthesised using waste molasses (BCM) or sucrose (BCS) as reducing agents during the synthesis process. These materials were subsequently applied to soil heavily contaminated with As, Cd, Cu, Pb and Zn as a result of historical smelting activity. The soil was planted with ryegrass seeds, and the control (unamended) variant and variant with pristine biochar (BC) were included for comparison. Soil solution was collected and analysed, and ryegrass biomass and contents of metals and metalloids in plants were determined. The application of all amendments resulted in soil pH increases of 0.7-1.2 units and significantly immobilised Cd, Pb, and Zn in soil compared to the control. MnOx-biochar composited further improved immobilisation of Cd and Zn compared to BC, yet promoted the increased release of As, Cu, Mn, and dissolved organic carbon. Concerning the metal uptake to shoots, the most effective was MnOx-biochar BCS, reducing the concentrations of Cd, Pb and As in shoots by 63%, 79%, and 76%, respectively. On the

other hand, both Mn-Ox biochar composites supported Cu and Mn translocation , as well as As and Pb in the case of BCM. Based on the tested amendments, BCS appears to be the most promising material for assisted phytostabilisation performed on heavily contaminated soil.

Optim'EHAU : a new projet to understand impacts of professional urban agriculture on water resources

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Topic: SUITMAs as sinks and source of pollutants
Keywords: urban food production, water consumption, monitoring, urban professional agriculture

Urban agriculture plays an important role in preserving and developing urban soil. It can take different forms in terms of site (open ground, wasteland, roofs, school yards, basements and so on) and production mode (ground or above-ground with substrate, hydroponic, aquaponic). Economic models are also various with association structures, collective or shared gardens and professional organisations. Professional urban agriculture, on the other hand, is distinguished by the creation of income and jobs linked to agricultural production, as well as by the services it offers, such as the sale of products. These constraints mean that professional farmers have to resort to more regular irrigation and the addition of nutrients. However, despite the development of this type of urban agriculture, there are no specific studies on the actual water consumption of professional urban farms nor on the effect of nutrient inputs on the quality of water percolating through the substrate and discharged into the sewer system, particularly in the case of rooftop agriculture.

With the aim of providing new insights into the impacts of professional urban agriculture, a research project called OPTIM'EHAU (Development of Optimized Water Management Systems for Horticulture and Professional Urban Agriculture) began this year and will last for 42 months. One of the project's aims is to quantify the water consumption of professional urban farms in Paris, for different sites and production methods: ground, roofs on substrates or hydroponic. A characterisation of the soils/substrates and the quality of the water discharged will also be studied. To this end, three urban farms in the 20th district of Paris will be monitored over a three-year period (volume of water

used for irrigation, soils/substrates water content, volume and global parameters water quality of exfiltrated water).

Finally, this project will enable to estimate whether this type of urban agriculture has an impact on water resources at the scale of an urban district.

Distribution of trace metals and rare earth elements in urban and mining soils and their uptake by plant

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Topic: SUITMAs as sinks and source of pollutants
Keywords: elements mobility, bioavailability, soil amendments, bioconcentration factor, American pokeweed (*Phytolacca americana*), radish (*Raphanus sativus*)

The presence in various terrestrial ecosystems and the increasing use of Rare Earth Elements (REEs) has enhanced the concern regarding their possible effects and/or impacts on the environment. The REEs comprise 17 elements from lanthanide group, plus yttrium (Y) and scandium (Sc). Except for promethium (Pm), REEs occur naturally at low concentrations throughout the Earth's crust and are key elements in many industrial sectors, due to their unique chemical-physical properties. Besides China, the countries with major reserves of REEs are Vietnam, Russia, and Brazil. In Italy, REEs can be primarily found in the Alpine regions from Friuli to Piedmont, in Liguria, Tuscany, northern Lazio, Abruzzo, and Sardinia. The natural environmental concentrations of REEs are relatively low and their availability for the biota have been rarely determined.

The present study has been developed within the framework of the PRIN project "EUREECA" (Rare Earth Elements in Urban and Mining Areas: an Emerging Concern for Soil and Human Health) which focus on the presence, mobility and ecological effects of REEs in different Italian soils. Soil from an urban and two mining sites were investigated for their chemical characteristics, trace metals, REEs contents and isotopic speciation. Moreover, the transfer of trace elements and REEs, into plant tissues was studied. As hyperaccumulator model plant, American pokeweed (*Phytolacca americana*) and as

accumulator plant, radish (*Raphanus sativus*) were chosen. The REEs content in the investigated soils was low and chemical speciation by different extractants showed low mobility as well. Data on plant element uptake showed that American pokeweed translocated lanthanum (La), praseodymium (Pr) and Y in the aerial parts, whereas the roots showed a selective absorption of La and Pr. Radish absorbed a more diverse range of REEs, especially in the roots, in which gadolinium (Gd), samarium (Sm), La, Pr, cerium (Ce) and neodymium (Nd) were detected. In the leaves of radish only Pr was found.

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Quantification and monitoring of trace elements trace elements in rooftop crops in Madrid: implications for food safety

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Topic: SUITMAs as sinks and source of pollutants
Keywords: urban agriculture, green roofs, food security, pollution, sustainable production, circular economy

The current agri-food system is facing increasing challenges related to environmental degradation and food security, largely due to its intensification and spatial disconnection from consumption centres. In response to these challenges, there is an increasing interest in integrating productive spaces within cities and adopting circular economy approaches. This includes the use of renewable organic waste-based inputs as substitutes for conventional agrochemicals.

Rooftop agriculture (RA) has emerged as a promising urban strategy, offering co-benefits such as rainwater management, improved building energy efficiency, and local food production. However, the implementation of this approach is accompanied by a number of uncertainties, particularly with regard to the potential for contamination risks arising from urban exposure and the utilisation of non-soil growing substrates.

This study was conducted over a period of three years on an experimental rooftop farm located in central Madrid (Spain). Tomatoes were cultivated during the summer months, while lettuce and Swiss chard were grown in the winter. The growing media used in this study consisted of composted organic residues (coffee by-products and seaweed) blended with or without biochar. The objective of the research was to evaluate the

dynamics of nutrient and trace element concentrations in the substrates, edible biomass, and leachates, with a focus on food safety and element translocation under urban farming conditions.

The findings demonstrated that the incorporation of biochar into the substrate led to enhanced stability, reduced electrical conductivity, increased nutrient retention, and mitigated the mobility of potentially harmful elements. It has been demonstrated that the concentrations of trace elements in fruits remained below the regulatory thresholds stipulated by the European Union, thereby confirming their safety for human consumption. Furthermore, a principal component analysis (PCA) revealed clear differentiation between mobile and retained elements, thus highlighting the role of biochar in modulating translocation pathways.

The findings indicate that the use of renewable compost–biochar blends as functional growing substrates in rooftop agriculture is a viable proposition. This approach is consistent with the principles of circularity and sustainability, thus providing a viable alternative for the safe, resilient, and localized production of food in urban environments.

Phytoremediation-agrivoltaics systems for heavy metal soils decontamination

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Topic: SUITMAs as sinks and source of pollutants
Keywords: soil remediation, soil biology, bioindicators of soil quality and functionality, genomics

Heavy industries have generated metal soil contamination in the last decades due to their pollutant emissions in the surrounding environment. This has created a growing demand for decontamination actions. Phytoremediation, exploiting the physiological features of specific plant species to remove, sequestrate, or destroy pollutants from contaminated soils represents a possible sustainable decontamination approach. This review intends to explore the benefits of combining phytoremediation and photovoltaic technology, to obtain agrivoltaics systems able to provide at the same time, soil remediation, electricity generation, and biomass production. Agrivoltaics makes agricultural production more resilient by reducing water evapotranspiration and providing controlled shading during the hottest periods of the year. A specific case study is analysed considering the contaminated area of Augusta, in Sicily (Italy). This review aims to examine those plant species that best fit in Augusta area to perform both phytoremediation and agrivoltaics. The selection criteria are based on photosynthetic efficiency, water usage, compatibility with photovoltaic technologies, economic value, and the site's characteristics. Three monocrystalline photovoltaic panels have been considered: vertical double-sided, classic single-sided, and semi-transparent single-sided. These photovoltaic panel configurations are evaluated by estimating the potential energy yield at the site of interest using the Pvsyst software. The Phytoremediation study has been led on three different plant species (Chrysopogon zizanioides, Cannabis sativa, and Arundo donax), analysing biomass reduction as a function of the pollutant and shading on site.

New chance for polluted lands: recovery of agricultural soil function by non-food farming and adapted soil management at degraded sites

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Topic: SUITMAs as sinks and source of pollutants
Keywords: wood biomass, soil pollution, potentially toxic elements, Technosol

In many regions of Europe, agricultural and marginal soils are contaminated with various types of pollutants. Despite this, such soils are still used for growing food and feed, leading to the uncontrolled transfer of contaminants into the food chain. The aim of the PoLaRecCE project is to develop solutions for restoring agricultural productivity on contaminated and marginal lands degraded by historical human activities. This paper presents strategies for restoring degraded soils for non-food agricultural production, developed for four pilot sites located in different regions of Central Europe. This approach helps preserve the essential functions of soil while minimizing the transfer of pollutants into the food chain. Non-food agricultural production is seen as a potential alternative source of income for farmers.

The first site is located in Liguria, Italy, on a Technosol developed from industrial waste. As Liguria is known as the most flower-rich region in Italy, we proposed repurposing the degraded area for flower production. The region appears particularly well-suited to cultivating frost-sensitive flowering plants, thanks to its favourable climatic conditions—provided that the soil properties of the degraded areas are also suitable.

The second pilot site is located in an agricultural area of Békés County, in southeastern Hungary. The land has been degraded by long-term unsustainable agricultural practices and is therefore no longer suitable for the safe production of food crops. Our proposed solution involves the selection of appropriate fast-growing tree species, which can also contribute to the partial phytoremediation of polluted soils.

The third pilot site was established in Ormož, in eastern Slovenia, in an area affected by former clay mining. The soil here has not been degraded by chemical contamination, but rather by surface deformation caused by excavation activities. The proposed solution for this site involves establishing a mulberry tree plantation. These trees can grow on relatively steep slopes and will serve as the foundation for developing silkworm breeding and the production of silk threads, which are used in manufacturing wound dressings.

The PoLaRecCE project was conducted in the frame of Interreg Central Europe Program co-funded by European Union.

Source apportionment of mobile heavy metals from artisanal non-ferrous mining site assisted by metallurgical organic pollutants

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Topic: SUITMAs as sinks and source of pollutants
Keywords: metallurgical organic pollutants, xanthates, PAHs, mercury, source apportionment, artisanal mining and processing

Artisanal and small-scale mining and processing (ASMP) activities still persist in developing countries, posing challenges for source identification and environmental enforcement of heavy metal(loid) (HMs) pollution. Meanwhile, knowledge regarding the distribution of metallurgical organic pollutants (MOPs) in ASMP tailings and their role in HMs source identification remains lacking. Xanthates and polycyclic aromatic hydrocarbons (PAHs)—typically derived from non-ferrous mineral beneficiation and smelting—were investigated in an abandoned non-ferrous tailings pond located in the Guizhou mercury mining area, China. Multi-faceted methodologies, including spatial visualization, correlation analysis, and positive matrix factorization (PMF), were employed.

Results showed severe contamination by Hg, Cd, and Zn in the pond, with maximum total concentrations of 391 mg/kg, 67.1 mg/kg, and 5,260 mg/kg, respectively. PAHs reached up to 234 μg/kg, exhibiting diagnostic signatures of smelting activities. Notably, this study first quantified three flotation xanthates (ethyl-, isopropyl-, and butyl-xanthate) in tailings, with concentrations ranging from 0.1 to 89.2 μg/kg. By integrating spatial correlations between HMs and MOPs, we determined that Cd/Zn contamination

primarily originated from zinc ore processing, while Hg contamination stemmed from two historical mercury smelting phases.

Advanced PMF analysis incorporating MOPs profiles and the hydrogeochemical indicator (dissolved Fe) further revealed that non-ferrous processing contributed 60.7–100% of mobile HMs. Additionally, 39.3% of mobile Hg and 31.0% of mobile Cd were redistributed via hydrogeochemical interactions and xanthate complexation during tailings aging. This field-based validation highlights the indicator roles of MOPs, offering a novel approach for source identification, environmental regulation, and risk assessment in ASMP sites.

Data sources and screening for sites with potential soil contamination in Ireland, for forthcoming EU soil monitoring law

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Topic: SUITMAs as sinks and source of pollutants
Keywords: EU Soil Monitoring Law, potentially contaminated soil, mining contamination, industrial contamination

The proposed EU Soil Monitoring Law (COM(2023) 416 final) will require member states to identify potentially contaminated soils. Investigation will be required, followed by site-level risk assessment, and potential risk-reduction measures. Ireland has existing survey and mapping on legacy mining sites, with available spatial data on site extents. Initial review comparing to vertical imagery suggests areas are well mapped, but instances of displaced sediment are also apparent outside the identified site boundaries, based on long-lasting unvegetated surfaces. Licenced industrial sites, and those with extensive publicly-available planning, emissions-control and incident-related documentation provide a rich resource for direct and indirect evidence for potential soil contamination. Active and decommissioned power generation sites, ports, transport hubs, and mineral-processing locations with complex histories suggest criteria that may be used for screening within identified classes of sites. Landfills from recent decades are well managed and documented, but earlier legacy facilities and irregular fills in extraction sites are a large population with little documentation. Small commercial facilities handling volatiles and solvents, such as fuel retailers, dry cleaners, and vehicle dismantlers, along with activities involving metals recovery, paint spraying, and agrichemical use, present a long list of decreasing scale operations for which investigation resources must eventually be limiting.

Experience in collating lists, categories, and information sources prompts criteria and levels that may be used to develop screening methods. Screening of candidate sites will help to protect a majority of compliant operators from unwanted association with investigation for potential contamination, in preparation of a publicly-accessible

register of contaminated and potentially contaminated sites. Screening can provide the required risk-based approach, give a means to prioritise investigative resources, and will prompt greater search effort focussed on higher-risk, lower-information cases. In advance of using informal sources, a robust system to facilitate responsible reporting while protecting actors will be required. With high stakes for site owners and operators, an early commitment in state systems to robust and transparent processes will be necessary to achieve accuracy, and to meticulously avoid false-positive identifications.

SUITMAs
to conserve and improve
soil quality and biodiversity

INVITED TALK

Effects of climate change on soil biodiversity

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: edaphic microbial biodiversity. soil health, carbon sequestration, climate change and agricultural soils, soil management

Climate change is increasingly recognized as a major driver of alterations in soil biodiversity, which plays a fundamental role in maintaining soil health and the sustainability of terrestrial ecosystems. Soil biota, including bacteria, archaea, fungi, nematodes, arthropods, and earthworms, regulate key ecological processes such as organic matter decomposition, nutrient cycling, soil aggregation, and carbon sequestration. However, rising global temperatures, changes in precipitation regimes, and the growing frequency of extreme weather events are altering the composition, diversity, and functioning of these communities.

Natural, forest, and agricultural soils are all affected, though the magnitude and nature of the impacts vary. In natural soils, climate-induced shifts in vegetation and moisture availability can disrupt long-established soil biotic networks. Forest soils, often rich in symbiotic fungi and complex trophic interactions, are particularly sensitive to warming and drought, which can lead to declines in microbial diversity and functional redundancy. Agricultural soils, already subject to intensive management, face compounded pressures as climate change interacts with land use, potentially reducing microbial diversity and increasing the vulnerability of agroecosystems to degradation.

Understanding how climate change affects soil biodiversity across these systems is essential for predicting ecosystem responses, informing land management, and ensuring long-term soil functionality. Promoting biodiversity-friendly practices and integrating soil biological indicators into climate adaptation strategies may offer pathways to enhance the resilience of soils under future climate scenarios.

Reclamation of moderately degraded urban soils: use of a cognitive model to link soil organisms' functional traits to soil processes & functions

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: ecological engineering, soil biology, soil compaction, soil functions

Human activities frequently lead to soil degradation, impairing its ability to deliver essential ecosystem services. In urban environments, soil degradation is often characterized by high bulk densities resulting from trampling and machinery use, as well as a loss of biodiversity, organic matter, and nutrients. Soil fauna, through their varied lifestyles, plays a vital role in maintaining soil functions across different scales. These functions are closely linked to the fauna's functional traits and, more specifically, their individual functional attributes.

Our research aims to advance "pedofauna engineering" as a practical tool for the ecological reclamation of moderately degraded urban soils. We developed a cognitive model that connects types of soil degradation, soil functions, and processes to specific fauna's functional traits, ultimately identifying soil organisms with the desired functional attributes of traits. To evaluate this approach, we focused on two contrasting forms of degradation: soil compaction and lack of chemical fertility.

Three different urban soils affected by these degradations were studied. Species of soil organisms carrying relevant functional traits' attributes were selected and inoculated under controlled conditions experiments. These included earthworms (*Lumbricus terrestris*, *Eisenia fetida*), woodlice (*Porcelio scaber, Oniscus asellus)* and millipedes (*Glomeris marginata, Tachypodoiulus niger*). At the conclusion of the experiments, a range of soil indicators were measured to monitor soil processes and assess functional restoration, including decompaction rates, macropore volume, feces quantity, water infiltration and retention, and nutrient concentrations.

The introduced soil organisms effectively decompacted the soil, primarily through the formation of macropores, significantly enhancing water infiltration. When combined

with selected organic amendments, these organisms – through their functional traits and attributes - also improved chemical fertility, thanks to their role in litter fragmentation and the creation of nutrient-rich biogenic aggregates. Additionally, we explored the impact of single-species versus multi-species introductions, revealing promising outcomes for the development of pedofauna engineering.

Litter C:N ratio and soil water retention drive early CO_2 and N_2O emissions from recycled litter on urban lawns

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: litter biochemistry, lawn management intensity, soil C and N content, water-filled pore space (WFPS), mineral N availability, N_2O emission factor

Urban green spaces (UGSs) play a vital role in enhancing urban sustainability by providing ecosystem services. Lawns, which cover up to 50–70% of UGSs globally, vary in vegetation type and generate substantial litter from trees, shrubs, and herbaceous plants. Much of this litter is exported, although recycling it into soil could improve soil health while reducing indirect greenhouse gas emissions associated with litter blowing, transport, and composting. However, litter decomposition may also lead to direct emission of nitrous oxide (N_2O)—a powerful greenhouse gas.

Litter biochemistry influence on N_2O fluxes during litter decomposition was studied on two soils from a low- and a high-intensity management lawn. The high-intensity management soil had higher organic C and N contents and greater water retention capacity. Five litter types, selected from twenty-eight representative UGS species, were chosen for their contrasting biochemistry (e.g., C:N ratio and lignin content). These litters were applied at the soil surface and incubated in the lab for 14 days (15°C, 100% field capacity). Carbon dioxide (CO_2) and N_2O emissions, along with mineral nitrogen dynamics, were measured.

Cumulative CO_2 and N_2O emissions depend on litter C:N ratio and soil water retention capacity. Green litter with low C:N ratio (i.e., Lolium) produced higher emissions, while senescent litters with high C:N ratios (e.g., Fraxinus, Meadow grasses) induced microbial nitrogen immobilization thus limiting emissions. The high-intensity soil showed the highest cumulative N_2O emissions across all litter types (averaging 1.5 kg N ha-1) due to higher water retention capacity. N_2O emission factors (1.2–3.7%) exceeded the IPCC

default for crop residues (0.6%). A power regression with C:N ratios from the 28 collected litter types suggested average N_2O emission factors of 1.5% for senescent and 3.5% for green litters.

These findings suggest for the first time that recycling litter on an intensively managed lawn soil can result in significant N_2O emissions, due to organically rich conditions promoting notably high-water retention capacity. However, litter recycling on a soil with lower water retention capacity, typically the low-intensity management soil, may represent a sustainable practice with low N_2O emission potential, while also providing substantial benefits for soil fertility, water cycling, and biodiversity.

Enhancing soil health and resilience in mediterranean organic olive orchards through cover crops and biocompost

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: soil fertility, nutrient cycling, ecosystem services, climate adaptation, pest control, sustainable land management

Food security is deeply rooted in the quality of agricultural soils, which directly influences human and ecosystem health. In Mediterranean agro-ecosystems, soil degradation driven by intensive farming practices and climate change represents a growing concern. Strategies that improve soil organic carbon inputs and biodiversity are essential for maintaining agro-ecosystem services and increasing soil resilience. Organic farming (OF) offers a holistic and sustainable alternative to conventional systems by minimizing chemical inputs and promoting long-term environmental health. Key practices include reduced tillage, integrated nutrient management, and maintaining permanent soil cover. Olive orchards are a characteristic crop of the Mediterranean basin, traditionally managed under rainfed conditions. However, in recent years, many orchards in Spain have undergone intensification, including irrigation and high-density planting systems. These changes have increased the demand for efficient resource management and have raised concerns about soil fertility and biodiversity loss. Climate change projections suggest increased vulnerability of Mediterranean crops, making it urgent to adopt resilient and adaptive farming strategies.

This study aims to evaluate the agronomic, environmental, and economic effects of using cover crops and biocompost—individually and in combination—in organic olive orchards through in-situ field experiments. We focus on their capacity to enhance soil health while maintaining or improving yield. Particular attention is given to carbon and nutrient cycling, soil carbon sequestration, and the impact on soil biodiversity, including beneficial arthropods that serve as natural enemies of pests. This research contributes to

identifying practical solutions that foster sustainable production, ecosystem resilience, and climate adaptation in Mediterranean agriculture.

