Raising Awareness of the Value of Soils as a Natural Resource

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By

Maria do Carmo Oliveira Jorge

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PREFACE

It gives me great pleasure to write the foreword to this book on soils by Dr Maria do Carmo Oliveira Jorge. Written for a diverse audience, students, teachers, nature enthusiasts and anyone interested in understanding the crucial role of soil. The text is designed to combine the formal and the informal, academic rigour and accessible language, in order to raise awareness and curiosity about soils. This book is part of the doctoral thesis studies developed in the Postgraduate Programme in Geography at the Federal University of Rio de Janeiro (UFRJ), where Maria do Carmo also defended her doctoral thesis in 2017, called 'Geotourism potentialities and geoconservation strategies in trails located in the southern region Ubatuba Municipality, São Paulo State', which highlighted the need for a soil book with this approach.

One of the other activities carried out during the fieldwork were workshops with children from state schools in Ubatuba, with theoretical and practical lessons. In these classes, the students had experience in determining texture, infiltration, pH and organic matter content. All this work had the active support of Mrs Anne Kamiyama, who has been our partner since 2013, owner of Sítio Recanto da Paz and where the idea for Ginger came from. In 2013 we started the first experiments, as well as collecting soil samples, monitoring erosion processes and creating geodiversity panels, located on a trail within the site. These teaching and research spaces encourage visits from children, teenagers, teachers, tourists and community residents interested in the subject. In this way, the author has sought to build bridges between scientific

knowledge and the curiosity that brings us closer to the world around us.

The author's approach makes it clear that soils are both the invisible guardians of life on Planet Earth and the great protagonists of our history. Under our feet, they sustain ecosystems, harbour astonishing biodiversity and provide the essential nutrients that feed plants, animals and, consequently, us human beings. Despite all this importance, soil is often seen as a mere physical support, or even an inexhaustible resource. This book has been designed in such a way as to teach, but also instigate and inspire the reader. It is an invitation to look at soils from a new perspective, seeing them as invisible protagonists, without whom life on Earth simply wouldn't be possible.

Throughout the pages, you'll find clear explanations of soils and their characteristics, illustrated examples and simple experiments to understand soil properties and their interactions, discussions on the role of soils in food production, maintaining biodiversity and environmental balance, as well as reflections on soil conservation and the impact of human actions, reinforcing the need for sustainable practices.

Of course, all this information is being told by an illustrious narrator, Ginger. Well, I hope this story arouses curiosity and, above all, encourages actions that value and preserve our soils. More than presenting concepts and information, this book aims to tell stories. Stories that begin thousands of years ago and extend into our lives, connecting the past, the present and the future. May each page be an invitation to look at soil with new eyes - not just as something we walk on, but as a living, dynamic and irreplaceable system.

Congratulations to Dr Maria do Carmo Oliveira Jorge, *caiçara*, born in Ubatuba, for the excellent work in preparing this book. I hope schools and society, as a whole, make the most of this Soil Book. It is unprecedented in Brazil and, perhaps, in the world.

Enjoy your Reading!

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Ubatuba, January 2025.

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To LAGESOLOS team for the support during my doctorate and post-doctorate.

PRESENTATION

Hello, my name is Ginger and I'm the character who will be leading this story, but first I need to introduce myself, after all, this whole narrative, from the moment I was born, begins with a typically tropical clod of earth.

It all started when researchers took a group of children to carry out educational activities about soils at ***Sitio Recanto da Paz***, a small farm in Ubatuba Municipality, in São Paulo State, Brazil. Entering into the richness that is the world of soils, and fascinated by the possibility of learning through play, the children began to mould small figures out of the clay soil, and one of these figures took on the shape I'm presenting here, and so I, Ginger, was born!

And why the gingerbread shape, after all, clay soils are perfect for creating so many other shapes and so many other characters, precisely because of their plasticity and special texture, which slips between the fingers but is firm enough to mould many designs.

Well, back to the dirt, my source material was geographically located in ***Sitio Recanto da Paz***, famous for its ginger plantations in the 1980s. At the time, the region was known for being a major national producer and exporter. Unfortunately, around 2002, the disease 'fuzariose' attacked and wiped out practically all the plantations. However, Mrs Anne, the owner of the farm, didn't give up on ginger, as she knew the benefits of the root's therapeutic properties. So she reduced the planting areas and switched to natural planting without pesticides, which is what saved the plantation. The farm thus became an example in the region and the plantation's

organic IBD certificate crowned Mrs Anne's efforts. Today she also produces many ginger derivatives, such as preserves, ice cream, biscuits, jams, cakes and liqueurs.

