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BIODIVERSITY
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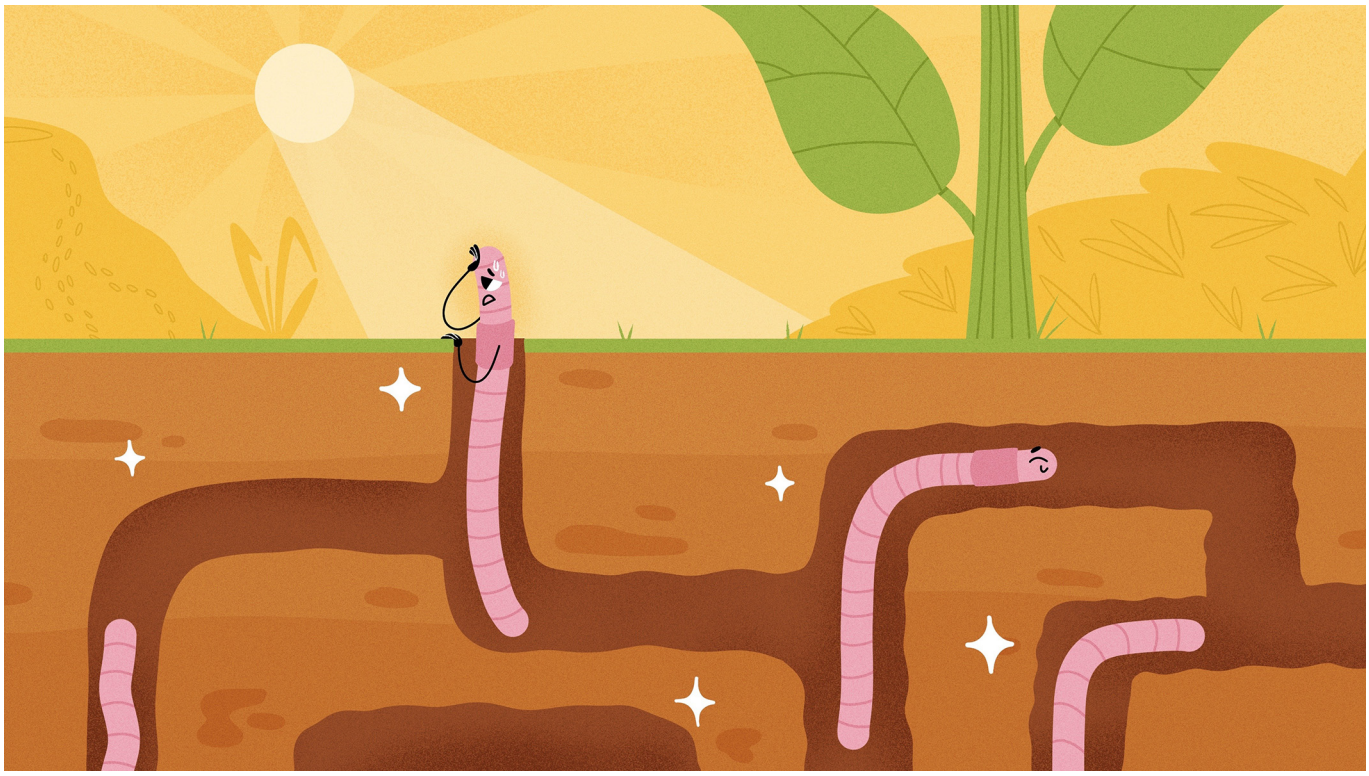

THE ADVENTURES AND CHALLENGES OF SOIL ENGINEERS

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YOUNG REVIEWERS:


ALMA
AGE: 12


BATOUL
AGE: 10


JOSEPHINE
AGE: 14


TAMMAM
AGE: 15

Tiny organisms like earthworms, ants, and termites play an essential role in maintaining healthy soils and ecosystems. They are often called "ecosystem engineers" because of their profound effects on ecosystem structure and functioning. One of their key effects arises through their burrowing activities, which is called bioturbation. Bioturbation mixes up the soil, which increases helpful bacterial activity and plant growth. Well-mixed soils are better at storing carbon, which can help reduce global warming. As global temperatures rise due to climate change, soil organisms face challenges to the stable living conditions they rely on. In this article, you will discover the importance of bioturbators, the impact of climate change on their activities, and how their work can help combat global warming.

WHAT IS SOIL?

Soil is everywhere. But what is it, really? Soil starts with rocks, but it is more than just broken rocks. When rocks break down, whether by water or wind, pure sand is created. Sand feels gritty, like sugar; it does not retain water, and almost nothing lives in it. Real soil is a mix of sand, which drains quickly; clay, which sticks together and holds water; and silt, which is a smooth, fine soil that holds some water and nutrients. Soil is also packed with organic matter, which is the broken-down remains of countless dead microbes, small animals like insects, and plants.

