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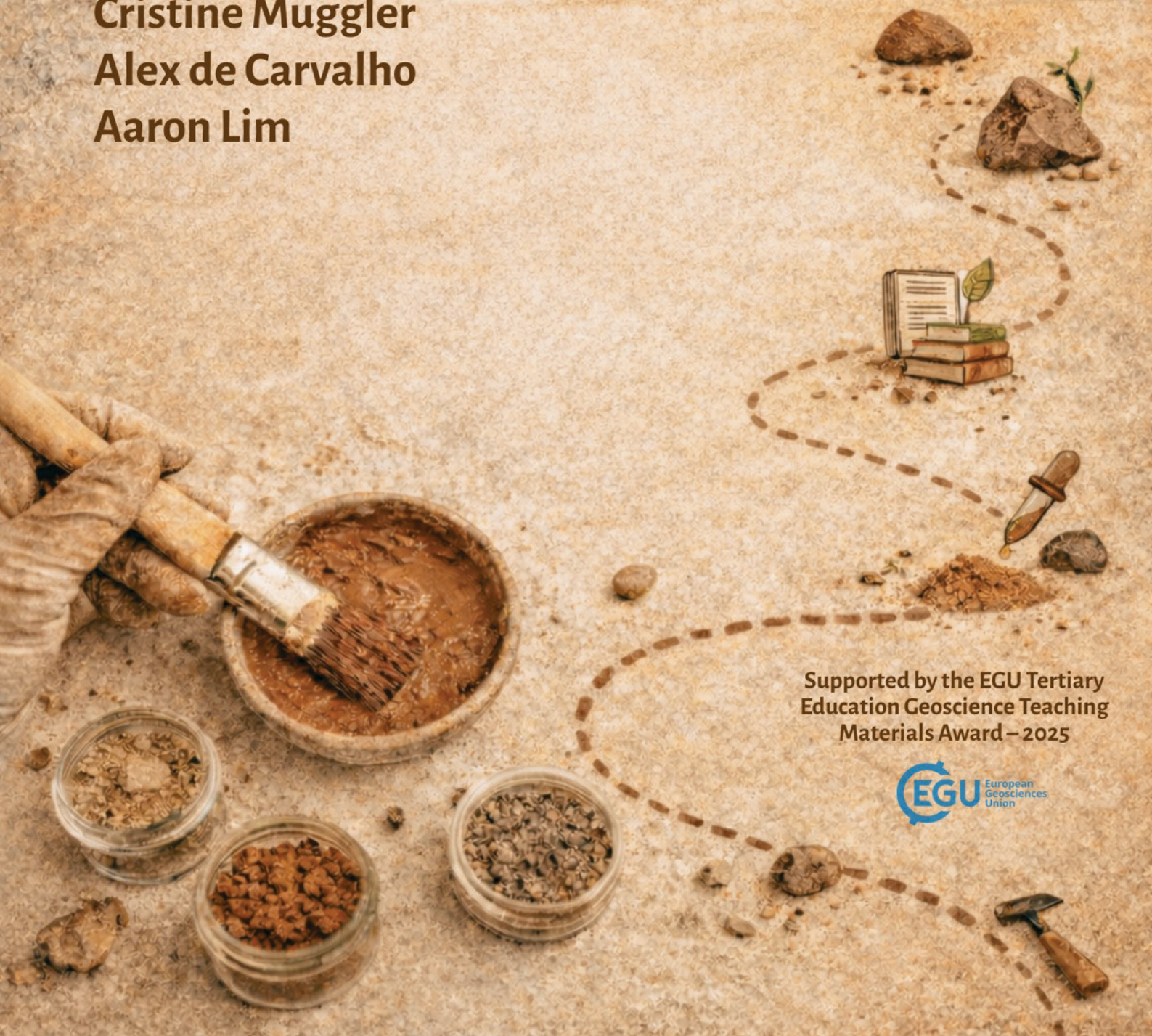
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Soil-based paint and geomaterials

a self-guided trail for geoscientist educators

Caroline Delpupo
Cristine Muggler
Alex de Carvalho
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Supported by the EGU Tertiary Education Geoscience Teaching Materials Award – 2025

Soil-based paint and geomaterials

a self-guided trail for geoscientist educators

First Edition

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2026

Preface

One recurring difficulty in Geoscience teaching is helping students connect abstract concepts with materials and processes they can actually observe. This self-guided trail was developed from that concern. It uses soil-based paint and other geomaterials as entry points for teaching, while also introducing soils as living systems structured by biological processes.

The material was designed to be low-cost, adaptable, and feasible in different educational contexts, including teacher education, university teaching, and outreach work with schools. The proposal is simple: to create conditions in which students can observe, handle, interpret, and discuss Earth materials through guided practice.

This material draws on several years of teaching, research, and outreach developed within the geography teacher education programme and the GEOTA Research Group and Lab at the Federal Institute of Minas Gerais (IFMG), in dialogue with the Graduate Programme in Geology at the Federal University of Ouro Preto (UFOP). The activities proposed here have been adapted and tested in both formal and non-formal educational settings. The presented self-guided approach reflects exchanges across different academic contexts that have treated soils and geomaterials as educational resources. In Brazil, the Soil Education Programme (PES) at the Federal University of Viçosa (UFV) provided an important reference. More recently, collaboration with University College Cork (UCC), Ireland, broadened this dialogue and supported the material's international development. Thus, this resource emerged from exchanges across these institutions, which contributed in different ways to its conceptual framing, methodological choices, and practical development.

The e-book was developed as part of the project selected for the EGU Tertiary Education Geoscience Teaching Materials Award 2025, funded by the European Geosciences Union. This support made it possible to consolidate materials, activities, and visual resources that had already been taking shape across teaching and outreach practice.

This e-book can be used both as a teaching resource and as a framework for educator training. It provides ready-to-use content and practical templates, but it is also intended to support reflection on how geoscientific knowledge may be taught in contexts with limited access to field sites, outdoor laboratories, or specialised infrastructure.

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How to use this e-book

This e-book is organised as a self-guided trail for educators who wish to plan and deliver learning activities with geomaterials, especially soil-based paint.

Each module combines conceptual discussion with practical guidance. Some also include short prompts that may help the educator adapt the activity to a particular audience or teaching context, such as: (i) Higher education (undergraduate and postgraduate courses); (ii) Teacher training programmes; and (iii) Community outreach and science communication (e.g. schools, museums, science fairs).

The modules may be followed in sequence, but they can also be used selectively, depending on teaching objectives, available time, and the profile of the group. The material is intended to be clear enough for independent use, while still leaving room for adaptation and integration into broader teaching plans.

You will find the following features throughout the e-book: (i) **Learning objectives** at the beginning of each module; (ii) **Step-by-step guides** for hands-on activities; and (iii) **Supplementary materials** including printable templates, workshop checklists and a glossary of terms to support interdisciplinary understanding. In addition, specific visual icons will help guide your experience (Figure 1).

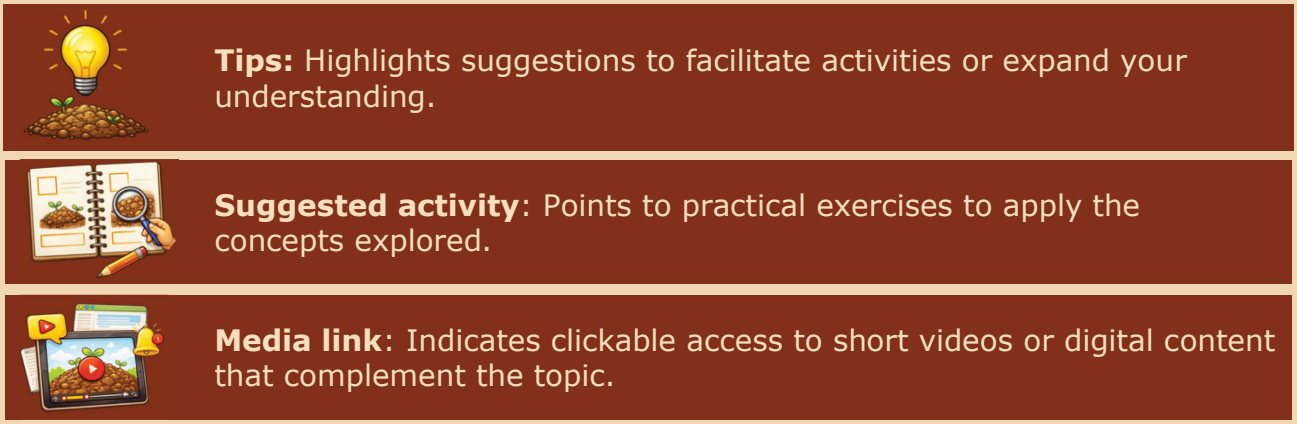


Figure 1. Icons used throughout this e-book: tips (lightbulb), activity suggestions (book), and digital resources (play symbol). AI-generated image (OpenAI/ChatGPT, 2025), edited by Caroline Delpupo using Canva® (Canva Pty Ltd., 2025).

The activities proposed here do not require specialised laboratories. Most can be carried out with simple tools and locally available materials, which makes the e-book especially useful where infrastructure and equipment are limited (Brevik et al., 2022).

The trail is intended to support teaching, but also to open possibilities for connecting Earth materials with local histories, places, and communities. Before moving to the modules, the welcome video below offers a brief introduction to the e-book.



Learning Objectives

Upon completing this self-guided trail, educators will be able to:

1. Recognise how geomaterials can be used in teaching, considering their scientific relevance, visual qualities, and pedagogical value;
2. Explain basic concepts in Pedogenesis, soil functions, and soil-rock-landscape relationships in ways that are accessible to different groups of learners;
3. Plan and carry out hands-on activities using locally sourced geomaterials, especially soils, in classroom, outreach, or laboratory-based settings;
4. Recognise soils as biologically structured systems and explain the role of soil biodiversity in soil functioning;
5. Use the soil-based paint workshop as an interdisciplinary teaching strategy linking Geoscience, art, environmental education, and cultural reflection;
6. Reflect critically on teaching practice and consider how tactile, visual, and participatory approaches may broaden student engagement in Geoscience education;
7. Adapt the material to different educational levels, from school outreach to higher education and teacher training; and
8. Encourage direct engagement with Earth materials in teaching.

Why geomaterials? Why soil-based paint?

Geomaterials such as soils, rocks, sediments, minerals, nodules and termite mounds are part of the material expression of Earth surface processes (Gray, 2013). While these materials are well established within geoscience curricula, opportunities for hands-on engagement are often limited in practice, particularly in urban settings or in contexts where access to specialist equipment and field sites is constrained.

When geomaterials are used in teaching, students work directly with materials they can handle, compare, and interpret. This shifts attention away from exclusively verbal or image-based explanation and allows observation to become part of the reasoning process.

Among these materials, soils are especially useful in educational practice because they are widely available and highly variable. They record aspects of environmental history, sustain ecosystems and agriculture, and often reflect the geology and climate of a region. Their differences in colour, texture, and composition make them particularly suitable for visual and tactile work (Wilding & Lin, 2006).

Soil-based paint is an educational tool that combines art and science. Derived from processed and filtered natural soils, this paint can be used to:

- Explore the mineralogical and chemical basis of soil colour;
- Discuss weathering, oxidation, and organic matter dynamics;
- Create opportunities for observation, comparison, and artistic experimentation; and
- Work with low-cost materials that can be sourced locally.

In this e-book, the soil-based paint workshop functions as an entry activity. It allows students to begin with observation, handling, and comparison, while opening discussion on soil formation, colour, materials, and landscape.

More broadly, working with geomaterials can help students read landscapes in material terms. Instead of seeing the landscape only as scenery, they begin to relate visible forms and colours to processes, materials, and environmental history.

Overview

This module introduces the main categories of geomaterials and their basic relationships. By comparing soils, rocks, sediments, and minerals, it supports interdisciplinary learning based on direct observation and locally available materials. It also anticipates a point developed later in Module 5: soil formation is not only physical and chemical, but also biologically regulated.

Learning objectives

- Understand what geomaterials are and how they are classified;
- Recognise the differences between soils, rocks, sediments, and minerals;
- Explain basic processes of soil genesis and pedogenesis; and
- Observe and identify local geomaterials in educational settings.

1.1 Definition and classification of geomaterials

Geomaterials are natural Earth materials found at or near the terrestrial surface. They include rocks, soils, sediments, and minerals, each with distinct physical, chemical, and structural characteristics.

In Geosciences, geomaterials are understood as both products and archives of Earth system interactions (Dokuchaev, 1967). The characteristics of a given geomaterial - such as colour, texture, composition or structure - reveal information about the processes that formed it. For example, a soil's profile can reflect weathering intensity, parent material, biological activity, or climatic variations over time.

Thus, observing and interpreting a geomaterial is an opportunity to understand its formational history and the environmental conditions under which it formed (Schaetzl & Anderson, 2005). This principle underpins the educational use of geomaterials: by analysing their properties, learners are invited to reconstruct past dynamics of the Earth's surface and deepen their understanding of natural systems.

In educational contexts, geomaterials serve not only as objects of scientific inquiry, but also as tactile, locally available resources that support interdisciplinary learning based on observation and material handling.

1.2 Introduction to soils, rocks, sediments, and minerals

The Earth’s surface is composed of a wide range of materials, each shaped by specific processes and playing distinct roles in natural systems. Among these materials, minerals, rocks, sediments, and soils form a continuum of transformation.

Minerals are the most basic components crystalline substances that combine to form rocks. Over time, rocks break down by weathering under the influence of climate, organisms, and topography, forming a weathering mantle and soils. With erosion, sediments are formed and may eventually consolidate into new rocks. Understanding the characteristics and relationships between these geomaterials is essential for interpreting landscapes, managing natural resources, and teaching geoscience in more concrete ways. Here is a brief definition of each of them (Figure 2).

Minerals: Naturally occurring, inorganic solids with a defined chemical composition and ordered atomic structure. Minerals are the building blocks of rocks and essential components of soils. Examples include quartz, feldspar, and iron oxides.

Rocks: Solid aggregates composed of one or more minerals. They are classified into igneous, metamorphic, and sedimentary rocks, depending on their origin and formation environment.

Sediments: Loose, unconsolidated particles derived from the weathering of rocks. Transported by water, wind or gravity, sediments are deposited in layers and may later lithify into sedimentary rocks.

Soils: Soils are porous systems composed of minerals, organic materials, water and air, and they are teeming with life. This is the main characteristic that distinguishes soils from sediments. During their formation - which occurs through processes of additions, losses, transformations and translocations of materials - soils also differ from other geological components in that they develop characteristic layers, known as horizons. Their ability to support plant life and store information about environmental conditions makes them unique among geomaterials.

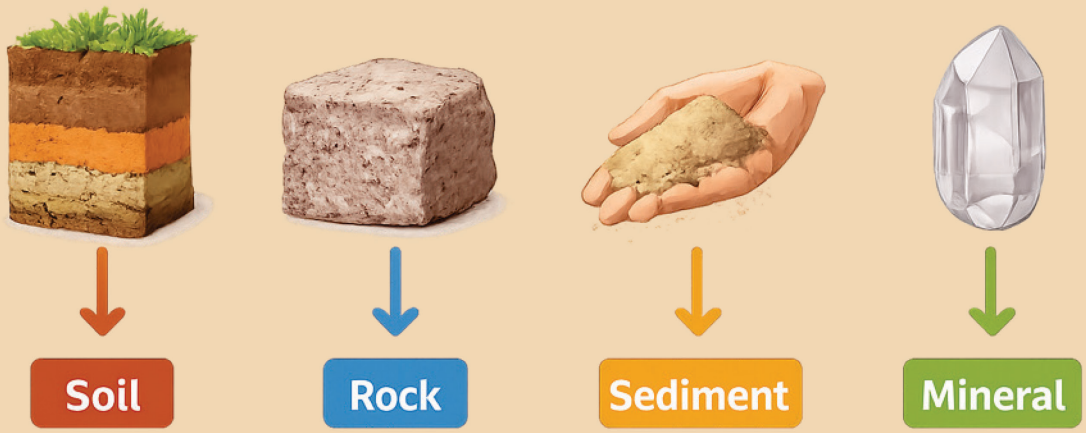


Figure 2. Basic comparison between mineral, rock, sediment, and soil, with examples of each geomaterial. AI-generated image (OpenAI/ChatGPT, 2025).

