ESA21 Environmental Science Activities for the 21st Century

Soil Composition

Introduction

Soil, dirt, sediment, what's the difference? Depending upon whom you ask, you might get a radically different answer. Some sources state that the only difference between them has to do with their location: soil is the unconsolidated material on the ground, dirt is that same matter on your hands or clothes, and sediment is the same material on the bottom of a river or lake. Others define the differences based upon the size and shape of the material grains. For the purposes of this activity, we are going to define things the following ways. Soil is a complex, unconsolidated mixture of inorganic, organic, and living material that is found on the immediate surface of the earth that supports plant life. Dirt is any fine-grained, unconsolidated mixture that comes from the ground. Sediment is granular material that has been eroded by the forces of nature. Thus, soil can be considered dirt, and it can consist of sediments, but dirt and sediments are not necessarily soil.

It is this last part of the definition of soil that is so important to us. Without soil, there would be no plant life on the surface of the land. Without plant life, we would not exist. We need it for food. We need it for oxygen. We need it for clothing and shelter. We need it for energy. There is a vital interplay between soil and plants, which makes it vitally important that we understand the fragile nature of soils.

Fig. 1: Soil runoff near a fresh clearcut (*Pratte*)

Given this important role, it is amazing that we often treat soil like dirt. We strip away the overlying vegetation to plant crops or build houses, exposing it to erosional forces that wash and blow it away. We pour toxic herbicides and insecticides on it, removing or changing the important organisms that make the soil what it is. We irrigate it with water bearing minute traces of salt, slowly killing the soil as the salt concentrations build up to lethal quantities.

Soil Forming Factors

The complex nature of soil means that the type of soil that a region has depends on many factors. To see this, just look at the soils you find in different locations. Is the soil in the desert like that in a rainforest? Is the soil in Arctic regions like that near the equator? What about the soil on a mountain compared to that in a valley? These locations all have different soils because of a myriad of factors. There is a significant amount of interplay between these factors, though, that complicates the process of soil creation. To see this, let's look at what some of the more important factors are[1].

One of the most important factors is the type of rock from which the inorganic material in the soil originated. The **parent rock** provides the soil with a great deal of the chemical backbone for the soil. For instance, a soil that contains sediment from limestone will be high in calcium, and will also have a basic pH. This will be much different than one that derives from granite, which will have a higher sodium or aluminum content and a pH that tends more toward neutral or acidic.

The type of parent rock will also affect the soil in other ways. The grain size of the inorganic materials is also affected by the parent rock's hardness, fracture characteristics, and the crystalline structure of any minerals in the rock. Rocks containing mica will produce small, flat grains like that found in clay, while rocks with a lot of quartz might produce rounder grains like that found in sand.

Of course, the parent rock for the soil might not be a local rock, though. This is because of another important factor, **topography**. Areas that are steeper will be more susceptible to mass wasting and erosional forces. This will remove much of the smaller grains of inorganic material, leaving behind only the larger variety. The smaller grains will be moved to places where the land is not as steep, such as a valley or an alluvial plain. This means that the parent rock for a local soil can actually be hundreds or even thousands of miles away.

Topography does not work alone in this regard. The **climate** of the region will also greatly affect this sedimentation process in several ways. Before the parent rock can become part of the soil, it must be broken down either physically or chemically. Rain, especially exceptionally acidic rain, will leach elements out of a rock, which moves them into the local soil as well as weakening the chemical bonds within the rock, making it more likely to fracture. Water and wind flowing across the rock can also physically breakdown the rock, as can ice that expands in cracks and pore spaces. The rain and wind also operate as erosional forces to move the weathered sediments to new locations.

But climate does not only affect the soil by weathering and erosion. The types of organisms that live on and in the soil also depend on the climate. Cacti do not grow well in cold locations that get a lot of rain, and worms have a tough time eating their way through frozen tundra. These **biotic factors** are very important to the soil, which, after all, is a mixture of inorganic, organic, and living matter. The waste products and dead remains of these organisms provide the organic material for the soil. These organisms also hold the soil in place, covering and protecting it from erosional forces that would strip material away. They might also help further break down the inorganic material in the surroundings, either chemically (acids from the organisms, such as pine sap) or physically (roots from a tree fracturing rock).

All of these factors depend on a even greater one: **time**. A soil does not just spring up overnight. Nor does it remain a constant. It takes time for all of these factors to play out and bring a soil to maturity. Imagine a region of freshly exposed rock. Depending upon the type of rock, it can take anywhere from a couple of years to thousands of years before any reasonable concentration of sediments begins to pile up. The organisms that can live on this small amount of fresh sediment might do well initially, but as a soil begins to take shape, it might become more advantageous for other forms of life to inhabit it. As the weathering and erosion proceed, the topography of the area will change, which might even change the climate as weather patterns might shift.