Tailoring calcium amendment strategies for alfalfa: long-term yield responses to raw, burned, and sulfate- based inputs across contrasting soils and stand types

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: Alfalfa stand maturity, lime amendment, sulfate-based amendment, soil texture

Alfalfa (Medicago sativa L.) is a high-value forage crop with strong ecological benefits but is particularly sensitive to soil acidity and nutrient deficiencies. While current fertilization guidelines in regions like Québec favor raw limestone ($CaCO_3$) exclusively, other calcium amendments, including burned limes (CaO, $Ca(OH)_2$) and sulfate-based materials, are commonly used elsewhere and may offer agronomic advantages. However, their effectiveness may vary with soil texture, root system maturity, and application method. This study evaluated the impact of nine calcium-based amendments: raw lime, burned lime, and sulfate-based non-liming materials, applied at a uniform spring rate (3 Mg ha^{-1} $CaCO_3$-equivalent or 1.2 Mg ha^{-1} Ca for anhydrite) on two alfalfa stands (establishment vs. maintenance) and two contrasting soil textures in Québec, Canada. Agronomic performance was monitored over four consecutive growing seasons.

Results revealed contrasting responses: newly seeded alfalfa on clay soil showed no yield response to amendments, while the mature stand on sandy soil exhibited strong and lasting responses. Sulfate-based treatments (CHAC, anhydrite, and lime-anhydrite) increased yields by up to 10,000 kg ha^{-1} over the control in favorable years, with gains persisting across four seasons after a single application. Mixed lime treatments ($CaCO_3$ + CaO and/or $Ca(OH)_2$) also outperformed raw lime without causing phytotoxicity.

These findings highlight the need for stand- and soil-specific calcium amendment

strategies. Sulfate-based and blended formulations applied every four years may sustainably enhance productivity in mature alfalfa systems on coarse soils. Exclusive reliance on raw lime may overlook the agronomic potential of alternative materials proven to be both effective and safe.

Rooting underneath sealed ground. Study of tree roots entering sewers underneath streets

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: rooting, street soils, sewer pipe, soil aeration, soil potassium

It looks like that sealed areas do not contribute to living sphere and have no meaning to plant growth. But in the protocols of sewage pipe inspection occurs the notice of pipe clogging by roots underneath streets and houses.

In cities sewer lines are often installed underneath streets. Roots of street trees enter weak points of pipe connections. This results in pipe clogging and with time by root growth in damage of the pipe. At two sites the soil around sewer lines damaged by roots was investigated.

The two investigated sewer pipes were located in 250 cm and 210 cm depth beneath the street surface. Samples were taken from the undisturbed soil, from the soil in the sewer trench, and above and below the sewer pipe. The samples were taken as disturbed samples and with 100 cm^3 rings as undisturbed cores. Particle size distribution, carbon content, C/N ratio, pH, bulk density, water content, pore size distribution, air and field capacity, and plant available phosphorus and potassium content were determined.

The soil was from loamy and silty sand. The organic matter content was very low. C/N ratio between 5 and 19, pH from 6.2 to 6.9. The bulk density of undisturbed soil was above 1.6 g cm^{-3}, in the soil of the sewer trench about 1.6 g cm^{-3}, and near the pipe about 1.5 g cm^{-3}. The pore size distribution showed the highest content of large pores above the sewage pipe this means the area of the highest air capacity. This region is strongly rooted. The content of available phosphorus is high in all soil samples. Thus, an influence on rooting density cannot be deduced. However, the available potassium content is elevated in the densely routed soil above the sewer pipes.

Soil rooting occurred primary in soil of lower bulk density and higher air capacity, and of higher available potassium content. That means, limiting factors for restricted rooting of

soils underneath street are low air capacity and low available potassium content. In well aerated soils under streets roots can occur and supply trees with water and nutrients.

Functions and ecosystem services of microbial community in subarctic urban soils

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: microbial community, biodiversity, urban soil, ecosystem services, subarctic

Arctic cities attract researchers' interest by a unique combination of extreme climatic conditions and anthropogenic pressure. The studies were conducted in recreational areas of the Kola region cities: Murmansk (68.58° N, 33.03° E), Monchegorsk (67.56° N, 32.52° E) and Apatity (67.33° N, 33.24° E), which differ in population, industry and climate. In the soil profiles of urban green infrastructure (UGI) objects, groups of diagnostic soil horizons were identified separately among the topsoil and subsoil ones: natural, man-changed and man-made. Chemical (pH, C, N, P, K, Ca, Mg, Cu, Ni) and microbiological (MBC, BR, qCO2, taxonomic diversity) properties of the urban and background soils were compared.

The most modified soil profile was typical of the Murmansk UGI, then Monchegorsk and, to a lesser extent, Apatity. The most favorable conditions for the microorganisms functioning and the soil carbon conservation in the UGI were formed in the topsoil natural horizons, then in the man changed horizons and, last of all, in the man-made ones. For all three cities, an increase in the proportion of stress-adapted microbes was observed, such as Actinobacteria among bacteria adapted to various types of pollution, and Ascomycota among fungi adapted to the decomposition of simple organic compounds and typical of disturbed ecosystems. Species richness, diversity, dominance

and evenness of bacterial and fungal communities were higher in urban soils. In cities, the proportion of mycorrhizal fungi decreased compared to the background area, which can negatively affect symbiotic relationships with plants, and an increase in saprotrophs, reflecting the redistribution of functional activity towards the decomposition of organic matter and adaptation to pollution.

Thus, in the urban conditions of the Subarctic, it is necessary to preserve natural undisturbed soil horizons, since they are characterized by a high potential for carbon deposition and the performance of important ecosystem services, such as the formation of a habitat for soil microbiota. The underlying soil horizons of the UGI were capable of accumulating a significant amount of organic matter, which deserves special attention when they are opened as a result of construction, reconstruction, etc. Under such conditions, active mineralization of the organic matter of these horizons is possible, which can serve as a risk of sharp and large losses of carbon in the form of CO_2 into the atmosphere of the city.

Impacts of sustainable agronomic practices on Balsamita yield: from soil health to bioactive compounds quality

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: medicinal plants, microbial inoculants, bioactive stability, soil health, comparative analysis

This study, conducted within the EU PRIMA project ReCROP, focuses on enhancing soil health and crop resilience in Mediterranean agroecosystems through the combined use of microbial inoculants, biofertilizers, and sustainable farming practices. The collaborative effort of Mediterranean countries involved aims to reduce the dependence on chemical fertilizers and improve soil fertility and water use efficiency. In particular, the research represents a comprehensive, three-year investigation (2022–2024) aimed at assessing the impact of agronomic treatments on soil properties and yield of *Tanacetum balsamita* L., a medicinal plant. When plants reached the period of highest polyphenols concentration (Balsamic time), leaf area, leaf count, biomass, antioxidant activity, bioactive products and essential oils were analysed to evaluate physiological responses to treatments. Additionally, the elemental composition of leaves was determined, providing insight on nutrient uptake. Beyond plant analyses, a long-term soil monitoring program was established, with yearly samplings since 2022 to evaluate how treatments induce changes in the chemical-physical soil properties, as the assessment of the potential sequestration of soil carbon through the Low Temperature Ashing (LTA) technique. By combining plant and soil analyses, this study provides a comprehensive assessment of treatment effectiveness, providing valuable insights into their role in enhancing plant growth, bioactive compounds quality over time, secondary metabolite production, and soil fertility.

From tundra to subtropics: agrochemical and microbiological parameters of soils in landscape analogues of Zaryadye Park — A unique green roof in the center of Moscow

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: green roofs, Technosols, urban microbiome, microbial diversity and functions

Zaryadye Park is a unique example of urban green infrastructure, covering an area of 10.2 hectares in the centre of Moscow. It is essentially a green roof whose vegetation reflects the diversity of natural biomes found across Russia's major climate zones — from tundra to steppe and subtropics. Is it possible to maintain optimal soil-ecological conditions and preserve a diverse soil microbiome that meets the needs of each landscape analogue within a metropolitan environment? To address this question, a comprehensive study was conducted on the agrochemical and microbiological properties of Technosols across 11 landscape analogues within the park.

The obtained agrochemical and microbiological indicators were compared with those of corresponding zonal analogues. A decrease in organic matter and potassium content, along with an increase in pH, available phosphorus, microbial biomass, and respiratory activity, was observed in the landscape analogues. Soil pH was found to be a key factor shaping the functional structure of the microbiome: more acidic conditions in tundra and coniferous forest soils supported higher microbial metabolic diversity. Zonal specificity was not observed; the landscape analogues exhibited an overall decline in species diversity and a simplification of the cultivated microbial community.

Using metabarcoding, the genetic diversity of the soil microbiome was studied in two of the most contrasting landscapes—mountain tundra and the 'glass bark' (a subtropical

analogue). A higher number of identified OTUs was observed in the mountain tundra landscape compared to the subtropics (602 and 530 for bacteria, and 221 and 215 for fungi), while higher diversity indices were recorded for the subtropical landscape. The functional diversity was largely similar across both landscapes: bacteria formed 57-58 groups, mainly chemoheterotrophs and aerobic chemoheterotrophs (28–32%). Fungi showed 13 groups in the subtropics (71% undefined saprotrophs) and 11 in the tundra, dominated by plant and undefined saprotrophs and copiotrophs (32%, 28%, and 20%).
Despite the use of soil substrates characteristic of zonal ecosystems and the maintenance of diverse plant communities, the uniform climatic conditions combined with intensive anthropogenic pressure led to the homogenization of the structural and functional characteristics of the soil microbiome in the landscape analogues.

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Effect of a constructed technosol on the microbial functional diversity in an urban afforestation site

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: arbuscular mycorrhizal fungi, soil metagenome, nature-based solutions, technosol, urban environment

The increasing expansion of urban environments around the world highlights the need to apply nature-based solutions (NBS) that can support the development of green urban areas, mitigate environmental and health risks and enable the recovery of degraded soils. Constructed technosols (CT) are promising tools to remediate contaminated sites and reduce the exploitation of natural soils.

In this study, using a multidisciplinary approach we aimed to characterise the long-term impact of a CT (composed of deep excavation soil obtained from construction sites, zeolites, compost and a commercial microbial inoculum) on soil microbial communities at the taxonomic and functional levels in a site located in the city of Turin (Northern Italy) also investigating the relationships occurring between microbiota and soil physico-chemical features and vegetation.

To explore microbiota assembly and functions the soil metagenome was sequenced. Libraries were both taxonomically annotated at the read level and assembled into contigs to profi le abundance of gene functional categories and metagenome-assembled genomes (MAGs). The microbial functional diversity in the CT was profoundly diff erent from that of the surrounding control soil, and the application of compost and microbial inoculum in the original CT appears to have contributed signifi cantly to the microbiota assembly. These diff erences include an increase in prokaryotic diversity and an impact on nitrogen, phosphorus and sulphur metabolism and also on mechanisms and types of antibiotic resistance. Moreover, the reconstruction of MAGs revealed in the CT the

presence of Planifi lum fulgidum, a bacterium previously isolated from compost. These results indicate that tailored design CTs can be powerful tools for NBS solutions in urban aff orestation interventions that can have signifi cant impact on soil microbiota composition and functioning with potential implications on plant growth and health.

Soil desealing: just an illusion?

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: soils, technosols, ecosystem functions, urban ecology, geochemical cycles, plants

A global crisis – biodiversity loss, biogeochemical cycles alteration, environmental and social injustice increase, climate disturbance – currently threatens many life forms on Earth. Soil intersects all these issues and is also one of the planet major resources for living organisms, including for mankind. Soil is involved directly or indirectly in more than half planet boundaries, all trespassed by now. In particular, land use changes are predominant as urbanisation is expanding, leading to soil destruction. The worst kind of soil degradation is by far produced by sealing, a process questioned for its direct and indirect consequences on biogeochemical and water cycles, local climate, biodiversity and landscape connectivity. Soil desealing is presented as one of the tools to face the aforementioned issues. Assessing if this statement is true becomes a growing subject for scientists and city planners.

To approach this issue, we study the ecological trajectory of a desealed urban soil. Two former parking lots were closed and desealed at the end of 2023/beginning of 2024. Half their surface was kept sealed as a negative control. The ecological trajectory is assessed with a multicompartmented approach linking water and biogeochemical cycles and soil and plant biodiversity and functionality. This project includes a monitoring phase during the two first years after desealing.

The soil water infiltration increases immediately and first pioneer plant species are rapidly increasing in biomass and diversity. Microorganisms are found under the bitumen, their composition does not change in the first months but their biomass seems to increase

after one year. The soil chemistry is stable on the same time span. However, the soil surface temperature decreases immediately after desealing, and is expected to be more and more different from bitumen as plants grow. These time lags illustrate the complexity of such systems and highlights the need to pursue this study beyond classical two years projects in order to characterize and quantify the ecosystem functionalisation that we already observe at the earlier stages.

Pilot-scale in situ assessment of desealing Strategies under different pedo climatic conditions

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: urban soils, desealing, field experiments, revegetation

Soil sealing (i.e., covering the soil with impermeable material) is one of the main causes of soil degradation in Europe. Although the strongly negative consequences of sealing on the bio-physicochemical properties and the functioning of soils are known, very little work has so far been devoted to the evaluation of the potential for soil renaturation after unsealing. The DESSERT project (Desealing of soils, ecosystem services and territory resilience – 2020-2024) supported by the French Agency for Ecological Transition (ADEME) aimed at (i) acquiring knowledge on the quality, functioning and capacity of unsealed urban soils to provide ecosystem services, (ii) proposing a typology of unsealing processes, (iii) evaluating of the performances of different unsealing practices in terms of renaturation of cities, (iv) implementing of laboratory experiments for the optimization of soil management following unsealing processes, (v) implementing and monitoring over time of in situ pilot sites and (vi) contributing to decision support via the development and wide dissemination of a multi-attribute tool to assist in the design of urban soils unsealing projects.

Within the framework of this project, in situ pilot scale plots were implement between November 2021 and March 2022 under three contrasted pedo climatic condition of Metropolitan France territory. For each site an impervious area of about 140 m2 was desealed (i.e. the surface impervious layer was removed) and separated into four sub-plots to test different soil management practices. Along an increasing intervention gradient the four modalities were: i) no further action on the soil; ii) decompaction and mixing of the top 30 cm; iii) decompaction, addition and mixing of green waste

compost in the top 30 cm in a 1:3 ratio; iv) excavation of the top 30 cm and replacement with a mixture of "natural" topsoil and compost in a 1:3 ratio. All treatments and sites were then sown with the same mixture of ten herbaceous species in spring 2022. Soil evolution (composition, functioning) was then analysed with regular sampling and in situ probes (temperature, humidity) and vegetation cover evolution was followed in terms of diversity, surface coverage and biomass production.

Effect of the type and degree of compaction of urban soils on the growth and response to water deficit of herbaceous plants

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: water-soil-plant relationships, compaction, water regulation, plant physiology, urban greening

Urban greening appears to be a solution for regulating the water cycle in the context of climate change. Sustainable management of urban green spaces requires the establishment of ecosystems that are resilient to extreme weather events. Urban soils have physical properties that can limit their capacity to infiltrate or retain water and restrict plant development. The aim of this work is to investigate the effects of urban soil characteristics, in particular their degree of compaction, on the growth of herbaceous plants and their response to water deficit. Two soils were studied in the Paris region, France: on the IRD campus (soil B) and on a brownfield site (soil PF). Their agronomic and physical properties were characterised in the field and in the laboratory. The influence of the degree of compaction on plants was tested in an experiment on mesocosms reconstituted from the two soils, sieved to 2 mm and compacted to two bulk densities. Two plant species with different root architectures were grown: a Poaceae (*Lolium perenne*) and a Fabaceae (*Medicago sativa*). Three watering scenarios were applied: (i) watering at a frequency and intensity corresponding to the regional average spring rainfall (control), (ii) control watering followed by reduced watering in amount and frequency (water deficit), (iii) control watering followed by reduced watering and control watering again (water deficit + recovery). Water consumption was monitored by weighing during the experiment, as well as growth, water status (stomatal conductance)

and physiology (chlorophyll content) of the plants. At the end of the experiment, plant biomass and composition, root morphological traits and mycorrhizal colonisation were determined. Soil B with a sandy clay loam texture had a higher hydraulic conductivity but a lower water holding capacity than the soil PF with a sandy loam to clay loam texture and more compacted. The preliminary results of the experiment showed an effect of the watering scenario and the degree of soil compaction on plant growth, but not on physiological parameters. Measurements on soils and plants, in the field and in mesocosms, will improve our understanding of the effects of urban soil characteristics on plant growth and their adaptation strategies to water deficit.

Mine soil rehabilitation: integrating field-based approaches and remote sensing tools

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: bio-indicators, remote sensing, soil functions, ecological rehabilitation, post-mining soil, soil health

Coal extraction increased significantly during the 19th and 20th centuries to meet growing energy demands, particularly for electricity production, heating, and powering steam engines. In Europe, around 50 mining areas were developed, notably in Germany, Poland, and Greece. Although coal production reached 480 million tonnes in 2020, demand has been declining. The European Union aims to shut down two-thirds of its coal-fired power plants and reduce CO_2 emissions by 55% by 2030, with the goal of achieving carbon neutrality by 2050.

Mining activities, whether underground or open-pit, cause severe soil degradation, affecting their physical, chemical, and biological properties. It is therefore essential to rehabilitate these soils once mining ceases. Current rehabilitation strategies no longer seek to restore ecosystems to their original state, but rather to recover key ecological functions and ecosystem services suitable for new uses.

Monitoring these processes remains challenging, especially at large spatial scales. On-site, soil sampling is still the reference method, but it is costly, time-consuming, and difficult to extrapolate spatially. In this context, remote sensing has become a valuable tool, although it does not provide direct information on soil processes.

This study proposes to combine field-based bioindicators (e.g. extracellular enzyme

activities, microbial respiration) with remote sensing indicators (NDVI) to assess soil rehabilitation at multiple spatial scales. The case study focuses on the Ptolemais mine in Greece, where seven plots across five zones were investigated: an unrehabilitated control, a recently restored area, two orchards, two cereal fields, and an acacia forest. Preliminary results indicate improved soil functioning in rehabilitated areas. For instance, enzyme activities involved in nutrient cycling were higher in orchard plots (apple and cherry). Additionally, NDVI values suggest better plant health in orchard and acacia forest zones.

Could invisible effects of land use and management on soil microbial communities durably impact carbon and nitrogen cycling in urban soils?

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: urbanisation, nitrogen geochemical cycle, organic matter, microbial function, management intensity

Urbanization profoundly alters nitrogen and carbon cycling through changes in land use and management intensity, affecting both soil functions and microbial communities. These shifts can degrade soil fertility and disrupt ecosystem processes. This study investigates how different urban land use types—including showcase gardens, parks, tree-covered areas, roadsides, residential zones, sport fields and unused areas—influence nitrogen dynamics and microbial functions. We used a multifaceted approach combining biogeochemical measurements (NH_4^+, NO_3^-, total N and C), functional assays (mineralisation, nitrification, potential denitrification), organic matter characterization (via Rock-Eval analysis), and molecular techniques (functional gene abundance and bacterial community profiling using Illumina MiSeq).

Results show land use significantly influences nitrogen processes. Showcase garden areas showed elevated nitrate levels, driven by fertilization and higher nitrification activity, whereas denitrification potential and related gene abundances were higher in parks and roadside soils. Structural equation modelling (SEM) revealed that soil organic carbon is a major driver of denitrification, and pH influences the abundance of ammonia-

oxidizing archaea (AOA). Water retention, often reduced in compacted soils, negatively affected the nitrogen cycle.

In terms of bacterial communities, the study reveals that bacterial functions linked to the nitrogen cycle vary according to land use. Lightly managed areas harbour more nitrogen-fixing bacteria, while intensely managed areas show a predominance of bacteria involved in nitrification. Furthermore, the absence of any significant correlation between the different stages of the cycle (mineralisation, nitrification, denitrification) in intensively managed areas indicates a breakdown in the nitrogen cycle, probably linked to excessive aeration, tillage and low organic matter accumulation or to difference in organics matter decomposition and stability.

These findings highlight the sensitivity of nitrogen cycling to urban land management. Crucially, the role of organic matter dynamics in this context requires deeper investigation. Future analysis using Rock-Eval will be key to understanding the quality, stability, and thermal reactivity of soil organic matter and its influence on microbial nitrogen transformations. This approach can reveal how different land uses affect organic matter decomposition and its capacity to support sustained microbial activity.

Assessing soil health at former thermal power plant sites

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: industrial soils, Technosols, soil functions

Soils inherited from heavy industrial activities are often perceived as highly degraded. However, their health status is more diverse than commonly assumed, and appropriate methods for evaluating the health of industrial soils remain largely underexplored. Former thermal power plants, in particular, present a wide variety of soil types due to the diversity of activities they once hosted, including: (i) areas with reinforced foundations for boilers (plant foundations); (ii) oil storage zones (oil deposits); (iii) coal storage areas on concrete slabs (coal deposits); and (iv) ash disposal sites for bottom ash and fly ash (bottom-ash and ash deposits).

This study aims to characterize the diversity of soil health states at former thermal power stations by assessing their physical, chemical, and biological properties. Two decommissioned thermal power plants with similar geological contexts were selected. Within each site, zones corresponding to different former industrial uses were identified. In total, twelve 100 m^2 plots of vegetation and soil, considered internally homogeneous but distinct from one another, were selected. Across these plots, twelve soil profiles and 68 soil samples (from surface layers and horizons) were collected and analysed for a wide range of physical, chemical and biological parameters, including plant communities, nematodes, and microbial populations.

Evaluation of the twelve profiles revealed that each soil exhibited unique characteristics. Even areas with similar historical uses displayed differences in the number of soil horizons, rooting depth, and organic carbon stocks—some soils even holding nearly twice the carbon stock compared to their control counterparts. Our results highlight

that soil degradation cannot be inferred solely from the type of past industrial activity. A functional, multi-parametric analysis is essential to accurately assess the potential of these soils for future uses. Furthermore, the integration of biological indicators alongside physico-chemical properties proved crucial, especially for evaluating dynamic functions such as soil fertility and greenhouse gas storage and sequestration. Ultimately, considering entire soil profiles rather than focusing solely on the surface layer reveals that the inherited vertical heterogeneity of highly anthropized soils has a major impact on their health status.

