Comparison of Soil in the Agroforestry Region and the Forest at Finca Las Piedras

Tisya Goel

Corresponding emails: tisyagoel@gmail.com & info@sustainableamazon.org

Abstract

Knowing the quality of soil is essential for plant growth and therefore human nutrition. The Alliance for a Sustainable Amazon is a non-profit organisation whose focus is reforestation. Understanding the soil is important for reforestation efforts. This brought up the need to test three major components of soil health — soil texture, soil structure and pH. The focus will be of two areas in the property: an agroforestry region where growth of plants is slow, and an area in the forest close to the camp. A visual assessment and the Jar test were conducted to look at soil texture, the slake test was used to look at soil structure, and baking soda and vinegar were used to get an approximation of the pH of the soil. The texture of the soil in the agro region was a slightly acidic sandy loam type of soil, with good structure. The soil in the forest had poorer structure, and was a neutral sandy clay loam type of soil. We can use this information as a baseline to look into what these types of soils generally need and how to maintain them. It can also be helpful in conducting further tests for more information on the soil, like an analysis on the minerals present in the soil.

Introduction

Soil is a mixture of organic matter, minerals, liquid, and organisms that together support life. It is present in all areas of science, and especially essential for conservation efforts. Soil science helps us act more efficiently. It helps understand optimal growth for things like agriculture, forests, wetland management, urban land use, and waste disposal (soils4teachers.org). The Amazon rainforest is one of the most diverse ecosystems on the planet, for both plants and animals. It also has areas of endemism, which means there are distributions of plant taxon that are only found in one specific geographic area. This may be attributed to a variety of distribution of soils, climate, geographical disturbances and periodic disturbances (Leal de Souza et al).

Soil in the tropical rainforest is usually old and very impoverished of nutrients. Most of the carbon and essential nutrients that are needed for survival are locked up in dead and decaying matter. As this organic matter decays, it's recycled so quickly and efficiently that very little, if anything ever reaches the soil at all. This rapid processing of all of the resources in the rainforest is called nutrient cycling, and it is how tropical rainforests remain so lush and vegetative despite the soil quality (worldrainforest.com). Microbial processes are especially important in such environments, because most of the nutrient stock is aboveground, and they do this by interacting with soil and plants (Flores et al., 2020; Moore et al., 2004; Milton and Kaspari 2007; Camenzind et al., 2018). Unfortunately, we know very little about plant soil interactions in tropical rainforests, and even less about soil microbial activity (Ritter et al., 2019; Flores et al., 2020). Mercury absorption in tropical soils is mainly affected by soil properties such as pH and clay content. Oxide levels are especially important for how mercury is held in the soil (Lima et al., 2022).

Topsoil is the uppermost layer of soil, typically found in the top 2 to 8 inches. It is the most fertile soil layer, rich in organic matter and nutrients necessary for plant growth. Topsoil is crucial for supporting plant life as it contains the highest concentration of essential nutrients and microorganisms that enhance soil fertility. Healthy topsoil is characterised by a crumbly texture, good drainage, and a balanced nutrient profile (jacksontwpfranklinoh.gov). The project will focus on this layer of soil. There are several physical and chemical characteristics that influence topsoil - salts and minerals, organic matter, coarse fragments (structure of the soil), pH, and texture (extension.usu.edu). Of these, looking at the structure, texture and pH are the most basic components, and simplest to look at and measure.

Soil texture refers to the ratios of sand, silt and clay in the soil. Mineral matter is the inorganic component of soil, and comes from weathered rock. Soils have varying sizes of mineral particles: sand, silt, and clay. Sand particles are the largest, therefore improve aeration and drainage but are low in nutrients, making them less fertile and gritty to the touch. Silt is medium-sized, retains water well and feels smooth. Clay is the smallest, and is good at holding both nutrients and water but their small size leads to poor aeration and drainage, forming hard clumps when dry and sticky masses when wet. Soil texture is crucial because it influences key soil properties, like water-holding capacity, permeability, and workability. The texture of the soil therefore also directly influences the structure of the soil (senecahs.org).

Soil structure refers to the arrangement of soil particles into aggregates or clusters. The size and connection of soil pores around aggregates are key for the movement of air, water, and nutrients. Soil structure impacts how well water is held and moves, how roots grow, carbon storage, erosion risk, and fertility (Brevik, & Burgess, 2014). Well-structured soil promotes efficient water infiltration and root growth, allowing plants to access water and nutrients more effectively. Good drainage means the soil is properly aerated, and prevents water from pooling or puddling on the surface, which could lead to root rot and other plant health issues. Well-structured soil is less prone to erosion, so the soil remains fertile and prevents the loss of valuable topsoil.

