Hawaii Soil Atlas

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Overview

The eight main Hawaiian Islands show tremendous diversity in soil types despite their small total land area. Soils vary because soil forming factors such as climate, topography, biota, and parent material can vary dramatically over small distances in Hawaii. For example, there are 57 individually mapped soil units on the island of Kauai and a total of 297 individual map units for all eight islands. Soils formed on the hot, dry, leeward coastal plains are different from soils found in the wet upland forests, which are again different from the soils formed in recent lava flows or volcanic ash deposits. Differences in physical, chemical, and biological properties mean soils perform differently one from the other. Differences in physical properties such as clay content make some soils well suited to flooded agriculture, whereas other soils with good drainage properties suited to upland agriculture. Acidic soils of the wet, windward areas of the islands would require lime and other soil amendments to increase their productivity while the neutral to slightly alkaline soils located on the dry, leeward coastal plains do not need lime. Identifying soils and understanding the differences and similarities in their performances and behaviors enables better management of this fundamental natural resource.

The Hawaiʻi Soil Atlas is an interactive tool that allows users to quickly locate and identify any soil across the Hawaiian islands, and acquire basic information about each soil. This tool condenses key data and characteristics of Hawaiʻi soils from the Hawaii Soil Survey, and summarizes them into a language and format understandable to a wide audience. The “Interactive Soil Map” provides concise descriptions of Hawaiʻi’s 297 different soil and land cover types, providing general information on the topographic location, climate, and more detailed information describing soil attributes such as water retention, fertility, acidity or alkalinity, organic matter, and physical structure. Numerical data of essential plant nutrients and properties related to soil productivity are also presented in graphs, with associated target levels also displayed to enable diagnosis of nutrient sufficiency or deficiency. Supplemental maps available for download in the “Downloadable Soil Maps” section display the spatial distribution of the major soil types (referred to as Orders in Soil Taxonomy), soil fertility classification, and important soil properties such as nutrient retention, organic matter, and soil shrink-swell potential. Links to websites containing detailed data and information used in the construction of this atlas are also provided near the bottom of the webpage. We hope that you will use the Atlas to explore the soils of Hawaiʻi and increase your knowledge of their important role in maintaining a healthy and functioning island ecosystem.

The data and information used to construct the Hawaiʻi Soil Atlas were derived from the Natural Resources and Conservation Service (NRCS) databases and websites. The Hawaiʻi Soil Atlas encourages the use of these other data sources; this atlas simply synthesized information from these sources into a format designed to best serve the wider community.

Conditions of Use

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All maps, data, graphs, and other information presented here are available for reproduction and distribution for non-commercial use. The map or data source must be prominently stated whenever presenting these data in any form or any product derived in whole or part from these data. Majority of the data and information used to construct the Hawaiʻi Soil Atlas were derived from the Natural Resources and Conservation Service (NRCS) databases and websites. The Hawaiʻi Soil Atlas encourages the use of these other data sources; this atlas simply synthesized information from these sources into a format we believed would best serve the wider community.

No Warranty or Liability
The Hawaiʻi Soil Atlas will not bear any responsibility for the consequences of using this data set, which are entirely the responsibility of the user. Sampling soils from every spot on every island is unfeasible, thus soil boundaries are estimated from multiple factors such as topography, climate, parent material, etc. As a result, soil boundaries are not exact, and may consist of mixtures of nearby soils. Depending on site conditions and management history, soil data can vary widely and may also not be exact. Every effort has been made to make all images, maps, graphs, data, and other information provided on this web site accurate and error-free. However, there is no guarantee to the accuracy of any images, maps, graphs, data, or other information. All content is provided without warranty of any kind.

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How to Use

Easy-locator tabs are located at the top of this webpage (top-border when scrolling down). Click on the desired tab to quickly scroll to the section of interest. Please read the “Conditions of Use” section before using the Hawaiʻi Soil Atlas for legal information. The “Glossary” section provides concise definitions of important soil concepts used frequently in the Soil Atlas. The “Methods” section describes the resources used and procedures followed to construct the “Interactive Soil Map” and its associated soil descriptions and fertility data graphs. The “Interactive Soil Map” is a user-friendly map: navigate the map using your mouse and scroller and click on an area of interest to generate relevant soil information and data in the tabs on the left side of the screen. Download maps of various soil properties relating to fertility and physical properties in the “Additional Soil Maps” section. Methods describing how these maps were constructed and the ArcGIS shapefiles of these maps are also available for download in that section. The “Links” and “References” sections provide websites and resources utilized and consulted for constructing the “Interactive Soil Map” and “Additional Soil Maps.”

