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OFFICE FOR CLIMATE EDUCATION

SOIL AND CLIMATE CHANGE A TEACHER'S HANDBOOK

SoilTribes

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SoilTribes

SoilTribes aims at establishing, activating, and empowering glocal ecosystems for soil values, roles, and connectivity through "back to Earth" narratives by bridging science, technology, arts, and community-driven action. Through knowledge-sharing, interdisciplinary collaboration, and community-driven initiatives, the project's mission is to foster a systemic, glocal approach to soil restoration, ensuring its long-term sustainability as a fundamental resource for future generations.

Created in 2018 on the initiative of the educational and scientific community, the Office for Climate Education (OCE) aims to organise strong international cooperation between scientific bodies, NGOs and educational institutions. This cooperation is essential to educate present and future generations about climate change. The mission of OCE and its partners is to promote climate change education worldwide through high-quality teaching resources, professional development courses and design and implementation of national and international operational projects.
In 2020, the Office for Climate Education became a centre under the auspices of UNESCO to promote climate change education internationally, focusing in particular on emerging countries.

CONTENTS

SOILTRIBES TRAIN-THE-TRAINERS PACK

This train-the-trainers pack equips educators with comprehensive materials focused on soil health as a key concept for environmental sustainability. It includes **12 well-structured lessons**—10 formal lessons and 2 non-formal activities—**accompanied by supporting videos** that demonstrate hands-on activities and feature expert explanations. These resources enable educators to guide students in understanding how healthy soils serve as a living foundation for ecosystems, climate resilience, and human well-being.

As part of the European SoilTribes initiative, these materials promote "back to Earth" narratives aimed at reconnecting communities with the importance of soil stewardship through shared knowledge and collective action. Given that healthy soils are increasingly threatened by climate change, intensive agriculture, and urbanisation, this educational framework addresses these challenges while empowering students to become advocates for soil health.

The lessons and activities created by the OCE **align with the competencies of the GreenComp framework** and incorporate diverse teaching methods. These educational resources help students develop a deep appreciation for soil health while providing them with practical knowledge to engage in soil conservation and climate action.

Part A: Digging into Soils - What Are They and Why Do We Need Them?

- What Types of Ecosystem Services Does Soil Provide?
- What Are Soils, and How Do They Form?
- What Are the Soil Properties?
- What Is Soil's Biodiversity Role?
- What Role Does Soil Play in the Water Cycle?
- What Role Does Soil Play in the Nitrogen Cycle

Part B: From the Ground Up - Soils, Climate Change and New Soil Horizons

- B1: How Do Our Actions Shape the Soil?
- B2: How Can Soil Be Part of the Climate Solution?
- B3: Why Should We Care About Soil?
- B4: How Can We Re-imagine Soils for a More Sustainable Future?

"The Soil in Our Hands" (Non-Formal Activities)

- Create Your Own Terrarium
- Soil Story Quilt

To complement this teachers' handbook, a collection of 12 video clips has been developed, showcasing hands-on activities and featuring scientists from the SOILTRIBES project. These videos are freely accessible on the OCE website and YouTube channel.

Hands-on experience videos

- Video 1: Revealing Soil Composition Using Decantation
- Video 2: Identifying Soil Structure with the Texture Triangle
- Video 3: Measuring Soil Air Content
- Video 4: Understanding Soil Cation-exchange Capacity
- Video 5: Observing Organic Matter Decomposition in Soil
- Video 6: Detecting Organic Matter in Soil
- Video 7: Measuring Soil Water Content
- Video 8: Measuring Soil Water Retention

Experts videos

- Video 9: What Are Soils and How Do Soils Form? | Giulia Bongiorno, Researcher specialized in soils - Wageningen University, Netherlands
- Video 10: How Do Human Activities Impact Soils? | Loes van Schaik, Researcher specialized in Soil Physics and Land Management - Wageningen University, Netherlands
- Video 11: How Do Climate Change (CC) Impact Soils and Therefore Human Activities? | Davide Cerati, Researcher - Politecnico di Milano, Italy
- Video 12: How are Soils Part of the Solution to Face Climate Change? | Martin Ziesak. Professor Emeritus Bern University & iFOS Forestry Solutions, Switzerland

SoilTribes — Teacher Pathway Guide

A structured overview of all 12 lessons and activities mapped to primary and secondary school levels — helping educators select, sequence, and adapt content for their learners.

Suggested Pathways at a Glance

Primary (7–12) — Introductory Track: A1 → A4 → A5 → B4 → NFA 1 (Terrarium) → NFA 2 (Quilt)
Lower Secondary (12–15) — Core Science Track: A2 → A3 → A5 → A6 → B2 → B4
Upper Secondary (15+) — Critical Inquiry Track: A2 → A3 → A6 → B1 → B2 → B3 → B4
Cross-curricular / Non-formal (All ages 9+): A1 → B4 → NFA 1 → NFA 2 — ideal for eco-clubs & community events

LEVEL: Primary (7–12 yrs) | Lower Secondary (12–15 yrs) | Secondary+ (15+ yrs) | All ages (9+)
DIFFICULTY: ● ○ ○ Introductory ● ● ○ Intermediate ● ● ● Advanced

PRIMARY Part A — Digging Into Soils Ages 7–12 · Foundational Knowledge

Lesson	Age	Subjects	Difficulty	Key Learning Outcomes	Teaching Methods	GreenComp	Recommended Pathway
A1 Ecosystem Services of Soil	Ages 9–12	Social Studies Natural Sciences	● ○ ○ Introductory	Link everyday objects to soil origins	Serious Game (Bingo)	Promoting Nature Systems thinking	Start here — ideal first lesson, motivates through play
A4 Soil's Biodiversity Role	Ages 7–11	Natural Sciences	● ○ ○ Introductory	Identify and classify soil organisms. Explain food web interdependence Observe decomposition processes. Propose actions to protect soil	Field Observation Role-play Experiment	Systems thinking Promoting Nature	Best for youngest learners (7–9), hands-on outdoor focus Pairs well with A1 or the Terrarium NFA
A5 Soil & the Water Cycle	Ages 9–12	· Natural Sciences	● ● ○ Intermediate	Compare soil as a water reservoir Explain soil as natural sponge & filter	Hands-on Experiment Document Analysis	Systems thinking Problem Framing Promoting Nature	After A1 or A4 -builds on foundational awareness Bridge to secondary: leads into B2 (climate solutions)
B4 Re-imagine Soils: Storytelling for Futures	Ages 9+	Humanities Civic Education Language	● ○ ○ Introductory	Reflect on how soil issues affect communities Imagine alternative soil futures Create fairytales promoting soil stewardship	Storytelling Creative Writing Art Guided Reflection	Futures Literacy Exploratory Thinking	Ideal capstone for primary — integrates empathy & creativity
NFA 1 Create Your Own Terrarium	2h Ages 9+	Arts & Crafts Gardening	● ○ ○ Introductory	Visualise soil ecosystem structure Understand layer relationships Build a self-contained ecosystem	Hands-on Craft Observation Scientific Drawing	Promoting Nature	Non-formal enrichment use alongside A2 or A4
NFA 2 Soil Story Quilt	2h Ages 9+	· Art & Craft · Storytelling	● ○ ○ Introductory	Explore soil justice through textile art Connect soil health to social vulnerabilities Express identity & land stewardship creatively	Textile Art Community Collaboration	Promoting Nature	Great community / cross-curricular event — pairs with B4

SECONDARY Parts A & B — Soils, Climate & New Horizons Ages 12–15+ · Deeper Inquiry

Lesson	Age	Subjects	Difficulty	Key Learning Outcomes	Teaching Methods	GreenComp	Recommended Pathway
A2 What Are Soils & How Do They Form?	9–15	STEM Chemistry Geography	● ● ○ Intermediate	Identify soil horizons & layers. Reconstruct a regional soil profile Model the process of soil formation	Serious Game Observation	Systems thinking	Recommended starting point for secondary — foundational structure Follow with A3 (properties) then A6 (nitrogen cycle)
A3 Soil Properties & Structure	9–15	Natural Sciences Chemistry	● ● ○ Intermediate	Explain texture & structure impact on life Identify soil texture by decantation. Explain the clay-humus complex	Lab Experiment Decantation	Systems thinking	After A2 — deepens understanding of soil composition Links naturally to A5 (water) & A6 (nitrogen)
A5 Soil & Earth's Water Cycle	9–12	Natural Sciences	● ● ○ Intermediate	Soil as reservoir & natural filter Permeability & retention experiments Impact of climate change on soil hydrology	Experiment Document Analysis	Systems thinking Problem Framing	Use alongside A3 to show physical-chemical connections
A6 Soil & the Nitrogen Cycle	13–15	Biology Chemistry	● ● ● Advanced	Understand soil as nitrogen cycle engine Describe nitrification & denitrification Identify environmental impacts of excess nitrogen	Observation Document Analysis	Systems thinking Promoting Nature	Requires A3 prerequisite — most advanced Part A lesson Bridges to B1 (human impacts) for upper secondary
B1 How Do Our Actions Shape the Soil?	15+	Social Studies Natural Sciences	● ● ○ Intermediate	Evaluate human impacts on soil (7 countries). Analyse sustainable soil management strategies	Case Studies	Systems thinking Promoting Nature	Open Part B — first lesson in 'From the Ground Up' block Follow with B2 (climate) or B3 (care & resilience)
B2 How Can Soil Be Part of the Climate Solution?	12–15	Natural Sciences	● ● ● Advanced	Explain soil's role in the carbon cycle Distinguish carbon sink vs source. Connect soil health to climate mitigation & adaptation	Experiment Document Analysis	Problem Framing Adaptability	After B1 — connects human action to climate impact Requires prior A5 or A6 for full depth
B3 Why Should We Care About Soil?	15+	Biology Geography Environmental Science	● ● ● Advanced	Diagnose soil problems using systems thinking Evaluate soil treatments & trade-offs Understand soil–society–climate links	Role-play Case-based Learning	Systems thinking Critical thinking	After B1 & B2 — synthesises & applies knowledge Strong capstone before B4 futures thinking
B4 Re-imagine Soils for a Sustainable Future	Ages 9+	Humanities Civic Education Language	● ● ○ Intermediate	Analyse intersectional soil justice issues Apply futures literacy & scenario thinking Create stories advocating for soil stewardship	Scenario Building Creative Writing Guided Reflection	Futures Literacy Envisioning Futures	Final capstone lesson — close the full curriculum cycle Pairs with NFA Soil Story Quilt for community action

PART A: DIGGING INTO SOILS
WHAT ARE THEY AND WHY DO WE NEED THEM?

DIGGING INTO SOILS

LESSON A1 WHAT TYPES OF ECOSYSTEM SERVICES DOES SOIL PROVIDE?

MAIN SUBJECTS	DURATION	AGE GROUP	TEACHING METHOD
Natural Sciences, Social Studies	1h	9-12 years old	Serious Game

OVERVIEW

In this lesson, students explore the vital ecosystem services that soils provide for human well-being and environmental health. Using the serious game **"Natural Resources Bingo"**, students trace everyday items back to their origins in soil. The lesson concludes by emphasising how human activities are degrading the environment's capacity to sustain essential ecosystem services crucial to our continued well-being.

GREENCOMP COMPETENCES

Promoting Nature, Systems Thinking

LEARNING OUTCOMES

By the end of the lesson, students will be able to:

- Connect everyday objects to the soil origin
- Identify the many essential functions that soil provides
- Categorise these functions into 4 types of ecosystem services

KEY CONCEPTS

Ecosystem Services, Natural Resource, Soil Health

Background for teachers

Ecosystem services are the direct and indirect benefits that human societies receive from nature. These resources and services from the environment, and specifically from soils, are separated into four distinct categories based on their contributions to the human species: regulating, provisioning, supporting, and cultural services.

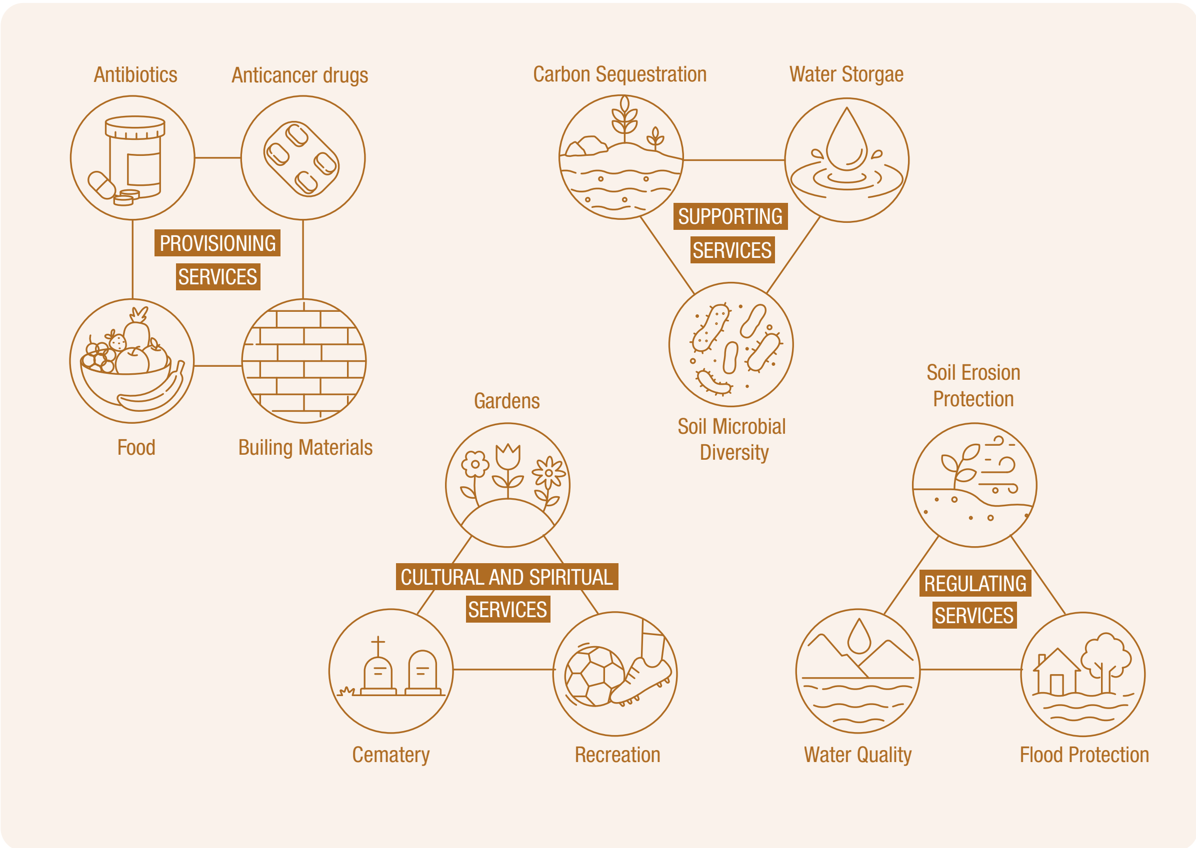


Fig. 1. Soil Ecosystem Services: Four Categories of Benefits Provided by Soils. Source: adapted from an infographic by European Environment Agency (2024)

PROVISIONING SERVICES

Soils are **the foundation for food and biomass production,** with an estimated 99% of the world's food coming from terrestrial environments. Beyond agriculture, soils provide essential raw materials for building, and they contain an archive of genetic resources utilised in biotechnology. Notably, soil organisms are a primary **source of medicinal products;** over half of the world's antibiotics (such as Penicillin and Streptomycin) and other drugs, such as the immunosuppressant Rapamycin, were isolated from soil fungi and bacteria. Soils also **contribute to energy needs** by providing fuel (such as wood) and substrates for renewable energy, such as biogas produced via anaerobic digestion.

REGULATING SERVICES

Soils play a vital role in regulating the global climate by functioning as a massive carbon sink, holding more than twice the amount of carbon currently contained in the atmosphere. In the carbon cycle, soil organisms regulate carbon flux; for example, scientists estimate that a single nematode species, Scottnema lindsayae, accounts for 7% of soil organic carbon turnover in some regions. Furthermore, soils act as natural buffers and filters, purifying the water we drink by removing pollutants and regulating the water cycle to mitigate natural disasters such as floods and droughts. Soil biodiversity also provides biotic regulation by keeping pests at bay and suppressing soil-borne plant diseases through competition and the production of toxic metabolites.

SUPPORTING SERVICES

Supporting services are essential for the production of all other ecosystem services. They include primary production, in which photoautotrophs such as cyanobacteria and algae fix atmospheric carbon to form the base of food chains.

CULTURAL AND SPIRITUAL SERVICES

These services include the non-material outputs of ecosystems that affect people's physical and mental states, such as aesthetic experiences, recreation, and spiritual or religious meaning. Soils serve as a physical platform for sports and leisure activities and as an archive of cultural heritage by preserving archaeological sites. Nature also facilitates learning and education; field observations of soil biodiversity and participation in citizen science programmes help society understand manifestations of global change and appreciate the "hidden" world beneath our feet.

SOIL HEALTH

The Intergovernmental Technical Panel on Soils (ITPS) defines soil health as ***"the ability of the soil to sustain the productivity, diversity, and environmental services of terrestrial ecosystems".*** Healthy soils form the foundation of numerous ecosystem services that benefit both nature and human societies. When soil health deteriorates due to erosion, contamination, or nutrient depletion, these ecosystem services are compromised. For instance, degraded soils store less carbon, filter water less effectively, and support reduced biodiversity. Recognising this critical connection, on December 16, 2025, the European Union passed its first comprehensive law on soil monitoring and resilience. This landmark legislation establishes a framework to restore and protect soil health, specifically to maintain the ecosystem services that healthy soils provide across member states.

PREPARATION 20 MIN

MATERIALS

- Print one **HANDOUT A1.1** and one **HANDOUT A1.2** per group of 5 students
- Print one **HANDOUT A1.3** per student
- Scissors

SUPPLEMENTARY MATERIAL

How Do Human Activities Impact Soils?
Loes van Schaik, Researcher specialized in Soil Physics and Land Management

INTRODUCTION 10 MIN

WARM UP 10 MIN

1. Ask the students,

> *"What are some ways that nature helps us or gives us things we need?".*

Encourage a brief discussion to explore their ideas based on what they already know—such as air, food, trees, animals, and especially water. Water is provided to us by nature — we do not make it ourselves. That makes water an example of a **provisioning service** — something nature provides that humans use.

As students share their ideas, chart their answers on the board or on a poster paper labelled «How Nature Helps Us!».

Help them group similar ideas (e.g., things we eat, ways nature protects us, things we use for fun). This helps build vocabulary and sets the stage for categorising ecosystem services later on.

2. Share the lesson's learning outcomes and ensure students understand them before moving on to the first activity. For example,

> *Today we're going to discover more about the amazing ways that nature, especially soil, helps people and the planet. We'll learn about the things it gives us, the ways it protects us, and why it's important to take care of it.*

PROCEDURE 40 MIN

NATURAL RESOURCE BINGO GAME 20 MIN

3. Announce that they will **play a bingo game** as a group of 5 to discover more about the ways nature — especially **soil** — helps humans and the environment.

4. Distribute **HANDOUT A1-1** to each group of students and ask them to cut out the "Natural Resources" and «Letters» cards if this hasn't been done yet.

Then distribute to each group the **HANDOUT A1-2,** and each student will take one of the bingo sheets. Make sure they understand the instructions correctly: a student draws a card from the "letters" pile and a card from the "natural resources" pile.

> **For example,** the letter "E" and the resource "plants": the group selects one of the objects obtained from a plant (soda, for example). The students then colour the soda on their individual activity sheet and tick the small "plant" drawing.

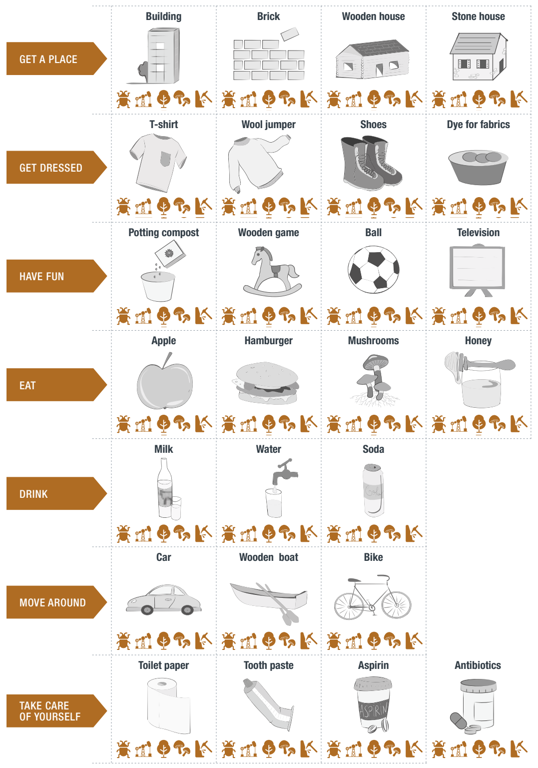
Encourage discussions among students, and help them identify the raw materials used.

> **TEACHER TIPS**
> **WATER AND EVERYDAY OBJECTS**
> On their activity sheet, students should systematically tick the small "mineral resource" drawing that includes water, because all everyday objects require water at some point in their production, exploitation, or transformation. This may involve washing fruits, making paper, the use of water by living beings for their growth, etc.

5. Once the game is finished for all groups (i.e., there is a winner in each group), ask students what resources everyday objects are made of. The natural resources in this game come either directly from the soil or from organisms that depend on it. They can be of animal origin (such as decomposers), plant, fossil (such as coal), or mineral origin. Some are collected and used directly (mushrooms, apples, honey, milk, water, etc.) And the brick wall? It is mineral matter from the soil (clay), but bricks are obtained after transformation (crushing, humidification, mixing, moulding, and finally firing the clay). Cars are made from a combination of these different resources (fossil fuels and mineral resources, sometimes animal resources) after transformation. Ask students:

> *What these resources are used for? Is it possible to classify these different uses?*

For this, ask them to cut out the images on their sheet and group the objects into categories of their choice. Below is an example of a possible categorisation.



SOIL ECOSYSTEM SERVICES CATEGORISATION 20 MIN

6. Explain to students that scientists use the term **"ecosystem services"** to describe the many benefits that nature freely provides to humans and other species.

Introduce the four main categories of ecosystem services:

- **Provisioning services —** These are the things we get directly from nature, like food and water; Easy way to remember: These are "provisions", like supplies you pack for a trip!
- **Regulating services —** These are the **natural processes** that help keep the environment clean and balanced, such as trees taking in carbon dioxide, soil filtering water.
- **Supporting services —** These are the **basic systems** that keep all the other services going, including soil formation and nutrient cycling.
- **cultural services —** These are the **non-material** benefits from nature that help us enjoy life, such as recreational and spiritual benefits).

Then invite students to match the various soil functions to each type of ecosystem service. Distribute **HANDOUT A1.3** per student.

7. Probe students to reflect:

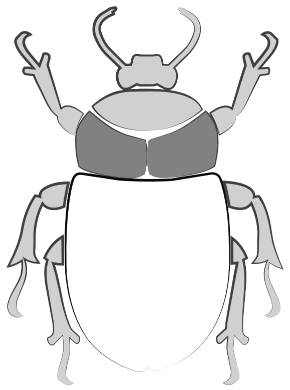
> *How does the health of soil affect the services it provides, and what would happen to plants, animals including humans if these services disappeared?*

WRAP UP 10 MIN

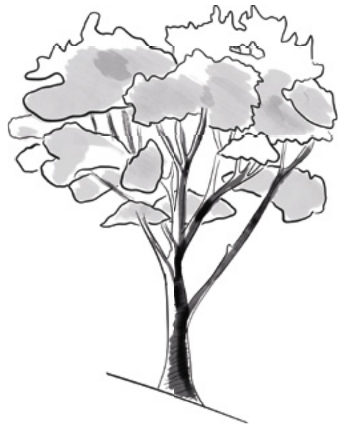
Ask students to write a short summary of the lesson to explain to others why soil is more than dirt and why preserving soil health is important to us and to the environment.Example of an answer:

> *Soil is more than dirt…Our food comes directly or indirectly from plants anchored in and nourished by soil. Soils provide habitat for soil organisms, and the water we drink and use every day has been filtered by soil. Soils process and recycle nutrients, including carbon, so that living things can use them over and over again. Soils serve as the foundation for the construction of roadbeds, dams and buildings. Preserving healthy soils is essential to ensure soils can continue to provide these essential services.*

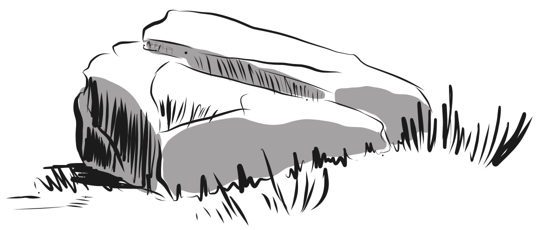
INSECTS



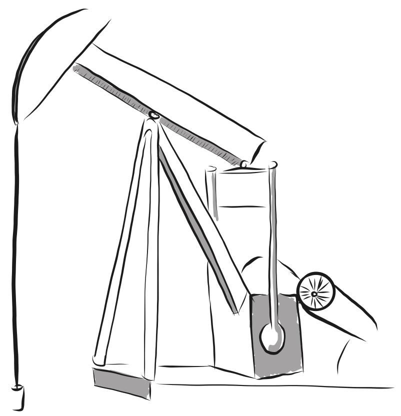
PLANTS



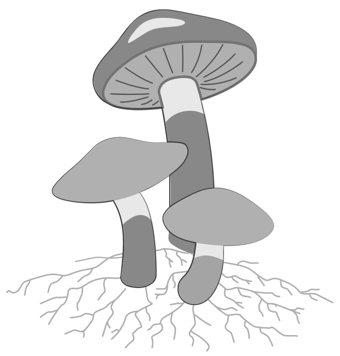
MINERAL RESOURCES



FOSSIL RESOURCES



DECOMPOSERS



HOW TO WIN

The first person to complete a row, column or diagonal (5 objects) wins. The first person to complete an object in each category wins.

I

T

E

M

S

RULES OF THE GAME

In turn, a game master draws a letter card and a resource card. The players mark an object that requires this resource in the column corresponding to the letter drawn. The game master puts the letter and the resource back into the pile, shuffles and passes to their neighbour who becomes the new game master.

BINGO GAME RULES

- → Get into groups of 5 students. Each person must have an ITEMS sheet in front of them. How to win? The first person to complete a line, column or diagonal (5 objects) wins!
- → Place a pile of ITEMS cards and a pile of RESOURCES cards in the middle of the table.
- → A student draws a card from each pile and places them face up to show the others. Players tick one of the objects that requires this resource to be manufactured or found in the column corresponding to the item.
- → Put the cards back in the pile. The next student shuffles each pile and draws a card from each again.

I	T	E	M	S
Apple	Aspirin	Ball	Antibiotics	Soda
Shoes	Brick	Tooth paste	Potting compost	Mushrooms
Hamburger	Building	Milk	Wooden house	Honey
Toilet paper	Wool jumper	Water	Dye for fabric	Television
T-shirt	Bike	Car	Wooden game	Stone house

ITEMS

Television	Wooden game	Brick	Building	Wooden house
Apple	Dye for fabric	Soda	Shoes	Bike
Wool jumper	T-shirt	Stone house	Hamburger	Ball
Tooth paste	Antibiotics	Wooden boat	Water	Honey
Potting compost	Car	Milk	Aspirin	Mushrooms

ITEMS

Wooden game	Soda	Building	Toilet paper	Milk
Stone house	Shoes	Wooden house	Car	Antibiotics
Honey	Tooth paste	Apple	T-shirt	Mushrooms
Water	Television	Aspirin	Hamburger	Wool jumper
Dye for fabric	Brick	Bike	Potting compost	Ball

I T E M S

Potting compost	Bike	Honey	Television	Milk
Building	Wooden game	Brick	Antibiotics	Tooth paste
Car	T-shirt	Mushrooms	Toilet paper	Water
Stone house	Dye for fabric	Aspirin	Wool jumper	Wooden house
Soda	Hamburger	Ball	Shoes	Apple

I T E M S

Apple	Brick	Shoes	Water	Aspirin
Wooden house	Ball	Stone house	Antibiotics	Bike
Dye for fabric	Mushrooms	Hamburger	Honey	Television
Soda	Potting compost	Tooth paste	Wool jumper	T-shirt
Building	Car	Wooden game	Toilet paper	Milk

HANDOUT A1.3 PAGE 1/2
HEALTHY SOILS FUNCTIONS AND ECOSYSTEM SERVICES

Direction
→ Review the list of soil functions below.
→ Place each soil function in the appropriate ecosystem service category.

Some may fit *more than one* — use your judgment and be ready to discuss!

Fig. 1: Adapted from FAO / Global Soil Partnership

HANDOUT A1.3 PAGE 2/2
HEALTHY SOILS FUNCTIONS AND ECOSYSTEM SERVICES

Soil Ecosystem Services

Provisioning services – What we get from soils	**Regulating Services –** Benefits from soils
Cultural services — Non-material benefits from nature that help us enjoy life such as recreational and spiritual benefits.	**Supporting Services –** Necessary for the production of all other ecosystem services

LESSON A2 WHAT ARE SOILS, AND HOW DO THEY FORM?

MAIN SUBJECTS	DURATION	AGE GROUP	TEACHING METHOD
Chemistry, Geography, Natural Sciences	2 class periods of 1h	9-15 years old	Observations, Serious Game

OVERVIEW
This lesson explores soil as a vital and complex layer of the Earth's surface. Students will examine soil horizons, which are the vertical layers that range from surface organic matter to bedrock. Through a board game, they will learn how soil forms over time through weathering and decomposition, and how these processes lead to the creation of distinct soil layers.

GREENCOMP COMPETENCES
Systems Thinking

LEARNING OUTCOMES
By the end of the lesson, students will be able to:

- Identify each soil horizon or layer
- Reconstruct the soil profile typical of their region
- Model the process of soil formation from initial bedrock weathering to a mature soil profile

KEY CONCEPTS
Bedrock, Decomposition, Organic Matter, Soil Formation, Soil Layers, Soil Horizon

Background for teachers

SOIL STRUCTURE
Soil is the thin layer covering the Earth's surface that results from the interaction of rocks, water, air, and living organisms. Soil is essential for plant growth, nutrient cycling, and water regulation.

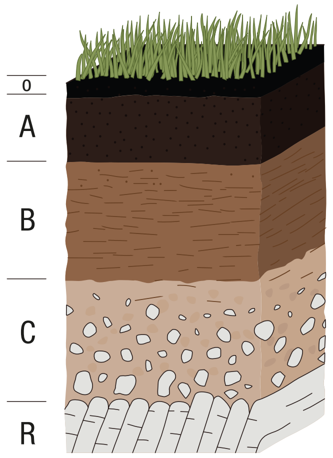


Fig. 1. Example of a Soil Profile Showing the Main Horizon

A soil profile is typically structured into layers called **horizons:**

- **Horizon 0** – The organic horizon, at the surface, consists mainly of plant debris and decomposed material.
- **Horizon A** – The topsoil contains a mixture of mineral particles (sand, silt and clay) and organic matter (humus). It is the most fertile layer for plant roots.
- **Horizon B** – The subsoil lies beneath and is characterised by the accumulation of minerals, such as clay, iron, and aluminium, leached from the upper layers.
- **Horizon C** – The parent materiel, is made of weathered rock fragments, which influence the soil's mineral composition.
- **Horizon R** – The lowest layer is the unweathere

Soils vary considerably across the world depending on climate, parent material, vegetation, and time.
Tropical soils often show nutrient depletion because heavy rainfall washes nutrients away, leaving the soil rich in iron and aluminium but low in fertility.
Temperate soils usually contain higher levels of organic matter and are more fertile. Arid soils are dry, low in organic matter, and prone to salt accumulation, while soils in cold regions are generally thin and slow-forming, with limited biological activity.

SOIL FORMATION
Soil formation begins with rock weathering, followed by the accumulation and decomposition of organic material. Water movement through the developing soil (leaching) transports materials downward, creating distinct horizons. Biological activity from roots and organisms mixes and aerates these layers. **The entire process requires centuries to millennia** and is influenced by parent material, climate, organisms, topography, and time.

Regional soil formation reflects local conditions.

Tropical areas develop iron-rich, nutrient-poor laterites due to intense weathering.
Temperate regions form fertile soils with thick organic layers ideal for agriculture.
Arid regions produce thin, sandy soils with little organic matter.
Polar regions develop shallow soils with permafrost where decomposition occurs slowly, and peat accumulates.

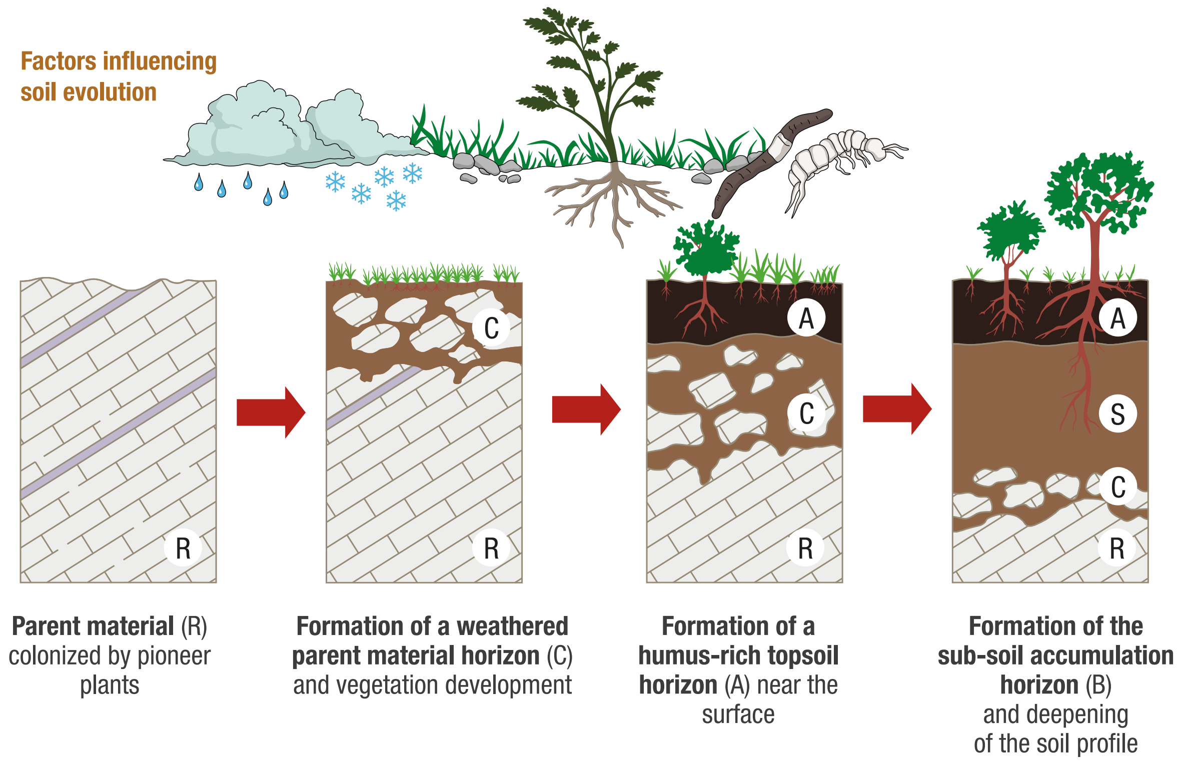


Fig.2 The Chronological Stages of Soil Formation and Horizon Differentiation

PREPARATION 1H

MATERIALS

- Pictures of cross sections of typical soils of your local area
- Samples of bedrock, accumulation layers… representing components of each layer of your selected local soil
- Print one **HANDOUT A2.1 - SET OF SOIL HORIZONS CARDS** per group of students
- Print one board game set per group of students **- HANDOUTS A2.2, A2.3, A2.4, A2.5, A2.6**

SUPPLEMENTARY MATERIAL

- **What Are Soils and How Do Soils Form? Giulia Bongiorno,** Researcher specialized in soils
- OCE's soil macrofauna identification key
- European Soil Atlas and world soil museum

INTRODUCTION 15 MIN

WARM UP 15 MIN

1. Start by asking students what soil is.
   What do we find in soil? Will it look the same if you keep digging?

   Have them draw their initial conception of what a soil is and how it is structured. Ask them to label this first drawing as "my initial representation of soil".

2. Then explain the objectives of this lesson:
   You'll learn about soils and how they form. First, we'll examine soil samples to identify the different layers and understand what soil in our region looks like. Then, we'll explore how soil develops over time.

PROCEDURE 1H30

PART 1 - SOIL ORGANISATION 45 MIN

3. Initial observation of an example of a cross-section of local soil.
Show selected pictures of cross-sections of soils typical of your area, such as the ones shown below.

Image 1 : Brown forest soil on a granite massif (Belin, Seconde, 2020)

Image 2 : Soil-croiss section in Morbihan (France) with a granite substratum. Picture by C. Walter.

Have students individually draw in their notebook what they notice about the soil cross-section sample. They should notice colour variations, rock fragments, roots, and the layered structure of soil. Instruct them to label the drawing as "representation of cross-section of soil at [indicate the location]".

TEACHER TIPS

Consider an outdoor class at a nearby forest where students can observe a soil cross-section. This can be a standalone activity (see other OCE lessons: The Soil Is A Major Resource and Forests, Humans And Climate Change). Discuss with students why observing forest soil, rather than agricultural land, allows examination of soil relatively untouched by human activity.

4. Matching exercise
Inform the students that they will work in groups to learn about the different layers of a soil profile. Divide the class into five groups, and distribute the mixed-up set of cards from **HANDOUT A2.1 - SOIL HORIZONS CARDS,** to each group. Have the students collaborate to match each soil horizon with its corresponding description. As a whole class, check for the correct match and discuss the order of the soil layers. Explain that scientists name these layers **"horizons"**. From top to bottom, these layers are:

- the soil **litter "O"** : organic matter-rich, composed of dead organisms such as dead fallen leaves and dead animals, as well as living organisms (e.g. earthworms, larvae, fungi) and refugee animals that inhabit the soil (e.g. reptiles, beetles, spiders)
- the **humus-rich topsoil "A"** with a lot of organic matter and some mineral elements,
- the **accumulation layer "B"** influenced by the leaching of the above layer
- the layer with **unconsolidated parent material "C"** (e.g. rock fragments)
- the **parent material "R"** (e.g. unweathered bedrock).