There are various types of soils, depending on the rocks they came from and the type of organic matter they trapped over time. Soils are good at holding water (like a sponge) and essential for plant growth, because plants get the nutrients they need from the soil. In turn, plants provide essential food and habitat for some animals. Soils change over time because they are continuously modified by the many organisms that inhabit them, including bacteria, fungi, worms, arthropods, and plants. Soils are alive and fragile. They can be affected by many things such as **compaction**, changes in the plants that grow in them, pollution, or global warming. Soils are an essential component of ecosystems, so we need to protect them from damage.

COMPACTION

When soil gets squished too much, making it hard for water, air, and roots to move through.

SOIL ENGINEERS

Among the many organisms that live in soils, earthworms, termites, and ants have a big impact and are thus called **soil engineers**. Earthworms dig tunnels and enrich the soil with organic matter. Some species of termites and ants build large, long-lived underground nests. The action of wiggling through and mixing the soil is called **bioturbation** [1]. Through bioturbation, soil animals move nutrient-rich soil particles from deep layers to the surface, where plants can use them. They also increase the amount of air between soil particles, and help water soak into the soil (Figure 1). Soil engineers can be compared to a gardener mixing soil with a shovel. The burrows of soil engineers can also be used by other organisms that help keep soils healthy, including microorganisms. The soils around large termite and ant nests are often richer than elsewhere, so lots of plants can grow there—even though some ants and termites feed on plants!

SOIL ENGINEERS

Animals like worms, ants, and termites that build tunnels and mix soil. These activities modify the soil structure, which often help plants and other animals.

BIOTURBATION

The action of moving and mixing soil particles.

BENEFITS OF HEALTHY SOILS

Despite their small size, soil engineers are important for nature and for humans. Their presence helps beneficial bacterial activity and increases plant growth, which is valuable for the entire ecosystem because plants sustain many animals. Soil engineers are also important for agriculture, as richer soils can lead to larger and more sustainable

Figure 1

Soil engineers like earthworms, termites, and ants enrich soil and boost plant growth by improving soil structure, nutrients, and air content.

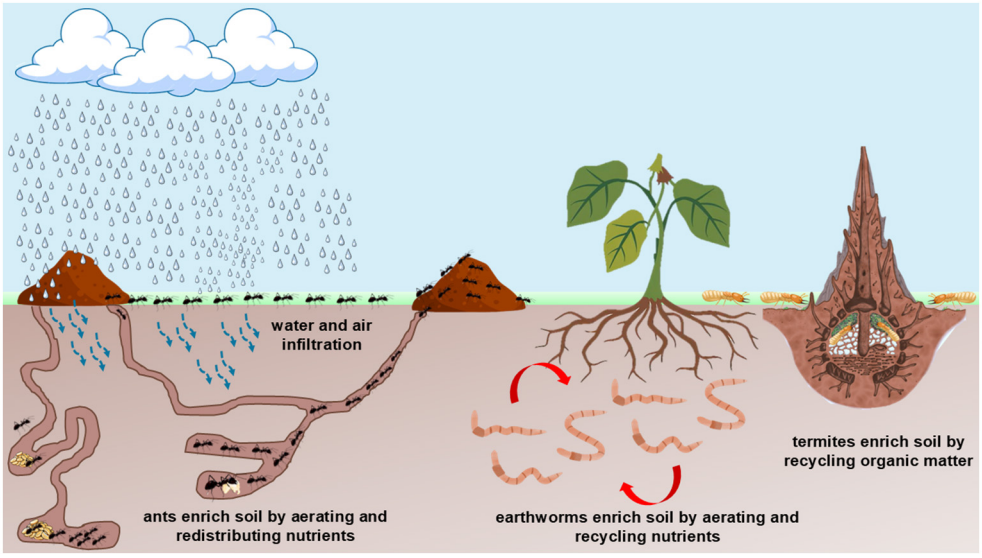

Figure 1

CARBON STORAGE

The process of trapping carbon dioxide from the atmosphere in plants and soil, keeping it out of the atmosphere.

BIODIVERSITY

The variety of life in a specific area, including animals, plants, fungi, and microorganisms.

harvests. Plants also contribute to **carbon storage**, which means removing the excess carbon dioxide (CO_2) from the air. Can you see why it is important to protect soils and the **biodiversity** they contain? But how will soil engineers and soils be affected by ongoing global warming?

RISING TEMPERATURES CHANGE THE GAME

The negative effects of global warming are easy to see, and they affect all of us. Our planet is surrounded by a blanket of air called the atmosphere. Humans have released large quantities of heat-trapping gases, through industrial and agricultural activities, which have made this blanket warmer. Humans also continue to cut down trees and reduce humid areas such as the peat lands and mangroves that naturally remove CO_2 from the air. The combined result is that the planet is getting warmer, and this causes big changes in nature [2]. The extra heat affects all ecosystems, habitats, and many species, including soil engineers. When the soil gets hotter and drier, the body temperatures of soil organisms can increase to a level that they cannot tolerate. Unlike us, these animals depend on the environment for temperature regulation—they cannot produce heat to warm themselves up or sweat to cool down.

