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Earth Science Education Activity

Web Soil Survey Teachers Guide — Climate Dynamics

INTRODUCTION

In today's rapidly changing world, fostering a deep understanding of the intricate relationships between soil and climate is more crucial than ever. As stewards of the planet, students stand at the forefront of addressing environmental challenges, and so empowering them with knowledge about the interplay between soil and climate is a pivotal step toward sustainable practices. The profound impact of these interactions extends far beyond the boundaries of individual ecosystems, influencing global climate patterns, biodiversity, and even the very foundations of agricultural and ecological systems.

Teaching students about the dynamic relationship between soil and climate is an investment in their environmental literacy and enables informed decision-making and transformative action. The inclusion of real-world data and examples enhances the educational experience by grounding theoretical concepts in tangible, observable phenomena. By delving into authentic, measurable data, students can cultivate the analytical skills necessary for critically engaging with the consequences of alterations in soil health on local and global scales like the deforestation-driven loss of carbon sinks to shifts in precipitation patterns impacting agricultural productivity.

Students can utilize Web Soil Survey (WSS) to explore a wealth of data and interpretations that link soil characteristics with climate dynamics. This online tool enables students to explore detailed soil information tailored to specific geographic locations. By leveraging the WSS, students gain insights into how soil properties, such as moisture retention and organic content, respond to climate conditions. This integration of technology not only enhances the learning experience but also fosters a practical understanding of how soil-climate relationships manifest in diverse landscapes.

As students explore soil and climate dynamics with the aid of real-world data and tools like the Web Soil Survey, they are empowered not just as learners but as active contributors to environmental sustainability. By comprehending the nuanced relationships between soil and climate, students have the knowledge needed to become advocates for responsible land use, resilient ecosystems, and a future where humanity lives harmoniously with the planet.

Read more about the relationship between soil and climate change in an article titled, "[What's soil got to do with climate change?](#)" published in GSA Today.

U.S. Department of Agriculture's Natural Resources Conservation Service (USDA NRCS) • www.soils.usda.gov

The USDA NRCS delivers science-based soil information to help farmers, ranchers, foresters, and other land managers effectively manage, conserve, and appraise their most valuable investment — the soil.

SOIL AND CLIMATE IN SCIENCE EDUCATION

Using soil data from the Web Soil Survey (WSS) in educational settings offers a unique avenue for investigating the intricate relationship between soil dynamics and climatic factors. Aligned with the National Research Council's Framework for K-12 Science Education, and in particular with the Next Generation Science Standards (NGSS), the study of soil through its interaction with climate systems provides for a comprehensive, three-dimensional approach to learning. The activities within this guide engage students with real-world soil datasets, facilitating connections with a diverse range of Disciplinary Core Ideas (DCIs), Science and Engineering Practices (SEPs), and Crosscutting Concepts (CCCs). Specifically,

- DCI:** Earth's Systems, Earth and Human Activity
- SEP:** Analyzing and Interpreting Data; Developing and Using Models; Obtaining, Evaluating, and Communicating Information
- CCC:** Patterns, Cause and Effect; Systems and System Models

Activities are also linked to specific NGSS performance expectations, in addition to a number of United Nations Sustainable Development Goals (SDGs). The SDGs are a universal call to action to end discrimination, protect the planet, and ensure prosperity for all. Addressing the SDGs can help students make connections between what they are studying and the major issues in society today; especially focusing on the role that geoscience professionals can play in addressing these issues and meeting the goals that the SDGs set to improve the quality of life for all people, as well as for the environment. The Education for Sustainable Development movement has gained significant traction since the inception of the SDGs. This underscores the urgent need to infuse sustainability principles across various academic domains and educational levels, fostering a collective ethos of responsible citizenship and transformative action that is essential for present and future generations.



SDG 13 specifically addresses climate action, emphasizing the urgent need to take action to combat climate change and its impacts. Soil plays a crucial role in achieving SDG 13 as it serves as both a source and a sink of greenhouse gases, influencing the Earth's climate system. Healthy soils can act as carbon sinks, sequestering carbon dioxide from the atmosphere and helping mitigate climate change. Conversely, degraded soils be a source of greenhouse gas emissions, exacerbating climate change. Therefore, sustainable soil management practices are essential for enhancing soil health, increasing carbon sequestration, and mitigating the adverse effects of climate change, thereby contributing to the achievement of SDG 13.

Learn about all 17 SDGs at sdgs.un.org

SUSTAINABLE DEVELOPMENT GOALS



credit: UN Sustainable Development Goals Program

INTRODUCTORY ACTIVITY: EXPLORING THE CONNECTION BETWEEN CLIMATE AND SOIL

Objective: Students will analyze real-world soil data to understand the impact of climate on soil properties and composition and to draw connections between climate patterns and soil characteristics.

Connections

NGSS

DCI: Earth's Systems, Earth and Human Activity

SEP: Analyzing and Interpreting Data; Developing and Using Models; Obtaining, Evaluating, and Communicating Information

CCC: Patterns, Cause and Effect; Systems and System Models

SDGs

2: Zero Hunger

4: Quality Education

6: Clean Water and Sanitation

11: Sustainable Cities and Communities

12: Responsible Consumption and Production

13: Climate Action

15: Life on Land

Activity

1. Begin by exploring possible connections between soil and climate.
 - a. Discuss with students what they know about climate, soil, and their interactions.
 - b. Conduct an Observation Walk outside, where students observe and note soil characteristics such as moisture, texture, and color based on environmental factors. Ask students to share their observations.
 - c. Have students hypothesize how their soil differs from that in other climates.
2. Group students and assign each group to one of the locations below. Students should navigate WSS and collect data from their assigned region, each of which has a distinct climate:
 - **Pacific Northwest (e.g. Seattle, Washington)**
With a temperate marine climate, the Pacific Northwest experiences mild, wet winters and dry summers. Students can analyze soil data from this region to explore the influence of consistent rainfall and moderate temperatures on soil properties, particularly in forested areas.
 - **Great Plains (e.g. Salina, Kansas)**
With a semi-arid continental climate, the Great Plains have a climate characterized by hot summers, cold winters, and low annual precipitation. Students can examine soil data from this region to understand how the semi-arid conditions and temperature fluctuations impact soil characteristics, especially in agricultural landscapes.
 - **Appalachian Mountains (e.g. Asheville, North Carolina)**
With a humid subtropical climate, the southern Appalachian region experiences hot summers and cool winters. Students can analyze soil data from this diverse landscape to explore the impact of varied elevations, precipitation levels, and forested ecosystems on soil properties. Optionally, have another group explore the city of Pittsburgh, PA to make comparisons with an area in the northern Appalachian region.
3. Discuss each region and its associated data as a class. Optionally, conduct a jigsaw where new groups form with at least one expert from each of the three region groups.
4. Ask students to analyze and interpret the data, identifying patterns and trends between soil characteristics and climate.

WSS INTERPRETATIONS RELATED TO CLIMATE CHANGE

Students studying climate change can explore various soil interpretations in the WSS that provide insights into soil characteristics relevant to **carbon sequestration and storage** and **climate-related natural hazards**.

Carbon Sequestration Potential

Carbon sequestration refers to the long-term storage of atmospheric carbon dioxide in various reservoirs. Soils can play a crucial role in this process. Soils act not only as a foundation for plant growth but also as a reservoir for storing and cycling carbon. The dynamics of carbon in soils are influenced by numerous factors, ranging from the decomposition of organic matter to the physical and chemical characteristics of the soil. Unraveling the mysteries of carbon sequestration in soils lays the foundation for sustainable land management practices and provides insights into mitigating the impacts of climate change.

Soil properties to examine related to carbon storage

- ◆ Soil organic carbon content and soil organic matter depletion
- ◆ Soil texture
- ◆ Soil pH
- ◆ Depth to any soil restrictive layer

NGSS Alignment

MS-ESS3-1 explores the connection between Earth's geological processes and resource distribution. Incorporating carbon storage and sequestration in teaching this standard is beneficial as these processes are intricately linked to soil formation, structure, and composition. Geological factors influence the capacity of soils to store and sequester carbon, making it crucial for students to study these relationships for a comprehensive understanding of Earth's systems and the responsible management of resources.