Effect of manure-based biochar application on soil chemical properties and crop growth

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: biochar, soil quality, application rate, wood chip, rice husk

Biochar has been extensively studied for its applications in soil pollution control, improvement of soil properties, and promotion of crop growth. This study evaluates the impact of three kind of biochar (wood chips, rice husk, and poultry manure) with different application rates (0, 2, 4, and 8 tons/ha) on the soil chemical properties and growth of *Lactuca sativa* (lettuce) during a 2-year consecutive application. Application of biochar led to a significant increase in soil EC (46.6~50.6%), soil organic matter (38.5~45.7%), calcium (8.0~37.7%), and sodium concentration (15.4~50.4%). In the first-year application, the highest increase of EC (93.6%) and Na^+ concentration (209.5%) was observed when 8 tons/ha of poultry-manure-based biochar was applied in the soil. Similarly, the highest increase of EC (67.3%) and available phosphorus (P_2O_5, 49.3%) was observed when 8 tons/ha of poultry-manure-based biochar was applied in the soil. However, a little change of soil chemical properties (1.3~13.3%) was observed when rice husk and wood chips-based biochar were applied to the soil, regardless of application rate. Growth of lettuce ranged 2.75~3.45 tons/ha, and the highest crop growth was observed when 4 tons/ha of poultry manure-based biochar was applied in the soil. This result indicated that the optimum application rate of poultry manure-based biochar in soil was 4 tons/ha, with the most balanced improvement in soil chemistry without excessive salinity buildup. The findings support the use of manure-based biochar as a sustainable amendment to enhance soil quality and productivity in agricultural systems.

Soil quality enhancement through crop-livestock integration: a four-year study in tropical agroecosystems

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: agricultural sustainability, soil quality, crop-livestock integration (CLI)

The Crop-Livestock Integration (CLI) system has been established as a promising strategy for agricultural sustainability, promoting efficient land use, reducing environmental impacts, and improving soil quality. This study was conducted over four years in Caiuá - São Paulo - Brazil, with the aim of evaluating changes in soil chemical attributes resulting from the adoption of different CLI system arrangements, in comparison with traditional cropping systems without pasture.

The 40-hectare experimental area, located on a Oxisol, was subjected to seven treatments involving rotations among soybean, corn, and different cultivars of Urochloa under grazing (*Urochloa brizantha* cv. BRS Paiaguás, *Urochloa brizantha* cv. BRS Piatã). Soil layers at depths of 0–0.10 m and 0.10–0.20 m were analyzed for organic matter, pH, and macronutrients.

The results indicated that the introduction of pastures into the cropping systems significantly contributed to the increase in organic matter (OM) content in the surface layer (0–0.10 m), particularly in the Soybean–Piatã treatment, which statistically outperformed the systems without pasture. The rise in OM is associated with the

vegetative cover provided by forage grasses, which enhances nutrient cycling, protects the soil against erosion, and stimulates biological activity. Potassium (K) levels varied among the treatments, with a notable increase observed in the Soybean–Corn + Paiaguás system.

Comparison with the initial characterization data showed that systems with pasture either increased or maintained OM and K levels in both soil layers, while exclusively agricultural systems showed declines, especially in the deeper layer. These results reinforce the role of CLI as a conservation practice, promoting improvements in soil structure and fertility over time.

The study concludes that the adoption of integrated systems supports soil conservation, improves its physical and chemical quality, and reduces the need for external inputs, highlighting it as a viable alternative for sustainable agriculture in tropical regions. Continued management is expected to enhance the observed benefits, bringing the system closer to its agronomic consolidation.

Unwelcome guests, unseen consequences: the microbial impact of plant invasions

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: exotic plants, soil enzymes, soil chemical properties, soil quality indicators

The global spread of invasive non-native species poses an environmental problem and real threat to biodiversity, affecting agriculture, animal health and human well-being. Invasive plants affect soil conditions through changes in soil chemistry and microbial community composition, leading to changes in soil functions. This study explored the effects of the non-native invasive species *Fallopia japonica* (Japanese knotweed) and *Solidago gigantea* (Giant goldenrod) on the soil ecosystem. These invasive plant species have in Slovakia the most significant negative impact on native communities and change the landscape structure. This research focused on selected invasive plant species and their impact on microbial enzymatic activity, a key indicator of soil quality and health. The activity of soil microorganisms has wide-ranging applications in soil ecosystem research. A mixture of stems, leaves and flowers was used in controlled container experiment. The plant material was decomposed for two years in plastic composters in a cold composting process. The container experiment spanned five months and consisted of five different substrate variants. Soil reaction, organic carbon content, total nitrogen content and soil enzyme activities (β-glucosidase, FDA hydrolysis, acid and alkaline phosphatases) were measured in soil samples. All samples were laboratory processed using standardized methodological procedures. The data were statistically analysed using R Studio software and subsequently interpreted. The research findings indicate that invasive plant species significantly influence soil biochemical parameters by modifying nutrient cycling and enzyme activity. These alterations lead to shifts in soil physicochemical properties,

potentially disrupting native soil ecosystem functions, such as carbon sequestration, nitrogen mineralization, and overall soil fertility dynamics.

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Application of artificial neural networks for the classification of different categories of agricultural soils

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: soil classification, artificial intelligence, pattern recognition, chemical and physical attributes, soil properties, supervised learning.

The correct identification and classification of soil types are essential for sustainable land use strategies, especially in the contexts of precision agriculture, environmental management, and natural resource conservation. This study aimed to apply an Artificial Neural Network (ANN) focused on pattern recognition to classify four widely representative soil classes from agricultural regions: Fluvisols, Arenosols, Lixisols and Ferralsols.

A total of 364 soil samples were analysed, characterized by physical attributes — such as soil macroporosity, soil microporosity, soil total porosity, soil bulk density, soil texture, water infiltration rate, and weighted mean diameter — and chemical attributes, including phosphorus, organic matter, pH, potassium, calcium, magnesium, potential acidity, and aluminium, along with the calculation of base sum, cation exchange capacity, and base saturation. The data were divided into two sets: 80% of the samples were used for training, and 20% for model validation. The adopted network was Pattern Recognition, specifically focused on recognizing patterns in the input data, and the software used was Matlab®.

The results demonstrated a high performance of the ANN in the classification task, achieving an accuracy rate of 99% across the 364 samples analysed. The network was able to distinguish soils with similar physicochemical characteristics with high precision, highlighting its effectiveness even in scenarios of high edaphic complexity.

In conclusion, the use of a pattern recognition network represents a promising approach for soil classification, providing valuable support for decision-making in pedological studies. This tool can enhance automation and efficiency in large-scale soil analysis, significantly contributing to the advancement of more modern and sustainable agronomic practices in Brazil.

ClApT - Climate adaptation tool for the district of Charlottenburg-Wilmersdorf of Berlin, Germany

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: climate adaption, de-sealing, decision tool, GIS, BGI implementation, Urban water balance

In order to increase resilience to climate-related risks, cities are faced with the challenge of integrating water-sensitive infrastructures into existing urban structures. Decision-makers are confronted with the complexity of the parameters that have to be taken into account in planning, and institutional capacities and competencies for climate adaptation must be expanded. At the same time, limited resources require the simplest and most efficient identification and selection of areas for implementation.

To achieve this goal, we developed a QGIS-based planning and decision-making tool in cooperation with the Charlottenburg-Wilmersdorf Environmental and Nature Conservation Dept. in Berlin. The project focused on: (i) Urban Design Thinking; (ii) geodata processing; (iii) developing and testing a climate adaptation tool with stakeholders; (iv) creating a guidance document; and (v) estimating water balance changes via blue-green infrastructure (BGI).

As a result, a flexible GIS tool (ClApT) was developed, implemented, and put into productive use, utilizing open GIS data from Berlin combined with the district's own datasets. ClApT, coupled with a simple urban water balance model, demonstrated that implemented BGI scenarios like de-sealing and infiltration, increasing infiltration by changing sealing materials, façade greening and bioretention can significantly improve the area's annual water balance. However, these scenarios also indicate that complete rainwater management in existing buildings requires a combination of measures and multi-purpose land use strategies, in which soil plays a major role.

Scientifically, the joint development and implementation of ClApT fostered mutual understanding for effective, goal-oriented planning. Under scientific supervision, ClApT is continuously refined to meet evolving needs. An extension is currently in development to identify and implement blue-green measures in public street spaces, such as parking areas (abstract desealing_BGI). The tool supports and accelerates local de-sealing and climate adaptation efforts, enhancing stakeholder understanding and process efficiency. ClApT is already being used in various district projects, including an analysis of the climate adaptation potential of all schools in the district of Charlottenburg-Wilmersdorf.

Edible mushrooms as bioindicators of soil pollution: environmental and health risk assessment

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: soil pollution, bioindicators, contamination factor, *Macrolepiota procera*, *Cantharellus cibarius*

Contaminated soil poses a significant risk to the other environmental components. Mushrooms are well known as excellent bioaccumulators of environmental pollutants originating from soil. Given that foraging mushrooms is a popular activity in Central Europe and they are an integral part of the local cuisines, analysing them from a risk assessment perspective is highly important. Between 2020 and 2024, a total of 128 samples of edible mushrooms (*Macrolepiota procera* and *Cantharellus cibarius*) along with corresponding soil were collected from selected locations across Slovakia. The total mercury content in both the soil and mushrooms was determined using an AMA-254 instrument. To assess the level of soil contamination with mercury, the contamination factor (Cf) was used. The mushrooms' ability to accumulate mercury from the soil was evaluated using the bioaccumulation factor (BAF), and the mercury concentration within the mushroom body was assessed using the translocation factor (Qc/s). To determine the health risks associated with the consumption of the studied mushrooms, the percentage of the provisional tolerable weekly intake (%PTWI) was used. The obtained results confirmed serious mercury contamination of soils, particularly in former mining areas. The mercury content in the soil significantly influences the mercury levels found in the stems and caps of the studied mushrooms. The results indicate that more mercury accumulates in the

caps than in the stems. Of the evaluated mushroom species, *Macrolepiota procera* proved to be the more effective mercury accumulator comparing to *Cantharellus cibarius*.

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Soil enzyme responses to sewage sludge amendments under contrasting metal(loid)s concentrations

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: enzyme production, pyrolysed amendments, compost, priming effect, contamination, biochemical impact

The application of sewage sludge-derived soil amendments, such as composted sewage sludge (CSS) and pyrolysed sewage sludge (PSS), can significantly influence soil biochemical functioning. In this study, soil enzyme activities were evaluated in response to CSS and PSS at two agriculturally used sites with contrasting soil conditions. While both sites received identical treatments, the enzymatic response varied strongly. At the first site, close to a coal mining area, total enzymatic activities were suppressed by both amendments compared to the control. In contrast, at the second site, a more pristine but less fertile area, enzymatic activities were unaffected or stimulated. Specifically, acid and alkaline phosphatases were inhibited in soil with elevated background contamination, whereas those enzyme activities were enhanced at the less disturbed site, indicating a distinct site-specific sensitivity of enzymes related to phosphorus. The suppression of enzyme activities at the first site can be linked to its higher background concentrations of risk metal(loid)s such as As, Cu, Ni, Pb and Zn, which can inhibit microbial activity and enzyme production even at moderate levels. Additionally, the presence of higher organic carbon content at this site may have contributed to a negative priming effect, where microbes preferentially utilise the more readily available carbon introduced through the amendments, reducing the need for extracellular enzyme production. In contrast, the lower contamination levels and different physicochemical conditions of the second site may have allowed a more favourable microbial response following sludge amendments.

These findings demonstrate the importance of considering both contamination levels and inherent soil properties when assessing the biochemical impact of sewage sludge-derived amendments in agricultural systems.

Are native plants survivors, or silent restorers? Insights from rhizosphere soils in phosphate mine sites

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: phosphate mine residues, native plants, rhizosphere soils, biogeochemical characteristics, reclamation, revegetation

The rhizosphere is a small area of soil affected by root activity that plays a critical role in improving the biogeochemical characteristics of degraded environments such as phosphate mine residues. The physicochemical properties of rhizosphere soils of the native plant species from phosphate mine sites were evaluated in this work. The main parameters measured were pH, electrical conductivity (EC), content of organic matter (OM), and available phosphorus. The phosphate mine residues were deficient in nutrient with low organic matter (did not exceed 0.54%) and high alkalinity (pH 8–9). The results showed that, in comparison to the bare phosphate residues, the rhizosphere soils had much lower pH levels, with maximum values of about 8.2. The microbial decomposition processes and root exudates (containing organic acid) are primarily responsible for this acidification effect. Higher levels of organic matter were found in rhizosphere soils with a decreased alkalinity, indicating increased biological activity and organic input from microbial byproducts and root biomass. The higher EC values in rhizosphere soils than bare residues further indicate their higher ionic content, which may be the result of enhanced nutrient cycling brought on by root-microbe synergies. Furthermore, the increase in phosphorus availability suggested that the rhizosphere change the

phosphate mine residue toward a nutrient-enriched substrates, which could promote plant colonization and growth in such areas. The study highlighted how native plant rhizospheres significantly improve the phosphate mining residues' quality through physicochemical and biological processes. The use of native vegetation as a low-input is a sustainable way to begin reclamation and revegetation in post-mining landscapes, particularly in alkaline regions with poor fertility and carbonate-rich substrates such as the phosphate mine residues.

Runoff-induced losses of water, soil, and nutrients under no-till agricultural hillslope in southern Brazil

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: soil management, phosphorus, potassium, runoff

Brazil is recognized as a global leader in the advancement of conservation agriculture, primarily due to the widespread implementation of the no-till system. Nevertheless, even within this conservation framework, hydrological processes such as surface runoff and soil erosion continue to occur, mobilizing sediments and nutrients toward adjacent aquatic ecosystems. These processes contribute to the deterioration of water quality and, ultimately, to environmental contamination. Therefore, this study aimed to assess water, soil, and nutrient losses under no-till agricultural hillslope in southern Brazil, under natural rainfall conditions. The hydrological and sediment transport dynamics were quantified by installing an H-flume at the outlet of a 2.5 ha hillslope managed under no-till system, with maize (*Zea mays*) and soybean (*Glycine max*) succession. This cropping system reflects the predominant grain production practice adopted by Brazilian farmers. Sediment yield and nutrient concentrations (nitrogen, N, phosphorus, P, potassium, K, calcium, Ca, and magnesium, Mg) in surface runoff were determined across 18 monitored rain-fall events between 2018 and 2023. The total precipitation recorded during the monitoring period 660 mm, of which 20% was lost as surface runoff. Cumulative sediment yield amounted to 9.1 tons. Nutrient losses varied significantly across the monitored events. Phosphorus losses ranged from 0.01 to 95 kg, K from 0.01 to 17.85 kg, and N from 0.01 to 98 kg. For Ca and Mg, the values ranged from 0.01 to 11.56 kg and 0.01 to 5.06 kg, respectively. The observed variability in nutrient concentrations indicates distinct hydrological and erosional responses among the events, with a single extreme event accounting for over 80% of the total nutrient losses. These findings suggested that the

current management system adopted for grain production was insufficient to effectively control surface runoff and prevent soil erosion on agricultural hillslopes. Consequently, nutrient depletion from agricultural fields not only reduces soil fertility but also increases production costs and elevates water treatment demands for human consumption. Therefore, the implementation of complementary conservation practices is essential to reduce sediment and nutrient transport into water bodies and mitigate associated socio-environmental impacts.

Application of biochar amendments for enhancing the quality of agricultural soils contaminated with heavy metals

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: biochar, soil contamination, heavy metals, soybean, soil quality, remediation

Biochar (BC), a material produced by biomass pyrolysis, emerges as a promising strategy for the remediation of heavy metal (HM) contaminated soils through immobilization, improving their physicochemical and microbiological properties, increasing their productive quality, and capturing carbon. Our objective was to determine the effect of BCs produced from soybean straw pyrolyzed at 300 °C (BCI), 400 °C (BCII), and 500 °C (BCIII) on the immobilization of HMs in agricultural soils contaminated with Pb, Cd, Cu, and Zn (SAC) and on soil quality. The SAC were collected near an open-air landfill of industrial waste in an urban area in Córdoba, Argentina. Subsequently, they were distributed into 4 treatments (n=8): SAC; SAC with BCI; SAC with BCII; and SAC with BCIII. They were incubated for one year in darkness at 65% of water holding capacity. Afterward, a complete soybean cultivation cycle was carried out, and the following variables were determined at the beginning and at the end of the incubation and post-harvest: HM mobility (Tessier sequential extractions), total carbon (C) and nitrogen (N), BC stability (TGA), soil aggregate stability, and microbial activity (FDA, dehydrogenase, glucosidase). The study revealed that the concentration of the four HM was significantly reduced in the bioavailable fraction across all BC treatments, throughout both incubation and cultivation. Furthermore, TGA demonstrated a direct relationship between BC stability and its production temperature. Interestingly, while soil aggregate stability improved

in all treatments over the course of the incubation and cultivation processes, BC did not influence this variable. However, BC amendment did significantly increase the total carbon content in the soil by 3.5 to 4 times and the total nitrogen content by 1.6 to 1.8 times. A slight decrease in both nitrogen and carbon was observed during the incubation period across all biochar treatments, with no further changes detected after cultivation. Importantly, the application of biochars led to an enhancement in the activity of soil microorganisms. These results demonstrate the efficiency of BC to immobilize HMs and improve the quality of agricultural soils regardless of the production temperature, positioning it as a potentially efficient and sustainable remediation technology.

Connecting adsorption mechanisms with heavy metal immobilization in biochar-amended contaminated soils

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: biochar, soil contamination, heavy metals, remediation, immobilization, adsorption mechanisms

Biochar (BC), produced through biomass pyrolysis, shows potential for remediating heavy metal (HM) contaminated soils via immobilization. This study investigated how soybean straw derived BCs, pyrolyzed at different temperatures (300, 400, and 500°C), influence HM distribution among chemical fractions in a contaminated urban agricultural soil (SAC), correlating results with adsorption mechanisms identified in aqueous solutions.

BCs were characterized for specific surface area, zeta potential (pζ), pH, C and N content, thermal stability (TGA), functional groups (FTIR), and crystalline composition (XRD). Adsorption isotherms for Cd, Cu, Pb, and Zn (present in SAC) were performed to determine maximum adsorption capacity. Metal-loaded BCs were analyzed by FTIR/XRD to identify dominant adsorption mechanisms. The SAC, collected near an industrial waste dump in an urban area in Córdoba, Argentina, was divided into four treatments: SAC, SAC+BC300, SAC+BC400, and SAC+BC500. These were incubated for one year (darkness, 65% water-holding capacity), with HM fractionation assessed quarterly via Tessier sequential extraction. BCs showed increased surface area, thermal stability, maximum adsorption capacity, C and N content and pH with higher pyrolysis temperature. The pζ measurements revealed negative surface charges even at pH 2, favoring cation adsorption, with BC400 exhibiting the highest colloidal stability. Functional groups (-OH, C=O, C=C, C-O, and CH) were stable across temperatures, though

some decreased due to lignocellulosic degradation. Calcite and silicates became more evident at higher temperatures, findings also found by XRD. Post-adsorption analyses showed complexation of all HMs with C=O groups (decreasing with temperature), Zn complexation with aromatic C–H groups (increasing with temperature), precipitation mediated by calcite of Cd, Cu, and Pb for BC400 and BC500. BC amendment reduced the available fraction of all HMs in SAC, shifting Cu to organic matter-bound fraction, attributable to stable complexation; Cd and Zn to carbonate-associated fraction, attributable to calcite-mediated precipitation or pH-sensitive complexation; and Pb to both fractions. Temperature-enhanced effects on immobilization were observed only for Cd and Zn. In conclusion, the adsorption mechanisms identified in aqueous experiments are strongly reflected in the changes observed in soil HM distribution after BC amendment, especially for Cd and Pb.

Urbanization effects on soil microbial communities and organic matter quality in Paris region

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: soil organic matter, microbial communities, urban-rural gradient, respirometry

Studying carbon stocks and fluxes in urban soils is becoming increasingly relevant, considering the continuous urbanization. Although they represent a relatively small area compared to forest or arable soils, urban soils could be considered as hot spots of anthropogenic carbon accumulation as it is estimated that they contain 3-5 times as much C per ha as natural soils. To date, few studies have investigated urban soil organic matter (SOM) quality and stability, i.e. its resistance to microbial decomposition. In this study, we investigated the relationship between soil microbial communities and SOM quality along an urbanization gradient. We also evaluated the ability of thermogravimetry to predict SOM mineralization kinetic parameters at a regional scale. In order to achieve this, 180 soil samples were collected from two different land uses (lawns and woodlands) along a gradient of urban pressure (rural, suburban and urban areas) in the Paris region (France). We determined SOM mineralization kinetic parameters by measuring CO_2 emissions in long-term incubations and the thermal stability of SOM by thermogravimetry combined with differential scanning calorimetry and evolved gas analyses (TG-DSC-EGA). The SOM quality was also characterized by using Middle Infra-Red Spectrometry (MIRS). Overall, SOM thermal stability increased from the rural to the urban areas in both land-use types. Urban woodland soils had greater SOM thermal stability than urban lawns, probably because the woodlands are much older than the lawns and because of historical soil management legacy in Paris region. Significant and strong relationships were found between microbial abundances, SOM thermal analysis indices (CO_2-T50 and energy density), mineralization kinetics parameters (mineralizable C and turnover) measured in the laboratory. MIRS analyses revealed different chemical compositions depending on

land use (higher aromaticity and condensation indices in lawns) and the urban gradient (lower polysaccharides content and aromaticity index in cities). This regional scale study suggests that 1) the thermal analysis of SOM, together with MIRS and soil physico-chemical measurements can be used to predict soil C mineralization potential and 2) SOM thermal stability and resistance to microbial mineralization are higher in urban soils, especially in woods.