5. Observation of material representing soil horizons.
Station each original group at a different soil horizon display. Have each group identify and study their assigned soil horizon. The example of soil horizon displays below descriptions of soil samples representing each soil horizon for a typical temperate soil forest, which can be adapted to your soil sample from your local area.

6. Jigsaw peer learning
Redistribute students to form new groups of five, with one member from each original group. In these new groups, students will teach each other about the horizon they studied. They should be able to reconstruct the soil profile with the correct order of horizons.

7. Wrap-up of part 1
Direct students to revisit their soil cross-section drawings and label each layer with the correct horizon name (O, A, B, C, R). Ask them to write their definition of soil in their notebooks. Facilitate a class discussion to develop a consensus **definition of soil** and record it on the board. Conclude by having volunteers share their ideas on soil formation processes, highlighting key factors such as weathering, organic decomposition, and time.

DISPLAY 1

Samples or pictures of decomposing leaves/plants. Dead animal organisms obtained from a Berlese experiment, or photos highlighting macro- and micro-organisms found in soils (e.g., woodlouse, spiders, earthworms, mites, beetles). A very simplified identification key, such as the OCE soil fauna interactive identification key can be used to help students identify the organisms.

DISPLAY 2

Sample of topsoil containing a fraction of humus associated with a short description, or questions to come up with a description of what it is (depends on your students' level) Example of description for a typical temperate forest topsoil:

> *It is soft and crumbly, with a dark brown to black colour (depending on the organic matter content, ranging from relatively light to dark brown). If you moisten it, it will probably have an earthy, mushroom-like odour. You can not see them, but some bacteria and fungi are present. It is mainly composed of humic acid and humin, which result from the decomposition of soil organic matter by decomposers. Some mineral particles are a mixture of sand, silt, and clay.*

Potential questions: How does it look (texture, colour, etc.)? If you moisten it, how does it smell?

DISPLAY 3

Sample from the accumulation layer (or equivalent) containing:

- Mineral material such as clay (provide the students with a very simple identification key for them to identify the clay material).
- Some materials contain iron oxide (easily identifiable by its reddish colour), or other elements such as aluminium oxide (yellowish colour) or calcium carbonate (whitish/grey colour).

Potential questions: How does it look (texture, colour, etc.)? If you compare the colour with the layers above, what do you think the organic matter content is?

DISPLAY 4

Samples of altered parent material. It could be rock fragments, from dust to larger ones. Showing weathering attributes.

Either a short description of what it is or questions to come up with a short description of what it is (depends on your students' level) Example of description for an altered parent material:

> *Crumbly rock that may have rounded edges (originally harder). Some original minerals are replaced by new ones (clay formation). Quartz, which is resistant to weathering, can still be observed. Through the weathering of original minerals, iron oxides appear and contribute to reddish, yellowish, or brownish colours.*

Potential questions: How does it look (texture, colour, structure, etc.)? Can you recognise some elements that are also present in another layer? Where do you think these rock fragments come from?

TEACHER TIPS: There might not be any rocks. The main thing here is that it is composed of minerals, without any organic matter.

DISPLAY 5

Samples of parent material. (e.g., bedrock such as granite).

Students have a simplified identification key to identify the rock. Identification relies solely on the rock's general colour, the colour of key minerals, and its overall appearance. The most important thing here is for them to observe that this rock shows similarities to the rock fragments from Display 4, but is unaltered. They have to come up with the idea that rock fragments from the Display 4 result from the weathering of the Display 5 rock.

TEACHER TIPS: To help students, you can indicate that this element is found at the bottom of the soil profile. Digging down to parent material might be difficult; in that case, use an equivalent material you can more easily find.

PART 2 - SOIL FORMATION 45 MIN

8. Introduction to the next activity

After learning how soils are organised, inform students that they will explore through a serious game the different processes and actors that slowly shape soils over time. It is a cooperative game in which they have to reconstruct the soil-forming process. The starting point is the bedrock, and from there, they will identify the steps needed to reach mature soil.

9. Warming up for the serious game

Distribute one board game to each group with the different soil formation steps, "ACTORS" cards, "DRAWINGS" cards, "STEPS" cards, "PENALTY" cards, and the rules of the serious game **(HANDOUTS A2.2, A2.3, A2.4, A2.5).**

Have one of the students from the group read the rules. Ask students clarifying questions to ensure everyone is clear on the objectives, the role of each card type, and how to play this serious game.

10. When the game is over (i.e., when every group of students has completed the soil-formation board game), ask one group to present their findings as a collective recap for the whole class. The complete board game should look like this.

TEACHER TIPS

You can introduce a bit of competition between the different teams. The winner would be the team with the most effective reconstitution of soil formation and the fewest sick earthworms. Depending on your students, you can choose to include or exclude this competitive aspect (it could be challenging for some students but also uncomfortable for others).

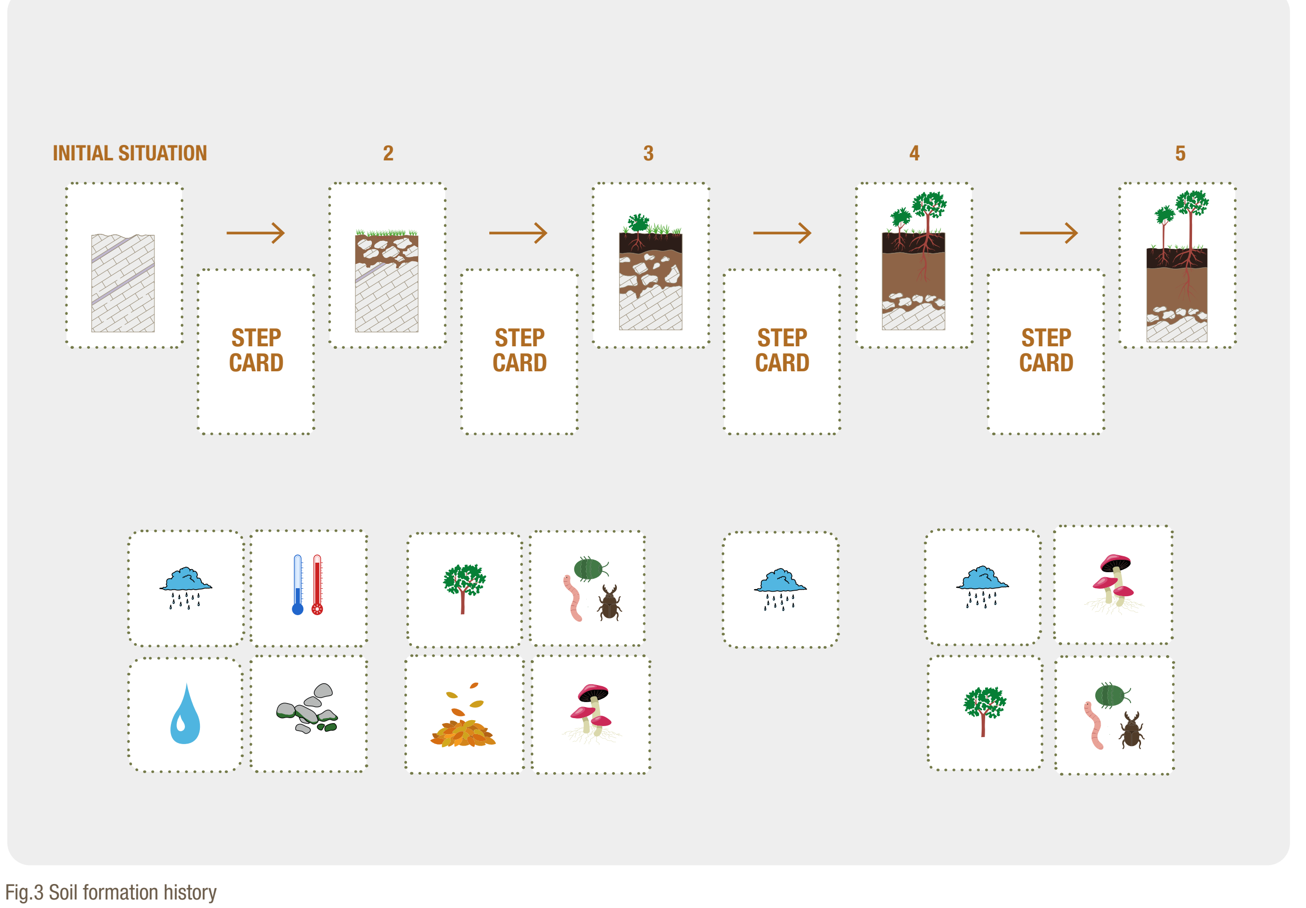


Fig.3 Soil formation history

11.Wrap up for part 2

Have students write a summary of the soil formation process in their notebooks. In addition, you may use these suggested questions as a post-game reflection:

- *What surprised you most about the sequence of soil formation?*
- *Which step in the soil formation process did you find most difficult to place correctly? Why?*
- *How has your understanding of soil development changed after playing this game?*
- *What connections did you notice between the different actors involved in soil formation?*
- *Which actors in the soil formation process seemed most crucial? Could you rank them in order of importance?*
- *What timeframes are involved in natural soil formation? How does this compare to soil degradation?*
- *How might this soil formation process differ in different biomes or climate regions?*

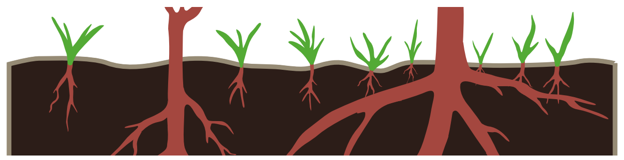
WRAP UP 5 MIN

Through this lesson, students discovered that soil is organised into distinct layers called horizons, each with its own unique composition and thickness. They learned that these horizons don't simply appear as stacked deposits but develop gradually through complex natural processes. The class came to understand that soil formation takes an extremely long time—often centuries or even thousands of years—to complete. When soil is damaged, it cannot quickly recover within a human lifetime.
This is why soil is considered as a **non-renewable resource** from our human perspective, highlighting the importance of protecting this valuable natural asset.

HANDOUT A2.1 PAGE 1/2

SOIL HORIZONS CARDS

Front cards / Back cards



Layer composed of dead organisms, such as fallen leaves or dead animals, as well as living organisms such as earthworms, fungi, spiders, and beetles.
→ LITTER LAYER

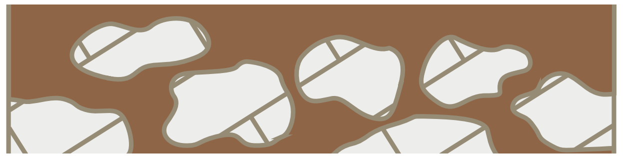
Layer composed of mineral matter and organic matter from the decomposition of plants and animals through the action of decomposers (i.e. earthworms, fungi).
→ TOPSOIL (including HUMUS LAYER)

Layer is usually lighter than the others because of its lower organic matter content. The colour can vary depending on the mineral content (e.g. a reddish tint may indicate the accumulation of iron oxide). The clay content is also higher than in the topsoil horizon.
→ ACCUMULATION LAYER

HANDOUT A2.1 PAGE 2/2

SOIL HORIZONS CARDS

Front cards / Back cards

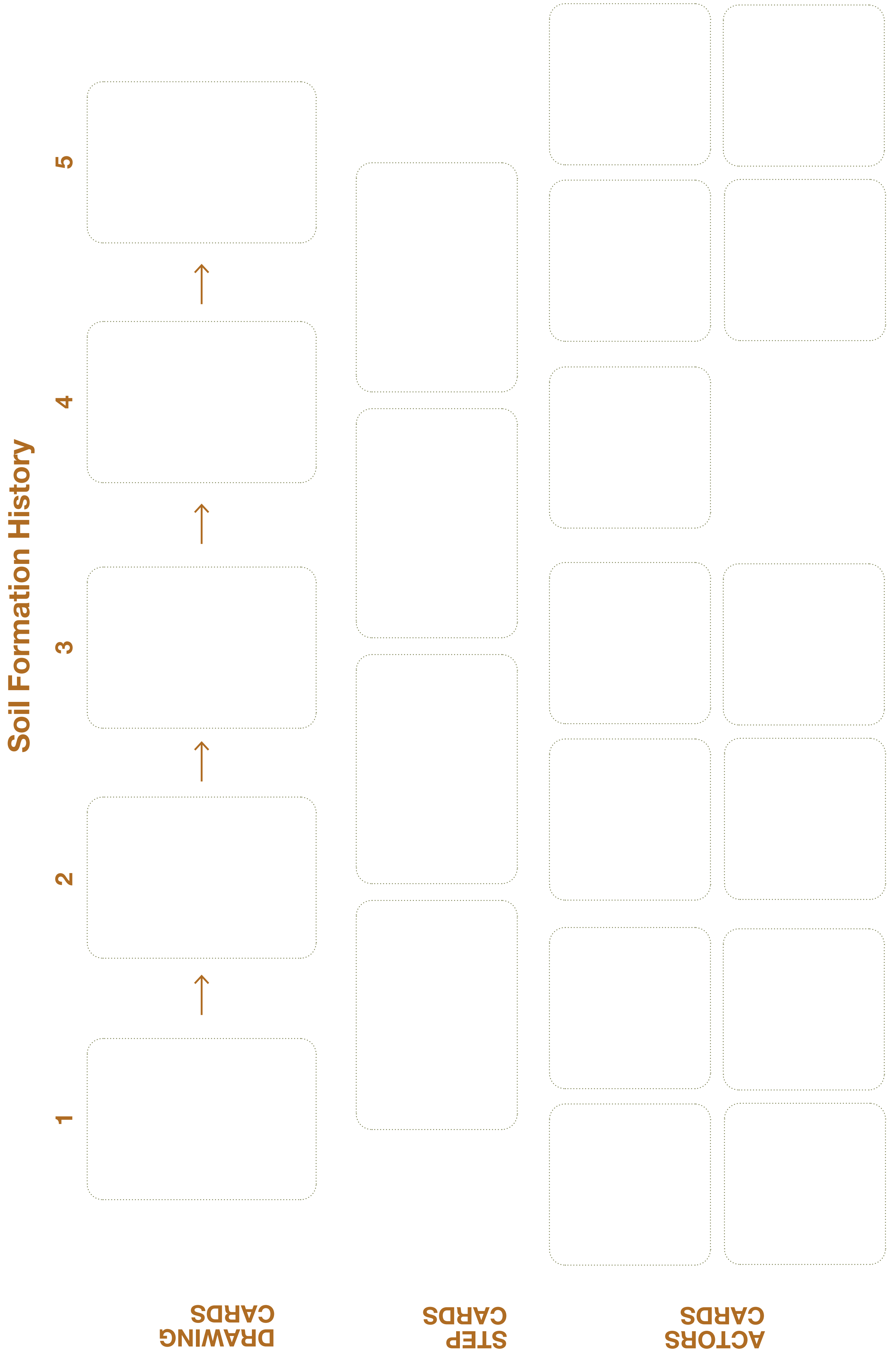


Layer composed of altered parent material (e.g. rock fragments) and mineral particles resulting from the weathering of the initial bedrock.
→ WEATHERED PARENT MATERIAL

Layer composed of the unaltered initial parent material (e.g., a granite).
→ PARENT MATERIAL (e.g. BEDROCK)

HANDOUT A2.2 PAGE 1/1

SOIL FORMATION BOARD GAME (TO PRINT IN A3)

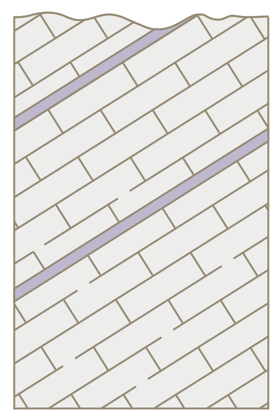


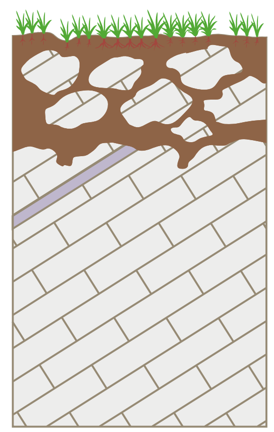
HANDOUT A2.3 PAGE 1/4

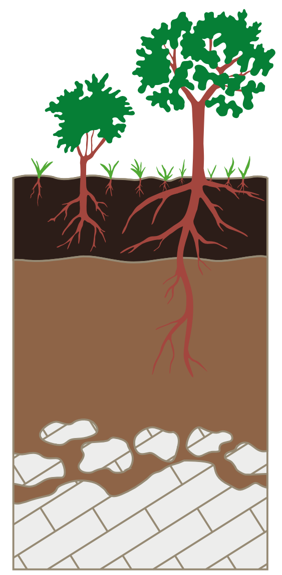
FORMATION BOARD GAME

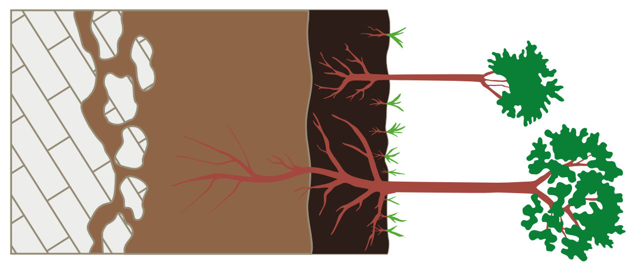
DRAWING cards The different states of the soil profile during the formation of the soil

INITIAL SITUATION







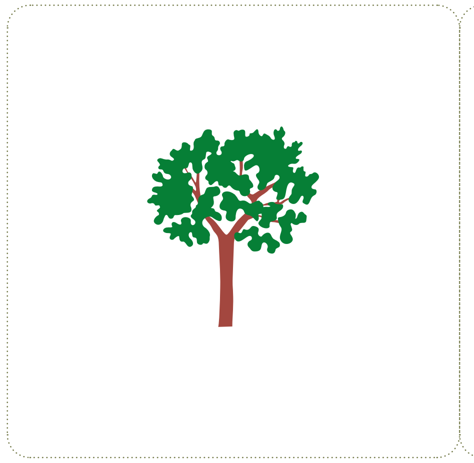
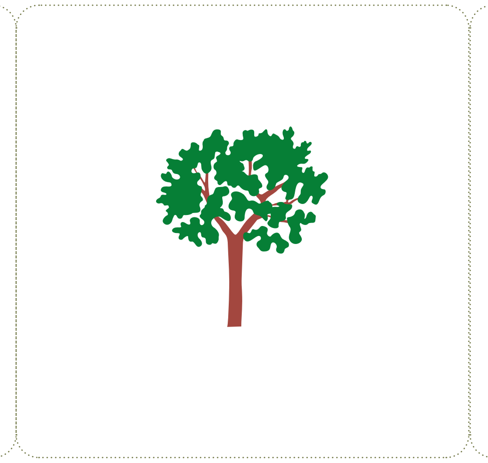
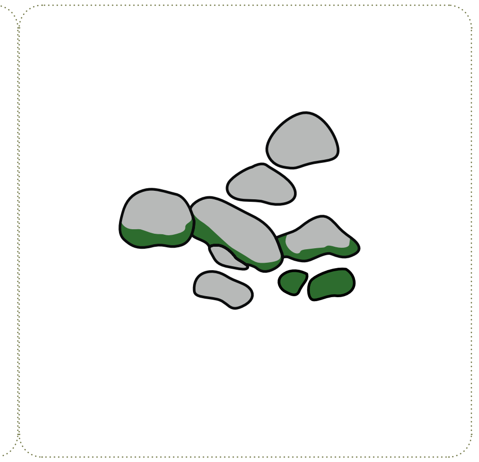


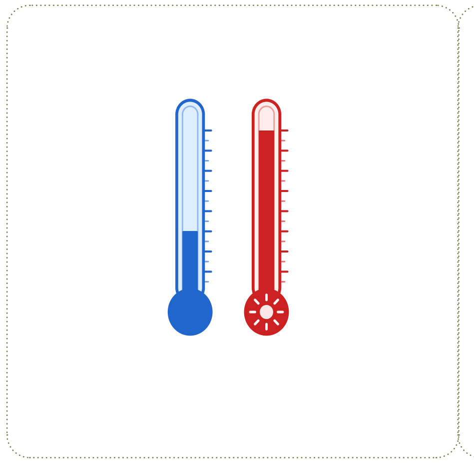
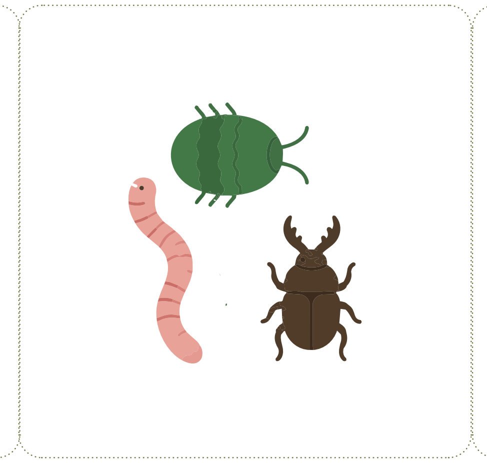
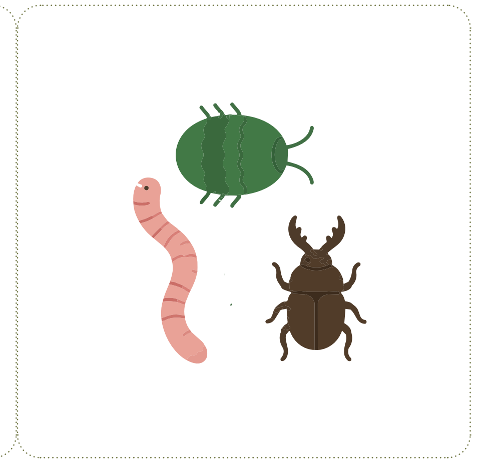
ACTORS cards

The different actors involved in the different steps of soil formation:

- → Precipitation
- → Pioneer vegetation (e.g., lichens, mosses)
- → Vegetation
- → Temperature changes
- → Rock dissolution and/or hydrolysis (i.e, chemical weathering of rock)
- → Living organisms (animals or plants)
- → Dead organisms (animals or plants)
- → Decomposers (e.g., earthworms, fungi, bacteria)





HANDOUT A2.3 PAGE 4/4
FORMATION BOARD GAME

PENALTY cards

Represented by sick earthworms, they are distributed when players realise they have made a mistake and want to exchange cards.

HANDOUT A2.4 PAGE 1/1
SOIL FORMATION BOARD GAME- MIDDLE SCHOOL VERSION

WEATHERING OF PARENT MATERIAL (E.G. BEDROCK)

→ **What happens:** Rocks at the Earth's surface are broken down into smaller particles through physical (temperature changes, freeze–thaw cycles, abrasion), chemical (dissolution, oxidation, hydrolysis), and biological processes (roots or lichens breaking rock).

→ **Result:** Formation of weathered parent material and fragments of rocks/mineral particles (loose, unconsolidated material) from solid rock.

Actors: precipitation, temperature changes, dissolution/hydrolysis, action of pioneer vegetation (mosses or lichens, vegetation roots).

STEP: Parent material to STEP: weathered parent material with pioneer vegetation and unconsolidated material above the parent material (bedrock).

ACCUMULATION OF ORGANIC MATERIAL AND HUMUS HORIZON FORMATION

→ **What happens:** Plants, microorganisms, and animals colonise the environment and add organic matter as they live and die. Dead plant leaves, roots, and animal remains begin to decompose.

→ **Result:** Formation of the topsoil with humus, which mixes with mineral particles and increases fertility. Clay-humus complex formation (middle school students- experts).

Actors: living and dead vegetation and animals, decomposers.

STEP: weathered parent material to STEP: topsoil humus-rich horizon (and CHC) formation and organic matter accumulation. Humus-rich topsoil forms, enriched with organic nutrients and mineral matter.

LEACHING (ELUVIATION) PROCESS AND HORIZON FORMATION

→ **What happens:** Rainwater percolates through the upper layers, dissolving and carrying soluble minerals (such as calcium, potassium, and iron) and clay particles downward. The leached materials are redeposited in deeper layers. Some horizons lose materials (eluviation), while deeper horizons gain them (illuviation).

→ **Result:** The upper layer loses material (eluviation). This creates lighter-colored, nutrient-depleted layers. The deeper layer becomes enriched (illuviation) with clay, iron, aluminium, and organic matter washed down from above. This creates a zone of horizon gain or an accumulation layer.

Actors: precipitation

STEP: humus-rich topsoil formation to STEP: horizon formation

FURTHER MIXING, SOIL FORMATION CONTINUES

→ **What happens:** Earthworms, insects, fungi, and bacteria continuously mix organic and mineral components, aerate the soil, and decompose organic matter. Over long periods, processes like leaching, mineral movement, and root activity separate the soil into distinct layers and horizons become well-defined. All these processes stabilise over time.

→ **Result:** Enhanced nutrient cycling. Soil structure, horizons, fertility, and water-holding capacity become well-defined. A mature soil profile capable of sustaining ecosystems.
O horizon: Organic litter
A horizon: Dark, humus-rich topsoil
E horizon: Leached, pale layer (not always present)
B horizon: Zone of accumulation
C horizon: Weathered parent material
R horizon: Parent material (e.g. bedrock)

Actors: precipitation, living animal and vegetal organisms, decomposers.

STEP: horizon formation to STEP: soil structuration and maturation

HANDOUT A2.5 PAGE 1/1

SOIL FORMATION BOARD GAME - PRIMARY SCHOOL VERSION

STEPS cards

The processes occurring during soil formation and the resulting outcomes.

TRANSFORMATION OF PARENT MATERIAL

The story of soil formation starts with the transformation of healthy rocks at the Earth's surface into smaller particles. The result of this transformation is the formation of a layer composed of damaged material.

Different actors are involved: precipitation, temperature changes, chemical reactions, vegetation (mosses or lichens, vegetation roots).

STEP: Parent material to STEP: damaged parent material with some vegetation on top of it.

INCREASE OF ORGANIC MATERIAL CONTENT

The soil formation continues. Plants, microorganisms, animals, colonize the environment and participate in the formation of another layer rich in dark organic matter and mineral particles.

Different actors are involved: living and dead vegetation and animals, decomposers.

STEP: Damaged parent material to STEP: organic matter-rich horizon formation.

ACCUMULATION OF ELEMENTS IN DEEPER HORIZONS

Precipitation water brings along some elements from the upper layer to be redeposited in deeper layers. Some horizons lose material, while deeper horizons gain them.

Actors involved: precipitation

STEP: organic matter-rich horizon formation to STEP: new horizon formation.

SOIL FORMATION GOES ON

The story of soil formation continues over long periods of time. Earthworms, insects, fungi, and bacteria continuously mix organic and mineral components, aerate the soil, and decompose organic matter. The soil is separated into distinct layers and horizons become well-defined. We obtain a mature soil profile capable of sustaining ecosystems.

Actors involved: precipitation, living animal and vegetal organisms, decomposers.

STEP: horizon formation to STEP: soil maturation.

HANDOUT A2.6 PAGE 1/1

SOIL FORMATION BOARD GAME - BOARD GAME RULES

Rules

You are a team of 4 players working together to recreate the history of soil formation on a board game that starts empty. Your goal is to place cards in the correct sequence with as few mistakes as possible.

Setup

→ Place all **Actor cards** face up beside the board, where everyone can see them
→ Place all **Drawing cards** face up beside the board, where everyone can see them
→ Distribute the **Step cards** evenly among players (each player receives 1-2 cards depending on team size)
→ The Drawing card #1 "Initial situation" is already placed on the board to start

Basic Turn Structure

1. Each player reads their own Step card(s) silently
2. The first player (e.g., youngest) reads their Step card aloud to the group
3. The group discusses whether this card should be the next in the soil formation sequence
4. Together, decide whether to place the card ("Yes") or not ("No")

If "Yes" (Card is Accepted)

1. The player places their Step card on the board after the previous card
2. As a group, select and place:
   → The appropriate Actor cards involved in this step
   → The corresponding Drawing card that illustrates this step
3. Play continues to the next player clockwise

If "No" (Card is Rejected)

1. The player keeps their card for a future round
2. Play continues to the next player clockwise

Error Correction

→ If you realise a card was placed incorrectly in a previous round, you may replace it
→ Each correction results in receiving a "sick earthworm" penalty card
→ Your goal is to complete the sequence with as few penalty cards as possible

End of Game

The game ends when all cards are correctly placed on the board, showing the complete soil formation history. At this point:
→ All Step cards are on the board in sequence
→ All Actor cards are placed in their correct positions
→ Players have no cards remaining in hand

LESSON A3 WHAT ARE THE SOIL PROPERTIES?

MAIN SUBJECTS	DURATION	AGE GROUP	TEACHING METHOD
Chemistry, Natural Sciences	3 class periods of 1h	9-15 years old	Experiment

OVERVIEW

Students investigate the key properties that allow soils to support ecosystems. They will examine soil as a three-phase system comprising solid minerals and organic matter, liquid water, and gas, and how this structure supports life. Through decantation experiments, they will identify soil textures based on the relative proportions of clay, silt, and sand, and study the clay-humus complex that helps retain water and nutrients.

GREENCOMP COMPETENCES

Systems Thinking

LEARNING OUTCOMES

By the end of the lesson, students will be able to:

- Explain that soil texture and structure determine the soil's capacity to support life
- Identify soil texture type using the decantation technique and the soil texture identification triangle
- Explain the role of the clay-humus complex in retaining water and nutrients through electrical charges

KEY CONCEPTS

Nutrient Retention Capacity, Soil Health, Soil Structure, Soil Texture, Soil Water

Background for teachers

SOIL STRUCTURE

Soil structure describes how soil particles combine into aggregates, or clumps, through electrical charges on the surfaces of minerals and organic matter. These aggregates vary in size and shape, from crumbs to blocks.

Healthy soil structure enables water movement and air circulation, providing plants with the balance of soil, air, water, and nutrients they need to grow.

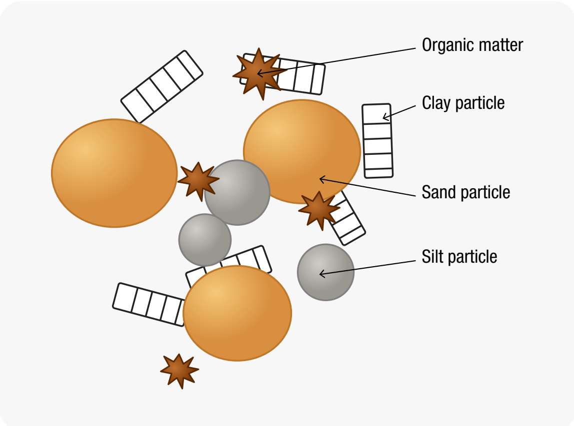


Fig 1. How soil particles may be arranged.

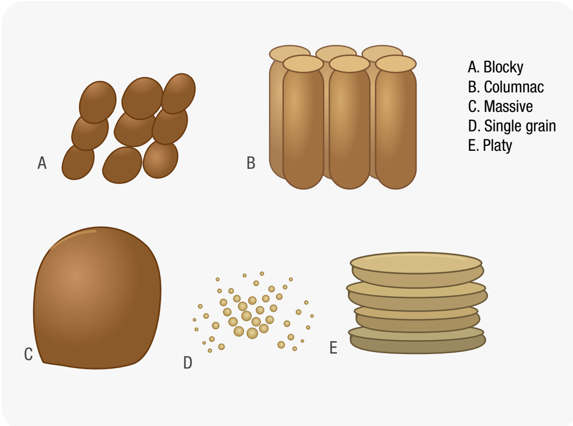


Fig 2. Examples of different types of soil structure.

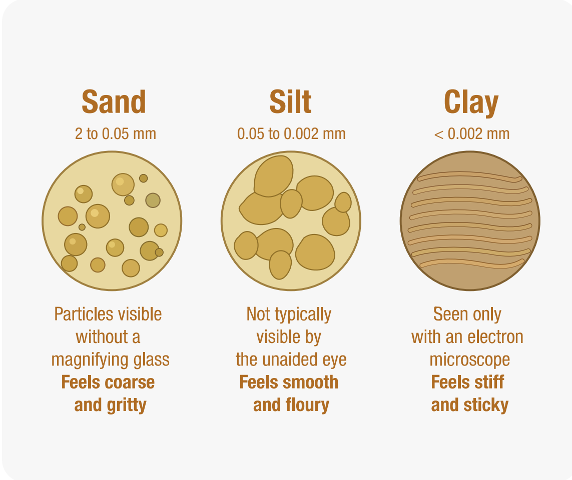


Fig. 3. Soil Particle Size Classes: Sand, Silt and Clay

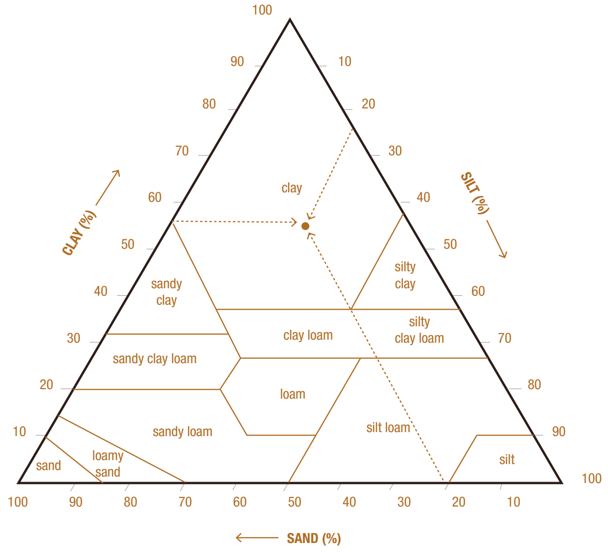


Fig. 4. Soil Texture Triangle Showing the 12 Textural Classes

SOIL TEXTURE

Soil texture refers to the proportions of sand (2.0 – 0.05 mm in diameter), silt (0.05 – 0.002 mm), and clay (less than 0.002 mm). When sand dominates, the texture is coarse; when silt or clay dominates, the texture is medium or fine.

Soils with similar distributions of sand, silt, and clay have similar properties and are therefore grouped into the same soil textural class. Twelve textural classes are recognised, and their compositions are designated on a textural triangle. Each corner of the triangle represents 100% of either sand, silt, or clay, and each represents 0 to 100% of a given fraction. The proportions of sand, silt, and clay define the twelve classes. Figure 4 depicts a soil with 20% sand, 25% silt, and 55% clay. Those three lines intersect within the boundaries of the "Clay" textural class, so the soil is a clay soil.

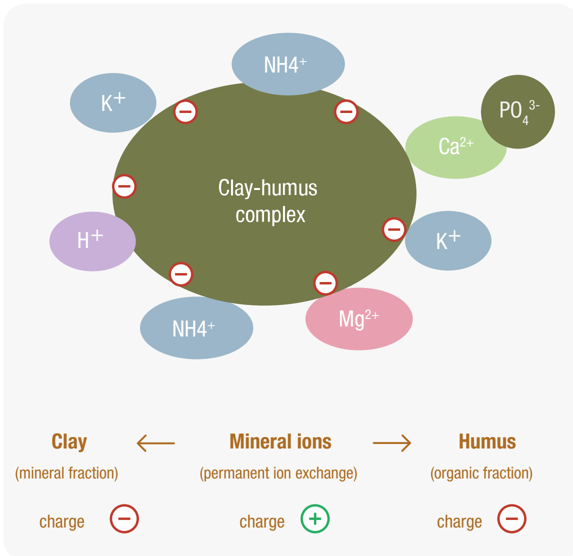


Fig. 5. The Clay-Humus Complex (CHC) and Cation Exchange Capacity (CEC)

Parent material, climate, topography, and vegetation influence soil texture, which serves as a key indicator of soil condition. Soil texture significantly affects water retention, plant-available water, nutrient-holding capacity, and root penetration. Additionally, texture influences soil workability and resilience to structural damage. For instance, clay-rich soils are more susceptible to compaction when organic matter content is low.

CLAY HUMUS COMPLEX (CHC) OR CATION EXCHANGE CAPACITY (CEC)

Cation Exchange Capacity (CEC) comes from the Clay Humus Complex (CHC), formed when clay and humus (decomposed organic matter) combine. CEC measures how well soil holds nutrients and water for plants.

Positively charged ions or cations such as potassium (K+), magnesium (Mg++), calcium (Ca++), ammonium (NH4+), and sodium (Na+) bridge clay and humus, forming a stable complex, the clay humus complex.

This complex is central to soil fertility. It retains water and nutrients, improves soil structure, and protects against erosion and nutrient loss, supporting healthy roots and soil life.

Clay soils have higher CEC because clay binds nutrients well, while sandy soils rely on organic matter for nutrient retention.

PREPARATION 1H

MATERIALS

- Soil samples, at least 500g per group of students
- 4-5 already decanted soil samples (see protocol on **HANDOUT A3.1**; prepare at least 24h before the day planned for experiment 2)
- **HANDOUTS A3.1, A3.2, A3.3** printed for groups of students
- Lab material as listed in the handouts

SUPPLEMENTARY MATERIAL

- Video "Understanding Soil Cation-exchange Capacity"
- Video "Identifying Soil Structure with the Texture Triangle"
- Video "Measuring Soil Air Content"
- Series of experts videos made by the OCE for the SoilTribes project
- Video "Revealing Soil Composition Using Decantation"

INTRODUCTION

WARM UP 10 MIN

1. Ask the students to recall what they learned from the previous lessons (see lesson A1).

2. Prompt with:

> *What plants need from the soil to grow?*

Guide students towards water from the soil nutrients, such as mineral ions (e.g., calcium, magnesium, potassium).