HS-ESS2-6 focuses on developing a quantitative model to describe the cycling of carbon among Earth's spheres. Including discussions on carbon storage and

sequestration in soils is pertinent because these processes play a significant role in the carbon cycle, illustrating to students how carbon moves and is stored within different Earth systems.

Sustainable Development Goals

2: Zero Hunger: Soil health is essential for food security and agricultural productivity. Sustainable soil management practices contribute to increased crop yields, improved soil fertility, and resilience to climate change, thereby supporting the goal of ending hunger.

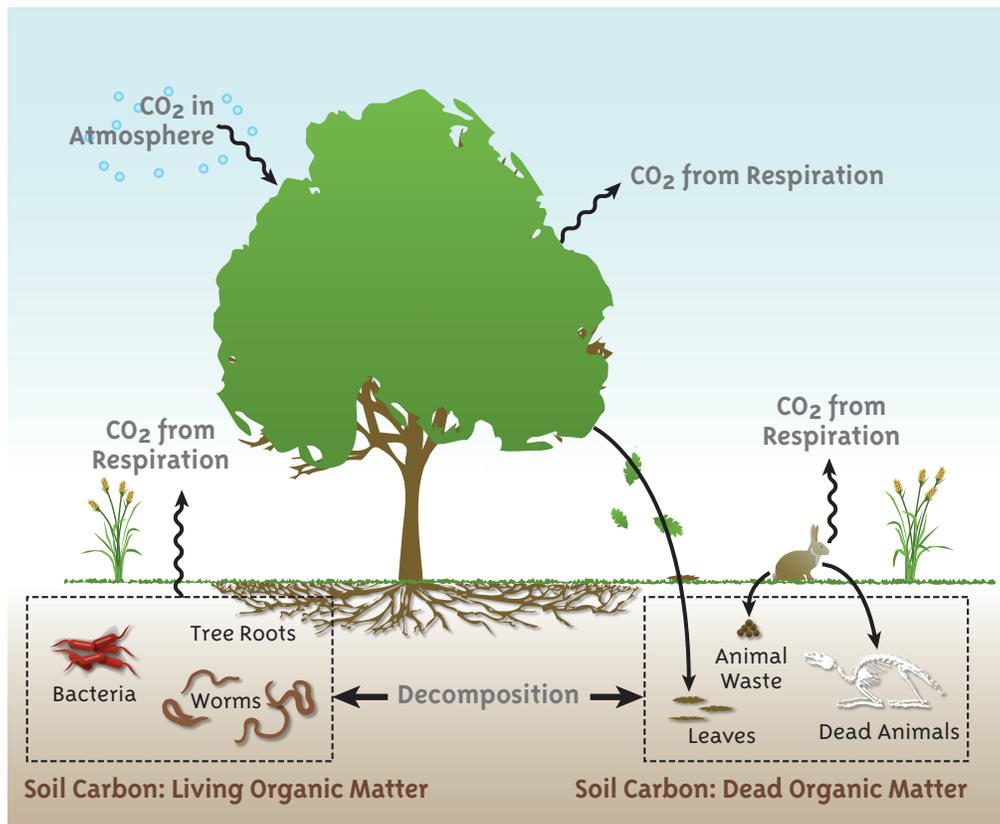
13: Climate Action: Soil carbon sequestration is an effective strategy for mitigating climate change by removing carbon dioxide from the atmosphere and storing it in the soil. Sustainable land management practices that enhance soil organic carbon contribute to climate change mitigation efforts.

15: Life on Land: Soil health is fundamental to terrestrial ecosystems and biodiversity conservation. Maintaining healthy soils supports diverse plant, animal, and soil microbe communities, enhances ecosystem resilience, and protects habitats, aligning with the goal of conserving and restoring terrestrial ecosystems.

17: Partnerships for the Goals: Achieving sustainable soil management and carbon sequestration requires collaboration and partnerships among governments, civil society, private sector organizations, and local communities. SDG 17 emphasizes the importance of multi-stakeholder cooperation and capacity-building initiatives to address complex environmental challenges, including soil degradation and climate change.

Soil Organic Carbon Content and Organic Matter Depletion

The intricate relationship between soil organic carbon content (or organic matter) and soil organic matter depletion plays a pivotal role in the complex processes of carbon storage within Earth's soils. Soil organic carbon content, a key component of soil health, is central to carbon cycle dynamics. Carbon, derived from the decomposition of plant and animal residues within soils, becomes a reservoir of sequestered carbon, significantly influencing the broader carbon cycle. Through photosynthesis, plants draw carbon dioxide from the atmosphere, converting it into organic compounds. When these plant residues decompose and organic matter accumulates in the soil, carbon becomes stably stored, contributing significantly to carbon sequestration.



Credit: Soil Science Society of America

Microbial decomposition, a crucial process in the carbon cycle, is intricately connected to soil organic carbon. Microbes break down organic matter within soil, releasing carbon dioxide in the process. The rate of microbial decomposition, influenced by factors like temperature, moisture, and nutrient availability, is crucial in determining the fate of soil organic carbon. Well-managed soils with an optimal balance can enhance carbon storage by fostering organic matter accumulation, offering a sustainable strategy for carbon sequestration.

The role of soil organic carbon extends beyond storage; it actively contributes to the formation of humus—a stable, complex organic substance. Humus, in conjunction with soil minerals, forms stable aggregates that protect organic matter from rapid decomposition. These aggregates create a physical environment conducive to carbon storage by shielding organic carbon from microbial degradation and environmental factors. Furthermore, soil organic carbon significantly influences soil properties such as water holding capacity and nutrient retention. High organic carbon content enhances a soil's ability to retain water and acts as a reservoir for essential nutrients, promoting healthier vegetation and sustaining the input of organic matter, thus contributing to carbon sequestration.

Negative consequences emerge when there is a depletion of soil organic matter. The vulnerability to organic matter depletion is influenced by factors such as temperature, water availability, soil aeration, and land management practices. Identifying and understanding areas at risk of depletion allows for targeted efforts to enhance carbon storage through sustainable land management practices. These practices, including cover cropping and reduced tillage, become essential components in mitigating the impacts of climate change and preserving soil health. Sustainable land management practices that nurture and preserve soil organic carbon and mitigate soil organic matter depletion are pivotal strategies in the global effort to combat climate change and build resilient ecosystems.

Differences between SOC and SOM

Soil Organic Matter (SOM) and Soil Organic Carbon (SOC) are related concepts but not entirely synonymous:

Soil Organic Matter (SOM) refers to the entire organic fraction within the soil, including various components such as living organisms (like microbes and roots), partially decomposed residues (like plant litter), and stable organic matter (humus). SOM is a broad term that encompasses all organic materials present in the soil.