CAN SOIL ENGINEERS AVOID THE INCREASED HEAT?

Ants are usually less sensitive to rising temperatures and dryness than earthworms and termites are, so they may play an important role in keeping the soil healthy in a warmer future [3]—but all bioturbators are important.

Termites and ants may be exposed to high temperatures when they forage for food outside of the nest. To escape the heat, some species change the time of day when they go outside (Figure 2A). However, this may affect their success at collecting food, as they may encounter different prey and predator species. Ants and termites may also be exposed to warming when they are in their nest. Some species build large, complex nests that provide stable temperature and humidity thanks to a complex system of tunnels allowing ventilation, but many species dig shallower nests and are affected by warming. They try to escape the heat by relocating their nest to cooler places, such as in the shadow of a tree. Some species build their nests in association with plants, which help prevent nest overheating during the day and loss of heat at night (Figure 2B). Another way to escape the heat is by digging deeper nests or adjusting the configuration and the connections between the various chambers and tunnels (Figure 2C) [4]. New nesting behavior can alter the effects nests have on soils, such as changing how soil particles and nutrients are mixed up across soil layers and how water penetrates the soil, which can then affect soil quality in ways that influence plants.

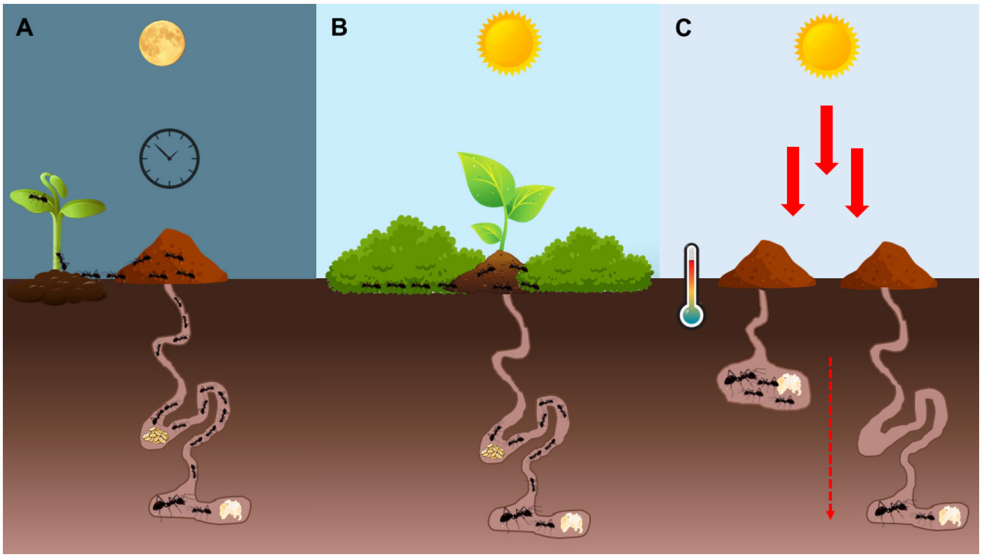

Figure 2

Ants use various strategies to escape soil heating. **(A)** The might change the times when they search for food. **(B)** They might build their nests in association with plants to prevent nest overheating. **(C)** They might dig deeper nests to escape temperature increases at the soil surface.

CAN WARMING AFFECT SOIL QUALITY?

POROUS

Soil with tiny holes that let air and water move through easily.

Plants need healthy, **porous**, and moist soil to thrive (Figure 3A). When the soil becomes too dry, plants have trouble growing (Figure 3B). Rainwater can easily pass through porous soils, which is not the case with dry soils. If soil engineers are harmed by warming, soil quality will likely get worse. As we have described, warming and drying can also affect other important parts of the soil, such as soil organic matter, communities of microorganisms, and the way nutrients move through the soil. These changes can weaken soil structure and even

EROSION

When wind or water washes soil away, leaving less soil for plants to grow.

DEGRADATION

When soil loses its nutrients or becomes weak, then plants cannot grow well and soil animals have a hard time living on it.

increase the risk of **erosion** or compaction. When soil quality declines, plants struggle even more, which affects the animals that depend on plants and the predators that rely on plant-eating animals. This shows how one problem, like global warming, can trigger many others, such as soil **degradation**, creating a cycle of challenges for entire ecosystems.

