Field Trip: Dig It! The Secrets of Soil

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1. Introduction

[MUSIC PLAYING]

Dig It! The Secrets of Soil is a traveling exhibit brought to you by the Soil Science Society of America. The 5,000-square foot exhibition reveals the complex world of soil and how this underfoot ecosystem supports nearly every form of life on Earth.

TEXT ON SCREEN - [John Havlin, SSSA Fellow and past President, Department of Soil Science, North Carolina State University]

We wanted to develop K through 12 curriculum materials so that, when the exhibit was delivered to a city, that these materials could be delivered to-- or made accessible to classroom teachers to incorporate in their classrooms. One of the most amazing things to us that we didn't expect was we have a room inside the exhibit that houses what we call soil monoliths.

And they're a slice of the soil profile from the surface, 3 or 4 feet deep. We take those out of the ground and encase them and in a glass enclosure for everyone to see, and we have one of those for every state and a few territories of the United States. And when children walk through that section, and adults, they're mesmerized by the variation in soils.

A lot of the lessons that we've learned from studying past cultures and why they failed seem to be lessons that we still have not learned to that. To get into this passion for soils and now finally understand this was something I

felt very strongly that I had to communicate it. It was my responsibility for the chance to have-- to study to do a doctorate, to give something back.

TEXT ON SCREEN - [Patrick Drohan, Ph.D., SSSA Member and co-founding member of Dig It!, Associate Professor Pedology, Penn State University]

And I felt very strongly that this was the best way to do it. I want them to see that their day is a product of the soil that they interact with, and it's everyone's responsibility to make sure this resource is treated with the utmost respect, and that we manage it in a way that allows those future generations to benefit from the way we have today-- but we leave that legacy even better.

For more information regarding the Dig It! Exhibit and its schedule of exhibition dates, visit www.soils.org.

TEXT ON SCREEN - [Tai McClellan, Ph.D. Student, Washington State University]

Hi. Welcome to the Dig It! Museum. Please join me on our journey today as we learn about the importance, the function, as well as the classification of our world's soils.

Throughout history, humans have depended on soil for their existence, as soil filters the air we breathe and the water we drink. Soil can provide fuel for our vehicles and is used as structural support for the buildings in which we live and work. Without soil, we would not have food to eat or clothes to wear.

Plants are dependent upon soil, as it supplies plants with nutrients and allows them to anchor their roots for proper growth. Soils are very important for life on Earth, yet not every soil is the same. In fact, the world has 12 different recognized soil types, known as soil orders.

Because soil behaves differently, depending on the soil order, knowing the type of soil upon which you work and play is important. We must know the particular soil order to predict its behavior and apply the best techniques for its management.

2. Soil Properties & Formations

[MUSIC PLAYING]

TEXT ON SCREEN - [Dig It! The Secrets of Soil: Soil Properties and Formations]

In just 1 teaspoon of healthy soil, there can be as much as 1 billion microorganisms, and this can account for up to 4,000 different species. So the microorganisms that are found in soil can be both good and bad. The good ones can be used for medicinal purposes, such as the antibiotics that we take to protect our own health as humans. Microorganisms can also be used to make biofuels that reduces our dependence on fossil fuels.

However, the bad microorganisms in the soil can cause diseases in animals, plants, and even humans. So soil microorganisms-- particularly fungi-- are important and decomposing organic matter. So in the process of breaking down organic matter, these fungi can secrete enzymes, which actually break up the carbon compounds and release nutrients back to the soil.

Not all soil microorganisms require oxygen to live and breathe. Some microorganisms can use sulfur, iron, or nitrogen to respire, instead of using oxygen. This allows them to grow in areas with low oxygen or no oxygen available, such as waterlogged soils. In protein-rich foods, such as legumes, the plants have evolved a special way of obtaining nitrogen, which not all plants can do.

These plants can form associations with bacteria and form nodules after they colonize their roots. These bacteria can extract nitrogen from the

atmosphere and turn it into forms which can be used by plants, such as ammonium.