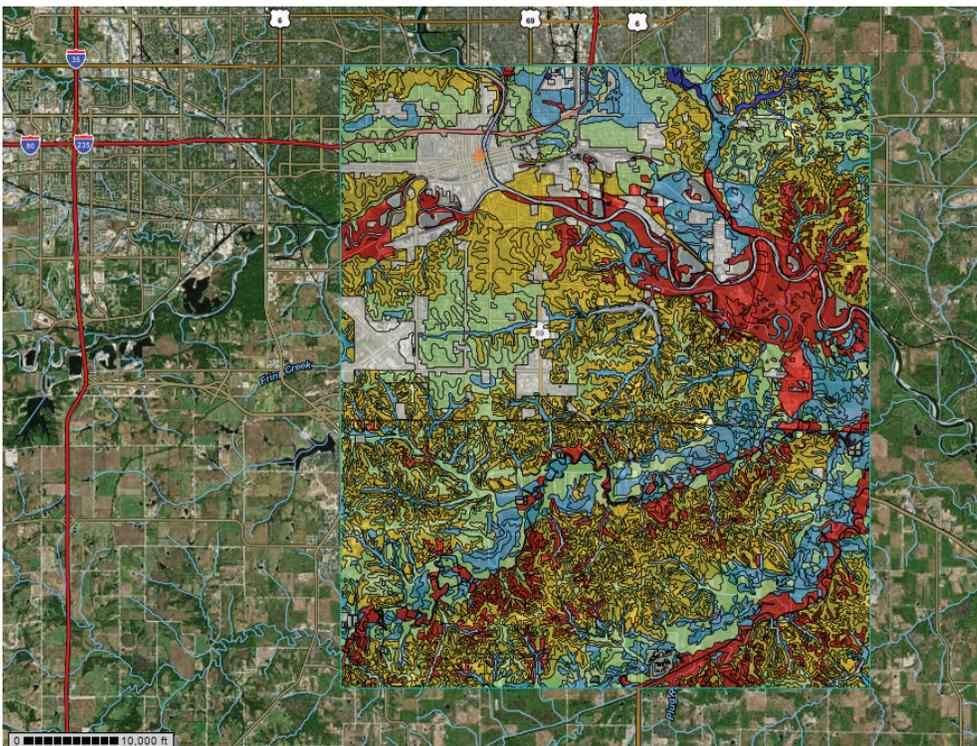
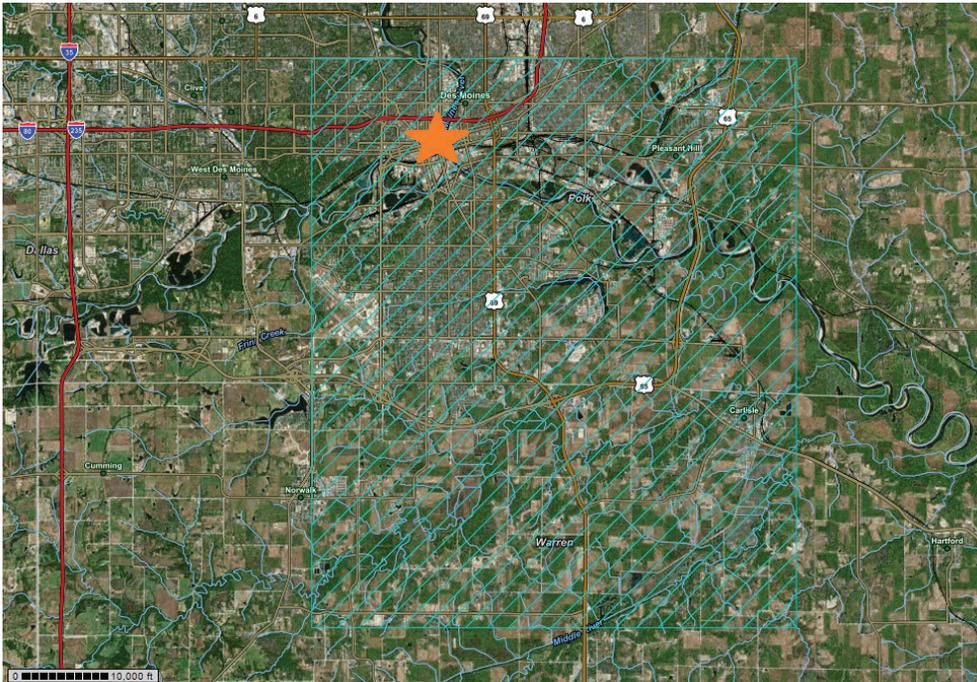
Soil Organic Carbon (SOC) specifically refers to the carbon component of SOM. It represents the organic carbon that is present in the soil's organic matter. SOC is a crucial aspect of soil fertility, nutrient cycling, and carbon sequestration processes.

► *How to Get there on WSS*

Soil Data Explorer > Soil Properties and Qualities
> Soil Health Properties > **Soil Health –
Organic Matter**

Soil Health — Organic Matter Map (Des Moines, Iowa)

The first image displays the selected Area of Interest (AOI). Notice the city of Des Moines is located at the top of the selected AOI. The second image is the Soil Health – Organic Matter soil map of the AOI. Areas in red and yellow have low amounts of organic matter, whereas areas in blue and purple have higher amounts of organic matter. Consider what the Organic Matter map may look like in an area farther away from the city. Explore different areas around Des Moines such as farmland and more natural areas away from infrastructure.



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

Soil Rating Polygons

-  ≤ 2.10
-  > 2.10 and ≤ 3.10
-  > 3.10 and ≤ 4.50
-  > 4.50 and ≤ 7.00
-  > 7.00 and ≤ 10.00
-  Not rated or not available

Quick Review of Soil Organic Carbon Content

Definition: Organic Matter Percent is the weight of decomposed plant, animal, and microbial residues expressed as a percentage of soil material less than 2 mm in diameter.

Significance of Soil Organic Carbon (SOC) Content:

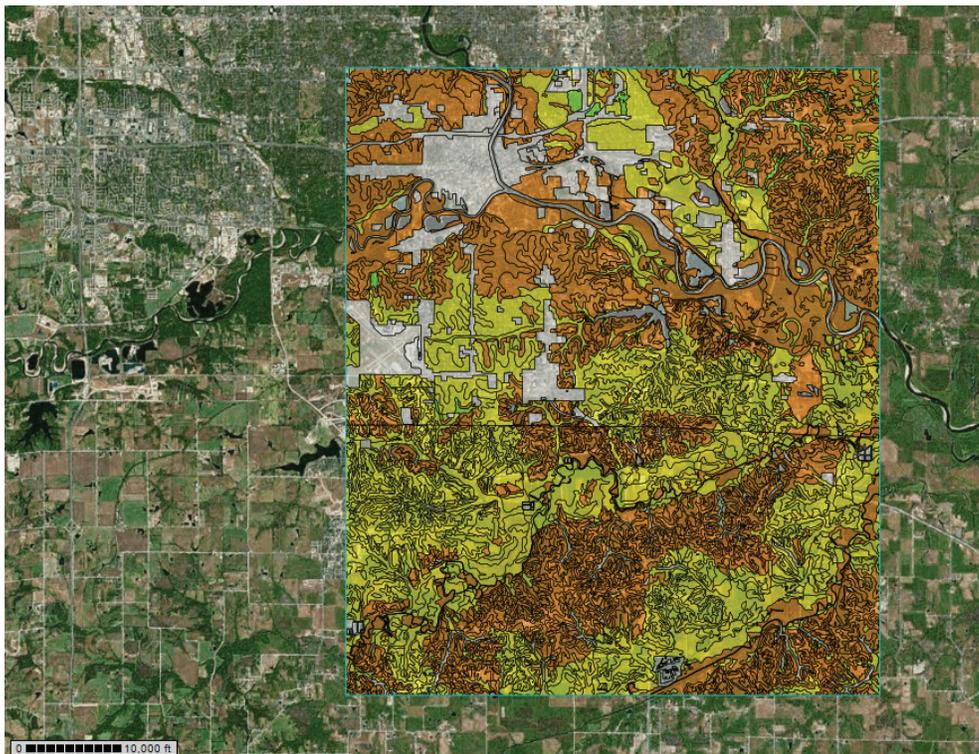
- ◆ **Carbon Sequestration:** SOC is a key component in carbon sequestration, playing a vital role in mitigating climate change by storing carbon in the soil. Areas with higher SOC act as a significant sink for carbon, helping mitigate climate change by storing more carbon in the terrestrial ecosystem.
- ◆ **Microbial Decomposition:** SOC serves as a substrate for microbial decomposition, influencing the release of carbon dioxide into the atmosphere and contributing to the carbon cycle. Higher levels of SOC often correspond to increased microbial activity, and consequently increased CO₂ emissions.
- ◆ **Soil Fertility:** Organic carbon content is linked to soil fertility, influencing nutrient availability and promoting healthier vegetation. Therefore, higher levels of SOC are generally associated with improved soil fertility.
- ◆ **Water Holding Capacity:** SOC improves soil water retention, aiding plants in times of water scarcity. Soils with elevated SOC levels typically demonstrate improved water-holding capacity, ensuring better support for plants during dry spells.
- ◆ **Climate-Resilient Agriculture:** Managing and preserving soil organic carbon is crucial for building climate-resilient agricultural systems, as it impacts soil health, productivity, and the overall sustainability of ecosystems. Increased SOC content enhances soil health, which, in turn, contributes to greater agricultural productivity and sustainability.