Evaluating soil quality and carbon storage in remediated site in Castenaso (Emilia-Romagna, Italy)

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Topic: SUITMAs to conserve and improve soil quality and biodiversity
Keywords: remediated soil, carbon stock, nitrogen stock, Visual Soil Assessment (VSA), soil quality

Restoration of degraded soil is crucial for improving its quality in rapidly urbanizing contexts. As part of the Interreg Central Europe PoLaRecCE project, which develops sustainable strategies and innovative techniques for recovering degraded soils intended for non-food agricultural use, a demonstration site was selected in Castenaso (Italy).

The site, situated close to the Idice River in Emilia-Romagna region, is approximately 24,000 m^2, and had been historically contaminated by glass-ceramic (VFA) residues from a former kiln and fly ash. Between 2009 and 2010, an in-situ remediation treatment mixing VFA with $Ca(OH)_2$ and smectitic marlstone was carried out to immobilise potential toxic elements and prevent their leaching into the surrounding environment. Previous analysis on soil toxicity, monitoring plan and leaching tests showed the effectiveness of the remediation and the mobility reduction of potentially harmful elements according to the environmental Italian regulation.

Fifteen years post-remediation, the site is a non-managed grassland. A field campaign was conducted with the aim to evaluate current recovery of soil quality, focusing on C and N storage capacity and Visual Soil Assessment (VSA) methodology. Soil samples were thus collected at five georeferenced sampling points (CST1–CST5) by soil horizons down to the geotextile layer, corresponding to depths between 18 and 24 cm.

Results indicate a mean stock of soil organic carbon (SOC) of 28.94±3.05 Mg ha^{-1}, below regional averages for arable soils and permanent grasslands. Similarly, the nitrogen

stock was low (3.00 ± 0.41 g kg^{-1}), and its amount is strongly related to low carbon stocks ($r2=0.859$; $p<0.01$). The VSA results reveal moderate overall soil quality (VSA index = 27.6), with major constraints related to poor soil structure (Visual score = 1.2), restricted rooting depth (Visual score= 0.9).

Data integration suggests that, despite remediation's effectiveness in contaminants immobilization, the soil quality remains poor.

Introducing plant species beneficial to pollinators, such as legumes or nectar-rich plants, can enhance soil organic carbon and nitrogen content while supporting biodiversity. This strengthens key ecosystem services such as pollination and carbon sequestration in the PoLaRecCE's non-food production perspective.

SUITMA Improvers and ecosystem services

Waste Materials as Resources for Soil Recarbonization: is it a sustainable solution?

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Topic: SUITMA Improvers and ecosystem services
Keywords: waste management, urbanization, nutrient cycling, pollutants, waste separation

World's population is increasingly concentrating in cities, leading to linear translocations of all kinds of resources from rural settings into urban areas and from there dominantly into landfills. On the other hand, agricultural soils are experiencing severe losses of soil organic matter, affecting crop productivity and contributing to climate change. Recarbonization of soils by application of organic waste materials, including wastewater, sewage sludge, compost, biochar is currently promoted. Yet urban organic waste materials generally have narrow C/N ratios and are thus readily mineralized, i.e. contribute to greenhouse gas emission if applied in large quantities. Additionally, they are polluted with soluble salts, heavy metals, and emerging contaminants as plastics in all sizes, pharmaceuticals, antibiotic resistance genes, etc., jeopardizing soil functions in the long term. We exemplarily analyse the feasibility of organic waste recycling of Mexico City, a megacity of 21 million inhabitants, which reuses wastewater since more than a century, produced compost out of domestic organic wastes for more than a decade and now is now shifting to convert these wastes into hydrochar, which could be used as soil amendment. In all three examples, we demonstrate that the concentrations of indicator pollutants added by urban processes are either already limiting waste material applications to periurban soil (heavy metals in wastewater irrigated soil), or will limit it in the near future (plastic contamination). To counteract soil pollution, governmental agencies in several countries have worked out regulations for waste material applications to soil, mostly establishing

maximum permissible limits for pollutants of known adverse effects, and sometimes also establishing load limits in space and time. Surveillance of these regulations implies costs and are work intensive, and can lead to contradictions between governmental programs. There is a need to increase interdisciplinary research and intergovernmental actions between urban planners, waste management experts, agricultural engineers and soil scientists to make urban wastes sustainable soil amendments. Pollutant control at the source and waste separation within cities are necessary to produce waste materials which can be used in the long-term to safely recarbonize soil.

Aggerosols - Technosols or natural soils?

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Topic: SUITMA Improvers and ecosystem services
Keywords: World Reference Base (WRB); Polish soil classification; artefacts; human-induced soil formation

Technosols are a group of anthropogenic soils whose formation and properties are strongly influenced by human intentional and direct activity, especially in urban, industrial, or transport-related environments. In international soil classification, particularly in the World Reference Base for Soil Resources (WRB), Technosols are defined quite narrowly—restricted to soil profiles that contain substantial amounts of man-made materials such as artefacts, technogenic hard material, or geomembranes within the upper 100 cm. These criteria mean that only soils with clear evidence of technical modification are classified as Technosols. However, national classification systems often take a broader approach. For example, in the Polish Soil Classification, 6th edition (2019), Technosols are also treated as anthropogenic soils, but the concept is expanded to include additional subtypes. Among them are Aggerosols—soils developed from thick layers of mineral material that have been artificially deposited (e.g. during road, external dumps or dam construction), but which show prevailing signs of natural pedogenic processes. These soils may lack a high content of artefacts, yet their anthropogenic origin is clear due to the modified topography and substrate. Unlike in WRB, where such soils are often placed among weakly developed groups such as Regosols (or other RSG), the Polish classification recognizes them explicitly as part of the technogenic spectrum.

This presentation aims to explore the conceptual and practical consequences of these differing approaches to classifying anthropogenic soils—especially those that lie at the interface between human-induced disturbance and natural soil-forming processes. The issue will be illustrated using particular, detailed examples of soil profiles, classified

in parallel according to both systems. These case studies highlight the challenges in delineating Technosols, the implications for soil cartography and land evaluation, and the broader question of how human activity is represented in soil classification frameworks.

Is the nitrogen cycle still coupled with the carbon cycle in global forests under climate change?

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Topic: SUITMA Improvers and ecosystem services
Keywords: long-term tree water use efficiency, warmer climate and drier future, rising atmospheric CO_2, nitrogen cycle carbon cycle and increasing climate extremes

Tree water use efficiency has increased globally in the past 150 years, but this has not been translated into global increases in tree growth consistently in space and time. Complex and dynamic forest ecosystems would respond non-linearly to climate change with multiple factors over a lengthy period and can have tipping points at which a sudden shift to a contrasting dynamic regime might occur. However, prediction of such critical points before they are being reached is extremely difficult. Indeed, our comprehensive studies undertaken in the last 20 years (mostly unpublished) have shown for the first time that long-term tree growth of global forests responded non-linearly to rising atmospheric carbon dioxide (CO_2) and water (H_2O) limitation. This is due to the significant trade-off relationships between rising atmospheric CO_2 and increasing water limitation, based on (a) the direct trade-off between rising CO_2 and reducing plant leaf stomatal conductance / hence increasing water limitation and (b) the indirect trade-off between the rising CO_2 (the primary greenhouse gas) and global warming / hence increasing water limitation from rising evaporation and transpiration.

We have tested the trade-off relationships between the rising CO_2 concentration and increasing water limitation model globally, and our exciting major findings have highlighted that *there is a widespread decline in recent tree growth beyond the tipping points of atmospheric CO_2*, leading to the positive feedback to climate change. It is interesting to note that the atmospheric CO_2 tipping points for a given biome (such as temperate forests) would be influenced by both biotic (e.g. tree species and age) and abiotic factors (e.g. water and N availability), but *there is a global convergence of atmospheric CO_2 tipping point at 353.9 ppm or in 1990*, which is surprisingly close to

the theoretical or model-predicted atmospheric CO_2 tipping point of 350 ppm for the planet. There is increasingly decoupling between the C cycle and hydrological cycle in global forests under climate change due to the trade-off relationships between rising atmospheric CO_2 and increasing water limitation. Is the nitrogen cycle still coupled with the C cycle in global forests under climate change?

How can functional soils be constructed?

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Topic: SUITMA Improvers and ecosystem services
Keywords: constructed soil, agriculture, material association, material proportion, soil layers

In Europe, where 60 to 70 % of soils are currently estimated to be degraded, several initiatives have recently been launched to i) better characterize soil threats, ii) preserve soils, especially against land take, or iii) restore degraded soils. In addition to decontaminating or de-sealing soils, building new soils appears to be a potential solution for restoring at least some of the soil functionality, especially where soils have been entirely removed or where soils are so degraded than other options are no more realistic. This study aimed thus at providing a global and systematic review on the design of constructed soils. The evolution of the number of studies over time, the geographical origin of the studies, the contexts and intended uses of constructed soils were first analysed. Then, the design of the constructed soils, i.e. the number, thickness and composition of each horizon in the constructed soils were reviewed. Soil construction is a recent topic. Studies on constructed soils come from various countries around the world but 71% are located in Europe. Soils are mainly constructed for urban development and rehabilitation of mines and quarries purposes. End uses of the constructed soils are mainly urban green spaces and semi-natural environments. The number and thickness of horizons depend on the conditions under which the constructed soils were studied and increase overall as we move from laboratory conditions to outdoor conditions in containers and open fields. Soils constructed under laboratory conditions generally consist of a single growth horizon for germination and initial plant development, whereas soils constructed in the field have growth horizons, development horizons that enable roots anchoring and nutrient supply for plant development and technical horizons for water management.

Numerous mixtures were tested, particularly in the growth horizons, and most of them

are composed of mineral materials and organic matter in growth horizons while deeper technical horizons are mainly composed of mineral materials, which is consistent with the composition of natural surface soils.

Thus, the constructed soils in outdoor containers and especially under field conditions are similar to natural soils.

The transplantation of a giant tree using peat-based growing substrates - a case study

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Topic: SUITMA Improvers and ecosystem services
Keywords: giant tree, tree transplant, peat, growing substrate

There are many giant trees (including old trees, protected trees, and natural monuments) in cities and provinces throughout Korea. These trees are increasingly threatened by various factors, such as ecosystem changes due to urbanization and industrialization, land-use changes, environmental pollution, and submersion caused by dam construction. As a result, the need for transplanting many giant trees has been recognized in Korea since the early 1980s. In this paper, we would like to share our experience in giant tree transplantation using a growing substrate developed from peat resources in Korea. The most notable case is the transplantation of a 780-year-old ginkgo tree (*Ginkgo biloba*) in Yonggye-ri, Andong, in 1993. The submersion of Yonggye-ri due to dam construction necessitated the relocation of this important tree. An earthen mound was built around the ginkgo tree, and upon its completion, the tree was lifted and transplanted 17.5 meters from its original position at a rate of 50 cm per day. The space between the original and new positions was filled with material taken from the upper part of the mound. The growing substrates used in this project showed superior water and nutrient retention capacity compared to coir dust- and moss peat-based substrates, which are commonly used components. Furthermore, the substrate can be mixed with other materials such as various chemical fertilizers, compost, perlite, vermiculite, zeolite, and other growing media. Given these properties, the peat-based growing substrates used in this study show strong potential for application to both indoor plants and agricultural purposes. Following the successful transplantation of the ginkgo tree, the Guinness World Record for "The largest tree to be transplanted" was awarded in 2013.

A geochemical, physical and agronomic evaluation of technosols made from construction and demolition fines mixed with green waste compost

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Topic: SUITMA Improvers and ecosystem services
Keywords: Technosol, construction and demolition waste, compost, soil porewater, urban greening

Construction and demolition fines (C&D) and green waste compost (GWC) are commonly generated urban waste materials that are repositories of geochemical value, and which could be re-utilised to manufacture technosols to replace sealed soils and aid urban greening. In a multi-year experiment bulk volumetric mixtures of 0-100% C&D and GWC were created and subjected to various testing. Agronomic assessment was carried out by way of pot and rhizobox plant growth experiments with ryegrass (*Lolium perenne*), barley (*Hordeum vulgare* L. cv. Optic) and pea (*Pisum sativum* L. cv. Corus) to determine germination, plant mass and rooting behaviours. Geochemical and mineralogical evaluation was achieved by soil solution measurements, combined with X-ray powder diffraction analyses, to characterise technosols' distinct deviations from a control agricultural sandy podzol (soil). Water retention curves (saturation – 300 kPa) were tested on intact cores (55 * 40 mm) sampled 7 years after establishment.

Germination and growth of ryegrass was up to 80-fold greater after 30-days in the technosol composed of equal volumes of the two waste materials (50% C&D: 50% GWC) compared to the control soil. In the rhizobox experiment, root surface areas of barley and pea were increased from 130-200 cm2 in this technosol, compared to < 30 cm2 in the control soil. Even the technosol dominated by C&D (90%) showed increased available water compared to the control soil. Elevated concentrations of Ca and Mg in pore waters (550-800 mg l^{-1}) were dominant features of the technosols produced, explained

by gypsum and calcite enrichment, in contrast to the control soil (< 50 mg l^{-1}); extended leaching tests demonstrated ongoing gypsum dissolution, whereas soluble Mg was rapidly depleted.

In summary, the performance of the technosols tested here as plant growth substrates was strong despite their evident geochemical and mineralogical distinction from soil. Geochemical evaluation demonstrates that a degree of caution is required to monitor and manage Ca rich leachates from this selection of materials. In general, the sourcing of well sorted base materials with a good balance of particle sizes, nutrients and organic matter will greatly assist the creation of high quality technosols for a range of urban applications.

Soil health in urban areas: use of compost for protection and improvement

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Topic: SUITMA Improvers and ecosystem services
Keywords: urban soil, urban agriculture, organic waste

Maintaining and enhancing soil health can be particularly challenging in cities, where soils are exposed to many degradation processes and can be deeply disturbed by anthropic activities and contamination. Urban waste management and recycling are important issues for the sustainability of cities. The organic fraction of urban wastes can be conveniently treated and recycled through composting, a biological process in which mesophilic and thermophilic microorganisms decompose organic wastes, leading to a stabilized product known as compost. Composted organic urban wastes are usually recycled as soil amendments in agricultural areas, but cities also offer opportunities for their reuse, which have been less explored to date, although they will undoubtedly gain importance in the future. First, composts can be employed as organic amendments in urban agriculture, which is rapidly developing in many cities under different modalities: home gardens, community gardens, allotments, school gardens or rooftop gardens. Utilization for the remediation of degraded urban soils or for soil construction in landscaping projects are also potential applications for composts, since the soils involved would benefit from increased soil organic matter levels. Finally, urban waste compost can also be used as a component of soil-less substrates for green infrastructures, such as green roofs or vertical gardens. Examples from recent studies undertaken in the city of Santiago de Compostela, in northwestern Spain, will be presented for discussion of all these aspects. Implementation of practices of recycling of composted urban waste within cities would represent an opportunity to manage the increasing amounts of

organic waste produced in urban areas in a simple and efficient way, increasing circularity of processes, while at the same time contributing to improve the properties and health of urban soils.

Indicators of soil health for evaluating the efficiency of Nature-based Solutions and restoration actions in degraded environments

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Topic: SUITMA Improvers and ecosystem services
Keywords: soil enzymes, stable isotope, post-fire, green infrastructure, post-storm, urban areas

The National Biodiversity Future Centre (NBFC) focuses on valorization and conservation of Italian and Mediterranean biodiversity. One of the main goals of the centre is to assess the efficiency of Nature-based Solutions (NbS) and restoration actions to preserve natural and anthropized areas. To monitor these interventions is crucial the selection and application of suitable indicators to assess the soil health. The aim of this work was to test the suitability of stable isotope composition and soil enzyme activities as indicators of soil health and validate their sensitivity to disturbance as fire, flooding, windstorms, and urbanization. The impact of fire severity on soil isotope composition and soil enzyme activities were studied in pine and chestnut forests in Monte Pisano (Pisa) to assess their suitability in monitoring soil health during natural post-fire revegetation. The studied soil indicators were also investigated in riparian woodlands (Parco Naturale del Po Piemontese) with different managements to define their role as drivers of plant richness and to select the best management practices in areas with flooding events. In post-windstorm sites (Vaia storm, Asiago, VI) the soil indicators were studied along gradients including forest stands with different damage degree to investigate the effect of windstorm on soil health and soil carbon sequestration capacity. Regarding the urban areas, the sensitivity of soil enzymes and stable isotopes to urbanization were studied in Italian cities to evaluate the role of green infrastructure as NbS in providing ecosystem

services, linking soil health to air quality. The NBFC research activities will deliver strategies, guidelines, databases, and tools to support the design and implementation of NbS and restoration actions that foster biodiversity and enhance soil health and resilience in both urban and natural settings.

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Positive feedback effect on the growth of black pines planted on artificial planting bases

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Topic: SUITMA Improvers and ecosystem services
Keywords: disaster prevention, biogeochemical cycles, coastal forest, elemental dynamics, essential element, civil engineering

Engineered planting bases are now required to establish artificial greenery areas in worldwide urbanized areas. Pedogenic development of planting bases is promoted by planted plant growth, in turn, less vegetation development is a strong drawback for development of artificial soil materials. Along the pacific coastal area in northern Japanese main island, embanked sandy materials construct planting bases in the Sendai Bay area to establish black pine forests as a disaster prevention band against Tsunami. However, there seems to be a large difference in pine growth between planting areas probably due to plant nutritional conditions derived from soil properties of planting bases. We checked essential elements in surface soils and litter layers. Litter samples were collected every month to track changes in microbial biomass to evaluate nitrogen dynamics in soil. Although plant litter was large in Spring and Autumn in the better growth sites, rather less amount was observed at the less growth site because of low plant production in the poor growth area. Microbial biomass N showed common seasonal changes along with litter fall in the better growth sites. However, the less growth site showed strongly acidic soil reaction accompanied by low microbial biomass, resulting in less release of biogenic elements essential for growth of planted black pines. Plant litter piled in the better growth areas contained high concentration of Ca and K, leading to higher potential to supply essential elements as compared to that in the less growth area. Differences in nutrient supply from the litter layer affect to stock of essential elements in the surface mineral soils. The relationship between the growth of black pine and elemental stock in the litter layer coupling within the surface mineral soils indicates a positive feedback effect on plant growth to establish the artificial greenery band along the seacoast.

Impacts of recycled concrete and asphalt aggregates on soil microbial functions and physicochemical properties: an indoor-mesocosm experiment

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Topic: SUITMA Improvers and ecosystem services
Keywords: Recycled aggregates (RAs), waste materials for soil construction, soil restoration, soil microbial activity, indoor-mesocosm experiment

Construction and demolition waste (CDW) represents the largest waste stream in Europe (40% of total waste generated) and is expected to increase by 2050. The inorganic and non-hazardous fraction (CER 17-09-04) can easily be converted into recycled aggregates (RAs) and, according to their properties, reused for various purposes. A recent interest was raised in their application for soil reconstruction (i.e., after de-sealing interventions); however, research on their impact on soil is still scarce, so this study aimed to assess the effects of RAs on soil microbial functions, soil physicochemical properties, and seed germination.

Thus, an indoor-mesocosm experiment was performed using two recycled aggregates (asphalt and concrete) mixed 1:1 (v/v) with standard soils (Lufa 2.2 and 2.1) under two distinct moisture regimes (standard and flooding). Columns were maintained under controlled conditions (15°C inside and 20°C outside the carts; 16:8h light-dark photoperiod) for 28 days. Soil enzymatic activities (dehydrogenase, acid/alkaline phosphatase, sulfatase, urease) and microbial basal respiration were investigated as microbiological endpoints, whereas pH, electrical conductivity, carbonates, total and organic carbon, and total nitrogen were measured as soil chemical parameters. At day-28, seed germination, plant length and biomass of *Lolium perenne* and *Medicago sativa* were also evaluated.

Results showed that RAs significantly affected microbiological parameters, across both soils and moisture conditions. After 28 days, all enzymatic activities decreased in the presence of RAs (reduction over 50% for asphalt and 70% for concrete) as well as basal respiration. Under standard moisture conditions, seed germination and plant development were reduced compared to the control, especially in the concrete treatment, likely due to the pH increase in RA-soil mixtures (from 5 in control to 10 in the RAs-mixtures). In contrast, under flooding conditions, seed germination was reduced in control soils compared to soil-RAs mixtures, because of their higher water retention, resulting in a water content greater than 80%.

This study shows that, at 1:1 volume ratio, RAs can disrupt multiple soil functions by reducing microbial activity (concrete and asphalt) and affecting plant growth (concrete), suggesting potential limitations to their use in soil restoration.