We learn about soils because we want and need clean water, air. We also need to nourish our bodies with food and healthy water. We also need feed, fuel, and fiber, as well as healthy ecosystems. We group soils based on their similarities and their characteristics, such as their texture, their color, and their structure.

It's important to analyze and characterize soils so that we can predict their behavior. And this will help us better manage soils to fit our needs as humans, as well as provide ecosystem services, which are important for our planet. We do this by using many tools and techniques which encompass many, many things, such as digging, smelling, touching, filling.

[MUSIC PLAYING]

Soils are formed in layers, which are known as horizons. These horizons form as you go down into the soil, and they are altered by the five soil forming factors-- parent material, time, climate, topography, and biological factors. Parent material includes rocks and other geological deposits from which soil is formed.

Time describes how long the soil has been developing. Climate refers to the weather in the area where US soil is located. Topography describes the position of the landscape where the soil is found. Biological factors describe the plants and animals which inhabit and affect the soil.

As scientists analyze these layers, they're able to group soils based on their similarities. There may be gradual or distinct changes throughout the layers, depending on how the soil formed. It is important to know that not all soils contain each of these layers, yet there are five basic layers in soil.

The O horizon is made of organic matter, which is comprised of decomposed and partially decomposed plant and animal residues. This horizon is sometimes made of newly deposited leaf debris as well. The A

horizon is known as topsoil, and is made of minerals and organic matter which has been decomposed and dried from the surface. There are many microorganisms in this layer as well.

The E horizon is known as a layer of loss, as it carries materials such as clay, organic matter, and nutrients to the layers below. The B horizon is a layer of gain, as materials wash from higher layers and are deposited here. The movement of materials through these layers is known as weathering.

The C horizon is a mineral layer, which most closely resembles the parent material from which the soil was formed. This layer is less affected by microbial activity and the loss and gain processes than any other horizon.

[MUSIC PLAYING]

The Dig It! Museum is unique because it has on exhibit an example of the monoliths, or the soil profiles, taken from all 50 states, as well as US territories. The soils shown here are these states' or territories' official soil series, basically based on information obtained by the NRCS, or the Natural Resource Conservation Service, as part of the US government. The soil monoliths that are displayed are important either due to their unique or special characteristics, or they are displayed because of their importance in agriculture.

The texture of the soil greatly affects how we need to manage the soil and how the soil function and behaves. There are three types of mineral components that greatly affect soil texture, and these differ in their size. First, you have sand, which is the largest of the soil grains. Then you have silt, followed by clay. So the size of the particles and soil greatly affects how water is able to move through the soil profile.

This demonstration shows that, in sand, since it has larger macropores, the water is able to infiltrate the soil much quicker, compared to that silt. And particularly, you can see here that the porous base inside a clay soil is so small that the water news very, very slowly, if at all. Sometimes this water

is caught up into the soil micropores, and doesn't distribute through the soil profile easily.

A loam soil contains moderate amounts of each sand, silt, and clay. It's good for growing crops, because it does allow for water to move through the soil, but yet it holds enough so that plant roots can take up this water. Soil structure is also important for healthy soils. Microorganisms and organic matter help to protect soil structure and keep soil held up into aggregates, or clumps, or clods. This aggregation is important for allowing water and air to move freely through soil.

Soils develop from parent material, or a rock from which is broken down to form these soils. The parent rocks are the primary source of minerals and soils. The primary minerals include quartz, mica, and feldspar. And to be primary minerals, they cannot change in their chemical structure than that upon first crystallization.

As the parent rock breaks down and forms soil, it can release important minerals, such as potassium, as well as phosphorus, which are important for plant growth. The oldest soils are made up primarily of secondary minerals. As the primary minerals dissolve, they read form new minerals. This is known as secondary minerals in the older soils.

Secondary minerals consist of silicate clays, as well as oxides. Soil is comprised of many materials, including minerals, water, air, and organic matter. 45% is mineral, 5% can be organic matter, whereas 25% is air and 25% is typically water.