Through guided observation and comparison, learners can begin to relate the properties of these materials to the processes and environments from which they derive.

1.3 Soil genesis and pedogenetic processes

Soil genesis, or pedogenesis, refers to the set of natural processes responsible for the formation and differentiation of soils from parent materials (Jenny, 1941; Simonson, 1959). Unlike sediments or unconsolidated surface deposits, soils represent organised systems, whose components - such as minerals, organic matter, water, air and living organisms - are arranged vertically and functionally into horizons that reflect their genesis (Brady & Weil, 2016; Soil Science Society of America, 2008).

The study of soil genesis is fundamental to understanding the Earth's surface as a dynamic interface shaped by multiple, simultaneous processes. These processes operate over time and space and result in the transformation of rock and sediment into living, reactive bodies (Huggett, 2023).

According to classical Pedology, as shown in Figure 3, soil development results from the interaction of five primary factors (Bockheim et al., 2005; Jenny, 1941):

- **Parent material**: the mineral or organic substrate from which the soil forms. It determines initial texture, mineral composition, and nutrient availability;
- **Climate**: including temperature and precipitation, which control the rates of weathering, leaching, and organic matter decomposition;
- **Organisms**: such as plants, animals, fungi, bacteria and humans, which contribute to bioturbation, organic input, and structural changes;
- **Relief (topography)**: affects water drainage, erosion, and exposure to climatic forces. Soils on slopes, for instance, tend to be thinner and less developed; and
- **Time**: allows pedogenetic processes to act and leave signatures in soil morphology. Older soils tend to exhibit more pronounced horizonation and chemical changes (Krasilnikov, 2023).

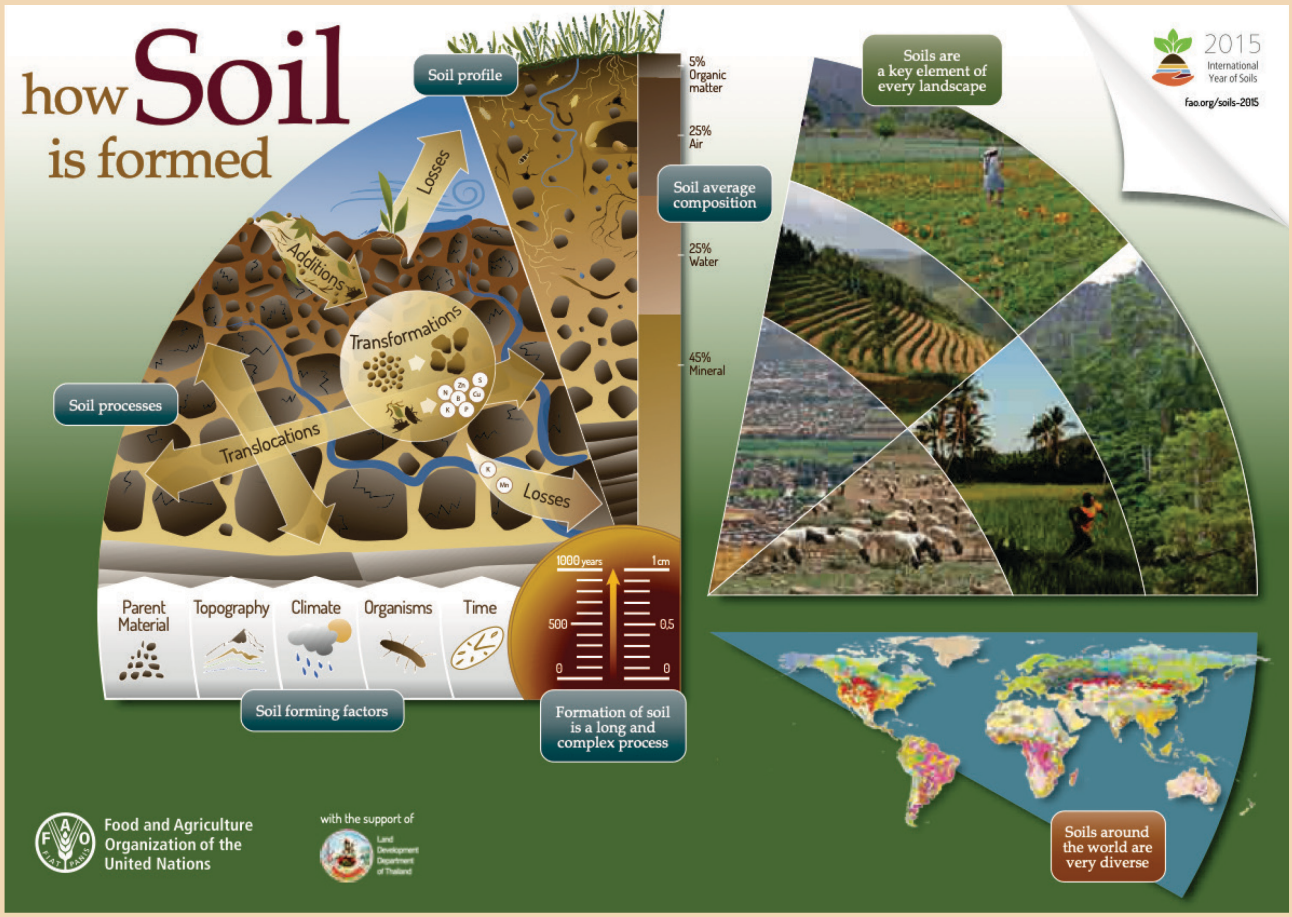


Figure 3. Illustration of the five soil-forming factors: parent material, climate, relief, organisms, and time - all contributing to soil genesis (FAO, 2025a).

Media link: High resolution FAO Infographic about *How soil is formed*.

1.4 Key pedogenetic processes

Some of the main processes that contribute to soil differentiation include (Brady & Weil, 2016; Simonson, 1959):

- **Weathering**: physical disintegration and chemical alteration of minerals;
- **Humification**: transformation of organic residues into humus;
- **Leaching**: removal of soluble substances from upper horizons;
- **Illuviation and eluviation**: vertical redistribution of particles and solutes;
- **Aggregation**: formation of soil structure through particle binding;
- **Colour changes**: related to oxidation-reduction reactions, mineral composition and organic matter.

The resulting soil is not a passive product of these processes. It is part of the landscape itself and records the interaction of lithosphere, atmosphere, biosphere, and hydrosphere over time.

By interpreting soil profiles, learners can uncover clues about the local and regional factors that shaped them - from climate conditions to biological activity and land use.



Suggested activity:
Identifying geomaterials in your surroundings

Objective: To engage students in observing, classifying, and discussing geomaterials in their immediate environment.

Materials:
- Printed Observation Sheets (Appendix A) or notebooks;
- Magnifying glass or hand lens (optional);
- Camera or mobile phone (for documentation); and
- Sample containers (if collection is allowed).

Step-by-Step Instructions:

1. Choose a site: ask students to explore a nearby area (schoolyard, garden, street edge, a construction site, or a natural trail) and identify visible geomaterials - rocks, soils, sediments.
2. Observe and record: encourage them to note colour, texture, grain size, moisture, layering, presence of organic material, biological activity, and location.
3. Take photos or sketch samples.
4. Back in the classroom, guide a discussion:
    - What kinds of materials were found?
    - Have you seen a material like this before? Where?
    - What do you think this material tells us about the environment where you found it?
    - How can we distinguish them?
    - What might their origin be?

This introductory activity prepares the group for later modules, in which these materials are examined more closely and may also be used in the preparation of soil-based paint.

If conducting a field visit, even within school grounds, is not feasible, you may conclude the theoretical lesson by asking students to bring geomaterials from their homes or surroundings to the next class. Encourage them to observe and record key properties discussed in this session (e.g., colour, texture, grain size, composition).

Overview

This module focuses on the vertical organisation of soils through the observation and description of soil profiles. It introduces key morphological features and offers a first contact with soil classification. Students are invited to describe real or virtual profiles and to relate morphology to soil formation and landscape function.

Learning objectives

- Define a soil profile and describe its main morphological features;
- Develop skills in observing and documenting soil horizons;
- Understand the purpose and principles of soil classification; and
- Apply observation techniques to real or virtual soil profiles.

2.1 What is a soil profile?

A soil profile is a vertical section of soil that reveals its internal organisation in the form of distinct layers, called horizons (Figure 4). These horizons reflect the complex history of the soil's formation and the processes that continue to shape it. Typically observed in a soil pit or roadside cut, the profile provides a snapshot of the pedosphere - the interface where atmosphere, biosphere, hydrosphere and lithosphere converge.

Each horizon in a soil profile has unique physical, chemical and biological characteristics, resulting from specific pedogenetic processes (Simonson, 1959). Their differentiation - in terms of colour, texture, structure, consistency and composition - forms the basis for soil description and classification.

Reading a soil profile helps learners reconstruct aspects of soil formation, discuss possible uses, and relate soil properties to ecosystem functioning (Schaetzl & Anderson, 2005).

2.2 Morphological attributes of soil horizons

Soil scientists describe soil profiles using a standardised set of morphological features, which serve as indicators of pedogenetic processes (FAO, 2006; Santos et al., 2025a; Soil Survey Staff, 2017). Key attributes include:

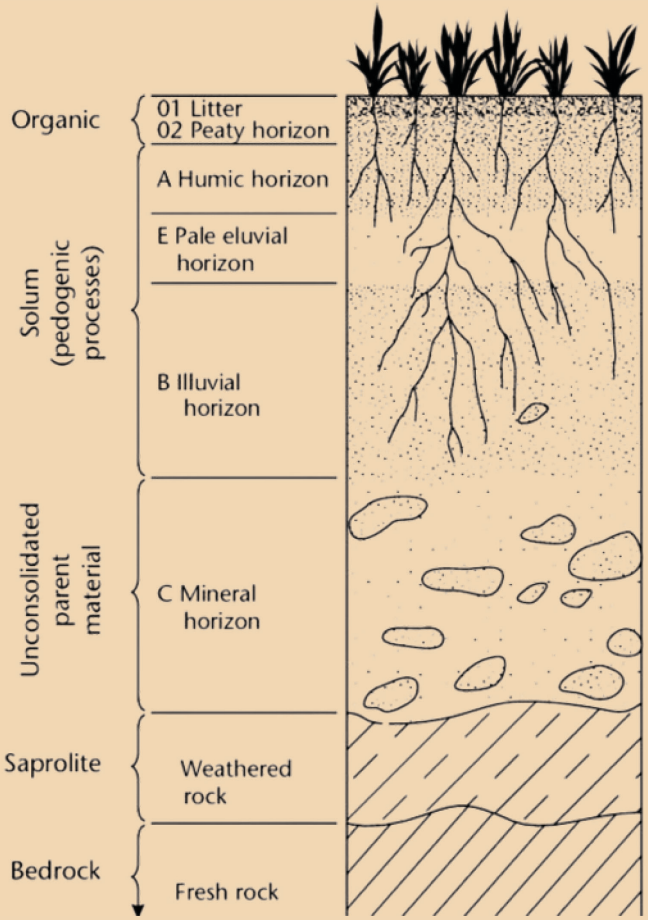


Figure 4. Schematic cross-section of a soil profile showing horizons O, E, A, B, C, saprolite and bedrock, each with distinct structure (McQueen & Scott, 2009).

- **Horizon boundaries**: the limits between horizons can be abrupt, clear, gradual or diffuse.
- **Colour**: often described using the Munsell system (Munsell Color, 2010), soil colour provides clues about mineral composition, drainage, oxidation, organic matter and redox processes.
- **Texture**: refers to the relative proportions of sand, silt and clay. Influences water retention, aeration and root penetration.
- **Structure**: the way soil particles aggregate into peds (granular, blocky, platy, etc.), affecting porosity and stability (Figure 5).
- **Consistency**: soil's resistance to deformation or rupture; can be friable, firm, sticky, etc.
- **Presence of roots, pores and organisms**: indicate biological activity and ecosystem functioning.
- **Effervescence and mottling**: signs of carbonate presence or fluctuating water tables.

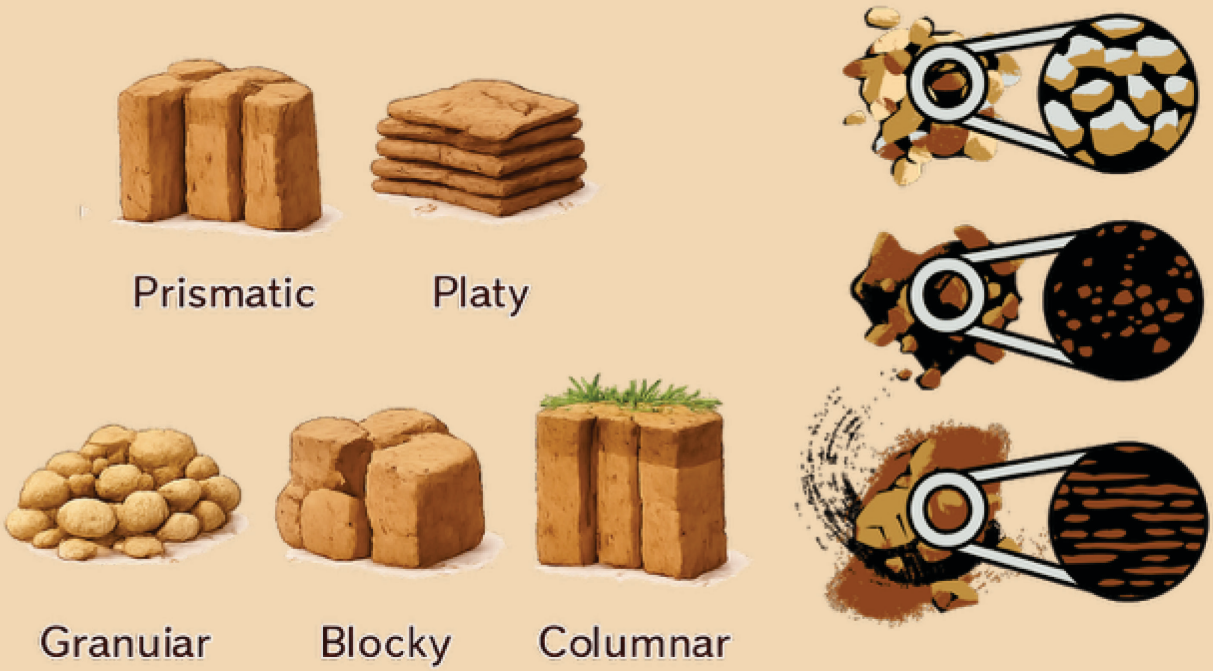


Figure 5. Common types of soil structure: granular, blocky, platy, prismatic, and massive. AI-generated image (OpenAI/ChatGPT, 2025), edited by Caroline Delpupo using Canva® (Canva Pty Ltd., 2025).

These observable properties are essential for identifying horizons and recognising patterns of transformation, translocation, and accumulation.

2.3 What's the name of this soil? An introduction to soil classification

Classifying soils means organising them into groups based on observable and measurable properties - such as horizon arrangement, colour, texture, structure, and presence of specific features like clay coatings, carbonates, or iron accumulation (Blum et al., 2017). In Pedology, these properties serve as diagnostic criteria that allow researchers and practitioners to compare, name, and map soils across different regions.

