Hilo

Hawaii State Soil

Soil Science Society of America

Introduction

Many states have a designated state bird, flower, fish, tree, rock, etc. And, many states also have a state soil – one that has significance or is important to the state. The **Hilo series** is the official state soil of **Hawaii**. Let's explore how the **Hilo series** is important to **Hawaii**.

History

The Hilo series was established in 1949 and was first mapped in Soil Survey of the Territory of Hawaii published in 1955. The Hilo series occurs on the Island of Hawaii, to the north of the town of Hilo. The Hilo soils are derived from volcanic *ash* and occur on the wet, rainy side of Mauna Kea volcano.

What is Hilo Soil?

Hilo soils are deep, well drained soils that formed in material weathered from volcanic ash deposits underlain by *lava flows*. These highly weathered acidic soils are known for their bright red color indicative of the iron and aluminum oxides that form in this warm and humid environment. Hilo soils formed on the low elevation slopes of Mauna Kea volcano, the second oldest volcano on the Island of Hawaii. The landscape was originally formed by lava flows 100- to 300-thousand years ago when Mauna Kea was actively erupting. In later stages of volcanic activity, *cinder cones* formed on the slopes of Mauna Kea, depositing layers of volcanic ash. Today's landscape consists of coastal cliffs and rolling hills that have been dissected by steep drainages that often feature breathtaking waterfalls.

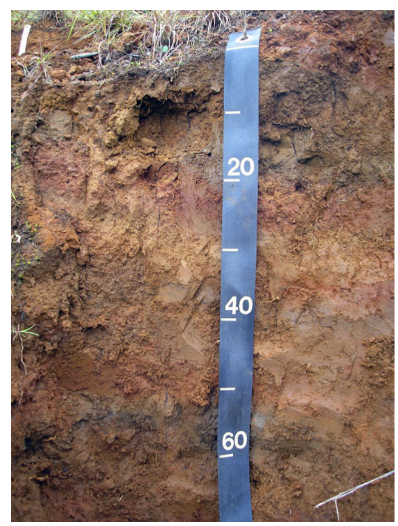

Fig. 1. Hilo soil profile. Credit: Amy Koch

Every soil can be separated into three separate size fractions called *sand*, *silt*, and *clay*, which makes up the *soil texture*. They are present in all soils in different proportions and say a lot about the character of the soil. Hilo soils have silty clay loam texture throughout the profile. The texture feels very smooth when the soil is moist due to the silt content. These soils have distinct horizons that reflect their history, including layers from different ash events and buried *topsoil* layers. In Hilo soil, the topsoil or A horizon (the layer of soil that we plow or plant seeds in) is dark brown and is typically 10 to 20 inches thick. The *subsoil* or B horizon (the layers below the topsoil) are dark reddish brown in color but can also be dark grayish brown. These soils are generally more than six feet deep to *basalt bedrock*. They are fertile soils rich in *organic matter* and nutrients and are considered prime agricultural land. (**Figure 1**)

Photo Soil Monolith: Chip Clark/Smithsonian Institution

Fig. 2 Hilo soil series is the official state soil of Hawaii. Credit: Smithsonian Institution.

Where to dig Hilo

Yes, you can dig a soil. It is called a soil pit and it shows you the *soil profile*. The different horizontal layers of the soil are called *soil horizons*. This does not mean that other types of soil cannot be found there but that the **Hilo** is the most common. Hilo soils occur on the eastern side of the Island of Hawaii along the Hamakua Coast, just north of the town of Hilo. Vegetation is green and lush due to the tropical trade winds that produce over 145 inches of rainfall per year. The Hilo soils are found at elevations from sea level to 2,500 feet where moist, humid conditions provide an active weathering environment. Small pockets of Hilo soil are also found in *kipukas* on Mauna Loa volcano. Kipukas are areas of older soils surrounded by younger lava flows. **Hilo** covers **29,874** acres of land in **Hawaii** County of **the state of Hawaii**. In all, there are a total of **248** named soils (series) in **Hawaii**. (**Figure 2**)

Importance

What makes the **Hilo** soil so important is its use and prevalence in the State. More than half of the Island of Hawaii is covered in young, barren lava flows that have no soil and no vegetation. Much of the remainder of the island consists of shallow (less than 20 inches) organic soils that have formed over young lava flows. By contrast, the Hilo soils are deep and fertile, making them conducive for growing crops, trees, and grazing cattle. These soils are highly utilized for agricultural as well as residential use.