[MUSIC PLAYING]

3. Soil Orders

[MUSIC PLAYING]

TEXT ON SCREEN - [Dig It! The Secrets of Soil: Soil Orders]

Soils play a critical part in each and every one of our lives, from the clothes that we wear to the food and water that we eat and drink, to sometimes the fuel that we use. Soils provide structural support for plant roots so that they can take hold and grow. They can filter the water and remove pollutants from the water, as well as clear the air that we breathe. Soils also provide mineral nutrients to plants, such as nitrogen, phosphorus, potassium, among others.

[MUSIC PLAYING]

In order for us to predict and manage soil behavior, we must be able to identify soil types. We can do this by learning about distinctive soil properties that provide tools for soil classification and identification.

So this world map depicts the 12 soils of the world. Now, scientists have developed these soil orders based on properties, which include color, texture, their type of minerals, as well as the organic matter content.

You can see here that there is some great variation amongst the different soils in the world. You can see that each country has very, very, very many different types of soils that differ greatly in their diversity. The 12 types of soil orders that scientists have characterized include andisols, entisols, inceptisols, alfisol, spodosol, gelisol, ultisol, histosol, oxisol, vertisol, aridisol, as well as mollisol.

Now, I'd like to first start with describing andisols. You can see here in the map of this world, andisols are the dark purple color. They are known as volcanic soils. And they were developed from ash, as well as cinders, during volcanic eruptions.

Andisols are extremely fertile. And they are known to have a very high water-holding capacity, meaning that they can hold more water than their actual weight. And this is because they contain minerals, such as allophane, which are amorphous. And their structure allows the soils to expand.

The second soil I would like to highlight would be the entisols. You can see here that they represent the orange color. Now, these soils are undeveloped, meaning that they don't have a distinctive layer formation. Either they're very young soils, such as what you would find maybe along a beach, or they're old soils where their top layer has been weathered away due to erosion.

So the third soil that I would like to highlight would be the inceptisols. Now, these soils are more developed than the entisols. And they show the first signs of soil formation, where you can actually see organic matter starting to accumulate in a top layer.

Alfisols are moderately developed soils, which are commonly found in forests where plant litter has accumulated in the top layer. These soils are good for farming.

Spodosols are found in cool, temperate climates, and are typically unfertile. Characterized by their bright color and acidity, these soils are typically very sandy, which allows soil water to carry organic matter through the soil.

Gelisols are frozen soils which are associated with permafrost. They are frozen for most of the year, yet the top layer can thaw in the daytime during summer months.

Ultisols are weathered soils of the tropics and the subtropics. These are common in forests and savannas, but are not naturally fertile for crop production.

Histosols are organic soils associated with wetlands. They are found in places where we consider to be peatlands, bogs, and marshes. They're characterized by a high amount of organic material that is partially decomposed.

Histosols are found in temperate, tropical climates, as well as cool climates.

Oxisols are highly weathered tropical soils. They are probably the most developed of all the soils. They have no obvious horizon differences and are characterized by their bright orange and red color. These soils have developed in hot, humid climates, such as the tropics, and are not naturally fertile.

Vertisols are soils which shrink and swell, and are known for high fertility. These soils pose many problems in construction and their management, as they crack when they are dry and swell when they're wet.

Aridisols are dryland soils, which occur in regions with little rainfall, yet irrigation allows these soils to support crop production. These soils support crops and microorganisms which are accustomed to long periods of drought.

Mollisols are the most fertile soils in the world and support grasslands and savanna prairies. These soils are known for their deep topsoil layer, which is rich in organic matter.

[MUSIC PLAYING]

4. Functions & Management

[MUSIC PLAYING]

TEXT ON SCREEN - [Dig It! The Secrets of Soil: Functions and Management]

How do we want the soil to function? What services can soil provide? Soil not only helps to provide humans with food, feed, fiber, and fuel, but also filters our water and air. Our drinking water is cleansed as it moves through the soil profile.