Rather than expecting students to memorise classification systems, this section introduces the logic behind them and encourages pattern recognition.

Several systems are used worldwide (Figure 6), such as:

- The World Reference Base for Soil Resources (WRB), promoted by the FAO (IUSS Working Group WRB, 2022);
- The Soil Taxonomy, widely used in the USA and by international agencies (Soil Survey Staff, 2022); and
- The Brazilian Soil Classification System (SiBCS) (Santos et al., 2025b).

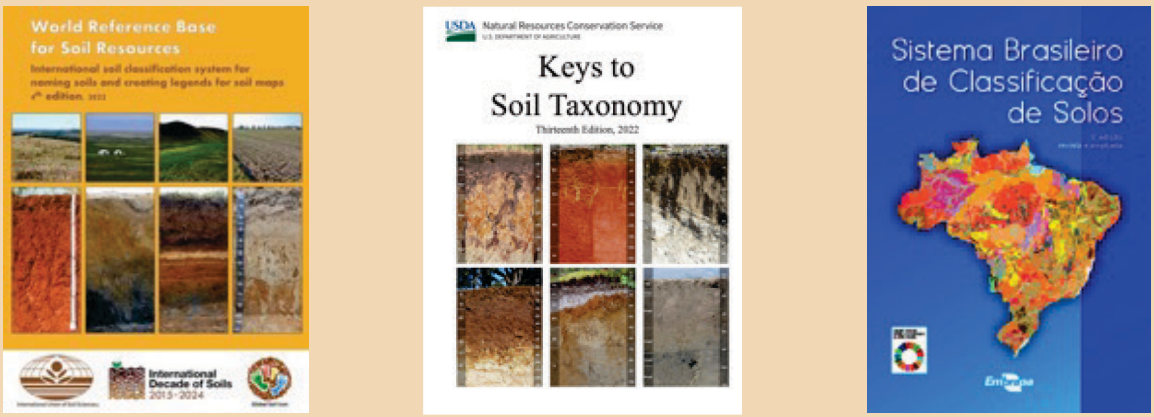


Figure 6. Examples of global soil classification systems including World Reference Base for Soil Resources (WRB), Soil Taxonomy (ST), and the Brazilian Soil Classification System (SiBCS) - used to organise and compare soils based on their morphological and chemical properties (IUSS Working Group WRB, 2022; Soil Survey Staff, 2022; and Santos et al., 2025b, respectively).

Media link: World Reference Base for Soil Resources (WRB).

For educational purposes, simplified classification keys or digital tools can be used to guide learners through basic steps:

1. How many horizons are present?
2. What is the colour and texture of each?
3. Are there signs of accumulation (e.g., clay, iron, organic matter)?
4. Are there features suggesting waterlogging, erosion, or other specific processes?
5. Are there features related to biological activity, roots, decomposed materials, living and dead organisms?

By following these clues, students can arrive at a preliminary name or class, such as:

- **Ferralsols**[1]: deeply weathered soils with red colour and granular structure;
- **Luvisols**[1]: soils with an accumulation of clay in the subsoil; and
- **Gleysols**[1]: soils with grey-blue colour and signs of poor drainage.

2.4 Virtual repositories of soil profiles

The point here is to encourage evidence-based reasoning rather than simple label assignment. Students should compare their descriptions with reference profiles available in soil surveys, atlases, or virtual repositories. Examples include digital

[1] According to IUSS Working Group WRB (2022).

collections such as the **ISRIC World Soil Museum** (Figure 7) (ISRIC World Soil Information, 2025) and the **Soilbook Soil Profile Network** (Figure 8) (Soilbook, 2025).

By exploring these curated databases, students can refine their interpretation, identify diagnostic features, and better understand how soil classification is applied in different landscapes and regions. This process strengthens their observational skills and reinforces the idea that soil classification is not just a technical task, but a tool for understanding the environment.

Media link: ISRIC World Soil Museum home page.



Figure 7. ISRIC World Soil Museum: an online tool to observe and compare soil profiles from around the world (ISRIC – World Soil Information, 2025).

Media link: Soilbook Soil Profile Network home page.

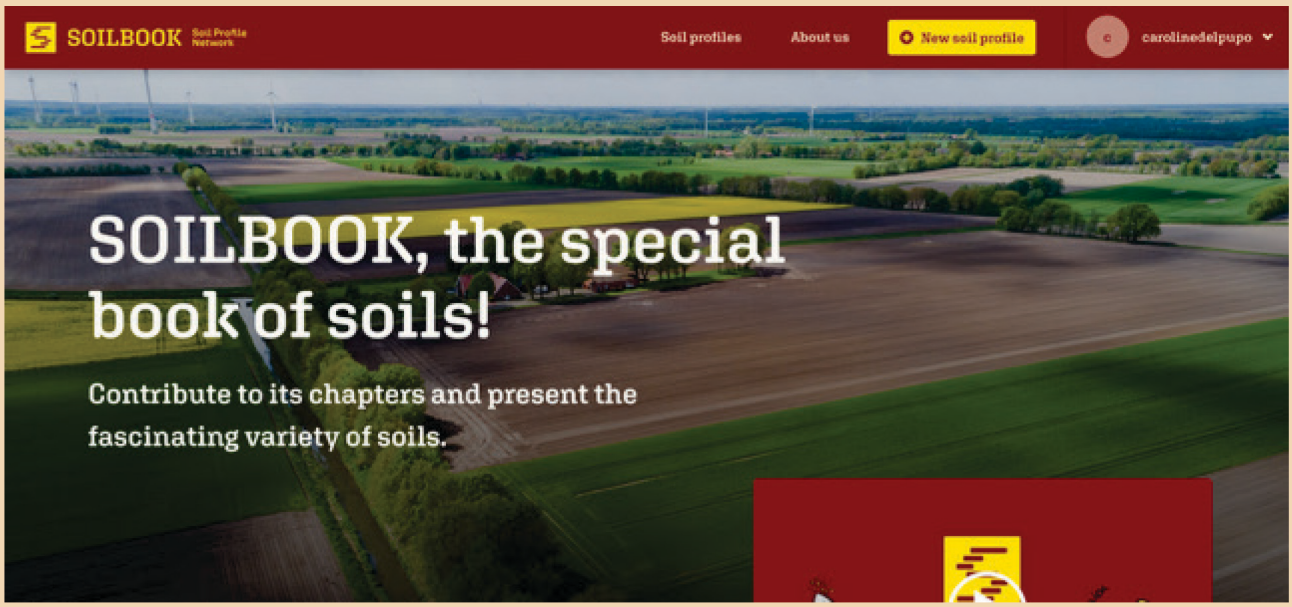


Figure 8. Soilbook home page (Soilbook, 2025).

In this way, classification becomes more than a naming exercise. It becomes a way of relating soil morphology to climate, geology, and ecological setting (Birkeland, 1999).



Suggested activity:
Describing a soil profile (real or virtual soils profiles)

Objective: To practice the observation, description and interpretation of soil profiles.

Option 1 Real profile (in the field or in a shallow trench on school grounds)

Required materials:

- Printed soil profile description sheet (for real or virtual profiles) (Appendix B) or notebook;
- Shovel or hand hoe (for opening the profile);
- Measuring tape or ruler;
- Hand lens (optional);
- Containers for sample collection (optional);
- Notebook and pencil for notes and sketches; and
- Mobile phone or camera for documentation.

***Step-by-Step Instructions*:**

1. Site selection: choose a safe, accessible location with exposed soil or where a shallow pit (up to 50 cm) can be excavated.
2. Profile opening: carefully expose a vertical soil wall, ideally with at least 20 cm of depth.
3. General observation: identify visible soil horizons by examining colour, texture, structure, roots, stones, concretions, etc.

4. Describe each horizon:
    - Depth (start and end);
    - Colour (using Munsell or visual reference);
    - Texture (sandy, silty, clayey or intermediate);
    - Structure (granular, blocky, massive, etc.);

- Life-related features (roots, channels, chambers etc.); and
- Presence of other features (concretions, accumulations etc.).

5. Take photographs of the entire profile and individual horizons.
6. In-class discussion: each group presents their findings and interprets the profile in terms of formation processes, functions, and possible land uses.

Option 2 Virtual profile (using digital monoliths or soil image archives)

Required materials:

- Internet access (preferably on a computer for better image viewing)
- Access to the World Soil Museum Virtual Monolith Gallery (ISRIC)
- Printed Soil Profile Description Sheet (for real or virtual profiles) (Appendix B) or notebook.

Step-by-Step Instructions:

1. Access the gallery: go to https://wsm.isric.org/gallery.html and select a monolith that interests you by country and/or by classification;



Media link: ISRIC World Soil Museum *Explore Collection* page.

2. Visual analysis;
3. Identify horizon boundaries by observing colour changes and textures;
4. Assess features such as granularity, presence of particles, concretions;
5. Consider possible structure (granular, massive, blocky - when visible);
6. Fill in the observation sheet, describing each horizon's attributes based on the image;
7. Optional extension: research the country/region where the profile was collected and relate it to the soil's formation environment; and
8. Final presentation: each student or group presents their virtual profile, discussing its characteristics and what it reveals about environmental conditions.

Whether the profile is real or virtual, the activity helps students see soil description as both observational and interpretive. It requires measurement, comparison, and inference, and can lead naturally into later discussions of classification, land use, and conservation.

Overview

Colour is one of the most immediate and useful properties observed in soil description. This module examines the main factors that influence soil colour, including mineral composition, organic matter, drainage, and oxidation. It also introduces a simplified interpretive guide and proposes the construction of a classroom soil colourteque[2].

Learning objectives

- Identify the main causes of colour variation in soils;
- Relate soil colour to environmental and pedogenetic processes;
- Use colour as an interpretive tool in soil observation; and
- Create and use a classroom resource (soil colour library) for learning and discussion.

3.1 Why soils have different colours?

Soil colour is one of the most immediate and visually striking attributes of the soil profile. The importance of soil colour as an environmental indicator has been widely recognised since Birkeland (1999). It reflects a combination of physical, chemical and biological factors, and serves as an important indicator of pedogenetic processes, mineral composition, organic matter content, and environmental conditions such as drainage and aeration.

Colour is not merely aesthetic - it is an essential tool in soil characterisation. Soil scientists often begin their descriptions by noting colour variations, as these can suggest the presence of iron oxides, humus, water saturation, or other key components.

For more precise description, soil scientists often use the **Munsell Soil Colour Chart** (Munsell Color, 2010), which standardises colour observation by hue, value, and chroma (Figure 9). This chart presents a collection of colour chips arranged by hue (dominant colour), value (lightness or darkness), and chroma (intensity). By comparing a moist or dry soil sample against the colour chips under natural light, one can assign a Munsell notation (e.g., 7.5YR 4/3) that accurately represents the observed colour. This information can then be recorded, shared, and interpreted in both scientific and educational contexts.

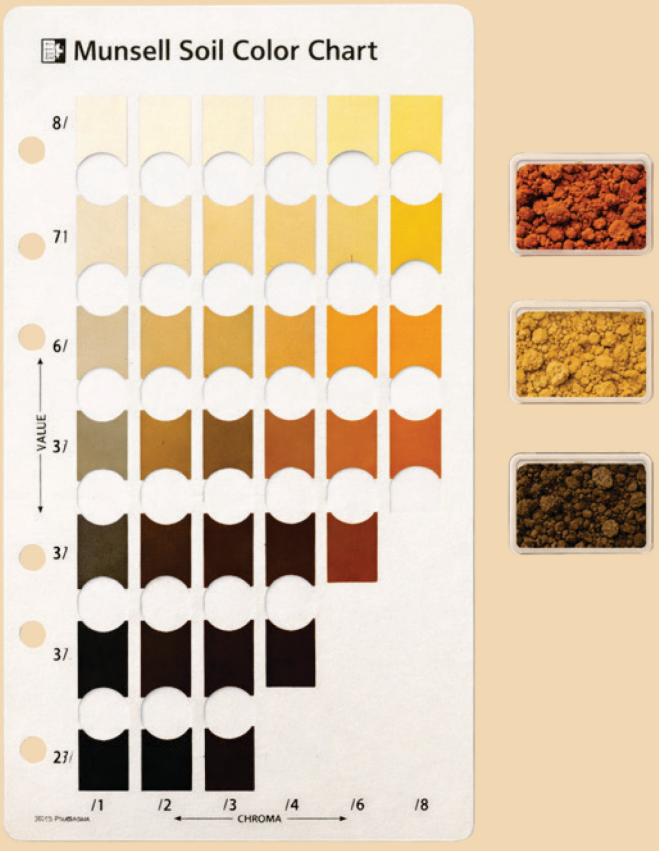


Figure 9. Munsell Soil Colour Chart alongside real soil sample. AI-generated image (OpenAI/ChatGPT, 2025), edited by Caroline Delpupo using Canva® (Canva Pty Ltd., 2025).

[2] A neologism used in this e-book to describe a library of soil colours collected for educational purposes, usually displayed in vials or jars.

3.2 Minerals, organic matter, waterlogging, and oxidation

The main factors influencing soil colour include:

- **Organic matter**: Presence of organic material, especially in the upper horizons, results in dark brown or black soils. Soils rich in humus are often found in temperate or wet environments.
- **Iron oxides**: Soils rich in oxidised iron tend to appear red, yellow or brown. The specific hue depends on the type and form of iron compounds present. For example, hematite gives soils a red colour, while goethite produces yellowish tones (Schwertmann & Taylor, 1989).
- **Waterlogging and poor drainage**: Prolonged saturation creates reducing conditions that cause iron to become soluble and leach out. The result is grey or bluish tones (common in *Gleysols*), often mottled with orange or reddish spots where oxidation intermittently occurs (Schwertmann & Taylor, 1989).
- **Parent material and mineralogy**: The mineral composition inherited from rocks or sediments also influences colour. For example, young soils developed from volcanic ash may exhibit grey or dark colours even with low organic matter.
- **Climate and weathering**: Warm, humid climates enhance weathering and leaching, favouring the formation and accumulation of iron oxides and the development of red and yellow soils (Birkeland, 1999; Brady & Weil, 2016; Jenny, 1941).

3.3 Colour interpretation table

These colour differences are not random. They usually reflect environmental conditions and pedogenetic processes that can be discussed with students in observational terms. Hartemink et al. (2014) and Sposito and Reginato (1992) emphasise the pedagogical potential of colour in communicating pedogenesis. Table 1 may be used as a classroom reference to support the interpretation of local or comparative soil samples.

Table 1. Soil colour interpretation table.

Soil colour	Likely cause	Example soil reference group (WRB)
Red	Presence of hematite. Goethite may also occur, and increasing amounts of goethite give the soil a more yellowish to orange colour.	Ferralsols
Yellow	Presence of goethite.	Acrisols
Brown	Mix of organic matter and iron oxides	Cambisols or Luvisols
Black	High organic matter	Histosols or Phaeozems
Grey / Blue	Waterlogging, iron in reduced form	Gleysols
White / Pale	Presence of quartz, kaolinite or carbonates.	Arenosols or Calcisols



Tips: While simplified, this table draws from WRB terminology to provide learners with a consistent global reference for soil classification and interpretation.



Suggested activity:
creating a classroom soil colourteque (soil colour library)

Objective: To build a shared resource - a physical library of local soil colours - and use it as a teaching and learning tool for interpreting soil properties and environmental conditions.

Materials:

- Small transparent containers or glass vials with lids;
- Soil samples from different locations (collected and prepared in advance or brought by students);
- Labels (location, depth, basic observations) and;
- Poster board or display box (optional, for class exhibition).

Step-by-Step Instructions:

Soil sample preparation: Collect soil samples from different places and prepare them in advance or ask students to bring them. The samples should be air-dried and lightly sieved to remove stones and larger organic fragments.

