

SOIL BIOLOGY & ECOLOGY: THE BASICS



Dan Răzvan Popoviciu

Bentham Books

Soil Biology & Ecology: The Basics

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ISBN (Online): 978-981-5313-29-1

ISBN (Print): 978-981-5313-30-7

ISBN (Paperback): 978-981-5313-31-4

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First published in 2024.

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PREFACE

Although few people acknowledge it, soil is one of the environments hosting the highest biodiversity on this planet. A multitude of micro-and macroorganisms, bacteria, fungi, protists, plants and animals populate the various types of soil.

Yet, a really remarkable thing about soil is not just its enormous biodiversity, but also the variety and complexity of interactions among present organisms. At this level, we can find complex symbioses, competition, predation and parasitism. These interactions are essential to the continuous recycling of bioelements, in decomposing organic matter and making available again its various components.

Thus, soil has a crucial contribution to the very existence of Earth's biosphere. It provides nutritional support to all land-based ecological communities and, is also the basis of any agricultural production, thus, of our everyday food.

This is why knowledge of all these aspects of soil biology and ecology is important to naturalists. This book is conceived as a guide to students, specialists and all people interested in natural sciences.

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CHAPTER 1

Soil as a Living Habitat, General Considerations

Abstract: Soils cover most of the Earth's landmasses. Soil is a complex system, under continuous evolution and in perpetual relation to the atmosphere, hydrosphere, lithosphere, and biosphere. It is polyphasic, composed of a solid (mineral and organic) fraction, but also of liquid and gaseous fractions. A key aspect is its stratification into several horizons. This complex structure determines the living conditions being provided to the local biota, but also a major diversification of soil types on our planet.

Keywords: Classification, Life conditions, Soil, Stratification, Structure.

INTRODUCTION

Understanding soil biota requires, first of all, understanding soil as a living environment.

The key aspects of this are defining and delineating soil from other environments, knowing its characteristics, its structural features, and the life conditions it offers to inhabiting organisms.

Defining Soil

A key issue in studying this environment is how to clearly define and delimit it.

According to the Soil Science Society of America, soil can be briefly defined as “*The unconsolidated mineral or organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants*” [1].

The same society also gives a more precise definition, stating that soil is “*The unconsolidated mineral or organic matter on the surface of the earth that has been subjected to and shows effects of genetic and environmental factors of climate (including water and temperature effects), and macro- and microorganisms, conditioned by relief, acting on parent material over a period of time*” [1].

According to this definition, soil consists of both organic and inorganic components, which are subjected to continuous transformations, due to various

environmental factors specific to our planet. Thus, the soil is clearly distinct from the *regolith* covering the surfaces of other planets in our Solar System – a layer of variable thickness, made up of mobile mineral fragments, but devoid of organic matter (or, at least not in substantial amounts), lifeforms and lacking exposure to a hydrosphere or even atmosphere [2].

Natural Resources Conservation Service (government entity subordinated to the United States Department of Agriculture), defines soil as “*Soil is a natural body comprised of solids (minerals and organic matter), liquid, and gases that occur on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter or the ability to support rooted plants in a natural environment.*” [3].

Thus, the soil is formed of diverse components, has its specific layering, and is under continuous evolution, but it is also characterized from a functional point of view, by its ability to support plant life. The latter is connected to a key feature, typical to soil, that makes it clearly distinct from non-soils: fertility.

Even more important, NRCS states there are some physical boundaries between soils and other environments. The upper limit is the interface between the soil and air or a shallow water layer.

In aquatic environments, it is necessary to distinguish soil from *sediments* (sand, mud, *etc.*). The arbitrary limitation, according to NRCS is that the water layer should be less than 2.5 m thick so that the underlying material could be considered as soil. This would correspond to the maximum insertion limit of rooted water plants [3].

It is also important to define the lower limits of soil. Unlike underlying materials, the soil is characterized by a continuous interaction with the atmosphere and hydrosphere. Most lifeforms (including plant roots) dwell within a thin layer of Earth’s lithosphere. This although there are living beings (mostly microorganisms) that can be found up to 5 km deep [4].

So, as a practical maximum lower limit, soil scientists take a depth of 2 m [3].

Soil Characteristics

There are several key features that define soil:

- Soil is a **system**. This means that it includes various types of components, integrated in a functional ensemble.

- It is a **natural** system because it is formed under the influence of natural, biotic, and abiotic factors.
- It is **complex** because the factors conditioning its genesis and structure are numerous.
- It is **polyphasic**, its genesis involves different successive temporal stages.
- It is **heterogeneous**, being formed of components having different physical states (mainly solid, but also liquid and gaseous).
- It is **polydisperse**, meaning that its solid phase – dominant – is found under different degrees of dispersion: coarse dispersions (suspensions: sand and dust grains), colloidal dispersions (such as some heavily soluble hydroxides, humus, and clay), and molecular/ionic dispersions (soluble salts).
- It is an **open** system, being constantly involved in matter and energy exchange processes with Earth's lithosphere, hydrosphere, atmosphere, and biosphere.
- It is a **polyfunctional** system, performing multiple functions [5].