Assessment of long-term effects of soil amendments on CO2 efflux in a reclaimed magnesite site (preliminary results)

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Topic: SUITMA Improvers and ecosystem services
Keywords: magnesite mining, CO_2 efflux, soil amendments, long-term monitoring, reclamation, biological activity

Soil CO efflux is a key indicator of both soil carbon dynamics and biological activity, offering critical insights into ecosystem functioning and soil health. This study presents the findings of a long-term monitoring effort allowing the reclamation of a degraded magnesite mining site. It builds upon the previous research titled "Reclamation of abandoned magnesite site using amendments and plantation", conducted from 2017 to 2020, where goat manure, sulfur, and gypsium were applied to improve soil conditions, and three tree species: *Cedrus libani*, *Robinia Pseudoacacia*, and *Pinus nigra*, were planted. In 2022, CO_2 efflux with a soil gas flux survey chamber (Licor 8200) and basal respiration measurements were carried out to evaluate the biological activity of the soil five years after treatment. The results indicated significant differences in CO2 efflux among the amendment treatments ($P<0.001$), while no significant differences were found among the tree species. The highest CO_2 efflux was observed in sulfur-treated plots (0.76 µmol CO_2 $m^{-2}s^{-1}$), followed by manure (0.74 µmol CO_2 $m^{-2}s^{-1}$), gypsium+manure (0.71 µmol CO_2 $m^{-2}s^{-1}$), sulfur+manure (0,63 µmol CO_2 $m^{-2}s^{-1}$), gypsium+sulfur (0.54 µmol CO_2 $m^{-2}s^{-1}$), gypsium alone (0.48 µmol CO_2 $m^{-2}s^{-1}$), and the control (0,44 µmol CO_2 $m^{-2}s^{-1}$). The basal respiration was observed in sulfur+manure 5,46 CO_2 g^{-1} h^{-1}, manure 5,44 CO_2 g^{-1} h^{-1}, sulfur 5,25 CO_2 g^{-1} h^{-1}, gypsium+manure 4,96 CO_2 g^{-1} h^{-1}, gypsium 4,66 CO_2 g^{-1} h^{-1}, gypsium+sulfur 4,06 CO_2 g^{-1} h^{-1}, and the control 4,41 CO_2 g^{-1} h^{-1}.

These outcome findings demonstrate that the initial amendments continue to positively influence soil biological processes. Consistent with the earlier recommendation that "adding manure, sulfur, and gypsum may improve the mining site conditions to adjust

the substrate conditions for plant growth" this study confirms the long-term benefits of combining these amendments to support successful reclamation in magnesite mining sites.

From urban waste to natural soil preservation: newly constructed Technosols evaluation for sustainable urban greening

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Topic: SUITMA Improvers and ecosystem services
Keywords: Technosols, geochemical analysis, health risks, construction and demolition waste, circular economy, land rehabilitation

Although soil is a non-renewable resource vital for life, supporting over 95% of global food production and harbouring more than a quarter of the world's biodiversity, its depletion continues to accelerate. This is largely due to expanding urbanization, infrastructure projects, and commercial development, which often encroach upon valuable natural and agricultural lands1. Such ongoing land conversion not only jeopardizes food security and ecosystem health but also results in fertile soils being transformed into urban areas where they become sealed, degraded, or contaminated.

To address this issue, our research investigates the potential of the creation of technosols-engineered soils made from construction and demolition waste (CDW) combined with organic by-products like municipal compost. CDW represents the largest waste stream in Europe, accounting for 37.5% of total waste by mass (approximately 800 million tons annually), making its recovery and reuse an urgent environmental priority. Moreover, the local availability of CDW helps reduce the environmental footprint associated with transporting materials over long distances.

Experimental sites have been established in the urban area of Turin (Italy), where different technosol formulations are being evaluated alongside natural soils for their potential to support plant growth. A quality assessment of the formulations was done by evaluating their physico-chemical properties, sustainability for seed germination, plant growth, their content of potentially toxic elements and their environmental/ecological risks. Soils were then periodically sampled for two years and analysed to monitor their

development and early-stage pedogenesis, and to assess agronomic, physicochemical, and microbiological properties. Different species of herbaceous perennials were grown on the technosols and monitored for morphological and physiological parameters. The transformation of urban waste into functional soil demonstrates potential not only for reducing the consumption of natural land but also for advancing a circular approach to resource use within urban environments.

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From waste to soil: constructing fertile Technosols with excavated mineral materials, milled asphalt and compost

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Topic: SUITMA Improvers and ecosystem services
Keywords: constructed Technosol, milled asphalt, compost, excavated mineral materials, soil fertility, plant diversity

Urban green spaces are increasingly valued for their role in enhancing quality of life, yet urban soils are often degraded, polluted, or unable to support vegetation. This commonly leads to importing natural soils from rural areas—an unsustainable and costly solution. Meanwhile, large volumes of urban mineral waste remain underutilized. Constructing Technosols, artificial soils made from recycled mineral waste and organic amendments such as compost, offers an advantageous alternative that supports biodiversity and promotes sustainable urban development.

This study investigates the potential reuse of milled asphalt (MA) from urban deconstruction as a component of constructed Technosols. Although soil desealing and renaturation are gaining momentum in European cities, the effects of MA on soil properties and plant growth remain poorly studied.

A long-term in situ experiment was conducted at the Tersen site in Louvres (northern Paris region, France), using excavated mineral materials (EMM) collected following topsoil removal. Technosols were formulated with 0–10% milled asphalt (MA; particle size <3.15 mm) for prairie plots composed of 15 plant species, and amended with 0–10% green waste compost (GWC) as an organic input. Various parameters were assessed, including soil physicochemical properties: pH, cation exchange capacity (CEC), water holding capacity (WHC), C/N ratio, soil chemical composition: X-ray fluorescence (XRF) and mid-infrared spectroscopy (MIRS), CO_2 emissions (Li-COR analyser), microbial abundance (qPCR), microbial activity (Biolog assay), and plant diversity.

The addition of compost significantly improved soil chemical properties, while MA had a limited effect, except for a slight increase in pH. MA reduced bulk density and WHC,

particularly in the absence of compost. Furthermore, MA influenced CO_2 emissions, microbial abundance, and microbial activity, although these effects were partially mitigated by GWC. Regarding plant diversity, MA had a significant impact on both the seeded and spontaneously established plant communities.

These results offer the first insights into using MA in constructed Technosols. GWC addition helped offset fertility losses associated with MA. Organic amendments played a key role in maintaining soil function, microbial communities, and plant diversity. This study highlights the potential of recycled materials for constructing fertile soils, contributing to circular economy practices and more sustainable urban ecosystems.

Turning waste into substrates enhance rooftop tomato production through microbial mediation

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Topic: SUITMA Improvers and ecosystem services
Keywords: organic waste, biochar, substrates, microbial biodiversity, food production, urban agriculture

Urban agriculture is emerging as a valuable strategy to mitigate the challenges posed by rapid urbanisation and global population growth. Among its forms, productive rooftops stand out as a sustainable solution, enabling food production, organic waste recycling, and the creation of green spaces by repurposing underutilized roofs. Leveraging natural resources, including plant-associated microbiomes, offers further potential to sustainably improve productivity and food quality. However, microbial communities inhabiting different organic amendments, such as compost and biochar (BC), remain poorly studied despite their relevance in shaping plant–substrate interactions.

The Madreenroof project, conducted on the rooftop of the Instituto de Ciencias Agrarias (ICA-CSIC) in the city of Madrid, aimed at investigating how different organic biomasses (i.e., spent coffee grounds, coffee silverskin, and seaweeds) composted with or without BC affect substrate properties, microbial communities, and tomato productivity. A commercial peat-based substrate was used as a benchmark.

Our results showed that feedstock type was the primary factor influencing substrate chemical and physical properties, and thus microbial communities. While BC addition improved compost quality, its role in shaping microbial communities was less pronounced than that of the feedstock. Alternative substrates exhibited higher phosphorus concentrations, pH, and electrical conductivity than peat. Microbial analysis revealed

that bacterial diversity was higher in alternative substrates, yet their overall taxonomic structure remained relatively consistent across treatments, indicating functional redundancy. Notably, we identified distinct microbial communities associated with each feedstock. Communities enriched in the composted seaweed biomass substrate were significantly and positively correlated with increased tomato yield.

These findings highlight the dual role of organic substrates in directly influencing plant growth through their physicochemical traits and indirectly through microbiome modulation. Selecting appropriate organic materials not only boosts rooftop vegetable production but also enriches urban microbial diversity in otherwise underexploited spaces.

Microbiological and enzymatic responses in waste-based reconstructed soil profiles

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Topic: SUITMA Improvers and ecosystem services
Keywords: reconstructed soils, by-products and waste, enzymatic activity, organic amendments

The restoration of soil functions is essential for the rehabilitation and requalification of sites degraded by natural or anthropogenic activities. Several processes have been developed to restore soil cover while simultaneously promoting environmental protection and ecological resilience. The reconstruction of new soils is a highly significant process in the field of soil science.

The use of by-products and waste materials can be considered a form of recycling. This study focuses on evaluating five soil profile types (C, P1, P2, P3, and P4) in terms of microbiological functioning and enzymatic activity within the soil–plant system.

The results showed higher levels of enzymatic activity in the surface horizon compared to the two lower horizons. The maximum value of β-glucosidase activity was estimated at approximately 90 µmol PNP g^{-1} h^{-1} in the control profile.

The plant species used (Medicago sativa) exhibited clear physiological responses, indicating that the organic treatments were applied at relatively high dosage. The amended profiles were compared to the control.

The findings suggested that the use of by-products, particularly a mixture of sludge, agricultural soil, and landfill soil, represented a viable alternative for improving the physical-chemical and biological properties of the soil.

Use of waste materials as feasible strategy for urban de-sealed soil reclamation: evidence from a restoration case study in Prato, Italy

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Topic: SUITMA Improvers and ecosystem services
Keywords: soil sealing, soil reuse, asphalt reuse, soil depaving, green infrastructures

Soil degradation is an increasingly urgent – yet often underestimated – environmental challenge. Among its various forms, soil sealing is the most severe, as it disrupts all soil-related ecosystem services. In addition to preventing further sealing and degradation, reversing soil sealing by removing unnecessary pavements in urban areas is emerging as a critical mitigation strategy. This practice helps restoring essential soil functions, while also enhancing public health and the quality of urban spaces. The desealing of underutilized surface can contribute to the long-term goal of "no net land take" by 2050. Despite its potential, urban de-sealing remains largely under-implemented. One of the main barriers is its high cost, as even the removal of a thin asphalt layer generates a substantial amount of waste, much of which ends up in landfills due to limited recycling options.

Here, we present selected findings from a one-year monitoring study conducted in a de-sealed urban area in the Municipality of Prato, Italy. The site, previously a ~170 m^2 parking area, was de-sealed in April 2024. The asphalt layer was removed, and urban excavated topsoil was applied over a base of existing rubble and stones. This topsoil was amended with crushed (< 2 cm) asphalt at varying rates (up to 50% w/w), along with a uniform addition of urban compost (5% w/w). All plots were sown with a standard urban grass seed mix, including species such as *Lolium perenne*, *Festuca rubra*, and *Poa pratensis*. We monitored vegetation growth and changes in soil physical, chemical, and

biological properties to evaluate the potential of this restoration approach to enhance de-sealed soil health.

The results indicated that plant biomass and soil chemical properties were basically unaffected by asphalt additions, while some physical characteristics, such as bulk density and permeability, were even improved. However, biological indicators—including microarthropod diversity and enzymatic activity—declined at the highest levels of asphalt incorporation. These findings suggest that, within certain limits, the asphalt from de-sealing operations can be reused as soil components, offering both environmental and economic benefits in urban greening initiatives. The study underscores the need for further research to optimize this approach and promote the broader adoption of sustainable land restoration practices in cities.

Development of good practices of managing urban "green" to achieve climate change adaptation and mitigation

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Topic: SUITMA Improvers and ecosystem services
Keywords: urban green, biochar, CO_2 flux, carbon storage, water use efficiency, Infrared Gas Analyzer (IRGA)

The urban green areas, such as recreational zones and parks, are particularly vulnerable to climate change impacts as the vegetation and the soil properties of these areas can be significantly affected compared to the other areas. There is a great need for practices and amendments that can help in mitigation of those areas from climate change. In this respect, there has been a great emphasis on biochar as a soil amendment recently. It is an end product obtained at the pyrolysis of biomass at high temperatures, usually between 300-900 °C. There is a significant amount of literature material that defines its potential for enhancing the carbon storage, water use efficiency, along with other soil properties, and CO2 efflux reduction.

For this matter, a study was designed in the Monza Park at a grassland study site area of 75x50 m2. A weather station was built near the study site for taking the monthly atmospheric measurements. Lysimeters were installed in each of the six plots for the water storage measurement of the soil. The area was further divided into 6 blocks and 18 subplots of 2x2 m, with three subplots for 3 replicates within each block. Soil physicochemical properties including soil organic carbon and water retention, were measured. Initial measurement of CO_2 efflux was measured by parameters of Net Ecosystem Exchange (NEE), light measurement 2 cycle, and Ecosystem Respiration (ER), dark measurement 1 cycle per subplot from the soil was measured using IRGAs (Infrared Gaseous Analyzer), each 7-10 days from January 2025 onwards. Biochar produced from

feedstock derived from wood origin was applied to the soil using the hole application method for the least disturbance of vegetation at the rate of 5,10,15,20,25 t/ha. The study aims to assess the application of biochar at different rates to determine which amount will be suitable for the reduction of CO_2 efflux from soil, along with enhancing the soil carbon content and water retention of the soil of the Monza Park. Thus, it adds to the enhancement of the soil properties of the urban green areas and the mitigation of CO_2 efflux from the urban green.

Effect of soil fauna inoculation on constructed Technosol

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Topic: SUITMA Improvers and ecosystem services
Keywords: reclamation, pedo-faunistical engineering, soil colonization, pedogenesis, fertility

In recent years, both legislation and public interest relating to ecosystem reclamation have soared. With functional soils being the bedrock of terrestrial ecosystems, effective and sustainable soil reclamation is now in high demand. Thus, many have turned to alternative soil building technologies, regrouped under the umbrella of pedological engineering. Previous studies have shown that soils built using organic waste are a viable alternative to the use of topsoil.

However, limits in the constructed soils functionality have been identified with this approach. Notably, the colonization of constructed soils by soil fauna is slow during the first years of existence of the soil. Lower abundance and diversity of fauna in those young soils might limit their ability to provide ecosystem services. Either having to wait longer or having to invest in more work and/or resources in order for these soils to fully fulfill their ecological potential may deter stakeholders from resorting to pedological engineering.

Thus, we studied a method of pedo-faunistical engineering, combining an already established soil construction process and soil fauna inoculation. The goal was to determine whether or not this new method helped soils provide ecosystem services quicker than pedological engineering alone.

Forty Technosols built inside wooden boxes (1*1*0.5m) and installed on a roof were monitored for one year. They were built with a thin layer of compost (5 cm) placed on top of excavated material (30 cm). Soils were inoculated with either earthworms, woodlice, collembola or not inoculated. For each condition, half of the soils were covered with thinly meshed nylon to limit spontaneous colonization.

Results allow us to conclude on the success of inoculation after 1 year by monitoring colonization by soil fauna and interactions with various indicators and processes (biomass production, pedogenesis). The first look at results shows that nematodes density is not significantly impacted by the type of organism inoculated. However, inoculation is expected to impact the proportions of nematodes trophic groups and soil stability.

Evaluation of the content of potentially toxic metals in environmental samples of the Belnianka River (southern Poland) in the light of geochemical indicators

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Topic: SUITMA Improvers and ecosystem services
Keywords: heavy metals, environmental samples, river, geochemical indicators

The paper presents the results of tests on the content of selected heavy metals (Cd, Cu, Cr, Ni, Pb, Zn, Co, Mn and Fe) in samples of water, bottom sediments and macrophytes. Samples for analysis were collected from the Belnianka River located in the Świętokrzyskie Voivodeship. The research was conducted in 2023–2024 at nine measurement points located in various sections of the river, including both natural and anthropogenically transformed areas. The Belnianka catchment area consists mainly of agricultural and forest areas. Built-up areas with residential and service functions are located primarily along the main communication arteries. Additionally, three municipal sewage treatment plants are located in the catchment area.

The primary goal of the research was to assess the impact of anthropogenic factors on the condition of the aquatic environment of the Belnianka River, while the secondary objectives were: (i) determining the content of heavy metals in water and bottom sediments and macrophytes, (ii) assessment of the quality of abiotic and biotic elements of the Belnianka River ecosystem based on selected criteria and (iii) determination of the abilities of macrophytes for use as a bioindicator.

The content of heavy metals in the samples was determined by atomic adsorption spectroscopy (AAS), while the contamination of bottom sediments with heavy metals was determined based on the obtained values of the geoaccumulation index (I_{geo}), enrichment factor (EF) and PEL (*probable effects levels*) and TEL (*threshold effects levels*) values.

Based on the analyses, it was concluded that the average content of metals determined

in bottom sediments was: Cu 2.2 - 4.8 μg·kg^{-1}, Cd 0.0 - 0.2 μg·kg^{-1}, Cr 0.6 - 3.5 μg·kg^{-1}, Ni 0.4 - 1.9 μg·kg^{-1}, Pb 1.0 - 4.6 μg·kg^{-1}, Zn 11.1 - 41.2 μg·kg^{-1} and Co 0.2 - 1.3 μg·kg^{-1}. For macrophytes, the highest concentrations Cr – 93.8 μg·kg^{-1} and Zn – 219.1 μg·kg^{-1} was recorded in the roots of *Acorus calamus* L. In turn, in *Sparganium erectum* L. em. Rchb. s.s. the highest amounts of the same elements, i.e. zinc and chromium, were also observed.

The use of bypass dust from cement plants and fruit and vegetable processing waste for the production of mineral-carbon material in the reclamation of acidified soils

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Topic: SUITMA Improvers and ecosystem services
Keywords: bypass dust, fruit processing waste, mineral-carbon material, acidified soil, reclamation

The aim of the study was to develop technology for the production of mineral-carbon materials from cement plant bypass dust and fruit and vegetable processing waste (apple pomace). The basic components of these materials were cement plant dust and fruit and vegetable processing waste, which are precursors of activated carbon. From a mixture of these components, after spirolyzing in an anaerobic atmosphere, a novel alkaline product with an active adsorption layer formed by activated carbon was produced. This product, created from industrial waste, can be used to deacidify soils and absorb chemical pollutants in them. Laboratory tests were conducted with the aim of:
determining the average physicochemical composition of dust from bag filters and bypass dust for mineral-carbon material synthesis technology, and plotting the average physicochemical composition of pomace from fruit and vegetable processing for mineral-carbon material synthesis technology;
development of mineral-carbon material preparation (composition, drying temperature, pyrolysis parameters in anaerobic atmosphere) and their characterization;
determination of the effect of mineral-carbon preparations on the acidity of selected soils with different granulometric composition;
developing a technological recipe for producing mineral-carbon material;
conducting pot tests for different types of soils (buffering capacity, change in pH value, hydrolytic acidity, sorption).
As a result of the research, a recipe was developed for the production of mineral-carbon materials from cement plant filter dust and fruit and vegetable processing waste for the

deacidification of soils and adsorption of environmental organic pollutants. It was found that the resulting product can be safely applied to highly acidified soils. The proposed formulation is currently patent pending.

A formulation support tool for the design of functional constructed Technosols

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Topic: SUITMA Improvers and ecosystem services
Keywords: artefacts, soil construction, predictive algorithm

The construction of Technosols refers to the intentional creation of soil-like systems using artefacts purposefully combined to support vegetation growth. This approach offers a promising response to urban greening challenges and represents a key opportunity to promote circularity in urban material management.

A major challenge in Technosol construction is the formulation of optimal "recipes"—that is, the selection and proportioning of their parent materials—to meet specific functional requirements depending on the intended land use (e.g., plant nutrient needs, load-bearing capacity, water infiltration and retention).

To address this, we developed a formulation support tool that recommends optimal combinations of parent materials to design functional, purpose-fit constructed Technosols. Users input a list of available parent materials along with their bio-physico-chemical properties. Based on these inputs and the target land use (e.g., green space, roadside planting), the tool outputs a ranked list of recommended mixtures. This ranking integrates three key criteria: agronomic performance, cost, and transport distance from source to site.

Our approach began with the creation of a comprehensive database containing over 600 entries describing both the properties of categorized parent materials (e.g., compost, sewage sludge, crushed bricks, deep soil horizons) and those of the resulting mixtures, including their mass ratios. Using this dataset, we developed predictive algorithms

capable of estimating mixture properties based solely on those of the input materials. We then defined decision rules to assign performance scores for each criterion by comparing predicted properties against target values tailored to each land use scenario. This scoring system forms the basis for the final ranking of mixtures. A web-based interface for the tool is currently under development and will be freely accessible.

The tool is now being presented to potential end-users—namely, French companies involved in Technosol construction—to gather feedback and enhance its functionality.

Mitigating effect of green infrastructure on the impact of urbanisation on ecosystem services of urban soils

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Topic: SUITMA Improvers and ecosystem services
Keywords: nature-based solution, green infrastructure, soil sealing, urban soil, ecosystem services, urbanisation

Urbanisation is a major threat to the environment. Soil sealing is the most intensive form of land take and is generally an irreversible process. Urban soils are significant part of the urban ecosystem, so it is very important to manage them properly, meaning ensuring soil quality is adequate to maintain plant productivity, improve water and air quality and support human healthy habitat. Urban soils provide a range of ecosystem services relevant to cities. They mitigate flooding, buffer the urban heat island effect, capture pollutants and are responsible for nutrient cycling and carbon storage. Unsealed soils host a wide range of soil organisms. Microorganisms are responsible for the healthy functioning of the soil ecosystem. They decompose organic substances, create soil humus, enable plants to take up available mineral nutrients in the soil and participate in the neutralisation of contaminants. An unsustainable urban landscape results in air, water and soil degradation as well as the fragmentation of natural habitats and decline in biodiversity. A sustainable urban landscape can be achieved through the use of nature-based solutions that support natural ecological functions by protecting ecosystems and recovering ecological capacity where it has been lost. One of the nature-based solutions particularly important in the city is green infrastructure.