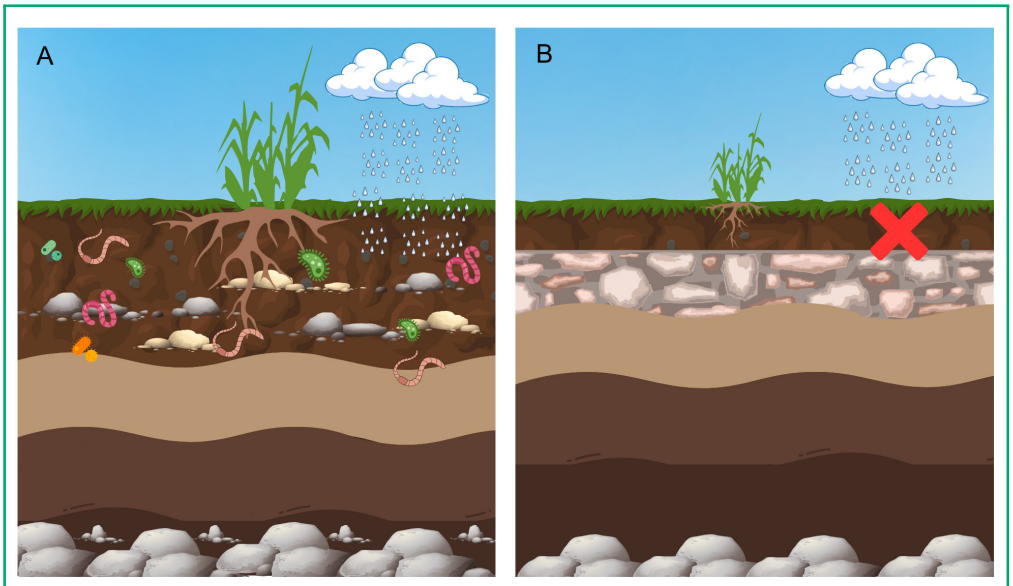

Figure 3

(A) Rain can easily penetrate through healthy, porous soil. **(B)** Hard, compacted soil keeps rainwater on the surface, so roots cannot develop well and grow strong.

CONCLUSION: TINY ORGANISMS, BIG EFFECTS!

Soils are vital for plants, which themselves support animal life. Organisms living in the soil, and soil engineers in particular, are crucial for soil health. These organisms may be small, but they are precious and play a big role in the functioning of our planet. So, protecting them is important! We can help to keep soil organisms healthy by using less energy, because energy production releases gases that increase global warming. Walking, riding a bicycle, and using public transport are good ways to decrease energy use. By combining the work of these incredible bioturbators with our everyday efforts, we may be able to create a powerful, positive impact to protect and preserve our planet.

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AI TOOL STATEMENT

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YOUNG REVIEWERS

ALMA, AGE: 12
Hi! I am Alma, 12 years old. I love mathematics and enjoy solving problems and thinking logically. I am also passionate about science, especially robotics. Two years ago, I took a robotics course that increased my interest and understanding. Outside of academics, I enjoy playing tennis and reading, it helps me stay active and focused. I consider myself a creative person who is always ready for new challenges and learning opportunities. I strive to grow and enjoy every step of the journey.

BATOUL, AGE: 10
Hi! I am Batoul, 10 years old. Reading novels is my favorite thing to do. I love the color white it makes me feel calm. Books take me into new and exciting worlds. I love writing; it lets my thoughts fly free. I enjoy quiet moments and big ideas. Every day, I learn something new.

JOSEPHINE, AGE: 14
My name is Josephine, I am 14 years old. I live with my mom and dad, my eight parakeets, two cockatiels and two dogs, Raven and Bruno. My favorite color is orange, and I love figure skating, swimming and play golf. I like to read; I like Greek mythology of historical fiction. I love animals, and I do not have a favorite since all have different skills and features. I enjoyed working on the article and I hope I get to work on more.

TAMMAM, AGE: 15
Hello, my name is Tamam. I am 15 years old. I enjoy reading and asking questions to expand my knowledge. I also love biology. I am looking forward to expanding my knowledge of health sciences.

AUTHORS

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Rafael works with wasps, bees, and ants. He is doing a postdoc at Sorbonne Université, in Paris, France, and works at the Institute of Ecology and Environmental Sciences of Paris (iEES Paris). He was born in Brazil and, during his PhD, he went to Belgium and the United States to do research internships. In Belgium, he studied different wasp species, including yellow jackets and hornets. In the United States, he worked on zombie wasps. He likes insects, ice-cream, karaoke, going to the cinema, traveling and spending time with friends. *rcsilva2812@usp.br

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Pascal works for the French Institute of Research for Sustainable Development at at the Institute of Ecology and Environmental Sciences of Paris. He is currently in deputation at the Institute of Technology of Cambodia, in Phnom Penh, where he

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Thibaud works for the French National Center for Scientific Research. He is based at the Institute of Ecology and Environmental Sciences of Paris where he studies the behavior and ecology of ants.