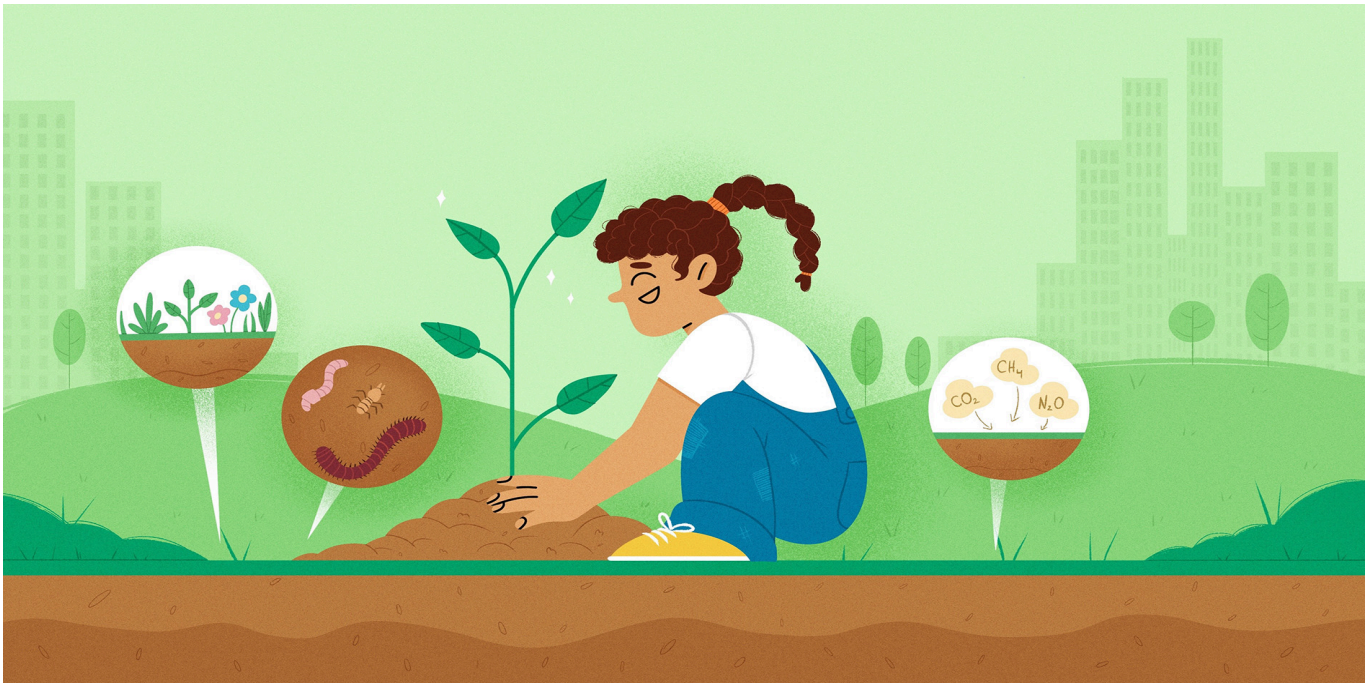
frontiers | Frontiers for Young Minds

EARTH SCIENCES
Published: 27 June 2024
doi: 10.3389/frym.2024.1270347



THE IMPORTANCE OF SOIL AND ITS ORGANISMS IN THE CITY

Maha Deeb [1*] ***and Monika Egerer*** [2]

[1] *Soils and Substrates Group, Institute Land-Nature-Environment, University of Applied Science of Western Switzerland Hepia, Geneva, Switzerland*

[2] *Urban Productive Ecosystems, Department of Life Science Systems, School of Life Sciences, Technical University of Munich, Freising, Germany*

YOUNG REVIEWERS:

ANNIKA
AGE: 13

JUDE
AGE: 15

In cities, the soil under our feet is important for making our cities green and giving us natural places to enjoy. Soil helps plants to grow, holds onto water when it rains, breaks down old materials, and cleans up harmful substances in the ground. Urban soils are also home for many animals and plants. But urban soils encounter tough challenges unique to cities. Soil does not have much space in the city, and it gets flooded with dirty water filled with pollutants. People walking, driving, and building on soils results in packed-down soil, which some plant species do not like to live in. When city soils experience such pressures, they cannot do their jobs well anymore and cannot provide us with the benefits they normally offer us. Fortunately, there are steps we can all take to improve this important resource.