A study on impact of urbanisation on the environment was carried out in 2022 in Lublin and Puławy. At sites with different building and vegetation intensities air temperature was measured and soil samples were taken to determine phosphorus, potassium, carbon, nitrogen, PAHs and metabolic activity. The analyses carried out have shown that urbanisation affects the loss of soil's capacity to fulfil the ecosystem services needed to create suitable and healthy habitat. In both cities, in areas with higher levels of

urbanisation, soil showed higher phosphorus, nitrogen and carbon content, higher PAHs accumulation and lower metabolic activity. Development also affects the temperature in the city. The more dense the build-up, the higher the average night-time temperature and the higher the number of tropical nights. The studies also showed that green infrastructure mitigates the negative effects of urbanisation by contributing to lowering temperatures, reducing contaminants in the soil and increasing soil metabolic activity.

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Urbic Technosoils of the Imeretinskaya Lowland (Russia) - Soils of the olympic construction site

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Topic: SUITMA Improvers and ecosystem services
Keywords: urbic technosoils, soil morphological characteristics, anthropogenic soils of the subtropics

The main part of the Imeretinskaya Lowland is currently occupied by the Federal Territory "Sirius", which is the youngest modern city located in the subtropical zone of the Russian Federation. The city was formed in 2020 by allocating territory from the resort city of Sochi. It is located on the Black Sea coast between the Mzymta and Psou rivers and includes all coastal cluster facilities built for the XXII Winter Olympic Games in 2014. The city's area is 14.19 square kilometers. Until 2010, the main soil types common on the lowland were Cambisols, Acrisols and Fluvisols. They were subject to moderate anthropogenic impact due to active agricultural activities and were classified as Anthrosols.

However, between 2010 and 2014, much of the area was significantly redeveloped during the construction of Olympic facilities. This led to serious changes in the soil cover. To raise the area above sea level by at least 4 meters, the native surface was backfilled using construction and natural mineral material. This led to the complete loss of most of the natural soils of the Imeretinskaya Lowland; subsequent landscaping of the territory was carried out mainly on artificial soil constructions.

As a result of the redeveloping, the modern territory of the city has a high degree of sealing, which reaches 60%. The city's soil cover is 90-95% represented by Urbic Technosoils, most of which are constructozems. These soils are characterized by a bipartite profile. The lower part is formed by technogenic or alluvial material; the surface horizons are usually represented by displaced humus horizons of chernozems, and rarely by displaced surface horizons of alluvial soils.

Natural soils - Fluvisols are found only as local areas. This does not allow us to speak about the preservation of significant soil areas. The remaining areas of natural soils of the Imeretinskaya Lowland can be observed only in the form of local areas – refugia. Their preservation is of high scientific importance, as it allows to trace both: the evolution of the soils of a given region and to have a reference for assessing the degree of anthropogenic impact on soils similar genesis.

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The transplantation of giant trees using peat-based growing substrates - success stories

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Topic: SUITMA Improvers and ecosystem services
Keywords: giant tree, tree transplant, peat, growing substrate

There are many giant trees (including old trees, protected trees, and natural monuments) in cities and provinces throughout Korea. These trees are increasingly at risk due to various environmental pressures, such as ecosystem changes from urbanization and industrialization, land use alterations, pollution, and submersion caused by dam construction. Consequently, the need for transplanting these giant trees has grown since the early 1980s. In this paper, we share our experiences with giant tree transplantation using *Life Soil* and *Life Mud*, two peat-based growing substrates developed in Korea. The standard transplantation process consists of two key steps: Step 1 – Root Ball Preparation (Year 1) and Step 2 – Transplantation (approximately one year later). These procedures will be discussed in detail in this paper. Peat-based substrates like *Life Soil* and *Life Mud* demonstrate excellent water retention capacity, facilitating the rapid establishment of transplanted trees. They have proven particularly effective in addressing issues from both drought and waterlogging in the root zones of giant trees within a year of application. Successful transplantation cases using *Life Soil* and *Life Mud* include the ginkgo tree at Cheongnamdae (basal diameter: 140 cm, age: 80 years, transplanted in 1983) and, the zelkova tree in Sindoan District (basal diameter: 200 cm, age: 600 years, transplanted in 1986), among more than 200 verified cases. Based on these positive outcomes, we are confident that peat-based growing substrates such as *Life Soil* and *Life Mud* have potential for broader application across a wide range of plant species and agricultural crops.

Hybrid green roof system combining constructed wetland and semi-intensive green roof with recycled crushed brick substrate: experimental and numerical study

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Topic: SUITMA Improvers and ecosystem services
***Keywords*:** recycled crushed brick, greywater treatment, nature-based solutions, green roof, constructed wetland, water and solute transport modelling

Water scarcity and the urgent need for sustainable urban water management call for innovative, circular solutions to recycle and reuse greywater. This study investigates a hybrid green roof system that integrates a constructed wetland (CW) and a semi-intensive green roof (GR), enabling onsite greywater treatment and reuse for irrigation. The system, experimentally tested by Petreje et al. (2023), is designed as a nature-based solution and incorporates recycled materials—including crushed brick and pyrolyzed sewage sludge—as substrate components to enhance circularity and sustainability.

A digital twin of the system was developed using HYDRUS-2D to simulate water flow and solute transport dynamics. Richards' equation was applied to model variably saturated water flow, and the advection–dispersion equation (ADE) was used to simulate BOD_5 transport with first-order degradation kinetics in the CW zone. The model was calibrated and validated using data from an experimental testbed located at Czech Technical University in Prague, incorporating irrigation schedules, local climate conditions, and measured inflow/outflow data.

The simulation results confirmed strong alignment with observed system behavior and revealed that water predominantly flows through the green roof's bottom mineral wool layer. Ongoing work includes scenario-based simulations exploring various system configurations, irrigation strategies, and climatic conditions (temperate and semi-arid), as well as sensitivity analysis of key design parameters such as substrate depth and irrigation frequency.

By integrating recycled materials into functional green infrastructure, this study supports the development of sustainable, scalable urban water recycling systems and contributes to advancing circular material use in construction.

Soil constructions of Nature-based Solutions (NBS) for moderate climate: monitoring and modelling

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Topic: SUITMA Improvers and ecosystem services
Keywords: soil construction, rain garden, soil water content, salinization, de-icing agents, HYDRUS 1D

Nature-based solutions (NBS) are natural-anthropogenic systems that harness the natural functioning of ecosystems to address environmental, social, and economic challenges in cities, including those caused by climate change. In the context of a changing climate, the local functions of NBS—such as stormwater drainage and purification—are becoming increasingly relevant not only for cities in oceanic, subtropical, and tropical climates, but also for settlements in temperate regions. As a result, the integration of NBS into urban landscaping and greening systems has become one of the global priorities in urban planning. However, a major limitation to the widespread adoption of NBS is the need to adapt these technologies to urban anthropogenic pressures, as well as to the climatic and regulatory conditions that govern the design, implementation, and maintenance of urban green infrastructure. Therefore, the main objective of the research was to analyze the relationship between the parameters of soil constructions of blue-green solutions and their effectiveness in stormwater drainage and treatment.

The research involved monitoring two experimental rain gardens year-round and modelling water-physical processes over the same season. This was followed by a validation of the measurement and model results. To assess the functional stability of

components in the experimental rain gardens, soil temperature was monitored using TR series DS1925L-F5 loggers, soil moisture was monitored with the Zenta z6-15719 system, CO_2 emissions were measured using a PP Systems EGM-5 gas analyzer, and plant photosynthetic activity was assessed with a SPAD-502 Plus meter. Winter monitoring revealed that soil structures incorporating peat allowed 18–40% less leaching of readily soluble salts compared to those using loam. However, this retention accounted for only a small fraction of the total salt concentration in meltwater runoff. During peak loads, peat-based rain gardens could retain larger volumes of water, but after the water inflow ceased, soil moisture decreased to minimum levels, as confirmed by modelling of these processes in the HYDRUS 1D software.

What drives ecosystem services' delivery by constructed urban soils in Wageningen: the first outcomes of the social survey and field experiment

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Topic: SUITMA Improvers and ecosystem services
Keywords: urban soils, ecosystem services, earthworms, Technosols, urban green space

Urbanization is accelerating worldwide, and in the Netherlands, it is predicted that urban areas will cover more than 17% of the territory by 2040. The development of urban ecosystems often involves the construction of Technosols—man-made soils whose formation, properties and functions are dominated by technical human activities. As a fundamental component of urban green infrastructures, Technosols contribute to important ecosystem services (e.g., flood mitigation and carbon sequestration). The provision of these ES is determined by Technosols design and management. Beyond physicochemical properties, biological components—particularly earthworms—strongly influence Technosols' ES, especially at the early stages after construction.

Earthworms, as soil and ecosystem engineers, enhance urban soil functions through burrowing and casting activities, modifying abiotic (e.g., porosity, aggregation) and biotic processes (e.g., nutrient cycling, plant productivity). Therefore, understanding the interaction between Technosol construction, earthworm abundance, and ES delivery is essential for sustainable urban soils development.

This study focuses on the city of Wageningen, known as the "City of Life Sciences" and includes two principal parts: 1) a social survey to explore spatial variation of Technosols properties and managements, and 2) field experiment to observe dynamics in Technosols' functions and ES in real-life conditions. Social survey revealed environmental (parent materials, land cover) and anthropogenic (management, gardeners' characteristics) factors behind variability in Technosols' properties. To date, 84 responses have been collected, showing a strong negative correlation between garden size and tile cover proportion. Moreover, over half of the participants expressed an interest in the soil

biodiversity of their gardens.

The ongoing field experiment simulates urban soil conditions to assess the effects of topsoil depth, vegetation type, and anecic earthworms on soil ES delivery. The initial results allowed to capture the effect of these factors on the dynamics in soil temperature, moisture and greenhouse gases emissions.

By analysing how management practices and earthworm abundance affect ES delivery—particularly regulating and supporting services—this research offers insights into how ecological and social factors co-shape urban soils. The results aim to foster greater public engagement, inform sustainable management strategies, and explore the potential of earthworm-based approaches to enhance ecosystem services in urban environments.

Synergies between urban ecosystem services of biochar-amended circular, engineered soils are soil-texture dependent and diminish with intensified stormwater events

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Topic: SUITMA Improvers and ecosystem services
Keywords: Technosols, circular economy, multifunctionality, sustainable drainage systems, carbon sequestration, fertility

The value of urban green infrastructure (UGI) stems from its multifunctionality: its ability to offer sustainable and effective solutions to the challenges of urbanization. For UGI to function effectively, viable urban soils are fundamental. To counteract the unsustainable practice of importing fertile soil from surrounding ecosystems, a movement towards re-utilizing surplus soils and sediments, as part of a circular city, has gained traction both in research and praxis. However, there are still open questions in how to engineer recycled soil systems to maximize their contribution to ecosystem functioning.

In the current case study, we combine a mineral, excavated subsoil with municipal green waste compost and a waste-based, high-quality biochar - shown to effectively retain a variety of stormwater pollutants. Our research then aims to quantify how mineral and organic elements of a circular, engineered soil contribute to three key urban ecosystem functions— perennial fertility, stormwater infiltration and carbon sequestration. We also evaluate how the same functionalities might react under intensified stormwater events. In coarser-textured soils, we saw addition of biochar at an economically-feasible level significantly increase infiltration under control watering conditions, while slightly slowing infiltration under intensive flooding and stagnation cycles. These results emphasize

how environmental conditions can influence the effect of soil amendments and we therefore advise practitioners to be cautious in a ubiquitous implementation of biochar across UGI systems. Furthermore, while biochar amendment had positive potential for plant vitality, again our results suggest systems heavily burdened by rainfall, in praxis typologies such as infiltration swales or bioretention cells, may not benefit from this level of implementation. Our results also show that while burial of biochar may be considered a novel method of carbon storage, it does not further stimulate the rhizodeposition and subsequential carbon sequestration by either of the forb or legume species tested. Overall, while neither an increase in the soil coarse fraction nor biochar amendment rescued the negative impact of intensified stormwater events on ecosystem functioning, the overall effect of biochar was largely neutral, suggesting successes in other functions, such as that of stormwater pollutant retention, could still validate biochar's use in engineered urban soils.

GreenLife4Seas project: a new LIFE for sediments and shells recovery and reuse

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Topic: SUITMA Improvers and ecosystem services
Keywords: dredged sediments, shell wastes, sediment decontamination, landfarming, building materials

GreenLife4Seas is an EU-funded project that addresses two major marine waste issues: dredged sediments and shell wastes from aquaculture and fisheries management. In the EU, around 200 million cubic metres of sediments, often containing hazardous substances, are dredged every year. Global production of marine bivalve exceeds 15 million tonnes per year; in Europe production has declined due to the high costs and difficulties of disposing of the shells, many of which are still illegally dumped into the sea. The project adopts a triple-helix model, integrating research, industry, and societal engagement, to develop sustainable, circular solutions. It aims to transform wastes into resources by combining shell powder with decontaminated or uncontaminated dredged sediments to produce three innovative building materials: paving blocks, breakwaters, and mass stabilization products. These materials are produced using a mobile prototype plant that operates directly in four ports: Bari, Barletta, and La Spezia (Italy) and Piraeus (Greece).

The sediment decontamination process, developed by CNR-IRET Pisa, is based on assisted landfarming. This involves adding microorganisms, enzymes, and nutrients (bioactivator products) to the sediments, alone or combined with mussel shells, to stimulate organic contaminants biodegradation. Meso-scale tests showed increased microbial activity and enhanced carbon and phosphorus cycling in all treated sediments compared to control untreated sediments. After seven weeks, hydrocarbon removal exceeded 50% in treated

sediments, compared to only 30% in untreated control sediments. These results suggest that bioactivators significantly accelerate the degradation of organic pollutants by improving nutrient balance and microbial richness.

Today, the shift to a circular economy for dredging sediments is necessary and supported by an increasing number of initiatives and transdisciplinary skills; however, political and societal barriers still exist that could hinder its practical implementation.

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What's beneath the surface? - how surface management shapes soil function in urban green spaces

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Topic: SUITMA Improvers and ecosystem services
Keywords: urban soils, soil health, soil management, urban green infrastructure, ecosystem services, nature-based solutions

Urban soils play a vital role in delivering ecosystem services such as water infiltration, retention, carbon storage, and pollutant filtration, yet they remain often understudied and undervalued in urban planning. There is still limited understanding of how different surface management types influence soil health and ecosystem service delivery in urban environments. To address this gap, this research examines how existing and commonly used surface management types, such as vegetation, grass, gravel, or bare soil, influence soil function in urban green spaces. The study focuses on tree pits and urban green areas to enable comparisons between sites with and without trees, in order to better understand how surface cover and tree presence influence soil health.

We use a combination of in situ measurements, such as water infiltration, soil compaction, and soil moisture, with laboratory analyses, including water retention, carbon content, aggregate stability, and pollutant concentration. These methods allow us to assess how soils respond to the different surface management types and how key soil properties change under extreme conditions, such as heavy rainfall. The study takes place in green spaces and tree pits located in different areas of Munich and Freising, Germany, with the possibility to expand to other cities to capture a broader urbanization gradient. Sites were selected to reflect a range of surface management types found in real urban settings.

By evaluating responses under both baseline and post-heavy rainfall conditions, we aim to identify the trade-offs associated with different surface types and promote soil-aware

strategies for resilient urban planning. Findings will be shared with local municipalities to support evidence-based decision-making.

Sustainable nitrogen fertilization to optimize chili pepper production in organic agriculture

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Topic: SUITMA Improvers and ecosystem services
Keywords: horticulture, enzyme stoichiometry, nitrogen supply, nitrogen cycle, optical sensors

Reducing fertilizer use is a crucial need in agricultural practices to achieve a sustainable food chain and improve soil health. The EU Nitrates Directive emphasizes nitrogen (N) supply in agriculture and the importance of its rational use. In this context, organic farming represents an environmentally friendly, circular economy approach to horticultural production even if optimizing N supply is still crucial to prevent its unnecessary leaching in the environment. In line with this need, the main goal of this work was the development of a sustainable strategy for chili pepper production, assuring an optimal N supply to meet the producer expectations and the soil quality preservation. The experiment was carried out at Azienda Agricola Marco Carmazzi (Italy), one of the main organic chili pepper producers in Europe, in an open-field cultivation with several cultivars of *Capsicum* spp.. During the first year of monitoring (spring-autumn 2023), after the soil application of manure and green compost (organic N 2.5%), plants were fertigated with fluid vinasse (organic N 2%). During the second year of monitoring (spring-autumn 2024) the application of manure and green compost was doubled while the fluid vinasse was halved. The physical and chemical soil properties, including total N and $N\text{-}NO_3$ contents, were monitored alongside the soil enzyme activities and stoichiometry, determined as an indicator of nutrient cycling. In parallel, plant health status using both non-destructive

(i.e., optical sensors) and destructive (i.e., lab quantification) measurements was assessed. The second year of monitoring highlighted in soil an increase of $N\text{-}NO_3$ fraction and a slower N cycling during the season, while in chilli pepper plants a worsening of quantitative and qualitative parameters (i.e., fruit biomass, capsaicin content, leaf chlorophylls). Results highlighted the importance of carefully select the N supply strategy to preserve soil health and productive standard, promoting a sustainable and soil-friendly use of N fertilization.

Constructed Technosol-based reclamation following the 2019 Brumadinho tailings dam collapse (Minas Gerais, Brazil)

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Topic: SUITMA Improvers and ecosystem services
Keywords: Dam failure, enzymatic activity, soil function, ecosystem rehabilitation monitoring

Technosols are a key component of SUITMAs (Soils of Urban, Industrial, Traffic, and Mining Areas), functioning both as indicators of anthropogenic disturbance and as potential tools for ecological rehabilitation. Constructed Technosols—engineered soils derived from human-made materials—have emerged as valuable resources for restoring degraded and artificial landscapes. In this study, we evaluated the evolution of a Technosol constructed from lateritic mining waste and stockpiled topsoil for environmental rehabilitation following the 2019 Brumadinho tailings dam collapse (Minas Gerais, Brazil). The assessment focused on Marco Zero (Mz), the first 5-hectare area rehabilitated using this approach. Soil sampling was conducted over a 2.5-year period across three landscape positions (Mz_upper, Mz_middle, and Mz_lower) and two native forest reference sites (R1 and R2). Physical, chemical, and microbiological indicators were analyzed, including pH, base saturation (PBS), soil organic carbon (SOC), and enzymatic activities (arylsulfatase and urease). Despite rehabilitation interventions, linear regression revealed no significant temporal trends. Arylsulfatase activity in the R1 and R2 areas indicated their stable and homogeneous nature, while PBS, pH, SOC, and Urease activity in Mz positions reflected reclamation efforts (Technosol construction, liming, and fertilization). These results highlight the slow, nonlinear path of Technosol development during the early phases of ecological restoration. The findings emphasize

the importance of long-term soil property monitoring to understand ecosystem functions better and guide adaptive management in human-impacted environments.

SUITMA
challenges for the future

INVITED TALK

The shocking impact of warfare on the soil

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Topic: SUITMA challanges for the future
Keywords: anthropocene, bombturbation, pedogenesis, radioactivity, soil health, soil pollution

Warfare represents one of the most dramatic ways in which human activity can alter soil, both during active conflict and in peacetime, such as at military training grounds and test-firing sites. Soil can be significantly affected across all its properties: physical, chemical, and biological.

Physical disturbances include soil displacement, removal, or sealing for the construction of ramparts and fortresses; compaction from heavy machinery and troop movement; excavation of trenches and tunnels; surface scraping for the emplacement of anti-personnel or anti-tank mines; and cratering caused by explosions. Chemical alterations are primarily caused by the release of pollutants, including explosive residues, unburned hydrocarbons, dioxins and polychlorinated biphenyls from defoliants and herbicides, heavy metals, and radionuclides. Biological impacts may arise indirectly from these physical and chemical disturbances, or directly through the intentional release of harmful organisms.

Recovery of affected soil properties may take decades, centuries, or remain incomplete, particularly because remediation efforts are often prohibitively expensive and/or partially ineffective. Military activity must therefore be recognized as a major anthropogenic driver of soil degradation, given the vast areas of the pedosphere currently and historically impacted on a global scale.

In an era when soil health is critical to food security and the continued provision of essential ecosystem services, large-scale conflict has become increasingly unsustainable

from an environmental perspective. This environmental cost should serve as a compelling additional reason – alongside ethical, social, and economic ones – for the international community to prioritize conflict prevention and resolution through sustained diplomacy.

A typology of multifunctional soils for spatial planning: example from Rennes Metropolis (France)

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Topic: SUITMA challanges for the future
Keywords: soil, ecological functions, indices, typology, map, model

Soil is a limited resource facing various threats due to human activities and climate change. Therefore, it is important to take it into account in territorial strategies, to optimize its use by preserving the best soils, reusing the artificialized ones and restoring the degraded ones. Soil is one topic among many others in planning. The soil monitoring law should boost its consideration in territorial management. The 2021 French Climate and Resilience law setting up the European no net land take and no degradation objectives already raised awareness on soils at national level. In this frame, soil ecological multifunctionality maps are increasingly integrated as basic knowledge for territorial spatial planning. The objective is to present the typology of multifunctional soils that was developed within the QuaSoZan project carried out on Rennes Metropolis (France) to facilitate the use of soil ecological multifunctionality maps in urban planning.

To map soil multifunctionality, the French MUSE method (Branchu et al., 2021) was adapted. The four following ecological functions were assessed: carbon storage (C), biodiversity storage (B), infiltration capacity (I) and agronomic capacity (A) of soils. The assessed soil multifunctionality is derived from the combination of the 4 soil ecological functions indices, by summing the score obtained for each function (1 to 5: very bad to very good), giving rise to a score ranging from 4 (very poor) to 20 (very good). An automatic classification using cluster dendograms, which represent the similarities between observations, was used to hierarchically structure the combinations of functions in the CBIA order. The clusters constitute the CBIA multifunctional soil types. The feedback of Rennes Metropolis urban planners is that the multifunctional CBIA soil typology makes the multifunctionality map more understandable and usable. It can help

to identify the soils that need to be preserved, and those that could be artificialized. Soil sampling on main soil typologies is now planned to check the accuracy of the spatial model.