3. Announce the learning outcomes and ensure students understand them before proceeding.

> *First, we'll examine soil samples to identify the different layers and understand what soil in our region looks like. Then, we'll explore how soil develops over time.*

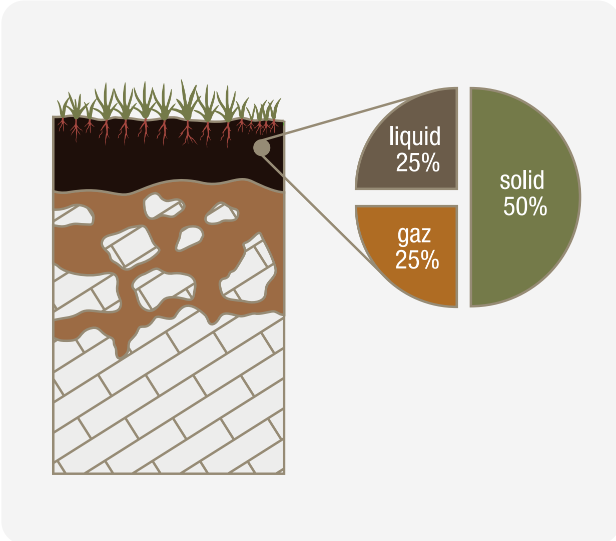


Fig. 6. The Three Phases of Soil: Solid, Liquid, and Gas.

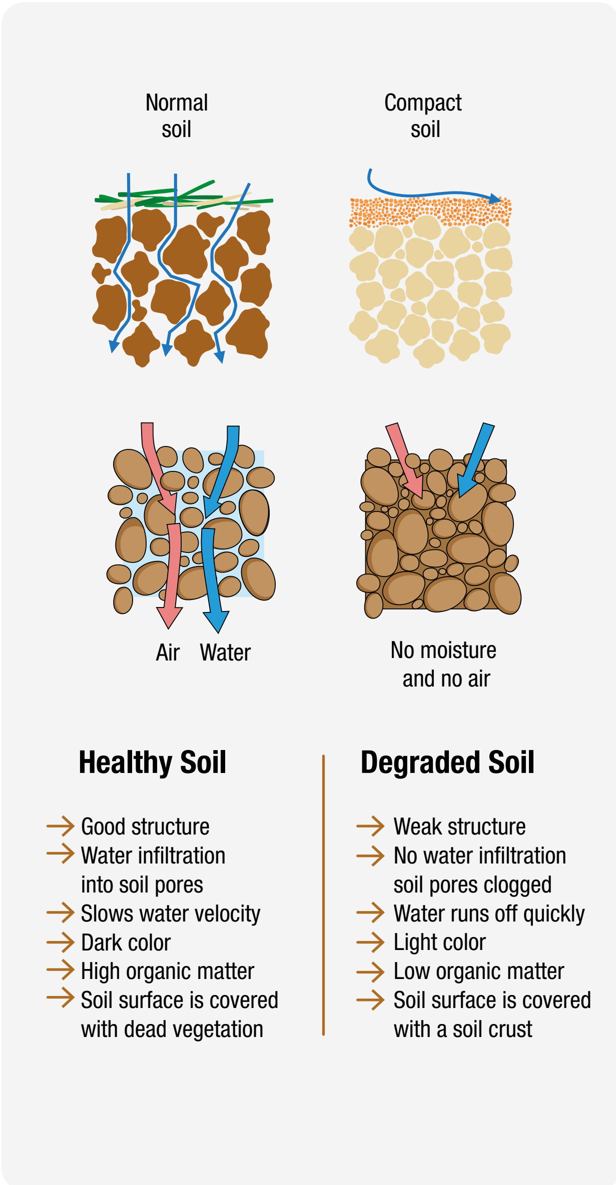


Fig. 7. Comparison of Water Infiltration in Healthy and Compacted Soil Structures.

PROCEDURE 1H30

EXPERIMENT 1 - INVESTIGATING SOIL SOLID, LIQUID AND GAS COMPONENTS 45 MIN

4. Begin with observations and hypothesis formation. Have students examine the soil samples at their stations and review the three states of matter (solid, liquid, gas). Ask students to predict how much liquid and gas their soil sample contains. Explain the materials and experimental protocols, then distribute **HANDOUT A3.1** to each group.

5. Guide students to record both qualitative observations and quantitative measurements of the soil's solid, liquid, and gas components in their notebooks.

6. During the wrap-up discussion, ask students if they were surprised by the quantities of air and water in their soil samples. Prompt critical thinking by asking:

> *What would happen to plants if soil becomes compacted, reducing space for air and water?*

7. Explain that soil consists of three main components:

- The solid phase (approximately 50% by volume): mineral grains, rock fragments, and organic matter
- The liquid phase (approximately 25%): primarily water containing dissolved salts
- The gaseous phase (approximately 25%): air

Ask students whether they came up with a similar ratio for their soil sample.

Explain that the soil structure results from the aggregation of solid components and spaces for air and liquid. Emphasise that healthy soil structure facilitates water movement and air circulation, providing plants with the optimal balance of physical support, oxygen, moisture, and nutrients necessary for growth.

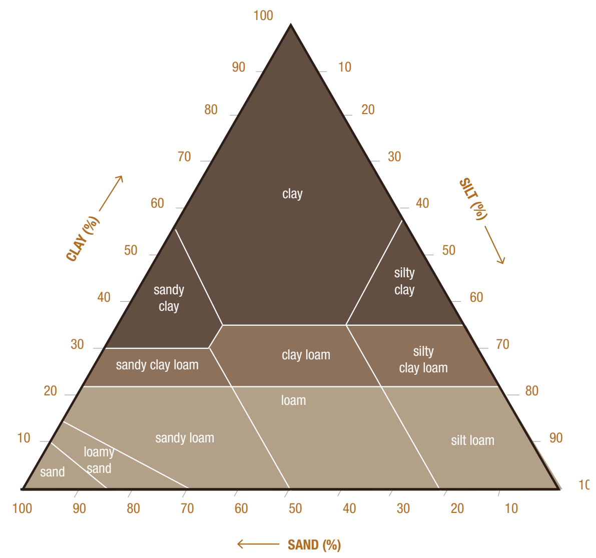


Fig 8. Texture Triangle

EXPERIMENT 2 - INVESTIGATING SOIL TEXTURE TYPE 1 H

8. Introduce this second set of experiments. Explain that soil is composed of different mineral particles that vary in size and that we will use **decantation** to separate these components based on their relative density. When soil is mixed with water and then allowed to settle, the heaviest particles **(sand)** sink first and form the bottom layer. Medium-sized particles **(silt)** settle next, creating a middle layer. The finest particles **(clay)** remain suspended longer and eventually form the top layer. Organic matter may float on the surface or form a distinct layer.

TEACHER TIPS

You can watch our tutorial video for this experiment to guide you through the methodology, or you can also find an online calculator if you wish to avoid printing the texture triangle. You just have to enter the percentages. See this one for example: https://www.landis.org.uk/services/tools.cfm where you just have to enter the percentages.

9. Before dividing into groups and distributing **HANDOUT A3.2**, clarify with students the objective of the activity: to identify the soil texture or relative proportion of sand, slit and clay and deduce the potential environment where the sample was collected. They will accomplish this by:

- Calculating the proportions of clay, silt, and sand in their sample after decantation
- Using the soil texture triangle diagram to classify their soil type based on these proportions.

TEACHER TIPS

You can choose two very different soil types: one from a cultivated field (sample A) and one from a forest (sample B). After determining the texture, students will try to associate each soil texture with an environment (a cultivated field or a forest). Depending on the time you have and your students' level, you can choose to include more than two soil types and/or give each group more than one soil sample to identify. The class can also engage in a statistical activity, comparing the proportions students found for the same soil sample and the textures they identified. This will help them strengthen their transversal skills.

10. Wrap up for experiment 2
Once the soil texture is determined, ask students to reflect on the possible consequences of different soil textures (e.g., water infiltration, vegetation growth).

Fig. 9. Results of the Methylene Blue and Eosin Experiment Showing Soil Cation Retention

EXPERIMENT 3 - INVESTIGATING A SOIL'S CAPACITY TO RETAIN CHARGED PARTICLES 45 MIN

11. Introduce the experiment and protocol, then divide students into groups and provide them with **HANDOUT A3.3.**

12. Remind students to draw a schematic representation of the experiment and record their observations in their notebooks.

13. Once all groups have completed their experiments, lead a class discussion to help students interpret their results. Share with students the expected results below.

- Eosin experiment: The eosin solution is negatively charged. After passing through the soil sample in the funnel, the eosin solution that comes out has the same colour (reddish) as the one in the control tube without soil. This means that the soil sample did not retain the eosin solution.
- Methylene-blue experiment: The methylene blue solution is positively charged. After passing through the soil sample in the funnel, the methylene blue solution that comes out is colourless, unlike the control tube. This means that the soil sample has the capacity to retain positively charged molecules. This is because soil elements are negatively charged and can bind to the methylene blue. This phenomenon can be attributed to the clay-humus complex (CHC) present in the soil.

14. Wrap up for experiment 3
In soil, the negatively charged clay-humus complex is crucial for retaining positively charged nutrients such as potassium andcalcium that plants use to grow.

WRAP UP 15 MIN

Ask students to write 2-3 sentences that connect these key concepts: soil structure, soil texture, water and air circulation, water and nutrient retention, and plant growth.For example:

> *Soil structure and texture work together to control how water and air move through the soil. Good soil allows water to flow while still retaining enough moisture and nutrients, which is exactly what plants need to grow strong and healthy!*

Then (re)introduce the concept of soil health:

> *Soil health depends directly on soil structure and texture! Healthy soil has the right balance of sand, silt, and clay particles (texture) arranged into strong crumbs or aggregates (structure). This creates the perfect mix of spaces for air, water, nutrients, and living organisms. When the structure and texture are balanced, water flows properly, nutrients stay available, roots can grow easily, and soil organisms thrive - all signs of healthy soil that can support vibrant plant growth and a strong ecosystem!*

HANDOUT A3.1 PAGE 1/1

INVESTIGATING SOIL SOLID, LIQUID AND GASEOUS PHASES

A. Soil Solid Components

Material

- soil sample
- sieve
- magnifying glass

Experimental protocol

1. Take a sample of soil in your hand and gently rub it between your fingers to sense the solid components. Alternatively, use a sieving method to separate particles according to size, and examine the tiniest particles using a magnifying glass.
2. Record in your notebook the sensation—whether it feels smooth or rough. This tactile quality results from the dimensions and proportions of mineral particles in the soil, which defines soil texture. Soil particles are classified into three size categories: sand (largest), silt (medium), and clay (smallest). The specific percentages of these three components determine the overall texture of the soil.

B. Soil Liquid Component

Material

- 2 beakers (V=200mL, for example)
- 1 weighing balance
- 2 x 50g of fresh soil
- plastic film (or something to cover the beaker)

Experimental protocol

1. Weigh each beaker and note the value
2. Add around 50g of soil sample (use the balance) to each beaker, and record the exact amount added for each in a table.
3. Place one beaker near a heat source for at least 24h and place the other at ambient temperature, covered with plastic film.
4. Weigh each beaker and note the value (calculate the difference between the initial weighing and the final one: it corresponds to the evaporated water).
5. *Optional for primary students*
   Calculate the water proportion in the soil (water proportion = water mass/soil sample mass x 100).

To discover this experimental protocol, please watch this video : **Measuring Soil Air Content**

C. Soil Gaseous Component

Material

- 2 small beakers (e.g. V=100ml)
- 1 large beaker (e.g. V=500ml)
- graduated cylinder (V=50ml)
- soil sample (enough to fill one small beaker)
- water
- a permanent marker
- a timer

Experimental protocol

1. Draw a mark on the large beaker a few centimetres from the top.
2. Place a small, empty beaker inside the large one and fill it to the mark with water.
3. Remove the small beaker and the water it contains.
4. Now, place the second small beaker filled with soil in the large one and wait for about 10 minutes (gas bubbles will escape).
5. Draw a second mark on the large beaker to indicate the new level of water.
6. Top up the water level in the large beaker to the mark using a graduated cylinder, noting the volume added, Vv.
7. *Optional for primary students:*
   Calculate the percentage of air initially contained in the soil:
   - Vv or air proportion is determined by volume of poured water
   - Percentage of air volume = (Vv/small beaker volume) x100

Fig. 1. Measuring Soil Air Content

HANDOUT A3.2 PAGE 1/2

INVESTIGATING SOIL TEXTURE

A. Decantation of a soil sample

Material

- 500ml to 1litre of water
- 1 sealable container (e.g. a jar)
- 100g to 300g of fresh soil

Note that what is important here is to have a ratio of approximately 1/3 soil and 2/3 water rather than absolute values.

Experimental protocol

1. Add between 100g and 300g of soil inside the container
2. Then add approximately twice this volume of water
3. Seal the container and mix thoroughly to obtain a homogeneous mixture
4. Wait a few hours to let the mixture settle

To discover this experimental protocol, please watch this video : **Measuring Soil Air Content**

B. Identification of soil texture type

Material

- a ruler
- a calculator
- and a settled soil sample from the previous decantation experiment

Experimental protocol

1. Identify the different layers from a decanted soil sample using the diagram to identify each type of soil components based on their relative position from top to bottom. →
2. Measure the total height of the soil mixture in the cylinder (from the top of the clay layer to the bottom of the cylinder).
3. Measure the thickness of each layer: the clay, the silt and the sand layer and note them in the corresponding area in the dedicated table.
4. Calculate the proportion of each layer in the mixture (i.e. **proportion of clay = height of the clay layer/total height x 100**) and note and report them in the corresponding area in the dedicated table.
5. Plot these percentages on the soil texture triangle: The texture triangle shows 3 sides and allows us to report a range of soil composition. Find each percentage on its corresponding axis (0% to 100%), draw lines inward, and end up with three lines that cross at one point in a specific dedicated area of the triangle labelled with the corresponding soil type as shown in the figure below. This will give you the texture of your soil sample.

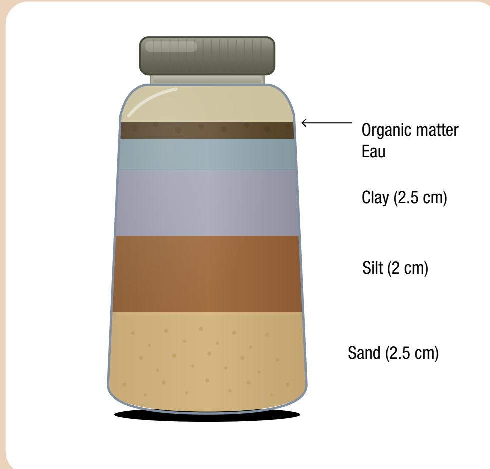


Fig 1. The Decantation Method: Identifying Soil Texture Layers

- On top of the mixture, we can observe the least dense elements, which are the remains of organisms (i.e. animals and plants).
- Under this first thin layer, we find a thicker layer of water.
- Under the water, we have a very thin and dark layer: the **humus.**
- Under the humus layer, we find the first layer composed of the finest solid mineral particles (< 0.002 mm in diameter): **clay** particles.
- Under the clay layer, we find the second layer, also composed of fine (between 0.002 mm and 0.05 mm in diameter) solid mineral particles: **silt** particles.
- Under the clay and silt layer, we find another layer composed of solid mineral particles, larger than the previous ones (between 0.05mm and 2mm in diameter): **sand** particles.

HANDOUT A3.2 PAGE 2/2

INVESTIGATING SOIL TEXTURE

Soil sample	Total height	Clay layer thickness	Silt layer thickness	Sand layer thickness	Proportion of clay (%)	Proportion of silt (%)	Proportion of sand (%)

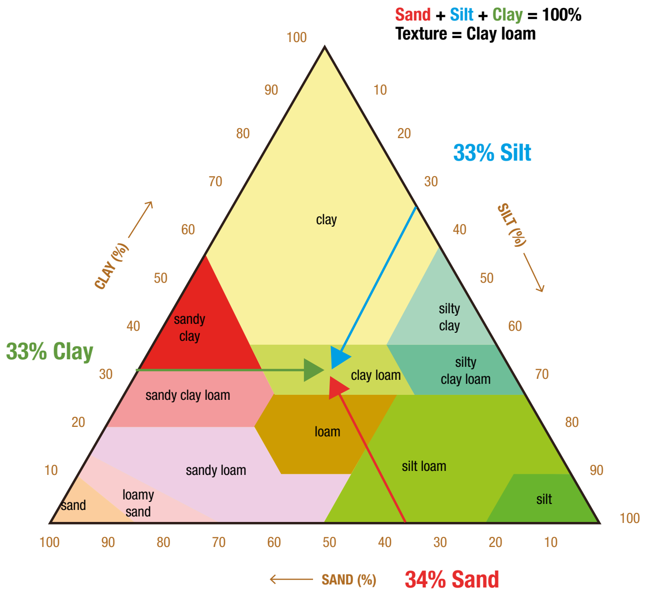


Fig 1. Texture Triangle

Fig 2. Texture Triangle

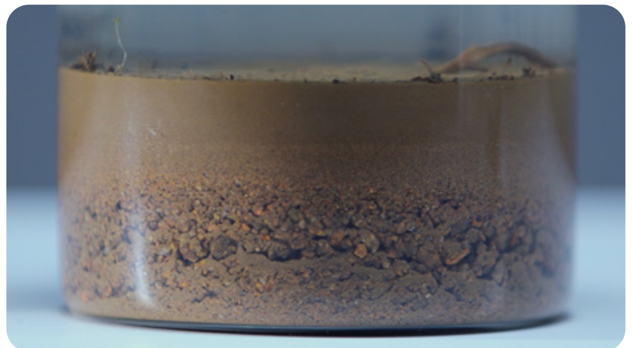


Fig 3. Soil sample after decantation

Identifying Soil Structure with the Texture Triangle

HANDOUT A3.3 PAGE 1/1

INVESTIGATING THE RETENTION CAPACITY OF CHARGED PARTICLES IN SOILS

Understanding Soil Cation-exchange Capacity

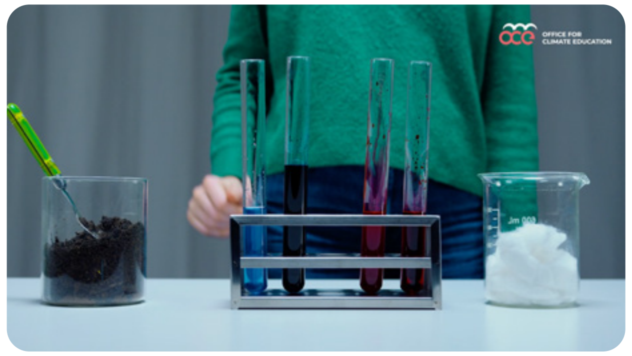
Middle school version

Material

- 4 test tubes
- 1 test tube rack
- 4 funnels, cotton wool
- Eosin solution (around 200ml)
- Diluted Methylene-blue solution (around 200ml)
- Forest or agricultural soil (break up large particles) (around 2 x 50g)

Experimental protocol

1. Place some cotton wool in two different funnels, packing it down sufficiently to block the funnels' opening but not so much that it would prevent the solution from passing through
2. Place the funnels in two different test tubes on the rack: one labeled control, one labeled test.
3. Put some soil in the funnel labeled test, above the cotton wool: approximately 5 cm (around 50g of soil).
4. Pour around 50ml of eosin solution into each funnel (n.b. it is a qualitative rather than a quantitative test).
5. Continue to pour eosin in the funnel filled with soil until it reaches the same level as the control in the second test tube. You might need at least 100 ml of eosin.
6. Repeat steps 1 to 5 with two new funnels (and new test tubes), including one filled with a new soil sample, but this time using diluted methylene blue instead of eosin.



LESSON A4 WHAT IS SOIL'S BIODIVERSITY ROLE?

MAIN SUBJECTS	DURATION	AGE GROUP	TEACHING METHOD
Natural Sciences	2-3 sessions of 1h	7-11 years old	Observations, Role-Play

OVERVIEW
This elementary science lesson introduces students to soil as a living, dynamic ecosystem. Students explore the hidden world beneath their feet, discovering the diverse organisms that make soil their home and understanding how these creatures form an interconnected «subterranean factory.» Through outdoor field observations, microscopic examination, interactive food web modeling, and long-term decomposition experiments, students learn how soil organisms work together to break down organic matter, cycle nutrients, build soil structure, and support life above ground. The lesson emphasizes the critical importance of soil biodiversity for ecosystem health and human well-being, while encouraging students to consider how their own actions can protect this vital resource.

GREENCOMP COMPETENCES
Promoting Nature, Systems Thinking

LEARNING OUTCOMES
By the end of the lesson, students will be able to:
- Identify various soil organisms and classify them into functional groups
- Explain how soil organisms interact in a complex food web, demonstrating interdependence
- Demonstrate through role-play and experiments how soil biodiversity contributes to essential ecosystem services (decomposition, nutrient cycling, soil structure formation)
- Observe and document evidence of decomposition processes and how they differ with and without living organisms
- Evaluate how human activities can impact soil biodiversity and propose simple actions to protect soil health

KEY CONCEPTS
Biodiversity, Decomposition, Ecosystems, Food Web, Humus, Interdependences

Background for teachers

Soil biodiversity, the Subterranean Factory of Life

DEFINITION OF SOIL BIODIVERSITY
Soil biodiversity is defined as the vibrant range of life forms living below the ground, encompassing the variety of organisms from genes and species to complex communities and the ecological complexes to which they belong. It is often used interchangeably with the term "below-ground biodiversity" and includes both soil microorganisms (bacteria, fungi, archaea) and soil fauna (nematodes, insects, earthworms). Scientists estimate that soil is home to **one-quarter of all living species on Earth,** though much of this life remains "out of sight and out of mind".

IMPORTANCE OF SOIL BIODIVERSITY FOR SOIL FUNCTIONS
Soil organisms act as the primary engine for the fundamental processes that allow soil to function. These essential functions include:

- **Soil Formation and Structure: "Ecosystem engineers"** like earthworms and termites create pore networks, tunnels, and passages that aerate the soil and allow water to permeate. Fungi and other microbes aid in the mineral weathering of parent materials and the formation of stable soil aggregates.
- **Nutrient Cycling:** Soil living organisms are responsible for the decomposition of organic matter, transforming waste into essential nutrients like nitrogen, phosphorus, and sulphur that are accessible to plants.
- **Water Purification and Storage:** Soils act as a natural filter and sponge; biodiversity helps soil absorb and store water, while microbes can degrade organic pollutants into non-toxic molecules, purifying groundwater.
- **Bioremediation:** Specific soil bacteria and fungi are used to clean contaminated land by metabolizing toxic compounds like oil spills or pesticides.

SOIL ECOSYSTEM
Soil biodiversity is a fundamental component for supporting and maintaining life above ground. It provides critical ecosystem services that are vital for food security, human health, and the production of raw materials like wood and textile fibers. A diverse soil system possesses functional redundancy, meaning that if some species are lost due to environmental stress, others can «fill the gap,» making the ecosystem more resilient and resistant to disturbances. Furthermore, soil serves as a «great medicine cabinet,» where organisms produce compounds used to create life-saving pharmaceuticals like penicillin and other antibiotics.

SOIL FOOD WEB
The soil hosts a vast and interdependent food web organized into different trophic levels and functional groups:

- Chemical Engineers **(Workers)**: Microorganisms like bacteria and fungi at the base of the web that decompose organic matter.
- Biological Regulators **(Supervisors)**: Small invertebrates (like protozoa and nematodes) that regulate the abundance of the «workers» by grazing on them, which boosts the release of nutrients.
- Ecosystem Engineers **(Architects)**: Larger fauna (like earthworms and ants) that design the physical structure of the soil environment. The complexity of these interactions ensures the cycling of energy from microscopic forms up to the megafauna that sustain higher-level predators.

SOIL BIODIVERSITY AND CLIMATE CHANGE
Soil biodiversity is a critical factor in global climate regulation through its role in the carbon and nitrogen cycles.

- Carbon Sequestration: Soils represent a massive reservoir, storing more than twice the amount of carbon currently held in the atmosphere. Soil organisms process this carbon, helping to keep it sequestered in the ground rather than being released as CO2
- Greenhouse Gas Regulation: Soil microbes carry out processes like nitrification and denitrification, which influence the emission of nitrous oxide (N2O), a potent greenhouse gas.
- Mitigation and Adaptation: Healthy, biodiverse soils provide nature-based solutions for climate mitigation and help ecosystems adapt to climate change by improving water retention and protecting against erosion during extreme weather events.

Sources:
- Orgiazzi, Alberto, et al., editors. Global Soil Biodiversity Atlas. Publications Office, 2016.
- Food and Agriculture Organization of the United Nations, et al. State of Knowledge of Soil Biodiversity: Status, Challenges and Potentialities, Summary for Policy Makers. FAO, 2020.
- European Commission. The Factory of Life: Why Soil Biodiversity Is So Important. Office for Official Publications of the European Communities, 2010

PREPARATION 1H

Field Site Selection and Preparation
- At least one week prior to the lesson, identify 3-4 suitable soil sampling locations near the school, such as: undisturbed natural area, garden or cultivated area, grassy area, area near tree roots
- Pre-dig small test pits to confirm suitability
- Collect preliminary soil samples to observe and identify organisms at the selected sites

Soil Organism Research
- Research local soil biodiversity to ensure regional relevance - reference resources:
  - → Global Soil Diversity Atlas
  - → European Atlas of Soil Biodiversity
- Focus on featuring clear images of: decomposers (bacteria and fungi), mesofauna (mites, springtails, nematodes), macrofauna (earthworms, beetles, ants, termites)

Wearable Soil Actor Cards
- Create cards approximately 10×15cm with:
  - → Front: Clear image of your selection of organisms with common and scientific name
  - → Back: Role in soil ecosystem and interesting facts

Alternatively, you can use the cards from **HANDOUT A4.1**
- Print on cardstock and laminate if possible
- Punch hole near top and thread yarn through for wearing
- Adjust selection to represent local soil ecosystem
- Prepare several pieces of yarn or string with large knot at one end

Additional Preparations
- Earthworm Farm: instructions for the set-up are on **HANDOUT A4.2** instructions. Note that you will need to start the farm 3-4 weeks prior to the lesson to see visible effects
- Decomposition demonstration set-up (follow **HANDOUT A4.2** for instructions). Allow 1 week to see some decomposition.

MATERIALS
- Magnifying glasses (one per pair of students)
- Optional: binocular microscopes

SUPPLEMENTARY MATERIAL
OCE soil fauna identification key

OCE soil foodweb animation

“Observing Organic Matter Decomposition in Soil”

INTRODUCTION

WARM UP 10 MIN

1. Hook: Stand with your students on the floor or playground and say,

> *Right now, we aren’t just standing on the ground. We are actually standing on the rooftop of a massive, hidden world!» Ask them: «If we are on the roof, what is happening in the ‘rooms’ downstairs? Who is building the hallways, and who is cleaning up the trash?*

2. The Context: Introduce soil as a **"subterranean factory"** where **25% of all species on Earth live and work.** Tell students that these tiny creatures are working day and night to keep our plants growing and our planet healthy. Use simple language to explain that soil is not just dirt—it’s alive!

3. Explain the learning outcomes for this lesson and make sure students understand them before engaging them into the first activity.

PROCEDURE

PART 1 - OBSERVATION OF THE “SUBTERRANEAN FACTORY” 60 MIN

4. Outdoor field observation (30 min)

- Take your class outside where they can safely access soil. Have students spend 5 minutes carefully looking around their surroundings. Ask them to point out **living things** (plants, insects, birds) and **non-living things** (soil, rocks, water, air, sunlight). Explain that an **ecosystem** is where living things interact with their environment, and this happens under our feet, too!

- Tell students that a **teaspoon of soil contains more tiny creatures than there are people on Earth.** As the teacher, carefully dig one small pit (15-30 cm deep) near some plants while students gather safely around to watch. This teacher demonstration is safer than having students dig individual holes. Show students how the soil changes as you dig deeper—point out differences in colour, moisture, and texture.

- With your soil pit open, invite students to look for the **«Architects»** (Ecosystem Engineers) like earthworms and ants, and the «super-highways» (tunnels) they build to move air and water. Gather students together to share what they found. Ask: *«Where did we find most living things?» (usually near the surface), «How did the soil change as we dug deeper?»,* and *«Why are these soil creatures important for plants?»* Emphasise that healthy soil is a community where living and non-living parts work together.

- Collect small soil samples from around plant roots (the «rhizosphere») and from inside earthworm tunnels (the «drilosphere»), where lots of tiny creatures live.

5. Back to school observation (30 min)

Back in the classroom, use magnifying glasses or binocular microscopes to examine the collected samples. Provide an identification key (e.g OCE interactive soil fauna identification key) to help students find:

- ***The Workers*** (Chemical Engineers): Tiny bacteria and fungal hyphae that decompose raw materials.
- ***The Supervisors*** (Biological Regulators): Protists and mites that control the activity of the Workers.

Display your selection of soil organisms cards with pictures, fun facts for additional exploration.

6. Have students draw the organisms they identify in their notebooks, focusing on the specialized roles these creatures play within the factory (workers, supervisors, architects). Make sure they indicate the name and size of the organisms.

PART 2 - EXPLORING THE ESSENTIAL ROLES OF SOIL FACTORY WORKERS 40 MIN

7. Warm up

Have students share the names and functions of soil organisms they observed or learned about in the previous session. Explain that today’s focus will be on exploring the specific functions these organisms perform in the "soil factory."

> **TEACHER TIPS**
>
> Use the fishbowl peer learning strategy where some students demonstrate while others observe, then rotate roles to ensure all students participate actively.

8. The Factory in Action (Modeling Functions)

- Divide the class into 3 groups. One group simulates how the factory departments function where the other group observes. Set the classroom to have a central area for the role play and students observing outside the circle. Designate an area as the “Plant Root” area.

- Assign to group A students one of the soil factory function

WORKERS (DECOMPOSERS)

→ **Role:** Break down «waste» materials (paper scraps) into tiny bits

→ **Represents:** Bacteria and fungi that decompose organic matter and cycle nutrients

SUPERVISORS (CONSUMERS)

→ **Role:** «Graze» on the Workers (by gently tagging them), triggering them to release nutrients to a designated «Plant Root» area

→ **Represents:** Protozoa, nematodes, and other predators that regulate microbial populations and release nutrients

ARCHITECTS (ECOSYSTEM ENGINEERS)

→ **Role:** Construct «pore networks» using tubes or blocks to create pathways for movement

→ **Represents:** Earthworms, ants, and other macro-organisms that create soil structure

Have students from group A perform their role. Probe the observing students with questions such as: “What connections did you observe between the different roles?», «How did the nutrients cycle through the system?» «What might happen if there were ten times more decomposers but the same number of supervisors?»

- Rotate the group of students with group B to perform the factory functions. Then introduce a system crash: an intensive tillage **()** that is disrupting or destroying the Architects’ tunnels. Have them perform the situation. Probe the observing students with questions such as: “What specific changes do you observe when the tunnels are disrupted?», «How are the other soil functions affected when the Architects can’t work properly?», «What would be the long-term consequences if this disruption continued?»

- Rotate the group of students, have group C perform the factory functions. Then introduce another system crash: soil **sealing ()** that is preventing organic matter from reaching the decomposers. Have them perform the situation (e.g covering the «factory» with a tarp to model soil sealing). Probe the observing students with questions such as: «What immediate changes occur when organic matter can’t reach the decomposers?», «How does this affect the ‘supervisors’ and their role?», «What might plants experience when this system breaks down?»

- Regroup the class and guide students to discuss:
  → How destroying tunnel networks affects water movement and organism mobility
  → How blocking organic inputs impacts decomposer populations
  → The cascading effects on plant health and soil resilience
  → Connections to real-world soil management practices
  → Actions can we take, such as composting, to keep the factory running

9. Extended learning: long-term experiments.

Set up two ongoing experiments for students to observe over time:

DECOMPOSITION DEMONSTRATION (HANDOUT A4.2)

→ Compare decomposition rates in sterilized vs. non-sterilized soil

→ Students document changes weekly to understand the essential role of microorganisms

EARTHWORM INVESTIGATION (HANDOUT A4.2)

→ Create worm bins to observe how earthworms transform organic waste. Students record observations of castings, soil structure changes, and plant growth effects over 3-4 weeks.

> **NOTE**
>
> These experiments provide tangible evidence of the concepts modeled in the roleplay activity.

PART 3 - MODELING THE INTERDEPENDENCE OF SOIL ORGANISMS (ROLE PLAY ACTIVITY, 40 MIN)

10. Warm-Up.

Begin by reviewing what students learned in Parts 1 and 2. Explain that today they'll play a game demonstrating how soil creatures depend on each other for food.

11. Soil Food Web Role Play

- **Modeling the Game** (5 min)
  First, demonstrate the game using two example cards that are relatable for students. As you demonstrate, think aloud about your strategy: «I'm looking at my card... I'm a worm, and it says I eat dead leaves. So I need to find who has the dead leaves card and connect with them.» When predators connect to prey, the predator holds the knotted end of the string while the prey holds the other end. Next, invite two students to try the game in front of the class using different cards. This gives everyone confidence before playing.

- **Building the Food Web** (15 min)
  Assign students to these roles without giving the cards yet:
  → 1 student each: wolf spider, mole, ant
  → 2 students each: earthworm, bacteria, fungi, nematode
  → Remaining students: half play fern, half play dead leaves/organic matter

  Distribute a necklace card and several strings to each student. Instruct them to read their cards to learn about their assigned creature. As a class, facilitate a discussion to help students understand how their creatures collectively represent the soil ecosystem they observed in part one. Encourage students to explore why there are many representations of ferns, dead leaves, and organic matter, while only one student represents creatures like the wolf spider, mole, or ants. This discussion can help deepen their understanding of ecosystem diversity.

  Tell them that the food web should begin the food web with dead leaves and ferns. Ask them why (primary producers). Ask students to explain their connections: «I'm connecting to the dead leaves because my card says earthworms eat decaying plant material.» Continue until all creatures are connected in the food web.

- **Testing Ecosystem Changes** (10 min)
  Test what happens when something disrupts the ecosystem. For example: «Oh no! Someone sprayed pesticides and all the ants are gone.» The student playing the ant sits down, and any creature that relies solely on ants for food must also sit down. This chain reaction continues up the food web. Demonstrate how one small change affects many creatures throughout the ecosystem. Explain that real food webs are even more complex, but the principle remains the same.

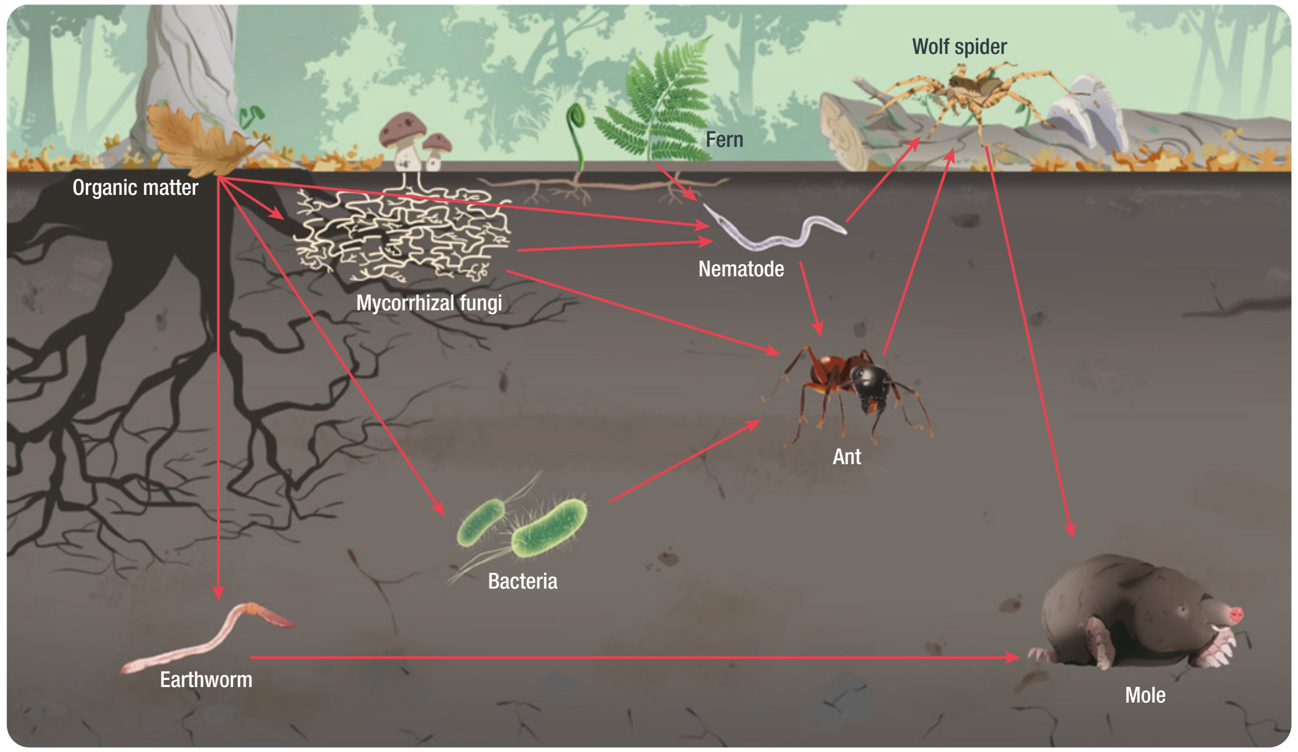


Fig. 1. The Soil Food Web: Organisms and Trophic Relationships. Source: OCE Soil Food Web Animation

12. Wrap-up Discussion (10 min).

Guide the discussion with simple questions:

- "What happened when one creature disappeared from our food web?"
- "Was there any creature that wasn't important? Why or why not?"
- "How do human activities affect soil creatures?"(-building on soil, using chemicals, cutting down trees)
- "What actions can we take to help soil creatures?" (composting, planting native species, avoiding chemicals)

WRAP UP

Remind the class that **"Life in soil drives life on Earth"**—this subterranean effort is what maintains our food supply and global health.

Alternative option to the role-play game:
soil food web multimedia animation

HANDOUT A4.1 PAGE 1/1

SOIL FOOD WEB ACTORS

ORGANIC MATTER

in forests is found chiefly beneath trees and plants, in the soil layer called the litter layer. We use the term 'organic matter' for everything that comes from dead animals or plants, mostly from dead leaves.

FERNS

are flowerless green plants which reproduce by spores rather than by seeds. Many fern species grow on the trunks and branches of trees. They can form a close relationship with mycorrhizal fungi, and some nematodes eat their roots.