Organic Matter Depletion (Des Moines, IA)

For the same AOI as used for Soil Health – Organic Matter, this soil map displays Organic Matter Depletion. Areas in orange and yellow have moderately high and moderate amounts of organic matter depletion, whereas areas in green (near the top of the map) have low amounts of organic matter depletion. Again, consider what the Organic Matter Depletion map may look like in an area farther away from the city. Explore different areas around Des Moines such as farmland, more natural areas away from infrastructure and human activity.

► How to Get there on WSS

Soil Data Explorer > Stabilities and Limitations for Use > Soil Health > **Organic Matter Depletion**



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

Soil Rating Polygons

-  OM depletion high
-  OM depletion moderately high
-  OM depletion moderate
-  OM depletion moderately low
-  OM depletion low
-  Not rated or not available

Quick Review of Soil Organic Matter Depletion

Definition: Soil Organic Matter Depletion refers to the reduction in the quantity of organic matter in the soil over time due to various factors, including microbial decomposition, land management practices, and environmental changes. It represents the decrease in the content of decomposed plant, animal, and microbial residues, which are essential components of soil organic matter.

Significance of Soil Organic Matter Depletion:

- ◆ **Carbon Storage:** Soil Organic Matter (SOM) is a primary component of carbon storage in soils, influencing the global carbon cycle.
- ◆ **Microbial Activity:** High levels of microbial activity can deplete organic matter within soils. However, depletion of organic matter due to human activity, such as tilling, can affect microbial activity, disrupting the balance of nutrient cycling and decomposition processes.
- ◆ **Soil Structure and Aggregation:** Organic matter plays a crucial role in maintaining soil structure and aggregation, which in turn affects water infiltration and root penetration.
- ◆ **Water Holding Capacity:** Organic matter contributes to the soil's water holding capacity, influencing its ability to retain moisture and resist drought.
- ◆ **Climate Resilience:** Managing soil organic matter is essential for building climate-resilient ecosystems, as it enhances soil fertility, nutrient availability, and overall soil health.

Extension Questions

1. Discuss the connection between land-use changes, deforestation, and soil organic matter depletion. How might reforestation initiatives contribute to carbon sequestration in soils?
2. Investigate the role of soil microbes in the decomposition of organic matter and its implications for carbon cycling. How can microbial activity be managed to enhance carbon sequestration?
3. Investigate the potential of cover cropping and agroforestry in promoting soil health and organic matter accumulation. How do these practices contribute to carbon sequestration in agricultural landscapes?
4. Explore the relationship between soil erosion, sedimentation, and the loss of organic matter. How can erosion control practices help in preserving soil organic carbon?
5. Consider the socio-economic aspects of promoting soil health and carbon sequestration. How might policies and incentives that encourage sustainable land management practices among farmers and landowners affect farm productivity and income opportunities?

ACTIVITY: Exploring Carbon Content Locally

Objective: Students create soil maps to investigate variations in organic matter across diverse local areas and gain insight into factors influencing these differences.

1. Divide students into groups and ask each group to explore a specific local area (e.g., city, farmland, forest, riverbank, different socio-economic areas)
2. Guide students to the WSS and demonstrate how to navigate through the system.
3. Provide time for each group to use WSS to create soil maps, focusing on organic matter and organic matter depletion of their selected Area of Interest (AOI).
4. Have each group add their maps to a shared class document or folder for display and discussion. Make sure that each group also includes information on where their AOI is located.
5. Facilitate a class discussion about the maps using the following prompts:
 - a. Discuss how soil organic matter content varies across different locations. Hypothesize why these variations might occur.
 - b. Identify areas on the maps with high or low levels of soil organic matter. Discuss potential factors contributing to these patterns and their impact on the local environment.
 - c. Analyze how land use patterns influence organic matter content and discuss implications for carbon sequestration. Examine how human activities, such as agriculture and urbanization, contribute to soil organic matter depletion. Use evidence from the maps to support claims.
 - d. Explore how natural factors and human interventions influence organic matter content.
6. Conclude the discussion with each group sharing insights on:
 - a. potential human impacts on soil health, and ideas for sustainable land management.
 - b. the ways in which local communities could be involved in soil conservation efforts.

Soil Texture

Soil texture is a critical factor influencing carbon storage within soil. It refers to the relative proportions of sand, silt, and clay particles that compose the soil matrix. The unique physical and chemical characteristics of each texture type significantly impact carbon dynamics. Finer-textured soils, such as those rich in clay, have a higher surface area and an abundance of micropores, providing ample sites for organic matter to adhere, facilitating carbon storage. This increased surface area allows for the adsorption of carbon compounds onto soil particles, contributing to the stabilization of organic matter within soil and shielding it from rapid decomposition.

Furthermore, the aggregation and stability of soil particles, influenced by soil texture, play a pivotal role in carbon storage. Clays and fine silts promote soil aggregation, forming stable structures that shield organic matter from microbial degradation and ensuring a more extended residence time for carbon in the soil. The slower decomposition rate observed in finer-textured soils is a testament to the crucial role that soil texture plays in carbon sequestration.

Soil texture also dictates microbial activity, a key contributor in the decomposition of organic matter. Coarse-textured soils, like sandy soils, generally exhibit lower microbial activity compared to finer-textured soils which have smaller pore spaces that create conditions conducive to slower microbial decomposition, thus favoring the accumulation of organic carbon over time. Additionally, the water retention and aeration properties influenced by soil texture impact carbon storage. Coarser soils, with their larger particles and pore spaces, drain quickly and may lead to drier conditions, potentially accelerating the decomposition of organic matter. In contrast, finer-textured soils, have higher water retention capabilities, creating a moist environment that encourages the preservation of organic carbon stores within soils.

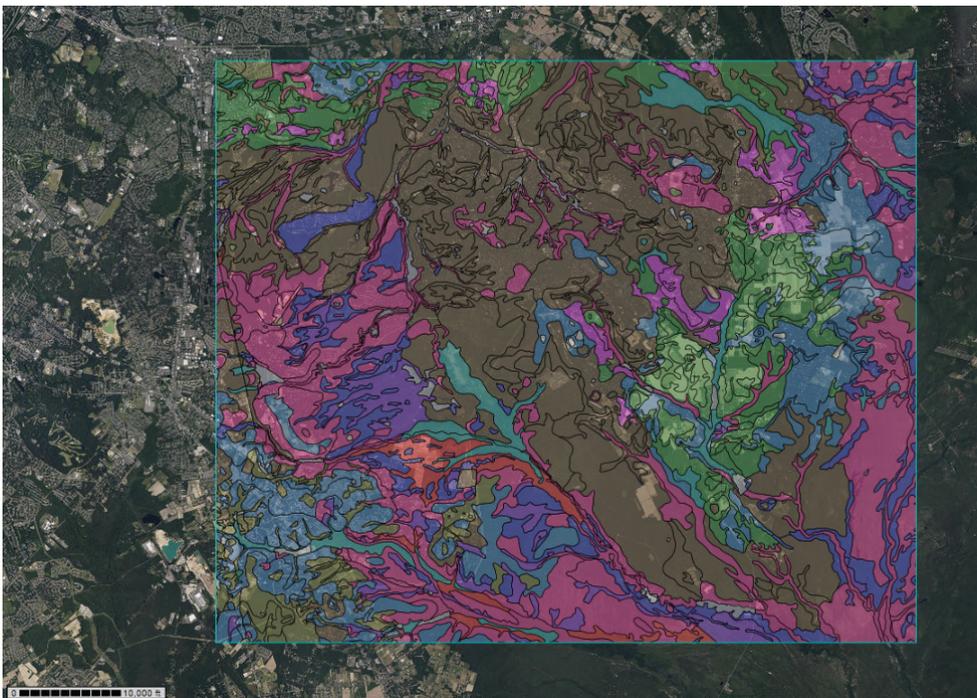
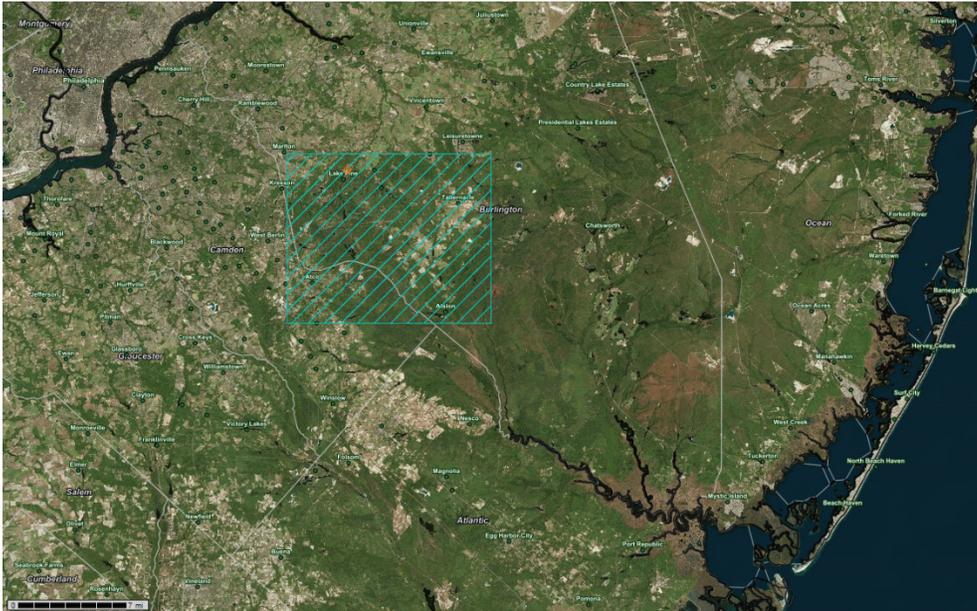
► *How to Get there on WSS*