Soil Atlas Methods

DATA ACQUISITION & MANIPULATION
Soil description and fertility data in the Hawaiʻi Soil Atlas were derived from three sources developed by the USDA NRCS: 1) Official Soil Series Descriptions (OSD), 2) National Cooperative Soil Characterization (NCSC) Database, and 3) Soil Survey Geographic (SSURGO) Database. For data and descriptions that spanned multiple soil depths (horizons), information from only the surface layers (O and A horizons) were utilized, or if only undiagnosed H horizons were available, then information from the upper 20 cm were used. For SSURGO data that consisted of multiple soil components (series) per mapunit polygon, only the dominant component was utilized for further analyses and processing. For example, on Hawaiʻi island, the mapunit polygon #2371347 is comprised of the Kapapala, Nanaia, and Ohaikea soil series as well as lava flows. However, since the Kapapala series comprises 85% of this mapunit area, this dominant component (soil series) was utilized when analyzing this mapunit. Detailed descriptions of data processing used to develop “Soil Descriptions” and “Soil Fertility Data” sections of the Hawaiʻi Soil Atlas are given below.

SOIL DESCRIPTIONS
Location: Describes where a soil series or land cover type is usually found in Hawaiʻi and what land uses it is suited for based on current land cover and topographical features. We used soil survey descriptions, Google Earth, and Worldview satellite imagery to describe location and estimate land use type. For the island of Kahoʻolawe, a “Current Clearance Map” developed by the Kahoʻolawe Island Reserve Commission was used to assess boundaries of hazardous areas still threatened by potentially unexploded ordinances.

Climate: Provides mean annual rainfall and temperature values averaged for each soil series. Mean annual rainfall shapefiles were acquired from the Rainfall Atlas of Hawaiʻi and analyzed for each soil series in ArcGIS using the “Zonal Statistics” tool. Temperature data were derived from the USDA-NRCS Official Soil Series Descriptions website.

Water: Describes various water-related characteristics of the soil series, such as water retention (expressed as %), permeability (drainage), and relation to soil erosion. Representative values of available water capacity data from the SSURGO database were used to estimate water holding capacity classes (Low= 0-0.06, Moderate= 0.07-0.13, High= 0.14-0.20, Very High > 0.20 AWC %). Classes were guided by the five-number-summary for AWC for all soils. Soil series descriptions were used in describing permeability, runoff, flooding, and wet/dry conditions.

Fertility: Describes general fertility, nutrient retention, and nutrient availability of the soil. Fertility classes were established based on soil taxonomy and clay mineralogy (**Fertile** = All Vertisols, Mollisols, and Aridisols and Inceptisols without Oxic, Dystric, or Andic descriptors (mineralogy= high activity clays); **Infertile** = All Oxisols, Ultisols, and Inceptisols with Oxic, Dystric, or Andic descriptors (mineralogy= low activity clays); **Fertile Andisols** = All Ustands and Torrands; **Infertile Andisols** = All Udands and Vitrands; **Organic Soils** = All Histosols; **Other** = Entisols, Spodosols, and other land types). Cation exchange capacity at pH 7 (CEC7) and effective cation exchange capacity (ECEC) data from SSURGO were used to estimate nutrient holding capacity classes based on the five-number-summary (Low= 0-15, Moderate >15-30, High >30-45, Very High >45 cmolc/kg). For all Andisols, Histosols, Oxisols, Spodosols, Ultisols, and Inceptisols with Oxic, Dystric, or Andic descriptors, ECEC data were used to assign nutrient classes. When ECEC data were lacking, CEC data were substituted. For all other soil types, CEC data were used. Mean calcium, magnesium, and potassium data were calculated using data from National Cooperative Soil Characterization data. When data were unavailable, then the following generalizations were followed: Deficient= Oxisols, Ultisols, and highly weathered Andisols (Udands) and Inceptisols (Oxic and Dystric Inceptisols); Well-supplied= Vertisols, Mollisols, Aridisols, Entisols, non-Oxic or non-Dystric Inceptisols, and less weathered Andisols (Ustands, Torrands, Vitrands). Other fertility information, such as abundance in salts, was derived from soil series descriptions.