Hilo soils are also very special due to their unique volcanic properties. They have low bulk density and high water holding capacity. These soils are almost always moist and are able to hold more than one hundred percent of their weight in water due to their volcanic mineralogy. When these soils are dried, they dehydrate irreversibly into hard sand-like particles.

Uses

In general, soils can be used for agriculture (growing foods, raising animals, stables); engineering (roads, buildings, tunnels); ecology (wildlife habitat, wetlands), recreation (ball fields, playground, camp areas) and more. Once covered in native forest, Hilo soils were likely used by the native Hawaiians for growing food as part of their *ahupua`a* system. In the late 1800s, these soils were used extensively for sugarcane crops, as evidenced by the small villages and surrounding communities that still exist along the coast today. Since the demise of the sugar industry in the 1990s, land use and ownership have diversified, creating many small farms and ranches. Hilo soils support the cultivation of root crops, such as ginger, taro, and sweet potato; orchard crops like macadamia nuts, avocados, coffee, bananas, and lychee; and a variety of other tropical fruits and vegetables. These soils are used for agroforestry, timber plantations, and grazing livestock, including cattle, goats, and sheep. Hilo soils also support roads, houses, and bridges. (**Figure 3**)

Fig. 3 Aerial view of the Hilo series showing a diversity of land uses, including orchards and cultivated crops. Credit: Amy Koch

Fig. 4 Extreme erosion occurred in a recently plowed field that was left uncovered.Credit: Amy Koch

Fig. 5 Cover crops can be beneficial when used to cover fallow areas or as part of a farmer's crop rotation. They can enhance the soil and decrease erosion. This photo shows a cover crop mix of multiple species. Credit: Amy Koch

Limitations

When a soil cannot be used for one or more of the described functions, it is referred to as a limitation. Soil experts, called *Soil Scientists*, studied **Hilo** soil and identified that it has **moderate** limitation for erosion. When left unvegetated or bare, these soils are very susceptible to erosion and loss of organic matter. Due to frequent trade wind-induced rainfall events, periods of heavy rainfall can occur at any time of the year. Hilo soils with steeper slopes have a higher the risk for erosion. When soil erodes from the landscape, it washes into local streams and rivers, which deposit into the ocean, causing poor water quality. (**Figure 4**)

Management

Hilo soils are well suited for agriculture production and other types of land use when the risk for erosion, its main limitation for use, is controlled. Conservation practices like grassed waterways or the use of cover crops can help keep the soil covered at all times, thus keeping it in place on the landscape and preventing erosion into waterways and the ocean.

Hilo soils are high in organic matter and have medium natural fertility but are more productive with added fertilizer. Hilo soils have a very high capacity to fix phosphorous due to their volcanic mineralogy. This makes phosphorus unavailable for plant uptake, so proper fertilization is required. The high organic matter in these soils helps them to hold onto other nutrients in the topsoil. If soils can be sweet or sour, Hilo soil is strongly sour, or, as Soil Scientists like to put it, they are extremely to strongly acidic. Rainfall is abundant and well dispersed throughout the year, so irrigation is seldom required for growing crops. (**Figure 5**)

Hilo Formation

Before there was soil there were rocks and in between, ClORPT. Without ClORPT, there will be no soil. So, what is ClORPT? It is the five major factors that are responsible for forming a soil like the Hilo series. It stands for **Cl**imate, **O**rganisms, **R**elief, **P**arent material and **T**ime. ClORPT is responsible for the development of soil profiles and chemical properties that differentiate soils. So, the characteristics of **Hilo** (and all other soils) are determined by the influence of ClORPT. Weathering takes place when environmental processes such as rainfall, freezing and thawing act on rocks causing them to dissolve or fracture and break into pieces. ClORPT then acts on rock pieces, marine sediments and vegetative materials to form soils.

Climate–Temperature and precipitation influence the rate at which parent materials weather and dead plants and animals decompose. They affect the chemical, physical and biological relationships in the soil. Hilo soils formed in a tropical and humid environment with year-round warm temperatures and abundant rainfall. These conditions accelerate weathering of volcanic ash soils.