Soil Data Explorer > Soil Properties and Qualities > Soil Physical Properties > **Surface Texture**

Soil, no matter where it is located at the surface of the soil profile or deep within the profile, will have a specific soil texture. On WSS, the interpretation only shares the soil texture at the surface.

Surface Texture (Medford, New Jersey)

The first image shows the selected Area of Interest (AOI) around Medford 25 miles southeast of Philadelphia, Pennsylvania and 40 miles west of the Jersey shoreline. The second image is the soil surface texture map of the same AOI. Notice the variety of textures that are present in and around Medford Lakes. Which textures do you see? How might a surface texture map look different in an area closer to Philadelphia, PA? What about in an area along the shoreline? Explore the surface texture of different areas around southern New Jersey such as areas with more infrastructure, more natural areas away from human infrastructure and activity, areas around the Delaware River, and areas near the coast.



MAP LEGEND

Area of Interest (AOI)

-  Area of Interest (AOI)

Soils

Soil Rating Polygons

-  Coarse sand
-  Fine sand
-  Fine sandy loam
-  Loam
-  Loamy fine sand
-  Loamy sand
-  Muck
-  Mucky peat
-  Peat
-  Sand
-  Sandy clay
-  Sandy loam
-  Slightly decomposed plant material
-  Not rated or not available

Quick Review of Soil Texture

Definition: Soil texture terms are defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 millimeters in diameter. "Loam," for example, is soil that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the content of particles coarser than sand is 15 percent or more, an appropriate modifier is added, for example, "gravelly."

Significance of soil texture:

◆ **Water Retention and Drainage:** Surface texture influences water infiltration and drainage rates, affecting soil moisture levels and groundwater recharge. Soils with coarse textures, such as sandy soils, typically have higher infiltration rates but lower water-holding capacity compared to fine-textured soils like clay.

◆ **Root Penetration:** Surface texture affects the ease with which plant roots can penetrate the soil, influencing nutrient and water uptake. Soils with looser, more friable textures typically offer less resistance to root growth, facilitating deeper root penetration and enhancing plant stability and nutrient uptake.

◆ **Aeration:** Soil texture determines the level of aeration, affecting the availability of oxygen to plant roots and soil microorganisms. Coarser textures allow for better air movement through the soil profile, promoting oxygenation and reducing the risk of anaerobic conditions, which can inhibit root growth and nutrient uptake.

◆ **Temperature Regulation:** Surface texture influences soil temperature by affecting heat absorption and retention. Coarse textures tend to heat up more quickly and cool down faster than fine textures. This regulation of soil temperature can impact seed germination, microbial activity, and overall plant growth and development.

◆ **Land Use Planning:** Understanding surface texture is critical for land use planning and management decisions. Different textures have varying capabilities for supporting infrastructure, agriculture, and natural habitats. Proper assessment of surface texture helps optimize land utilization and minimize environmental degradation.

Extension Questions

1. How does soil texture influence carbon storage and sequestration potential, and what role does it play in mitigating the effects of climate change?
2. In what ways do different soil textures affect water retention and nutrient availability, and how do these factors impact carbon cycling within ecosystems?
3. Explore the relationship between soil texture, land use practices, and carbon emissions. How do agricultural activities on different soil textures contribute to greenhouse gas emissions?
4. Investigate the impact of soil texture on soil microbial communities and their role in organic matter decomposition. How do microbial activities vary across soil textures, and how does this affect carbon turnover rates?
5. What challenges and opportunities arise from implementing soil texture management strategies, like conservation tillage and cover crops, to enhance carbon sequestration across diverse soil types and mitigate climate change?

ACTIVITY: Exploring Surface Texture Locally

Objective: Students create soil maps to investigate variations in surface texture across diverse local areas and gain insight into factors influencing these differences.

1. Divide students into groups and ask each group to explore a specific local area (e.g., city, farmland, forest, riverbank, different socio-economic areas)
2. Guide students to WSS and demonstrate how to navigate through the system.
3. Provide time for each group to use WSS to create soil maps, focusing on the surface texture of their selected area.
4. Have each group add their maps to a shared class document or folder for display and discussion. Make sure that each group also includes information on where their AOI is located.
5. Facilitate a class discussion about the map(s) using the following prompts:
 - a. How does soil texture vary across different locations?
 - b. Identify areas on the soil texture maps with distinctive characteristics. What factors might contribute to these patterns? What natural factors contribute to variations in soil texture?
 - c. How might land use impact soil surface texture?
6. Conclude the discussion with each group sharing insights on:
 - a. possible human impacts on surface texture, such as construction or farming practices, and potential impacts on the carbon storage potential of soils.
 - b. the ways in which local communities could be involved in soil conservation efforts.

Soil pH

Soil pH, a measure of soil acidity or alkalinity, is influenced by various factors, including parent material, climate, vegetation, and human activities. These factors collectively shape the chemical composition of the soil and contribute to its pH level. Parent material, derived from geological sources, can introduce certain minerals and compounds that influence soil acidity or alkalinity. Climate, particularly precipitation patterns, can affect pH through leaching processes that remove ions from the soil. Vegetation exerts an influence through root exudates and organic matter decomposition, which can alter soil pH over time. Human activities, such as agriculture and industry, introduce chemicals and pollutants that can shift soil pH levels. Understanding the interplay of these factors is crucial for comprehending the dynamics of soil pH and its implications for ecosystem health and carbon storage.

Soil pH exerts influence on the intricate processes of carbon storage within the soil. One primary pathway through which pH impacts carbon storage is by affecting microbial activity. Microbial communities engaged in organic matter decomposition operate within an optimal pH range, which is specific to each community. Soils with pH levels beyond these ranges may experience diminished microbial activity, impacting the rate of decomposition and, subsequently, carbon storage.

Additionally, soil pH contributes to the stabilization of organic matter. In soils with neutral to slightly acidic pH, organic matter tends to be more stable and less susceptible to rapid decomposition. This stability arises from interactions between organic compounds and soil minerals, including the ions that influence pH. On the contrary, extremely acidic or alkaline soils may foster conditions that lead to increased decomposition rates, potentially affecting the overall carbon storage capacity. The pH-mediated stability of organic matter is an essential aspect of understanding how soil properties influence the longevity of carbon storage.

Soil pH also plays a role in determining the chemical forms of carbon present in the soil. The production of organic acids during decomposition influences the solubility and mobility of carbon compounds in the soil solution. Changes in pH levels can alter these chemical forms, thereby influencing the dynamics of carbon

storage. Understanding the chemical transformations that occur in response to varying pH conditions provides valuable insights into the mechanisms governing carbon sequestration.