Soil pH influences how well plants can access essential nutrients and affects the activity of soil microorganisms. A pH level that is too high or too low can limit nutrient availability and impact plant health (Zhang et al., 2016; Dewangan et al., 2023). For example, acidic soils (low pH) can inhibit the uptake of calcium and magnesium, because they decrease the amount of exchangeable calcium and magnesium in the soil. Alkaline soils (high pH) can limit the availability of iron and phosphorus due to the elevated bicarbonate levels (Dewangan et al., 2023).

I will be conducting three different tests on the topsoil of the forest, and comparing it to the topsoil in the agroforestry region of the property. These tests will be looking at the soil texture, structure and pH. The tests will be ones that can be replicated at home easily, allowing anyone to be able to gather base information on the quality of their soil.

The Alliance for a Sustainable Amazon (ASA) is a non-profit organisation that aims to protect the Amazon rainforest. Their area of operation is in Madre De Dios, which is in the southeastern part of Peru. Finca Las Piedras is the research and education centre of ASA. At ASA, understanding the quality of soil is important for their reforestation efforts. There are different agroforestry and reforestation plots scattered in the property with varying amounts of success. One focus of this project is the agroforestry region, where guava trees were grown to increase the nitrogen level in the surrounding soil. Despite that, the growth rate of banana trees in the area was quite slow. The aim of this project is to find out how the quality of the soil affects the growth of plants in this agroforestry plot compared to the forest.

Methods

Three samples of soil were taken for each area, picked randomly. The agroforestry region has an abundance of guava and citrus trees, while also having a few banana trees. The forest has a varying diversity of soil. An area close to camp was picked, and three random points in the area were generated on QGIS.

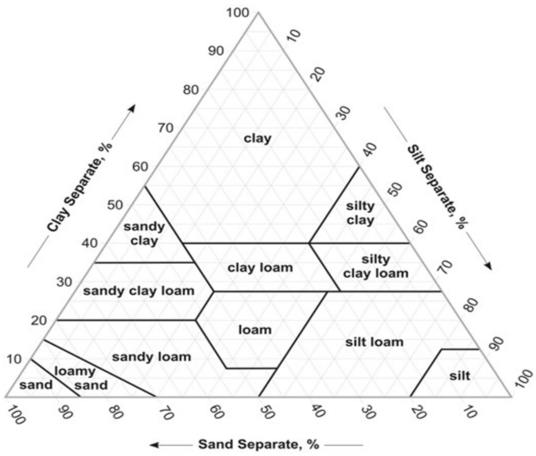
Soil Texture

a. The Jar Test: Dig a hole down a few inches and collect the soil. Clean of twigs, leaves and other debris. Fill a container to around one-third to one-half of its capacity. Add water to the container until it is filled to the shoulder. Shake the container vigorously for 3-5 minutes to suspend the soil particles in the water. After shaking, let the mixture sit undisturbed for 24 hours. The soil will settle into distinct layers. Observe and record the thickness of each layer (sand, silt, and clay) to estimate the soil texture. Calculate the percentage of sand, silt and clay in the soil sample. Compare your results to the USDA Soil Texture Triangle Key (Figure 1).

Once the percentages of each are obtained, a diagonal line can be drawn at each percentage point. The area in which the three points meet is the type of soil.

b. Visual Assessments: Take a small handful of topsoil in your palm. Add water and try to make a bolus. Then take your thumb and index finger and try to make a ribbon about 2 mm in thickness. Measure the length of the ribbon. Keep a small portion of the soil in your palm, and add excess water to it. Rub it against your palm and feel the texture. Take note of if the soil feels gritty, smooth or both. Compare observations in the USDA Texture by Feel Key (Figure 2).

Figure 1: USDA Soil Texture Triangle Key.