1. **Colour observation and recording**: Ask students to carefully observe the soil samples and record their colours using the visual colour interpretation table (simplified guide).
2. **Library assembly**: Place the observed samples in small, labelled containers and organise them in a visible space in the classroom.
3. **Discussion**: Guide students in comparing the samples and interpreting their colours. What might each colour suggest about the origin or condition of the soil? What similarities or contrasts can they observe?
4. **Extension**: Invite students to propose hypotheses based on colour - such as drainage quality, parent material, or degree of weathering - and design mini-investigations or field observations to explore these ideas.



Tips: Here, the term *colourteque* is used to describe a small teaching collection of soil colours organised for classroom observation.

The resulting collection can be used in later lessons as a simple reference for discussing colour, classification, landscape interpretation, and even visual experimentation with soil-based paint. A short video is also available to illustrate how a classroom soil colourteque may be assembled.



Media link: Creating a classroom soil colourteque

Overview

This module presents a step-by-step guide to a soil-based paint workshop in which students transform local soils into natural paint. The activity combines material preparation, scientific discussion, and artistic experimentation (FAO & ITPS, 2015).

Learning objectives

- Prepare and process soils for use in educational paint production;
- Understand the physical properties of soils through hands-on manipulation;
- Foster connections between science, art, and sustainability and;
- Conduct classroom or community-based workshops using soil-based paint.

Workshops that use soils as pigments illustrate the principle of *learning through matter*, a concept highlighted by Brevik et al. (2022) and Hartemink et al. (2014) as an effective interdisciplinary teaching strategy in the Geosciences. In Brazil, classic references on the pedagogical use of soil-based paint can be traced to the works of Carvalho et al. (2007) and Lima et al. (2002), which laid important foundations for integrating soils into educational and artistic practices.

Before beginning the practical steps of the workshop, it is important to have a clear overview of the process as a whole. The sequence presents the key stages involved in making soil-based paint - from preparing and refining the soil material to mixing, applying, and transforming it into an expressive medium.

***Step-by-Step Instructions*:**

Step 1 – Preparing the materials

Arrange all materials required for the workshop on a table. Cover the surface with newspapers or scrap paper to minimise mess. The materials needed are listed below (Figure 10):

1. Dry soil samples (collected from varied locations with distinct colours);
2. Mortar and pestle, rolling pin, or stones (for crushing);
3. A container with water;
4. PVA glue;
5. Newspapers or scrap paper;
6. Measuring spoon;
7. 500 ml plastic containers with lids;
8. Disposable coffee cups (50 ml) or similar;
9. Wooden craft sticks (ice lolly sticks) or similar;
10. Commercial fine mesh sieve (≈ 0.5 mm);
11. School paintbrushes, sponges, or improvised applicators; and
12. White sheets of paper, individual small canvases, a large canvas for collective painting or printed templates for soil-based paint workshop (Appendix C).



Figure 10. Illustrated toolkit for soil paint workshop, including mortar, glue, spoon, cups, sieves, and brushes. AI-generated image (OpenAI/ChatGPT, 2025).

Ideally, the activity should take place in a ventilated area or outdoor space with access to water and surfaces suitable for mixing and painting.

Step 2 – Introducing the activity

Gather the students around the table so that all materials are visible to everyone. Ask for silence and introduce the activity. The following text can be used as a guide:

Today we will carry out a soil-based paint workshop. We will explore where soils are found in our landscape, how they form, how they differ from one another (soil types), what each colour represents, and what functions soils perform in the environment.

Step 3 – Preparing the soils to become paint

(1) Begin by showing the variety of colours present in your soil collection.
(2) Ask whether any students have seen similar soils around the city. If so, where?
(3) Ask students how they would define soil. Allow them to speak freely and encourage discussion.
(4) You can use the following definition to support the discussion:

Soils are natural bodies composed of mineral and organic materials that occupy most of the Earth's surface mantle. They derive directly from the weathering of rocks or may develop over sediments that have been mobilised across the landscape. Soils contain living organisms, may support vegetation where they occur, and can be modified by human activities.



Tips: The main objective here is to emphasise the differences between soils, rocks, and sediments.

(5) Take one soil sample and show students its structural aggregates (clods). Explain that, thanks to these aggregates, soil contains pores through which small animals can move and roots can grow; it also stores water, even during dry periods, and retains organic matter.
(6) Explain that, for paint production, the soil must be made very fine. This requires breaking down the aggregates so that the paint adheres better to the surfaces being painted.



Tips: Soil aggregates are not merely physical structures; they are often stabilised by biological agents.

Step 4 – Crushing the soils

The video below shows the basic steps involved in preparing the samples.



Media link: Preparing soils: crushing, sieving, and visual analysis

(1) Place a small amount of soil into the plastic mortar. Use circular movements with the pestle until the aggregates are completely broken down.



Tips: the smaller the amount, the easier it is to crush the soil.

(2) Students will notice that some soils are easier to crush than others. Ask students why this happens.



Tips: more developed soils or soils richer in clay tend to have more stable aggregates and are therefore harder to crush.

Step 5 – Sieving the soils

(1) Once the aggregates are fully crushed, transfer the soil from the mortar to the sieve. Always use the sieve together with a tray or container underneath to collect the fine material.
(2) Show students any material that remains on top of the sieve.
(3) Ask them what these materials are called.
(4) Explain that the material that passes through the sieve is finer and more suitable for making paint.



Tips: not all soils have the same proportions of sand and clay. Sandy soils will yield less fine material, whereas clay-rich soils will provide more material for paint production.

(5) Discard the sand that remains on the sieve.
(6) Repeat the entire process for the other soil samples (different colours), keeping them separate.
(7) Organise the sieved soils into containers so students can access them easily. Place one tablespoon of soil in each container.



Tips: all spoons should be the same size, as they will be used as measuring units.

Step 6 – Making the soil-based paint

(1) Give each student one disposable coffee cup (50 ml) and one wooden stick.
(2) Ask each student to place **two spoonfuls of soil of the same colour** into their cup.
(3) Then ask them to add **two spoonfuls of water**.
(4) Finally, ask them to add **one spoonful of white glue**.
(5) Instruct students to mix the contents thoroughly using the wooden stick.



Tips: Remember: soils differ from one another, so it may be necessary to adjust the consistency. If the paint is too thick, add a little more water. If it is too liquid, add a small amount of soil.

A short video shows the mixing process and some basic adjustments to paint consistency.



Media link: Making soil-based paint: mixing and adjusting

Step 7 – Painting

(1) Distribute one white sheet or painting canvas to each student or printed paintable templates (Appendix C).
(2) Make paintbrushes available to everyone.
(3) As paints of different colours have been prepared, encourage students to share their paints with one another.
(4) Painting is free. Allow students to exercise their imagination.

Another short video documents examples of individual and collective work produced during the activity.



Media link: Painting with soil-based paint: individual and collective expression.

Step 8 – Reflections during painting

(1) Encourage discussion during the activity by posing the following questions: Why do soils have different colours?



Tips: Soil colour depends on its components and the conditions under which it formed. These include parent material (bedrock), landscape position, climate (hot, cold, dry, humid), vegetation, and biological activity.

- **Red**: iron-rich minerals formed under drier conditions
- **Yellow**: iron-rich minerals formed under more humid conditions
- **Black**: high organic matter content
- **Brown**: mixture of organic matter (black) and iron minerals (red and yellow)
- **Greyish**: soils found near rivers or in poorly drained areas that remain waterlogged for most of the year

(2) Why are soil-based paints considered environmentally and socially sustainable materials?



Tips: Soils are easily found in nature and therefore represent low-cost raw materials. They are durable and can be used for painting houses, furniture, and artwork. They also reflect the colours of local soils, strengthening connections with place and community. Commercial paints, by contrast, are more expensive and require complex industrial processes that generate polluting residues.

Step 9 – Cleaning up

(1) Ask students to discard any remaining paint in an appropriate location.
(2) Ask each student to thoroughly wash the paintbrush they used so it can be reused in future workshops.
(3) Dispose of residues properly and clean the space where the workshop took place.

Step 10 – Displaying the paintings

An important part of the workshop is deciding what will happen to the students' paintings.

(1) Create a classroom gallery or mural using student artworks;
(2) Include written labels describing each soil's origin, colour, and characteristics;
(3) Scan or photograph the results to build a digital portfolio;
(4) Share the exhibition with the school community to promote awareness of soil diversity and geoscience education.

This final stage helps the activity remain visible after the workshop and makes it easier to connect the work produced with wider discussions in the school community.

Overview

Soils are biologically structured systems. Beneath the surface there is a dynamic community of organisms involved in decomposition, nutrient cycling, aggregation, and soil formation. From microorganisms to burrowing vertebrates, soil life operates at different spatial scales and contributes to the physical and chemical organisation of soils.

Learning objectives

- Describe soil biodiversity across spatial scales;
- Explain the distribution of organisms along soil horizons;
- Recognise organisms as agents of soil formation; and
- Relate soil biodiversity to ecosystem services and sustainability.

5.1 The hidden world beneath our feet

Soil hosts one of the most diverse biological communities on Earth, much of which remains invisible to the naked eye (FAO, 2020). A single gram of soil may contain billions of microbial cells and thousands of taxa, reflecting an extraordinary level of taxonomic and functional diversity (Torsvik & Øvreås, 2002; Fierer, 2017). Despite this complexity, soil biodiversity has historically received less attention than aboveground ecosystems (Barrios, 2007).

The soil environment provides a mosaic of microhabitats defined by pore space geometry, moisture gradients and organic matter availability (Paul, 2015). Within this heterogeneous matrix, microorganisms colonise microsites, roots exude organic compounds that stimulate microbial activity, and invertebrates navigate interconnected pore networks. This spatial heterogeneity supports coexistence and functional redundancy, which contribute to system resilience (Bardgett & van der Putten, 2014).

Figure 11 illustrates the range of soil organisms and organises them by size and ecological function (FAO, 2025b). It helps make visible the idea of soil as a biologically structured system rather than an inert substrate.

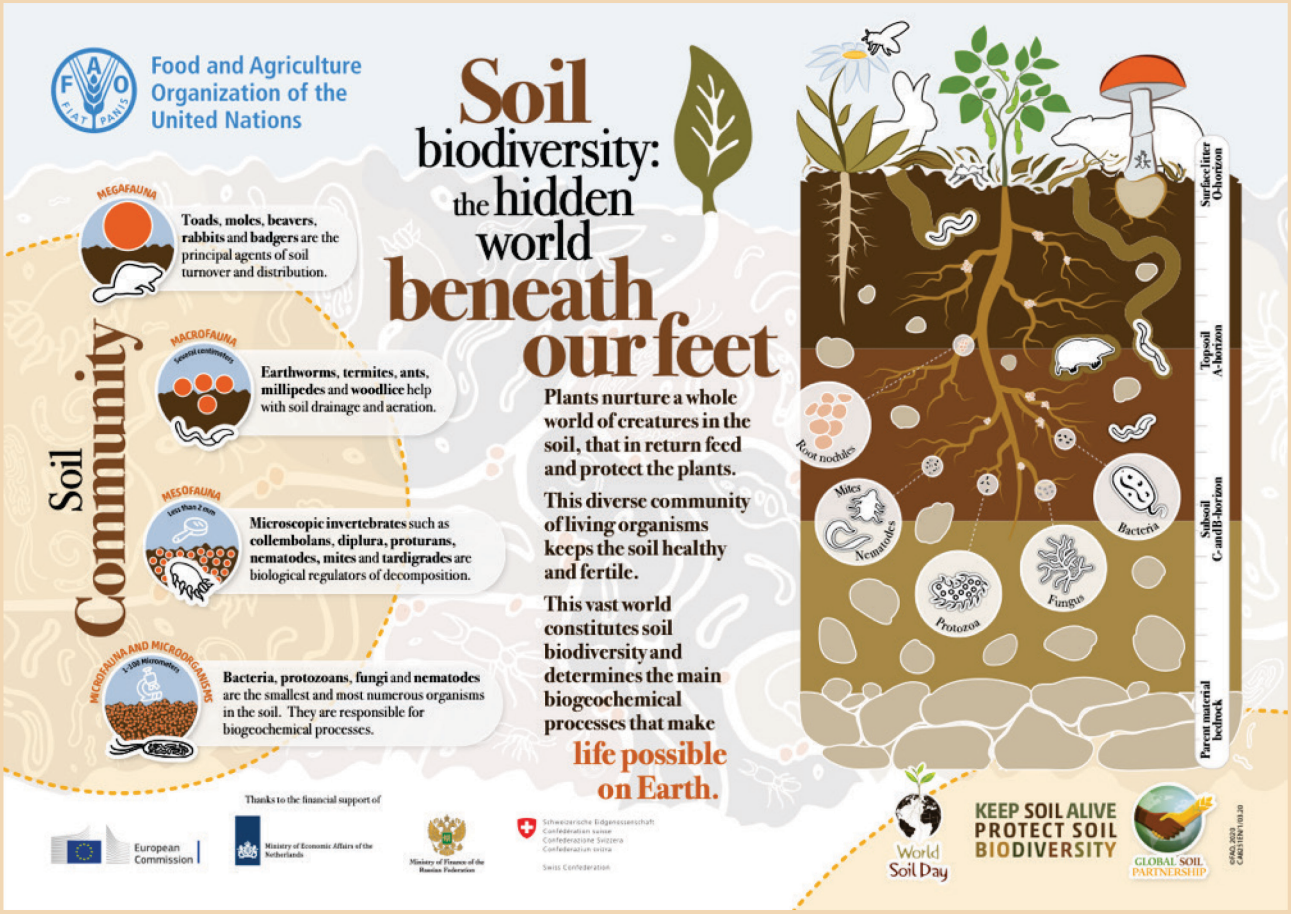


Figure 11. Soil biodiversity diagram (FAO, 2025b).

Media link: High resolution FAO Infographic about *Soil biodiversity*

The diagram illustrates the remarkable range of soil life, from microorganisms at the micrometre scale to megafauna capable of redistributing soil material. It also highlights the functional roles of these organisms in decomposition, aeration and biogeochemical regulation (FAO, 2025b).

Tips: Soil is not inert matter. It is a biologically active environment.

5.2 Biodiversity across spatial scales

Soil biodiversity can be organised according to body size and ecological function. This classification helps to clarify how organisms operating at different spatial scales contribute to soil processes in complementary ways.

Microorganisms including bacteria, archaea, fungi and protozoa dominate numerically and constitute the metabolic core of the soil system (Paul, 2015). A single gram of soil may contain billions of microbial cells, many of which regulate fundamental biochemical transformations such as carbon decomposition, nitrogen mineralisation, nitrification and denitrification (Torsvik & Øvreås, 2002; Paul, 2015).

Mesofauna, typically ranging from a few hundred micrometres to a few millimetres in size, include mites, springtails (Collembola) and small nematodes. Although less abundant than microorganisms, they play a critical regulatory role in decomposition dynamics (Bardgett & van der Putten, 2014). By fragmenting plant residues and grazing on microbial biomass, mesofauna influence nutrient release and control microbial population structure, thereby affecting energy flow within soil food webs (Lavelle et al., 1997).

Macrofauna such as earthworms, termites, ants and beetle larvae operate at a larger spatial scale and exert direct structural influence on soils (Lavelle et al., 1997). Through burrowing, ingestion and casting, these organisms mix organic and mineral fractions, create biopores and enhance aeration and infiltration. Earthworm casts often differ chemically and physically from surrounding soil, contributing to heterogeneity and aggregate stability (Six et al., 2004).

Megafauna, including burrowing vertebrates such as moles and rodents, contribute to soil turnover and redistribution at broader spatial scales (Wilkinson et al., 2009). Their activity may influence microtopography, vertical displacement of soil material and long-term pedogenic patterns, linking biological disturbance to geomorphological processes (Schaetzl & Thompson, 2015).