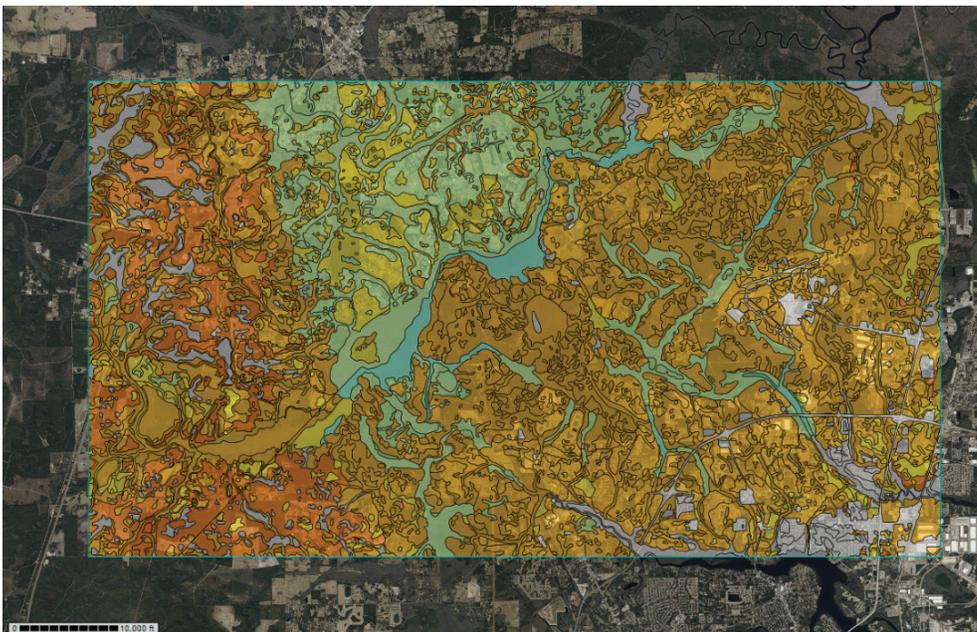
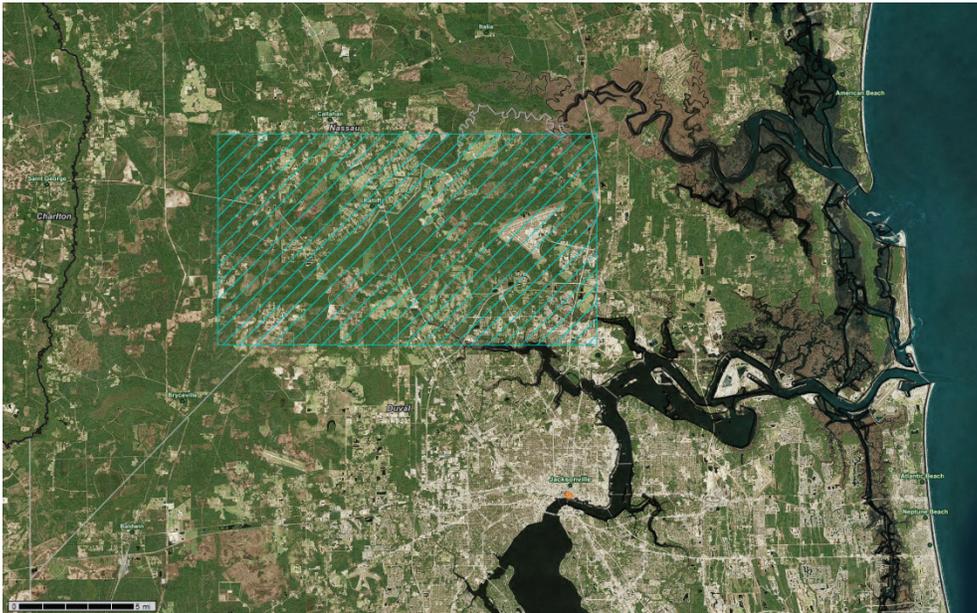
In addition to microbial activity and chemical transformations, soil pH influences plant productivity and, consequently, the amount of organic carbon input into the soil by roots. Plants have specific pH requirements for optimal water and mineral uptake from the soil, and variations in pH can impact nutrient availability. In turn, this can affect plant productivity and the quantity of carbon input through root exudates and organic residues. Recognizing the interconnectedness of pH with plant-mediated carbon input is crucial for comprehending the broader implications of soil pH on carbon storage. As soil pH regulates these multifaceted processes, sustainable soil management practices that address pH considerations contribute to optimizing conditions for effective carbon sequestration.

► *How to Get there on WSS*

Soil Data Explorer > Soil Properties and Qualities > Soil Chemical Properties > **pH (1 to 1 Water)** > select Surface Layer or All Layers

Soil pH (Jacksonville, Florida)

The first image displays the selected Area of Interest (AOI). Notice the city of Jacksonville is located just south of the selected AOI. The second image is the soil pH map for the same AOI. Areas in red and orange identify acidic soils, light green and blue identify areas with relatively neutral soils, and purple areas identify alkaline soils. What features may influence the soil pH in this area? Consider what the soil pH map may look like in an area farther away from the city. Explore different areas around Florida such as farmland, wetlands, forests, additional cities, and coastal areas.



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

Soil Rating Polygons

-  Ultra acid (pH < 3.5)
-  Extremely acid (pH 3.5 - 4.4)
-  Very strongly acid (pH 4.5 - 5.0)
-  Strongly acid (pH 5.1 - 5.5)
-  Moderately acid (pH 5.6 - 6.0)
-  Slightly acid (pH 6.1 - 6.5)
-  Neutral (pH 6.6 - 7.3)
-  Slightly alkaline (pH 7.4 - 7.8)
-  Moderately alkaline (pH 7.9 - 8.4)
-  Strongly alkaline (pH 8.5 - 9.0)
-  Very strongly alkaline (pH > 9.0)
-  Not rated or not available

Quick Review of Soil pH

Definition: Soil reaction is a measure of acidity or alkalinity. In general, soils that are either highly alkaline or highly acid are likely to be very corrosive to steel. The most common soil laboratory measurement of pH is the 1:1 water method. A crushed soil sample is mixed with an equal amount of water, and a measurement is made of the suspension.

Significance:

◆ **Nutrient Availability:** Soil pH directly influences the availability of essential minerals for plant growth. Different nutrient elements have varying solubilities across different pH ranges. For instance, acidic soils tend to have higher levels of aluminum and manganese toxicity, while alkaline soils may restrict the availability of phosphorus, iron, and zinc.

◆ **Microbial Activity:** Soil pH significantly influences microbial communities and their metabolic activities. Microorganisms responsible for nutrient cycling, organic matter decomposition, and disease suppression exhibit preferences for specific pH ranges.

◆ **Crop Productivity and Sustainability:** Optimal soil pH levels are essential for maximizing crop productivity and ensuring long-term sustainability in agricultural systems. pH management practices, such as liming acidic soils or acidification of alkaline soils, are critical for improving nutrient availability, enhancing microbial activity, and promoting healthy plant growth. Effective soil pH management contributes to resilient and productive agricultural ecosystems.

◆ **Soil Chemistry:** Soil pH directly influences soil chemistry, affecting the solubility and availability of various nutrients essential for plant growth and microbial activity. pH levels can influence chemical reactions such as nutrient transformations, mineral weathering, and the mobility of toxic elements, thereby shaping soil fertility and overall ecosystem dynamics.

◆ **Environmental Impact:** Soil pH levels can impact environmental processes such as nutrient leaching, metal toxicity, and soil erosion rates. Acidic soils, for instance, may increase the solubility of toxic elements like aluminum, posing risks to aquatic ecosystems through runoff and groundwater contamination. Conversely, overly alkaline soils may limit nutrient availability, affecting plant health and ecosystem productivity.