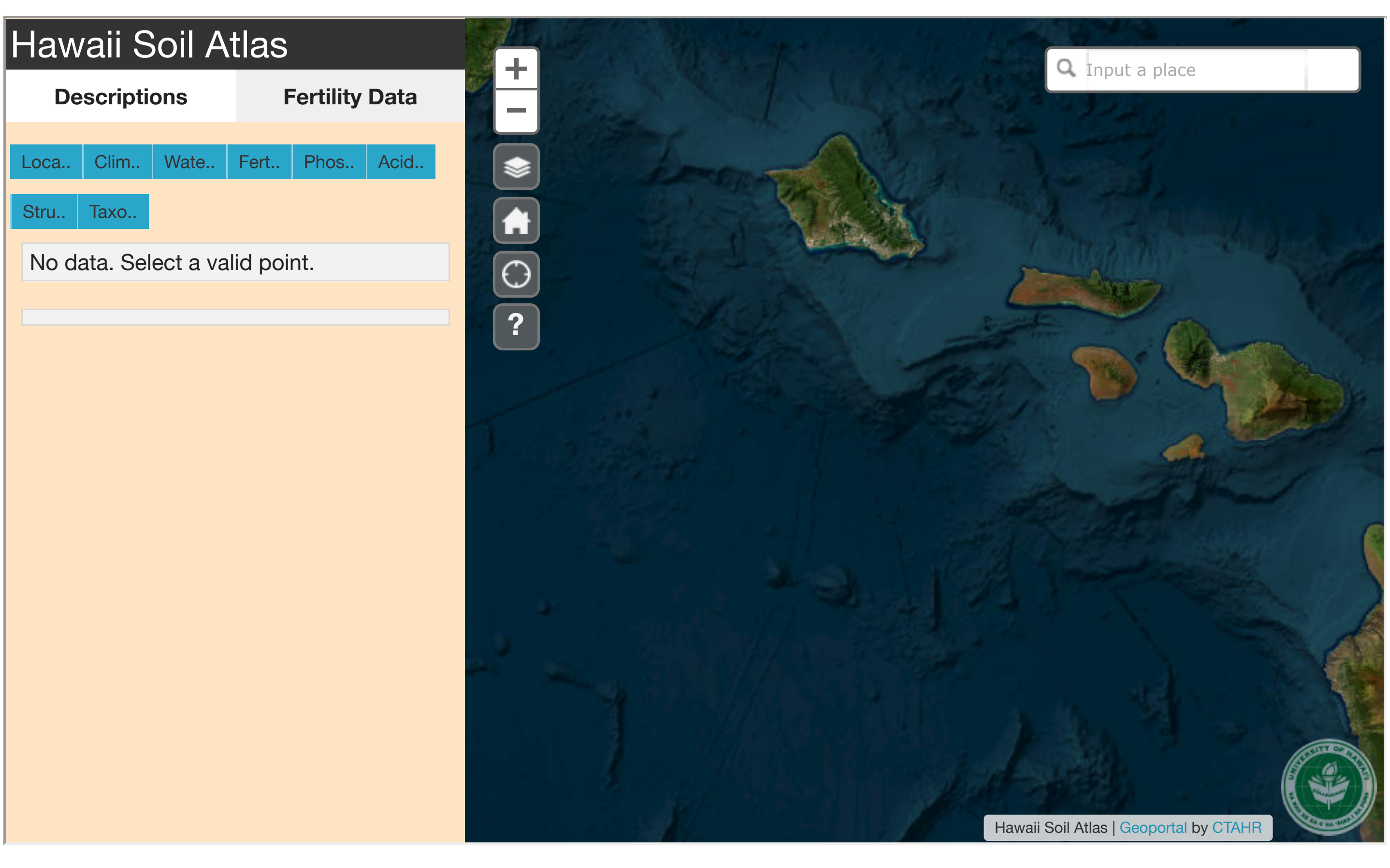
Phosphorus Reactivity: Phosphorus is an essential plant nutrient, but soils composed of oxide and amorphous clay minerals bind phosphorus strongly, making it unavailable to plants. This field describes a soil’s phosphorus retention capacity (i.e. as Phosphorus Reactivity Index % increases, phosphorus retention increases, reducing plant available phosphorus in the soil). Phosphorus reactivity and retention classes were based on New Zealand Phosphorus Index data from the National Cooperative Soil Characterization Database (Low= 0-25%, Moderate= 26-50%, High= 51-75%, Very High= 76-100%). Due to the unavailability of phosphorus data for many soils, generalized or expected classes were developed for those soils using available New Zealand Phosphorus Index data along with soil taxonomy and mineralogy. **Low** = Vertisols (smectitic or halloysitic mineralogy); Entisols (carbonatic or mixed mineralogy); and Histosols (ferrihumic mineralogy). **Moderate** = Spodosols; Mollisols (mixed, kaolinitic, or parasesquic mineralogy); Inceptisols (mixed mineralogy); Oxisols (*Eutro* great group class); and Andisols (Vitrands with glassy or mixed mineralogy). **High** = Aridisols (mixed, parasesquic, kaolinitic, or isotic mineralogy); Entisols (isotic or *Andic* classes, or volcanic ash influence); Mollisols (*Andic* subgroup); Inceptisols (ferrihydritic mineralogy, or *Andic* or *Oxic* subgroups); Histosols (volcanic ash influence); Ultisols; Oxisols (Torrox, Ustox, Udox, or Perox with ferruginous, kaolinitic, or sesquic mineralogy); Andisols (Vitrands with ferrihydritic or amorphic mineralogy). Very High = Andisols (Torrands, Ustands, and Udands with ferrihydritic, amorphic, or isotic mineralogy).