Morphological Characterization of Soil

As a complex system, soil is made up of different components. This complexity can be seen, for instance, in its vertical stratification (as soil consists of several **horizons**).

Horizon succession usually follows the scheme shown in Fig. (1) (obviously, this is a general model, while variations can occur from one soil type to another; some horizons may be missed, while others are present).

Thus, we may successively encounter:

- **O horizon**, superficial, rich in organic matter. It is mostly developed in forest areas, as well as in some grasslands (pastures, prairies). Its presence is due to plant tissue decomposition (especially leaves from woody plants). It can be subdivided into three categories, or sub-horizons, depending on the degree of organic matter decomposition: plant litter (O_l), fermentation horizon (O_f), and humification horizon (O_h).
- **A horizon**, also called surface horizon or topsoil, contains a mix of organic and mineral matter.

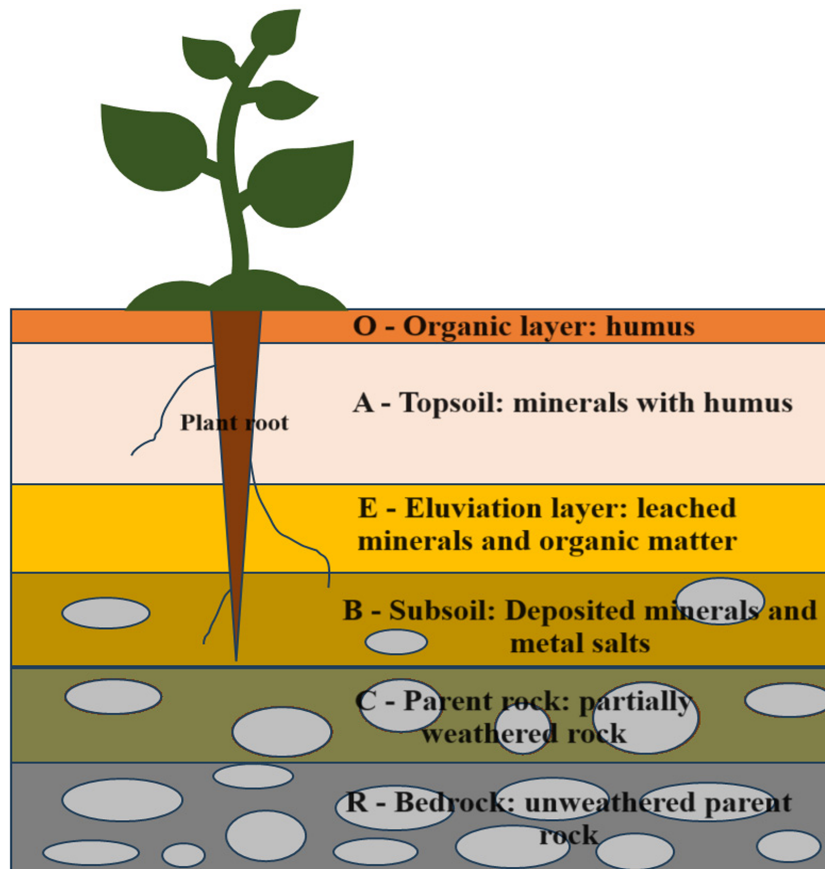


Fig. (1). The main horizons that compose a typical soil profile according to Science Facts [6].

- **E horizon** has a low content of clays, iron and/or aluminium compounds and stable minerals. It is formed through eluviation (“leaching”) of the mineral content by water. On the other hand, it is enriched in silica.
- **B horizon** (subsoil) is the layer where clays, metal oxides, *etc.* coming either from the bedrock or from upper horizons (if present), or even formed *in situ* tend to accumulate. Usually, iron oxides give it a reddish color.
- **C horizon** is a mineral one, with low or zero organic matter content and a low influence on atmospheric, hydrospheric, or biospheric processes. This is where carbonates coming from upper horizons tend to crystallize.
- **R horizon** is the bedrock. Depending on geographical location, it can be found at a depth of a few centimeters or a few meters below the surface [7].

Each horizon can have subdivisions and there can also occur specific horizons (P horizon – peanut, specific to peatlands, G horizon – gleic, saturated with water, *etc.*) [5], that make the object of pedology.

In characterizing soils, an important aspect is their structure, which allows for distinguishing several types of soils. Structure is given by the assembly, or lack of assembly of component particles into aggregates. Thus, there are glomerular, granular, prismatic, polyhedric angular and subangular, columnar, lamellar soils, *etc.* A good soil structure is considered to be the one that allows air and water to permeate (Fig. 2) [5].