SOIL ECOSYSTEM SERVICES

The benefits that soils provide to humans, including water regulation, nutrient storage and cycling, food production, erosion, disease and flood control, habitat for organisms and waste decomposition.

BIODIVERSITY

The variety of living organisms, such as plants, animals, and humans, and their interactions within a specific environment.

HAVE YOU EVER ENJOYED URBAN NATURE?

Skipping along under trees' shadows, playing in the park, picking dandelions from the sidewalk cracks—these are some of the ways we can interact with nature in the city environment. Urban nature consists of living systems found in cities, which contain plants and animals. These areas are often managed by people in various ways. Urban nature includes small urban parks, trees growing along streets, gardens, and larger urban forests or even untouched wilderness areas.

Nature in cities is helpful for humans in many ways, which are called **ecosystem services**. Nature makes our cities look beautiful, helps cool cities so that we use less energy in hot weather, stops flooding, makes the air cleaner, and sometimes provides food. Urban nature is home to many kinds of plants and animals, which is called urban **biodiversity**. Most importantly, having nature in our cities is not just good for plants and animals—it also helps us feel happy and healthy (Figure 1).

Figure 1

The presence of nature in urban areas has several advantages. **(a)** It creates green spaces and supports cultural heritage. **(b)** It helps control floods. **(c)** It provides habitats for plants and animals, as well as food and flowers for people. **(d)** It helps to keep cities cool. Urban nature also captures air pollution and can support structures like green roofs, walls, and permeable pavements, which enhance air quality, provide insulation, and help manage stormwater. These benefits have a positive impact both locally and globally (photo credit: Landry Collet).

SOIL IS THE KEY TO HEALTHY URBAN NATURE

Think of soil as the city's hidden brown infrastructure. Soil is important for plants because it gives them nutrients, water, air, and carbon. Soil also stimulates plant growth by supporting communities of helpful organisms.

In urban areas, soil acts as a natural cleaner by getting rid of contaminants or fixing them so they do not transfer to our water or affect animal life [1]. These contaminants include heavy metals from sources like old paint, car fumes, batteries, chemical fertilizers, pesticides, and burning coal [2]. Organic contaminants can come from electrical equipment, burning petroleum, oil, and gas products. Other

contaminants include radioactive materials, tiny plastics, pathogens from animal and human waste, and pharmaceutical products like antibiotics. However, when these contaminants accumulate over time in the soil, there comes a breaking point where the soil can no longer function as a natural purification system [3].

SOIL ORGANIC MATTER

The broken-down parts of dead plants and animals that turn into nutrients, helping plants grow.

Soil comes in various colors: brown, black, red, yellow, or even white. The color of the soil depends on where it comes from and what is in it—such as certain types of nutrients and **organic matter**. When plants and animals die, they become organic matter, which keeps soil healthy and functioning. If nutrients and organic matter are washed out of the soil, it is difficult for plants to grow (Figure 2A).