pH and Acidity: Soil pH is a measurement of the acidity or alkalinity of a soil, and it is an important soil property governing many biological, physical, and chemical processes. This field provides expected pH ranges of the soil series, detrimental effects from very low or high pH levels, and recommended activities to remediate detrimental pH levels. Ranges of pH were derived from SSURGO pH data. Acidic, neutral, and alkaline pH classes were modified from those described in the NRCS Field Book for Describing and Sampling Soils (Extremely Acidic: $pH < 4.5$; Strongly Acidic: $4.5 \geq pH \leq 5.2$; Moderately Acidic: $5.3 \geq pH \leq 5.7$; Slightly Acidic: $5.8 \geq pH \leq 6.2$; Near Neutral: $6.3 \geq pH \leq 6.7$; Neutral: $6.8 \geq pH \leq 7.2$; Slightly Alkaline: $7.3 \geq pH \leq 7.7$; Alkaline: $pH > 7.8$). Lower and upper boundaries of pH ranges were used to determine acidity descriptors. If pH as measured by water was not available, then pH as measured by $CaCl2$ served as a substitute.

Physical Structure: Describes quality of soil structure in relation to engineering and cultivation activities. Also highlights any obstacles to engineering and cultivation such as shrink-swell properties, presence of stones and shallow bedrock, and steepness of slope. Engineering and cultivation potential were summarized from “soil structure grade,” “rupture resistance,” and “manner of failure” measurements in the Soil Survey series descriptions, as described in the NRCS Field Book (Weak= smeary, fluid, loose, soft, very friable. Moderate= moderate structure, moderately to slightly hard, firm to friable. Strong= strong structure, hard to very hard, very firm to extremely firm). Other properties, such as shrink-swell, were also summarized from Official Soil Series Descriptions.

Soil Fertility Data
Soil fertility data were compiled from the NRCS National Cooperative Soil Characterization Database. Total carbon, base cations (calcium, magnesium, potassium, sodium), cation exchange capacity, pH, and New Zealand Phosphorus Index data were collected. Total carbon data was preferred over organic carbon data due to 1) the ineffectiveness of the method used to measure organic carbon (Soil Survey Laboratory 2004) and 2) the low content of carbon-based minerals in Hawaiʻi’s soils, which does not impede the total carbon procedure. However, if total carbon data was missing, then organic carbon data served as a substitute. For soil series with multiple samples and/or horizons, data among these samples and horizons were averaged, and the mean and standard deviation were reported. In the case that soil series were missing fertility data altogether, data from soils with similar taxonomy for at least the subgroup level or higher were substituted. If multiple soils met the subgroup criteria, then family classes, geographic distribution, parent material, and climate were also considered.