These groups do not act separately. Their activities overlap across spatial scales, linking decomposition, structural change, and nutrient cycling in the soil profile (Bardgett & van der Putten, 2014). Decomposition emerges from overlapping activities that connect macro-fragmentation, mesofaunal processing and microbial mineralisation, reinforcing the concept of soil as a multi-layered biological system rather than an inert substrate (FAO, 2020).

5.3 Soil horizons and biological distribution

Biological activity is not uniformly distributed throughout the soil profile. It is generally most intense in surface horizons, particularly the O and A horizons, where organic residues accumulate and root density is highest (Schaetzl & Thompson, 2015). These layers provide energy sources and favourable environmental conditions for microbial growth and faunal activity.

However, biological influence extends beyond surface layers. Burrowing organisms such as earthworms and termites transport organic material downward, while roots penetrate deeper horizons and alter local chemical conditions through rhizodeposition (Lavelle et al., 1997; Paul, 2015). Microbial processes in subsurface layers may influence redox dynamics and mineral transformations, contributing to horizon differentiation over time (Schaetzl & Thompson, 2015).

The vertical distribution of organisms therefore links biological processes to soil morphology. Horizon development reflects not only climatic and lithological controls but also sustained biological activity acting over pedogenic timescales (Jenny, 1941).

5.4 Soil biodiversity and sustainability

Soil biodiversity underpins essential ecosystem services, including nutrient cycling, carbon sequestration, water regulation and plant productivity (FAO, 2020). Functional diversity enhances resilience, allowing soil systems to maintain stability under environmental stress (Bardgett & van der Putten, 2014).

Land-use intensification, excessive agrochemical application and frequent disturbance may reduce soil biodiversity and alter community composition (FAO, 2020). Such changes can impair decomposition pathways, weaken aggregate stability and reduce nutrient-use efficiency, thereby compromising soil functionality (Six et al., 2004).

Maintaining soil biodiversity is therefore part of sustainable land management, not an additional concern. It supports the long-term structure and functioning of soil systems (Lehmann & Kleber, 2015).



Suggested activity: exploring soil biodiversity through the FAO interactive platform

Objective:
To investigate soil biodiversity across scales using the FAO interactive platform, and to connect biological diversity with soil structure, pedogenesis and ecosystem functioning.

Required materials
- Computer or tablet with internet access;
- Projector (if conducted collectively);
- Access to the FAO interactive soil biodiversity platform;
- Worksheet or field notebook; and
- Optional: printed soil profile diagram for annotation.

***Step-by-Step Instructions*:**

1. First contact: entering the hidden world
Ask students to access the FAO interactive platform individually or in small groups.



Media link: FAO interactive soil biodiversity platform.

Prompt them to explore freely for 5–10 minutes, navigating through:
- The different organism groups
- The soil food web representation
- The ecosystem services sections

Ask them to note three elements that surprised them.

2. Organising biodiversity by scale
Divide students into small groups. Assign each group one biological scale:
- Microorganisms
- Mesofauna
- Macrofauna
- Megafauna

Each group must answer:
1. What organisms belong to this group?
2. What ecological functions do they perform?
3. At what spatial scale do they operate?
4. How might they influence soil structure?

Groups prepare a short conceptual summary (diagram or mind map).

3. Linking biodiversity to pedogenesis
Using the interactive content, ask students to identify:

- How biological activity influences aggregation
- How organisms contribute to horizon differentiation
- How burrowing affects soil morphology

Students annotate a soil profile diagram, indicating where biological activity is most intense and why.

This step connects directly to Modules 1 and 2.

4. Soil biodiversity and sustainability
Direct students to the ecosystem services section of the platform.

Ask them to identify at least three services supported by soil biodiversity, such as:

- Nutrient cycling
- Carbon sequestration
- Water regulation
- Food production

Then ask: How would loss of biodiversity affect each of these services?

Students write a short paragraph (150–200 words) synthesising their conclusions.

Reflection prompts

- Why is soil biodiversity often neglected in environmental debates?
- How does digital visualisation help make invisible processes visible?
- Can interactive platforms replace field observation? Why or why not?
- How could this resource be adapted for secondary school teaching?

Overview

This module examines how soils function within ecosystems and landscapes. It introduces the main environmental roles of soil and relates soil properties to landforms and geological substrates. The activity proposed at the end encourages students to interpret landscape images through visible geomaterial patterns.

Learning objectives

- Identify and describe key environmental functions of soil.
- Understand soil-litho-topo relationships.
- Interpret landscape features based on visible soil characteristics.
- Develop spatial thinking skills using satellite or landscape imagery.

6.1 What soils do: ecosystem roles and environmental importance

Soils are multifunctional systems that support both natural ecosystems and human activities. Rather than treating soil as a passive substrate, this section emphasises its role as an interface where physical, chemical, biological, and human processes interact. Their functions are essential for environmental balance, food security, climate regulation and landscape stability (Adhikari & Hartemink, 2016; Dominati et al., 2010; Lal, 2004; FAO & ITPS, 2015; Keesstra et al., 2016).

The Food and Agriculture Organization of the United Nations (FAO) has played a central role in synthesising and disseminating educational materials that highlight these functions (FAO & ITPS, 2015). The schematic representation presented in Figure 12, produced by the FAO, is widely used in soil education worldwide and provides a clear visual framework for understanding the multiple roles soils perform within Earth systems.

Figure 12. Soil functions. Soils deliver ecosystem services that enable life on Earth – Infographics (FAO, 2025c).



Media link: High resolution FAO Infographic about *Soil functions*.

Among their core functions, soils:

- **Host biodiversity**, serving as habitat for an immense diversity of organisms - from microorganisms to invertebrates - that drive soil processes and ecosystem resilience.
- **Regulate water flow** through infiltration, storage and gradual release, reducing surface runoff, flooding and erosion while sustaining groundwater recharge.
- **Cycle nutrients** by decomposing organic matter and transforming elements such as nitrogen, phosphorus and sulphur into forms accessible to plants.
- **Store carbon**, making soils one of the largest terrestrial carbon reservoirs and key actors in climate regulation and mitigation strategies.
- **Filter and buffer pollutants**, trapping contaminants and reducing their transfer to water bodies, thus protecting water quality and ecosystem health.
- **Provide the physical foundation for human activities**, including agriculture, infrastructure, housing and transportation networks.

Understanding these functions helps learners recognise soils as a critical natural resource, whose degradation compromises ecological integrity and human well-being. By using FAO educational frameworks and visual tools, educators can connect local soil observations to global environmental challenges, reinforcing the relevance of soils in sustainability debates, land-use planning and climate action.
Understanding these functions helps students see soils as critical components of environmental systems and public life. It also creates a basis for later discussion of land use, degradation, and conservation.

6.2 Soil and landscape relationships

Soil properties are not randomly distributed in space, as shown in Figure 13. Instead, they tend to vary in repeatable patterns because water, sediments, and energy move through the landscape in organised ways. A classic way to describe this is the idea of a soil catena (or toposequence): a linked sequence of different soils along a slope that share the same broad climate and parent material but differ because of their position in the terrain (Milne, 1935). This soil–landscape thinking underpins much of Pedology and Pedogeomorphology, helping us interpret both how soils formed and how they function today (Birkeland, 1999; Huggett, 1975; Schaetzl & Anderson, 2005).

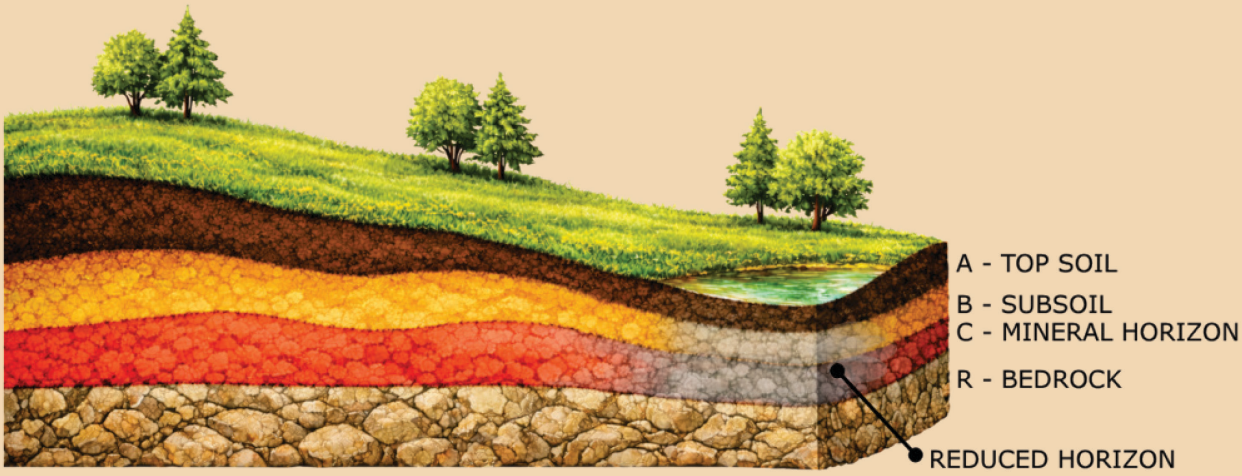


Figure 13. Schematic landscape cross-section illustrating a soil catena (toposequence) and the systematic variation in soil properties according to topographic position (hilltop, slope, lowland) (Birkeland, 1999; Daniels & Hammer, 1992; Gerrard, 1981; Huggett, 1975; Milne, 1935; Ruhe, 1956; Schaetzl & Anderson, 2005). AI-generated image (OpenAI/ChatGPT, 2025), edited by Caroline Delpupo using Canva® (Canva Pty Ltd., 2025).

Across many landscapes, a few controls are especially influential:

Topography (relief and slope position)
Soils on upper slopes and steep midslopes are often thinner and less developed because erosion can remove material faster than horizons can form. By contrast, soils in footslopes and valley bottoms may be deeper because they receive and accumulate downslope material (colluvium), sometimes developing thicker surface horizons or buried layers. This is one reason why soil patterns often repeat from one hillslope to the next within the same region (Huggett, 1975; Schaetzl & Anderson, 2005).

Drainage patterns (water pathways and wetness)
Water does not simply infiltrate vertically: it also moves laterally downslope and concentrates in hollows and valley floors. Where soils remain saturated for long periods, oxygen becomes limited and redox (reduction–oxidation) processes may produce grey colours, mottling, and other hydromorphic features. In practical terms, poorly drained positions are more likely to show gleying and waterlogging signatures than well-drained shoulder or crest positions (Birkeland, 1999; Schaetzl & Anderson, 2005).

Vegetation cover (inputs and feedback)
Vegetation influences organic inputs, root activity, aggregation, and bioturbation, shaping soil structure and horizon development. At the same time, vegetation also responds to soil moisture and fertility, creating feedback that reinforce spatial patterns (Schaetzl & Anderson, 2005).

Climate zones (rate and direction of change)
Climate provides the long-term background conditions controlling weathering intensity, leaching, and organic matter turnover. Along a single hillslope, climate may be similar everywhere, but climate strongly influences the *type* of soils that can form and how quickly soil differences emerge across the landscape (Birkeland, 1999).

Geological substrate (parent material and sediment redistribution)
Mineralogy and initial chemical composition matter: soils formed on different rocks or sediments can develop contrasting textures, colours, and nutrient availability. Even within one slope, the parent material may change downslope due to colluvial inputs,

alluvial deposition, or the exposure of different geological units (Birkeland, 1999; Schaetzl & Anderson, 2005).

These relationships are not only descriptive. They can also help predict where certain soils or properties are more likely to occur along a slope. Pedogeomorphological approaches often divide slopes into landform elements (for example, crests, midslopes, footslopes, and valley bottoms) to explain why certain soils and properties occur where they do. Field studies repeatedly show that mapping landform units can clarify soil distribution and variability across complex terrain (Birkeland, 1999; Daniels & Hammer, 1992; Gerrard, 1981; Huggett, 1975; Milne, 1935; Ruhe, 1956; Schaetzl & Anderson, 2005).

Today, soil–landscape analysis is also strengthened by digital terrain analysis, which uses Digital Elevation Models (DEMs) to derive variables such as slope, curvature, and indices of potential wetness useful predictors of soil patterns at broader scales (Moore et al., 1991; Wilson & Gallant, 2000). This perspective directly feeds into digital soil mapping, where soil observations are linked quantitatively to environmental covariates (including terrain attributes) to model soil classes or properties across a region (McBratney et al., 2003).

Taken together, these relationships form the basis of soil–landscape analysis, which remains useful in environmental interpretation and land management (Birkeland, 1999; Schaetzl & Anderson, 2005).

6.3 Reading the landscape through soils

Soils are not only products of the environment but also powerful tools to decipher landscape history. Their horizons, colours, structures and compositions encode signals from:

- Past climatic conditions (e.g. weathering intensity, leaching);
- Geomorphological processes (e.g. sedimentation, erosion, slope dynamics);
- Vegetation and land use change (e.g. charcoal layers, compaction, horizon mixing); and
- Human intervention (e.g. terracing, mining, urbanisation).

By observing soil features in situ, or through monoliths and profile descriptions, students can discuss how environmental conditions change over time and how soils both record and influence those changes. In this sense, soils may be approached not only as natural materials but also as records of landscape history. This perspective can be traced back to Dokuchaev (1967) and remains relevant in later interpretations such as those of Resende et al. (2014) and Moscatelli and Marinari (2024).



Suggested activity: reading soils in the landscape

Objective:
To engage students in interpreting the relationship between soils and landscape features using visual analysis of satellite images, landscape photographs, or topographic maps. The aim is to infer geomaterial distribution, soil functions, and environmental dynamics based on visual cues.

Materials needed:

- Satellite images (e.g., Google Earth, Sentinel Hub, Copernicus Browser);
- Photographs of different landscapes (mountains, valleys, plateaus, riverbanks, agricultural fields, urban areas);
- Topographic or relief maps (optional); and
- Projector and screen (for group work) or printed materials (for individual/small group work).



Media link: Google Earth home page.

Step-by-Step Instructions:

1. Select 2–4 contrasting landscape images

Choose satellite or ground-level images that show:

- Variations in topography (slopes, flatlands, depressions)
- Different vegetation cover and land uses (forests, crops, cities)
- Evidence of geomorphological or pedological processes (erosion, waterlogging, vegetation patterns)

2. Group analysis

Divide the class into small groups. Assign one image to each group or allow groups to rotate between different stations.

3. Observation prompts

Ask students to analyse their image and respond to guided questions such as:

- What landscape elements can you identify (hilltops, slopes, valley bottoms, riverbanks, etc.)?
- Where do you think soils are more developed or less developed?
- Are there signs of erosion, sediment accumulation, or water retention?
- What geomaterials (soils, rocks, sediments) are likely present in different parts of the image?
- How do vegetation patterns relate to landscape position and possible soil types?

4. Draw geomaterial zones (optional)

Ask students to sketch or overlay coloured areas indicating where they believe different types of soils or geomaterials occur (e.g., reddish soils on slopes, dark soils in lowlands, bare rocks on ridges).

5. Connect to soil functions

Prompt students to consider:

- What soil functions are most important in this landscape? (e.g., water regulation, nutrient cycling, erosion control)
- What land uses seem appropriate or risky for the terrain and likely soil types?

6. Class discussion

Each group presents their findings and reasoning. Discuss how visual interpretation and geomaterial knowledge can help inform land management decisions.

Variation (extension):

Invite students to bring images from their own neighbourhoods or rural areas they know. Repeat the exercise using familiar landscapes, enhancing the sense of place and relevance.

Overview

This final module considers how soil-based paint activities may be extended beyond the classroom. It discusses adaptation to different educational levels, possible interdisciplinary uses, and examples drawn from outreach activities developed by the GEOTA Group.

Learning objectives

- Adapt soil-based paint workshop for different age groups and school contexts;
- Integrate the activity across disciplines such as Art, Geography, Chemistry, and Science;
- Learn from real outreach experiences to improve local implementation; and
- Encourage students to engage with their environment and communities through geoscience education.