MYCORRHIZAL FUNGI

an the forest can develop a critical 'root' web. This deep soil web can associate with tree or fern roots, providing plants with nutrients in exchange for carbon (energy). Some nematodes eat them.

BACTERIA

are microscopic (invisible to the naked eye) living organisms that consist of a single cell. Bacteria play an essential role in the decomposition of organic matter, and nematodes and ants eat them.

NEMATODES

also called roundworms, are named for their body shape. There are more roundworms in the world than any other multicellular creature! They feed on plant roots, bacteria, fungi, and even nematodes themselves, and are eaten by spiders or insects, like ants.

ANTS

are social insects that live in colonies, which consist of the queen, female workers, and males. The queen is the only one that can lay eggs. Female workers are responsible for providing the colony with food, such as fungi, nematodes, or bacteria.

WOLF SPIDERS

get their name from the way they hunt, which is similar to the way wolves hunt: they generally wait for their prey to wander close by, and then rush out to kill it. Wolf spiders live on the soil's surface and catch insects, like ants, as well as nematodes.

MOLES

are small mammals living underground. Their poor eyesight is balanced by their acute senses of smell and touch. They have powerful claws that let them dig through the ground to find their prey: earthworms.

EARTHWORMS

live in damp, loose soils or in loose leaf litter. They play a key role in forest and farm ecosystems by aerating and enriching the soil with their mineral droppings. Their typical diet is decomposing organic matter.

HANDOUT A4.2

SOIL DECOMPOSITION DEMONSTRATION

Observing Organic Matter Decomposition in Soil

Materials

→ Soil samples
→ 2 petri dishes
→ a hot plate
→ pieces of paper
→ water

Directions

→ Divide the soil sample into 2 parts (soil sample 1 and soil sample 2).
→ Use the hotplate to heat one part of the soil sample 2 for about 20 minutes to kill the soil.microorganisms and create a "sterilised" soil sample.
→ Wait for the heated soil sample to cool off.
→ Fill one petri dish with the soil sample 1 and the other with the soil sample 2 ("sterilised").
→ Add a piece of paper (same paper type and size) on the top of each soil samples.
→ Add some water to humidify the paper and soil sample on each petri dish.
→ Put the cover on each of the petri dishes.
→ Place the petri dishes if possible near a source of heat or in a warm place.
→ Monitor the changes of the pieces of paper regularly.

HANDOUT A4.3

EARTHWORM FARM

Materials

→ Large glass measuring cylinder or aquarium
→ soil
→ compost
→ small pebbles or organic waste that can be used to provide aeration (e.g. coffee grounds or cocopeat), leaves.

Directions

→ Fill the farm with moistened soil that is not too compact, mix it with compost and small pebbles (or organic equivalent). Water lightly and place the earthworms on top. You can buy earthworms from fishing tackle dealers.
→ Put the cover on and place a black cardboard cover on each side. It is interesting to arrange the soil in strata in the worm farm, preferably strata of different colours (soil/compost/sandy soil, for example).
→ Place various leaves of different species of varying toughness on top of the soil.
→ The earthworms can be kept like this for years if they are regularly given leaves and plant based waste, and if the soil is lightly watered if it dries out.
→ The results in these videos:
https://www.youtube.com/watch?v=lKk7dsanqjM
https://www.youtube.com/watch?v=XVjTwkrVhtY

Students can document and record in their journals weekly:
→ Changes in soil structure (compaction, tunnels, aggregates)
→ Rate of organic material breakdown
→ Production and characteristics of worm castings
Moisture distribution throughout the soil

LESSON A5 WHAT ROLE DOES SOIL PLAY IN EARTH'S NATURAL CYCLE?

MAIN SUBJECTS	DURATION	AGE GROUP	TEACHING METHOD
Natural Sciences	2-3 sessions of 1h	9-12 years old	Document Analysis, Hands-on Experiments

OVERVIEW
This lesson examines soils as essential reservoirs that store and circulate water and nitrogen across Earth's major systems (atmosphere, lithosphere, and biosphere). Students will investigate soil permeability and water retention to understand how soils facilitate groundwater recharge despite containing only 0.004% of Earth's water. The lesson concludes by assessing how human activities disrupt this natural cycle.

GREENCOMP COMPETENCES
Problem Framing, Promoting Nature, Systems Thinking

LEARNING OUTCOMES
By the end of the lesson, students will be able to:
- Compare the relative size of soil as a water reservoir to other Earth water reservoirs
- Explain one of the soil main function as a natural sponge and water filtering system
- Use an experimental model to compare the differences in water retention and permeability between healthy and degraded soils
- Explain how climate change impacts the soil's ability to retain and filter water

KEY CONCEPTS
Infiltration, Permeability, Reservoir of Water, Retention Capacity, Runoff

Background for teachers

SOIL AND WATER CYCLE

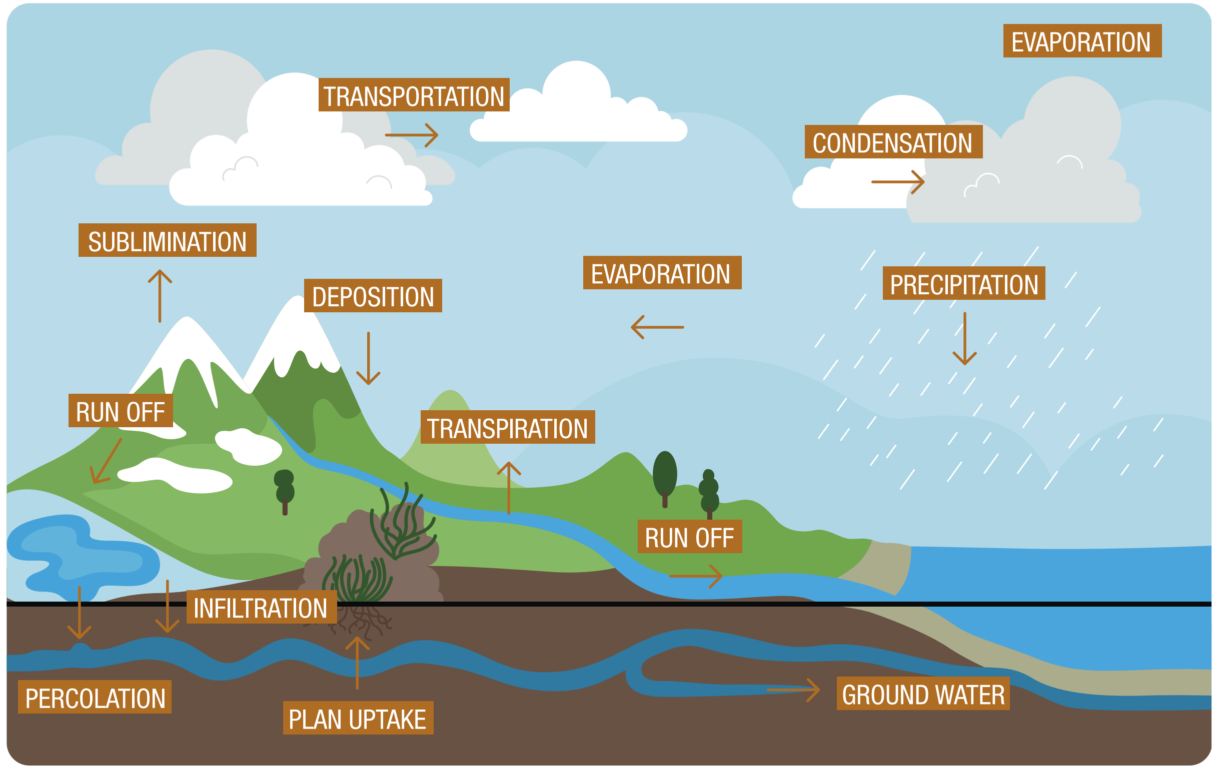


Fig. 1. The Water Cycle: Main Reservoirs and Fluxes

WATER CYCLE IN ACTION
Water can be found in three states: **gas** (water vapour in the air), **liquid** (oceans, rivers, groundwater, rain, etc.), and **solid** (glaciers, snow crystals, hail, and ice). Water constantly moves between the oceans, the atmosphere, and land. The reservoirs and the fluxes are the building blocks of the water cycle:
- Surface water of oceans, lakes and soil **evaporates** – the warmer it is, the higher the rate of evaporation.
- Water in plants also evaporates through a process known as **evapotranspiration.** For children, the concept of evaporation often stops at the simple observation of puddles that disappear. To illustrate evapotranspiration and evaporation from land, encourage them to collect a few plant samples and a shovelful of soil (ideally after recent rainfall). When placed in plastic bags in a warm place, soil moisture will evaporate and condense on the inner surface of the bags as small droplets.
- Similarly, water vapour in the air **condenses** into fine droplets that form clouds before falling as rain onto oceans and land.
- Some of the rain **infiltrates** the soil and replenishes the water tables (groundwater). When the soil is saturated with water, some of it **runs off** into the rivers and lakes.

SOIL'S CRITICAL ROLE IN THE WATER CYCLE
The soil plays a crucial role in the water cycle through several key processes:

1. **Infiltration** – Soil absorbs precipitation, allowing water to move below the surface rather than running off immediately.
2. **Storage** – Soil acts as a reservoir, holding water that can later be used by plants or slowly released to groundwater
3. **Filtration** – As water moves through soil, contaminants and particles are filtered out, improving water quality
4. **Groundwater recharge** – Soil facilitates water movement into deeper aquifers, replenishing groundwater supplies
5. **Plant uptake** – Soil moisture is absorbed by plant roots and eventually released to the atmosphere through transpiration

These soil functions help regulate the flow of water between surface water, groundwater, and atmospheric water, creating a more stable water cycle. Soil characteristics like texture, structure, and organic matter content directly influence how efficiently these processes occur.

PREPARATION 1H

MATERIALS
- Sample of degraded soils (soil found around the school for example), dried soil
- Sample of soils from forest, cultivated fields…
- Printed **HANDOUTS** per group of students : **A5.1, A5,2, A5.3 + HANDOUT A3.1** (optional)

TEACHER TIPS

In primary school, students have learned to name matter naturally present in our environment, in all its forms, living or non-living, transformed or manufactured. Most often, teachers use water to illustrate what matter is and its properties. This lesson expands that to look at cycles (flows and reservoirs).

INTRODUCTION

1. Remind students of states of matter. Ask them to: identify the three states of matter: liquid, solid, and gas. Give examples of state changes in everyday life: ice cube formation (solidification), shower wall condensation, thawing (melting). Identify movements of matter in nature: waves, clouds, etc.

2. Inform students that today's lesson will focus on the important role of soil in the water cycle. Share the learning outcomes for this lesson, ensuring that students fully understand them before moving on to the first activity.

PROCEDURE

PART 1 - WATER IN SOIL 20 MIN
3. Ask: "*Where is water found on Earth?*" (oceans, lakes, ice). After mentioning oceans, lakes, ice or snow, guide them to think about underground resources and soil. Ask how we could measure water content in soil. The idea of weighing before and after drying should emerge.

4. If students have experimental competencies, let them design and conduct their own experiment or use experimental protocol on liquid phase of soil from **HANDOUT A3.1 INVESTIGATING SOIL SOLID, LIQUID AND GASEOUS PHASES.** By calculating the mass difference, students discover that soil is a reservoir capable of holding a significant proportion of water.

5. Sum up your observations: soils do contain a certain proportion of water. The soil is therefore a **reservoir.** The proportion of water in the soil varies according to a number of factors, including porosity, the season, depth, plant cover and recent climatic conditions (rain, drought, etc.). A typical range for a forest soil is between 15% and 35% of the total mass of the soil. Depending on the type of soil, its retention capacity is more or less important (very high for clay soils and/or soils rich in organic matter).

PART 2 - SOIL AS A SPONGE, INVESTIGATE SOIL PERMEABILITY AND RETENTION CAPACITY 40 MIN

6. Begin by asking students: "*Where does water in soil come from?*" Guide the discussion toward rainfall and the process of infiltration. Explain that soils act like sponges—they allow water to pass through (permeability) and can store water (retention capacity). Introduce the second experiment, which will investigate:

- **Permeability:** How quickly water flows through different soil types
- Water retention**:** How much water remains in the soil after drainage

7. Demonstrate the experimental setup. Show students how to:

- Measure equal volumes of water to pour through each soil sample. Measure the height of the soil sample from the bottle neck to the top surface
- Time how long it takes water to begin dripping through
- Calculate the infiltration rate by dividing the height of the soil sample by the time it took to stop dripping
- Collect and measure the water that passes through
- Calculate retention by subtracting collected volume from initial volume

8. Distribute **HANDOUT A5.1** and ensure all groups have necessary materials. As students conduct their experiments, circulate to ask probing questions:

- "*What differences do you notice between soil types?*"
- "*Which soil is allowing water to pass through most quickly? Most slowly?*"
- "*What might explain these differences?*"

9. After all groups complete their data collection, facilitate a class discussion:

- Compare results across soil types
- Create a simple class data table or graph showing permeability and retention values
- Discuss real-world implications:

  → Healthy forest soils typically demonstrate balanced properties—good infiltration preventing runoff, while retaining adequate moisture for plant growth
  → Sandy soils generally show high permeability but low retention
  → Clay-heavy soils often have low permeability, potentially leading to waterlogging or runoff
  → Compacted or degraded soils may have poor infiltration, increasing erosion risk.

10. Connect these findings to environmental concepts: flood prevention, groundwater recharge, plant growth, and ecosystem health.

11. Wrap up. Ask: "*How might human activities change soil's ability to act as a sponge?*" (Answers might include: deforestation, construction, farming practices, etc.).

PART 3 - THE SCALE OF SOIL AS A WATER STORAGE, BATHTUB ANALOGY 20 MIN

12. Begin by asking students: "*How much water is stored in soil?*" Ask students to imagine all Earth's water fitting into a **100-liter bathtub.** Have them predict how this water would be distributed among different reservoirs by creating their own visual representations. Use a globe or diagram to indicate these reservoirs visually while discussing the proportions.

> "If all Earth's water equaled 100 liters, estimate how much would be in each reservoir. You can draw, create a chart, or describe your ideas in writing."

13. Reality Check. After students complete their predictions, distribute **HANDOUT A5.2** to reveal the actual proportions:

- Oceans and seas (saltwater): 96.7 liters
- Ice caps and glaciers: 2.1 liters
- Groundwater: 1.0 liter
- Surface water (lakes, rivers): 0.02 literAtmospheric water: 0.001 liter
- Soil water: only 0.004 liter (or 4 mL, about the volume of a teaspoon)

Have students compare their initial predictions with actual figures and revise their representations.

14. Discussion Points

- Despite containing only 0.004% of Earth's water, soil moisture is critically important for terrestrial life
- Soil serves as the interface between groundwater, surface water, and atmospheric water
- The small amount of soil water regulates much larger freshwater fluxes

> **TEACHER TIPS**
>
> When reviewing student work, emphasize how most people intuitively overestimate the amount of accessible freshwater on Earth, highlighting the precious nature of this resource.

PART 4 - CLIMATE CHANGE IMPACT ON WATER CYCLE AND SOIL FUNCTION 30 MIN

15. Begin with a class energiser: "*Let's act out the water cycle!*"

- Half the class: Arms up slowly = "Evaporation" (water going UP into the sky).
- Other half: Wiggle fingers down = "Precipitation" (water falling DOWN as rain).
- Teacher calls «Climate Change!» → Everyone moves FASTER!

Introduce today's activity: "*When Earth gets warmer, the water cycle speeds up. Today we'll explore what that means using science data!*". Explain that students will work in groups of 4 to analyze the information extracted from the report that scientists compiled to study climate change.

16. Look at the diagram and the data table on your handout.

Question 1. Calculate total evaporation: Water evaporating from Land: 74 km³, Water evaporating from Ocean: 470 km³. Total going UP = _____ km³

Calculate total precipitation: Rain falling on Land: 120 km³, Rain falling on Ocean: 424 km³. Total coming DOWN = _____ km³

Compare them : *"What do you notice when you compare these two numbers?"*

Answer: They're equal! (544 = 544) The water cycle is balanced - what goes up must come down!

"The amount of water in the atmosphere stays the same. -Water keeps moving but the total stays constant!"

17. Question 2. Look at your diagram again. Focus just on the ocean:
Ocean loses (evaporation): 470 km³. Ocean gains (precipitation): 424 km³
Do the math: 470 - 424 = _____ km³
"The ocean is losing 46 km³! But we know the ocean isn't shrinking, so... Where do those 46 km³ come from?"
Hint: *"Look at the arrows on the diagram. What flows from land to ocean?"*
Answer: Rivers and underground water (called «watercourses» or «runoff») bring 46 km³ from land back to the ocean! The cycle stays balanced.
Visual check: Have students trace the path with their finger: Ocean → Sky → Land → Rivers → Ocean

18. Read Document 1 together (whole class or in pairs). Discussion prompts after reading:
"*What happens when Earth gets 1°C warmer?*" (1-3% more evaporation and rain)
"*The reading says 'when it rains, it often pours harder than before.' What does that mean?*"
Answer: Instead of gentle steady rain, we get heavy downpours
"*The reading mentions BOTH floods AND droughts. How can both happen?*"
Answer: Some places get too much rain at once (floods), other places dry out more (droughts).
"*What's the 'pot of water' comparison about?*".
Answer: When you heat water, it boils faster and makes more steam - same with Earth!
Key takeaway: Climate change makes wet times WETTER and dry times DRIER.

19. Question 4. "*Now let's connect what we learned about the water cycle to what happens underground.*" "Based on Document 1, how does climate change affect groundwater *recharge? Think about: How the TYPE of rain is changing (gentle vs. heavy) What you know about infiltration and runoff*".

- What type of rain happens more with climate change? Answer: Heavy downpours, intense storms
- What happens when rain falls too fast? Answer: Soil can't absorb it quickly enough
- Where does that water go instead? Answer: It runs across the surface to rivers and oceans (runoff)
- Does it reach groundwater? Answer: No! It goes straight to rivers instead of soaking deep into the ground

Example of a complete answer for Students: "*Climate change causes more intense rainstorms instead of gentle steady rain. When rain falls too hard and fast, the soil cannot infiltrate (soak up) the water quickly enough. Instead, the water becomes runoff, flowing rapidly across the surface into rivers and oceans. This means even though it might rain MORE total, we could have LESS groundwater available because the water doesn't have time to soak down and recharge the aquifers.*" Real-world connection: "It's like pouring water on a sponge. Pour slowly = sponge absorbs it. Pour fast = water runs off the sides!"

20. «Let's see how this creates a problem that keeps getting worse...»

Climate change → More evaporation. Soil dries out faster. Dry soil erodes (blows away) or burns in wildfires. Damaged soil can't hold water anymore. Rain becomes runoff instead of soaking in. Soil gets EVEN DRIER → (back to step 2)

"This is called a vicious cycle or feedback loop - it keeps making itself worse!"

Student task: Draw arrows connecting these steps in a circle on their handout

21. "*The good news? Healthy soil can help solve this problem!*" Healthy soil has 4 superpowers:

- **Infiltration** (Acts like a sponge) Soaks up intense rain → Prevents floods
- **Storage** (Acts like a water tank) Holds water for plants → Helps during droughts
- **Filtration** (Acts like a coffee filter) Cleans water as it soaks through → Gives us clean drinking water
- **Recharge** (Acts like filling a battery) Sends water deep underground → Refills groundwater for the future

WRAP UP

Have students summarize why healthy soil is the defense against the effect of climate change on water cycle:

- **Infiltration:** Absorbs heavy rain (preventing floods).
- **Storage:** Holds water for droughts.
- **Filtration:** Cleans the water.
- **Recharge:** Moves water down to aquifers.

HANDOUT A5.1 PAGE 1/1

SOIL'S WATER PERMEABILITY AND RETENTION CAPACITY EXPERIMENT

Material

→ A 500 ml plastic bottle, with its mouth covered by several layers of gauze secured with an elastic band around the neck, and the bottom of the bottle cut open with scissors, as shown in the figure.
→ 2 graduated cylinders of 250 ml
→ 250 ml of fresh soil collected from around the school
→ 250 ml of dried fresh soil
→ 250 ml of fresh soil of another type (forest soil, clay soil or from a cultivated field...)
→ Place 250 ml of soil in the bottle.
→ Position the bottle above the graduated cylinder. Measure out 250 ml of water and pour it onto the soil sample as shown in the adjacent image.
→ Measure the height of the soil sample in the bottle with a ruler (record in cm, from the bottom to the surface of the soil sample).
→ Start the timer the moment water starts coming out of the bottle and stop it when the flow stops. The difference between the volume of water added to the soil and the volume collected when it stops flowing indicates the soil's water retention capacity. The measured time in seconds gives us an estimate of the soil's permeability: the longer it took for water to move through the soil, the less permeable it is, and vice versa. Have students calculate the soil permeability rate by dividing the height of the soil sample in the bottle by the time it took for the water to stop flowing.
→ Compare the retention capacity and permeability of the different soil samples.

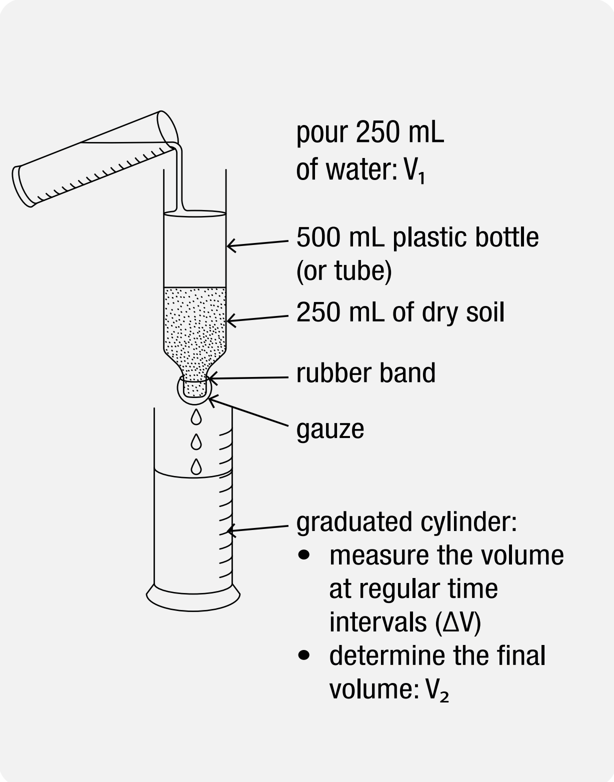


Fig. 1. Experimental Setup for Measuring Soil Water Permeability and Retention Capacity

Experimental protocol

Data table: soil's water permeability and retention capacity in different soil samples

	SAMPLE 1	SAMPLE 2	SAMPLE 3
Initial volume of water poured (Vi in ml)			
Final volume of water collected (Vf in ml)			
Soil water retention capacity (Vi - Vf, in ml)			
The time it takes to stop the flow of water			
Soil permeability (in cm per second)			

HANDOUT A5.2 PAGE 1/1

PROPORTION OF WATER STORED IN EARTH'S DIFFERENT RESERVOIRS DOCUMENT ANALYSIS

Question: Using the information about the amount of water, represent the distribution of water in the Earth's major reservoirs. What do you notice about the quantity of freshwater without ice, and the soil water content?

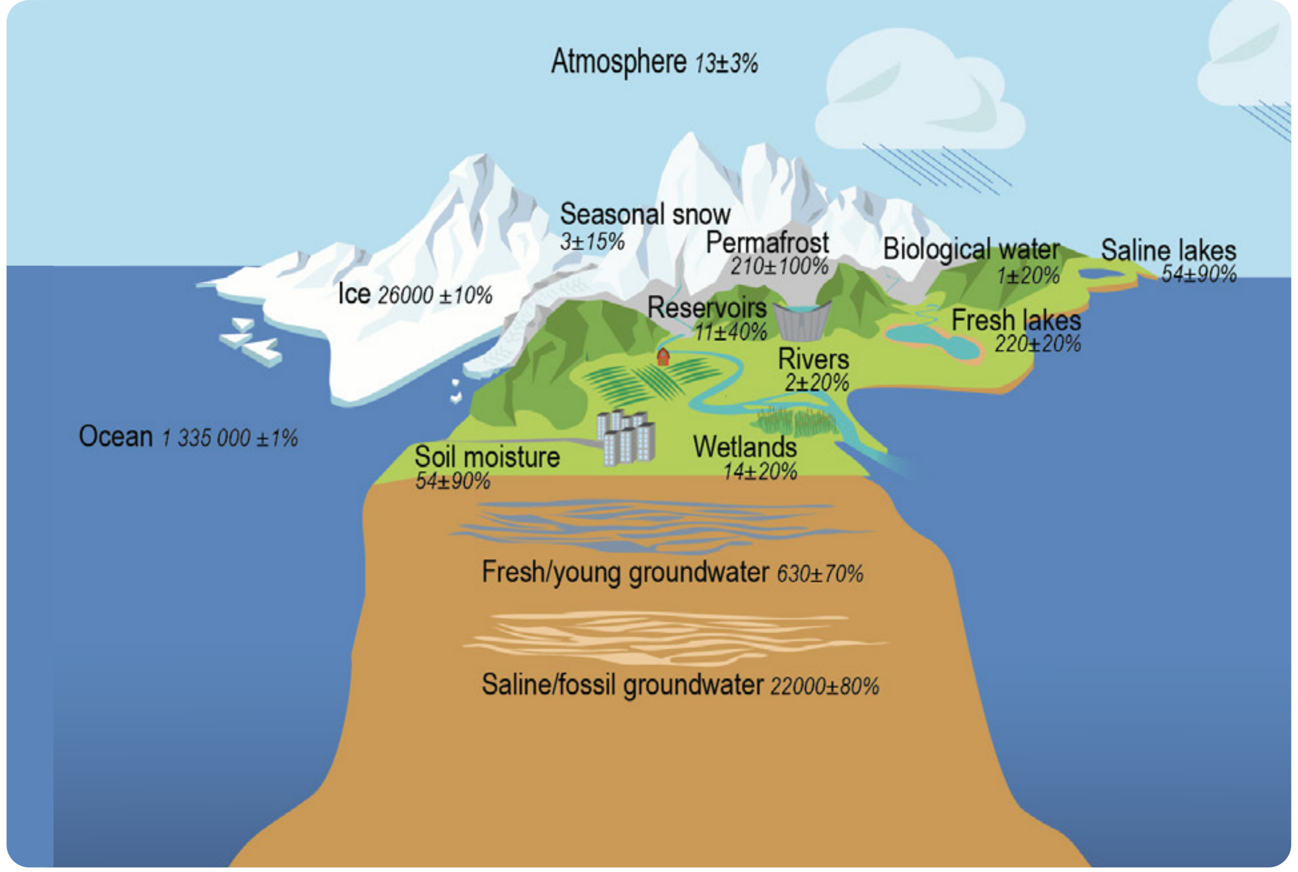


Fig. 2. Proportion of Water Stored on Earth in Different Quantity of water in thousands of km³. The "± x%" indicates the relative uncertainty (or relative error margin) of the estimated value. Source: IPCC AR6 WG1, Chapter 8, Figure 8.1 (2021)

Ocean, inland seas and saline lakes	96,7 liters
Ice caps, glaciers, ice floes,…	1,9 liter
Saline groundwater	1,6 liter
Freshwater without ice: groundwater, lakes, rivers	0,07 liter
Soil water content	0,004 liter
Atmosphere (air moisture, clouds,…)	0,001 liter

Table 1. The quantity of water stored in different reservoirs was scaled down to 100L. (The total slightly exceeds 100% because of rounding.)

ANNUAL WATER FLOXS ON EARTH (THOUSANDS OF KM³/YEAR)

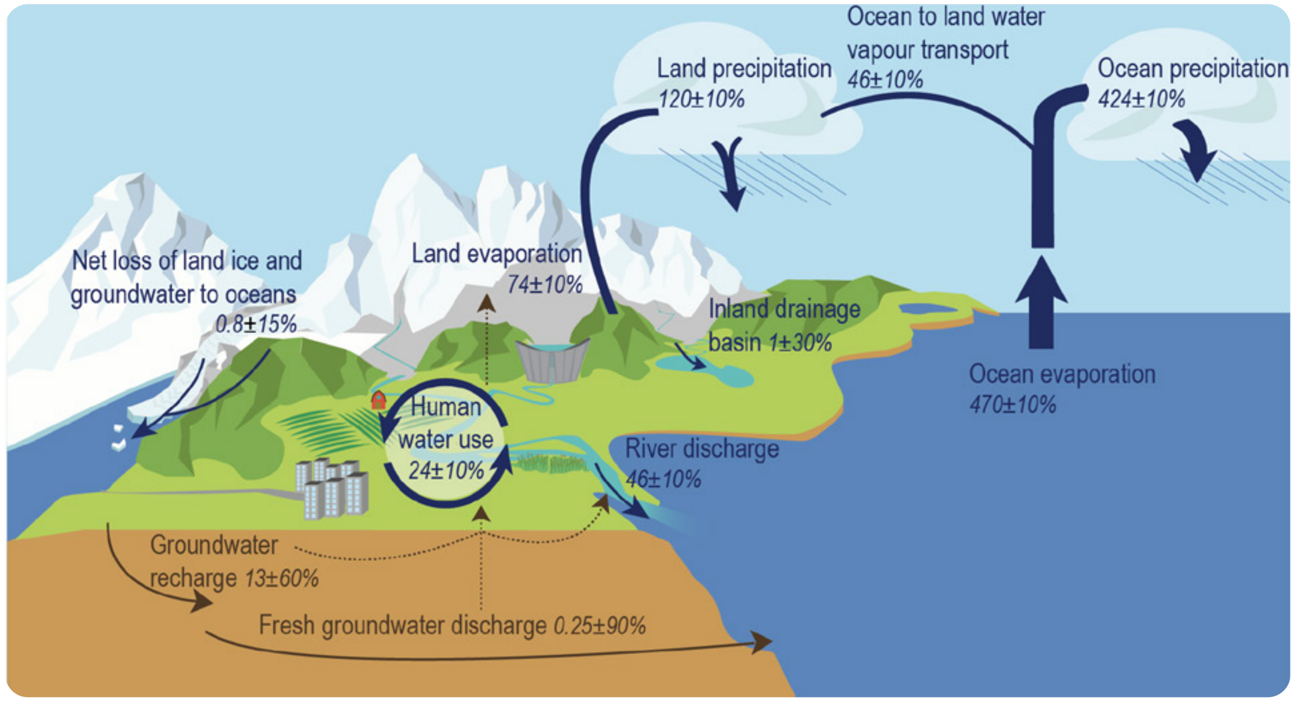


Fig. 1. Source: IPCC AR6 WG1, Chapter 8, Figure 8.1b (2021)

TABLE 2. VOLUME OF WATERS FLOWING FROM DIFFERENT RESERVOIR

Ocean Evaporation	470 Km^3
Land Evaporation	74 Km^3
Ocean Precipitation	424 Km^3
Land Precipitation	120 Km^3
Contribution to Ocean from Watercourses	46 Km^3

DOCUMENT 1: OBSERVED CHANGES IN THE WATER CYCLE.

The Earth's water cycle is changing because of global warming. Here's what scientists have found:
When Earth gets 1°C warmer, the amount of water that evaporates and falls as rain increases by 1-3%.
The air now holds more moisture than before. Rain and snow storms are becoming more intense - when it rains, it often pours harder than before.This means floods can be worse when they happen. Both extreme wet and dry conditions are becoming more severe - so some places experience heavier rainstorms while others face worse droughts. When the air is warmer, it can carry more water vapor from oceans to land, making storms even stronger.
Think of it like turning up the heat on a pot of water - everything speeds up! The warmer air can hold more moisture, so when rain clouds form, they can dump more water at once. This is why we're seeing both stronger rainstorms and worse flooding in some places.
These changes aren't the same everywhere on Earth, but scientists are very confident these patterns are happening because of human-caused global warming.

Adapted from: 2021, IPCC, Assessment Report 6, WG1 (The Physical Science Basis), ch8 and ch11. Published on the IPCC website (https://www.ipcc.ch/report/ar6/wg1/figures/chapter-8/figure-8-1)

Question 1 Calculate the total water evaporating from Land (74 km³) + Ocean (470 km³). Compare this to total precipitation on Land (120 km³) + Ocean (424 km³).

Question 2 The oceans lose 470 km³ to evaporation but only get 424 km³ back from rain. Where does the missing water come from?

Question 3 Based on the text, how does a warmer climate affect the intensity of storms?
Connecting Soil and Groundwater (This question connects to your earlier soil experiment)

Question 4 If climate change causes rain to fall in short, violent bursts rather than steady showers, how does this affect groundwater recharge? Use the terms 'infiltration' and 'runoff' in your answer.

DIGGING INTO SOILS

LESSON A6 WHAT ROLE DOES SOIL PLAY IN EARTH'S NATURAL CYCLE? NITROGEN CYCLE

MAIN SUBJECTS	DURATION	AGE GROUP	TEACHING METHOD
Biology, Chemistry	1H30	13-15 years old	Document Analysis, Observations

OVERVIEW

This lesson examines soils as essential reservoirs that store and nitrogen across Earth's major systems (atmosphere, lithosphere, and biosphere). Students explore the role of soil in the nitrogen cycle, examining how organisms transform organic nitrogen into plant-available forms. The lesson concludes by assessing how human activities disrupt this natural cycle.

GREENCOMP COMPETENCES

Promoting Nature, Systems Thinking

LEARNING OUTCOMES

By the end of the lesson, students will be able to:

- Understand that soil acts as the nitrogen cycle engine
- Describe how soil organisms make atmospheric nitrogen usable for plants
- Explain how soil animals (including earthworms) affect nitrogen in soil
- Identify environmental impacts of excess nitrogen (pollution, acidification, greenhouse gases)

KEY CONCEPTS

Denitrification, Nitrification, Nitrogen-Fixing Bacteria, Root Nodules

Background for teachers

SOIL AND NITROGEN CYCLE

Soil acts as a critical biological engine for the nitrogen cycle, a process essential for global nutrient cycling and terrestrial fertility. Because nitrogen is the most important nutrient for plant growth, its availability—controlled largely by soil organisms—directly dictates ecosystem health and productivity. The following sections summarise the specific roles and processes soil plays in the nitrogen cycle:

1. BIOLOGICAL NITROGEN FIXATION

Soil microorganisms can take gaseous nitrogen (which makes up 80% of the atmosphere) and convert it into ammonia, a form plants can utilise.

- Symbiotic Fixation: The most prominent example is Rhizobium bacteria, which form nodules on the roots of legumes (like beans and peanuts). In forests, actinomycetes such as Frankia form similar associations with trees, sometimes fixing more nitrogen than legume crops.
- Non-Symbiotic Fixation: Free-living organisms, including aerobic bacteria (Azotobacter), anaerobic bacteria (Clostridium), and photosynthetic cyanobacteria, also fix nitrogen directly in the soil.

2. NITROGEN MINERALISATION (AMMONIFICATION)

When plants and animals die, decomposers in the soil transform the organic nitrogen (found in proteins and amino acids) into inorganic forms.

- Ammonification: Most microorganisms involved in decomposition convert organic nitrogen into ammonium (NH4+).
- Nutrient Release through Grazing: Soil animals like protozoa and nematodes play a vital role here; as they graze on bacteria, they consume more nitrogen than they need and release the excess back into the soil as ammonium.

3. NITRIFICATION

While some plants can use ammonium, many require nitrate (NO3-). This transformation occurs in two steps mediated by specialised bacteria:

- **Step 1:** Bacteria such as Nitrosomonas and Nitrosococcus convert ammonia to nitrite.
- **Step 2:** Bacteria such as Nitrobacter and Nitrococcus convert nitrite to nitrate.
- **Archaea:** Recent evidence suggests that archaea also play a significant, though still largely unexplored, role in these soil nitrogen transformations.

4. THE ROLE OF "ECOSYSTEM ENGINEERS"

Larger soil animals, particularly earthworms, drastically influence nitrogen dynamics. Their burrows and casts create favourable environments for microbial activity, and their body tissues and excreta (urea and ammonia) are rapidly mineralised by the soil microbiota. Earthworm populations in agricultural systems can contribute significant nitrogen fluxes, ranging from 10 to 74 kg per hectare annually.

5. ENVIRONMENTAL IMPACTS AND GREENHOUSE GASES

The soil's role in the nitrogen cycle has significant implications for the atmosphere and soil health:

- Nitrous Oxide (N20): This potent greenhouse gas (310 times more powerful than C02) is produced as a byproduct of soil nitrification and denitrification processes.
- Soil Acidification: Excessive nitrogen fertilisation can lead to soil acidification. The process of nitrification releases hydrogen ions, which lowers soil pH, potentially reducing the availability of other essential nutrients and harming soil biodiversity.
- Pollution: Excess nitrogen that is not taken up by crops can leach into groundwater or enter surface water through runoff, leading to eutrophication and the loss of aquatic biodiversity.

PREPARATION 1H

- Print out the **"STATION CARDS"** for each table.
- Provide the necessary materials listed for each station.
- Put the "Nitrogen Cycle Map" image (blank) at every station or on a central wall so students can connect each station to the bigger process.