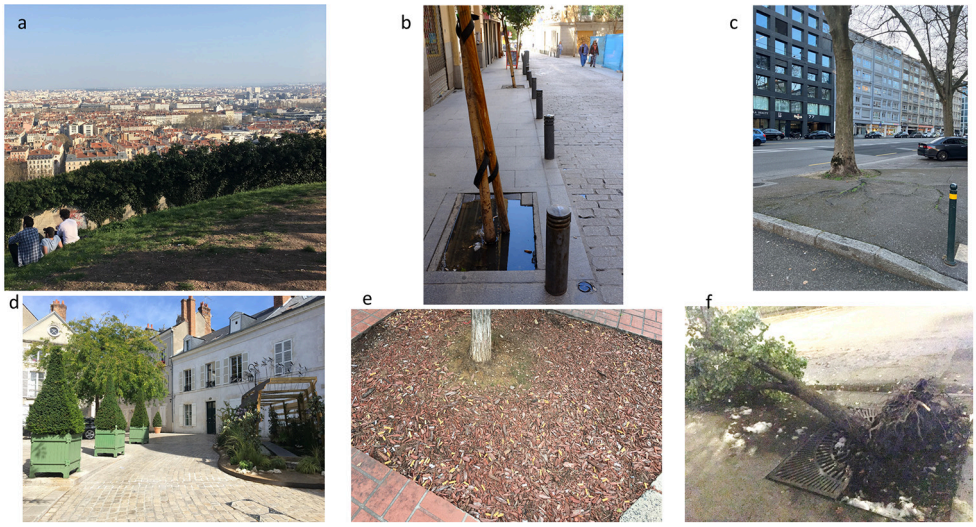


Figure 2

Urban soils face many challenges. **(a)** This lovely park in Lyon, France is experiencing a reduction in plant growth due to loss of soil nutrients caused by erosion. **(b)** Water accumulating around a tree in Madrid, Spain, because the soil has been compacted and cannot absorb the water. **(c)** The roots of this tree in Geneva, Switzerland, are reaching out of the sidewalk in search of water. **(d)** Trees in Orleans City near Paris are isolated, making it difficult for soil organisms to work as a team. **(e)** Trash accumulated under a tree in Boston, USA. **(f)** A tree damaged in a storm due to poor soil structure, in New York City, USA (photo credits: Landry Collet).

The texture of soil describes the size of the tiny mineral particles found in the soil. Sand, like the grains you see at the beach, is considered a large mineral. Silt is an average-size mineral, while clay particles are very small. Most soils are a mix of these minerals. Tiny particles like silt, clay, organic matter, and nutrients are grouped in different forms and shapes called **soil aggregates**. The arrangement of soil aggregates creates the soil structure. The structure of soil can contain pores (tiny spaces) and channels that help air and nutrients move through the soil, which is healthy for plants and other soil organisms. If the soil becomes compacted, some of these pores will disappear, and water will not infiltrate the soil easily (Figure 2B).

SOIL AGGREGATES

Groups of soil particles bound together to form larger, more stable units. These aggregates are formed by the arrangement of primary mineral and organic soil particles through physical, chemical, and biological activities occurring below ground.

Soil aggregates also protect water from escaping or evaporating too quickly, before plants or soil animals can use it. However, if soil aggregates are destroyed, plant roots are forced to search for water—sometimes by growing upward through the sidewalk (Figure 2C). Soil organisms enhance soil structure. However, their movement and behavior can be negatively affected by the lack of connectivity between green spaces (Figure 2D) and the presence of human waste,

such as cigarette butts (Figure 2E). As a result, their ability to form aggregates is reduced. A healthy soil structure supports plant roots, protects them, and allows roots to easily penetrate into the soil. When the soil structure is poor, plants may become unhealthy or even die (Figure 2F).

Soil aggregates also help to fight climate change by storing gases like carbon dioxide, methane, and nitrous oxide, keeping them out of the atmosphere where they contribute to global warming. A significant portion of the world's carbon and nitrogen reserves are stored in the top-most meter of soil, making it the largest carbon and nitrogen store on land. Thus, protecting soil structure in cities can improve local climate and help stop climate change in the long run.