7.1 Adapting the workshop for different educational levels

The soil-based paint workshop can be adapted to different age groups and educational settings by adjusting language, conceptual depth, and the type of reflection expected from students.

Primary school (ages 6-10)
At primary level, the emphasis can remain on sensory exploration, observation, and creative work. Students may be encouraged to touch, smell, and compare soils, while linking colours and textures to familiar places, plants, or stories.



Tips: Focus on colours and textures of soils, where soils come from, and how nature provides materials for art.

Secondary school (ages 11-17)
At secondary level, the activity can be used to introduce basic concepts from Geography, Chemistry, and Environmental Science, including soil formation, weathering, erosion, ecosystems, and land use.



Tips: Focus on pedogenetic processes, the meaning of soil colour, ecosystem roles of soils, and local environmental interpretation.

Higher education (undergraduate and teacher training)
In higher education, especially in courses related to Geography, Geology, Pedology, Conservation and Restoration, Biology, Chemistry, and Art Education, the workshop can support the connection between conceptual content and practical activity.

It can be used to discuss observation, classification, communication of scientific content, and the design of outreach activities. In this sense, it works not only as a classroom exercise, but also as a case of low-cost, place-based geoscience teaching.

The workshop also allows discussion of soils in relation to landscape interpretation, territorial identity, and community engagement, particularly where locally sourced materials can be incorporated into teaching practice.



Tips: Focus on soil classification, soil–landscape relationships, sustainability in education, and designing educational resources.

Graduate education and outreach-oriented practices
At graduate level, the workshop may also be approached as an outreach strategy, especially in programmes that value public engagement, teacher education, and science communication.

Graduate students can adapt and implement the activity in schools, teacher education initiatives, community partnerships, or science communication projects. Doing so requires them to translate specialised content into accessible language and to work with audiences beyond the university.

In this way, the workshop may contribute to forms of graduate training that connect research, teaching, and outreach more directly.



Tips: Graduate students may be encouraged to offer soil-based paint workshop as part of teacher education initiatives for local primary and secondary schools.

In all cases, the activity works better when the language, goals, and expected forms of reflection are adjusted to the students involved. Its flexibility is one of its practical strengths.

7.2 Interdisciplinary possibilities

One of the strengths of Pedology is its capacity to work in dialogue with other fields (Oliveira et al., 2021). The soil-based paint workshop makes that dialogue visible in practical terms.

Because the activity combines observation, handling, interpretation, and visual work, it creates opportunities for interdisciplinary teaching in ways that are relatively easy to implement (Muggler et al., 2006).

By linking scientific content with artistic and contextual work, the activity helps students recognise connections between natural systems, cultural expression, and everyday environments.

Geography
Students explore the spatial distribution and formation of soils, learn to read landscapes through geomaterials, and reflect on environmental dynamics. The activity deepens understanding of territory, geomorphology, land use, and place-based knowledge, all of which are central to geographic education.



Media link: To explore further possibilities for applying this approach in Geography Education and for addressing themes such as Geodiversity and Geoconservation, see the work by Dutra (2024).

Geology and Pedology
The workshop supports the interpretation of soil formation processes, parent materials, weathering pathways, and soil–landscape relationships. By observing colour, texture, and structure, students link mineralogy and geological context to pedogenesis, strengthening their ability to analyse Earth surface processes and environmental archives.

Conservation and Restoration
For students in Conservation and Restoration, soil-based paint provides an opportunity to discuss natural pigments, material compatibility, and the historical use of earth materials in artistic and architectural heritage. The workshop encourages reflection on sustainable practices, material authenticity, and the relationship between cultural heritage, landscape, and natural resources.

Biology
The activity facilitates discussion on soil as a living system, highlighting biological activity, organic matter dynamics, and interactions between soils, vegetation, and microorganisms. Students can relate soil properties to ecosystem functioning, biodiversity, and environmental resilience.

Science and Chemistry
The workshop opens doors to discussions about the composition of matter, mineralogy, and pedogenesis. Concepts such as oxidation, organic and inorganic matter, weathering, and chemical reactions involved in pigment behaviour become tangible and relatable through the manipulation of real-world materials.

Physics
From a physics perspective, the activity allows exploration of particle size, light absorption and reflection, texture, viscosity, and material behaviour. Concepts related to friction, cohesion, and the physical properties of granular materials can be introduced through the preparation and application of soil-based paint.

Mathematics
Mathematical reasoning supports the workshop through measurement, ratios, proportions, and data recording. Activities such as preparing paint mixtures, describing soil profiles, and comparing samples involve applied mathematics and contribute to the development of quantitative and spatial thinking skills.

Physical Education
Although less directly associated with soil studies, the activity can also be discussed in relation to sensory perception, motor coordination, and forms of embodied learning, especially when organised in collective or outdoor settings.

Art and Visual Literacy
Soil-based paint reconnects artistic expression with natural materials and environmental perception. Students are invited to explore texture, colour theory, composition, and to reflect on land-based art practices and cultural traditions of using earth pigments. The activity aligns with contemporary ecological art movements as well as ancestral and community-based artistic techniques.

Environmental Education and Citizenship:
Because it uses accessible materials and draws on local soils, the workshop can also support discussion of environmental responsibility, local identity, and the value of natural resources in everyday life.

In practice, schools can adapt the workshop to project-based learning, interdisciplinary units, or thematic weeks such as Earth Day, Soil Week, or Environment Month. This flexibility makes the workshop suitable for interdisciplinary projects and collaborative work among teachers from different areas.

7.3 Outreach in public schools: experiences from the GEOTA Group

The GEOTA Research Group (Geography and Environmental Themes), based at the Federal Institute of Minas Gerais (IFMG, Brazil), has developed and refined soil-based paint workshop in collaboration with local public schools, particularly in the Quadrilátero Ferrífero region - one of Brazil's most geodiverse and historically significant mining territories (Figure 14).

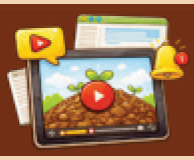


Figure 14. Example of outreach activities carried out as part of the GEOTA Project in IFMG, Brazil.

These outreach initiatives show how soil, often treated as ordinary or barely noticed, can become a starting point for dialogue, creativity, and local interpretation. Students investigate the soils of their surroundings and use them as materials for representation and discussion (Brevik et al., 2022).

Importantly, the GEOTA Group's experience builds upon a Brazilian tradition of Soil Education inspired by Muggler et al. (2006), whose constructivist and Freirean perspectives emphasise learning through investigation, participation, and the integration of local knowledge into scientific understanding. These principles - rooted in the Programa de Educação em Solos e Meio Ambiente (PES) at the Federal University of Viçosa - continue to shape the ways in which soil becomes both subject and medium of interdisciplinary learning and community engagement (Muggler et al., 2006).

The GEOTA experience shows that geoscience education need not be confined to the classroom or laboratory. On the contrary, transforming schools and campuses into open, dynamic learning spaces - connected to the community - can reshape educational routines and relationships. Courtyards, gardens, and nearby green areas become pedagogical territories, fostering interaction, experimentation, and visibility.



Media link: GEOTA's Instagram home page for more activity examples.

Conversely, the city itself becomes an open-air laboratory (Brilha, 2025). Parks, squares, urban forests, and conservation units offer real-world conditions for field-based learning, reinforcing the connections between geodiversity, environmental awareness, and local culture. These activities are not only pedagogical complements to traditional theoretical lessons; they also strengthen students' sense of place and belonging.

The experience developed by GEOTA suggests that geoscience education can remain rigorous while also being accessible, low-cost, and closely connected to community life (Dutra, 2024; Lacerda et al., 2024; Paula, 2024; Paula et al., 2024; Rosa, 2025; Rosa & Delpupo, 2024; Salit et al., 2025).

Closing reflections

This educational trail, from observing soils in the landscape to producing paint from them, proposes a way of teaching in which soils are treated not as background elements, but as materials that can be observed, interpreted, and discussed (Richter & Billings, 2015).

Bringing soils into the classroom as both scientific objects and working materials can help students relate conceptual discussion to observation and practice. In this context, soils may be approached as records of environmental history shaped by climate, biology, geology, and human action.

Each horizon, colour, and texture becomes part of that process. When students compare samples, describe profiles, or prepare soil-based paint, they are not only applying concepts; they are working directly with the material basis of those concepts.

This kind of activity invites forms of learning in which observation, handling, and interpretation are closely linked. In that setting, painting is not only an artistic exercise, but also a way of discussing environmental processes and place.

Beyond the classroom, the approach may also help reconnect schools and communities with local environments and with the less visible material dimensions of the landscapes they inhabit.

In this sense, geoscience education should do more than transmit information. It should also create opportunities for careful observation, interpretation, and responsible engagement with Earth materials and processes.

References

Adhikari, K., & Hartemink, A. E. (2016). Linking soils to ecosystem services - A global review. Geoderma, 262, 101–111. https://doi.org/10.1016/j.geoderma.2015.08.009

Bardgett, R. D., & van der Putten, W. H. (2014). Belowground biodiversity and ecosystem functioning. Nature, 515(7528), 505–511. https://doi.org/10.1038/nature13855

Barrios, E. (2007). Soil biota, ecosystem services and land productivity. Ecological Economics, 64(2), 269–285. https://doi.org/10.1016/j.ecolecon.2007.03.004

Birkeland, P. W. (1999). Soils and geomorphology (3rd ed.). Oxford University Press. https://global.oup.com/ushe/product/soils-and-geomorphology-9780195078862?cc=ie&lang=en&

Blum, W. E. H., Schad, P., & Nortcliff, S. (2017). Essentials of soil science: Soil formation, functions, use and classification (World Reference Base, WRB). Schweizerbart Science Publishers. https://books.google.com/books?id=r6qeEAAAQBAJ

Bockheim, J. G., Gennadiyev, A. N., Hammer, R. D., & Tandarich, J. P. (2005). Historical development of key concepts in pedology. Geoderma, 124(1–2), 23–36. https://doi.org/10.1016/j.geoderma.2004.03.004

Brady, N. C., & Weil, R. R. (2016). The nature and properties of soils (15th ed.). Pearson. https://books.google.ie/books/about/The_Nature_and_Properties_of_Soils.html?id=l5R2DAAAQBAJ&redir_esc=y

Brevik, E. C., Hannam, J. A., Krzic, M., Muggler, C., & Uchida, Y. (2022). The importance of soil education to connectivity as a dimension of soil security. Soil Security, 7, 100066. https://doi.org/10.1016/j.soisec.2022.100066

Brilha, J. (2025). Geoheritage and geoparks. In E. Reynard & J. Brilha (Eds.), Geoheritage: Assessment, protection, and management (2nd ed., pp. 503–516). Elsevier. https://doi.org/10.1016/B978-0-443-28997-2.00026-1

Canva Pty Ltd. (2025). Canva [Graphic design platform]. https://www.canva.com/

Carvalho, A. F., Honório, L. M., Almeida, M. R., Santos, P. C., & Quirino, P. E. (2007). Cores da Terra: Fazendo tinta com terra [Booklet]. Universidade Federal de Viçosa. https://observatorioambiental.wordpress.com/wp-content/uploads/2011/02/manual_tinta_terra.pdf

Daniels, R. B., & Hammer, R. D. (1992). Soil geomorphology. John Wiley & Sons. https://www.wiley.com/en-us/Soil+Geomorphology-p-9780471511533

Dokuchaev, V. V. (1967). The Russian chernozem (N. Kaner, Trans.). Israel Program for Scientific Translations. (Original work published 1883). https://books.google.ie/books/about/Russian_Chernozem.html?id=gXM_AAAAYAAJ&redir_esc=y

Dominati, E., Patterson, M., & Mackay, A. (2010). A framework for classifying and quantifying the natural capital and ecosystem services of soils. Ecological Economics, 69(9), 1858–1868. https://doi.org/10.1016/j.ecolecon.2010.05.002

Dutra, P. A. G. C. (2024). A Geografia escolar enquanto lócus de abordagens geoconservacionistas: Reflexões sobre o papel de ações de educação geocientífica e ambiental para a formação docente (Master's dissertation). Instituto Federal de Minas Gerais, Campus Ouro Preto. https://hdl.handle.net/20.500.14387/1839

European Union, Copernicus Programme. (2025). Copernicus Browser [Computer software]. https://browser.dataspace.copernicus.eu/

Fierer, N. (2017). Embracing the unknown: disentangling the complexities of the soil microbiome. Nature Reviews Microbiology, 15, 579–590.

Food and Agriculture Organization of the United Nations. (2006). Guidelines for soil description (4th ed.). Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/4/a0541e/a0541e.pdf

Food and Agriculture Organization of the United Nations. (2020). State of knowledge of soil biodiversity: status, challenges and potentialities. Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/interactive/soil-biodiversity/en/

Food and Agriculture Organization of the United Nations. (2025a). How soil is formed [Infographics]. Retrieved December 19, 2025, from https://openknowledge.fao.org/server/api/core/bitstreams/49b919a3-5530-410a-99b2-cfe4a4261e89/content

Food and Agriculture Organization of the United Nations. (2025b). Soil biodiversity, the hidden world beneath our feet [Infographics]. Retrieved December 19, 2025, from https://openknowledge.fao.org/server/api/core/bitstreams/8f792132-1515-4ef7-abda-c0bbc641b6ba/content

Food and Agriculture Organization of the United Nations. (2025c). Soil functions. Soils deliver ecosystem services that enable life on Earth [Infographics]. Retrieved December 19, 2025, from https://openknowledge.fao.org/server/api/core/bitstreams/5934eac5-9dfd-4c09-85be-693e4b59a7cc/content

Food and Agriculture Organization of the United Nations, & Intergovernmental Technical Panel on Soils. (2015). Status of the world's soil resources (SWSR) – Main report. Rome: Food and Agriculture Organization of the United Nations. https://www.fao.org/3/i5199e/i5199e.pdf

Gerrard, A. J. (1981). Soils and landforms: An integration of geomorphology and pedology. George Allen & Unwin. https://onlinelibrary.wiley.com/doi/abs/10.1002/gj.3350170313

Google. (2025). Google Earth (Version Web) [Geospatial data platform]. https://earth.google.com/web/

Gray, M. (2013). Geodiversity: Valuing and conserving abiotic nature (2nd ed.). Wiley-Blackwell. https://www.wiley.com/en-es/Geodiversity%3A+Valuing+and+Conserving+Abiotic+Nature%2C+2nd+Edition-p-9780470742150

Hartemink, A. E., Balks, M. R., Chen, Z. S., Drohan, P., & Field, D. J. (2014). The joy of teaching soil science. Geoderma, 217–218, 1–9. https://doi.org/10.1016/j.geoderma.2013.10.016

Huggett, R. (2023). Soil as part of the Earth system. Progress in Physical Geography: Earth and Environment, 47(3), 454-466. https://doi.org/10.1177/03091333221147655

Huggett, R. J. (1975). Soil landscape systems: A model of soil genesis. Geoderma, 13(1), 1–22. https://doi.org/10.1016/0016-7061(75)90035-X

ISRIC – World Soil Information. (2025). World Soil Museum – Virtual monolith gallery. Retrieved December 19, 2025, from https://wsm.isric.org/gallery.html

IUSS Working Group WRB. (2022). World reference base for soil resources: International soil classification system for naming soils and creating legends for soil maps (4th ed.). International Union of Soil Sciences (IUSS). https://files.isric.org/public/documents/WRB_fourth_edition_2022-12-18.pdf

Jenny, H. (1941). Factors of soil formation: A system of quantitative pedology. McGraw-Hill. https://books.google.com/books/about/Factors_of_Soil_Formation.html?id=8xMZAAAAYAAJ

Keesstra, S. D., Bouma, J., Wallinga, J., Tittonell, P., Smith, P., Cerdà, A., Montanarella, L., Quinton, J. N., Pachepsky, Y., van der Putten, W. H., Bardgett, R. D., & Moolenaar, S. W. (2016). The significance of soils and soil science towards realization of the United Nations Sustainable Development Goals. SOIL, 2(2), 111–128. https://doi.org/10.5194/soil-2-111-2016

Krasilnikov, P. V. (2023). Sola incognita: Unsolved problems of genetic soil science. Eurasian Soil Science, 56(4), 483–493. https://link.springer.com/article/10.3103/S0147687423040026

Lacerda, L. H., Vieira, T. V. C., Salit, J. da S., Santos, A. C. R. da S., Carvalho, A. de, & Delpupo Souza, C. (2024). iGEO: Concepção e implantação de banco de práticas para o ensino de geociência em Ouro Preto (MG) [Conference presentation]. Seminário de Iniciação Científica (SIC), Planeta IFMG 2024, Ouro Preto, MG, Brazil. https://doi.org/10.29327/23586052.1037570

Lal, R. (2004). Soil carbon sequestration to mitigate climate change. Geoderma, 123(1–2), 1–22. https://doi.org/10.1016/j.geoderma.2004.01.032

Lima, V. C., Lima, M. R., Sirtoli, A. E., Souza, L. C. P., Melo, V. F., & Silva, M. (2002). Projeto Solo na Escola: O solo como elemento integrador do ambiente no ensino fundamental e médio. Expressa Extensão, 7(special issue), 20–28.