SUPPLEMENTARY MATERIAL

Animation PBS

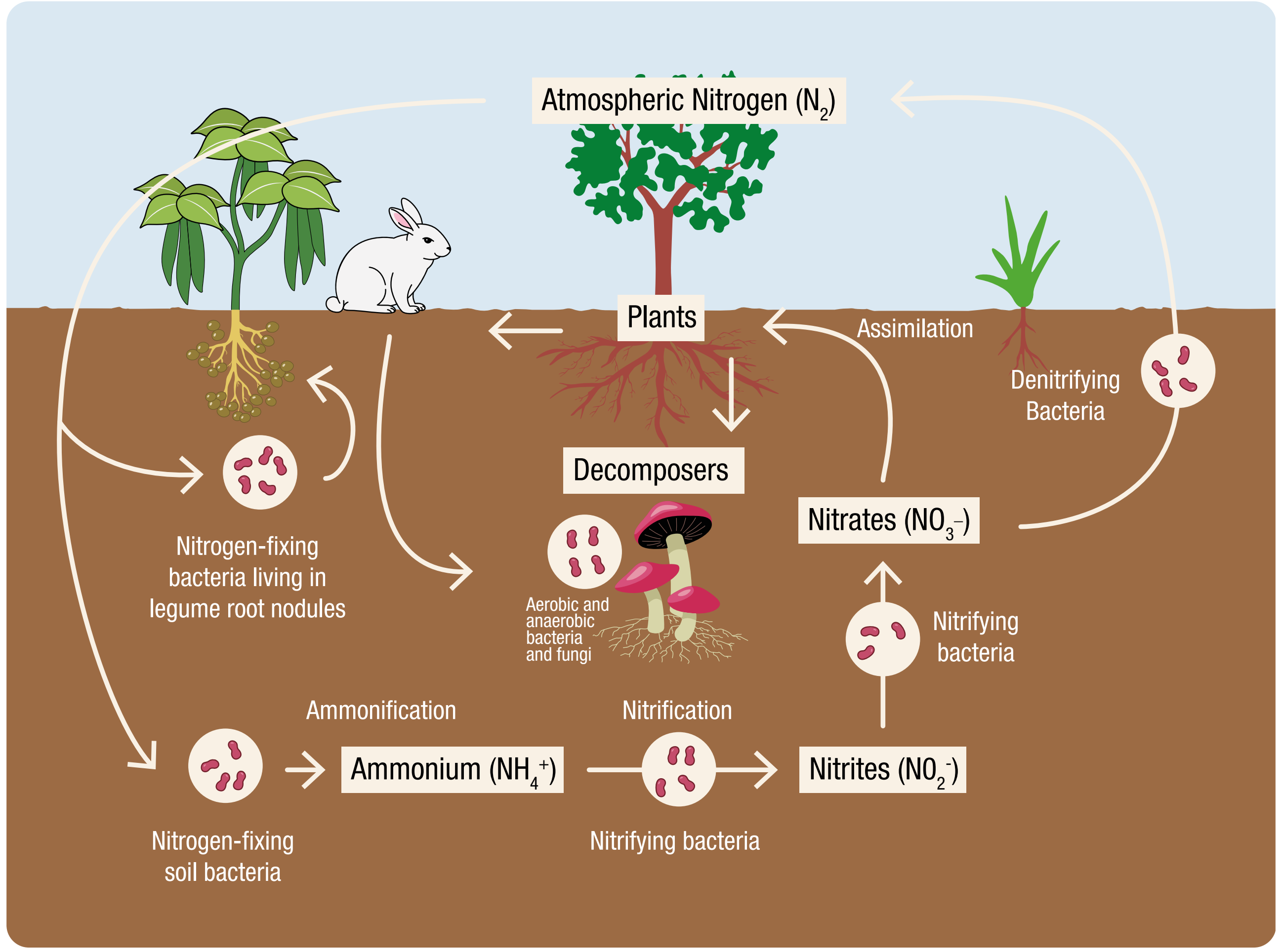


Fig. 1. The Soil Nitrogen Cycle: Key Processes and Organisms.

INTRODUCTION 5 MIN

1. Hook: The Invisible Nutrient. Begin by showing students a healthy plant (preferably with visible green leaves). Ask: "What do plants need to grow?" Students will likely mention water, sunlight, and soil. Then reveal that 78% of the air around us is nitrogen, yet plants are "starving" for it!

2. Write on the board: "How does nitrogen—essential for all life—move from the air into living things and back again?"

3. Inform about the lesson outcomes before proceeding to the activities.

PROCEDURE 70 MIN

4. Background Mini-Lecture. Share these key points (5 min)

- Nitrogen is everywhere: It makes up 78% of Earth's atmosphere, but exists as N_2 gas—two nitrogen atoms stuck together so tightly that most organisms cannot break them apart.
- Why nitrogen matters: Nitrogen is essential for DNA, proteins, and chlorophyll. Without it, plants cannot grow, and without plants, food webs collapse.
- The problem: Plants contain nitrogen (especially in leaves), but they cannot "breathe in" nitrogen gas from the air. They need it in solid forms like ammonia (NH_3) or nitrate (NO_3^-).
- The solution: Soil is the engine of the nitrogen cycle. Bacteria, fungi, earthworms, and other soil organisms transform nitrogen into forms that plants can use. Today, you'll discover how this "biological engine" works.

5. Introduce the Stations. Display a simplified nitrogen cycle diagram (or draw one on the board). Explain that students will rotate through five stations, each exploring a different part of the cycle:

STATION 1: How bacteria "catch" nitrogen from air (nitrogen fixation)
STATION 2: How decomposers recycle nitrogen from dead things (mineralization)
STATION 3: How bacteria transform ammonia into nitrate (nitrification)
STATION 4: How earthworms turbocharge the nitrogen cycle (ecosystem engineers)
STATION 5: What happens when the cycle breaks down (environmental impacts)

Inform students they'll have 12 minutes at each station. Complete all activities and record your observations in your journal. Divide your classroom into 5 groups and assign them to each station.

WRAP UP 15 MIN

Class Discussion: Connecting the Stations
Bring the class together. Use these guiding questions to synthesize learning:

- "Which stations involved bacteria? What did you notice about where these bacteria live and what they need?"
- "How are STATION 1 (nitrogen fixation) and STATION 3 (nitrification) similar? How are they different?"
- "If earthworms disappeared tomorrow, what would happen to the nitrogen cycle? Use evidence from STATION 4."

Display this question on the board and have students write a response on an exit ticket (index card or half-sheet): ***"If we sterilized the soil and killed all the bacteria, fungi, and earthworms, could we just add chemical nitrogen fertilizer to make plants grow forever? Why or why not?"***

Scaffolding prompts (write on board):
- Think about soil structure and aeration...
- What would happen to dead plant material without decomposers?

Consider the environmental impacts from STATION 5...

Expected Answer

No, soil cannot be replaced by chemicals alone. Students should mention several key points:

- **Soil structure collapse:** Without earthworms to create burrows, soil becomes compacted. Water and oxygen cannot penetrate, killing plant roots.
- **No nitrogen cycling:** Dead plant material wouldn't decompose (no mineralization), and ammonia wouldn't convert to nitrate (no nitrification). Nitrogen would accumulate in unusable forms.
- **Environmental disaster:** Chemical fertilizers would leach directly into waterways (no organisms to absorb or transform them), causing massive pollution, algal blooms, and dead zones.
- **Acidification:** Continuous chemical fertilizer use without biological buffering would acidify soil, making it toxic to plants.
- **Loss of resilience:** The "biological engine" of soil provides flexibility—organisms adapt to conditions. A purely chemical system is rigid and fragile.

Soil is not just "dirt"—it's a living ecosystem. The nitrogen cycle depends on the biological engine (bacteria, fungi, earthworms, other organisms) working together. Chemicals alone cannot sustain life.

HANDOUT A6.1 PAGE 1/1

NITROGEN CYCLE LEARNING STATIONS

STATION 1: "CATCH AIR NITROGEN!" (BIOLOGICAL NITROGEN FIXATION)

Question: How do plants get nitrogen from the air?

Materials

→ Legume plant root (peas, soybeans, lentils, or lupins)
→ Magnifying glass
→ Fine tweezers and scissors
→ Images of root nodules (provided)

Background Information

The atmosphere is 78% nitrogen gas (N_2), but plants cannot use it directly—they need it in solid form! Special bacteria called Rhizobium live inside bumps on legume roots called nodules. These bacteria perform biological nitrogen fixation: they capture nitrogen gas from air pockets in the soil and convert it into ammonia (NH_3), which plants can use to make proteins and DNA. Nitrogen is a limiting nutrient—without enough of it, plants cannot grow properly, no matter how much sunlight or water they receive.

Procedure

→ Carefully examine the legume root. Look for small, round bumps (nodules) attached to the roots.
→ Using tweezers, gently remove one nodule. Cut it in half with scissors.
→ Observe the inside color with your magnifying glass. A pink or reddish color indicates active nitrogen fixation!
→ The pink color comes from leghemoglobin, a molecule produced when bacteria and plants work together.

Journal Tasks

→ Draw: Sketch a root with nodules. Label the nodule and the bacteria inside.
→ Write the equation: N_2 (gas from air) → NH_3 (ammonia—plant food)
→ Explain: Why do we call this a "partnership"?
(Hint: bacteria get sugar from the plant; the plant gets nitrogen from the bacteria.)

HANDOUT A6.2 PAGE 1/1

NITROGEN CYCLE LEARNING STATIONS

STATION 2: "FROM DEAD STUFF TO PLANT FOOD" (MINERALIZATION & AMMONIFICATION)

Question: How do decomposers recycle nitrogen from dead organisms?

Materials

→ "Organic Matter" cards (pictures of dead leaves, food scraps, dead insects)
→ "Decomposer" cards (bacteria and fungi)
→ "Grazer" cards (protozoa and nematodes—microscopic animals)

Background Information

When plants and animals die, their bodies contain organic nitrogen (proteins, DNA). Decomposers—bacteria and fungi—break down this organic matter through mineralization (also called ammonification), releasing nitrogen as ammonium (NH_4^+). Tiny soil animals called grazers (protozoa and nematodes) eat bacteria and release extra nitrogen as ammonium in their waste. This makes nitrogen available to plants again!

Activity

→ Select three "Organic Matter" cards (examples: dead leaf, apple core, dead beetle).
→ Match each with appropriate "Decomposer" cards. Who breaks down each type of matter?
→ Add "Grazer" cards to show how they speed up the process by eating bacteria.

Journal Tasks

→ Create a flow diagram: Dead Organism → Decomposers → NH_4^+ (Ammonium)
→ Explain: Why are decomposers called "nature's recyclers"? What would happen to nitrogen if decomposers didn't exist?

HANDOUT A6.3 PAGE 1/1

NITROGEN CYCLE LEARNING STATIONS

STATION 3: "TWO-STEP CONVERSION FACTORY" (NITRIFICATION)

Question: How does ammonia become nitrate?

Materials

→ Microbe cards labeled "Step 1 Bacteria" (Nitrosomonas, Nitrosococcus)
→ Microbe cards labeled "Step 2 Bacteria" (Nitrobacter, Nitrococcus)
→ Mystery helper card (Archaea—ancient microorganisms)

Background Information

Many plants prefer nitrate (NO_3^-) over ammonium (NH_4^+). Nitrification is a two-step process that converts ammonium into nitrate:
→ Step 1: Bacteria like Nitrosomonas convert ammonium (NH_4^+) into nitrite (NO_2^-).
→ Step 2: Different bacteria like Nitrobacter convert nitrite (NO_2^-) into nitrate (NO_3^-).
These bacteria need oxygen to work—they're like tiny factories powered by oxygen! Archaea (ancient microbes) can also help with Step 1.

Activity

Arrange the microbe cards in the correct sequence on your workspace.

Journal Tasks

→ Create a flowchart: NH_4^+ (Ammonium) → [Step 1 Bacteria] → NO_3^- (Nitrite) → [Step 2 Bacteria] → NO_2^- (Nitrate)
→ Why do these bacteria need oxygen?
(Hint: They use oxygen to get energy from the chemical reactions.)

HANDOUT A6.4 PAGE 1/1

NITROGEN CYCLE LEARNING STATIONS

STATION 4: "ECOSYSTEM ENGINEERS" (EARTHWORMS & NITROGEN CYCLING)

Question: How do earthworms help nitrogen move through soil?

Material

→ Observation of earthworm farm (see **HANDOUT A4.3** for instructions) OR video of earthworms in soil (https://www.youtube.com/watch?v=XVjTwkrVhtY)
→ Calculator

Background Information

Earthworms are called "ecosystem engineers" because they physically change their environment in ways that help other organisms. They:
→ Dig burrows that allow air and water to penetrate deeper into soil
→ Produce waste (casts) rich in nitrogen—up to 5 times higher than surrounding soil!
→ Create conditions that help nitrifying bacteria (from Station 3) thrive

Data: Nitrogen in Soil vs. Earthworm Waste

NITROGEN TYPE	REGULAR SOIL	EARTHWORM CASTS
Nitrate (NO_3^-) content	0.004‰	0.022‰

Note: ‰ means "parts per thousand." Earthworm casts contain 5.5× more nitrate than regular soil!

Math Activity: Calculate Nitrogen Contributions

Earthworm populations add between 10 kg and 74 kg of nitrogen per hectare per year, depending on soil health. Calculate the impact on a 5-hectare farm:
→ Scenario A (Healthy Soil): Worms add 74 kg/hectare. Total nitrogen = _____
→ Scenario B (Degraded Soil): Worms add only 10 kg/hectare. Total nitrogen = _____
→ Difference: How much nitrogen "fertilizer" does the farmer lose with degraded soil? _____

Journal Tasks

→ Show your calculations for all three questions above.
→ Explain the connection: How do earthworm burrows help the bacteria from **STATION 1** (nitrogen fixation) and **STATION 3** (nitrification)? (Hint: Both types of bacteria need oxygen!)

STATION 5: "WHEN NITROGEN GOES WRONG" (ENVIRONMENTAL IMPACTS OF NITROGEN)

Question: What happens when the nitrogen cycle gets out of balance?

Denitrification—Nitrogen Returns to Air

Denitrification is the process where bacteria (Pseudomonas, Paracoccus, Thiobacillus, Bacillus) convert nitrate (NO_3^-) back into nitrogen gases (N_2 or N_2O) that escape to the atmosphere. This happens in oxygen-poor environments: waterlogged soils (rice paddies, wetlands), sediments, and sewage treatment plants.
Why does this matter?
→ For agriculture: Soil loses fertility as nitrate "escapes" instead of feeding plants.
→ For climate: Nitrous oxide (N_2O) is a powerful greenhouse gas—300× stronger than CO_2!
→ For water treatment: Engineers use denitrifying bacteria to remove excess nitrate from wastewater before releasing it to rivers.

Agricultural Nitrogen Loss & Pollution

Intensive farming removes nitrogen from soil because crops are harvested and don't decompose back into the soil. Farmers add chemical fertilizers (ammonia NH_3, nitrate NO_3^-) to replace it. However, excess fertilizer can wash out of soil (leaching) and pollute rivers, lakes, and groundwater, causing:
→ Algae blooms: Excess nitrogen feeds algae, which block sunlight and deplete oxygen when they die, killing fish.
→ Health risks: High nitrate in drinking water is dangerous, especially for infants.

Data: Impact of Nitrogen-Fixing Bacteria on Crop Yield. Crop: Lupin (a legume) grown on 10,000 m² of farmland

GROWING CONDITION	SEED HARVEST (TONNES)	NITROGEN IN SEEDS (%)
WITHOUT nitrogen-fixing bacteria	2.2	4.4%
WITH nitrogen-fixing bacteria	4.2	6.0%

Key observation: With nitrogen-fixing bacteria, farmers get nearly double the harvest AND higher-quality seeds with more protein!

Journal Tasks

→ Compare: Look at the lupin data. How much more crop did the farmer get with bacteria? Calculate the percentage increase in harvest.
→ Explain denitrification: Write the equation: NO_3^-(nitrate) → N_2 or N_2O (gases). Why is this process both helpful (in sewage treatment) and harmful (in agriculture and climate)?
→ Problem-solving: Farmers want to reduce fertilizer use and pollution.
Based on what you learned in **STATIONS 1 AND 4**, suggest two sustainable strategies they could use.
(Hint: Think about legumes and earthworms!)

PART B: FROM THE GROUND UP
SOILS, CLIMATE CHANGE,
AND NEW SOIL HORIZONS

LESSON B1 HOW DO OUR ACTIONS SHAPE THE SOIL?

MAIN SUBJECTS	DURATION	AGE GROUP	TEACHING METHOD
Natural Sciences, Social Studies	1h20	15+	Case Studies

OVERVIEW

In this lesson, students will analyse the impacts of human activities on soil functions in seven countries: Denmark, France, Italy, Poland, Portugal, Romania, Spain. They will explore how sustainable soil management strategies can preserve healthy soil and limit soil degradation.

GREENCOMP COMPETENCES

Promoting Nature, Systems Thinking

LEARNING OUTCOMES

By the end of the lesson, students will be able to:

- Evaluate the impact of some human activities on soil functions and health
- Examine how simple sustainable soil management strategies can help restore soil functions

KEY CONCEPTS

Soil Degradation, Soil Health, Sustainable Soil Management

Background for teachers

Human activities and soil degradation

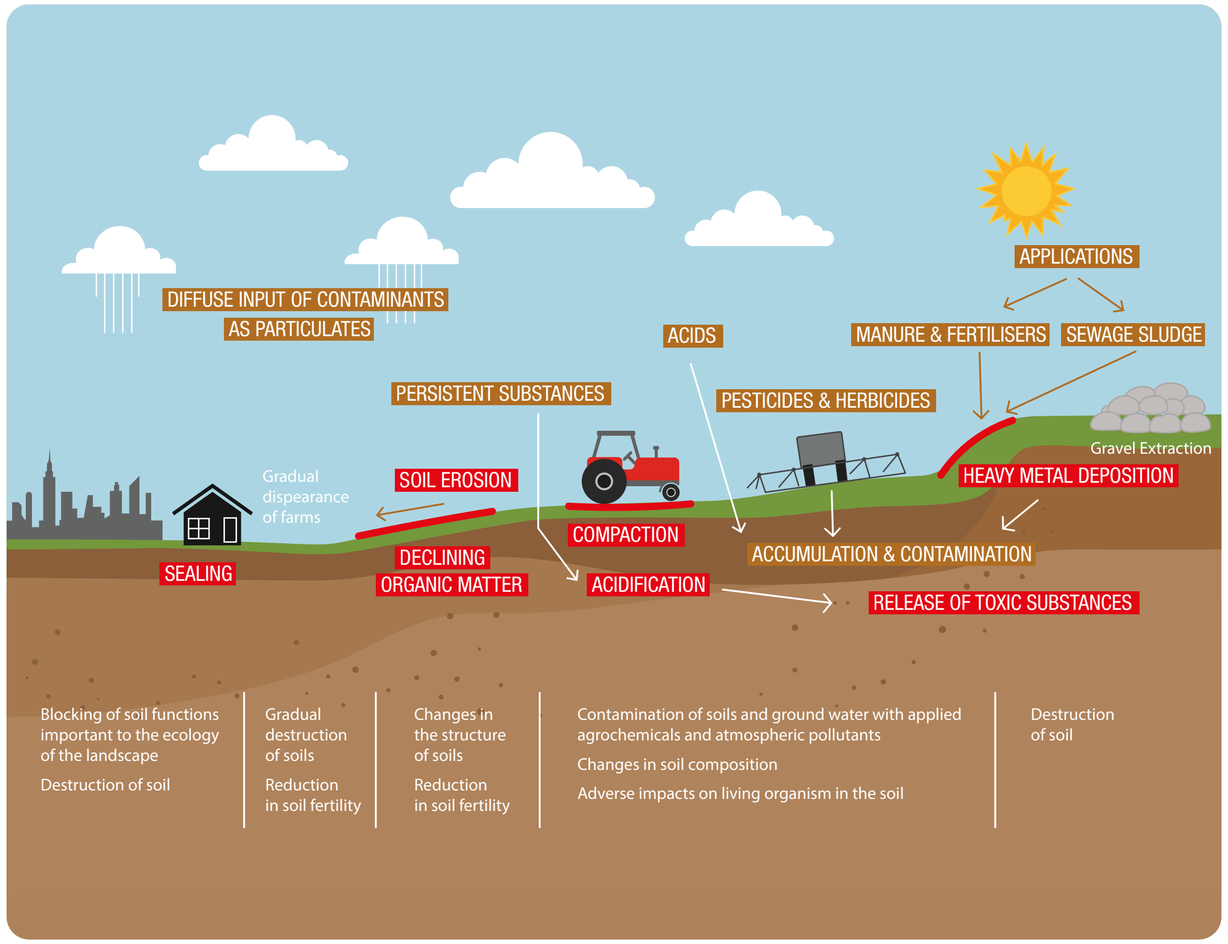


Fig. 1. Impact of human activities on soil, causing risk of soil degradation. Source: adapted from XXXXXX

Soil degradation refers to the decline in soil health that reduces its capacity to perform essential functions. Human activities are the primary contributors, with about 63% of soils in the European Union affected.

Key types of soil degradation include:

1. SOIL EROSION

- Water and wind erosion: caused by poor land management practices such as deforestation and overgrazing.
- Tillage erosion: caused by agricultural practices (ploughing, cultivation) that gradually move soil downslope.

2. SOIL SEALING AND LAND TAKE

Permanent covering of soil with materials like asphalt and concrete due to urbanisation and industrialisation, preventing water infiltration.

3. SOIL COMPACTION

Soil densification caused by heavy machinery, livestock trampling, and urban pressure from foot and vehicle traffic.

4. SOIL POLLUTION

Pollution from industrial emissions, excessive agricultural inputs, and mining, leading to high levels of harmful chemicals in the soil.

5. DECLINE IN ORGANIC MATTER AND CARBON

Intensive agricultural practices and peatland degradation reducing soil organic matter and diminishing soil health.

6. SALINISATION AND ACIDIFICATION

- Salinisation: caused by unsustainable irrigation and poor drainage.
- Acidification: caused by the use of nitrogen fertilisers and industrial pollutants.

7. LOSS OF SOIL BIODIVERSITY

Human activities reducing soil life through monocultures, pesticide use, and mechanical disturbances, leading to reduced biodiversity.

PREPARATION

MATERIALS

- Print **HANDOUTS B1.1, B1.2, B1.3, B1.4, B1.5, B1.6, B1.7** per group of students
- Print **HANDOUT B1.8** for each student.

SUPPLEMENTARY MATERIAL

How Do Human Activities Impact Soils ?

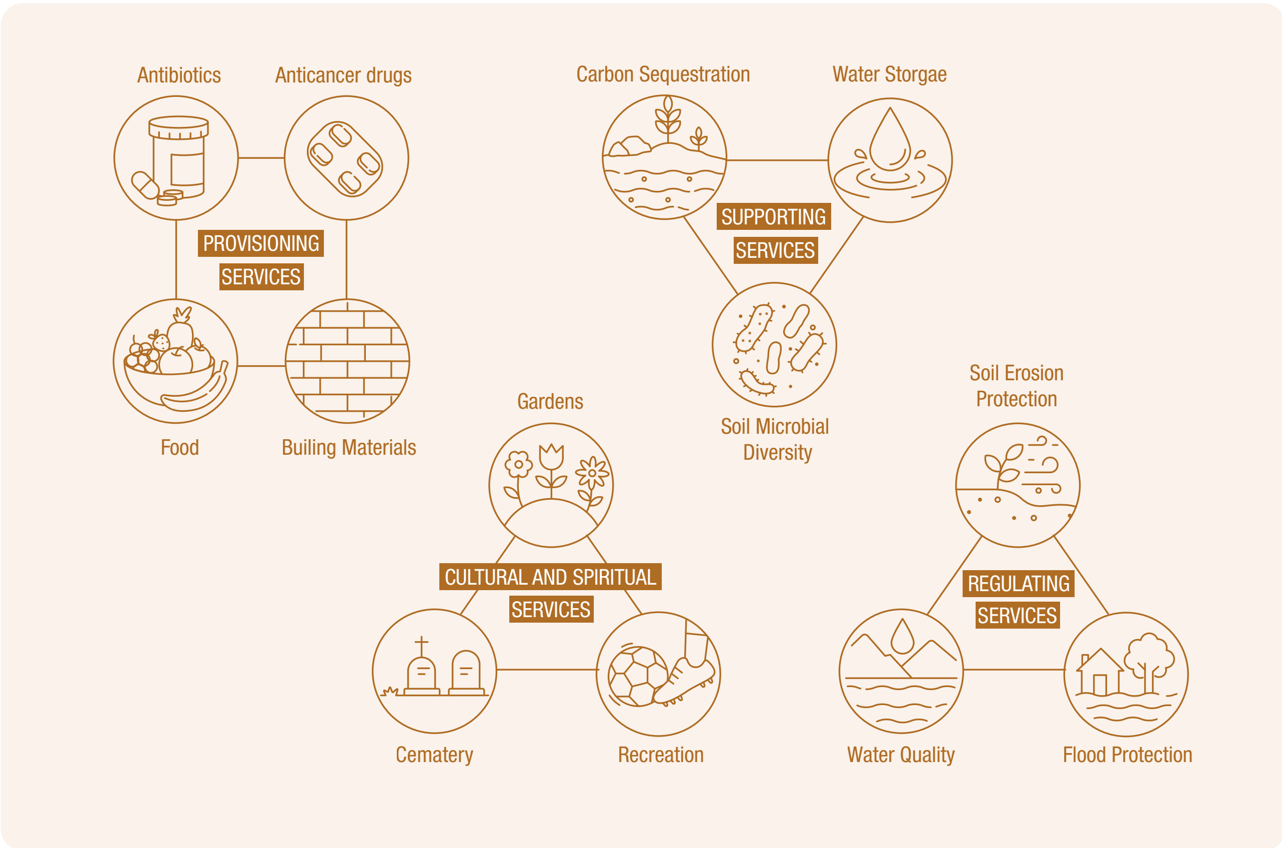


Fig. 2. Soil Ecosystem Services: Four Categories of Benefits Provided by Soils. Source: European Environment Agency (2024)

INTRODUCTION

WARM UP 10 MIN

1. Invite students to share what they already know about soil ecosystem services and the essential functions that soils provide.

2. Share the expected learning outcomes for the session and ensure students have understood them before explaining the activity.

PROCEDURE 1H

PART 1: EXAMINING CASE STUDIES OF HUMAN IMPACT ON SOIL FUNCTIONS ACROSS EUROPE 40 MIN

3. Ask students to think of different ways human societies affect soil and write their ideas on the whiteboard. These may include urbanisation, pollution, climate change, erosion, and deforestation.

4. Ask them to discuss the specific soil and land damage caused by human activities in their area, and to link these impacts to particular soil functions. For instance, deforestation directly affects carbon capture and climate regulation, while urbanisation or intensive agriculture affect habitats for organisms.

5. Then present the procedure to your students: working in groups, they will analyse the impacts of human activities on natural environments and soils across seven countries (Denmark, France, Italy, Poland, Portugal, Romania, Spain) and link these examples to specific soil functions.

6. Consider using a jigsaw puzzle strategy for this activity:

- **Phase 1:** Each group of students becomes country experts by analysing the documents for their assigned country. You will need at least seven groups, each with up to four students, working on one case study per country. Distribute one copy of the relevant country case study **HANDOUT (B2.1-B2.7)** per group.
- **Phase 2:** Students are reorganised into new groups, each including one expert from each country. They then work together on **HANDOUT B1.8.**

7. As a wrap-up for Part 1, conduct a whole-class discussion:

> *How are human activities affecting soil in the different case studies across Europe? What types of impacts did we find on land and soil, and how are they linked to soil functions?*

Conclude by highlighting that soil functions are similarly affected by different soil management practices across Europe.

PART 2: EXPLORING SUSTAINABLE SOIL MANAGEMENT PRACTICES TO MAINTAIN HEALTHY SOIL 20 MIN

8. Display the "Keys to Healthy Soil" infographic and discuss how these practices contribute limit soil degradation

9. Invite students to return to **HANDOUT B1.8** and have them discuss in group what sustainable soil management practices could be recommended to limit soil degradation or restore soil functions in the cases they studies.

Fig 1. Keys to Healthy Soil.

WRAP UP 10MIN

Invite students to reflect on their learning:

> *Were they surprised by the extent of soil degradation? Looking at our local environment, which of the four 'Keys to Healthy Soil' from the infographic (avoid disturbance, boost biodiversity, keep soils covered, protect roots) would be most beneficial to implement in our region, and why?*

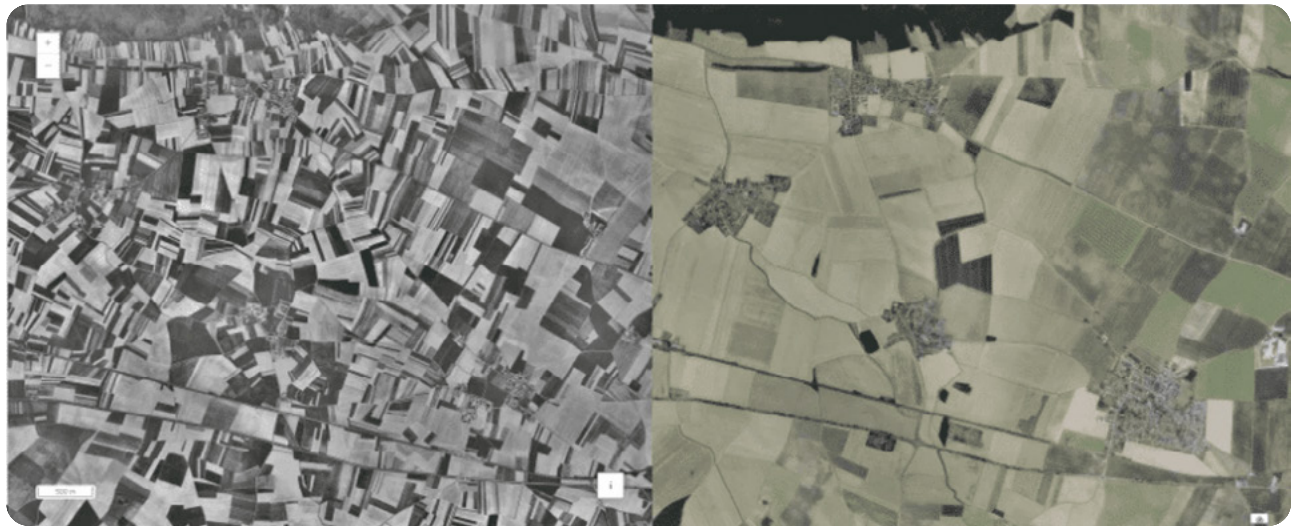
You can conclude the lesson with some good news: in December 2025, the EU adopted its first Soil Monitoring and Resilience Law in response to the significant challenge of soil degradation across Europe, where 60–70% of soils are in an unhealthy state. The goal of this new law is to create a common EU-wide framework for monitoring soil health, addressing soil contamination, tracking land use (including soil sealing and removal), and supporting sustainable soil management practices. This legislation puts the EU on a path toward achieving healthy soils by 2050.

HANDOUT B1.1 PAGE 1/2

CASE STUDY 1: INTENSIVE AGRICULTURE IN THE BEAUCE AREA OF FRANCE

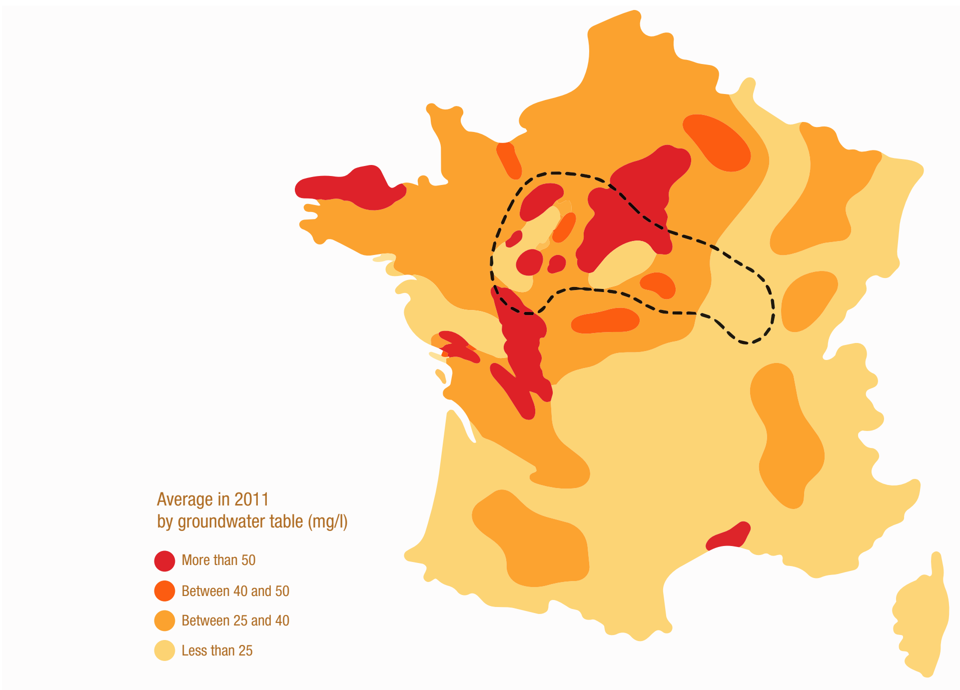
The Beauce, an agricultural region in France, south of Paris with sandstone bedrock and rich soils, has long been productive, yielding large quantities of cereals (maize, wheat, etc.) each year. It is known as the "granary of France" and is now considered an example of an agroecosystem dominated by intensive agriculture.

DOCUMENT 1. AERIAL/GROUND PHOTOS OF THE BEAUCE REGION (INTENSIVE AGRICULTURE)



An illustration of the simplification of agricultural landscapes. Left: before 1945; right: after the 1970s. The effects of land consolidation, specialisation and farm enlargement in the Beauce region (Revue Histoire, 2022)

DOCUMENT 2. MAP REPRESENTING THE AVERAGE CONCENTRATION OF NITRATE IN GROUNDWATER IN FRANCE IN 2011. THE DOTTED LINE REPRESENTS THE BEAUCE REGION



HANDOUT B1.1 PAGE 2/2

CASE STUDY 1: INTENSIVE AGRICULTURE IN THE BEAUCE AREA OF FRANCE

Question 1 Look closely at the fields in both images. Are they all the same shape? Do you see any forests or trees?

Question 2 What has changed between 1950 and 2025?

Question 3 What do you think happens to the water when it rains?

Question 4 Could this type of farming harm the soil? If so, how?

Question 5 Find areas on the map with very high nitrate levels. What do you think causes this?

Question 6 What could be done to protect the soil and water?

Question 7 Describe which soil function(s) is/are impaired by this recent land management?

Question 8 Write a short paragraph linking all the documents and any additional information you may have gathered to explain how intensive agriculture in the Beauce region affects the soil, the environment, and the human population.

USEFUL LINKS

EU regulation for nitrate contamination: Groundwaters should contain less than 50 mg/l nitrates

DOCUMENT 1. PHOTO OF AN ILLEGAL LANDFILL

Source: National Archives and Records Administration

DOCUMENT 3. LIFE EXPECTANCY IN ITALY AND CAMPANIA (NAPOLI REGION)

	CAMPANIA	ITALY
Men	76.91	78,44
Women	83,5	83,97

Source: Istat 2006

DOCUMENT 2. EXCERPT FROM A RESEARCH ARTICLE

"Over the past three decades, criminal organisations operating in the area (known as "Camorra") have turned illegal waste trafficking into a prosperous business, with estimated revenues of 600 million Euros per year in Campania alone. The widespread incineration of waste, including plastic and rubber materials, solvents, waste from non-authorised leather factories (mainly based on Chinese undocumented workers) in such a highly populated area, has caused concern about the hazardous effects related to the uncontrolled release of dangerous pollutants into the environment, primarily dioxins, polychlorinated biphenyls (PCBs) and heavy metals. The risk of environmental and biological contamination in the "Land of Fires" has been tackled by several public health interventions, some of which have required specific legislative measures."

Source: Heavy Environmental Pressure in Campania and Other Italian Regions: A Short Review of Available Evidence, Mazza et al., Int. J. Environ. Res. Public Health 2018,

Question 1 What are the people in the photo doing?

Question 2 What kind of consequences could their actions have on the land and the environment?

Question 3 What differences do you notice in life expectancy between Campania and the rest of Italy?

Question 4 What can be the causes (at least 2) in the difference in life expectancy shown in Doc 3?

Question 5 Describe which soil function(s) is/are impaired by this recent land management?

Question 6 Write a short paragraph linking all the documents and additional information you may have gathered to explain how illegal human activities north of Naples in Italy affect the soil, the environment, and the human population.

HANDOUT B1.3 PAGE 1/2

CASE STUDY 3: INDUSTRIAL HERITAGE OF MINES (POLAND)

In Poland, in the Katowice region, intensive industrial activity, including mining for various minerals, has been ongoing for many years. These activities have impacted local soil and the environment, altering the landscape.

DOCUMENT 1. PHOTOS OF THE LANDSCAPE OF THE MINING REGION NEAR THE VILLAGE OF TARNOWSKIE GORY.

1A. The mine was still active in 1941. It extracted various minerals, including zinc, lead, and silver. On the right, a spoil pit has formed from the accumulation of soil and stones (called dolomites) as byproducts of the mining activities.

1B. This photo was taken at the exact location in 2016, after the mines were shut down in 2006.

DOCUMENT 2. DIAGRAM SHOWING THE VARIOUS IMPACTS OF MINING AND INDUSTRIAL RESIDUES (CALLED SIDERURGY) IN THE REGION.

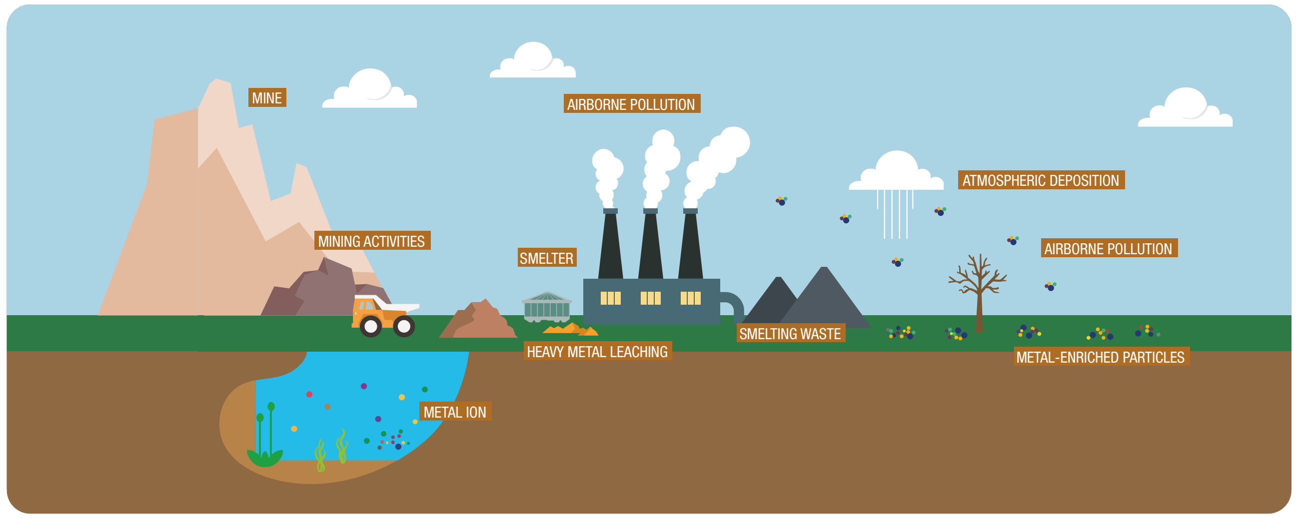


Fig 3. Adapted from XXXXX

HANDOUT B1.3 PAGE 2/2

CASE STUDY 3: INDUSTRIAL HERITAGE OF MINES (POLAND)

Question 1 What changes do you notice between the two photos?