SOIL IS "ALIVE" WITH RICH BIODIVERSITY

Soil pores are homes for numerous living organisms that form the soil's biodiversity. While we often talk about the Amazon rainforest containing over half of the world's estimated 10 million species of plants and animals, just a handful of soil can have hundreds of thousands to possibly millions of species! Soil biodiversity is a fascinating world filled with organisms of many sizes (Figure 3). Some soil organisms are visible to the naked eye, while tiny microorganisms are hard to see without a microscope [4]. Microorganisms, including bacteria and fungi, decompose organic matter such as leaves, branches, and dead animals in the soil. When microorganisms die, they serve as a food source for other soil animals and plants. Earthworms mix the soil through their movement, creating new pores and aggregates that serve as habitats for other organisms. Soil organisms are excellent at recycling. A special team of soil organisms can even clean our drinking water by destroying contaminants

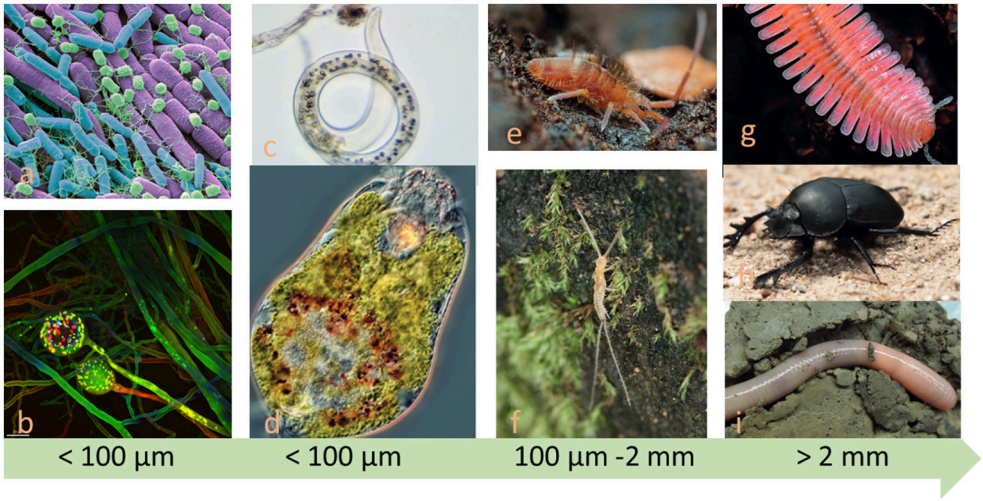


Figure 3

Figure 3

Soil organisms come in many sizes. **(a)** Bacteria and **(b)** fungi are examples of soil microorganisms. **(c)** Nematodes and **(d)** rotifera are also very tiny. **(e)** Collembolans and **(f)** diplura are still small but visible to the naked eye. **(g)** Myriapods, **(h)** the Egyptian scarab beetle, and **(i)** earthworms are examples of larger soil animals [photos credits: Steve Gschmeissner **(a)** Evan Bush **(b)** Global Soil Biodiversity Atlas **(c, d, e, f, g, h, i)**].

and thus preventing contaminants from getting into rivers and oceans [5]. Other teams of soil organisms can control pests or disease-causing organisms.

By working together, soil organisms improve soil health, purify water, reduce pollution, and improve soil structure and organic matter. In addition, they reduce greenhouse gases. Soil organisms work in teams to provide all the ecosystem services mentioned above. For instance, earthworms and plants can work together, which encourages many microorganisms that can help plants grow and improve soil structure. Soil is like a busy neighborhood where many organisms work together to keep things functioning properly.

URBAN SOIL FACES MANY CHALLENGES

Urban soil faces many challenges. One issue comes from covering the soil with concrete or pavement, which is called **soil sealing**. This stops water and air from getting into the soil, and it is one of the leading causes of unhealthy soil in urban areas. Covering the soil poses a threat to biodiversity, increases the risk of floods and water scarcity, and contributes significantly to global warming.

Soil erosion is another problem. Erosion occurs when soil nutrients and carbon get washed away by water or blown away by wind.

Soil contamination: urban soils can become contaminated with chemicals from cars, engines, plastics, soap from building washing, animal poop, nicotine from cigarette butts, and pesticides. Contaminants lower soil biodiversity, kill beneficial organisms, and reduce the ability of soil organisms to break down contaminants. In addition, the use of chemical fertilizers reduces the soil's ability to balance its nutrient content. Contamination can impact human health if people are exposed to contaminated soil.