From research to practice: the genesis of a guide to help reduce urban soils sealing

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Topic: SUITMA challanges for the future
Keywords: urban soils (de)sealing, management practices, decision support, multidisciplinarity, multi-stakeholder partnership

Soil sealing is a very real and growing phenomenon in our cities. While soil sealing has historically been justified by health issues, it also responds to very practical expectations in terms of mobility and housing, in line with the massive urbanisation. Paradoxically, Ekranic Technosols, which are the living environment of most of the population, have long been neglected by research. Yet they are closely linked to major environmental issues. Soil sealing has serious consequences, for example in terms of loss of biodiversity, increased flooding and development of urban heat islands. The French multidisciplinary and multi-stakeholder research project DESSERT had the aim of gaining a better understanding of the functioning and capacity of urban soils to provide ecosystem services before and after desealing. Based on both an inventory of sealing practices and laboratory and field experimental approaches, the aim was also to describe sealing operations and their support from an operational perspective. A guide is the result of the collaboration between partners. It provides a scientifically based aid to the design of

desealing operations, as well as explaining the various benefits of desealing. In addition to describing the steps and documents required to carry out these operations the guide highlights their fundamental role in achieving cities with a high level of ecological functions and ecosystem services. Illustrated with numerous examples, the guide is aimed at landscape designers and urban planners but is also accessible to anyone wishing to (re)discover urban soils.

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Quantifying ecosystem services of green roof substrates - coupled hydraulic-thermic properties from sample preparation to performance assessment

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Topic: SUITMA challanges for the future
Keywords: climate adaption, functional de-sealing, ecosystem service, thermal performance, hydraulic performance

Green roofs are promoted as a promising nature-based solution offering regulating ecosystem services for problems such as urban heat islands, indoor heat stress, urban flooding etc. However, not only must a green roof be assessed for its grey energy and CO_2 footprints, but the ecosystem services it provides should be critically assessed before implementation.

The thermal performance of a green-roof regarding building-cooling depends largely on the coverage with plants (shading), loss of latent heat due to water vaporization, and thermal behavior, i.e., heat storage and transmission. The thermal behavior depends largely on the water content and thus on the pore-size distribution of the green roof substrate. Both thermal and hydraulic properties of the substrate must be known for rigorous assessment.

In our contribution, we introduce the assessment of the above-described ecosystem services from sample preparation and measurements of hydraulic and thermal properties to numerical simulations across a variety of green roof substrates and climatic conditions. We show that (i) water supply is critical and hence the cooling effect is limited in summer, when maximum plant coverage is needed and (ii) thermal conductivity is high in winter, when maximum insulation performance would be needed. Thus, the implementation of green roof systems is questionable not only in terms of its installation-related carbon footprint but also in terms of their thermal ecosystem services.

Ski slope management and its ecological impacts on mountain grasslands: soil and biodiversity perspectives

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Keywords: ski resorts, ski slopes, mountain ecosystems, soil properties, eDNA, soil animal diversity

The Dolomites' ski resorts generally demand strict management practices, such as slope grading, vegetation removal, artificial snowmaking and snow grooming to sustain the ski slopes. While such actions are still essential to preserve the slopes, they correspondingly cause significant environmental impacts.

The objective of our study was to evaluate the impact of ski slope management on soil properties and biodiversity (soil micro- and mesofauna) with a pairwise plot design approach and comparing managed ski slope plots (IN) against their surrounding natural plots (OUT) across the five experimental sites (S1-S5) at different elevations. Soil physical and chemical factors (comprising pH, texture, total organic carbon (TOC), total nitrogen (TN), soil aggregate stability (SAS), and TOC: TN ratio) were analyzed; furthermore, soil biodiversity was also assessed through the environmental DNA (eDNA) extraction followed by sequencing through amplifying the Cytochrome c oxidase subunit I (COI) gene.

Accordingly, minor changes in soil texture and SAS were observed at some experimental locations, yet again, differences were significant regarding other soil parameters. The ski slope soils showed higher pH levels and a lower TOC, TN, and TOC: TN ratio, all pointing to a pronounced loss of topsoil due to erosion, vegetation loss, and artificial snow use. Besides, though the ski slope management did not affect the total species richness, alpha diversity dropped significantly in sites (S2 and S3). Likewise, beta diversity exhibited significant changes or dissimilarities in species composition, indicating changes

in community structure and habitat distribution. Climate change, such as variability and increment of temperature, could make worse these effects. Therefore, our study emphasizes the ecological impact of ski slope management and the significance of believing eco-ski resort management is an appropriate skiing practice to reduce the loss of soil biodiversity and quality.

University campuses as living labs to study carbon stocks and fluxes in urban green infrastructure?

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Topic: SUITMA challanges for the future
Keywords: constructed Technosols, carbon sequestration and emissions, maintenance of green spaces, monitoring

Development of urban-green infrastructures is considered an efficient nature-based solution (NBS) for C sequestration. The potential of NBS for C sequestration is often based on aboveground biomass and often overlook the contribution of urban soils. Urban soils vary from just affected by humans to fully human-made. Analysis of the spatial relationships between soil C stocks, CO_2 emissions and UGI management and maintenance is necessary to support decisions in UGI planning aiming to facilitate C sequestration and contribute to achieving C neutrality. the demand in carbon sequestration and microclimate regulation assessments to support decision-making in UGI planning, management and maintenance is constrained by the lack of comprehensive approaches to quantify these ES considering UGI their horizontal and vertical structure, spatial heterogeneity and temporal dynamics. An Urban Living Lab (USLL) approach can be considered a possible solution.

USLL is a relatively novel but increasingly developing concept aiming to support multi-stakeholder engagement and co-production in exploring ecosystem processes and developing UGI in a real urban setting. Although university campuses, as a rule, cover only a small part of the city area, they have clear advantages for developing ULL focused on UGI-based solutions for C sequestration and microclimate regulations. The research aims to develop a prototype of an urban soil living lab (USLL) to support C-smart decisions in soil construction, planning and maintenance of urban green spaces. The USLL shall be a platform for co-creation of soil constructions to support various types of NBS units (e.g.,

lawns, flowering herbs or rain gardens) and for monitoring their effects on C balance. Monitoring techniques include 1) measuring soil C stocks at multiple locations with further digital soil mapping; 2) analyzing soil organic matter fraction (mineral associated and particulate organic matter fractions); 3) continuous measurement of soil respiration during the season (e.g., by gas analyzer); 4) continuous monitoring of soil temperature and moisture at multiple points by manual and autonomous sensors with extrapolation based on remote-sensing data on surface temperature; 5) assessing C sequestration in aboveground biomass based on regular mowing or Li-Dar scanning; 6) setting up long-term experiments to study the effects of management and maintenance regimes on C balance. The prototype was tested at three university campus areas located in different climate zones: in Wageningen (the Netherlands), Moscow and Apatity (Russia). Considering topsoil C stocks, ratios between mineral associated (MaOM) and particulate organic matter (POM) C-fractions and C-CO_2 emissions/ soil C stocks ratio, soils under trees were shown as the most efficient in C accumulation, whereas lawns were potential C sources. Moreover, lawn maintenance caused high soil CO_2 emissions which were intensified by favorable microclimatic conditions.

Temporal dynamics of urban soil health

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Topic: SUITMA challanges for the future
Keywords: urban soil, pedogenesis, soil health, land-use change, temporal assessment

Assessing the health of urban soils is a key requirement for optimizing the planning and design of cities in response to the environmental issues they face (*e.g.* water cycle regulation, climate regulation, preservation of biodiversity, food production, vegetation support and urban greening, urban heat islands). Among the main challenges to achieve such assessment is the fact that urban soils are subject to numerous pressures and potentially rapid and frequent changes. However, current methods for assessing soil health are mainly based on a one-off diagnosis of the soil at a given point in time. Their trajectory is the concomitant result of an evolution related to pedogenesis under natural factors and of potentially sudden and rapid transformations related to changes in land use and associated practices and management. These transformations can lead to a partial or complete change in the state of the soil and its capacity of functioning. They have impacts on the manageable but also on the inherent soil properties, making it difficult to define a framework to assess soil health in urban environment. The monitoring of such soils requires to consider the specificity of their dynamics of evolution.

To illustrate this, we first conducted a cognitive experiment by comparing the evolution of soil health over a century of a wide range of urban soils (*e.g.* urban green area, agricultural plot turned into a residential area, garden soil, industrial soils). Then, lysimetric monitoring of various urban soils was also conducted which illustrates the importance of considering their dynamics. The results presented, from various situations in different urban case studies, demonstrate that the temporal dynamics of urban soils

are an essential concept to take into account in the assessment of their health, as they are part of a constantly changing urban environment.

Reactivity of road asphalt buried in soils after de-sealing operations

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Topic: SUITMA challanges for the future
Keywords: ekranic technosol, pedology, carbon stock, rock-eval analysis, incubation, stabilisation

The number of soil de-sealing operations is growing in EU countries, helped by laws that encourage to compensate soil artificialisation. The aim of this work is to study the fate of road asphalt when incorporated in soils after de-sealing operations. Considering these sealing materials as a substrate for pedogenesis and by focusing on the fate of the carbon they contain, the study aims to answer the following questions: (i) can road asphalt be biodegraded by soil microorganisms? (ii) if yes, is this biodegradation influenced by soil properties?

To address these questions, we selected 4 soils following a gradient of perturbations by human activities (forest, permanent grassland, de-sealed and industrial soils) and mixed them with milled asphalt (MA, < 1 mm). Mixtures were incubated at 24°C and 80% WHC for 83 days and CO_2 emissions of these bitumen-enriched soils were measured periodically to compare them with values for the same soils without bitumen. At the beginning and end of the incubation, bitumen from these different soils is characterised by Rock-Eval analysis.

More CO_2 was produced in all samples with MA except for de-sealed soils, but only a small part of the additional CO_2 seems to come from bitumen degradation. The main part is explained by changes in physicochemical properties of the soils mixed with MA. RE analysis show an increasing proportion of more thermal recalcitrant carbon compounds

in soils with MA at the end of experiment. Our results improve the comprehension of carbon dynamics in de-sealed soils.

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Prioritizing urban soil sampling for climate change mitigation based on greenspace management intensity and urban heat analysis

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Topic: SUITMA challanges for the future
Keywords: urban greenspaces, urban heat island (UHI), soil sampling strategies

Urban heat island (UHI) effects lead to elevated air temperatures in urban environments, which increases soil temperatures. Studies have consistently shown a strong positive correlation between air and soil temperatures in urban environments. Elevated soil temperatures influence key soil processes such as microbial activity and transpiration, particularly in poorly managed urban greenspaces where soil functioning is diminished. Soil temperature data is relatively scarce compared to meteorological records, and measurement accuracy tends to be low, making reliable soil temperature data difficult to obtain. This challenge is particularly relevant in urban areas, where soil temperature is not commonly included in monitoring. As a result, urban soil temperature studies rely on land surface temperature modelling and estimations. This is a practical alternative for capturing the spatial variability of urban soil temperatures, enabling researchers to assess UHI across different greenspaces and type of management.

In Santiago de Chile, annual air temperatures have increased by 0.0087 °C yr^{-1} since 1912 reflecting the impact of urbanization. Recent records from the La Platina meteorological station (INIA; Instituto de Investigaciones Agropecuarias) show that soil temperatures at 10 cm depth have surpassed 30 °C in summer months over the past three years (2023 - 2025). In Santiago de Chile, urban heat distribution maps combining satellite-derived land surface temperature (LST) and ground-based air temperature with machine learning

now offer high-resolution (10m) representations of urban heat heterogeneity. These maps were developed by the SantiagoHot initiative with funding of NOAA (National Oceanic and Atmospheric Administration) and show temperature variations of up to 10 °C within the city in summer. They can facilitate to prioritize soil sampling e.g. for accurate estimation of soil organic carbon (SOC), irrigation needs and assessment of temperature-sensitive microbial processes. To evaluate the strength and limitations of the high-resolution SantiagoHOT heat maps they are compared with conventional satellite sources (e.g. MODIS, Sentinel, Landsat), and used for selecting soil-sampling and monitoring sites in greenspaces with different management regimes. So, comparing high-resolution SantiagoHOT heat maps with conventional satellite sources will provide insights into the strengths and limitations of different approaches for urban soil sampling and monitoring, focusing on type of greenspaces and management status.

Climate adaptation by de-sealing public street spaces in Berlin: Blue-Green Perspectives

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Topic: SUITMA challanges for the future
Keywords: de-sealing, GIS tool, BGI implementation, parking spaces, climate adaption

Urbanization is characterized by increased soil sealing, leading to environmental challenges such as urban heat islands, biodiversity loss, and disrupted water cycles. Climate change effects—rising temperatures and extreme weather—necessitate adaptation measures. De-sealing urban spaces and the implementation of Blue-Green Infrastructure (BGI) can help mitigate these issues and increases urban resilience. While research highlights ecological benefits—such as converting parking lots into green areas there is a gap in understanding practical implementation, especially in public street spaces. Examples from Lyon, Amsterdam, and Paris offer valuable strategies for transforming urban spaces.

This study focuses on side spaces of public urban streets used as parking areas in Charlottenburg-Wilmersdorf, Berlin, evaluating their potential for de-sealing measures. Necessary geospatial data were evaluated and processed using open-source QGIS. An assessment conducted with pre-defined criteria determined viability of measures in specific areas. The research supports existing municipal plans and aims to provide practical guidance.

Six suitable de-sealing measures were preselected for analysis, categorised as easy to implement —such as 1) partial de-sealing, 2) basic surface infiltration, and 3) de-sealing and creation of seating areas —and more complex measures, including 4) tree planting, 5) infiltration basins, and 6) rain gardens.

Field validations on the surface level confirmed the GIS assessment's accuracy, though classification discrepancies highlight areas for improvement. The analysis indicates

about 75% of parking spaces can accommodate at least one measure without requiring any site preparation. The results support a structured assessment of the potential of these measures. The GIS tool has broad applications in de-sealing street spaces. This work contributes to sustainable urban development by highlighting the potential of side spaces in streetscapes for implementing de-sealing and climate adaptation strategies.

Exploring the link between land take and soil sealing in European cities

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Topic: SUITMA challanges for the future
Keywords: Soil sealing, Land take, Urban development type, Spatial patterns, Landscape composition, Compactness

Soil sealing occurs when soil is covered by impervious materials, typically due to land take from urbanization and infrastructure development. These processes have steadily increased in European cities due to growing urban land demand. The land take–soil sealing link varies by geographical context, with sealed soil ranging from 30% to 75% in affected areas, reflecting diverse urban development types. The European Commission set two targets: "no net land take" (in the "Soil Strategy", first mentioned in 2011) and "no net soil sealing" (in the "Soil Mission"). This study explores how urban spatial patterns, landscape composition, and urban development types influence the land take–soil sealing link over time.

We computed the soil sealing to land take ratio (SLTR) for each Functional Urban Area (FUA) in Europe and UK in 2012 and 2018 (latest available data). To identify spatial patterns, we classified cities by country and region and applied statistical analyses. Two hypotheses were formulated: (1) SLTR is higher when the landscape composition of an urban area is predominantly artificial rather than agricultural; (2) SLTR increases as urban development leads to higher levels of compactness in urban areas rather than sprawl patterns. To test the first hypothesis, FUAs were classified based on landscape composition. The second hypothesis was tested using three landscape metrics describing different compactness/sprawl aspects: shape irregularity (edge density), patch dispersion (nearest neighbour index), and patch aggregation (percentage of like adjacencies).

The results show a general reduction in SLTR, with a median of -0.36 from 2012 to 2018, indicating a trend toward lower-intensity urban development. The UK-Ireland region saw a greater decrease, while southern region showed smaller reduction. At the national

level, Cyprus had the highest average increase, and Lithuania the largest decrease. The prevalence of developed land use in FUA tends to increase the SLTR, while agricultural decreases it (hypothesis 1). Furthermore, the results demonstrate a strong correlation between SLTR and two metrics, edge density and percentage of like adjacencies, while showing no correlation with nearest neighbour index (hypothesis 2). The study's outcomes can inform policies at various planning levels to achieve European sustainable urban development targets.

Development of an interactive platform for processing soil characterization data using Artificial Intelligence

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Topic: SUITMA challanges for the future
Keywords: pedology, Anthropocene, war contamination, emerging contaminants.

Soil characterization traditionally relies on physico-chemical analysis methods and field observations, which help assess parameters such as texture, structure, pH, organic matter content, and the concentration of trace metal elements. However, these methods generate large amounts of heterogeneous data, which can sometimes be complex to interpret. In this context, artificial intelligence (AI) offers innovative perspectives to enhance the analysis, interpretation, and valorisation of soil characterization data.

The objective of our work is to develop an interactive interface based on algorithms and the use of convolutional neural networks (CNNs) to predict and interpret data related to soil characterization. The approach involves creating an interactive platform that leverages machine learning to process local or external databases. Preliminary tests have enabled the generation of readable visual representations of the data, offering comparisons with data from other sources and interpretations aligned with standards and threshold values for various parameters.

This tool has allowed for a preliminary assessment of soil pollution levels based on the measurements and data received. The results are promising. However, the use of AI in this field requires careful attention to data quality, model interpretability, and the validation of results through field studies.

Collaboration between soil science experts, data scientists, and database experts is

essential to fully harness the potential of these tools. AI represents a methodological revolution in soil science, offering powerful tools for understanding, predicting, and soil managing systems in a context of global change and increasing pressure on natural resources.

To walk, observe and interpret urban soils

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Topic: SUITMA challanges for the future
Keywords: volcanic urban landscape, geobiodiversity, paleosols, sense of place, mindfulness

The main campus (Ciudad Universitaria) of the National Autonomous University of Mexico (UNAM) in Mexico City is an excellent place to spark curiosity and interest in urban soils. Within its grounds, visitors can observe three main types of land use found in urban areas worldwide: natural soils, transformed soils, and sealed soils. This diversity creates a palimpsest of opportunities to explore, observe, and interpret soil from multiple disciplines and perspectives. To foster lasting behavioral change, we propose three soilurban-pedestrian tours across the campus, specifically designed for both geoscience students and the general public. These tours will stimulate meaningful connections with oneself, others, and nature. Experience-based strategies, incorporating mindfulness, will drive this transformation by engaging participants physically, cognitively, and emotionally. Through these tours we will encourage people to observe the contrasts between areas with natural soils (Leptosols) and modified soils (Technosols), prompting reflection on the dynamics occurring within urban spaces and the impact of soil characteristics on urban ecosystems. Observe and interpret to understand, appreciate, and protect. In designing the route, we have carefully included stops at key reference points to illustrate specific aspects, such as pedogenetic processes (biological weathering of the rock, leaching, accumulation of organic matter), soil functions, their relevance to environmental health and their crucial role in urban sustainability. We also included sites where Paleosols can be seen. This sites offer the opportunity to reflect about on history and past cultures.

Carbon storage and age of sealed urban soils: a case study from Berlin's Oldest Marketplace

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Topic: SUITMA challanges for the future
Keywords: carbon storage, radiocarbon dating, cultural layer, soil sealing, anthropocene

Urban soil sealing disrupts natural soil processes, but under fossilizing conditions, such soils can preserve organic carbon stocks over long-time periods. This study examines carbon stored in deep anthropogenic soil layers beneath *Molkenmarkt*, Berlin's oldest marketplace, located in the city's center. This location has been in continuous urban use since the 13th century.

Two soil profiles were sampled from depths of 1.80 to 3.70 m (medieval context) and 1.40 to 3.00 m (19th-century latrine). Lab analyses show soil organic carbon (SOC) stocks of 20.9 kg m^{-2} in the medieval profile and 23.0 kg m^{-2} in the 19th-century latrine. These high values are related to cultural layers with high carbon contents and bulk densities that were preserved by long-term sealing and thus a lack of oxygen exposure. Other studies of sealed soils in Berlin reported SOC stocks of 1.8 kg m^{-2} (0–100 cm) (Kosie project 2023), and 4.0 kg m^{-2} in topsoil (0–20 cm), with up to 24.7 kg m^{-2} in subsoil (20–100 cm). The SOC stocks found in this study stem from greater depths and at the higher end of the carbon storage range of the subsoil values assessed previously.

According to preliminary archaeological dating of artefacts, the cultural layers give insights into land use changes, including organic-rich fills with wood and charcoal (late 13th century) and glacial sands with traces of prehistoric activity (ca. 8000–1000 BC) and already published data such as a dendrochronologically dated courtyard layer

(1329 ± 10 years). Radiocarbon dating results will be compared to archaeological dating, which offers a chance to reflect critically on how useful D^{14}C-dating is in urban soils. This study demonstrates that substantial amounts of carbon can be stored in deep urban soil layers. It also raises questions about how these layers can be dated and interpreted, and the potential role of cities as long-term carbon sinks.

Construction and demolition waste as parent material of Constructosols

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Topic: SUITMA challanges for the future
Keywords: humic substances, humic acid concentrate, soil improvement

Urban areas are subject to extensive land surface transformations, especially in construction sites. This creates the necessity to recreate the soil cover around newly built structures, providing the possibility of various forms of land use. The formation of new soil cover must also take into account the complexity of technical underground infrastructure. At the same time, newly formed green areas must demonstrate soil structure stability, as well as the ability to absorb and retain rainwater. These latter aspects are particularly challenging given the typical pattern of periodic water shortages in the rainfall-retention water management systems of SUITMAs. The creators of constructed technogenic substrates have always aimed to provide plants with good growth and development conditions by offering materials of high fertility. The challenge today is to incorporate various waste materials into this process, which supports the implementation of a circular economy model.