Question 2 How would you describe the mining industry in this region and its potential effects on the local geology?

Question 3 Explain the diagram (Doc 2) in your own words.

Question 4 What are the negative impacts of the mining industry?

Question 5 In your opinion, are these impacts limited to the soil, or do they affect other parts of the environment as well?

Question 6 Describe which soil function(s) is/are impaired by this recent land management?

Question 7 Write a short paragraph linking all the documents and any additional information you may have gathered, to explain how the mining industry in Poland affects soil, the environment, and the human population.

In southern Spain, there is a region with intensive agriculture focused on growing vegetables, such as tomatoes, under plastic greenhouses. This industry supplies tomatoes to the entire European market year-round.

DOCUMENT 1. VARIOUS VIEWS OF THE ALMERIA REGION, FROM SATELLITE IMAGERY TO GROUND-LEVEL PERSPECTIVES.

You can access this document via the multimedia animation at https://www.oce.global/animations/agriculture-final-version-3/agriculture.html.

DOCUMENT 2. VARIOUS USES OF PLASTIC IN AGRICULTURE IN ALMERIA

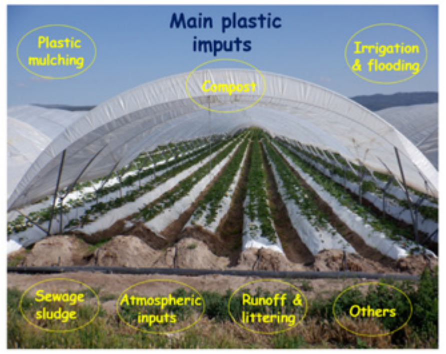


Fig 1. Source: Mongil-Manso et al. (2023)

DOCUMENT 3. HOW PLASTIC AND OTHER POLLUTANTS FROM AGRICULTURE REACH THE SOIL AND GROUNDWATER.

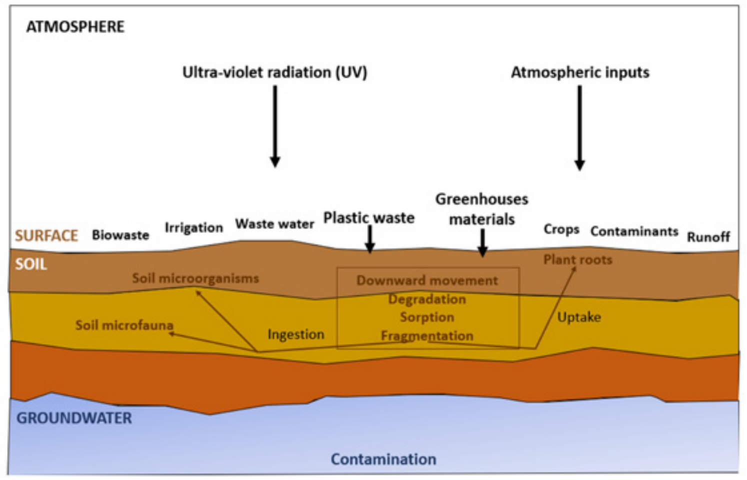


Fig 3. Source: Mongil-Manso et al. (2023)

Question 1 Based on the photos, how would you describe the environment in this region?

Question 2 What kind of impacts might this type of agriculture have on the soil in southern Spain?

Question 3 Can you describe the path of a specific plastic element, such as greenhouse materials, from its use in agriculture to its infiltration into soil and groundwater?

Question 4 How might this affect biodiversity?

Question 5 Describe which soil function(s) is/are impaired by this recent land management?

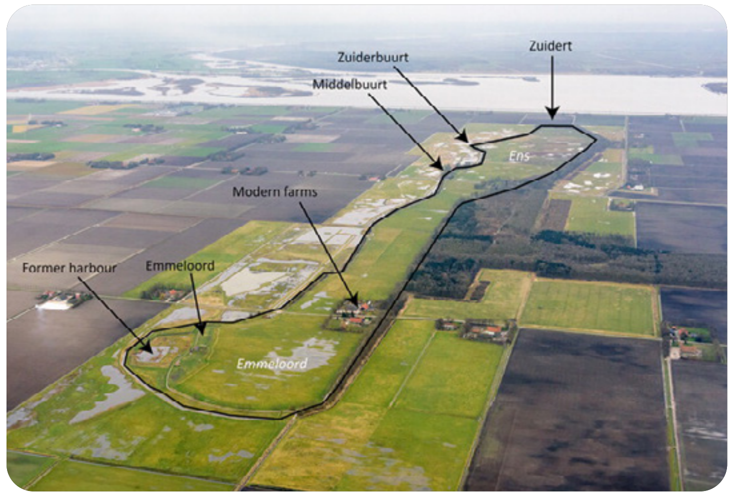
Question 6 Write a short paragraph linking all the documents and any additional information you may have gathered to explain how greenhouse agriculture in southern Spain affects the soil, the environment, and the human population.

HANDOUT B1.5 PAGE 1/2

CASE STUDY 5: PEAT SOIL OXIDATION IN DENMARK

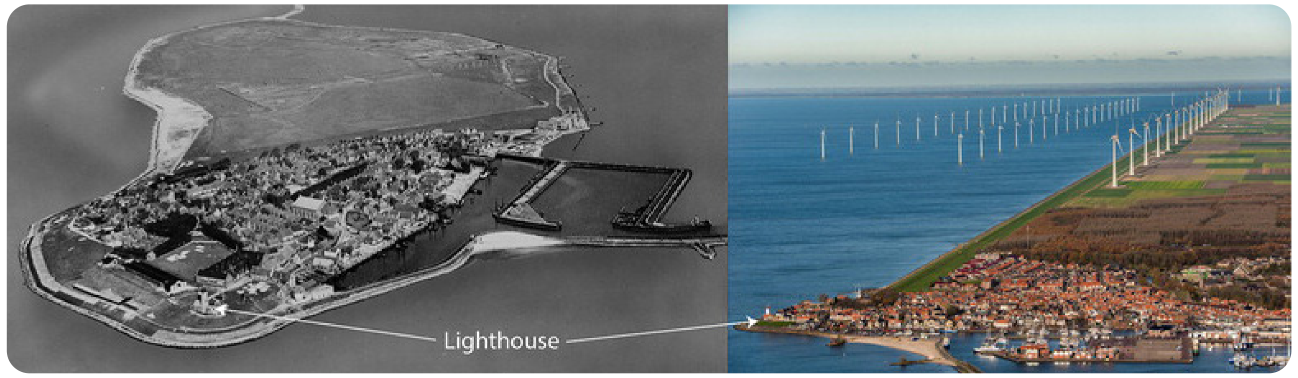
In Denmark, the land is very flat, and much of it lies below sea level. Since the Middle Ages, farmers and engineers have used dams and land reclamation techniques to gain land from the sea. These newly reclaimed areas are mainly used for agriculture, but also for urban development and other uses.

DOCUMENT 1. THE ISLAND OF URK AND SCHOKLAND BEFORE AND AFTER THE POLDERS WERE BUILT.



South-facing aerial photograph of the Noordoostpolder region, depicting the modern-day polder landscape (arable fields and farms) and the former island Schokland (black outline) with its abandoned settlements (Y.T. van Popta).

DOCUMENT 2. THE ISLAND OF URK BEFORE (LEFT) AND AFTER (RIGHT) THE RECLAMATION OF THE ZUIDERZEE.



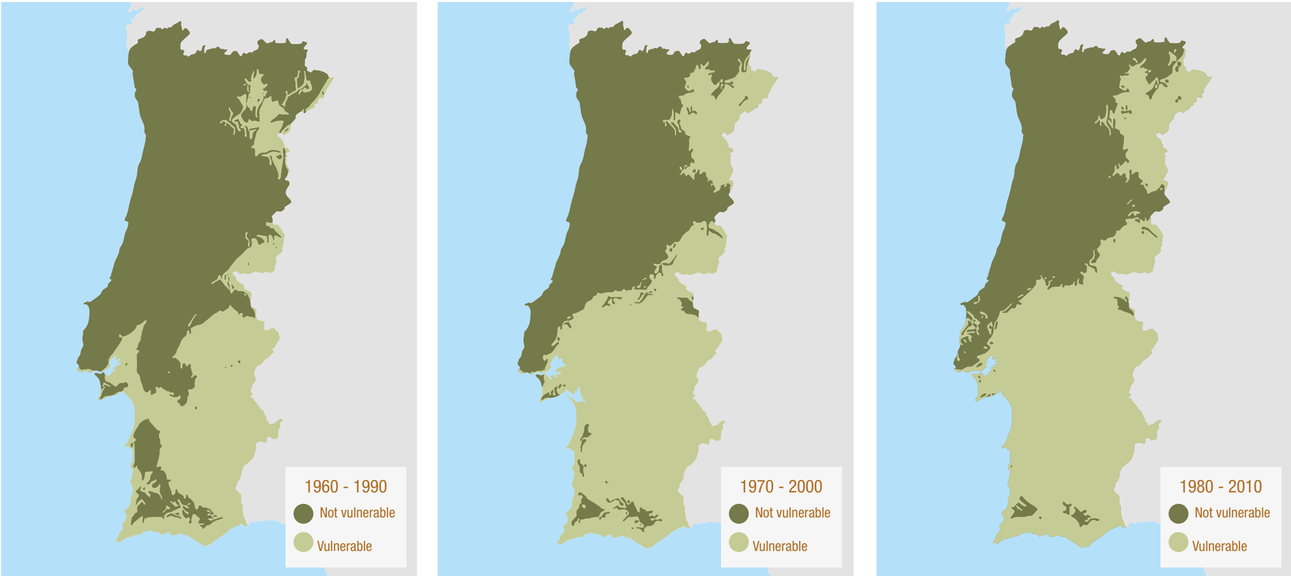
HANDOUT B1.5 PAGE 2/2

CASE STUDY 5: PEAT SOIL OXIDATION IN DENMARK

Conclusion Describe which soil function(s) is/are impaired by this recent land management?
Write a short paragraph linking all the documents and any additional information you may have gathered to explain how polders in Denmark affect the land, the soil, the environment, and the human population.

Desertification occurs when the local climate is hot, and the soil becomes dry. In Portugal, the local environment is conducive to desertification, with high temperatures and low rainfall. Human-induced climate change is increasing temperatures and reducing rainfall, which further raises the risk of desertification. Some agricultural regions with intensive practices, such as Alentejo, may contribute to this process.

DOCUMENT 1. EVOLUTION OF DESERTIFICATION IN PORTUGAL



DOCUMENT 2. EXAMPLE OF INTENSIVE AND EXTENSIVE AGRICULTURE IN RURAL REGIONS OF PORTUGAL, SUCH AS ALENTEJO

Question 1 Comment on the maps in Document 1. How has desertification evolved in Portugal since 1960?

Question 2 What is the situation in the Alentejo region?

Question 3 Based on the photos, which type of agriculture (intensive or extensive) has a higher impact on the land?

Question 4 What factors can contribute to desertification?

Question 5 Describe which soil function(s) is/are impaired by this recent land management?

Question 6 Write a short paragraph linking all the documents and any additional information you may have gathered to explain how desertification in Portugal affects the land, the soil, the environment, and the human population.

HANDOUT B1.7 PAGE 1/2

CASE STUDY 7: DEFORESTATION IN ROMANIA

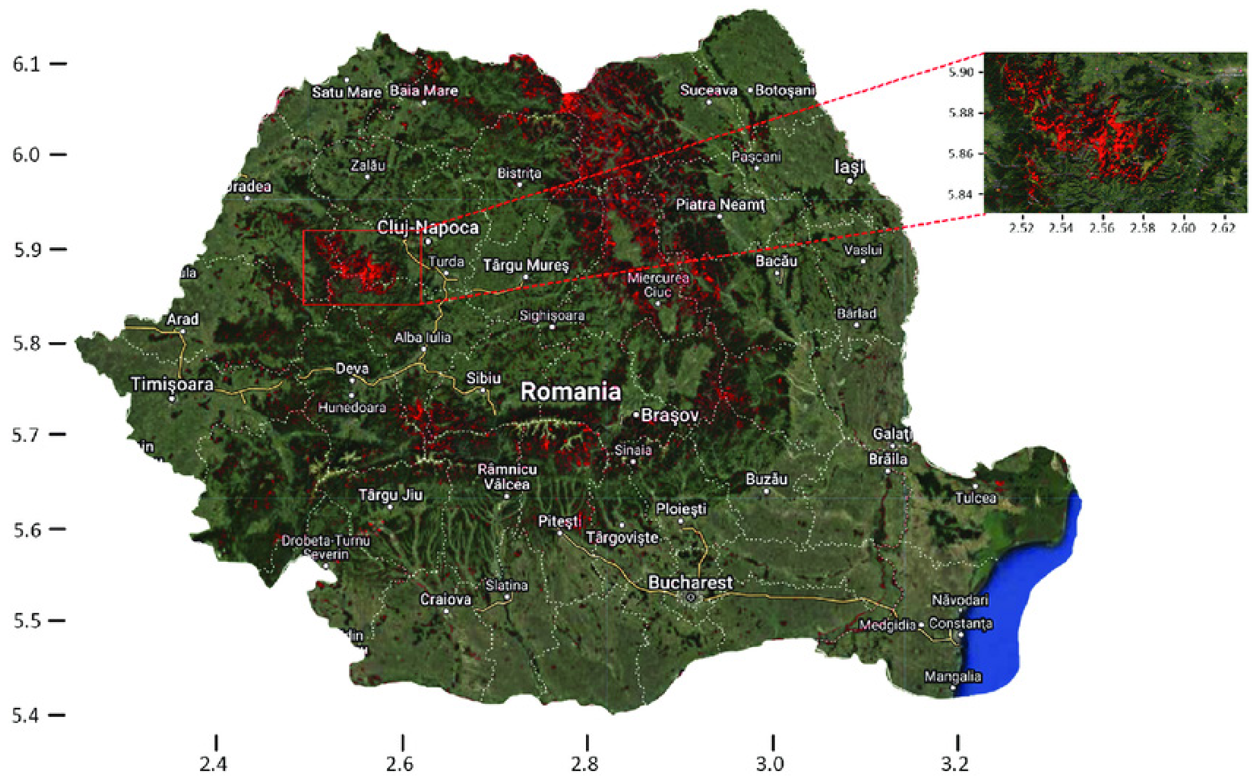
Romania, notably the Carpathian Mountains, is heavily forested and contains some of the oldest primary forests in Europe. However, over the past decades, illegal deforestation has increased in these regions, threatening these unique ecosystems.

DOCUMENT 1. PHOTOS OF (A) A HEALTHY FOREST IN ROMANIA AND (B) A FOREST THAT ILLEGAL LOGGERS RECENTLY CUT.

credit (a): Zaid Irshaid,

source

DOCUMENT 2. MAP SHOWING FOREST LOSS IN ROMANIA BETWEEN 2000 AND 2021, DEPICTED IN RED. IN THE TOP-RIGHT CORNER, AN ENLARGED IMAGE HIGHLIGHTS AN AREA WITH SEVERE DEFORESTATION IN THE WESTERN CARPATHIANS



HANDOUT B1.7 PAGE 2/2

CASE STUDY 7: DEFORESTATION IN ROMANIA

Question 1 Describe the two photos. What differences do you notice between them?

....

....

....

Question 2 How do you think the soil differs between the healthy forest and the recently logged area?

....

....

....

Question 3 Describe the map in Document 2. Can you estimate how significant the deforestation in Romania has been between 2000 and 2021?

....

....

....

Question 4 Describe which soil function(s) is/are impaired by this recent land management?

....

....

....

Question 5 Write a short paragraph linking all the documents and any additional information you may have gathered to explain how deforestation in Romania affects the land, the soil, the environment, and the human population.

....

....

....

HANDOUT B1.8 PAGE 1/1

OVERVIEW OF CASE STUDIES OF HUMAN ACTIVITIES AND THEIR IMPACT ON SOIL FUNCTIONS IN SOME EU COUNTRIES SUGGESTED IMPRESSION A3 FORMAT

CASE 1 **Illegal landfills** (Italie)
Impact on soil functions:

Suggested strategies to limit the impact:

CASE 2 **Intensive Greenhouse Agriculture Production** (Spain)
Impact on soil functions:

Suggested strategies to limit the impact:

CASE 2 **Desertification** (Portugal)
Impact on soil functions:

Suggested strategies to limit the impact:

CASE 1 **Intensive Agriculture** (France)
Impact on soil functions:

Suggested strategies to limit the impact:

CASE 1 **Soil Peat Oxidation to create new land** (Denmark)
Impact on soil functions:

Suggested strategies to limit the impact:

CASE 1 **Industrial heritage of mines** (Poland)
Impact on soil functions:

Suggested strategies to limit the impact:

CASE 1 **Deforestation** (Romania)
Impact on soil functions:

Suggested strategies to limit the impact:

LESSON B2 HOW CAN SOIL BE PART OF THE CLIMATE SOLUTION?

MAIN SUBJECTS	DURATION	AGE GROUP	TEACHING METHOD
Natural Sciences	2h30	12-15	Document Analysis, Experiment

OVERVIEW
In this lesson, students conduct experiments to learn how healthy soils combat climate change. Through hands-on activities, they will discover how soils store carbon and reduce erosion while managing water flow during heavy rainfall. This lesson emphasises the importance of protecting soil health to mitigate and adapt to climate change.

GREENCOMP COMPETENCES
Adaptability, Problem Framing

LEARNING OUTCOMES
By the end of the lesson, students will be able to:
- Explain the role of soils in the carbon cycle
- Explain the importance of soil as carbon sinks
- Explain how managing healthy soils can contribute to mitigating and adapting to climate change

KEY CONCEPTS
Adaptation, Carbon Cycle, Carbon Sink, Carbon Source, Erosion, Mitigation

Background for teachers

SOIL AND CLIMATE CHANGE
Soil is a major carbon reservoir that functions as both a **carbon sink** when organic matter remains in the soil and a **carbon source** when carbon dioxide is released during decomposition. Additionally, soil provides structural stability for infrastructure and buildings—a function increasingly threatened by climate change as **extreme weather** events intensify and potentially accelerate soil **erosion.**
Soil degradation has worsened in recent years through multiple processes: wind and water erosion, compaction from heavy machinery, urban sprawl, salinisation from improper irrigation, acidification from inappropriate fertiliser use, and contamination from industrial and agricultural activities. Climate change exacerbates these problems through temperature fluctuations, altered precipitation patterns, and changes in atmospheric composition.
We can address the climate crisis and its impacts on soil health through two complementary approaches:

1. MITIGATION
Limiting climate change by reducing greenhouse gas emissions and implementing carbon dioxide removal strategies such as reforestation, which enhances the soil's natural carbon sequestration capacity.

2. ADAPTATION
Addressing climate change consequences by reducing vulnerability of people, ecosystems, and infrastructure to climate impacts, including implementing soil conservation practices that maintain stability and function.

Both mitigation and adaptation strategies are essential components of an effective response to climate change and its effects on soil systems.

PREPARATION

PRE-KNOWLEDGE REQUIRED FOR THIS LESSON
Students should have an understanding that:
- Carbon Dioxide or CO2, is one of the greenhouse gases
- Current anthropogenic greenhouse gas emissions, such as CO2, are responsible for climate change, and global CO2 emissions have increased since the Industrial Revolution.
- Plants release CO2 during respiration and absorb CO2 for photosynthesis.
- LINK ?

MATERIAL
- Print one **HANDOUT B2.1, B2.2, B2.**3 per group of students
- Soil samples and other material as listed on **HANDOUTS B2.1** and **B2.3**

SUPPLEMENTARY MATERIAL
Detecting Organic Matter in Soil

MANDATORY! TO DO A FEW DAYS OR A WEEK BEFORE THE LESSON.
You need to collect soil samples. Depending on the time, you can either do it with the students during a dedicated activity (i), ask the students to do it at home (ii), or do it by yourself (iii). In all cases, you should pick several samples from at least two different areas: from a forest, for example (“natural” soil), and from a cultivated area or near a road (“artificial” soil). Thus, each group of students should have a minimum of two soil samples (“natural” and “artificial”). Make sure your samples are large enough (approximately two to three cups per group of students) to conduct several experiments. You can collect it up to 3-4 days before the experiments, but no longer, so that it remains fresh.

INTRODUCTION

ACTIVATION OF PRIOR KNOWLEDGE 10 MIN
1. Begin the lesson with a brief knowledge activation check. Here are some probing questions along with the expected answers (in parentheses).

- What is one of the main gases that cause our planet to warm?
(Carbon dioxide: CO2 is one of the main gases implicated in global warming, due to its role in the greenhouse effect. Its quantity has increased significantly since the Industrial Revolution, due to the combustion of organic matter.)
- Does all the CO2 emitted by humans on Earth accumulate in the atmosphere? If not, where else is the CO2 stored? *(Oceans)*
- How about soils? *(Soils are critical because they can store carbon as organic carbon).*
- But how does carbon get from the air into the soil? *(Plants capture CO_2 from the atmosphere through photosynthesis and turn it into organic matter: leaves, roots, and stems. When plants die or shed parts of themselves, some of this carbon becomes part of the soil. Microorganisms in the soil break down some of this material, releasing a little CO_2 back into the air, but a large portion can remain stored in the soil for years, decades, or even centuries.)*

Alternative option: consider using the OCE multimedia animation on the [Carbon Cycle]

2. Announce the learning outcomes for this lesson and verify that students understand them.

PROCEDURE

PART 1: EXPLORING HEALTHY SOIL AS A CARBON RESERVOIR 40-60 MIN
3. Soil Sample Comparison Activity (20 min)
Introduce the first activity: students will compare two soil samples to understand soil composition, quality, and organic matter content through observation and a simple chemical test. Divide students into small groups and distribute soil samples (at least one "natural" soil rich in organic matter from a forest/garden and one "artificial" or degraded soil) and one **HANDOUT B2.1**. Have students carefully examine both samples using sight, touch, and smell. Guide students to record observations about colour, texture, smell, and visible components. Ask groups to hypothesise which sample contains more organic carbon and why.

4. Hydrogen Peroxide Test (15 min)
Distribute materials (containers, spoons, soil samples, hydrogen peroxide). Have students predict which sample will react more with hydrogen peroxide. Guide students through the procedure of testing both samples. Ask students to observe and record the bubbling reaction (indicating the presence of organic carbon). Facilitate a discussion comparing reactions between samples. Students should be able to conclude that healthy soils have more organic matter than degraded soils. Ask students where they think the carbon in the organic matter in soils comes from?

5. Document Analysis (15 min)
Have students examine the diagrams in handout B2.2 and the guiding questions to help them understand how soils function as both carbon sinks and sources. Examples of guiding questions:

- How does carbon move from the atmosphere into soil?
- What is the role of *photosynthesis* and *plants*?
- What role do soil *decomposers* play?
- What factors can tighten or break the soil carbon loop?
- How might **climate change** alter this balance?
- What’s the relationship between soil **structure,** organic matter, and carbon-holding ability?

Encourage students to annotate diagrams, make connections, and discuss ideas in small groups before a brief plenary discussion.

6. Wrap-up for part 1
Use this close-style assessment to reinforce understanding and review language. Present the text below (via slide, print, or board). Students complete individually or in pairs.

Fill in the blanks below with the best choice of words: soil respiration | carbon dioxide (CO_2) | oxygen | photosynthesis | carbon reservoir | soil organic matter | decomposers | Carbon sink | primary producers

Soils are a major _________ because they store large amounts of ________ such as decomposed plant and animal material.

Plants absorb _______ from the atmosphere through _________ and use it to grow. When plants die, their leaves, roots, and stems become part of the soil.

________ (like bacteria, fungi, and earthworms) break down this organic matter. Some of the carbon is released back into the atmosphere as CO_2 through ______, but a significant portion remains in the soil as organic carbon.

Over time, this process allows soils to accumulate carbon, making them one of the largest ________ on Earth.

PART 2: EXPLORING HOW HEALTHY SOIL LIMITS EFFECTS OF HEAVY RAINFALL 45-60 MIN

1. Introduce this soil erosion activity. "Have you noticed how floods and heavy rainstorms are becoming more common? Climate change is increasing the frequency of **extreme weather events,** especially intense rainfall. This puts pressure on our landscapes, particularly the **soil that supports all life.**

2. Show a demo model (set up ahead of time or use a photo). "What happens when rain hits bare soil vs. covered soil?" Ask students to make hypotheses:

- "Which bottle will erode more?"
- "What will the collected water look like?"
- "What role does soil coverage play?"
- "Should the bottles be at the same angle? Why?"
- "What amount of soil and water is fair for testing?"

3. "How would **clay vs. sand vs. silt** impact our results?"

4. Distribute **HANDOUT B2.3** and materials (plastic bottles, scissors, soil samples, organic material, water). Have students apply equal amounts of water to both bottles. Ask them to carefully observe what happens to the soil surface and water runoff. Guide them to record observations about water clarity and soil movement.

5. Analysis and Discussion (15 min)
Have groups compare results with other teams. Discuss why the covered soil shows less erosion. How can farmers, gardeners, and cities use this knowledge? What are **climate-adaptive practices** (e.g., planting cover crops, building terraces)?

WRAP UP 20 MIN

Provide definitions:
- Adaptation = Actions that help us live with the effects of climate change
- Mitigation = Actions that reduce the causes of climate change

Have students share their key takeaways from the experiments and summarise in their own words:
- How do healthy soils help mitigate climate change? (storing carbon)
- How do healthy soils help adapt to climate change impacts? (reducing erosion, better water management)

Create a three-column table on the board: "Solutions," "Adaptation," and "Mitigation". Ask students to suggest soil management practices and classify them. Examples to include: crop rotation, reducing pesticide use, planting cover crops, collecting rainwater.

SOLUTIONS	ADAPTATION?	MITIGATION?
Cope with increased variability in rainfall by improving irrigation by collecting rainwater	×	
Growing crops resistant to drought	×	
Using renewable energy in farms		×
Reducing food waste		×
Crop rotation: Changing what type of plants are grown each season	×	×
Reducing the use of pesticides and chemical fertilisers	×	×

Display the "Keys to Healthy Soil" infographic and discuss how these practices contribute to climate solutions

Fig 1. Keys to Healthy Soil.

HANDOUT B2.1 PAGE 1/1

EXPLORING ORGANIC MATTER CONTENT IN VARIOUS SOIL SAMPLES HANDS-ON EXPERIMENT

Material

→ 2 containers
→ 1 spoon
→ sample of healthy soil
→ sample of damaged/poor soil hydrogen peroxide (30% solution) which can be used to detect the presence of organic matter (the stronger is the reaction (bubbles or foam) the higher is the organic matter content.

Soil contains particles of different sizes:

- **Gravel:** Particles as large as your fingertips
- **Sand:** Visible particles smaller than gravel
- **Silt:** Very fine particles visible only with a lens; feels smooth
- **Clay:** Microscopic particles that feel slippery
- **Organic matter:** Decomposed plant and animal material that enriches soil

Note: Agricultural soil ideally contains approximately 50% sand, some silt, and a small amount of clay.

Experimental Protocol

1. Examine both soil samples carefully using your senses (sight, touch, smell).
2. Record your observations in the table below:

CHARACTERISTICS	HEALTHY SOIL SAMPLE	DAMAGED SOIL SAMPLE
Color		
Smell		
Texture		
Visible components		
Reaction with hydrogen peroxide		

3. Compare the samples: What similarities do you notice? What differences stand out?
4. Based on your observations, which sample do you think contains more organic matter? Explain your reasoning.
5. Predict which soil sample will react more strongly with hydrogen peroxide and explain why.
6. Place one spoonful of healthy soil in one container. Place one spoonful of damaged soil in the second container.
7. Add an equal amount of hydrogen peroxide (about 2-3 drops) to each container.
8. Observe the reaction in each container and add your observations to the table.
   - Look for bubbling
   - Note the intensity of bubbling
   - Measure how long the reaction continues

Questions

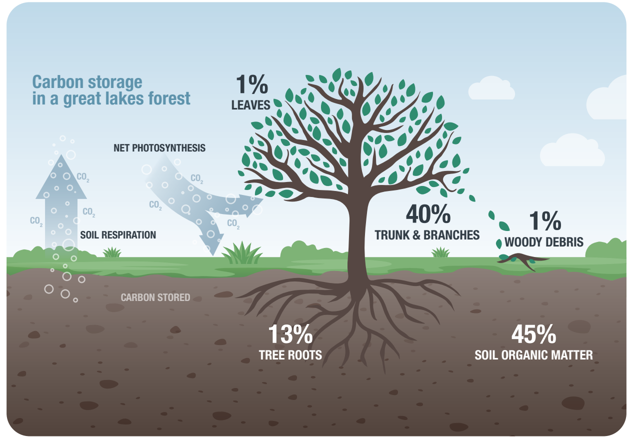
→ What happened when you added hydrogen peroxide to each soil sample?
→ How did the reactions compare between the two samples?
→ What does the bubbling reaction indicate about organic matter content?
→ Based on your observations and test results, which soil has more organic matter?
→ Why is organic matter important for soil health?
→ What practices might help improve damaged soil?

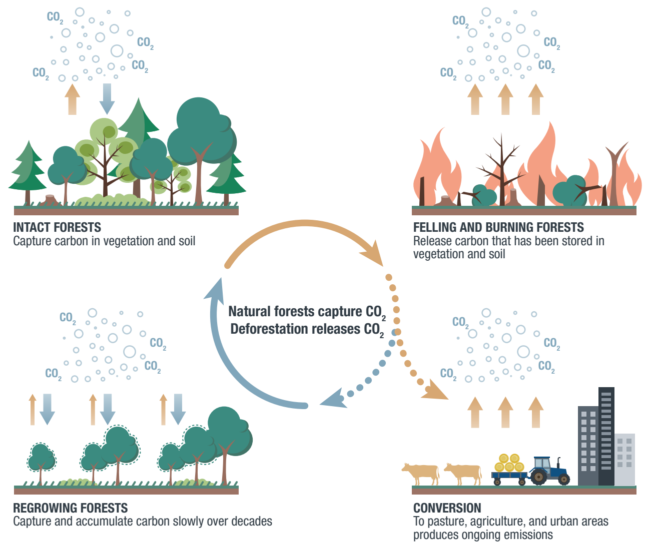
HANDOUT B2.2 PAGE 1/1

EXPLORING CARBON FLOW AND SOILS DOCUMENT ANALYSIS

DISTRIBUTION OF CARBON STOCKS ACROSS MAJOR EARTH RESERVOIRS

RESERVOIR	STOCKS (GIGATONNES OF CARBON)
Ocean	38,700
Atmosphere	829
Biosphere: Oceanic animals and plants	about 400
Biosphere: Land animals and plants	about 200
Soil, rocks and sediments	3750
Fossil fuels	1000 - 2000





HANDOUT B2.3 PAGE 1/1

EXPLORING HOW HEALTHY SOIL CAN LIMIT THE EFFECT OF HEAVY RAIN **HANDS-ON EXPERIMENT**

When it rains, water that is not absorbed by plants, evaporated by the sun, or soaked into the ground gradually flows through the topsoil downhill into nearby water bodies such as lakes, rivers, and streams. This water can carry soil particles from one place to another, a process known as erosion. Erosion occurs slowly when the water flow is gentle, but if the water flows quickly, it can lead to significant topsoil loss and, in some cases, result in landslides.

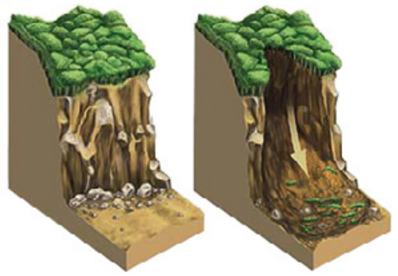


Fig. 1. Soil Erosion
Source: Encyclopædia Britannica, Inc.

Material

→ plastic bottles
→ scissors
→ soil samples
→ dead leaves
→ water

Fig. 2. Soil Erosion Model

Procedure

1. Fill three vertically cut bottles with soil.
2. Cover one soil sample with grass, mulch, or dead leaves, and leave the other soil sample bare.
3. Pack the soil in each bottle.
4. Suspend the bottles over the 2 cups (you can use a string to
5. keep the cups attached to the bottles) at a 25 to 40° angle with the necks facing downward. Get creative in finding ways to keep the bottles at the same angled position
6. Run water over the top of the soil in each bottle (if your soil hasn't had time to settle, you should discard the first few centimetres from each cup).
7. Use your rain simulator (or watering can) to apply equal amounts of water to each bottle.

Erosion and soil

Questions

1. Compare the differences in the clarity of the water in each cup and with other groups with the same angle and the same soil (especially if they have different equipment):
2. How could you explain the differences?
3. Observe the soil surface before, during and after the "rain event"; which soil is best suited to limit landslides?

LESSON B3 WHY SHOULD WE CARE ABOUT SOIL?

MAIN SUBJECTS	DURATION	AGE GROUP	TEACHING METHOD
Biology, Environmental Science, Geography, Social Studies	2h	15+	Case-Based Learning, Role-Play

OVERVIEW

This lesson uses a **doctor/patient metaphor** to highlight the importance of **soil health.** Students play “Soil Doctors” and “Soil Patients” in a role-play game called **“Root Causes”**. They diagnose common soil health conditions based on real-life examples and propose treatments after weighing benefits, side effects, and trade-offs. They also explore the concept of resilience by seeing how real-life treatments hold up when faced with climate change-driven and human-induced “emergencies”. By comparing their ideas with real outcomes, students practice critical thinking and scientific reasoning as they reflect on why some treatments succeed while others fail, and on how soil health connects to society and the environment. The lesson highlights the interconnections between soil, society, and climate, showing students why caring for soil is essential to sustaining life on Earth.

GREENCOMP COMPETENCES

Critical Thinking, Systems Thinking

LEARNING OUTCOMES

By the end of the lesson, students will be able to:

- Diagnose common soil problems and recognise interconnections using systems thinking.
- Evaluate soil treatments, considering effectiveness, side effects, trade-offs, and resilience.
- Understand how soil health links to the environment, society, and climate change.

KEY CONCEPTS

Climate Resilience, Social and Environmental Justice, Soil Health, Sustainability

Background for teachers

Healthy Soils for a Healthy, More Resilient Planet

Often taken for granted, soils are more than just “dirt beneath our feet”. They are living, dynamic systems that form the foundation of terrestrial ecosystems, support plant growth and biodiversity, cycle and store water and nutrients, and sustain food production and human livelihoods (FAO & ITPS, 2015; Lal, 2021).

Soils are also the largest terrestrial carbon reservoir, storing more carbon than vegetation and the atmosphere combined (Lal et al., 2021; FAO, 2017). This carbon is primarily stored as soil organic matter, which includes plant residues, roots, microbial biomass, and stable humic compounds (Six et al., 2002). However, the ability of soils to sequester and store carbon is not uniform or unlimited. It depends on interconnected factors such as climate, topography, parent material, soil texture and structure, organic matter content, and biological activity (Rodrigues et al., 2023; Wiesmeier et al., 2019; Basile-Doelsch et al., 2020).

Globally, soils are under severe pressure from human activities, including unsustainable farming practices, deforestation, overgrazing, urbanisation, and land-use change, which have led to widespread degradation (FAO & ITPS, 2015; IPCC, 2019; Amundson et al., 2015). According to the FAO’s global assessment, about one-third (approximately 33%) of all land is moderately to highly degraded as the result of multiple threats, including erosion, loss of organic matter and biodiversity, nutrient imbalance, salinisation, compaction, acidification, sealing, waterlogging, and contamination (FAO & ITPS, 2015). Degraded and poorly managed soils release greater amounts of carbon dioxide, methane, and nitrous oxide, further contributing to climate change. In fact, nearly two-thirds of global nitrous oxide emissions come from agriculture, primarily from nitrogen fertilisers, which have increased ninefold since 1961 (IPCC, 2019). Climate change is intensifying these pressures through more frequent and severe droughts, heatwaves, floods, and storms, creating a self-reinforcing cycle of degradation and climate stress (IPCC, 2022).

Soil health issues extend far beyond the soil itself; they reflect and reinforce wider social, economic, and political challenges. Like with climate change, the impacts of soil degradation are uneven, falling hardest on vulnerable communities like smallholder farmers, Indigenous communities, and marginalised groups, particularly in the Global South (FAO & ITPS, 2015; Morton, 2007; IPCC, 2022). These communities often have limited access to resources and financial support, leaving them with unequal capacity to adapt to changing conditions and increasing their risk of poverty, food insecurity, conflict, and migration.

Maintaining healthy soils is a critical foundation for resilience. As illustrated in the game “Root Causes”, soil management practices can buffer against stresses such as nutrient loss, erosion, and moderate drought under normal conditions, but they may be less effective or fail under climate extremes such as floods, severe droughts, or heatwaves. This is why addressing these challenges requires integrated strategies that strengthen resilience, take into account socioeconomic consequences, consider trade-offs, and promote equity through inclusive, locally informed approaches.

It can take hundreds to thousands of years to form just one centimeter of fertile topsoil, highlighting the urgency of protecting and restoring this critical resource (Montgomery, 2007; FAO & ITPS, 2015). Caring for soils has the power to transform a vicious cycle of degradation into a virtuous one: healthy soils hold more water and nutrients, increase crop productivity, support biodiversity, and store carbon from the atmosphere. Maintaining healthy soils is therefore one of the most effective ways to combat climate change, generating lasting benefits for ecosystems, communities, and the planet.