McBratney, A. B., Mendonça Santos, M. L., & Minasny, B. (2003). On digital soil mapping. Geoderma, 117(1–2), 3–52. https://doi.org/10.1016/S0016-7061(03)00223-4

McQueen, K. G.; Scott, K. M. (2009). Rock weathering and structure of the regolith. In: Scott, K. M.; Pain, C. F. (eds.), Regolith science. Collingwood: CSIRO Publishing, Chapter 6. https://doi.org/10.1071/978064309826809.105.126.2009.9

Milne, G. (1935). Some suggested units of classification and mapping, particularly for East African soils. Soil Research, 4(3), 183–198. https://books.google.ie/books/about/Some_Suggested_Units_of_Classification_a.html?id=KWHZvQEACAAJ&redir_esc=y

Moore, I. D., Grayson, R. B., & Ladson, A. R. (1991). Digital terrain modelling: A review of hydrological, geomorphological, and biological applications. Hydrological Processes, 5(1), 3–30. https://doi.org/10.1002/hyp.3360050103

Moscatelli, M. C., & Marinari, S. (2024). Digging in the dirt: Searching for effective tools and languages to promote soil awareness. Soil Security, 16, 100167. https://doi.org/10.1016/j.soisec.2024.100167

Muggler, C. C., Pinto Sobrinho, F. A., & Machado, V. A. (2006). Educação em solos: Princípios, teoria e métodos. Revista Brasileira de Ciência do Solo, 30(4), 733–740. https://doi.org/10.1590/S0100-06832006000400014

Munsell Color. (2010). Munsell soil color charts. Munsell Color. https://munsell.com/

Oliveira, F. S., Furquim, S. A. C., Pereira, M. G., Delpupo Souza, C., Silva Neto, E. C., Calegari, M. R., & Costa, A. M. (2021). A pedologia e seus diálogos científicos: Abordagens analíticas transversais para o estudo dos solos. In L. F. Souza-Filho, R. C. da Silva, F. R. C. F. César, & C. M. M. Souza (Eds.), Tópicos em ciência do solo (Vol. 11, pp. 1–54). Sociedade Brasileira de Ciência do Solo. https://www.researchgate.net/publication/388647554_A_PEDOLOGIA_E_SEUS_DIALOGOS_CIENTIFICOS_ABORDAGENS_ANALITICAS_TRANSVERSAIS_PARA_O_ESTUDO_DOS_SOLOS

OpenAI. (2025). ChatGPT (GPT-4.1) [Large language model]. https://chat.openai.com/

Paula, G. M. F. (2024). Práticas laboratoriais como recurso didático para a elaboração de atividades para o ensino de solos: estudo de caso dos alunos do Ensino Médio da Escola Estadual de Ouro Preto (Undergraduate thesis). Instituto Federal de Minas Gerais, Campus Ouro Preto. https://hdl.handle.net/20.500.14387/1613

Paula, G. M. F. de, Oliveira, D. A. de, Delpupo Souza, C., Carvalho, A. de, Lacerda, L. H., Salit, J. da S., Vieira, T. V. C., & Santos, A. C. L. dos. (2024). Práticas laboratoriais como recurso didático para a elaboração de atividades para o ensino de solos na Escola Estadual de Ouro Preto (MG) [Conference presentation]. Educação, Comunicação e Inovação na Ciência do Solo para o Bioma Amazônico, Porto Velho, RO, Brazil.

Resende, M., Curi, N., Rezende, S. B., Corrêa, G. F. & Ker, J. C. (2014). Pedologia: Base para distinção de ambientes (6th ed.). Editora UFLA. https://www.scribd.com/document/640113831/pedologia-base-para-distincao-6-EdRI

Richter, D. D., & Billings, S. A. (2015). One physical system: Tansley's ecosystem as Earth's critical zone. New Phytologist, 206(3), 900–912. https://doi.org/10.1111/nph.13338

Rosa, N. G. C. (2025). Educação para riscos hidrológicos: a escola como espaço de conscientização em uma comunidade vulnerável de Raul Soares (MG) (Master's dissertation). Instituto Federal de Minas Gerais, Campus Ouro Preto. https://hdl.handle.net/20.500.14387/2729

Rosa, N., & Delpupo Souza, C. (2024). Desastres hidrológicos em Raul Soares (MG): Resultados parciais de uma pesquisa em ensino de Geografia [Conference presentation]. Seminário dos Estudantes de Pós-Graduação, Planeta IFMG 2024, Ouro Preto, MG, Brazil. https://doi.org/10.29327/23586052.997396

Ruhe, R. V. (1956). Geomorphic surfaces and the nature of soils. Soil Science, 82(6), 441–456. https://doi.org/10.1097/00010694-195612000-00001

Salit, J. da S., Lacerda, L. H., Santos, A. C. R. da S., Vieira, T. V. C., Oliveira, M. S. de, Carvalho, A. de, & Delpupo Souza, C. (2025). Oficina de tintas sustentáveis de solos como ensino informal de pedologia e geomorfologia [Poster presentation]. XV Simpósio Nacional de Geomorfologia, Natal, RN, Brazil. https://2025.sinageo.org.br/evento/gerenciador-arquivo/files/SINAGEO_CAPAS_CADERNO.pdf

Santos, H. G., Jacomine, P. K. T., Anjos, L. H. C., Oliveira, V. A., Lumbreras, J. F., Coelho, M. R., Almeida, J. A., Cunha, T. J. F., & Oliveira, J. B. (2025). Sistema brasileiro de classificação de solos (6th ed.). Embrapa. https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1176834/1/Sistema-Brasileiro-de-Classificacao-de-Solos-2025.pdf

Santos, R. D., Santos, H. G., Ker, J. C., Anjos, L. H. C., & Shimizu, S. H. (2025). Manual de descrição e coleta de solo no campo (8th ed.). Sociedade Brasileira de Ciência do Solo. https://www.sbcs.org.br/loja/

Schaetzl, R. J., & Anderson, S. (2005). Soils: Genesis and geomorphology. Cambridge University Press. https://books.google.ie/books/about/Soils.html?id=xASdKCoT6McC&redir_esc=y

Schwertmann, U., & Taylor, R. M. (1989). Iron oxides. In J. B. Dixon & S. B. Weed (Eds.), Minerals in soil environments (2nd ed., pp. 379–438). Soil Science Society of America. https://acsess.onlinelibrary.wiley.com/doi/10.2136/sssabookser1.2ed.c8

Simonson, R. W. (1959). Outline of a generalized theory of soil genesis. Soil Science Society of America Journal, 23(2), 152–156. https://doi.org/10.2136/sssaj1959.03615995002300020021x

Sinergise. (n.d.). Sentinel Hub [Geospatial data platform]. https://www.sentinel-hub.com/

Soil Science Society of America. (2008). Glossary of soil science terms. https://www.soils.org/publications/soils-glossary

Soil Survey Staff. (2017). Soil survey manual. U.S. Department of Agriculture, Natural Resources Conservation Service. https://www.nrcs.usda.gov/sites/default/files/2022-09/The-Soil-Survey-Manual.pdf

Soil Survey Staff. (2022). Keys to soil taxonomy (13th ed.). United States Department of Agriculture, Natural Resources Conservation Service. https://www.nrcs.usda.gov/sites/default/files/2022-09/Keys-to-Soil-Taxonomy.pdf

Soilbook. (2025). Soilbook: Soil profile network. https://www.soilbook.info

Sposito, G., & Reginato, R. J. (1992). Opportunities in basic soil science research. Soil Science Society of America. https://doi.org/10.2136/1992.opportunitiesinbasic

Wilding, L. P., & Lin, H. (2006). Advancing the frontiers of soil science toward a geoscience. Geoderma, 131(3–4), 257–274. https://doi.org/10.1016/j.geoderma.2005.03.028

Wilson, J. P., & Gallant, J. C. (Eds.). (2000). Terrain analysis: Principles and applications. John Wiley & Sons. https://www.wiley.com/en-us/Terrain+Analysis%3A+Principles+and+Applications-p-9780471321880

Appendix A – Printable observation sheet – geomaterials in your surroundings

Observation Sheet – Geomaterials in your surroundings

Student Name: _____
Location of observation: _____ **Date:** _____

Describe the area you are observing:
☐ Schoolyard
☐ Garden
☐ Roadside
☐ Riverbank
☐ Construction site
☐ Natural trail
☐ Other: _____

Types of geomaterials observed (tick all that apply):
☐ Soil
☐ Rock
☐ Sediment
☐ Mineral
☐ Termite mounds
☐ Other: _____

Select one geomaterial to analyse and explore your sample with your senses. Take a moment to observe the material and explore it with your senses. Ask yourself:

1. What does it feel like? Is it rough, smooth, sandy, sticky, soft, or hard?
2. What does it look like? Can you see different colours, textures or layers? Are there grains, roots, pebbles or organic fragments?
3. Does it have a smell? Earthy? Wet? Metallic? Can you identify any particular scent?
4. How does it behave when you press it? Does it crumble? Does it stay together? Does it feel moist or dry?
5. Try rubbing it gently on the paper. What colour does it leave? Is the colour intense or pale? Uniform or mixed?

Use your answers to help describe the material and mark the most appropriate option for each feature in the table below. Careful observation is the first step in geoscientific inquiry.

Sample:						**Rubbing area**
Colour (visual)	red	yellow	brown	black	white	
Texture	coarse	fine	smooth	rough		
Presence of layers?	yes	no				
Visible particles?	yes	no				
Moisture condition	moist	dry				
Presence of organic material?	yes	no				
Presence of biological activity?	yes	no				
Notes						

Reflection prompts:

1. What kinds of materials were found?
2. Have you seen a material like this before? Where?
3. What do you think this material tells us about the environment where you found it?
4. How can we distinguish them?
5. What might their origin be?

Appendix B – Printable soil profile description sheet (for real or virtual profiles)

Soil profile description sheet (for real or virtual profiles)

Observed by: _____ **Date:** _____
Location: _____
Landscape position (e.g., slope, flat, valley): _____
_____
Number of horizons: _____
Total profile depth (cm): _____

Profile origin:
☐ **Real (field)**
☐ **Virtual (image)**

Horizon Description Table

Horizon	Depth (cm)	Colour (dry)	Texture	Structure	Other observations

Legend for observation:

- **Colour**: Describe visually or use Munsell chart if available.
- **Texture**: Sandy, loamy, clayey, etc.
- **Structure**: Granular, blocky, massive, etc.
- **Other observations**: Roots, pores, concretions, organic matter, mottles, smell, effervescence, etc.

Reflection/interpretations prompts:

Use your observations to reflect on the soil formation and its environmental context:

1. What can the horizon sequence tell us about the soil formation processes?
   (e.g., accumulation of organic matter, leaching, clay movement)
2. Is there any indication of water saturation or drainage conditions?
   (e.g., grey colours, mottling, gleying)
3. What is the likely parent material of this soil?
   (e.g., granite, basalt, sediment, other)
4. How might climate have influenced the soil properties you observed?
   (e.g., red colours often indicate well-drained conditions and intense weathering, commonly associated with warm climates; black may indicate organic-rich, cool or wet environments)
5. What land use would this soil best support?
   (e.g., agriculture, forestry, conservation, urban use)
6. Do any features suggest human influence or disturbance?
   (e.g., ploughing marks, artefacts, unusual layering)
7. Compare this profile with others (real or virtual). What similarities or differences do you notice?
8. How does this soil reflect its landscape position?
   (e.g., is it located on a slope, hilltop, or lowland? How does that influence its depth and development?).