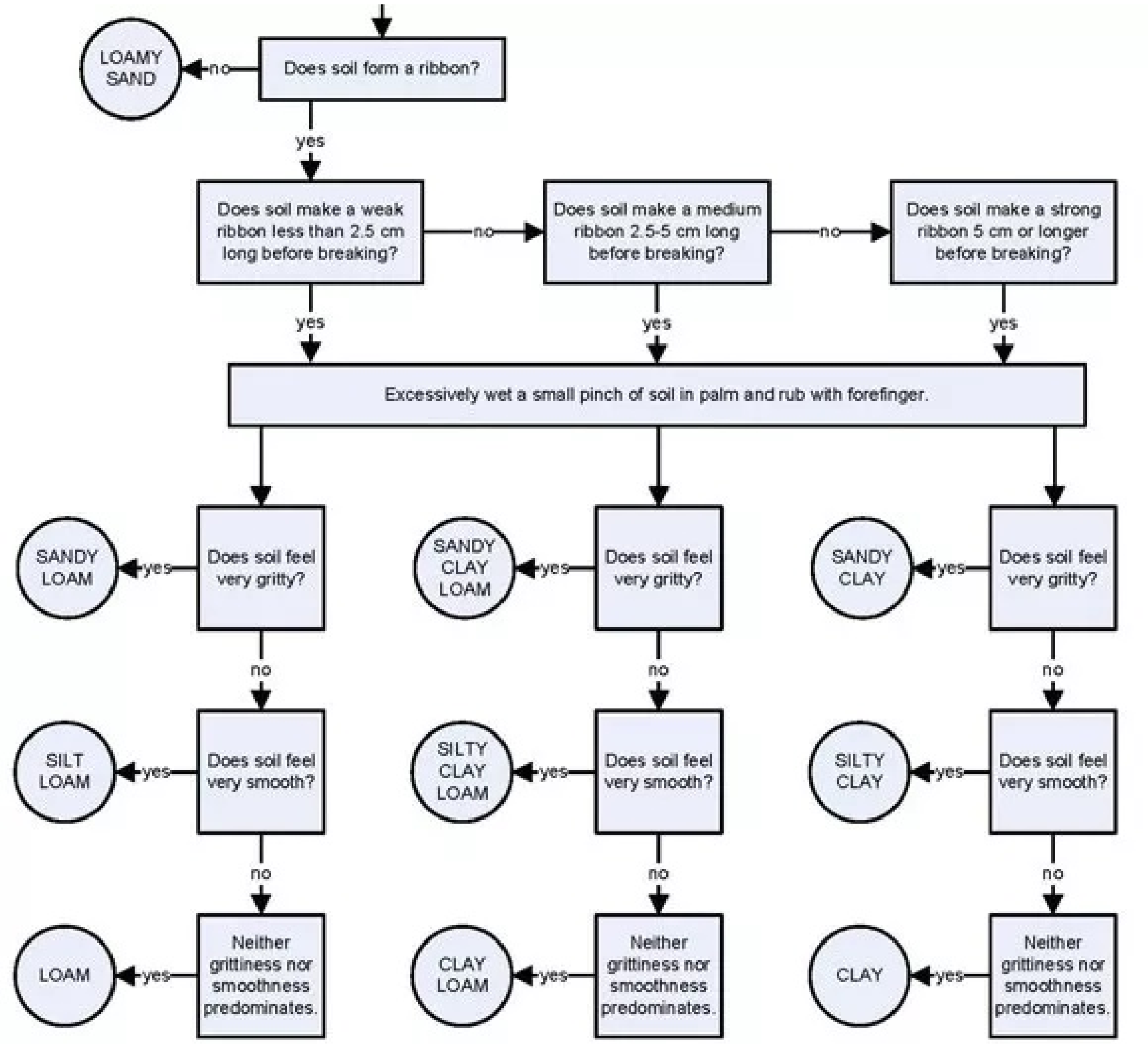


pH Testing

Collect the soil and remove clumps and debris. Add distilled water to the soil to create a mud-like consistency. Add ½ cup of vinegar to the soil mixture. Observe for any fizzing, foaming, or bubbling. If any reaction occurs, the soil is alkaline. Add ½ cup of baking soda to the soil mixture. Observe for any fizzing, foaming, or bubbling. If any reaction occurs, the soil is acidic.

I used ethanol to test acidity with baking soda, and distilled water to test alkalinity with vinegar. I wanted to use as little distilled water as possible, so I used ethanol as a substitute — Ethanol has a 7.3 pH.

Figure 2: USDA Soil Texture by Feel Key.



Although it reacts with vinegar to make an ester, it doesn't react with baking soda at all. So I conducted my baking soda tests with ethanol, and vinegar tests with distilled water.

Soil Slake Test

Prepare a jar with a wire mesh that fits over the top. Fill the jar with water so that the soil will be submerged when placed inside. Add the soil to the jar and start a stopwatch. Record the time it takes for the soil aggregates to break down. This provides an indication of the soil's structure and aggregate stability.

Results

The soil in the agro region is a sandy loam that is slightly acidic. It also has good structure, as determined by the slake test. The soil in the forest is a sandy clay loam that is neutral. While it has relatively good structure, it is not as good as the soil in the agro region.