Soil compaction: due to constant car or foot traffic, soil aggregates can become compressed. This means the air is squeezed out from between the soil particles, resulting in compacted (packed down) soil (Figure 2A). Compacted soil does not allow the root systems of plants to penetrate easily, reducing pore spaces and decreasing the ability of water to soak into the soil. If many pores become filled with water, plants and soil organisms cannot get the oxygen they need to live (Figure 2B).

Lack of biodiversity: finally, it is difficult for soil organisms to interact, collaborate, or reproduce with each other when plants are isolated from each other, such as when they are planted in containers (Figure 2D). This can reduce soil biodiversity and the healthy functions of city soils.

SOIL SEALING

Covering soil with impermeable materials (e.g., roads and buildings) due to urban development. This alters soil functions, degrades habitats, fragments natural areas, and modifies landscapes.

SOIL EROSION

The process where rain and wind wash away fertile soil, leaving land unable to grow plants. Sometimes, this soil ends up in water, harming aquatic life.

SOIL CONTAMINATION

Human-made substances (like residue of burning coal, oil, chemical bug and weed killer, nitrogen from fertilizer, plastic, etc) that accumulate in the soil, posing a risk to the environment.

HOW CAN WE IMPROVE URBAN SOILS?

We can make urban soils better by protecting them and helping them to recover. One way is by protecting natural areas within cities, providing places where soil can stay healthy and perform its functions. We can also connect these natural areas with pathways or corridors so plants and animals can move around between small habitat patches. Although it may be challenging to establish corridors in cities, linking small habitats like steppingstones can help support biodiversity. Increasing the size of urban green ecosystems is even better (but more expensive), as this can help reduce human-caused pressure on natural ecosystems.

When soil gets damaged, especially in places prone to flooding, we can plant certain plants that use rainwater to grow. This helps clean the water and stop floods, saving money on flood cleanup. These special areas are called stormwater management systems, and they are an inexpensive, environmentally friendly way to prevent flooding while also restoring the natural environment. We must also take steps to prevent soil sealing and **urban sprawl**, as well as combat pollution by reducing traffic and encouraging the use of public transportation and bike paths.

URBAN SPRAWL

The spread of cites over large areas with lots of houses, shops, and roads, leading to more driving and less green space.

Even contaminated soil in urban areas still provides us with various services. It is important to avoid touching soil that may be contaminated and to always wash your hands after contact. Contaminated soil may have a bad smell, an absence of plants or only one type of plants, or water accumulation on the surface. When contaminated soils are identified in an urban area, policymakers and scientists can take the necessary steps toward improving soil health.

WHAT CAN CITIZENS DO?

Now you know what soils in our cities can do and why they are important for nature and people. You also learned that urban soils face many challenges. How can we keep soils—and thus ourselves and communities—healthy? Small actions from each citizen can make a big difference in protecting urban soil health. Here are some examples of simple "pro-soil" actions:

- Create diverse plant communities, including trees and shrubs. Plants have root systems with varying depths and shapes, which encourages communities of organisms to live there. Planting enhances soil quality by improving soil structure along with water and nutrient storage.
- Minimize food waste and recycle organic waste, potentially by **composting**. Compost is a natural additive that can enhance soil quality.

COMPOSTING

The natural process of breaking down organic waste, like plant and animal scraps, into a nutrient-rich soil amendment. It recycles waste and improve soil functions.

- Avoid using plastics. When tiny particles of plastic get into the soil, they can be harmful and challenging to remove.
- Whenever possible, consider walking or using a bike, to reduce both the production of heat and the damage that vehicles can cause to soil.
- Educate your neighbors and government officials on their essential role in improving soil services. Biodiversity above ground supports below-ground biodiversity in the soil. Thus, maintaining and creating new, biodiverse, "wild" urban nature spaces can help to keep soil healthy.

In conclusion, we encourage you to look down at the "dirt" beneath your feet—touch, explore, and appreciate the beautiful life in urban soils and the important functions these soils provide. We should all try to create more space for "brown" in our cities, and enhance urban nature from the ground up!