Soils are constantly changing. However, before mankind became ubiquitous, this change was often gradual and slow. Today, **human activity** has become one of the greatest factors affecting a soil. As stated before, we move large sections of sediments, we irrigate soils that never had water, and we change the organisms that live on and in the soil. We make molehills out of mountains, and vice versa.

Soil Horizons

If you were to begin digging into a mature soil, you would notice that the color, texture, and other properties of the soil changed as you went deeper. If you were to dig deep enough, you would see that the soil appeared to be in very distinct layers. These layers, known as soil horizons, occur because of the different chemical and biological processes that take place in these zones.

Depending upon the type of soil, there can be up to 5 different horizons. These are denoted by the letters O, A, B, C, and E. Not all soils will have these horizons, with some immature soils having none. Most soils have at least three of these (A, B, and C).

If it is present, the top horizon will by the O layer, which is comprised of organic matter (Figure 2). This layer is normally found in forest soils, where dead leaves and other detritus can build up on a yearly basis. Below the O layer will be the A horizon, which is where the organic material is mixed in with the inorganic material. This layer is usually darker in color, and if present, means that the soil will generally be fertile for plant life. In a forest environment, there will sometimes by an E horizon below the A that is a result of water becoming acidic as it passes through the O and A horizons and then leaching minerals out of the soil. Below this horizon if it is present, or below the A if it is not, is the B layer, which is where the minerals and clay grains accumulate. In some regions, this layer can be very thick and tightly pored, resulting in hardpan that can very effectively impede the flow of water through it. Below the B horizon is the C, which contains the parent inorganic material for the soil. It is little affected from the original soil before it matured.

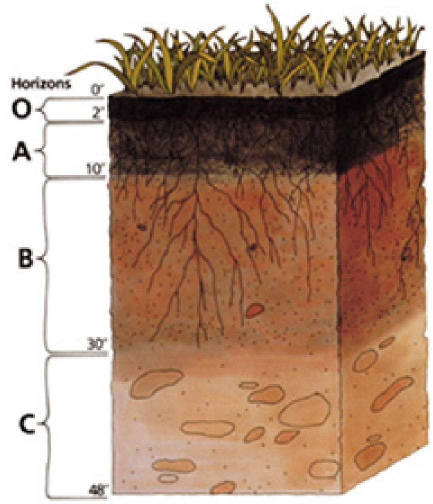

Fig. 2: Sample soil profile (*USDA*)[2]

Types of Soil

In 1975, the U.S. Department of Agriculture created a taxonomic scheme that grouped all soils into one of 12 major groups known as orders. Underneath these orders are smaller groups and sub-groups. In all, there are over 100 different types of soil that have been classified by scientists. We do not have the time or space to list them all here. For our purposes, we will stick to the 12 orders of soil[3].

Alfisols are a well-developed, highly fertile soil that forms in forests. These soils have undergone some leaching (water stripping some chemicals from the soil as it percolates through it), leaving them with a subsurface layer of clay. This clay allows these soils to remain moist, which helps to keep them fertile. They are usually found in temperate zones, which makes them ideal for farming. In the U.S., a wide swath of land from south Texas up through Michigan is composed primarily of this soil type.

Andisols are formed from the ash and ejecta from volcanoes. These soils are very high in glass grains and materials with pores. This latter property means that these soils have a high ability to hold water. In the U.S., these soils are found mostly in the Hawaiian Islands and the Northwest near the active and recently active Cascade Mountains.

Aridisols, as the name implies, are soils that form in regions that are dry for long periods of the year. These soils have a high calcium carbonate concentration, with layers of clay, silica, salt, and gypsum in the subsurface regions. They make up about 8% of the land in the U.S., existing mostly in the desert Southwest.

Entisols are characterized by being fairly new soils, which means that they have not had much time to develop any horizons or substrata. They are usually found on rocky hillsides, but they can also be found on river deltas and shorelines. Essentially, all soils that do not fit into one of the other 11 orders is classified as an entisol. In the U.S., the greatest concentration of these soils is found in the Rocky Mountain and High Plains regions.

Gelisols form in locations that have permafrost within 2 meters of the surface. This means that they are limited to regions near the Poles, or in high, mountainous zones. Because organic matter does not decompose at a fast rate in such areas, gelisols contain a lot of carbon material. In the U.S., these soils are found mostly in Alaska.

Histosols are soils that contain at least 20-30% organic material and are more than 40 centimeters thick. They are found in locations where the presence of water prevents organic matter from decomposing quickly. This means that histosols are commonly found in low-lying swampy regions. The Gulf Coast and Great Lakes regions contain most of the histosol soils in the U.S.

Inceptisols are slightly more mature versions of entisols. They have begun to develop soil horizons, but have none of the features found in the 10 other orders. As with entisols, they are found mostly in mountainous or hilly regions, such as in the Rocky and Appalachian Mountains.

Mollisols are found in grassland areas and have a relatively rich, dark-colored surface zone as a result of the organic matter from the being added from the grass. The fertile nature of these soils makes them excellent media for growing grain crops. The Great Plains region of the U.S., the Breadbasket to the World, is an example of this type of soil.