Extension Questions

1. How does soil pH influence the capacity of soils to store and sequester carbon, and how might changes in pH affect carbon cycling in terrestrial ecosystems?
2. What is the relationship between soil pH and microbial activity in organic matter decomposition, and how does pH variation impact the efficiency of carbon storage in soils?
3. How does soil pH determine the chemical forms of carbon present in the soil, and how might shifts in pH levels influence the mobility and stability of carbon compounds?
4. What are the implications of soil pH on plant productivity and carbon input into the soil through root exudates and organic residues, and how does pH variation affect the quantity and quality of carbon input by plants?
5. What challenges arise in managing soil pH in the context of climate change, and how can sustainable soil management practices address pH fluctuations to optimize carbon sequestration and mitigate climate-related impacts?

ACTIVITY: Soil pH Locally

Objective: Students create soil maps to explore variations in soil pH across diverse local areas and gain insights into the factors influencing these differences.

1. Divide students into groups, assigning each group to a specific local area (e.g., city, farmland, forest, riverbank, different socio-economic areas).
 - a. potential human impacts on soil pH and soil health, and ideas for sustainable land management.
 - b. the ways in which local communities could be involved in soil conservation efforts.
2. Guide students to the WSS and demonstrate how to navigate through the system.
3. Provide time for each group to use WSS to create soil map(s), focusing on soil pH within their selected area. Ask students to examine the soil pH at the surface and other depths in the soil.
4. Have each group add their maps to a shared class document or folder for display and discussion. Make sure that each group also includes information on where their AOI is located.
5. Facilitate a class discussion about the maps using the following prompts:
 - a. Discuss variations in soil pH across different locations and at varying depths.
 - b. Identify areas on the maps with high or low soil pH levels. Discuss potential factors contributing to these patterns and their impact on the local environment.
 - c. Examine how human activities, such as agriculture and urbanization, contribute to soil pH variations. Use evidence from the maps to substantiate claims.
 - d. Explore the influence of natural factors and human interventions on soil pH, such as influences of marine processes, presence of pine needles, areas with high rainfall or volcanic activity, urbanization, and/or agricultural practices.
 - e. Analyze how land use patterns affect soil pH and discuss implications for carbon sequestration.
6. Conclude the discussion with each group sharing insights on:

Depth to Any Soil Restrictive Layer

A soil restrictive layer refers to a soil layer that greatly limits the movement of water, air, and roots due to certain physical, chemical, or thermal properties. These layers can include bedrock, cemented layers, dense layers, and frozen layers, creating challenging conditions for plant growth and soil health.

The depth to any soil restrictive layer is intricately connected to climate dynamics that shape soil development. Factors such as precipitation, temperature, and vegetation patterns influence the formation of these restrictive layers. In regions with distinct climate characteristics, the interaction between climatic variables and soil processes can lead to the development of layers that impede water movement and root growth. This interplay is vital in understanding the broader context of carbon sequestration in soils.

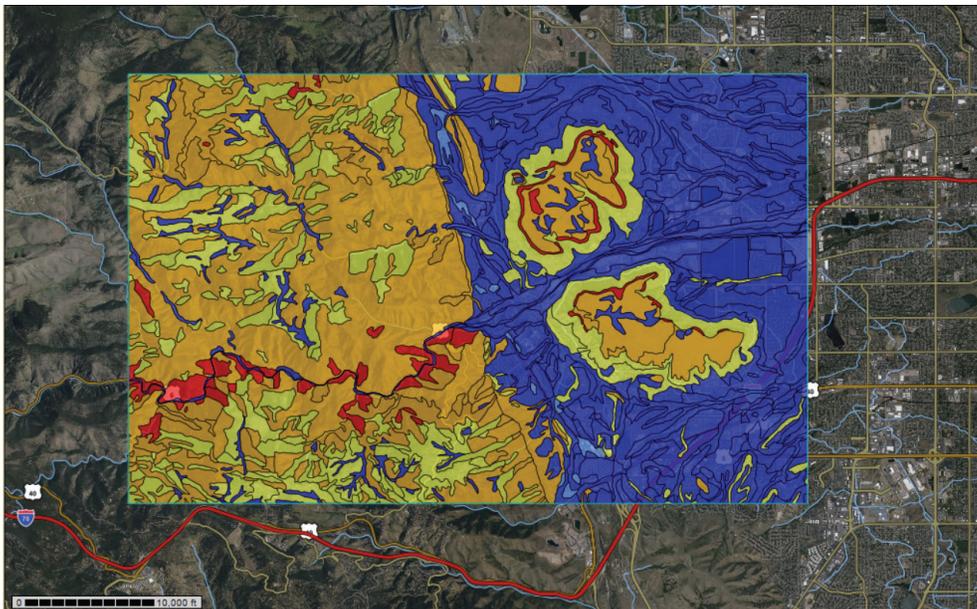
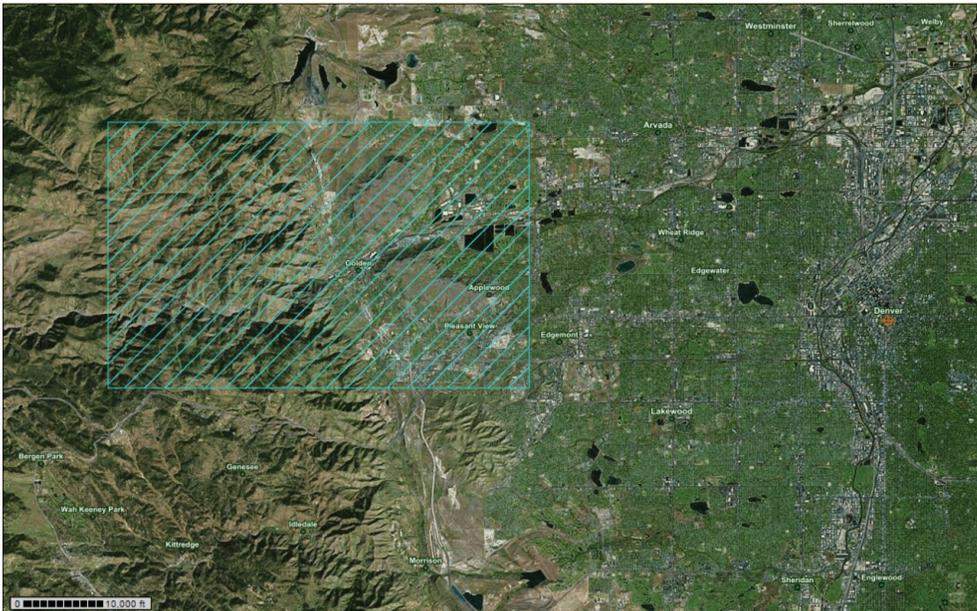
The depth to soil restrictive layers plays a crucial role in shaping the depth to which plant roots can penetrate. In areas where restrictive layers are present, root growth may be constrained, affecting the input of organic matter into the soil. Organic matter, derived from plant residues, contributes significantly to soil carbon content. Therefore, the depth and characteristics of soil restrictive layers directly impact the organic carbon inputs into the soil, influencing its potential for carbon sequestration.

► *How to Get there on WSS*

Soil Data Explorer > Soil Properties and Qualities
> Soil Qualities and Features > **Depth to Any Soil Restrictive Layer**

Depth to Any Restrictive Layer (Denver, Colorado)

The first image displays the selected Area of Interest (AOI) west of Denver. The second image is the map of depth to soil restrictive layer for the same AOI. Areas in dark blue have a restrictive layer > 200 cm, light blue 100-200 cm, yellow 50-100 cm, orange 25-50 cm, and red 0-25 cm. What might you predict the restrictive layer to be? (Remember, restrictive layers are typically compacted layers, dense clay horizons, or bedrock, that impede root growth, water infiltration, or nutrient movement through the soil profile.) Consider what the map may look like in other areas around Denver.



MAP LEGEND

Area of Interest (AOI)

-  Area of Interest (AOI)

Soils

Soil Rating Polygons

-  0 - 25
-  25 - 50
-  50 - 100
-  100 - 150
-  150 - 200
-  > 200
-  Not rated or not available

Quick Review of Depth to a Soil Restrictive Layer

Definition: A "restrictive layer" is a nearly continuous layer that has one or more physical, chemical, or thermal properties that significantly impede the movement of water and air through the soil or that restrict root growth or otherwise provides an unfavorable environment for roots. Examples are bedrock, cemented layers, dense layers, and frozen layers.