It's a great privilege to tell this rich story, as well as others to come in this book, because telling stories is one of the best ways of sharing knowledge and arousing curiosity in people. In fact, it was the children's curiosity that transformed that clod of soil into something magical, a chatty doll that loves to tell stories.

Moulding Ginger was just the beginning - it symbolised the connection they created with nature, with the earth and with the knowledge that soil can offer. So my story begins with the simplicity of a clay soil play. As the children moulded Ginger, they began to understand that soil wasn't just dirt; it was a rich universe, full of life, history and possibilities. Ginger came to represent this new friendship with nature, a symbol of the link between caring for the environment and a sustainable future.

So, from now on, my mission is to tell the story of my ancestors and draw attention to the future of soils on planet Earth. Formed millions of years ago, soils fulfil countless functions and provide many environmental services that make life on our planet possible. Soils are present in people's daily lives, directly and indirectly, and in a variety of ways. However, soils are generally undervalued, as people don't fully appreciate their importance. For a long time, soils have formed the basis of human infrastructure, the habitat of organisms, the supply of building and artistic materials and crucial cultural heritage. Soils also help produce food, fibre and fuel. Soils are also a source of energy and pharmaceutical resources. Soils help regulate climate and flooding, filter and purify water and contribute to nutrient cycling and carbon sequestration. Because of soil's services, it was recognised in 2015 at the launch of the 'International Year of Soils'.

I hope this story inspires you to explore the world of soil, to create other characters and, above all, to reflect on the future and the importance of looking after the land that sustains us. Best regards,

Ginger

CONCEPTS:
WHAT DEFINES US

The word soil comes from the Latin solum, meaning ‘surface of the ground’, but it is a dynamic concept that goes far beyond the simple idea of ‘earth’.

My definition can vary, depending on the focus of the observer - like a farmer, who sees me as a source of nutrients and the necessary medium for plant growth. For a geographer, it’s a complex and heterogeneous medium, made up of minerals, organic matter, water, air and living organisms, and a natural resource that is fundamental to the earth’s balance. For forest engineers, agronomists and ecologists, soil is a part of the environment conditioned by living organisms. For geologists, soil is the product of the weathering of rocks on the planet’s surface. For the civil engineer, soil is the material that serves as the basis for built infrastructure, or as the raw material for the construction of facilities such as embankments and roads. For the archaeologist, soil is an archaeological deposit that helps reconstruct historical records. Therefore, each of these concepts fulfils the purpose of each objective.

For me, soil is like a book that holds the secrets of time, offering a glimpse into the past and sustaining the life that develops on it. The definition of soil, then, depends not only on what it is, but also on how it is used and appreciated by those who depend on it. This multiple perspective is what makes soil

so fascinating and so fundamental to our understanding of the world around us.

In short, soils are indispensable for life on the planet. Not only do they support food production and biodiversity, but they also play fundamental roles in environmental processes that maintain the balance of ecosystems and contribute to human well-being. From this perspective and in contrast to the concept of biodiversity, I would like to bring up the concept of geodiversity, which is the set of non-living elements on the planet, made up of rocks, relief, water, the atmosphere and, of course, soils.

Soil, as an element of geodiversity, is also evaluated in research and scientific work, according to its intrinsic, scientific, historical, cultural, educational, aesthetic, tourist, economic and functional values.

And what do you think the definition of soil is?

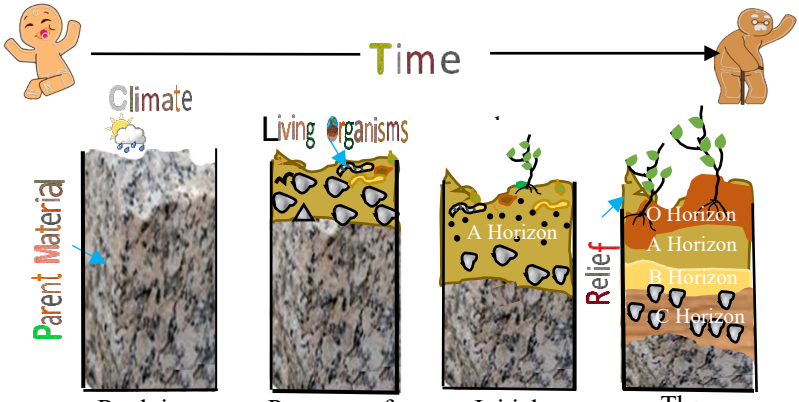
On the Process of Soil Formation

In order to understand the complexity of the process of soil formation and evolution and the importance we play for life on the planet, I'm going to look at a few key concepts that will help you understand this. These are two concepts that are deeply interconnected: pedogenesis and weathering. Understanding these definitions makes it easier to enter this fascinating world of soils.