Oxisols are the heavily oxidized soils found in tropical and subtropical rainforest. These soils have undergone heavy amounts of weathering and are very low in fertility outside of the very thin layer of organic material on the surface. Because water has leached most of the other minerals out of the soil, oxisols are very high in concentrations of aluminum and iron and are mined extensively in countries where rainforest are being chopped down. In the U.S., oxisols are limited to regions of Hawaii.

Spodosols are highly acidic soils that form in coniferous forests. Water leaching through these soils becomes acidic, which causes heavy weathering of the lower horizons in the soil. Much like the oxisols, this leads to high concentrations of aluminum and iron in the subsurface horizons. These soils have a very low fertility for any kind of crop other than trees that favor acidity like pines. The Northeastern U.S. and the Upper Peninsula region of Michigan are where these soils are found in the U.S.

Ultisols are very similar to spodosols in that they are highly leached, acidic soils in forest environments. They are characterized by a subsurface clay layer that is high in iron, and are found in temperate and subtropical zones that receive a fair amount of rain. The southeastern region is the primary location for these soils in the U.S.

Vertisols are clay-rich soils that experience swelling and shrinking depending upon the water content. These soils are an engineering nightmare, as the total volume of the soil changes depending water. They are limited in the U.S. to sections of Texas and the Delta region of Mississippi.

Additional Reading

The following link provides an excellent primer on soil. The site is maintained by the Department of Agriculture and also contains a links to additional resources.

USDA	**Topic**: Soil Education **Summary**: Contains information about soil and soil resources. **Link**:http://soils.usda.gov/education/

References

1 http://www.soils.umn.edu/academics/classes/soil2125/doc/slab2sff.htm, September 25, 2005
2 http://soils.usda.gov/education/resources/k_12/lessons/profile/, September 25, 2004.
3 http://soils.ag.uidaho.edu/soilorders/orders.htm, September 25, 2004.

Activity

In this week's activity, we are going to see how some of these factors can affect the soil in our own region. We will be taking soil samples from four different locations to see if there are any noticeable differences between them. Since we are localizing our study, it would be extremely difficult to get soil samples that would vary significantly in climate, time, or parent rock. Any soil that we take from our area should have very nearly the same of these. Therefore, what we will be testing is how topography, biotic factors, and mankind affect the soil.

Part One

You will need to collect three soil samples for this activity. Each soil sample that you collect should fit in a quart-sized jar. These samples should be taken from the following characteristic locations:

Sample One - The Hill Sample - take from the side of a hill, the greater the degree of slope, the better.
Sample Two - The Yard Sample - take from a level surface, such as your backyard.
Sample Three - The River Sample - take from the side of a creek or river.

For all of these locations, you need to note the amount of slope and the type of vegetation that is found there.

These samples need to come from locations that are not near one another. A distance of a quarter mile or more between them would be best, as distances closer than this might lead to samples that do not vary that greatly. Of course, this requirement means that you will not be able to get all of the soil samples from property that you own. This means that you will need to show some prudence in picking locations from which to draw your samples. You might want to work with some of your classmates to insure that you can get all three types of locations. Whatever you do, do not trespass on private property to get the soil samples. You should also not get the samples from any national or state parks or forests, as it is illegal to remove things from these locations.

Part Two

Now that you have your soil samples, you are ready to determine the type of soil that you have from its texture. The website

http://uwarboretum.org/eps/research_act_classroom/rain_garden/2%20Perform%20Site%20Analysis/Identifying%20Soil%20for%20RG%202-3.pdf

has a flowchart that should help you in determining what type of soil that you have. Use this information to fill in the table on the worksheet. Once you have filled in the table, answer the questions underneath it.

Part Three

Now that we have categorized the soils based upon texture, let us analyze them based upon the types of particles found in the soil. To help us in this, we will use the procedure spelled out on the following website:

http://weather.nmsu.edu/Teaching_Material/soil456/soiltexture/soiltext.htm

Once you have completed the instructions there, fill in the table on the assignment sheet, and answer the remaining questions.

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Activity Sheet
Soil Composition

Name:

Soil Type: Signify the soil type of each sample using the website key

Location	Slope	Local Vegetation	Sample Color	Type
Hill				
Yard				
River				

1. Which sample contains the most organic matter? Is this what you expected?

2. Which sample contains the most large particles? Is this what you expected?

3. Are there any color variations in the samples? Is this what you expected?

	Hill Sample	Yard Sample	River Sample
Total depth of soil			
Depth of clay			
Depth of silt			
Depth of sand			
% sand (depth of sand/depth of soil)			
% silt (depth of silt/depth of soil)			
% clay (100% - (% sand + % silt)			
Identify the soil type of each sample (clay, silt, sand or loam)			

4. Did the results of this analysis match the previous analysis?