Soil Texture

a. The Jar Test was conducted first. A clump of soil was added to a glass bottle, and then water (Table 1). An average of all three samples for each location was taken (Figure 3).

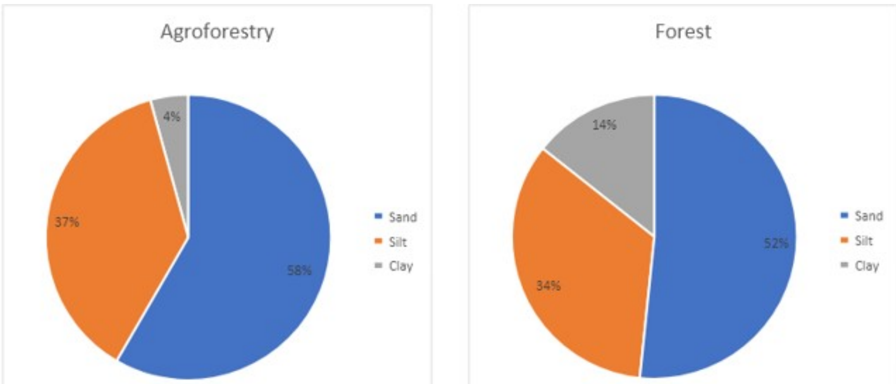
Table 1: Measuring the length of sediment deposition of sand, silt, and clay in all three samples of the Finca and of the Forest. The measurements in centimetres have been converted to percentages. An average of all three samples for each location was taken.

	Finca (cm)			Forest (cm)		
	S1	S2	S3	S1	S2	S3
Sand	4 (61%)	2 (55%)	3 (59%)	4 (49%)	3.8 (49%)	4 (57%)
Silt	2 (31%)	1.5 (42%)	2 (39%)	3 (36%)	3 (38%)	2 (28%)
Clay	0.5 (8%)	0.1 (3%)	0.1 (2%)	1.2 (15%)	1 (13%)	1 (15%)

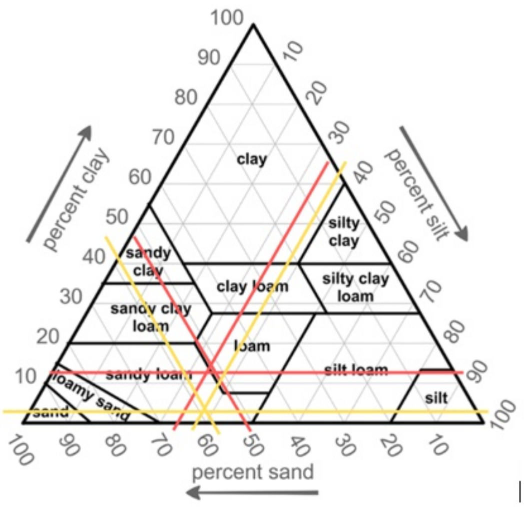
Figure 3: Average of sediment deposition in the two sites

Agroforestry Average:
Sand - 58.3
Silt - 37.3
Clay - 4.3

Forest Average:
Sand - 51.6
Silt - 34
Clay - 14.33



According to the soil texture triangle:



Finca: sandy loam
Forest: Loam

b. Estimating soil texture by hand. According to USDA Key:
Finca: Soil kind of crumbles as I try to form a ribbon, so it is a sandy loam.
Forest: Soil made a ribbon as long as 3 - 3.5cm before breaking, and feels very gritty, so it is a sandy clay loam.

The Slake Test

A clump of soil was added to the mesh in the jar filled with water, and observed for 10 minutes.
Agroforestry: A large clump of the soil remains intact even after 10 minutes. Some particles of soil float to the bottom immediately after dumping the soil in the water. This was true for all three samples.
Forest: The soil remained largely intact after 10 minutes, but not completely. The water was very slightly dusty with soil, and not completely clear like in the soil sample from the agroforestry region.

pH Test

Finca soil fizzed a little with the baking soda, therefore it must be slightly acidic. There were very tiny bubbles appearing in the mixture. It did not react at all with the vinegar. The forest soil didn't fizz with either baking soda or vinegar. There was no reaction.

Discussion

The tests determined the soil in the forest to be a sandy clay loam and the soil in the agroforestry region to be a sandy loam. This alone can help with future tests that need to be conducted on the soil, since knowing the soil type can help understand what more should be known, and how to improve the quality.