Map (full screen map)



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Downloads

- Download Info (README)
- All Properties
- Nutrient Holding Capacity
  - Image
  - Shapefile
- Fertility Class
  - Image
  - Shapefile
- Organic Matter
  - Image
  - Shapefile
- Acidity
  - Image
  - Shapefile
- Shrink Swell
  - Image
  - Shapefile
- Soil Order Series
  - Image
  - Shapefile
- Water Permeability
  - Image
  - Shapefile

Glossary

- Available water capacity:
- Cation exchange capacity (CEC): The amount of cation nutrient that a soil can retain for plant use. It is measured as the sum of exchangeable base cations (calcium, magnesium, potassium, and sodium) plus total soil acidity (aluminum and hydrogen) at a specific pH, usually 7.0 or 8.0. CEC is expressed in centimoles of charge per kilogram of soil or other adsorbing material.
- Effective CEC (ECEC): The amount of cation nutrients a soil (or other adsorptive material) can retain at its native pH. It is measured as the sum of exchangeable cations (aluminum, calcium, magnesium, potassium, and sodium). ECEC is expressed in centimoles of charge per kilogram of soil or other adsorbing material.
- Nutrients:
  - Essential nutrients: A chemical element (nutrient) that is required for normal plant growth.
  - Micronutrients: a chemical element (nutrient) needed only in small amounts for plant growth. Examples include zinc, manganese, iron, and copper. Differing from macronutrients that are needed in larger amounts, and include nitrogen, phosphorus, potassium, and calcium.
- Organic matter: Any soil material that is part of or originated from living organisms.
- Phosphorus reactivity (retention): The strong adsorption of phosphorus nutrients by soil minerals, usually crystalline and non-crystalline oxide minerals, so that phosphorus is not available for plant use.
- Soil order: A group of soils in the broadest category in Soil Taxonomy. The properties selected to distinguish the orders are reflections of the degree of horizon development and the kinds of horizons present. Currently there are 12 soil orders in the USDA classification system: Alfisols, Andisols, Aridisols, Entisols, Gelisols, Histosols, Inceptisols, Mollisols, Oxisols, Spodosols, Ultisols, and Vertisols.
- Soil pH: The degree of acidity or alkalinity of a soil as expressed in terms of the pH scale
- Soil series: The lowest and most restrictive category in Soil Taxonomy, consisting of soils that are similar in all major profile characteristics.
- Soil structure: The arrangement of soil particles into larger aggregates and distinct patterns.
- Soil taxonomy: the science of classification of soils; laws and principles governing the classifying of soil. Also a specific soil classification system developed by the U.S. Department of Agriculture.
- Soil tilth: The physical condition of soil related to its ease of tillage, fitness of a seedbed, and impedance to seedling emergence and root penetration. Good soil tilth equates to easier tillage, root penetration, and seedling emergence.
- Water permeability: The ease with which liquids pass through a bulk of soil.

*Synthesized from Brady and Weil (2010), Natural Resources Conservation Service (2014), and Soil Science Society of America (2014)

Helpful Links

Geospatial Data Gateway/Soil Survey Geographic Database (USDA-NRCS)
http://datagateway.nrcs.usda.gov/GDGOrder.aspx

Glossary of Soil Science Terms (SSSAJ)
https://www.soils.org/publications/soils-glossary

National Cooperative Soil Characterization Database (NCSS
http://ncsslabdatamart.sc.egov.usda.gov/

Official Soil Series Descriptions (USDA-NRCS
https://soilseries.sc.egov.usda.gov/osdname.asp

SoilWeb (UC Davis - Soil Resource Laboratory)
http://casoilresource.lawr.ucdavis.edu/soilweb/

Web Soil Survey (USDA-NRCS)
http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

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