Contaminants can be absorbed by soil, or prevented from entering the air that we breathe. However, we must be careful of what and how much we add into soil. Even those soil acts as a great buffer and filter, inputs can lead to environmental pollution.

Throughout history, humans have learned a lot about soil and soil fertility. Along the way, humans have also discovered ways to manage soil properties in order to meet their needs for food and shelter. No soil illustrates this better than the terra preta of the Amazon, which was amended with charcoal, among other substances, to enhance the fertility of the otherwise infertile tropical soil.

TEXT ON SCREEN - [Tai McClellan, Ph.D. Student, Washington State University]

As you can see here with the dark earth soils, they're much darker in color, as well as much more fertile than the typical infertile tropical soils beneath. Now these soils are thought to get their fertility from charcoal that has been added by the indigenous people thousands of years ago. And this charcoal is thought to help maintain and hold nutrients that have been added through the addition of compost, which includes green waste material, as well as fish byproducts.

This soil is important, because it represents very fertile pockets within the Amazonian basin, which is surrounded by largely infertile soil. Now researchers are interested in this soil, because they're hoping to mimic these practices, maybe perhaps through charcoal additions, and to enhance the fertility of tropical soils, which are known for their infertility. Particularly they're interested in having soils hold and maintain nutrients that could be subsequently available for plant uptake.

We often think about agriculture and sustaining human populations when we discuss soil management. However, the fertility of the soil must be replenished or built up in order to continue supporting civilizations. Soil amendments provided by humans and processes mediated by soil

microorganisms play important roles in maintaining or enhancing soil fertility.

The quest for a more fertile soil to support agriculture has been a theme of all civilizations, and not limited to the tropics. In early European civilizations, villages were built on fertile soil, known as loess. Loess is a silty soil, which typically is blown and deposited by wind. This soil can be very deep and very rich, but is prone to erosion, and maybe result to eventual loss of farmland.

Civilizations have not only managed soil for agricultural purposes, but also for engineering and construction. The desirable soil properties for engineering and construction might be very different than agriculture. Rather than fertility, engineers might seek soil that serves as a strong foundation for buildings and roads. Some soils, those that shrink or swell or sink when thawed, might pose an enormous challenge to engineers.

Engineers need to know the texture of the soil. For instance, is it sandy? And also, what type of clay it may hold, and whether that clay is unstable.

In soils that experience freezing, ice crystals can form in soil. However, when these soils slump, they can pose risks for the structures that they hold, and potentially break the foundation. This is important, if we think about the permafrost soils, and how building on top of permafrost soils can lead to potential damages to foundations as temperatures rise.

Soil provides the foundation for us to construct buildings, as well as to support and give nutrients to crop growth. And finally, soil provides ecosystem services for which to serve as habitats for wildlife and plants, as well as cleanse water and air.

How we interact with soil is very important in its ability to perform these functions. For instance, putting heavy machinery and equipment can cause soil compaction. And covering this with concrete can reduce its ability to filter water and cleanse this water.

It is also important to apply the proper amount of fertilizer to soil, because applying too much fertilizer can lead to pollution downstream, as these fertilizers can seep into the soil, and then enter the groundwater, and eventually lakes and streams. For instance, mineral fertilizers, pesticides, and even soil sediments can end up downstream from the farm. It can enter groundwater, and eventually lakes, stream, and the ocean. And it can negatively affect the ecosystems.

Also, pollutants can enter the air and have a negative effect on air quality.

Tillage is the conventional farming method used to prepare the soil for planting seeds. Tillage is the manipulation of soil by physical, chemical, or biological causes, and provides many beneficial functions, such as optimizing conditions for germination, seed establishment, and crop growth, weed control, control of plant diseases, nutrient recycling, correcting soil compaction, land leveling, facilitating irrigation, and crop residue management.

Tilling causes a loss of organic matter and soil erosion, yet simple management practices can be applied to reduce the adverse effects of tillage. Practices such as minimum till and no-till farming have been adopted to further aid in controlling soil erosion and loss of organic matter. However, any tillage practice may be utilized as long as appropriate management practices are implemented.