PREPARATION

MATERIAL

For each pair of students, prepare a “Patient File” which includes the following elements:

Envelope 1

Part 1: Consultation & Diagnosis

- **Patient Card**
- HANDOUT B3.1: CONSULTATION & DIAGNOSIS
- **Diagnosis Table**

Envelope 2

Part 2: Treatment

- HANDOUT B3.2: TREATMENT PLAN
- **General Treatment Guide**
- An envelope marked “Report 1 (patient letter) containing the patient’s **Real-World Case Report 2**

Envelope 3

Part 3: Climate Emergency!

- HANDOUT B3.3: CLIMATE EMERGENCY!
- **Climate Emergency Card**
- An envelope marked “Report 2 (patient letter) containing the patient’s **Real-World Case Report 3**

All the above documents, apart from the envelopes and post-it notes, are provided at the end of this lesson.

This lesson includes ten possible patient cases to choose from, based on real-life examples. They were selected to highlight the diversity of soil health conditions, management strategies, and environmental contexts across different regions, and to demonstrate that, as with human health, there is no one-size-fits-all solution. Each case study is grounded in a real location and documented extreme weather event, and the soil health challenges faced by the region are well established in the literature.

The treatments and outcomes presented are composite scenarios synthesised from peer-reviewed research, extension publications, and real-world farming experiences. They represent realistic management responses to the most common global soil health challenges (erosion, soil organic matter loss, biodiversity loss, compaction, waterlogging, nutrient imbalance, sealing, contamination, acidification, and salinisation), including their potential side effects and trade-offs supported by scientific evidence. Treatment options are intentionally streamlined to facilitate gameplay, reduce cognitive overload, and help students focus on key concepts and comparisons.

Treatment options are also simplified. **The General Treatment Guide** is designed to be applicable across all cases without overwhelming learners, and the treatments presented within each case are illustrative examples rather than an exhaustive list of all possible interventions. It should be emphasised that the treatments presented in each case are not prescriptive recommendations. The objective is to illustrate the complexity of soil health challenges and to encourage students to critically evaluate effectiveness, context suitability, and long-term consequences of treatments, while also taking into account resilience.

This structure allows you to choose the cases to match your learning goals. For example, you could compare:

- How similar soil conditions may require different

treatments depending on the social, ecological, or climatic context
- How the same treatment can perform differently (or similarly) in different places
- How similar extreme weather events can lead to different outcomes depending on local conditions

TEACHER TIPS

Consider adding props like lab coats, clipboard, surgical masks, and stethoscopes to make the activity more immersive!

INTRODUCTION

1. As a warm-up to the role-play, ask:
What does healthy soil look like? What does unhealthy soil look like? Can you give some examples of unhealthy soil? Why is soil health important beyond growing food? (For more background information, you can watch the short videos by the Food & Agriculture Organization, which are provided at the end of the lesson).

2. Then, tell students that they will play a game called "**Root Causes**" to learn about soil health. They will role-play as "Soil Doctors" and "Soil Patients" to diagnose their patient, discuss different treatment options, and compare their diagnosis and treatment plan with what happened in the real case. Guide the students through the activity one step at a time, giving instructions at the start of each step rather than all at once. This helps prevent confusion and keeps students from feeling overwhelmed.

3. Divide the class into pairs and ask them to decide who will play the "Soil Doctor" and who will play the "Soil Patient". Hand out a "Patient File" to each pair and remind them to wait to open the envelopes until you say so.

PROCEDURE

PART 1 - CONSULTATION & DIAGNOSIS 20 MIN

Tell them they can open the envelope for Part 1

4. The game begins with the "Soil Patient" coming in for a consultation about their health issues. The "Soil Patient" starts by introducing themselves (their name and location) before reading the quote and list of symptoms on their **Patient Card**.

5. The "Soil Doctor" listens and checks off the symptoms using the **Symptom Checklist** on HANDOUT B3.1. The diagnosis is made by tallying the number of points for each matching symptom following the instructions on HANDOUT B3.1 to find the primary, secondary, and tertiary conditions with the help of the **Diagnosis Table.** If there is more than one condition with the same number of points, they will write them all in the final diagnosis.

PART 2 - TREATMENT 25 MIN

6. Once everyone has completed Part 1, they can open the envelope for Part 2, containing the **General Treatment Guide,** HANDOUT B5.2: TREATMENT PLAN, and an envelope marked "Report 1 - (patient letter)" containing their patient's **Real-World Case Report 2**. The "Soil Doctor" and "Soil Patient" work together to design a treatment plan by choosing treatments from the General Treatment Guide, which they will write down on HANDOUT B5.2. Their treatment plan must address their patient's conditions, while also taking into account the benefits, side effects, and trade-offs of the treatments proposed.

7. Once they have selected their treatments, they can open the envelope marked "Report 1 - (patient letter)" to reveal the diagnosis and illustrative examples of treatments and outcomes documented in the **Real-World Case Report 2,** and then answer the reflection questions on HANDOUT B5.2.

PART 3 - CLIMATE EMERGENCY! 20 MIN

8. Once everyone has completed Step 2, announce to the class that a climate emergency has occurred (this can be emphasised with a flashing light, siren, or other visual/audio cue to make the scenario more immersive).

9. In the previous step, students observed the outcomes of treatments used for their patient's chronic issues. Now, they will explore how the same treatments perform under the climate emergency. Tell them they can now open the envelope marked "Part 3", containing their patient's **Climate Emergency Card,** HANDOUT B5.3 - CLIMATE EMERGENCY!, and an envelope marked "Report 2 (patient letter)".

10. The "Soil Patient" reads the **Climate Emergency Card,** which describes an extreme weather event that occurred in the real-life example.

11. Working together with the "Soil Doctor", they write a prediction on HANDOUT B5.3 about how the treatments listed on **Real-World Case Report 2** will perform in the face of this emergency.

12. Once they have made their predictions, they may open the envelope marked "Report 2 (patient letter)" to reveal the outcome of the real-life example on **Real-World Case Report 3,** which they will use to answer the reflection questions on HANDOUT B5.3.

WHOLE-CLASS DISCUSSION & WRAP-UP 30 MIN

13. Draw a table on the board or a large sheet of paper, with the following column headings across the top: **Patient Name, Patient Location, Soil Conditions, Treatments.**

14. Give each pair four large post-it notes in different colours, one for each category. Ask students to write the correct information for their patient on the post-it that matches the category. For example, if Patient Name is blue, they write their patient's name on the blue post-it. Once completed, they should place the notes in the appropriate column on the board to create an overview of all the cases studied.

15. Start the class discussion by asking questions that help students identify patterns and make comparisons across cases. For example:

- *What patterns do you notice?*
- *Which soil conditions are the most or least common?*
- *Which conditions often occur together and why?*
- *Which treatments appear in multiple cases?*
- *Which only appear in some cases? Why?*

16. Now, make an imaginary line across the room to represent the overall health of each Soil Patient. Explain that one end of the line signifies "much better", the other "much worse," and the middle represents "no change" or "mixed outcomes". The objective of this exercise is to observe how each patient's health evolved throughout the game, based on the treatments they received and the students' subjective assessments. Reassure students that their positioning is not meant to be exact; the focus is on thoughtful evaluation, comparison, and discussion, rather than precision.

17. Ask all students to position themselves anywhere along the line according to the health status of the patient in their case at the start of the game, before any treatments were applied. This represents the baseline condition (based on the diagnosis and symptoms described on their **Patient Card** from part 1).

18. Next, ask them to position themselves along the line according to their patient's health status after treatment, based on the information provided in their **Real-World Case Report 2.** Invite a few volunteers to briefly explain their reasoning.

19. Ask students to position themselves again, this time according to their patient's health status after the extreme weather event in Part 3, based on the information provided in their **Real-World Case Report 3.** Invite a few volunteers to briefly explain their reasoning.

20. Students may shift in different directions along the line, reflecting the range of outcomes. Many students will shift towards "worse", highlighting how climate shocks intensify existing soil problems as well as the benefits and limitations of treatments under climate change.

21. Some treatments are clearly unsustainable, worsening soil conditions even under normal circumstances and performing even worse after the extreme weather event. Other treatments may increase resilience, but still fail under extreme stress. Some strategies may protect against one type of extreme event, such as drought, but leave the soil vulnerable to others, like flooding.

22. This illustrates that resilience and adaptation cannot rely on a single strategy; rather, they require a combination of treatments and management practices adapted to the local context and informed by broader social, economic, and governance factors.

23. Start a class discussion by asking students to reflect on the changes they observed across all the cases studied, using the following questions as a guide:

- *Who noticed the biggest change in soil health between the baseline condition at the start of the game and after the extreme weather event?*
- *Which treatments helped patients in normal conditions but failed during an extreme weather event? Did any treatments provide partial benefits, even if the overall outcome was still worse?*
- *What does this tell us about climate change resilience (the ability to resist, recover from, and adapt to the impacts of climate change, including extreme weather events) and about the trade-offs involved in choosing treatments?*

24. Now ask students to think beyond the physical outcomes (what improved or worsened) and reflect on the social and environmental dimensions of soil health and climate change, considering questions of fairness, equity, and climate justice: who benefits, who is at risk, and how unequal access to healthy soils shapes opportunities and vulnerabilities. You

can use the following questions to guide your discussion:

- *If soil health is weakened by climate change, who and/or what is most at risk (e.g. farmers, ecosystems, wildlife, communities)?*
- *Are the treatments available, accessible, and affordable to everyone? Do they benefit all people and ecosystems equally?*
- *Did any patients receive treatments that created unintended side-effects? If so, who and/or what was harmed?*
- Who and/or what benefits from healthy soil? Who *and/or what is harmed by unhealthy soil?*
- *In what ways do unequal access to healthy soil and sustainable land management create social or environmental inequalities?*
- *How does poor soil health highlight inequalities in communities and ecosystems?*
- *How can we help the soil become more resilient to climate change while promoting fairness and equity?*

WRAP UP 30MIN

25. Wrap up with a collective brainstorming to come up with a set of "**Doctor's Recommendations**" for maintaining healthy and resilient soils based on what they learned from the activity. Since there is no one-size-fits-all solution, they should focus on broad guidelines that can be applied to any context, rather than recommendations that only apply to a specific region or case. Possible recommendations might include:

- **Minimise Disturbance** — Reduce practices that damage soil structure (e.g., no-till or reduced tillage, contour plowing, terraces, limiting chemical fertilisers and pesticides, rotational grazing).
- **Maintain Living Roots** — Keep plants growing in the soil year-round (e.g., cover crops, perennials) to feed organisms and store carbon.
- **Keep Soils Covered** — Use mulches, crop residues, or green manures to protect soil from erosion, drying, and nutrient loss.
- **Enhance Biodiversity** — Support diverse crops, plants, and soil life (e.g., crop rotation, intercropping, polycultures, agroforestry, integrating livestock, integrated pest management, pollinator plantings, organic fertilisers)
- **Consider Side-Effects and Trade-Offs** — Think critically about the benefits and drawbacks between interventions and treatments (e.g., fertilisers boost short-term yields but may cause runoff, dependency, or long-term decline), who and what is affected, and how.
- **Plan for Resilience** — Build soil systems that can resist, recover, and adapt to stresses like droughts or floods, balancing short-term needs with long-term sustainability.
- **Monitor and Adapt** — Keep observing outcomes, adjust management, and learn from successes and failures.
- **Promote Equity and Accessibility** — Good soil care should balance the needs of soils, animals, ecosystems, and people, with particular attention to vulnerable groups such as smallholders, women, the elderly, and Indigenous peoples who often face higher exposure to soil degradation and climate extremes, yet have less influence on decisions.

VIDEOS

- Healthy soils: the foundation of healthy food and a better environment
- Let's talk about soil
- Soil 101
- Soils: a hidden resource
- Sustainable soil management: A major step in achieving the Sustainable Development Goals
- The Status of the World's Soil Resources

Instructions

→ Ask your patient what symptoms they are experiencing. Tick each symptom that matches on the **Symptom Checklist** below.
→ Each symptom shows how strongly it links to different soil conditions (e.g. "Patient feels thin, loose, or sandy" → Erosion = 3, SOM Loss = 1).
→ For each ticked symptom, record the points for each soil condition on the **Diagnosis Table**.
→ Add up the points for each soil condition. The highest total is the primary problem, the next highest is secondary, and the third is tertiary. If there is more than one condition with the same number of points, write them all down. This will be your diagnosis.

Symptom Checklist

Patient feels thin, loose, or sandy	Erosion = 3 SOM Loss = 1
Patient feels hard/packed down	Compaction = 3 Sealing = 1
Patient feels crumbly, not spongy	SOM Loss = 3 Biodiversity Loss = 1
Patient feels muddy, sticky, or slimy	Waterlogging = 3
Patient feels dry, compacted, and lifeless below the surface	Sealing = 3
Patient has bare patches or areas with little plant cover	Erosion = 3 SOM Loss = 1
Patient has gullies, ruts, or small channels	Erosion = 3
PPatient has a white crusty layer on the surface	Salinisation = 3
Patient has very pale colour	Nutrient Imbalance = 2 SOM Loss = 1
Patient has strange/unusual colours (e.g., blue, black, bright white)	Contamination = 3
Patient smells sour, rotten, or metallic	Acidification = 2 Contamination = 2
Patient is covered by buildings, pavement, or concrete	Sealing = 3

Plants are weak, yellow, or stunted	Nutrient Imbalance = 3 SOM Loss = 1
Plants grow poorly even with fertiliser	Nutrient Imbalance = 2 Acidification = 2 / SOM Loss = 1
Plants are uprooted or grow poorly due to soil loss	Erosion = 3 SOM Loss = 1
Plants are uprooted or grow poorly due to soil loss	Waterlogging = 3
Fewer plants survive and plant growth is uneven	Biodiversity Loss = 3 SOM Loss = 1
Water pools on the surface after it rains	Waterlogging = 3 / Salinisation = 1 Sealing = 1/ Compaction = 1
Patient can't hold onto water	SOM Loss = 3 / Compaction = 2 Erosion = 1
Patient feels too dry	Nutrient Imbalance = 2 SOM Loss = 1
Patient feels too wet	Waterlogging = 3
Patient notices fewer insects, fungi, or animals	Biodiversity Loss = 3 SOM Loss = 1
Patient feels lifeless and tired	Biodiversity Loss = 2 SOM Loss = 2 / Nutrient Imbalance = 1

Diagnosis Table 1/2

SOIL CONDITION	DESCRIPTION	MAIN DRIVERS	POINTS
Erosion	When topsoil is worn away by wind, water, or human activity, removing nutrients that plants need.	• Deforestation and land clearing • Overgrazing by livestock • Intensive tillage and poor farming practices • Construction and road building • Extreme rainfall, storms, and floods	
Acidification	When soil becomes more acidic than normal, reducing nutrient availability and affecting plant growth.	• Overuse of nitrogen fertilisers (especially ammonium-based) • Continuous cropping without lime or organic matter • Acid rain from industrial pollution • Removal of alkaline crops/products (like legumes or hay) without replenishing	
Sealing	When soil is covered by buildings, pavement, or other surfaces that block water and air.	• Urban expansion (buildings, asphalt, concrete) • Roads, parking lots, and industrial zones • Poor planning that covers fertile soils permanently	
Soil Organic Matter (SOM) Loss	When soil loses organic matter like decomposed plants and animals that help it stay fertile and hold water.	• Intensive tillage breaking down organic matter • Monoculture cropping without residue return • Overgrazing and deforestation • Burning crop residues • Drainage of wetlands and peatlands	
Waterlogging	When too much water stays in the soil and roots cannot get enough oxygen.	• Poor drainage systems • Heavy clay soils that hold water • Excessive irrigation • River or coastal flooding • Rising groundwater tables	

Diagnosis Table 2/2

SOIL CONDITION	DESCRIPTION	MAIN DRIVERS	POINTS
Salinisation	When salt builds up in the soil, making it harder for plants to absorb water and grow.	• Over-irrigation with salty water • Poor drainage leading to salt build-up • Rising salty groundwater • Clearing deep-rooted vegetation in dry areas	
Compaction	When soil becomes hard and dense, making it hard for roots and water to get through.	• Heavy machinery use on wet soils • Repeated trampling by livestock • Lack of crop rotation (especially with deep-rooted plants) • Reduced soil cover exposing soil to pressure	
Biodiversity Loss	When there are fewer living organisms in the soil, such as insects, worms, fungi, and microbes, reducing soil fertility and plant health.	• Monoculture farming • Heavy pesticide and fertiliser use • Deforestation and habitat loss • Soil sealing and urbanisation • Overgrazing and erosion	
Contamination	When chemicals or pollutants are present in the soil, which can harm plants, animals, and people.	• Industrial waste dumping • Mining activities • Use of untreated sewage sludge • Pesticide and herbicide overuse • Oil spills and accidents	
Nutrient Imbalance	When soil lacks the right nutrients for healthy plant growth.	• Overuse of single fertilisers (like nitrogen only) • Continuous monocropping without replenishment • Poor soil management (erosion washing nutrients away) • Removal of crop residues without return • Acidification locking up nutrients	

Diagnosis

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Your Treatment Plan (Write BEFORE opening the envelope marked “Report 1")

Work together with your patient to design a treatment plan using the General Treatment Guide. Choose 2-3 treatments you think will help and explain why, including expected benefits and any possible side effects or trade-offs.

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Reflection Questions (Answer AFTER opening the envelope marked “Report 1"):

1. Compare your diagnosis and treatment plan to the diagnosis and main treatments used in the real world on Real-world Case Report 2. Explain the similarities and differences, and why you think the real-world treatments were chosen.

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2. After seeing what happened in real life, would you keep your treatment plan? If not, what would you change and why?

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General Treatment Guide 1/2

TREATMENT	USED FOR	BENEFITS	SIDE EFFECTS & TRADE-OFFS
Soil Cover & Organic Matter (e.g., Mulching, crop residue retention, compost/manure, green manures, biochar, soil cover with plants or litter)	• Erosion • SOM loss • Nutrient imbalance • Compaction • Biodiversity loss	• Builds fertility • Improves water storage • Uses low-cost, locally available materials • Protects from heavy rains, floods, and heat	• Compost/manure may be unavailable to poor farmers or compete with fuel uses • Potential conflict between soil needs vs. farmer needs (crop residues sometimes used for fodder)
Plant Diversity & Rotation (e.g., Cover crops, intercropping, crop rotation, hedgerows, integrating legumes, native vegetation buffers)	• Nutrient imbalance • SOM loss • Erosion • Biodiversity loss • Compaction	• Improves soil fertility and pest control • Deeper/mixed roots improve soil structure and water infiltration and buffers against floods and droughts • Provides fuel, fodder, and supports food diversity and local livelihoods	• May require extra land or labour • Short-term yield reductions if cash crops are replaced with cover crops • Uneven access to seed diversity
Fix Soil Chemistry (e.g., Fertilisers (organic or synthetic), liming acidic soils, micronutrient additions)	• Nutrient imbalance • Acidification	• Rapid boost to yields and food security • Lime neutralises acidification and improves nutrient availability	• Synthetic fertilisers are costly • Risk of dependence • Pollution risk (air and water) • Overuse accelerates climate change (N_2O emissions, lime has high carbon footprint)

General Treatment Guide 2/2

TREATMENT	USED FOR	BENEFITS	SIDE EFFECTS & TRADE-OFFS
Ecosystem & Habitat Restoration (e.g., Agroforestry, farmer-managed natural regeneration (FMNR), Indigenous-led restoration, community forest management, peatland rewetting, replanting deep-rooted native vegetation, green spaces, polder rehabilitation)	• Erosion • SOM loss • Salinisation • Waterlogging • Sealing • Biodiversity loss	• Increased carbon storage (trees and peatlands) • Trees and wetlands regulate local rainfall and water flows • Reduces flood/drought risks • Supports Indigenous/communal rights and local livelihoods	• Slow results (benefits take years) • Possible conflicts over land rights • May reduce land available for farming or other uses
Efficient Water Management (Drainage, Irrigation, Infiltration) (e.g., Drip irrigation, scheduling, drainage canals, rainwater harvesting, terracing, contour farming, infiltration ditches, raised beds, urban green infrastructure like permeable pavements, green roofs, rain gardens)	• Waterlogging • Salinisation • Erosion • Sealing • Compaction	• Improves crop survival in floods/ droughts • Reduces salinity • Uses less water, which can reduce conflict over access and use • Rainwater harvesting can provide shared water resources	• Irrigation can worsen salinity or drain aquifers • Drainage may cause water quality issues downstream • Costs and infrastructure may exclude small farmers • Can favour commercial farms over smallholders
Contamination Management (e.g., phytoremediation (plants absorb toxins), soil washing, barriers/ containment, safe disposal, and reducing inputs of pesticides/industrial waste)	• Contamination • Sealing • Biodiversity loss	• Reduces human health risks • Restores land for safe agriculture • Protects water sources • Creates "green jobs" in remediation	• Expensive and slow process • May push contaminated soils into poorer regions • Requires technical expertise and monitoring

Prediction (Answer BEFORE opening the envelope marked "Report 2"):

The "Soil Patient" reads the Climate Emergency Card aloud. Together, make a prediction about how the real-life treatments on the Real-world Case Report 2 will perform against the extreme weather event.

Reflection Questions (Answer AFTER opening the envelope marked "Report 2"):

1. Compare your predictions to the actual outcomes in Real-world Case Report 3 . How did the real-life treatments perform after the extreme weather event compared to normal conditions (according to Real-world Case Report 2)?

2. Did any treatments help the soil become more resilient to climate change (helping to resist, recover from, or adapt to the extreme weather event)?

PATIENT CARD - A

Patient: Greta Geröller
Location: Ahr Valley, Germany

PATIENT CARD - B

Patient: Ravi Khetan
Location: Indo-Gangetic Plain, South Asia

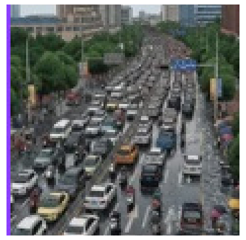
PATIENT CARD - C

Patient: Fatoumata Diara
Location: Central Sahel Grasslands, West Africa

PATIENT CARD - D

Patient: Kiara Clayton
Location: Murray-Darling Basin, Australia

PATIENT CARD - E



Patient: Li Shi
Location: Zhengzhou Megacity, China

PATIENT CARD - F

Patient: Thida Dinsiwong
Location: Ayutthaya Industrial Estates, Thailand

↗ For the materials for each **Patient Card** navigate into this file

PATIENT CARD - G

Patient: Chen Chihong
Location: South China Red-Soil Tea Belt

PATIENT CARD - H

Patient: John Roe
Location: Iowa Corn Belt, USA

PATIENT CARD - I

Patient: Bina Char
Location: Bangladesh Coastal Polders

PATIENT CARD - J

Patient: Larissa Silva
Location: Central Amazon Peat Soils, Brazil

HANDOUT B3.3 PAGE 7/9

EXEMPLE DOCUMENTS FOR CASE A

PATIENT A

Patient: Greta Geröller
Location: Ahr Valley, Germany

Patient Says:
"*When heavy rain falls, more of my precious topsoil gets washed down my steep hills, leaving behind rills and gullies and muddying the rivers and streams below. I feel exposed, thin, and too weak to support healthy plants.*"

Symptoms:
- I feel thin, loose, and sandy.
- I have bare patches and areas with little plant cover.
- I have gullies, ruts, and small channels.
- I'm very pale.
- My plants are uprooted and grow poorly due to soil loss.
- My plants are weak, yellow, and stunted.
- I have trouble retaining water.
- I feel lifeless and tired.

CLIMATE EMERGENCY CARD - PATIENT A

Extreme Rainfall & Flash Floods
Patient: Greta Geröller
Location: Ahr Valley, Germany
When: 14 - 15 July 2021

What Happened:
On July 14, 2021, the Ahr Valley, a wine-producing region in the western part of Germany, was hit with record-breaking rainfall (100–150 mm - more than a months' worth of rain in just 24 hours!), resulting in the worst flood the area has seen in 700 years. Rivers overflowed and flash floods tore through vineyards and fields, sweeping away homes and destroying crops. Over 130 lives were lost, 750 were injured, families were displaced, and infrastructure losses were estimated in the tens of billions of euros. Many farmers lost their land and polluted sediments were carried into rivers, degrading water quality and harming fish and aquatic life.

HANDOUT B3.3 PAGE 8/9

CLIMATE EMERGENCY!

Real-World Case Report: **Ahr Valley, Germany (Patient A)**

Diagnosis
Erosion, Nutrient Imbalance, Soil Organic Matter (SOM) Loss

TREATMENT	USED FOR	DID TREATMENTS HELP?	SIDE EFFECTS & TRADE-OFFS
Terracing & Contour Farming	Erosion SOM Loss	Partly. Water spread more evenly, which slowed water runoff and lowered erosion in normal heavy rain. Slopes became more stable, SOM increased, and more topsoil was preserved.	• Expensive • Needs a lot of work, good drains, and regular maintenance • Clogged drains can cause water to spill and erode
Cover Crops / Green Manure	SOM Loss Nutrient Imbalance Erosion	Yes. Bare soil was protected and living roots fed soil life, while helping to keep the soil in place. Soil structure and SOM improved and soil was better able to store and recycle nutrients.	• Can compete with main crops for space, water, and sunlight • Needs careful management to avoid pests or weeds • Benefits drop if terminated too early or poorly managed
Heavy Chemical Fertiliser Use	Nutrient Imbalance	Partly. Fed crops and boosted yields in the short term, but over time, too much fertiliser depleted SOM, polluted water, and led to further nutrient imbalance.	• Expensive • Risk of dependence • Nutrients can wash into rivers and harm ecosystems • Risk of SOM decline and weakened soil structure

Real-World Case Report: **Ahr Valley, Germany (Patient A)**

Climate Emergency!
Extreme Rainfall & Flash Floods (2021)

TREATMENT	OUTCOME
Terracing & Contour Farming	Partly. There was less runoff and erosion on gentler slopes, but many poorly built and maintained terraces and contour strips were overwhelmed by the record flash flooding, which carved deeper gullies and caused more landslides and erosion.
Cover Crops / Green Manure	Yes, mostly. Fields with cover crops held onto more soil and recovered faster, but crops were flattened and compost washed away where floods were more severe.
Heavy Chemical Fertiliser Use	No. Chemical fertilisers washed away into rivers, polluting water downstream, and leaving soil less stable and fertile. Nearby water sources became unsafe, chemicals caused algae blooms and fish deaths in rivers, hurting the fishing industry.

LESSON B4 HOW CAN WE RE-IMAGINE SOILS FOR A MORE SUSTAINABLE FUTURE?

MAIN SUBJECTS	DURATION	AGE GROUP	TEACHING METHOD
Civic Education, Environmental Science, Humanities, Language	3h	9+	Art-Guided Reflection, Backcasting, Creative Writing, Group Discussion, Scenario Building, Storytelling

OVERVIEW
Students reflect on their personal experiences with soil and how soil is represented in different cultures. Drawing inspiration from myths and fairytales from around the world, they create original stories about common soil issues. They explore different possible story endings that consider multiple perspectives, and then imagine what could be done to achieve a "happily ever after" ending that promotes justice, sustainability, and soil stewardship.

GREENCOMP COMPETENCES
Exploratory Thinking, Futures Literacy

LEARNING OUTCOMES
By the end of the lesson, students will be able to:
- Reflect on and explain how soil issues affect people, communities, and ecosystems differently.
- Demonstrate futures thinking and futures literacy skills by imagining and describing alternative soil futures.
- Translate stories to action by creating fairytale endings that promote soil stewardship and just outcomes for communities and ecosystems.
- Demonstrate imagination and empathy by reflecting on human responsibilities for soil and the ideas of justice and equity.

KEY CONCEPTS
Agency, Futures Literacy, Futures Thinking, Justice, Soil Stewardship, Sustainability, Systems Thinking

Background for teachers

Fairytales for the Future

This lesson uses storytelling and creative exploration to develop key competences in Futures Thinking and Futures Literacy, following UNESCO's Futures Literacy Framework.

- **Futures Thinking** is about analysing what could happen in the future based on current knowledge, identifying potential consequences, and planning actions to achieve desirable outcomes.
- **Futures Literacy** is the capacity to imagine multiple possible futures, challenge existing assumptions, and reflect on the values that shape our choices in the present.

Students apply both approaches to create their own stories to explore how values such as fairness, care, and stewardship can guide sustainable, "happy endings".

Each phase of the lesson — from the sensory warm-up to the story construction and reflective discussion — supports one or more core Futures Thinking and Futures Literacy competencies:

- **Anticipation & Exploratory Thinking:** Instead of focusing on one fixed outcome, students envision multiple story endings (nothing changes, worse, better, happy ending) and predict the effects on soil, humans, and non-human characters.
- **Systems Thinking:** In the warm-up, students observe how soil, plants, animals, and humans are all interconnected, while reflecting on their own relationship to these systems. When creating their stories, they consider how their characters' choices affect other characters and the wider system.
- **Exploring Assumptions:** Students examine positive and negative connotations of soil in language and culture to uncover hidden beliefs and values that influence how people relate to soil. As they create their stories, they continue to question these assumptions by imagining alternative futures that challenge existing narratives about humans and nature.
- **Creativity and imagination:** Allowing students to tell their stories through different formats such as acting, drawing, writing, or music lets them express themselves, stretch their imaginations, and generate novel ideas using skills they are most comfortable with.
- **Backcasting:** Students start with a "happy ending" and identify steps and actions that could lead to that desirable future.
- **Perspective-Taking:** Including human and non-human characters and reflecting on how they are affected by different choices helps students consider multiple viewpoints.
- **Adaptability:** Students adjust and revise their stories in response to different possible endings and unexpected events introduced by the Story Surprise Cards.
- **Values and Ethics Awareness:** Students discuss and reflect on fairness, justice, and care as guiding principles for a happy ending.
- **Agency and empowerment:** Students make choices for their characters, recognising how human actions can influence outcomes in stories and real-life soil systems.
- **Reflection:** Group discussions connect fictional futures to present-day responsibilities and actions for soil care and sustainability.

Myths and fairytales provide a rich, natural context for developing Futures Thinking and Futures Literacy. These stories are universal across cultures and generations, often highlighting the deep and primal connection between humans and soil systems. Their simple, familiar structure makes them especially accessible to young learners, who can easily recognise, understand, and recreate them. Traditionally, these stories have been used to help people make sense of change, uncertainty, and human-nature relationships. They invite audiences to imagine alternative worlds, explore moral choices and "what if" scenarios, and consider the consequences of human actions, which are key aspects of futures-oriented thinking. Adapting and reimagining these narratives also allows students to engage with real-life issues in a safe space, helping them work through complex emotions and making abstract concepts like justice, ethics, and sustainability more tangible.

PREPARATION

MATERIAL
- Whiteboard or flipchart and markers
- Paper/notebooks
- Handout B4.1: My Soil Story (one per student)
- Story surprise cards

INTRODUCTION 20 MIN

WARM-UP
1. (Re)connect students personally and emotionally to soil and the natural environment through sensory exploration and a short memory exercise.

- 1a. Outdoor option
  Take students to a nearby green space such as a park, garden, or school courtyard. Invite them to explore respectfully and mindfully: smell the grass and plants, touch the soil and leaves, notice textures, colours, temperature, and moisture. Observe living things in and around the soil (insects, worms, roots, birds, small animals). Give them a few minutes to quietly reflect on and express how the soil and its surroundings feel (physically) and how they make them feel (emotionally), for example compared to being in the classroom or at home.
- 1b. Indoor option
  Bring samples of soil, plants, and leaves for students to touch and smell, or ask them to close their eyes and imagine their favourite outdoor place to play. Encourage them to think about the sensations, textures, smells, and feelings associated with their imagined or sample environment.

This helps students see that soil is more than just dirt: it is a living system that supports all kinds of life.

TEACHER TIPS
If students find it challenging to express their emotions, you can use emotion cards to support them, such as those from the activity "How do you feel about climate change? Working on emotions".

PROCEDURE 2H

PART 1 - EXPLORING REPRESENTATIONS OF SOIL 45-60MIN

2. Ask students to sit or lie down (ideally in the grass if possible) and think about their favourite memory related to soil. For example, they could describe the feeling of cool grass underneath their feet on a warm summer day, crunching leaves on the ground in the fall, squishing mud between their fingers, or building sand castles on the beach.

3. Invite a few volunteers to share their memories and encourage them to be descriptive. Write down key words on the board or flipchart.

4. Continue to brainstorm other words or common sayings that come to mind when you think of soil. Examples include: “Mother Earth,” “down to earth,” “treated like dirt,” “uprooted,” “native soil,” “putting down roots,” “being grounded,” “you reap what you sow,” “six feet under”.

You could also ask them to think about synonyms for soil in your local language or other languages, which may differ according to quality, type, and use.

5. Group the words and common sayings into positive and negative connotations. For example:

Positive:
- “Mother Earth” → nurturing, giver of life
- “Native soil” → home, heritage, identity
- “Putting down roots” → settling down, belonging, establishing stability
- “Down to earth” → practical, realistic, humble
- “Being grounded” → balance, strength, stability

Negative:
- “Treated like dirt” → disrespected, disregarded, devalued
- “Biting the dust” → failure, death, defeat
- “Uprooted” → displaced, disconnected, lacking stability
- “Soiled reputation” → corruption, loss of purity, ruined

Both (context-dependant):
- “You reap what you sow” → responsibility, fairness, justice

This highlights the dual nature of soil: it can give life, provide stability, and connect us to home, but it can also be degraded, neglected, or symbolise loss and failure. In stories, this duality creates both the conflict and resolution.

It also demonstrates that soil is not just physical, it is symbolic: it carries stories about life, death, growth, justice, and belonging. Understanding these perceptions is important because human attitudes shape how we value and care for soil. In other words, language frames reality: thinking of soil as “dirty” or “life-giving” influences how we treat it.

If time allows, you can go deeper into different representations of soil, for instance in art, literature, poetry, music, television, film, and local culture.

You could do this by:

- Printing out excerpts from poems, books, or song lyrics and ask to highlight words related to/associated with soil and discuss the meanings, symbols, and whether they are positive or negative representations
- Showing them screenshots or short video clips from popular films and television shows and asking them to discuss how soil is represented.

Examples in film and television:

- WALL-E (2008): Earth is a barren wasteland covered in trash due to overconsumption and environmental neglect. The surviving plant in a boot represents hope, regeneration, and the return of life to the soil.
- Lords of the Rings Trilogy: The fertile soil of the Shire represents peace, home, and abundance, while Mordor’s barren volcanic landscapes symbolise destruction and corruption.
- Avatar: The Last Airbender the concept of bending elements – water, Earth, fire, and air — emphasising maintaining natural balance and harmony between these fundamental elements. The show explores the consequences of disrupting this balance.
- Alice's Adventures in Wonderland: Alice’s fall through a hole in the ground becomes a portal to another world, symbolising transition, discovery, and transformation.
- The Grapes of Wrath: The story is set during the American Dust Bowl and illustrates how soil degradation and drought can lead to social and economic hardship.
- The NeverEnding Story: The destruction of Fantasia symbolises the loss of imagination, connection, and care for the living world.

PART 2 - GENERATING NEW REPRESENTATIONS OF SOIL 45-60MIN

6. Read 2-3 short myths or fairytales from around the world that have a connection to soil. Examples include:

- Jack and the Beanstalk (England)
- The Turnip (Russia, Eastern Europe)
- Anansi and the Yam Hills (West Africa, Ghana)
- The Calabash Child (Nigeria)
- Abuk (South Sudan)
- Oldoinyo Lengai (Maasai, Northern Tanzania)
- The Rice Goddess (Philippines, South Asia)
- Bhumi Devi (India)
- Corn Mother (Native American Nations, Cherokee/ Haudenosaunee)
- The Three Sisters (Native American Nations)
- Maya Maize God (Mesoamerica, Mayan culture)
- The Earth Diver (Native American Nations)
- Papa-tu-ā-nuku (Māori, New Zealand)
- Taro myths (Hawai‘i & Polynesia)
- The Clay of Adam (Abrahamic traditions)

Start a brief discussion:

> *What do these stories have in common? What is the problem, solution, and moral/lesson? What role does soil play and how is it portrayed (positively or negatively)? How did humans or other beings interact with the soil?*

7. Students now get to create their own stories using **HANDOUT B.4.1: MY SOIL STORY.** Encourage them to be creative and use any format that allows them to tell their story (drawing, acting, singing, making a comic, etc.). Older students can research real-world soil issues for inspiration.

WRAP UP 30 MIN

8. Ask a few volunteers to share their story (2-3 minutes each) with the class.

9. Lead a reflective discussion using the following questions as a guide:

- *What do your stories teach us about how we should care for the soil?*
- *What actions made things better or worse for the soil? Which actions were fair or unfair and to which characters?*
- *How were characters affected by soil problems? Were they affected differently?*
- *If magical elements were used to solve a problem, how could it be solved in real-life without magic?*
- *If non-human characters solved the problem, how could humans take action instead?*
- *How did the Story Surprise Card change the way you thought about your story’s ending? What did it teach you about unexpected events in real life?*
- *What actions can humans take today to promote fairness and long-term soil health?*
- *Did imagining different possible futures for your story help you think differently about soil? If so, how?*
- *Did thinking about the future of soil in your story change how you view your role or choices in caring for it?*

HANDOUT B4.1 PAGE 1/2

MY SOIL STORY

Part A - Building Your World

Question 1 Where does your story happen? (farm, village, city, forest, desert, mountains…)

Question 2 Who are the main characters? Include at least 1 non-human character (tree, worm, squirrel, river, soil).

Question 3 What is the soil problem? What caused it? Who is helped? Who is hurt?

Question 4 What message or lesson do you want your reader to learn?

Question 5 What would happen if… Nothing changes? Things get worse? Things get better?

Part B - Shaping Your Story

Question Pick a "Story Surprise Card". How does this change your story? Think about how the soil, humans, and non-human characters are affected.

Imagine three different endings. For each one, write what happens to:

The soil - The people or community - The animals, plants, or other non-human characters

1) Nothing changes - 2) Things get worse - 3) Things get betterman characters are affected.

Question What can be done to give your story a happy ending? How can you make sure that everyone/everything gets a happy ending? Think about specific actions that people or communities took, and what values (care, fairness, teamwork) helped make it possible?