In the course of the analyses, the properties of many construction materials used over different building periods in western Poland regions were examined. These materials included: clinker brick, aerated concrete, roof tiles, ventilation blocks, demolition brick, concrete, mortar, and metallurgical slag waste. To determine their physico-chemical and chemical characteristics, the materials were ground to obtain a fraction below 2 mm. Their potential to alter soil pH and salinity, as well as the content of total and water-soluble elements were measured. Next, the technogenic substrates were constructed using a soil of loamy sand grain-size composition, fractionated cement-lime rubble (<2, 2–5, and 5–20 mm), ash from solid fuel combustion, coffee grounds, and a soil solid improver based on lignite. The possibility of stabilizing the obtained Constructosols using sodium and potassium aluminosilicates was also examined. The results indicated a

low potential impact of construction materials on soil environment according to Polish legal standards (based on heavy metal, PAH, and PCB content). Many of them alkalize the soil, and some also showed potential for soil salinization. The constructed substrates generally had a slightly alkaline pH, except those stabilized with aluminosilicates, which were strong alkalic. Only the coffee grounds demonstrated a mild acidifying effect on the substrate.

Surface sealing characteristics shape soil properties in urban and peri-urban areas: case evidence from the REUSES project

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Topic: SUITMA challanges for the future
Keywords: ekranic technosols, pedogenetic process, impermeable surface, de-sealing

Soil sealing compromises essential soil ecosystem services by blocking exchanges between soil and the other matrices, thereby affecting carbon sequestration, water infiltration, and purification processes. According to the European Environment Agency, over 1.1 million hectares of land were sealed across the European Union between 2000 and 2018. In response, various strategies have been proposed, including such as de-sealing techniques aimed at restoring soil functionality.

The REUSES (Restore Urban Sealed Soil for Alternative Ecosystem Services) project operates within this context, with the goal of converting abandoned sealed soils into community gardens. This study investigated how the characteristics and uniformity of surface sealing materials influence the pedological properties (morphological, physical, chemical, and mineralogical) of soils within the REUSES project.

Two sites within the Municipality of Ancona, representing urban and peri-urban contexts, were examined. While both sites showed similar issues, such as soil compaction and low nutrient content, the type of covering materials led to distinct pedogenetic outcomes. In the urban site, the degraded and heterogeneous sealing layer facilitated, even if minimally, water infiltration and/or capillary rise. The presence of calcareous allochthonous materials further promoted the mobilization and accumulation of

secondary carbonates. Conversely, the peri-urban site, characterized by a homogeneous and entirely impermeable asphalt cover, experienced severe anoxic conditions, especially in the surface horizons, due to the disruption of interactions among the atmosphere, hydrosphere, and pedosphere. These findings highlight the importance of assessing spatial variability in urban soil conditions to develop targeted and effective remediation strategies. Future research should explore the long-term impacts of de-sealing and soil rehabilitation under various urban planning scenarios to better support the restoration of soil ecosystem services.

Towards a webtool helping spatial planners and designers to better integrate soil in their process and practice

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Topic: SUITMA challanges for the future
Keywords: webtool, soil, planning, design

Soil is an essential part of the Earth continental surface, but it is submitted to a multitude of threats. The associated degradation is at risk for human being and ecosystems. That is why the integration of soil in spatial planning and design is essential. Spatial planners and designers however usually lack knowledge on soils. In addition, soils are not directly considered in current sectorial regulations. The European soil monitoring law should help increase awareness on soils and promote the use of the various tools and methods already developed to qualify soils. To fill the lack of tools to help planners and designers find out the right soil tools/methods to answer their needs along their process, the EU funded SPADES project is developing a webtool called Navigator.

The objective of this abstract is to present the users' need analysis to the soil community to get its feedback as a target group of the soil-planner Navigator.

The users' needs analysis is based on meetings with stakeholders from the pilots involved in the SPADES project, on a taskforce of stakeholders from the SPADES pilots and other volunteers. National and international events are also opportunities to interact directly with professionals and experts.

Urban soil threats in the European Union, a systematic review

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Topic: SUITMA challanges for the future
Keywords: urban soil, pollution, compaction, soil organic carbon, hydrocarbons

This study aims to provide a comprehensive overview of the current state of urban soils in the EU, identify knowledge gaps, and inform policy decisions. We conducted a bibliometric analysis of peer-reviewed articles published between 1968 and 2023, using databases such as Scopus and Web of Science. The analysis included 2372 articles, which were filtered to remove duplicates and irrelevant studies, resulting in a final dataset

of 603 articles. The majority of urban soil data is available for Italy, Spain, and Poland, with 13% of the data coming from these countries, followed by the UK with 10%. The most frequently studied urban soil threats are soil organic carbon (81% of publications), heavy metals (72%), and soil nutrients (23%). The study also found that 51% of research has been carried out in large cities/areas with an area of 100-1000 km^2, while small towns/areas with areas of 10-50 km^2 account for 19% of the research. We also analysed the data availability for different urban areas and found that 310 individual urban areas are represented in the dataset, with a combined urban population of approximately 200 million. The number of samples per article ranges from 1 to 64,000, with a median of 34.5 samples per article. Surface samples (topsoil) are the most popular, accounting for 81% of publications, while subsoil samples and whole soil profiles account for 11% and 14% of publications, respectively. The bibliometric analysis revealed that the number of articles published on urban soil threats has increased over time, with a peak in recent years, and the top 10 authors in the field have published almost one-third of the total available data. The journal "Science of the Total Environment" is the most frequently cited, with 208 articles. With this study, the importance of urban soil research, has been revamped and emphasizes the need for further research to address knowledge gaps and inform policy decisions.

Road infrastructures and the direct and induced impacts on soil sealing. An analysis on the highway A35 in Italy

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Topic: SUITMA challanges for the future
Keywords: soil & land consumption, soil sealing, land use changes, infrastructure, highway, Brebemi

Seal sealing was identified as one of the main soil degradation processes in the EU's soil thematic strategy. Studying the contemporary soil sealing processes is urgent to tackle with the challenges for the future sustainable management of soil & land in relation to urban planning strategies.

The contribution investigates the impacts on land-use changes and on the increase of soil sealing derived from the construction of a new road infrastructure, such as highways. Such infrastructures are relevant cases since they can impact both directly and indirectly on the land cover: directly if we consider the soil sealing produced by the infrastructure itself (the natural soil taken to realize the highway); indirectly if we consider the inducted transformations enhanced by the realization of the highway (e.g. other new infrastructures connected to the highway or productive and logistic areas close to it).

This analysis can be regarded as part of a broader reflection on the environmental impacts of road infrastructures, which can affect not only the territory directly involved in the realization of the road, but also a broader buffer zone, the so-called road-effect zone (i.e. the buffer area in which it is possible to detect environmental impacts caused by the infrastructure). The influence of the infrastructure in the increase of urban sprawl is well known. Nevertheless, it is still little investigated how quantifying the road-effect zone in the case of the impacts on land transformations and soil consumption. To expressly measure this influence, the study focuses on the case of the Italian highway 35, also known as Brebemi (since it connects the cities of Brescia and Milan, by passing thought the Bergamo Province), recently realized in the Lombardy Region (Italy). It represents one of the first scientific quantification of direct and inducted land transformations

related to this new mobility infrastructure. The results demonstrate the heavy direct impact on soil consumption (278.3 ha), but also an alarming inducted soil consumption due to the secondary infrastructures realized in connection to the new highway (116.8 ha) and to the new urbanization increase in a buffer zone of 1km (650ha).

Soil formation processes promote spatial dependence of physicochemical properties in anthropogenic soils

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Topic: SUITMA challanges for the future
Keywords: pedogenesis, humus accumulation, human-transported materials, Andosols, spatial dependence, urban greenery area

High spatial variability in anthropogenic soils results from land construction processes, such as excavation, filling, and embankment construction with on-site disturbed soils or human-transported materials. This variability makes it challenging to describe a four-dimensional representation (space, depth, and time). Recent studies in mining soils have demonstrated that ^A horizon has strong spatial dependence, which is a concept in which properties change depending on geographical distance, compared to deeper horizons. Although such phenomena might also occur in natural soils, few studies have investigated the relationship between spatial dependence and pedogenesis. This study aims to clarify the soil formation processes in anthropogenic soils and their relationship with the spatial dependence of soil physicochemical properties.

The study sites are greenery areas established 9, 15, and 52 years old. The ^A horizon was characterized by black coloration and crumb structure and had developed from the ^C horizon constructed using Andosols as planting embankments. Soil samples were collected using a grid sampling method taking into account soil horizon and soil material. The following physicochemical properties were determined: pH, electrical conductivity, total carbon (TC), total nitrogen (TN), pyrophosphate-extractable carbon, aluminium, iron (Cp, Alp, and Fep), nitrate nitrogen (NO3-N), and ammonium nitrogen (NH4-N). Semivariogram analysis was conducted to evaluate spatial dependence.

Soil properties in the ^A horizon showed higher coefficients of determination than those in the ^C horizon. TC and Cp increased significantly with the time since afforestation and were positively correlated with Alp and Fep. These findings indicate that spatial dependence of soil organic matter was developed through the formation of Al/Fe-

humus complexes. Alp and Fep slightly increased in 9- and 15-year-old sites, implying that amorphous Al and Fe, which have existed since the initial soil material arrangement, mainly contribute to humus retention. Inorganic nitrogen content (NO3-N and NH4-N) was higher in the ^A horizon and exhibited shorter semivariogram ranges, indicating that biological activity and atmospheric deposition drive their spatial heterogeneity. Our results highlight the co-development of soil properties and spatial structures through pedogenesis in anthropogenic soils.

Podosol: soil of unfortified walkways, squares and roads

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Topic: SUITMA challanges for the future
Keywords: Urban soils, Podosol, unfortified walkways, soil formation, soil properties, heavy metals, dust

In park areas and churchyards occur predominantly unfortified pathways. Some less travelledust d roads, squares and parking areas are unfortified too. With time some soil development takes place in the unconsolidated material. Main factor of soil development is the continuous movement of the surface layer by walking and driving. Therefore, this type of soil is named Podosol (podos = foot in ancient Greek). Examples of Podosols will be presented.

Result from Podosols of park areas, churchyards and a small parking square of the Ruhr Area, Germany will be presented. Samples were taken from the unfortified area under trees and between trees, and adjacent lawn. According to the main characteristic of strong change of surface layer of Podosol, samples were taken in 4 depth segments to 5 to 12 cm depth. The investigations were: gravel content, grain size distribution, C and N content, C/N ratio, pH, carbonate and heavy metal content.

Due to the gravel content the soil has a fine earth content of 58% (mean of n=60). The fine earth consists of silty sand with a silt content of 18%. The soils of the adjacent lawns are from loamy sand or sandy loam with a silt content of 24%. The calcium carbonate content of the fine earth of Podosols is 55%, of lawn 4%, according to carbonate content the pH ($CaCl_2$) is 8,0 and 7.3, the Corg content 8. 6 and 7.9%. C/N ratio of Podosols varies from 0.5-308, of lawn 12-23. Podosols can have a high heavy metal content. Pb of surface layer of Podosols was from 6 to 360 mg kg-3, of lawn 72-540 mg kg-3. Cd of surface layer was from 1 to 23, resp. 4-11 mg kg-3. A strong regional relationship exists between Cd and Fe (R^2=0.70).

Podosols are soils of frequent moved surface layers, they are an important part of recreation and traffic areas of cities. Due to their reduced fine earth content, they are

drying fast. This and the silt fraction favour the formation of dust. Thus walkers, and particular children and dogs can be endangered by the heavy metal content of the dust.

Impacts of the first world war on the properties and functioning of forest soils in the Champagne region (France)

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Topic: SUITMA challanges for the future
Keywords: soil, First World War, polemoforms, pollution, bombturbation, forest

Military activities greatly and durably deteriorate soils, from a physical, chemical and biological point of view. More than a century after the end of the first World War (WW1), soils in the Champagne region (France) still have visible (in forest) or hidden (in agricultural context) marks of the conflict.

Recently, academic research regained some interest for this conflict and its consequences, but most of the studies on soils focused on the most strongly affected areas of the former front. Thus, representativity of the pollutions/disturbances studied can be questioned.

This study aims at evaluating the influence of the main disturbances associated with WW1 on current functions of soils through a multi-disciplinary and a multi-scale approach. Only the most common and representative remains of war disturbances are considered, such as shell holes and trench networks. Here, the focus will be put on a site called "Côte 108", a hill with soils developed on a chalk bedrock where mine warfare took place between the end of 1914 and 1916 and where a forest has been planted after the war due to the amount of devastation.

Based on recent and ancient aerial photography, LIDAR images and documents from the military archives, areas with high density of polemoforms were selected. Several soil profiles have been described, sampled and physical and chemical analyses were conducted, focusing mainly on the changes in the horizon sequences, water reserve, organic matter content and the possible trace metal pollution caused by the war.

Despite an estimated density between 50 and 135 shell holes/ha in the studied area, our results show levels of trace metal comparable to background values with occasional slight enrichments in Pb and Zn. Organic matter content between 13% and 38% was measured

at the bottom of the studied polemoforms. Disturbances in the horizon sequence were also revealed such as a thicker organic layer at the surface, a higher proportion of coarse material and, in some profiles, a buried organo-mineral horizon.

These results will be extrapolated at a larger scale and should help us to enlighten our understanding on how wars impact the soil environment and related services.

Soil type and content of macro-elements determine hotspots of Cu and Ni accumulation in soils of subarctic industrial barren: inference from a cascade machine learning

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Topic: SUITMA challanges for the future
Keywords: heavy metals, digital soil mapping, gradient boosting machines, smelter impact, aerial pollution

Aerial technogenic pollution from the activity of ferrous and non-ferrous metallurgy resulting in degradation of vulnerable natural ecosystems is a principal environmental problem in Russian Arctic. The industrial barren in the vicinity of Monchegorsk (Kola Peninsula) has been forming since 1950-s in the impact zone of the copper-nickel smelter. Soil heterogeneity, complete or partial degradation of vegetation and rugged terrain intensified by soil erosion result in complex lateral spatial redistribution patterns of aerial deposits Cu and Ni emitted by the smelter. In this research, we applied cascade machine learning (gradient boosting machines) to quantitatively describe these patterns. An extensive soil sampling campaign (n=506) across an area of 343 ha has revealed an extremely high levels of contamination (max bulk concentrations of Cu and Ni - 29.87 and 30.12 g/kg). We showed that soil types and the content of macro-elements (Ca and Fe) mapped based on the conventional set of predictors (topography, hydrology, landscape' spectral properties) explained spatial variability and especially hotspots of Cu and Ni

contents with a higher accuracy compared to the models where interactions between macro-elements and heavy metals are not considered. This approach is a promising tool for mapping heavy metals' distribution in eroded, degraded and highly polluted areas, which can be very useful to support land reclamation plans and allocate bioremediation measures.

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Soilless substrates from buffalo livestock waste and zeolite-rich tuffs

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Topic: SUITMA challanges for the future
Keywords: peat, buffalo livestock waste, zeolite-rich tuffs, horticultural substrate

The issue of peat in substrates for horticultural production has become increasingly urgent due to the environmental implications associated with the protective role of peat wetlands as carbon sinks. As recently established by laws introduced in England, it appears imperative to find sustainable alternatives to this traditional resource in soilless substrates. The main organic matrices used as alternatives to peat in growing media include compost, biochar, coconut fibre, hemp fibre and wood waste. In the search for low-cost alternatives in the Campania region, the material present in greatest quantity and which also contains excellent physical and nutritional characteristics is buffalo manure, an organic fertilizer rich in essential nutrients for plants. On the other hand, the Campania region hosts numerous buffalo farms which annually generate significant quantities of livestock effluents in areas designated as vulnerable to nitrate pollution. Farmers must develop new strategies to relocate and profitably reuse this waste in larger and more suitable agricultural areas.

The synergistic use of zeolitic tuffs and compost from buffalo livestock waste could create a balanced nutrient release profile, ensuring that nitrogen remains accessible to plants over time. This combination could improve the nutritional efficiency of the substrate and also promote healthier plant growth by maintaining optimal nutritional balance. Furthermore, zeolite's ability to further reduce nutrient leaching contributes to a more sustainable and environmentally friendly cultivation system.

The implementation of EU Regulation 2019/1009, which promotes the production of fertilizers, including soilless substrates, from secondary raw materials, further

encourages this approach. In many regions of EU, substrates intended for cultivation are required to meet specific legal parameters to ensure their safety, effectiveness and suitability for horticultural use. In particular, the constitution of the soilless substrate must be consistent with the specific needs of the cultivated plant species, the market demand, the convenience of using substrates instead of conventional cultivation.

Lignite as a source of modern manufactured soil organic improvers

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Topic: SUITMA challanges for the future
Keywords: humic substances, humic acid concentrate, soil improvement

Soil humus is one of the fundamental elements of the solid phase of soil. It determines its physico-chemical properties, influencing, among others: soil structure, ion sorption, and water retention. It is also the largest reservoir of organic carbon on the Earth's surface. Stabilization of humus resources is currently the subject of numerous scientific studies and cultivation technologies. Various potential sources of humus are being investigated, including carbon-based materials eliminated from energy applications. Technologies for extracting humic acids and using concentrates derived from them in procedures for soil enrichment and reclamation are also being developed. Due to the low nuisance level of applying these soil improvers, managers of urban green spaces tend to view them positively. However, in the context of SUITMAs matrices complexity the concepts of using humic acid concentrates and other improvers of urban soil are still in the refinement stage.

The humic acid concentrate Florahumus® and complex soil improvers containing it were analyzed. The raw material for their production was lignite from the Sieniawa mine, located in western Poland. The improvers were applied in both liquid and solid form to soils with simple and complex matrices, such as Constructosols. Their impact on basic soil characteristics, ion sorption, water retention, water flow in the soil, chemical properties, and the growth and development of selected plants were studied. The results obtained indicate a significant change in the chemical-physical characteristics and water conditions of soils improved with humic acid-based materials. This approach increased water retention in light soils, while simultaneously increasing filtration rates and reducing capillary rise. A positive plant response to soil improvement was also observed, demonstrated by increased root and above-ground biomass. However, the

investigated materials have been found to be not easy to apply in difficult soil conditions, especially due to their alkalizing potential and high leaching susceptibility.

The use of lignite-based soil improvers aligns with the principles adopted by the European Union for sustainable management with care for groundwater resources facing the challenges caused by climate changes. The great variability of Technosols, Regosols, and specially constructed soils remains a challenge for techniques aimed at improving their fertility.

Distribution and mobility of ammunition-derived heavy metals in historic shooting range soils in the Berlin Metropolitan Area

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Topic: SUITMA challanges for the future
Keywords: antimony, emerging contaminants, shooting range soils, urban geochemistry, sequential extraction, risk assessment

Soils and landforms of war in the Berlin Metropolitan Area have been recognized as moderately to extremely contaminated sites. Thereby, ammunition-derived heavy metals (Cu, Pb, Sb, Zn) play the key role in multi-contamination of shooting range soils. As case studies on the fate of antimony (Sb) are still underrepresented in the urban context, emphasis was put on Sb distribution and its mobility under varying soil conditions. Therefore, two historic shooting ranges (recreational / military) in the BMA have been investigated in detail to assess the respective pseudo-total HM contents as well as general and site-specific parameters.

14 topsoil samples and 21 subsoil samples from the Murellenschlucht military shooting range with a broad range of pH values, humus content, and amount of sesquioxides have been further analyzed through modified sequential extraction procedures (SEPs) to study HM mobility. This sequential approach is necessitated to assess the potentially bioavailable, mobile, and strongly adsorbed HM fractions to estimate the environmental risk potential under field conditions.

This study shows that spatial distribution and contamination with ammunition-derived HMs depend on multiple factors such as degree of anthropization, amount and type of ammunition, and distance from the shooting position. Concerning environmental risk assessment, large proportions of potentially bioavailable and mobile Cu and Pb could be dissolved, whereas Sb in the respective fractions was rather immobile. Nonetheless, the readily soluble Sb concentrations exceeded the German test value for soil-to-groundwater transfer in 80% of the samples. Regarding soil parameters, soil pH and

humus content were found to be contributing factors for Sb solubility or retardation. Citric acid, as a proxy for humic acids and used for dissolving the strongly adsorbed Sb fraction, mobilized a further 40% of the total Sb content, on average. This result reveals that although sesquioxides play a key role in Sb immobilization, particularly under acidic soil conditions, Sb poses a risk to the environment in the long term. Further research should, therefore, be extended to other urban soils affected by Sb input or legacy contamination.

Efficiency of Nature-based Solutions in Urban Areas: Identifying Soil-Plant-Atmosphere Indicators

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Topic: SUITMA challanges for the future
Keywords: soil-plant-atmosphere systems, soil health, indicators, stable isotopes, stoichiometry

The significance of nature-based solutions (NbS) for restoring soil health in urban settings is increasingly acknowledged. Numerous scientific studies have proposed different soil health indicators to assess how effectively NbS can deliver ecosystem services, such as supporting carbon and nutrient cycling. Notably, the soil-plant-atmosphere system holds a central position in ensuring the success of NbS interventions in cities. This makes the selection of targeted indicators related to this system essential.

A case study was performed within the municipality of Firenze (Tuscany, Italy), evaluating several NbS across different land uses—including modern and historical parks, water retention basins, and street trees. The sites were chosen based on criteria such as green cover and the degree of landscape fragmentation. In each location, key indicators for the soil-plant-atmosphere system were monitored. These included soil enzyme activities, isotopic markers in soil and plants, plant functional traits, and parameters related to air quality.

The air quality index—determined using concentrations of NO2, PM2.5, PM10, and O3—showed significant variation between urban and suburban zones. Additionally, measurements of δ13C and δ15N isotopic signatures, along with enzymatic stoichiometry, offered valuable insights into how the selected NbS functioned across the area.

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