Pedogenesis (pedo: soil + genesis: origin) is responsible for the process of origin, or soil formation, and occurs mainly due to the action of weathering, which is responsible for breaking down the parent rock and gradually transforming it into smaller particles.

The time it takes for soils to form, their depth and structure will always be related to the elements at work in this process, which will, of course, depend on their place of origin. Imagine, for example, a hot place and a cold place. How will each element play a role in these scenarios?

The active elements in the soil formation process



Well, after introducing the people responsible for our formation, I'm going to show you the role of each of them in this process. As for the source material, formed by any type of rock on the planet, I couldn't fail to mention my friends igneous, metamorphic and sedimentary rocks. I could praise many qualities of these friends, and of course many differences, but I'll stick to their degree of hardness, or their resistance to the elements. Remember when I mentioned weathering? Well, it has to do with the disintegration or breaking down of rock particles, the structures of which fragment into smaller particles, until the soil is formed.

I think it's important to give a brief introduction to my friends - the rocks, so as to explain why they are so hard. Igneous rocks come from magma or lava, I'd say it's the 'molten rock' inside the Earth and when the magma cools, it turns into a hard rock, such as basalt (very common in volcanic rocks) and granite.

Sedimentary rocks, on the other hand, are a different process and involve sediments, of course. Sedimentary rocks are formed from fragments of other rocks, sands, minerals, which accumulate in layers and, over time, compact and harden; sandstone is a good example.

As for metamorphic rocks, they were once another type of rock (igneous or sedimentary), which underwent changes due to the heat and pressure inside the Earth. It's as if the Earth presses down on the rock and heats it up, transforming it into something new; good examples are marble and gneiss.

I think these explanations are important because they will help you understand the degree of hardness of rocks, because hard rocks are very resistant and difficult to break. Soft rocks, on the other hand, are more fragile and can be scratched or even broken easily.

In my case, I can say that my source material is granite, a very resistant rock. I wonder how long it took this rock to break down into smaller pieces and start the process of forming me.

But of course, in this process of rocks breaking down into smaller particles, the climate, represented by rainfall and temperature, helps a great deal. In tropical regions, such as Brazil, the combination of abundant water and heat significantly accelerates the process of weathering, which is the breaking down of rocks, very different from regions with cold, temperate and arid climates.

Oh, and in the process, thanks to all my friends who make up the fauna and flora on this planet. Plants, animals and microorganisms, which play a very important role in soils, especially in the stages of biological weathering and in the production of organic matter, which makes us very healthy and fertile.

When it comes to physical weathering, have you ever thought about the role of plant roots? They are able to penetrate

the cracks in rocks, and with the pressure they exert, they also contribute to the physical fragmentation of rocks. Roots also stand out for releasing organic acids that accelerate the chemical decomposition of minerals, making nutrients more accessible (chemical weathering) and when plants die, their leaves, branches and roots decompose, forming the soil's organic matter, which is fundamental for fertility (biological weathering).

And what about my friends, the explorers of the underground world? Wow, what a great engineering job earthworms, ants and other invertebrates do, because they love to dig and by doing so they move the soil, facilitating aeration and water infiltration, which speeds up weathering. The work of my microorganism friends (bacteria, fungi and algae), who are so small and so great in their mission, is related to the decomposition of organic matter, as they transform it into humus, a nutrient-rich layer in the soil. Another commendable work of my friends from the Rhizobium genus consists of nitrogen fixation, i.e. they transform atmospheric nitrogen into forms usable by plants, as do some fungi and bacteria, which can release acids that help solubilise minerals, such as phosphorus, making them more available to plants.

Regarding the characteristics of the extremely diverse relief, due to a complex combination of geological, climatic and erosive factors that have moulded the surface over millions of years, it also has a very special relationship with the formation and distribution of soils, as it has a major influence on erosion processes.