Organisms–This refers to plants and animal life. In the soil, plant roots spread, animals burrow in, and bacteria break down plant and animal tissue. These and other soil organisms speed up the breakdown of large soil particles into smaller ones. Plants and animals also influence the formation and differentiation of soil horizons. Plants determine the kinds and amounts of *organic matter* that are added to a soil under normal conditions. Animals breakdown complex compounds into small ones and in so doing add organic matter to soil. Hilo soils developed under the cover of a native forest ecosystem with high turnover of organic debris due to a year-round growing season and warm conditions conducive to an active microbial community. This forested environment likely contributed to the high organic matter levels seen today in the Hilo soils.

Relief–Landform position or relief describes the shape of the land (hills and valleys), and the direction it faces which makes a difference in how much sunlight the soil gets and how much water it keeps. Deeper soils form at the bottom of

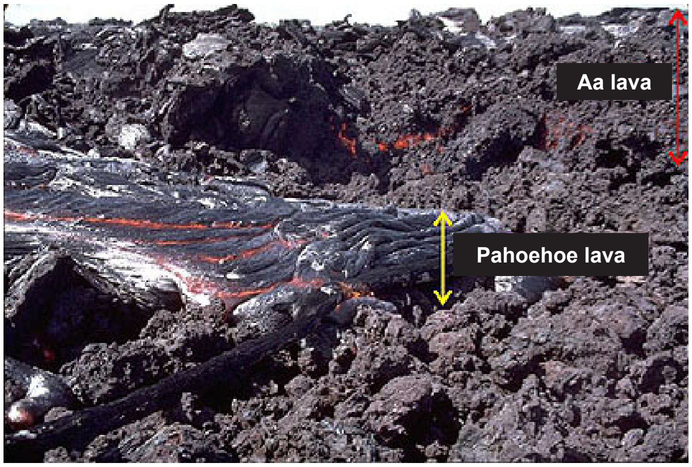

Fig. 6 Aa and Pahoehoe lava flows. Credit: Oregon State.

the hill rather than at the top because gravity and water move soil particles downhill. Hilo soils occur on the lower flank of the wet, rainy side of Mauna Kea volcano. The landscape was formed from a combination of *`a`a* and *pahoehoe* lava flows that are overlain by cinder cones and volcanic ash deposits. (**Figure 6**) Pahoehoe lava flows tend to be smooth and ropy while `a`a flows are blocky and hummocky. After Mauna Kea eruptions ceased, the trade wind-induced rains weathered the landscape, which is now characterized by steep and narrow drainages and rolling hills.

Parent material (C horizon) – Just like people inherit characteristics from their parents, every soil inherits some traits from the material from which it forms. Some parent materials are transported and deposited by glaciers, wind, water, or gravity. Hilo soils formed in-situ, or in-place, on the landscape on which volcanic ash was deposited by Mauna Kea cinder cone eruptions. These highly weathered soils are known for their bright red color indicative of the iron and aluminum oxides that form in this warm and humid environment. These soils have distinct horizons that reflect their history, including layers from different ash events and buried topsoil layers that were covered by later ashfall events.

Time – All the factors act together over a very long period of time to produce soils. As a result, soils vary in age. The length of time that soil material has been exposed to the soil-forming processes makes older soils different from younger soils. Generally, older soils have better defined horizons than younger soils. Less time is needed for a soil profile to develop in a humid and warm area with dense vegetative cover than in a cold dry area with sparse plant cover. More time is required for the formation of a well-defined soil profile in soils with fine textured material than in soils with coarse-textured soil material. The landscape that supports Hilo soils was originally formed on 100- to 300-thousand year old Mauna Kea lava flows. During later stages of volcanic activity, cinder cones deposited stratified layers of volcanic ash. These volcanic ash deposits have weathered over several thousand years to form Hilo soils.