The soil texture triangle after the jar test showed the soil in the forest to be a loam, not a sandy clay loam. However, clay has a lower density than water, therefore it is colloidal—meaning it likes to stay in suspension. Therefore the clay layer can take a long time to fully sink. Generally, we would add Calgon or Borax to help settle the clay. However, due to constraints in time and resources, my water was not clear at the end of the experiment, and clay remained floating in suspension. Therefore, the true percentage of clay in all samples of soil is higher. Due to this, the test to estimate soil texture was also conducted. According to the texture by feel test, the soil in the forest is a sandy clay loam, which is approximately 20-35% clay, less than 28% silt, and 45% or more sand. Since the jar test also clearly shows a higher percentage of clay in the forest soil, the forest is categorised as a sandy clay loam and the agroforestry is categorised as a sandy loam according to the tests.

The slake test showed that the soil has good drainage in the agroforestry region. Soil that remains intact has good structure and higher organic matter than one which disintegrates. The soil samples from the forest remained largely intact. This shows us that the soil in the forest has good structure, although it is worse than the soil in the agroforestry region in the property. The higher clay content of the soil in the forest would explain the poorer performance in the slake test. The higher quantity of clay makes the soil harder and less aerated. This means that the poorer quality of soil in the forest could also lead to production of more runoff than the agroforestry region, or even any other climate region.

Since the soil from the agroforestry region fizzed a little with the baking soda, it means the soil is at least slightly acidic. This is good for guava, citrus and banana trees, who need slightly acidic soil to grow. This means, the pH is not the reason for the slow growth of banana trees in the area, since they need a similar pH to citrus and guava trees, and those are growing well in the area. The reason behind the slow growth of some plants like the banana plants could be the minerals present in the soil. Further research could look at the microbes and minerals like nitrogen and phosphorus present in the soil. The soil from the forest did not react with either baking soda or with vinegar, which suggests that the pH of the soil is in the neutral range. This is strange because the orangish yellowish colour to the soil is characteristic to acidic soil, and characteristic of containing high amounts of toxins.

The results have shown that the soil in the forest is neutral and has relatively good structure. However, soil in the tropical rainforests like the Amazon are known for having very poor quality soil. Generally, the structure of the soil in these places is slightly acidic soil and high amounts of runoff. One reason for this could be variability. The Amazon rainforest is extremely diverse, both in plants and animals. A part of the reason for this is the variability in soil as well. The existence of endemisms there is a direct consequence of that.

Works Cited

Lima, F. R. D., Pereira, P., Silva, E. C., Junior, Vasques, I. C. F., Oliveira, J. R., Windmöller, C. C., Inda, A. V., Weindorf, D. C., Curi, N., Ribeiro, B. T., Guilherme, L. R. G., & Marques, J. J. (2022). Geochemistry signatures of mercury in soils of the Amazon rainforest biome. Environmental Research, 215, 114147. https://doi.org/10.1016/j.envres.2022.114147

Flores, B.M., Oliveira, R.S., Rowland, L. et al. Editorial special issue: plant-soil interactions in the Amazon rainforest. Plant Soil 450, 1–9 (2020). https://doi.org/10.1007/s11104-020-04544-x

De Souza, J. J. L. L., Fontes, M. P. F., Gilkes, R., Da Costa, L. M., & De Oliveira, T. S. (2018). Geochemical Signature of Amazon Tropical Rainforest Soils. Revista Brasileira de Ciência Do Solo, 42(0). https://doi.org/10.1590/18069657rbcs20170192

Importance of Topsoil, https://jacksontwpfranklinoh.gov/wp-content/uploads/2013/04/Importance_of_Topsoil1.pdf. Accessed 22 August 2024.

Butler, Rhett A. Soils and Nutrient Cycling, 31 July 2012, https://worldrainforests.com/0502.htm. Accessed 22 August 2024.

Dewangan, Shailesh Kumar & Shrivastava, S & Kumari, Lilawati & Minj, Prashant & Kumari, Jayanti & Sahu, Reena. (2023). "THE EFFECTS OF SOIL PH ON SOIL HEALTH AND ENVIRONMENTAL SUSTAINABILITY: A REVIEW.". 10. 611-616.

Koenig, Rich, and Von Isaman. "Topsoil Quality Guidelines for Landscaping | USU." USU Extension, Utah State University, December 2010, https://extension.usu.edu/yardandgarden/research/topsoil-quality-guidelines-for-landscaping. Accessed 22 August 2024.

"Soil Basics." Soils 4 Teachers, https://www.soils4teachers.org/soil-basics. Accessed 22 August 2024.

"Understanding Soil Texture and Structure." Seneca High School, 22 January 2007, https://www.senecahs.org/pages/uploaded_files/Soil%20Texture%20and%20Structure%20E%20Unit.pdf. Accessed 22 August 2024.