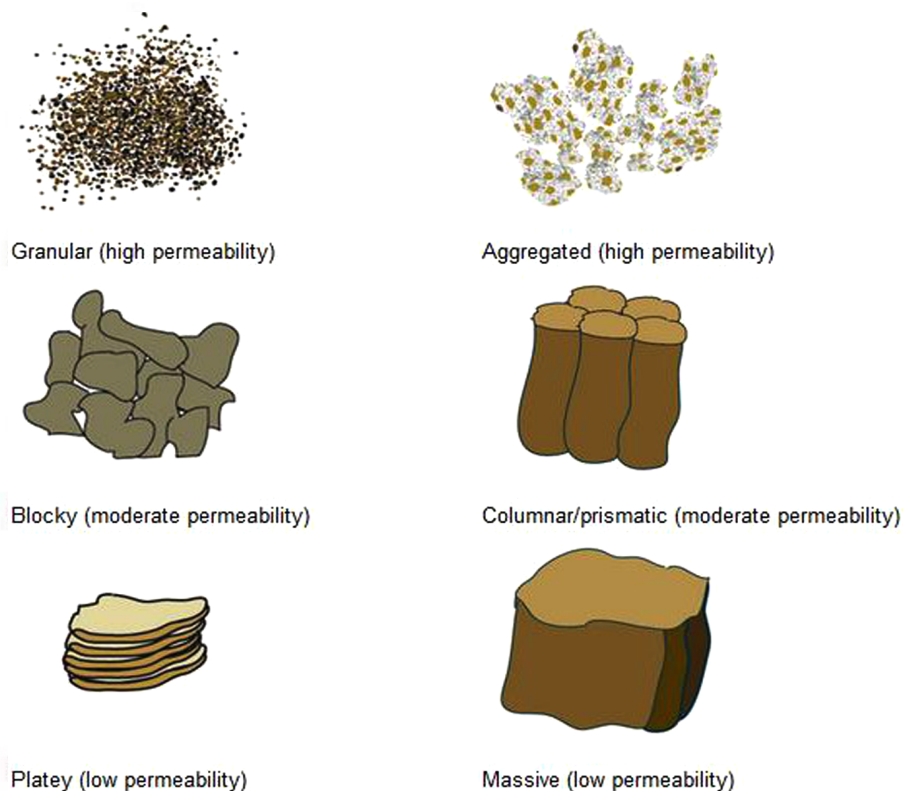


Fig. (2). Soil types according to structure and permeability to water [8].

Considering the composition, a typical soil is made up, on average, of around 50% solid matter (45% being mineral and just 5-10% organic matter). The remaining 50% (40-60%) consists of interstitial spaces (pores), where the gaseous fraction (air) and the liquid one (water) are hosted, each forming 20-30% of the total mass [9].

Thus, any soil is formed of the following components:

- Solid inorganic matter (dominant), comprising both rock fragments and primary minerals (derived from rock disaggregation) and secondary minerals formed due to the weathering of primary ones.
- Solid organic matter, comprising dead organisms, under different stages of decomposition (but also, obviously, living microorganisms) and organic substances newly synthesized at soil level (humic compounds, or simply **humus**).
- Soil solution (water containing variate amounts of dissolved mineral salts). Soil water can be found in the following forms: **hygroscopic water** (with a strong physical bound, due to adhesion forces, to soil grains), **pellicular water** (weakly bound, covering soil grains), **capillary water** (contained in soil pores) and **gravitational water** (free, easily replenished due to rain, easily accessible to plants, but also easy to be lost through leaking and evaporation), of which a fraction sinks towards more profound soil layers [5, 7].
- The gaseous component is, basically, air coming from the atmosphere, but with a somewhat different composition, due to specific biological or chemical processes. Thus, soil air usually contains 78.5-80% nitrogen (compared to 78% in the atmosphere), 10-20% oxygen (compared to 21%), 0.2-3.5% carbon dioxide (in the atmosphere 0.04%), also hosting relatively large amounts of water vapor, hydrogen sulfide, methane, ammonia [5].

Another key aspect is texture. Soil texture is due to the distribution of various granulometric classes of soil particles, of which we can mention gravel (grains over 1 mm in diameter), sand (0.01-1 mm, with various subclasses), dust, mud, and colloids, commonly known as clays (a component made up of grains below 0.01 mm and chemically active).

According to texture, we can distinguish sandy, sandy-loamy, loamy-sandy, loamy, loamy-clayey, clayey-loamy, clayey, and heavy clayey soils [5].

Finally, another important consideration in soil characterization is water content. Soils can be unsaturated (liquid water does not fill interstitial spaces completely), saturated, or even flooded (water level is above the upper soil interface; (Fig. 3). This is an extremely important aspect, that regulates oxygen permeability and the distribution of soil microbiota.