Ecoregions, Soils and Land Use in Hawaii

The State of Hawaii consists of eight major islands that have relatively uniform *geology* due to their volcanic origin. Each island formed from molten rock that erupted from a *hot spot* deep beneath the ocean floor. The hot spot is a nearly stationary place at the bottom of the ocean where molten rock erupts from the

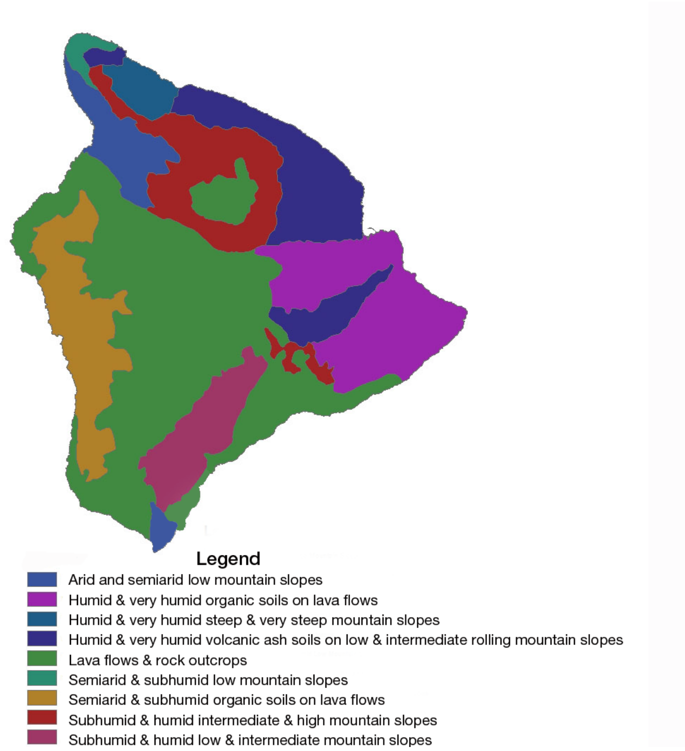

Fig. 7 A view of the different ecoregions found on the Island of Hawaii. The driving soil forming factors that create different soil types are climate and time. Credit: Natural Resources Conservation Service. Map created by Amy Koch.

center of the earth. Over time, the molten rock cools and slowly builds a volcano, deep below the ocean's surface. Eventually, the volcano continues to build up and up, until it grows above the ocean, forming an island. Meanwhile, the ocean floor drifts to the northwest, gradually moving the island away from hot spot, which slows volcanic activity. Eventually the eruptions stop when the volcano becomes extinct. In the Hawaiian Islands, the Island of Hawaii currently sits above the hot spot and is actively erupting. Hawaii Island is the youngest island, whereas Kauai and Niihau are the oldest islands in the state (approximately four to six million years old). (**Figure 7**)

Time and climate are major factors in creating different *ecoregions* across the Hawaiian Islands. Over time, as the islands continue to weather and move away from the hot spot, parent materials (volcanic ash and basalt bedrock) continue to weather, forming deep soils. Climate is the major factor that drives soil formation across the islands, as variations in precipitation and temperature create many different climatic zones. Annual rainfall can range from almost none to over 400 inches. The windward (north and northeast) side of the islands receives heavy annual rainfall as a result of the moist trade winds, while the leeward (west) side receives little rainfall. Temperatures decrease with increasing elevation. Elevations range from sea level to almost 14,000 feet, with the highest mountains found on the younger islands of Hawaii and Maui. Combinations of these climatic factors create unique ecoregions.

Humid and Very Humid Volcanic Ash Soils on Low and Intermediate Rolling Mountain Slopes: The Hilo soils formed in this ecoregion that occurs on the windward, wetter side of the Islands of Hawaii and Maui. The area is on rolling mountain slopes that have been eroded by steep-sided gulches. Elevation ranges from near sea level to 6,000 feet (0 to 1,830 meters). Geology consists of volcanic ash underlain by basalt. Some areas have

Glossary

Ash: Fragments of lava fine enough to drift on the wind.

`A`a lava: A basalt lava flow with a rough, jagged surface.

Ahupua`a: [Hawaiian] land division usually extending from the uplands to the sea

Basalt: A common dark grey to black rock composed mainly of microscopic crystals of pyroxene and plagioclase.

Bedrock: A general term for the solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

Cinder cones: A conical hill formed by the accumulation of cinder around a volcanic vent. Most cinder cones have craters in their summits.