On slopes, for example, soil has different characteristics when compared to flat areas, because on slopes, gravity makes it easier for rainwater to run off, which can contribute to increased erosion. Soil eroded on slopes can accumulate in lower, flatter areas, where there is less water run-off. It is a fact that in these sloping areas, water tends to run off more quickly,

making infiltration more difficult and the soil ends up drier. On the other hand, flat areas allow for greater water retention, favouring the formation of wetter, thicker soils. This factor influences the type of vegetation and soil biological activity. Remember that there may be exceptions to these characteristics, as everything in nature will always depend on their controlling factors.

In this explanation of relief and soils, I couldn't fail to mention the amount of sunlight that soils receive, which can also be influenced by the relief slope, since slopes facing the sun tend to be hotter and drier, while those facing shaded areas tend to be cooler and wetter, and this ends up having an impact on the weathering process and the development of organisms in the soil.

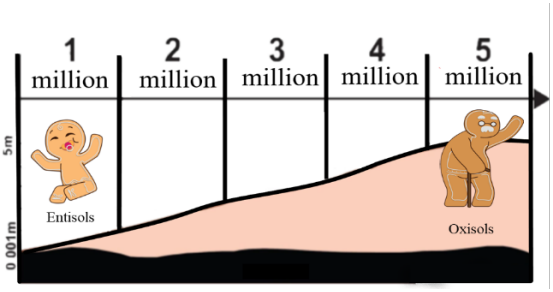
About Time and Age

To tell the story of the time and age of soils is to explore yet another fascinating chapter of planet Earth. Soils bear the marks of time from the most recent periods to the most distant, over millions of years.

Although I haven't yet talked about the profile of soils, with their horizons, I'm going to make an analogy here with trees, because trees have rings to tell their age, and soils reveal their past from these horizons, formed through slow but continuous processes.

So Mr Time, all my respect and admiration, because I can only imagine how many secrets and stories you have about my ancestors, because we know that the formation of a soil is a slow and gradual process that can take hundreds to thousands of years, depending on the climatic, geological and biological conditions of the environment.

I would like to take this opportunity to point out that the rate of soil formation is not keeping pace with the rate of soil degradation, which is increasingly growing and impoverishing the soil, so I would like to warn you about the importance of this finite resource.



The formation of superficial soil layers can take a few hundred years, while deeper and more complex layers, with well-defined soil horizons (layers), such as the B horizon (subsoil), which is rich in minerals leached from the upper layer, can take between 2,000 and 10,000 years or more. Overall, it is estimated that it can take anywhere from a thousand to tens of thousands years to form a deep soil with well-defined horizons.

PHYSICAL AND CHEMICAL WEATHERING

Remember the degree of hardness and disintegration of rocks? Well, I'd like to take this opportunity to talk a little more about the intrinsic relationship between physical and chemical weathering, which, despite having different mechanisms, are processes that complement each other in the task of transforming rocks into soils.

It's important to understand that physical weathering occurs through processes that disintegrate the rock without altering its chemical composition. Another simple piece of information, but one that also causes confusion, concerns physical and mechanical weathering, as they are the same process, consisting of the fragmentation of rocks through physical processes. It is mainly caused by variations in temperature, the action of water and wind. In this process, it is very important to understand what thermal expansion and contraction are. Think of something that expands and contracts, and what the consequences of this are.

In areas with large temperature variations between day and night, rocks expand in the heat and contract in the cold, which causes cracks to form and eventually the rock to fragment.

But how can this happen in cold areas? This is where the role of water comes in: when it manages to infiltrate the cracks in the rock, it freezes and the increase in volume of the ice creates pressure in the cracks, breaking the rock.

Chemical weathering alters the chemical composition of rocks and minerals, transforming them into new compounds, facilitating decomposition. This type of process is more common in hot and humid climates, where water plays a very

important role, as it acts as a solvent and catalyst for various chemical reactions.

These are complex processes because they involve a lot of chemical reactions and you need prior knowledge to move forward with this story, but I think it's important to introduce some names, such as Hydrolysis, Oxidation, Carbonation and Leaching.