ACKNOWLEDGMENTS

This work was carried out within the research training group Urban Green Infrastructure, funded by the German Research Foundation under grant 437788427 - RTG 2679.

REFERENCES

1. Egendorf, S. P., Cheng, Z., Deeb, M., Flores, V., Paltseva, A., Walsh, D., et al. 2018. Constructed soils for mitigating lead (Pb) exposure and promoting urban community gardening: the New York City Clean Soil Bank pilot study. *Landsc. Urban Plan*. 175:184–94. doi: 10.1016/j.landurbplan.2018.03.012
2. Paltseva, A. A., Deeb, M., Di Iorio, E., Circelli, L., Cheng, Z., and Colombo, C. 2022. Prediction of bioaccessible lead in urban and suburban soils with Vis-NIR diffuse reflectance spectroscopy. *Sci. Total Environ*. 809:151107. doi: 10.1016/j.scitotenv.2021.151107
3. Paltseva, A., Cheng, Z., Deeb, M., Groffman, P. M., Shaw, R. K., and Maddaloni, M. 2018. Accumulation of arsenic and lead in garden-grown vegetables: factors and mitigation strategies. *Sci. Total Environ.* 640:273–83. doi: 10.1016/j.scitotenv.2018.05.296
4. *Global Soil Biodiversity Atlas - ESDAC - European Commission*. Available online at: https://esdac.jrc.ec.europa.eu/content/global-soil-biodiversity-atlas (accessed March 26, 2024).
5. Deeb, M., Groffman, P. M., Joyner, J. L., Lozefski, G., Paltseva, A., Lin, B., et al. 2018. Soil and microbial properties of green infrastructure stormwater management systems. *Ecol. Eng*. 125:68–75. doi: 10.1016/j.ecoleng.2018.10.017

SUBMITTED: 31 July 2023; **ACCEPTED:** 31 May 2024;
PUBLISHED ONLINE: 27 June 2024.

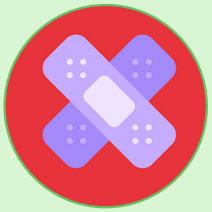
EDITOR: Dominik K. Großkinsky, Austrian Institute of Technology (AIT), Austria

SCIENCE MENTORS: Catherine A. Walsh and Maaria Rosenkranz

CITATION: Deeb M and Egerer M (2024) The Importance of Soil and Its Organisms in the City. Front. Young Minds 12:1270347. doi: 10.3389/frym.2024.1270347

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS



ANNIKA, AGE: 13

My name is Annika, I am 13 years old and live in Germany. I enjoy playing ice hockey, tennis, soccer and cello. I am also a member of our school orchestra. In my free time I love to meet up with friends. At school my favorite subjects are sports and English.

JUDE, AGE: 15

I enjoy playing guitar in my spare time, when I am not walking my cat. I often spend time with my two loving brothers. In the summer, I enjoy doing water sports in the lake district along with hiking and paddle boarding. I have lived in the UK all my life and love the weather for about 2 weeks per year, so I look forward to doing more traveling.

AUTHORS

MAHA DEEB

A French researcher originally from Syria, Maha realized at a young age that food security is a major issue in impoverished countries. As a result, she studied soil science to ensure that every child has access to food and water, particularly in areas where resources are scarce. She received a grant from France and earned her Ph.D. from the Paris-Est University. She has been teaching soil science at universities around the world, including Damascus University in Syria, Paris-Est and Lorraine Universities in France, Brooklyn College in New York, USA, RUDN University in Moscow, Russia, and TUM University in Munich, Germany. She continues to develop innovative methods to fight soil degradation at the HEPIA laboratory in Geneva. Her commitment lies in preserving soil as a precious resource, so

that one day, all children around the world can enjoy nature and consume healthy food. *mahadeeb.y@gmail.com

MONIKA EGERER

Urban nature is important for biodiversity and people. Understanding how urban nature, such as gardens and parks, functions is thus important to science and society. My research addresses the ecological and social characteristics of urban nature. My goal as a scientist is to deepen our understanding of and inform the management of nature in cities for plants, animals, and people.