Clay: A soil particle that is less than 0.002 mm in diameter. Clay particles are so fine they have more surface area for reaction. They hold a lot of nutrients and water in the soil. A clay soil is a soil that has more than 40% clay, less than 45% sand and less than 40% silt.

Ecoregion: Represents areas with similar biotic and abiotic characteristics which determine the resource potential and likely responses to natural and man-made disturbances. Characteristics such as climate, *topography*, geology, soils, and natural vegetation define an ecoregion. They determine the type of land cover that can exist and influence the range of land use practices that are possible.

Geology: The study of the physical earth, its composition (materials), history and processes (physical and chemical) that act on it.

Horizon: see Soil horizons

Hot spot: A volcanically active area of abnormally hot rock 50 to 150 miles across, which is underlain by a plume of hot rock rising from deep in the earth's mantle.

Kipuka: An area of older land surrounded by younger lava flows.

Lava flow: A solidified body of rock formed from the lateral, surficial outpouring of molten lava from a vent or fissure.

Leaching: The removal of soluble material from soil or other material by percolating water.

Organic matter: Material derived from the decay of plants and animals. Always contains compounds of carbon and hydrogen.

Pahoehoe lava: Basalt lava with a smooth, billowy, ropy surface

Sand: A soil particle between 0.05 and 2.0 mm in diameter. Sand is also used to describe soil texture according to the soil textural triangle, for example, loamy sand.

Silt: A soil particle between 0.002 and 0.05 mm diameter. It is also used to describe a soil textural class.

Soil Horizon: A layer of soil with properties that differ from the layers above or below it.

Soil Profile: The sequence of natural layers, or horizons, in a soil. It extends from the surface downward to unconsolidated material. Most soils have three major horizons, called the surface horizon, the subsoil, and the substratum.

Soil Scientist: A soil scientist studies the upper few meters of the Earth's crust in terms of its physical and chemical properties; distribution, genesis and morphology; and biological components. A soil scientist needs a strong background in the physical and biological sciences and mathematics.

Soil Texture: The relative proportion of sand, slit, and clay particles that make up a soil. Sand particles are the largest and clay particles the smallest. Learn more about soil texture at www.soils4teachers.org/physical-properties

Subsoil: (B horizon) The soil horizon rich in minerals that eluviated, or leached down, from the horizons above it. Not present in all soils.

Topography: The shape of the land surface. (Relief: refers to differences in elevation of different points in a region.)

Topsoil: (A horizon) The horizon that formed at the land surface. Mostly weathered minerals from parent material with a little organic matter added.

volcanic ash over cinders. The vegetation in this area consists of rain forest at the upper elevations and mixed trees, shrubs, and grasses at the lower elevations where non-native invasive plants dominate. Native forest and remnant patches include ohia lehua, koa, and hapuu treefern. Much of the land at the higher elevations in this area is in a forest reserve that provides watershed and habitat and protection for rare, threatened, and endangered plant species. Most of the land at the lower elevations is rangeland or cropland, including orchards. A large part of this area was used for non-irrigated sugarcane for about 100 years, until the sugar plantations shut down in the 1990s. Some of the areas once used for sugarcane are now used for cattle ranching, the production of macadamia nuts, trees for biomass, or small truck farms. The major resource concerns are water erosion, nutrient and pesticide runoff and *leaching*, surface compaction, spread of invasive plants and animals, and plant disease. Conservation practices on cropland and rangeland generally include erosion and flood control, deep tillage, weed control, and brush management.

Additional Resources

Soil! Get the Inside Scoop. David Lindbo and others. Soil Science Society of America, Madison, WI.

Know Soil, Know Life. David L. Lindbo, Deb A. Kozlowski, and Clay Robinson, editors. Soil Science Society of America, Madison, WI.

Web Resources

SOIL SCIENCE LINKS:

Smithsonian Soils Exhibit—http://forces.si.edu/soils/Stuttgart OSD, USDA NRCS

Soils for Teachers—www.soils4teachers.org

Soils for Kids—http://www.soils4kids.org/

Have Questions? Ask a Soil Scientist—https://www.soils4teachers.org/ask

Soil Science Society of America—https://www.soils.org/ /

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