HANDOUT B4.1 PAGE 2/2

MY SOIL STORY STORY SURPRISE CARDS

Tired of humans mistreating the land and taking more than they need, Azra, the Earth Guardian, gives the soil a voice that humans can hear.

A mysterious traveller gives you a special potion.

"One drop a day, and your land will overflow with fruits and vegetables! But be careful: if you use too much, the soil will get sick and nothing will grow."

The king demands more and more drops be used to grow extra food to sell at the market. He gets richer with every harvest, but soon the soil is too weak and now it is hard to grow anything at all.

Everyone in the land loved chocolate so much that they started planting cocoa beans all over the kingdom. Fields once filled with a rainbow of fruits and vegetables were now packed with cocoa trees, upsetting the balance of the land.

One day, a pest arrived (whose favourite food is cocoa trees), and ate up the entire crop in just two days. With no other plants to eat, people and animals must find other ways to get food.

The Queen declares that all the fertile land now belongs to her and her friends. But feeling generous, she allows everyone else to share a single plot the size of a basketball court.

Upset that humans were warming the world by burning fossil fuels and cutting down trees, Azer the Sky God begins to weep.

Her tears fall day and night, flooding the fields and washing away the fertile topsoil, making it impossible for crops to grow.

King Sylvar ordered all the trees in the kingdom to be cut down to build his castle.

"Ten gold coins for each tree that is cut!"

At first, the people grew rich. But the forest soon disappeared and animals lost their homes. In summer, the land became hotter and drier, and when it rained, the soil quickly washed away. Soon it was hard to grow food.

Lord Beton has been ordered to build as many homes, roads, and castles as possible. Soon, every part of the land is covered and people come from far and wide to admire the mighty grey kingdom.

But since all the soil is trapped beneath concrete, animals have nowhere to live, and people can no longer grow their own crops, so they must get food from nearby kingdoms.

Denaro the Coyote arrives with a gift of magic seeds.

"These seeds will grow the most delicious fruits and vegetables that you have ever tasted! But be careful: for every seed you plant, one of your neighbour's plants will wither and die."

LESSON NFA1 CREATE YOUR TERRARIUM

MAIN SUBJECTS
Arts and crafts, gardening

DURATION
2h

AGE GROUP
9+

OVERVIEW
Participants create miniature terrariums that serve as visual analogies for natural soil ecosystems. Each terrarium features three distinct layers that represent:
- Bedrock (foundation layer)
- Soil (middle layer)
- Vegetation (surface layer)

LEARNING OUTCOMES
By the end of the lesson, students will be able to:
- Visualise the structure and composition of soil ecosystems
- Understand the relationship between different soil layers
- Observe how plants interact with their underground environment
- Create a self-contained ecosystem that they can continue to observe over time

This experiential learning approach transforms abstract soil science concepts into tangible models that participants can build, observe, and maintain.

PREPARATION

MATERIAL
- Handouts XX to print out for participants
- Transparent large jars, bowls, bottles… to host a small ecosystem
- Small rocks, sand, pebbles… to mimic bedrock
- Soil, compost, humus… to mimic soil
- Small plants, ferns, moss…
- Video tutorial: https://www.youtube.com/watch?v=fOdqUfhMpNk&t=3s

INTRODUCTION 10 MIN

1. Begin with a group discussion about the different types of ecosystems that participants are familiar with, whether they are nearby or far away. Ask whether they believe that the plants and animals in a specific ecosystem thrive in similar types of soil. Conclude the discussion by emphasising that different soils support different ecosystems. Highlight that the variability in soil and ecosystems is influenced by bedrock conditions and local climate.

2. Next, invite participants to create their own small ecosystems in terrariums.

PROCEDURE 1H30

3. You can ask participants in groups or individually to reflect on the terrarium they want to create. Will it reflect a tropical, temperate or desert ecosystem, for instance? Invite them first to draw and legend their terrarium. They can use Handout 1 to understand which layer of actual soil is represented by each component of the terrarium and Handout 2 to find examples of specific ecosystems and how it can be recreated in a terrarium.

TEACHER TIPS

Scientific drawing: in a classroom and for researchers, it is very important to draw and legend devices, natural elements and so on. Scientific drawing reflects reality, highlighting various elements that show the understanding of the object (shape, proportions, function and so on). A scientific drawing needs a title, a scale and a caption.

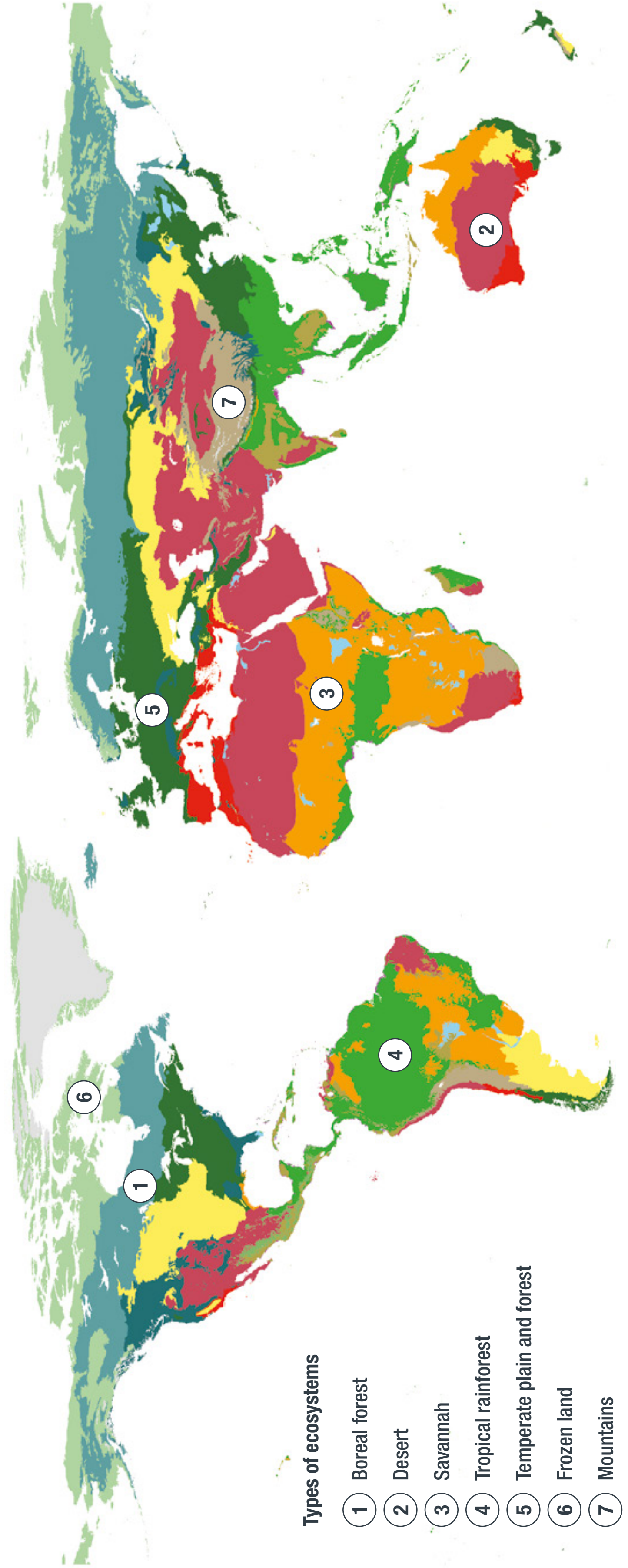
4. Participants create their terrariums using appropriate tools and elements. They can be guided using the Handout below.

WRAP UP 20 MIN

5. Finish up with a small exhibition of the terrariums and let participants explain what they created, to which type of ecosystems is it related, but also why do they like it? What is so important and personal about their terrarium? You may choose to keep the terrarium in the classroom / communal area, or each participant can take it with them. Recommend that they take care of it by watering it (depending on the ecosystem type, you may need more or less water), by cutting or removing and replacing dead parts, and by cleaning the glass if needed.

HANDOUT 1 PAGE 1/1
ECOREGIONS OF THE WORLD

MAP SHOWING TERRESTRIAL ECOREGIONS OF THE WORLD



Types of ecosystems

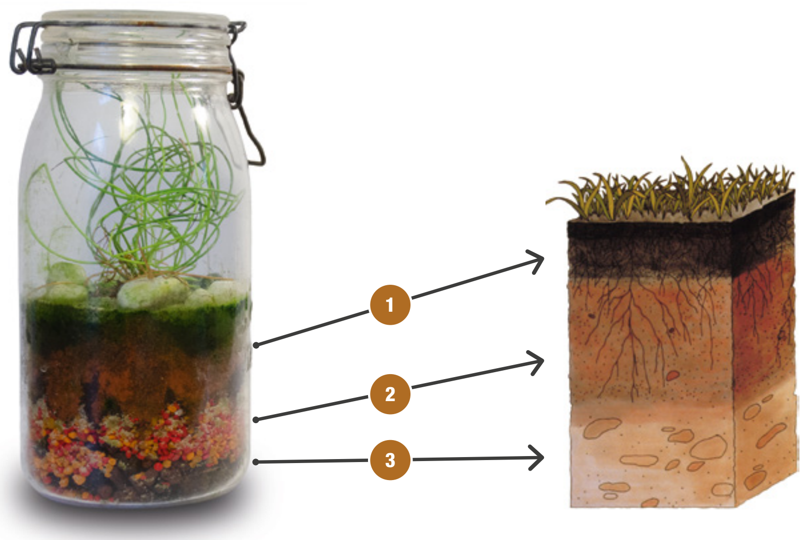
1. Boreal forest
2. Desert
3. Savannah
4. Tropical rainforest
5. Temperate plain and forest
6. Frozen land
7. Mountains

Biome

- Tropical & subtropical moist broadleaf forests
- Tropical & subtropical dry broadleaf forests
- Tropical & subtropical coniferous forests
- Temperate broadleaf & mixed forests
- Temperate conifer forests
- Boreal forests / Taiga
- Tropical & subtropical grasslands, savannas & shrublands
- Temperate grasslands, savannas & shrublands
- Flooded grasslands & savannas
- Montane grasslands & shrublands
- Tundra
- Mediterranean forests, woodlands & scrub
- Deserts & Xeric shrublands
- Mangrove
- Rock & ice

Source: Adapted from Olson et al., Terrestrial ecoregions of the world: A new map of life on Earth. BioScience, Volume 51, Issue 11, November 2001, Pages 933–938

HANDOUT 2 PAGE 1/1
ECOREGIONS OF THE WORLD



Source: United State Department of Agriculture (adaptation)

1. Potting soil (mixture of compost and soil): rich in organic matter, analogous to litter and humus. This is where the roots will develop. It contains the soil macrofauna (earthworms can be added, for example).
2. Gravel, sand, clay or coal: poor in organic matter, allows aeration and contains water. Analogous to clay or sandy soil. Charcoal is not mandatory but it helps to reduce odours.
3. Pebbles, rock, slate, coarse sand: mainly minerals and rock. Analogous to bedrock and to the weathered part of bedrock that turns into soil.

ECOREGION	SOIL	PLANTS	COMMENTS
Boreal forest	Poorly developed acidic soil (e.g. heathland), sand and slate	Lichens, mosses (sphagnum), carnivorous plants, fir shoots	Often acidic, wet and cold soils. A bog can be created (mosses and carnivorous plants). Moisten well but do not leave in the heat
Desert	Sand, pebbles and gravel	Cacti and succulents	Little watering, keep warm
Savannah	Potting soil, sand, clay and pebbles	Grasses, small bushes, peanuts	Medium watering, keep warm
Tropical rainforest	Potting soil, humus, gravel	Mosses, epiphytic plants, pothos, orchids	Constant moistening, best is a closed terrarium, keep warm
Temperate forest	Potting soil, sand, gravel	Mosses, lichens, ferns, tree shoots	Medium heat, medium moistening
Arctic zone	Rocks, sand, gravel	Lichens and mosses	Closed terrarium, keep it cold
Mountain	Rocks, acid soil	Little mountainous plants, lichens, mosses	Keep it cold

THE SOIL IN OUR HANDS

LESSON NFA2 SOIL STORY QUILT

MAIN SUBJECTS
Art and Craft, Storytelling

DURATION
2h

AGE GROUP
9+

OVERVIEW
Participants create a communal soil justice quilt by contributing individually crafted square panels using recycled and found materials. Each panel represents a real-life soil justice story from around the world. Through storytelling and textile art, participants explore how soil connects to social and environmental justice.

LEARNING OUTCOMES
By the end of the lesson, students will be able to:
- Understand social and environmental justice issues related to soil.
- Explore links between soil health and social and environmental vulnerabilities.
- Express perspectives on justice, identity, and land stewardship through textile art (quiltmaking) and visual storytelling.

Background for facilitators

Story quilting combines the art of quilting with the rich tradition of storytelling to share personal, historical, or cultural narratives. This practice fosters community through "sewing circles," where people sit and sew together, sharing skills, conversation, and support. For many women, these sewing circles serve as an important source of empowerment and social connection.

Quilting often involves reusing old fabrics and materials, embodying the principles of sustainability and creativity. The process of quilt-making can be helpful in processing emotions, celebrating joy, honouring loss, and (re)building relationships. Across the globe, story quilts have been used as powerful tools for marginalised communities, blending tradition and art with activism and advocacy. Quilts have been used to honour lives, protest injustices, and raise awareness for important issues.

For example, friends, family, and community members have made collaborative AIDS memorial quilts to honour those lost to HIV/AIDS as a way of turning grief into awareness and collective remembrance. In Mexico, Indigenous women create Oaxacan quilts using traditional techniques to tell stories that address themes such as migration, land rights, and environmental concerns. In Canada, the Quilt of Belonging, featuring over 260 panels created by various cultural groups, including Indigenous nations and immigrant communities, has become a national symbol of unity in diversity.

Story Quilting and Craftivism

Fig. 1. AIDS quilt, Washington, D.C

Fig. 2. Quilt of Belonging at the Inaugural exhibition at the Canadian Museum of Civilization, Gatineau, Quebec, Canada

Craftivism is a form of "gentle protest", describing an act of creation which is motivated by social justice or political activism (Greer, 2014). As a pedagogical approach, craftivism has the potential for giving voice, defending rights, expanding autonomy, and opening up possibilities for young people (Roswell and Shillitoe, 2019). Therefore, story quilting serves as a powerful educational tool, enabling people of all ages and backgrounds to engage with complex issues in a creative way. This practice fosters personal reflection, creative expression, and a sense of agency, making it a vital component of contemporary activism.

PREPARATION

MATERIAL

For Discussion
- Sticky notes,
- Flipchart,
- Whiteboard,
- Markers,
- Pencils,
- Pens

For Story Inspiration: Soil justice stories, printed for each participant according to age level:
- "Curious" for upper primary students
- "Advanced" for middle school students
- "Expert" for high school students

For Individual Quilt Panels
- Large pre-cut fabric or felt squares (one per participant)
- Fabric scraps (e.g., cotton t-shirts, jeans, canvas bags)
- Natural dyes (e.g., beetroot, turmeric, onion skins, coffee, tea)
- Yarn, buttons, ribbons, lace, twine
- Scrap paper or cardboard (e.g., old packaging)
- Natural materials (e.g., soil samples, leaves, twigs, seeds)
- Paints, pastels, or natural pigments

For Quilt Assembly:
- Needle and thread,
- Fabric glue,
- Safety pins,
- Scissors

Optional: A large backing cloth (e.g., an old sheet or blanket) to attach the panels

TEACHER TIPS

Using recycled, found, and natural materials (as long as they are clean and dry) is not only good for the environment, it also reflects traditional quilt-making practices, where old fabrics were used to create something new and meaningful. Encourage participants to explore materials, textures, colours, and even scents to help tell the story in a creative and personal way!

INTRODUCTION 20-30 MIN

WORD ASSOCIATION WARM-UP 10 MIN

1. Start by asking the participants: What words, images, ideas, or feelings come to mind when you think of soil? (e.g., earth, brown, dirt, mud, life, plants, garden, nature, etc.). This could be through a word cloud, sticky notes, or writing the words on the board or flipchart. At this stage, there are no right or wrong answers. The goal is to get a sense of what they know or think about soil, what they care about, and what they are curious about when it comes to soil.

2. Next, ask them to group their responses into categories, for example:

- Living things: worms, insects, fungi, plants, roots, microbes
- Non-living things: dirt, rocks, sand, mud, clay, minerals
- Actions or uses: gardening, planting, digging, farming, composting
- Physical properties: brown, grey, cold, warm, soft, hard, wet, dry, porous
- Feelings/emotions: grounding, messy, dirty, comfort, calm, alive, nurturing
- Changes/processes: erosion, decomposition, regeneration
- Cultural/social: home for people, habitat, farmland, sacred land, garden
- Functions/roles: supports plants, filters and holds water, recycles nutrients, stores carbon

This helps highlight patterns, gaps, and misconceptions (e.g., soil seen as "dirt" instead of a living system).

3. Connect their ideas to formal definitions of soil, for example:

> *Soils are complex mixtures of minerals, water, air, countless organisms and organic matter, that is the decaying remains of once-living things. It forms at the surface of land – it is the 'skin of the earth.' Soil is capable of supporting plant life and is vital to life on earth.* (Soil Science Society of America)

DISCUSSION 10-20 MIN

4. Ask: *why do you think soil is important?*

Key Information The Importance of Soil

Soil is the foundation of life. It is important because it performs many critical functions that people and ecosystems depend on. Soil supports plant growth, provides a home for many organisms (e.g., worms, insects, bacteria, microbes, fungi, small burrowing animals like moles and groundhogs), stores and filters water, recycles nutrients, stores carbon, exchanges gases with the air, and provides a foundation for buildings and roads.

You can highlight the importance of soil by sharing a few key facts:

- **95% of the food that we eat is dependent on soil**
- **Soils are alive:**
  → Soils are one of the most biodiverse ecosystems on the planet
  → It is estimated that **more than half of all earth species live** in the soil
  → **One gram** of soil (a quarter of a tablespoon) can harbour **up to 10 billion organisms** — that's more than the number of people living on the planet!
- **Soils help fight climate change:**
  → Soil is a **major component of the global carbon cycle.** Most of the carbon is stored as organic carbon in soil layers, especially in the topsoil, and this storage varies depending on soil type, vegetation, and land use.
  → Globally, soils store **more carbon than the atmosphere and all of the world's plants and forests combined.**
  → Healthy soils have the potential to offset 5-15% of global fossil-fuel emissions by storing carbon and reducing greenhouse gases.
  → They can also help to prevent floods and mitigate droughts by retaining and filtering water, supporting resilient ecosystems.

FACILITATOR TIPS: Use the facts to make a quick quiz to keep the energy up!

5. Explain that soil can only perform these vital functions when it is healthy. Then, ask: *What makes soil healthy?*

Key Information What is Healthy Soil?

Healthy soil is soil that is alive and able to perform the essential functions that humans and ecosystems depend on. Like any living system, soil can also become "sick" or degrade. Things like erosion, pollution, compaction, loss of biodiversity, and poor farming and land management practices disrupt the balance of water, air, organic matter, and living organisms that soil needs to stay healthy.

Healthy soil supports healthy life for everything that depends on it. This connects to the concept of **One Health**—the idea that the health of people, animals, and ecosystems (including soil) is deeply interconnected. Some studies even suggest that exposure to microbes in healthy soil may have positive effects on human digestion, immune function, and mental well-being!

6. Now, transition to a discussion about soil justice by asking:

- *Does everyone have the same access to healthy soil?*
- *If your answer is no, why not? What factors affect access to healthy soil?*
- *Do you think this is fair?*
- *If soil is essential for food, water, climate, and ecosystems, who or what is harmed when access to healthy soil is lost or when it becomes damaged, polluted, or taken away?*

Key Information Soil Justice

Not all soil is created equal. According to the UN's Food and Agriculture Organization (FAO), **one-third of the world's soils are now moderately to severely degraded,** mostly due to human activities like intensive agriculture, urbanisation, and unsustainable land use.

We are losing topsoil **10-40 times faster than it forms.** Some estimates suggest that the equivalent of **30 football pitches of fertile soil is lost every minute!** Depending on local conditions, it can take up to **1,000 years to form just 1 cm of topsoil,** but **it takes a matter of moments to lose it.** This is why soil is considered a **non-renewable resource,** and why it is so important to protect and care for it. The way we use and care for soil has direct consequences for people, animals, and ecosystems.

Soil justice is about the fair and equitable recognition, protection, and stewardship of soil, ensuring that all people, communities, and living beings have access to healthy, living soil, and that no one—human or non-human—is unfairly harmed by soil degradation, pollution, or loss. This includes considering who benefits from healthy soil, who bears the burden when soil is damaged, and how people, ecosystems, and future generations are affected by the way soil is used and cared for.

PROCEDURE 1 H

7. Hand out the soil justice story examples to each participant based on their level (e.g., "Curious" for upper primary, "Advanced" for middle school, or "Expert" for high school). Give participants 5 minutes to read the stories individually. Participants are also welcome to find or create their own story to base their quilt panel on.

8. In pairs or small groups (3-4), give participants 3 minutes to discuss:

- *What surprised you about these stories?*
- *What inspired or moved you?*
- *What questions or thoughts came up?*

9. Each participant chooses one story and creates a quilt panel to represent it. While working on their panel, ask them to reflect on:

- *What do you want others to know about this story?*
- *What materials, colours, or textures could help you tell the story?*
- *How is the story connected to justice, and how can you show that in your panel?*

10. Ask each participant to write a short message to accompany their quilt panel. This message will be placed in a "secret pocket" hidden or attached to their panel. Encourage participants to be creative in how they hide and express their message (e.g., a drawing, symbol, or other visual representation).

Examples include:

- *A personal reflection on what the story means to them*
- *A question they want others to think about*
- *A central emotion or reaction*
- *A call to action or something they hope people will do*
- A hope or wish for people, communities, or the environment

11. When everyone has finished, gather the individual panels and decide as a group how to arrange them before creating the collective quilt.

12. Once the quilt is assembled and displayed, allow time for everyone to explore each other's work.

Encourage participants to interact with the panels in pairs or small groups or individually by:

- Finding one they like that is not their own and describing how it makes them feel,
- Guessing the hidden message and the story that inspired it, and
- Trying to match each quilt panel to the story it represents.

You can give them sticky notes to mark their guesses or record their reflections.

13. Invite volunteers to talk about their quilt panel and how it reflects the story they chose. Ask them to be specific about their choice of materials, symbols, and any challenges they may have encountered. Encourage other participants to respond, ask questions, or comment on each story.

WRAP UP 10 MIN

Finish by facilitating a group discussion:

- *What do these stories tell us about how people, animals, and living things are connected to the soil?*
- *Are there any similarities between the quilt panels? Any differences?*
- *Can you think of examples of soil justice in your community/town/city/country?*
- *What can we do in our own communities to care for the soil and support justice?)*

SOIL JUSTICE STORIES FROM AROUND THE WORLD CURIOUS

WANGARI MAATHAI AND THE GREEN BELT — KENYA

Many years ago, people in Kenya were cutting down too many trees for firewood and to make room for farms. Without trees, wind and rain washed the soil away, taking with it the nutrients that plants need to grow healthy and strong. This is called soil erosion. When this happens, crops like maize, beans, and vegetables don't grow well and families have less food to eat and sell at the market. Streams dried up, animals lost their homes, and women had to walk farther every day to find clean water and wood. A scientist named Professor Wangari Maathai listened to women in villages who were worried about feeding their families and came up with a simple idea: plant more trees! Trees hold soil in place with their roots, soak up rainwater, and also give shade, shelter, fruit, and wood. Together, they started the Green Belt Movement, and have planted over 51 million trees across the country! The land became healthy again, crops and streams returned, and women have become leaders in caring for the earth. Her idea showed the world that even small actions, like planting trees, can make a big difference!

PRAIRIE DOGS AND THE GREAT PLAINS — USA

Prairie dogs are small animals that dig huge underground towns on the American grasslands. Their tunnels help air and water get deep into the soil, which makes grasses grow stronger and keeps the land healthy. Prairie dogs are called a "keystone species" because they play an important role in keeping nature in balance. Their towns support over 150 other species, like burrowing owls, foxes, and the endangered black-footed ferret. But, some people thought prairie dogs were pests and got rid of them to build houses, roads, and farms. This destroyed most of their habitat—about 95% is gone! Without prairie dogs, the soil became hard and dry, and many plants and animals that depended on them disappeared. Now, Native American tribes like the Ogala Lakota and conservation groups are working to protect and bring back prairie dog colonies. Thanks to their efforts, the soil is healing, animals are returning, and people are learning to respect nature. This story shows that protecting prairie dogs helps protect the land and everyone and everything that depends on it!

TERMITES AND THE SAVANNA SOIL — AFRICA

In the grassy savannas of Africa, termites build giant mounds—some are even taller than a person! Inside, they are busy digging tunnels and growing fungus for food. Their tunnels help move air and water through the soil, making it rich, moist, and full of nutrients. This helps plants grow strong and healthy, even during droughts when there is little rain. Some farmers thought termite mounds were a problem and flattened them to make space for farms. But without the mounds, the soil became hard, dry, and dusty. Plants couldn't grow well and animals and people had less food. Now, local communities and scientists are working together to protect termite mounds. The soil is healthier, plants are greener, and crops grow better. This shows that even the smallest creatures can have a huge impact!

SOIL JUSTICE STORIES FROM AROUND THE WORLD ADVANCED

SÁMI REINDEER HERDERS AND THAWING PERMAFROST — NORTHERN EUROPE

The Indigenous Sámi people have herded reindeer across the Arctic regions of Norway, Sweden, and Finland for centuries. They rely on permafrost—soil that stays frozen year-round. Permafrost helps store carbon, keeps the ground solid, and supports the Arctic ecosystem. But climate change is causing the permafrost to thaw, making the ground muddy and unstable. This makes it hard for reindeer to walk through and lichen, their main food source, gets buried or destroyed. The changing soil and melting landscape are not only harming the animals, but also threatening Sámi culture, food systems, and traditional way of life. In response, Sámi communities are using traditional knowledge and modern tools like GPS tracking to guide herds to safer areas, working with scientists to monitor soil and permafrost loss, and speaking at international climate meetings to demand action and respect for their rights. This story shows us that soil, climate, and justice are deeply connected and how traditional knowledge and science can work together to help us care for the land.

FARMERS VS BIOFUEL EXPANSION — TANZANIA

In the 2000s, foreign companies, like Sun Biofuels from the UK, began leasing large areas of land in Tanzania to grow jatropha, a plant that can be turned into biofuel. Local villagers were promised good jobs, "clean energy", and benefits for their communities. Thousands of hectares of farmland were cleared to plant jatropha, replacing traditional crops like millet, maize, and cassava. The soil was overused and lost nutrients, leaving the land less fertile and unable to grow healthy crops. Many villagers lost the land their families had farmed for generations, which caused food shortages and made people poorer. To fight back, farmers, activists, and organisations protested to defend their land rights and food security. Some land was eventually returned, but the damage to the soil and community was already done. This case shows that "green" solutions like producing biofuel can still cause environmental and social injustice if they ignore the needs of local people and the health of the soil.

COMMUNITIES AND THE VANISHING FARMLAND — EGYPT

The Nile Delta in Egypt has less than 2% of the country's land but produces more than 50% of its food, thanks to its rich, deep soil. But since the 1970s, massive urban growth has paved over more than 70,000 hectares of this fertile farmland to build new houses, roads, and factories. When farmland is covered with concrete or asphalt—a process called soil sealing—the soil can no longer support plants. This loss is permanent: once the soil is buried, it can not be used for farming again. As a result, Egypt has to import more food, which raises prices and makes the country more dependent on other countries. Urban sprawl also creates another problem: the urban heat island effect. Cities with lots of pavement and little green space can get up to 7°C hotter than the surrounding countryside. Some students and community groups are trying to help by mapping these hot spots and creating rooftop gardens to bring plants back into the city and reduce heat. This story shows how important it is to plan and share land in ways that consider and balance the needs of farmers, city dwellers, and future generations.

HANDOUT 2 PAGE 3/3

SOIL JUSTICE STORIES FROM AROUND THE WORLD EXPERT

OIL SANDS & INDIGENOUS LAND RIGHTS — CANADA

Beneath some of the world's largest peat soils, the province of Alberta's oil sands hold massive oil reserves and store huge amounts of carbon. To extract the valuable oil, forests and soil are stripped away, leaving behind vast quantities of toxic chemicals across a large amount of land, including areas owned by Indigenous communities. In 2023, a spill from the Kearl mine released 5.3 million litres of toxic wastewater, contaminating water, wildlife, and food sources of local communities. Recent studies show polluting emissions may even be up to 6,300% higher than reported. In response, the Athabasca Chipewyan First Nation is suing regulators for violating treaty rights to clean land and water. Their ongoing resistance highlights how soil health, Indigenous sovereignty, and environmental justice are closely linked.

DAEWOO LAND GRAB — MADAGASCAR

In 2008, the Korean company Daewoo Logistics tried to lease 1.3 million hectares—nearly half of Madagascar's arable land—for industrial farming to grow corn and palm oil. This meant that locals risked losing their rice fields, which had fed communities for generations. Hundreds of thousands of people, including farmers and students, protested the foreign land grab, which led to the president being ousted. The lease was eventually cancelled, and the public resistance led to new land reform laws in Madagascar and inspired global movements against large-scale industrial land grabs. This case shows how local communities can stand up for their rights to healthy soil, food, and land.

THE DONGRIA KONDH VS VEDANTA RESOURCES — INDIA

The Dongria Kondh are an Indigenous community living in the Niyamgiri Hills, situated in one of the poorest regions in India. Their lives, culture, and spirituality are deeply connected to the soil, forests, and rivers of their sacred homeland, which is central to their identity and way of life. In the 2000s, the British-owned company Vedanta Resources sought to mine $2 billion worth of bauxite, a mineral used to make aluminium. Vedanta cleared forests and built a refinery without permission, taking over 60 hectares of forest. This contaminated the soil and water, caused health problems, and displaced over 100 families. The Dongria Kondh protested locally, nationally, and internationally, defending their land, forests, and way of life, and inspiring tribal communities across India and the world. The case raised major human rights concerns, including the lack of free, prior, and informed consent (FPIC) for land acquisition, violations of Indigenous and environmental rights, and damage to human and ecosystem health. Their struggle demonstrates soil justice in action, showing how communities can protect both people and nature when they fight for fair access, responsibility, and decision-making over the land that sustains them.

GLOSSARY

ADAPTATION The process of adjusting to current or expected climate change impacts. In human systems, the aim of adaptation is to reduce risks, increase resilience or seize on beneficial opportunities. In natural systems, human intervention may facilitate adjustments to expected climate change impacts.

BIODIVERSITY The variety of species (flora and fauna) that live on Earth or in a particular ecosystem.

CARBON CYCLE Carbon is a chemical element which can be found in many molecules, in living beings as well as in non-living materials. Carbon is stored in huge amounts in what are called “reservoirs” on Earth – the most important being the ocean and the soil. While the total amount of carbon on the Earth remains constant, it does not always stay in one reservoir but often moves between them: these movements are called "flows". Such "flows" of carbon between various reservoirs together constitute the carbon cycle.

CARBON DIOXIDE (CO_2) A gas produced by the combustion of carbon (for example: fossil fuels). It is also produced by living organisms while breathing. CO_2 contributes to the greenhouse effect.

CARBON SINK Natural reservoir that stores carbon-containing chemical compounds accumulated over time. Carbon sinks help reduce the amount of atmospheric CO_2. Natural sinks are soil – the largest carbon store – and part of the biosphere via photosynthesis by terrestrial plants and marine phytoplankton and algae, a process that incorporates atmospheric CO_2 into sugars using solar energy.

CLAY Soil particles smaller than 0.002mm or 2µm, also a soil texture class.

CLIMATE An average pattern of weather conditions – such as temperature, precipitation, humidity, wind, air pressure – for a particular region over a long period of time (months, years, decades, centuries or more).

CLIMATE CHANGE Climate change refers to several global phenomena. For example: changes in temperature, precipitation, extreme events, sea level rise and ocean acidification. The term is most often used to describe the current human-induced climate change, which began around 1850 and is characterised by an increase in the global average temperature. The term “global warming” is also used.

ECOSYSTEM The totality of living beings in each environment, plus the environment itself. In an ecosystem, everything is interconnected and interdependent.

ECOSYSTEM SERVICES Humans directly or indirectly benefit from ecosystems, which provide them various services. These services are grouped into four categories: provisioning, regulating, supporting and cultural. For example, ecosystems produce oxygen (through photosynthesis) and food, and they provide us with raw materials. Ecosystems also preserve soil fertility, fertilise plants and protect coasts.

EROSION (SOIL) is a physical phenomenon that results in the removal of soil and rock particles by water, wind, ice and gravity.

EXTREME WEATHER EVENT A rare meteorological event with a strong negative impact on human society and ecosystems (e.g. tornadoes,major fires, droughts, or heatwaves). Climate change is increasing the frequency and amplitude of some extreme events worldwide (extreme cold events are reduced however).

FOOD WEB A food web is a representation of the “prey-predator” relationships in an ecosystem. It is a web rather than a chain, meaning that one organism may eat several species, and a species may be eaten by multiple organisms.

GREENHOUSE EFFECT Incoming solar radiation that crosses the atmosphere, is absorbed by the Earth’s surface and hence warms it. The absorbed solar radiation is emitted as infrared radiation (heat). Some of this infrared radiation is “trapped” on its escape towards space by greenhouse gases in the atmosphere and is sent back towards the Earth’s surface – heating it up even more. This is called the greenhouse effect.

GREENHOUSE GAS (GHG) Greenhouse gases cause the greenhouse effect. Greenhouse gases are mainly water vapour, carbon dioxide, methane, nitrous oxide and ozone.

HORIZON Single layer in soil profile with similar properties or material but which differs at least in one property, e.g. colour or texture from adjacent horizons above or below in the profile;

HUMUS Organic compounds in soil, exclusive of undecayed plant and animal tissues, their partial decomposition products, and the soil biomass; a term often used synonymously with soil organic matter, its structure is amorphous, specific weight is low and surface area high. Humus is important for soil fertility, and helps to bind soil particles and aggregates together.

ION Electrically charged atom or group of atoms.

LEACHING The Removal of soluble materials from one zone in soil to another via water movement in the profile.

MITIGATION Human intervention to reduce global warming by reducing GHG emissions or by enhancing GHG sinks.

PEATLAND A generic term for any wetland where partially decayed plant matter accumulates

PHOTOSYNTHESIS The biological process by which green plants, algae, and certain bacteria use light energy, usually from the sun, to convert carbon dioxide and water into glucose to produce organic matter.

PRIMARY PRODUCTION Primary production is the process by which a primary producer (a cell or an organism) produces its own organic matter using mineral materials. For example, photosynthetic living beings only use water, CO_2 and light to grow.

SAND Soil particles between 0.05 mm and 2 mm used as a texture class name for coarse soil materials. Unlike clays, sandy soils do not shrink and swell on drying and wetting and, unless artificially compacted, are rapidly permeable.

SILT Soil particles between 0.002 mm and 0.05 mm used as a texture class name for medium and medium-fine soil materials. .

SOIL Soil is defined as the top layer of the Earth’s crust, situated between the bedrock and the land surface. It serves as a dynamic interface between the ground, air, and water.
The composition of soil includes five main components:
- Mineral particles, primarily consisting of silica and a mixture of trace metals.
- Organic matter, containing a wide variety of organic compounds.
- Water, which fills pore spaces in all but the driest conditions.
- Air, which occupies the remaining pore network.
- Living organisms, which range from microscopic bacteria to mammals like moles.

SOIL ACIDIFICATION Process whereby soil becomes acid (pH < 7) because acid parent material is present or in regions with high rainfall, where soil leaching occurs. Acidification can be accelerated by human activities (use of fertilisers, deposition of industrial and vehicular pollutants)

SOIL CONTAMINATION is the occurrence of a substance in soil above a certain level. Contamination can be diffuse or local and is due to many anthropogenic activities, such as industrial production, traffic, farming practices and waste disposal.

SOIL DEGRADATION Soil degradation means the loss of soil health, quality and productivity, and can be a consequence of water erosion, coastal erosion, wind erosion, salinity, loss of organic matter, fertility decline, soil acidity, etc is the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. It refers to the physical, chemical, and biological condition of the soil, which determines its ability to provide essential ecosystem services.

SOIL HEALTH Soil health is the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. It refers to the physical, chemical, and biological condition of the soil, which determines its ability to provide essential ecosystem services

SOIL COMPACTION is the term for the deterioration of soil structure (loss of soil features) by mechanistic pressure, predominantly from agricultural practices.

SOIL ORGANIC MATTER The organic fraction of the soil exclusively comprising undecayed plant and animal residues. See also humus.

SOIL POROSITY Volume of water and air that can be held in a soil; ratio of the volume of voids to the total volume of the soil.

SOIL PROFILE Vertical section of soil horizons from the upper layer to the parent material, showing the arrangement (configuration) of soil horizons typical for single soil types and used as a basis for soil classification.

SOIL SALINISATION is the accumulation of soluble salts of sodium, magnesium and calcium in soil to the extent that soil fertility is severely reduced.

SOIL STRUCTURE Soil structure is the arrangement of soil particles into groups called aggregates. These aggregates vary in size and shape, ranging from small crumbs to large blocks. Good soil structure matters because it lets water soak in and extra water drain away. It also helps air move through the soil. Soil, air, and water are all needed for healthy plant growth and nutrients

SOIL TEXTURE Soil texture is defined by the proportions of sand-, silt-, and clay-sized mineral particles in the soil. Texture can be coarse (sand particles predominate), medium (silt particles predominate), or fine (clay particles predominate).

SUSTAINABLE SOIL MANAGEMENT PRACTICES Practices that maintain or enhance the ecosystem services provided by the soil without impairing the functions that enable those services or harming other parts of the environment.

WATER RETENTION The ability of soil to hold water for a period that is longer than infiltration, normally 48h in a freely draining soil. It strongly depends on organic matter and bulk density. Soil texture also influences water retention.

TILLAGE A mechanical cultivation of agricultural soils by the plough to different depths (20 – 30cm) deep, creating arable land.

WEATHERING The breakdown and changes in rocks and sediments at or near the Earth's surface produced by biological, chemical, and physical agents or combinations of them.

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