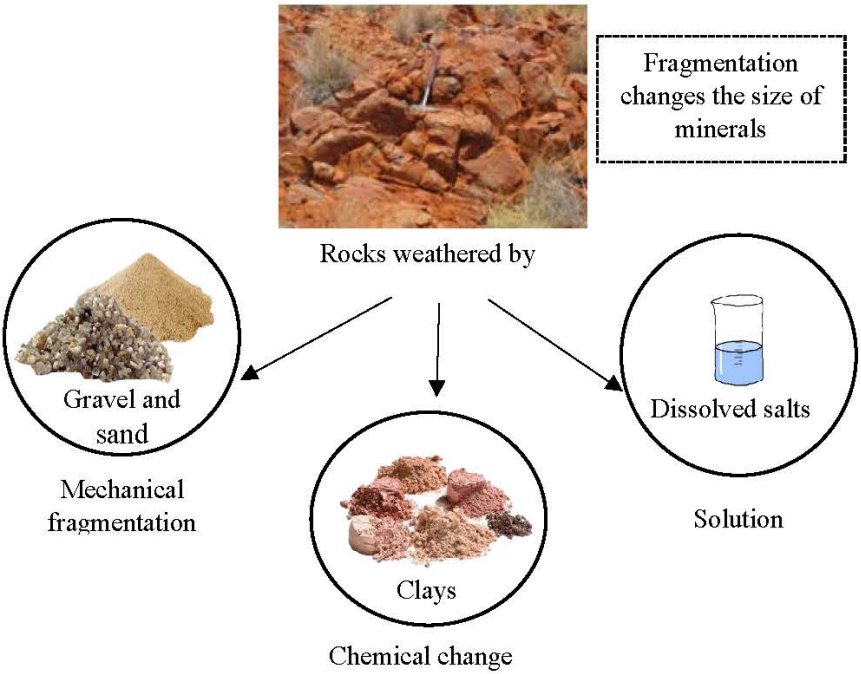
Hydrolysis is the contact of water that reacts with minerals present in the rock, such as feldspars, transforming them into clays, releasing elements such as potassium, sodium and calcium, which can be absorbed by plants. I'll talk a bit about these elements throughout the story. I'd also like to emphasise that clay is so important that if I were to tell you all about it, I'd write many chapters in this book.

Oxidation occurs when oxygen reacts with iron-containing minerals to form iron oxides (such as rust), which are less cohesive and make it easier for the rock to break down. This oxidation process is analogous to rusting of iron and changes the colour of minerals. Iron oxidation is an important chemical process that influences the colour of soils, especially those with reddish, yellowish and orange tones. Highly weathered tropical soils tend to accumulate residual iron and aluminium oxides.

Carbonation is a process in which the carbon dioxide present in rainwater helps to erode certain rocks. To explain it simply, we can say that it is a type of chemical weathering in which certain rocks, such as limestone, slowly erode when they come into contact with water.

Leaching is the process by which rainwater infiltrates the soil and carries dissolved nutrients and minerals. This process is very common in humid, tropical climates where there is a lot of rainfall. Oxisols, typical of tropical and subtropical climates, are deep and rich in iron and aluminium oxides, but poor in essential nutrients due to intense leaching. These soils

require specific management practices to maintain fertility and enable sustainable cultivation.



Dissolution and/or chemical changes modify the mineral components of soils, producing clay and salts. Some of these salts are retained around the clays. The rest may be dissolved and percolate to the water-table or to ground-water or enter waterways.

Elements Active in the Process of Soil Formation: Lichens

When talking about the process of soil formation, I emphasise the role of lichens and their pioneering spirit, as they are always the first to settle in inhospitable places, such as newly exposed rocks, soils without vegetation, among others.

Speaking of age, lichens are probably one of the oldest organisms on our planet. There are currently around 20,000 lichen species catalogued. They vary in terms of shape, size and habitat.

Fascinating and resilient, that's how I describe these organisms that are essential to many ecosystems and capable of surviving in environments that would be inhospitable to most life forms.

Lichens play an essential role in soil formation, as they are true 'biological engineers', especially in the initial stages of weathering, when they colonise rock surfaces, preparing the environment for the colonisation of other organisms and starting the cycle of soil enrichment. Their ability to decompose rocks and add organic matter makes them essential in the early stages of pedogenesis (soil formation).

Rock covered by lichens, Rio de Janeiro-Brazil. Photos: Maria do Carmo Oliveira Jorge

Tips

You should know that lichens come in a variety of colours and sizes and inhabit a variety of environments, many of them with extreme conditions. They are also important indicators of air quality, due to their extreme sensitivity to atmospheric pollution.