Appendix C – Printable and paintable templates for soil-based paint workshop

SOIL-BASED PAINT WORKSHOP

SOILS AS A SUSTAINABLE AND ACCESSIBLE ALTERNATIVE FOR GEOSCIENCE EDUCATION PRACTICES



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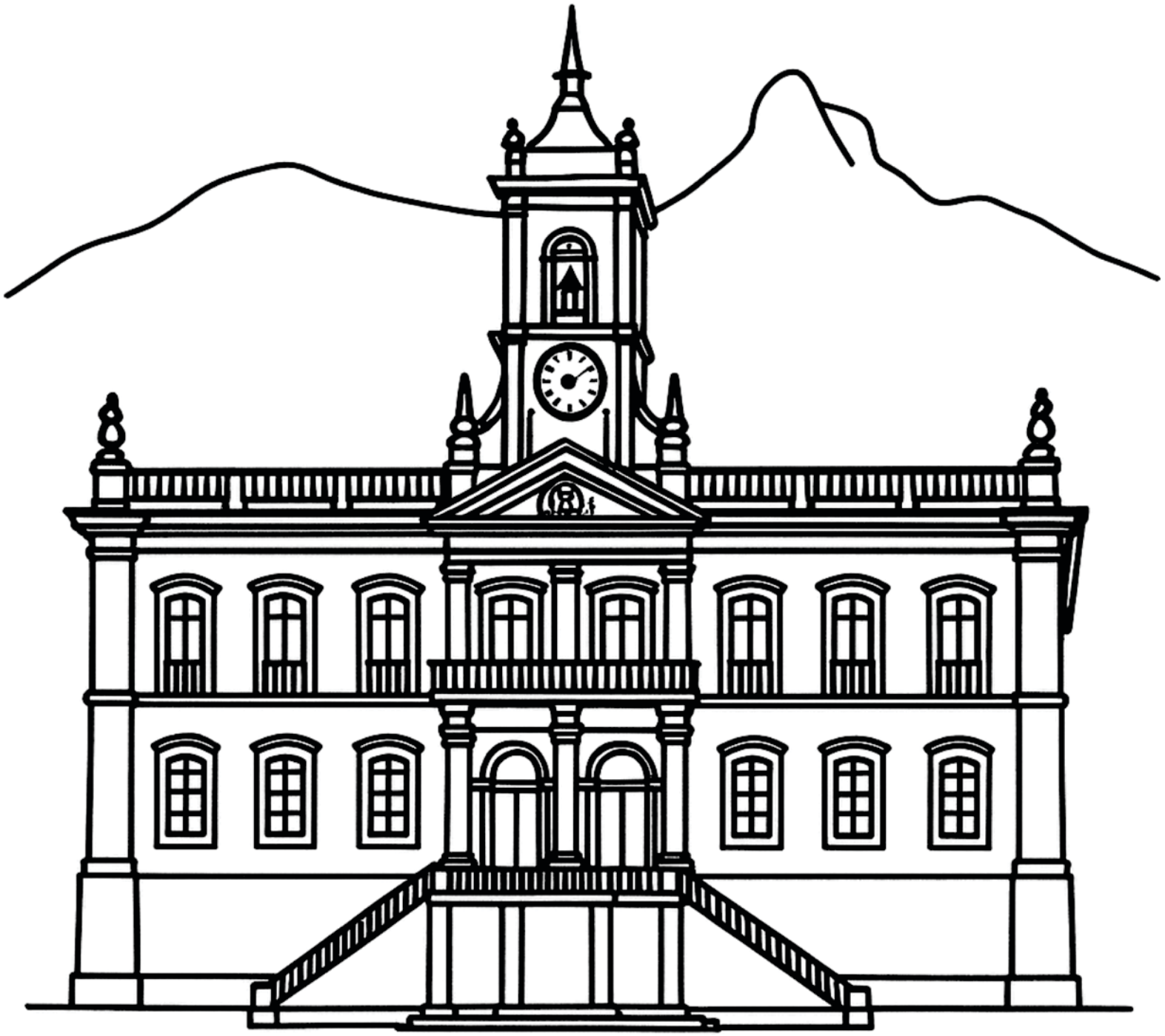
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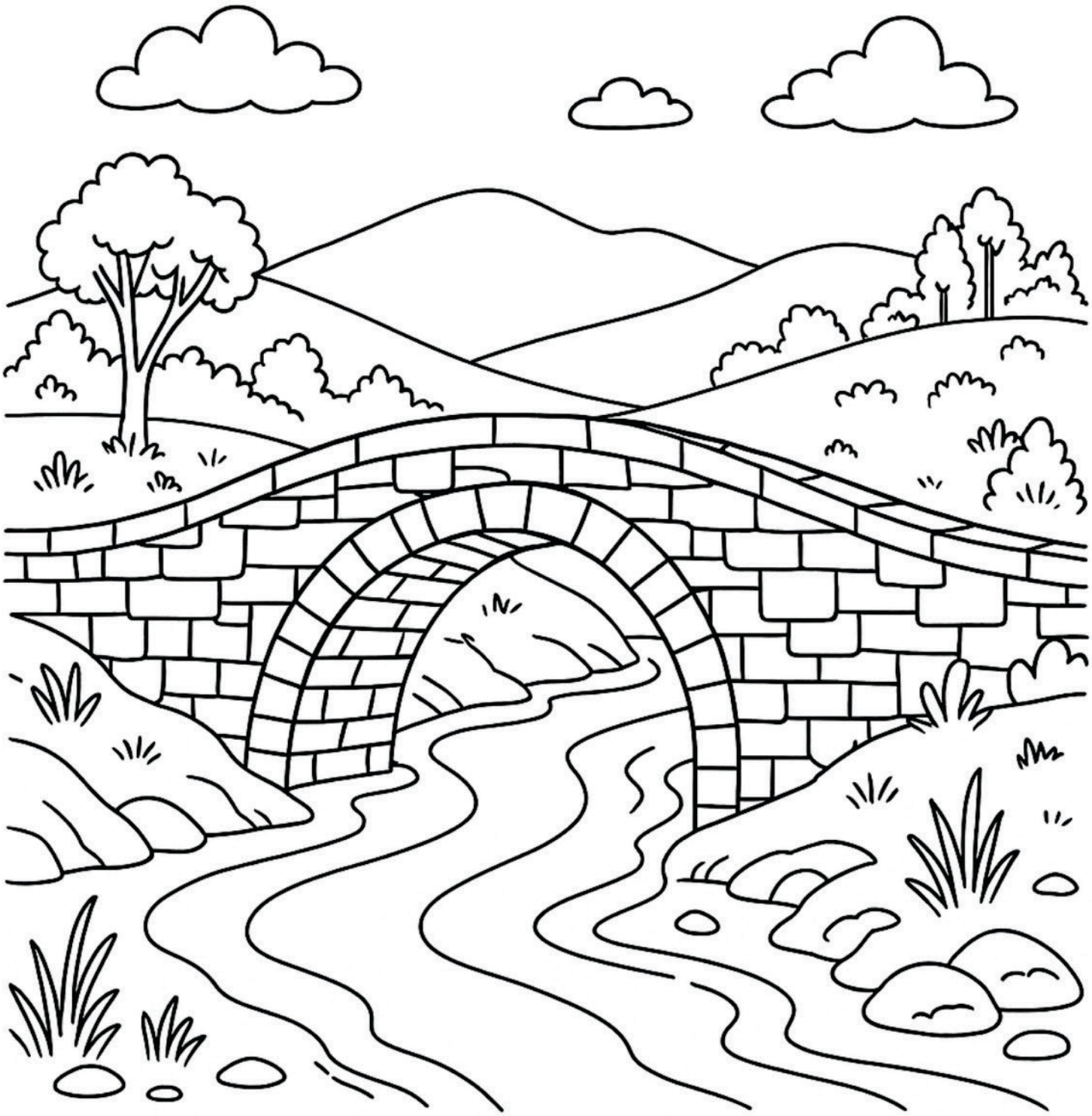
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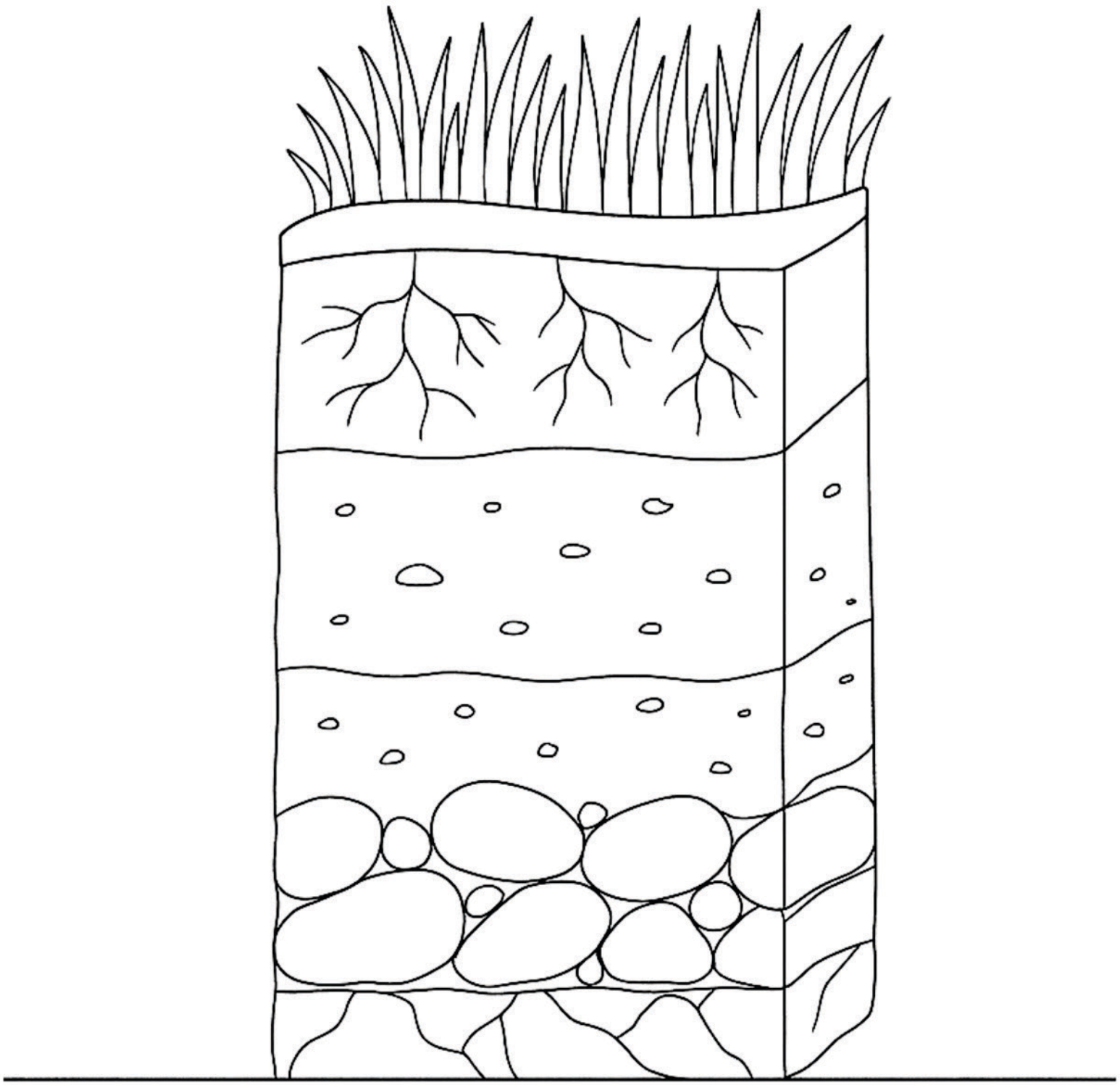
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Appendix D – Glossary of terms[3]

Acrisols *– Strongly weathered, usually acidic soils characterised by clay accumulation in the subsoil and low base saturation; colours are often influenced by hydrated iron oxides (e.g. goethite), commonly giving yellowish-brown tones.*

Aggregation *– The process by which soil particles bind together to form larger structural units called aggregates or peds, which affect porosity, water retention, and root growth.*
Arenosols *– Sandy, often quartz-rich soils with weak horizon development and low nutrient reserves; their light colours commonly reflect high silica content and limited accumulation of organic matter or clay.*

Bedrock (Parent rock) *– The solid rock layer beneath soil or superficial materials, which may serve as the source material (parent material) for soil formation through weathering.*

Calcisols *– Soils characterised by significant secondary accumulation of calcium carbonate, often in arid to semi-arid environments; they commonly have pale colours and alkaline reactions due to carbonate presence.*

Cambisols *– Young to moderately developed mineral soils with incipient horizon differentiation; colours may reflect a mix of iron oxides and organic matter, often producing brown to dark brown shades, without strong evidence of advanced clay illuviation.*

Carbon sequestration *– The process by which carbon dioxide is captured and stored in soils, vegetation, or geological formations, helping to regulate atmospheric CO_2 levels.*

Catena (Toposequence) *– A linked sequence of different soils along a slope that share broadly similar climate and parent material but differ due to their position in the landscape, reflecting systematic changes in drainage, erosion, and deposition.*

Clay *– The finest soil particle size, less than 0.002 mm in diameter. Clay influences water retention, plasticity, and chemical reactivity in soils.*

Colourteque *– A neologism used in this e-book to describe a library of soil colours collected for educational purposes, usually displayed in vials or jars.*

Eluviation *– The downward removal of materials (e.g. clay, iron, organic matter) from upper soil horizons due to water movement.*

Ferralsols *– Soils typically formed under intense weathering in tropical environments, often well-drained and deeply developed, with colours commonly influenced by abundant oxidised iron oxides (e.g. hematite), which can produce strong red hues.*

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[3] The terminology presented in the glossary is based on: Brady & Weil (2016), ISRIC – World Soil Information (2025), IUSS Working Group WRB (2022), Soil Science Society of America (2008), Soil Survey Staff (2022), UK Soil Observatory [UKSO] (2025).

Field capacity *– The amount of water retained in the soil after excess water has drained away, indicating the soil's water-holding capacity.*

Geodiversity *– The variety of geological environments, phenomena, and processes, including minerals, rocks, fossils, soils, and landforms.*

Geomaterials *– Naturally occurring Earth materials, including soils, rocks, sediments, and minerals, used in geoscience education and research.*

Goethite *– A hydrated iron oxide mineral (FeO(OH)) common in soils; it often contributes yellowish-brown colours and forms under weathering conditions where iron remains in hydrated forms.*

Gleysols *– Soils affected by prolonged waterlogging, leading to oxygen limitation and iron reduction; they commonly show greyish, bluish, or greenish colours and mottling associated with gleying processes.*

Hematite *– An iron oxide mineral (Fe_2O_3) that commonly gives soils strong red colours; it typically forms under warm, well-drained conditions with a high degree of oxidation.*

Horizon *– A layer within a soil profile that differs in colour, texture, structure, or composition from adjacent layers, formed by pedogenetic processes.*

Histosols *– Soils dominated by organic material, usually very dark, with thick organic horizons and low bulk density; they form where organic matter accumulates faster than it decomposes, commonly under wet or cold conditions.*

Humification *– The decomposition of organic residues into humus, a stable organic component of soil that improves fertility and structure.*

Humus *– A relatively stable fraction of soil organic matter formed by decomposition and transformation of plant and animal residues; it contributes to dark colour, aggregation, nutrient retention, and water-holding capacity.*

Illuviation *– The accumulation of materials (e.g. clay, iron, organic matter) in lower soil horizons, typically following eluviation.*

Luvisols *– Mineral soils with a subsurface horizon enriched in clay through illuviation and relatively higher base saturation; surface and upper horizons may show colours shaped by a combination of iron oxides and organic matter, often with clear textural contrast to the subsoil.*

Mineral *– A naturally occurring, inorganic solid with a definite chemical composition and crystalline structure. Examples: quartz, feldspar, goethite.*

Munsell Soil Colour Chart *– A standardised system used to describe soil colours based on hue, value (lightness), and chroma (intensity).*

Organic matter *– Decomposed plant and animal material in the soil that improves nutrient content, water retention, and biological activity.*

Pedogenesis *– The process of soil formation and development through physical, chemical, and biological interactions over time.*

Pedology *– The scientific study of soils in their natural environment, including their formation, classification, and mapping.*

Pedotransfer functions (PTFs) *– Empirical equations or models used to estimate difficult-to-measure soil properties (e.g. hydraulic conductivity, available water capacity) from more easily measured attributes such as texture, organic matter, and bulk density.*

Phaeozems *– Mineral soils with a thick, dark, organic-rich topsoil (mollic horizon) and relatively high base status; their colour reflects high organic matter content and strong biological activity.*

Profile (Soil profile) *– A vertical section of soil showing the sequence of horizons from the surface to the underlying bedrock.*

Quartz *– A common silicate mineral (SiO_2) that dominates many sands and contributes to light-coloured, nutrient-poor parent materials; it is highly resistant to weathering.*

Redoximorphic features *– Soil colour patterns and mottling produced by reduction–oxidation processes, typically under periodic or prolonged saturation, often indicating waterlogging and fluctuating oxygen conditions.*

Saprolite – *Deeply weathered rock that retains the original rock structure but has lost much of its strength and coherence through chemical weathering.*

Sand *– Soil particles between 0.05 mm and 2 mm in diameter. Sandy soils drain quickly and feel gritty.*

Sediment *– Loose, unconsolidated materials (e.g. sand, silt, clay) transported by water, wind, or gravity and deposited in layers.*

Silt *– Soil particles between 0.002 mm and 0.05 mm in diameter, contributing to a smooth soil texture and moderate water retention.*

Soil-based paint *– Paint made from natural soils mixed with water and glue, used as a sustainable and educational alternative to synthetic paints.*

Structure (Soil structure) *– The way soil particles are arranged into aggregates. Types include granular, blocky, platy, and prismatic.*

Texture (Soil texture) *– The proportion of sand, silt, and clay in soil, influencing its feel, water retention, and permeability.*

Topography *– The shape and features of the land surface, influencing water flow, erosion, and soil development.*

Weathering *– The breakdown of rocks and minerals by physical, chemical, or biological processes, contributing to soil formation.*

Weathering mantle *– The layer of weathered material that overlies fresh bedrock, including soil, saprolite and other unconsolidated materials produced by weathering processes.*



Soil-paint artwork (3x2 m) produced during a soil-based paint workshop at the Federal Institute of Minas Gerais (IFMG), Ouro Preto, Brazil (2023). The piece is a reinterpretation of The Starry Night (1889) by Vincent van Gogh, created by local basic education students under the guidance of undergraduate Geography teacher education students Bruna Oliveira and Geovana de Paula.