When we grow crops in soil, this results in a loss of nutrients, as the crops take up the-- these nutrients from the soil. Farmers can then return or increase the fertility of the soil by applying fertilizers, whether it be synthetic or organic, as well as growing certain plants, such as legumes, which can actually enhance the soil fertility. New technology is enabling farmers to add the right amount of fertilizers at the right time in order to maximize crop growth, by applying the right amount of fertilizers, while also minimizing potential pollution.

Often, humans have sometimes put more than just a footprint in soil. At times, human activities have led to the formation of anthropogenic soil, or human-made soil, such as backfilling new soil or landfills.

Under natural conditions, soil forms through interactions in time with the climate, as well as microorganisms. However, humans have altered the condition of soil in several ways. For instance, here you can see how soil was backfilled into pre-existing soil, which caused differences in the ability of plants to grow in that area.

Here, you can see a fluffy soil was deposited around the root ball of these cherry trees. However, this caused major drainage problems, and the cherry trees could not tolerate these conditions. So as a result, scientists realized that what they should do in order to enhance soil drainage is to backfill with denser soil, and allow soil in-- soil-water infiltration.

Humans can greatly alter the soil landscape. In this picture, you can actually see how along the Anacostia River, it was once a wetland. But humans soon developed a landfill. Humans have altered the soil in some ways that are disastrous, which means that the soil can't perform its critical functions of filtering the soil water, cleansing the atmosphere, as well as providing appropriate structure for the foundation upon which we live.

In order to maintain healthy, productive soils, we must protect the soils from losses due to wind or water erosion. And soils with a loss of soil fertility, due to either highly-weathered soils or hot, dry climates, or through their overuse, we must learn to restore their soil fertility. This is especially hard in places such as sub-Saharan Africa, where you can have greater uptake of nutrients than that which is returned by farmers.

If the soil does not have time to rest and rebuild its nutrient content, then farmers have to find ways to increase the soil fertility. This can be accomplished through the addition of fertilizers, which can also include organic matter, to maintain the organic matter content. So farmers can plant high-yielding crop varieties, and they can combine this with the addition of mineral fertilizers, as well as compost and manure.

Additionally, farmers can grow plants such as legumes, which actually take nitrogen from the atmosphere and add it to the soil. And that then becomes plant-available nitrogen. Farmers can gain greater yields through using crops that are more adapted to their environment, as well as more efficiently using their water and fertilizer resources.

Soils are renewable, but it takes many, many, many thousands, if not millennia, for soils to develop. And this occurs through the alteration of soil minerals, which develop into soils through the interaction of climate, as well as microorganisms and plants over long periods of time. In order to manage soils, we must use new techniques as well as old knowledge in order to prevent the degradation of soil.

So after a fire, the soil surface can repel water. This can lead to surface runoff, which can then cause the increased occurrence of mudslides, as well as flash-flooding events. Humans have responded to this by decreasing the disaster that can be caused by these mudslides. For instance, you can build channels or ditches for which to channel the mudslide and prevent the destruction of homes and houses.

The way we manage soils affects soil function. We need healthy soils for optimal function. This may include maintaining aeration, water drainage, organic matter, diverse microbial communities, and nutrient cycling.

Nutrients that we apply to soil as fertilizer, such as nitrogen, can be taken up by plants, and ultimately become part of our own bodies as we eat these plants. However, we still have to remember to manage the resources properly, because this nitrogen can also end up in lakes and streams and the air.

Thank you for learning about the importance of soil. Because soil is a vital resource upon which life depends, the ability for soil to perform its critical functions is an absolute necessity. This includes supporting plants from which we derive our food, feed, fiber, and fuel, to providing strong foundations for our homes, to improving water and air quality.

Since soil sustains us, we must continue learning about how to maintain or improve soil health without degradation or pollution. Strategies might involve improving the use of fertilizers and other inputs, maintaining soil organic matter, and selecting soils with the best properties for its intended use.