Significance:

◆ **Root Penetration:** The depth to restrictive layers determines the depth to which plant roots can penetrate the soil profile, influencing plant growth, nutrient uptake, and overall ecosystem productivity. Shallow restrictive layers can restrict root development, limiting access to water and nutrients, and impacting vegetation composition and diversity.

◆ **Water Movement:** The depth to restrictive layers influences water drainage and infiltration rates, which are critical for managing soil moisture levels and preventing waterlogging. Shallow restrictive layers can impede water movement, leading to poor drainage and increased risk of waterlogged conditions, affecting plant growth and soil health.

◆ **Soil Stability:** The depth to any soil restrictive layer is fundamental in assessing soil stability and its ability to support structures, roads, and vegetation. Understanding the depth to restrictive layers helps in planning construction projects, as shallow restrictive layers may necessitate special engineering solutions to prevent structural failure or soil instability.

◆ **Land Use Planning:** Depth to restrictive layers informs land use planning and agricultural practices, such as guiding decisions on crop selection and irrigation. Shallow restrictive layers may limit development options or require special engineering considerations, influencing zoning regulations and development policies to ensure sustainable land use practices and minimize environmental impact.

◆ **Carbon Sequestration:** The depth to restrictive layers significantly affects soil conditions crucial for carbon sequestration, influencing organic matter input, microbial activity, and decomposition rates. Soils with shallow restrictive layers may impede root penetration and limit organic matter accumulation, thus affecting the capacity of the soil to store carbon.

Extension Questions

1. How does the presence of restrictive layers impact the movement of water and air within the soil, and consequently, the availability of nutrients for plant growth and microbial activity?
2. Discuss the implications of soil restrictive layers on root penetration and plant development. How might plants adapt to or struggle with these conditions, and how does this influence carbon input into the soil?
3. Explore the relationship between soil depth, restrictive layers, and carbon sequestration potential. How might the depth to restrictive layers influence the storage and turnover of organic matter in the soil?
4. Consider the role of soil management practices, such as tillage and amendment application, in mitigating the effects of restrictive layers on carbon sequestration. How can these practices be optimized to enhance carbon storage in soils with restrictive layers?
5. Investigate the long-term consequences of soil restrictive layers on soil structure, fertility, and resilience to environmental stressors. How might changes in climate patterns exacerbate or mitigate the impacts of restrictive layers on carbon dynamics in the soil?

ACTIVITY: Depth to Restrictive Layer Locally

Objective: Students create soil maps to investigate variations in depth to restrictive layers across diverse local areas and gain insight into factors influencing these differences.

1. Divide students into groups and ask each group to explore a specific local area (e.g., city, farmland, forest, riverbank, different socio-economic areas).
2. Guide students to WSS and demonstrate how to navigate through the system.
3. Provide time for each group to use WSS to create soil maps, including the “Depth to Any Restrictive Layer” and also “Depth to Bedrock” of their selected AOI.
6. Conclude the discussion with each group sharing insights on:
 - a. Possible implications of depth to restrictive layers for agriculture and natural resource management. How might farmers and environmental planners adapt their practices based on soil depth limitations?
 - b. The broader significance of soil depth and restrictive layers in the context of global environmental challenges, such as climate change and land degradation.

Note: *When soil scientists conduct fieldwork, they sample down to 200 cm. If there is a restrictive layer within that 200 cm, it is included in WSS. If scientists did not encounter a restrictive layer, that area is classified as >200 cm.*

4. Have each group add their maps to a shared class document or folder for display and discussion. Make sure that each group also includes information on where their AOI is located.
5. Facilitate a class discussion about the map(s) using the following prompts:
 - a. Discuss the variations in depth to restrictive layers across different locations. What patterns do you observe?
 - b. Identify areas with shallow or deep restrictive layers on the maps. What factors might contribute to these differences?
 - c. Consider the role of geological processes in shaping soil depth. How might factors like erosion, deposition, and weathering influence the presence of restrictive layers?
 - d. Analyze how land use patterns influence the depth to restrictive layers. How might human activities such as urbanization or agriculture impact soil depth?
 - e. Consider the implications of >200 cm soil depth classifications. What challenges might arise when interpreting soil maps with depths exceeding 200 cm?

CULMINATING ACTIVITY: Exploring Soil Health and Carbon Dynamics using Web Soil Survey Maps

Objective: Students will analyze soil data to investigate the relationship between soil properties and carbon sequestration.

Connections

NGSS

DCI: Earth's Systems, Earth and Human Activity

SEP: Analyzing and Interpreting Data, Developing and Using Models, Obtaining, Evaluating, and Communicating Information

CCC: Patterns, Cause and Effect, Systems and System Models

SDGs

2: Zero Hunger

4: Quality Education

11: Sustainable Cities and Communities

12: Responsible Consumption and Production

13: Climate Action

15: Life on Land

Activity

1. Begin with a brief discussion about the importance of soil in carbon sequestration and its role in maintaining ecosystem stability. Emphasize the concept of stability and change in soil properties.
2. Guide students to the WSS and demonstrate how to navigate through the system.
3. Instruct students to choose different study areas on the Web Soil Survey platform. Encourage them to explore diverse regions, considering factors like land use and vegetation types. Some locations could include:
 - ▶ **Olympic National Forest, Washington:**
This region is characterized by dense forests and diverse ecosystems. Explore the soils in the Olympic National Forest to understand how the temperate rainforest environment influences soil health and carbon storage.

- ▶ **Tallgrass Prairie National Preserve, Kansas:**
The Tallgrass Prairie region has unique grassland ecosystems. Investigate the soils in this area to explore possible relationships between the grassland environment and soil characteristics that impact carbon sequestration in a prairie setting.
- ▶ **Okefenokee Swamp, Georgia:**
Wetlands, such as the Okefenokee Swamp, play a crucial role in carbon storage. Explore soils in this swampy area to understand how waterlogged conditions impact soil health and organic carbon content.
- ▶ **Rocky Mountain National Park, Colorado:**
The Rocky Mountains present diverse ecosystems, from alpine environments to subalpine forests. Investigate soils in this region to understand the impact of altitude and vegetation on soil properties and carbon dynamics.
- ▶ **Adirondack Mountains, New York:**
Explore the soils in the Adirondack Mountains to understand how the northern hardwood forests influence soil health and organic carbon storage.
- ▶ **Sonoran Desert, Arizona:**
Arid environments present unique challenges for soil health. Explore soils in the Sonoran Desert to understand how low precipitation and specific plant adaptations influence soil properties and carbon dynamics.
- ▶ **Chicago, Illinois:**
Areas like downtown Chicago offer a unique environment for studying soil dynamics in an urban setting. Investigate soils in this area to understand how urbanization and infrastructure impact soil health and carbon storage in densely populated regions.

4. Have students create maps of the soil data of their chosen areas. Ask them to analyze and compare soil properties, focusing on organic carbon content, soil texture, and pH. Ask students to also make note of when the data was made available for their AOI, found in the “AOI Properties” left side bar.
5. Facilitate a class discussion based on the students' findings. Encourage them to share the variations they observed in soil properties among different locations. Discuss how these variations might influence carbon sequestration and overall ecosystem stability. Some example discussion questions could include the following, which can be adapted based on the AOIs that students choose:
 - ▶ How do the soil characteristics in the Pacific Northwest (Olympic National Forest) differ from those in the Southeast (Okefenokee Swamp)? Discuss how these differences may impact the potential for carbon sequestration in these ecosystems.
 - ▶ Based on the soil data from the Great Plains (Tallgrass Prairie National Preserve), how does the presence of grasslands contribute to carbon storage? Consider the role of root systems and microbial activity in these ecosystems.
 - ▶ Explore how the soil properties in the Rocky Mountains (Rocky Mountain National Park) differ from those in the Sonoran Desert (Arizona). How does the climate of each region impact soil health, and consequently, the potential for carbon sequestration?
 - ▶ In the Adirondack Mountains (Northeast), discuss any indications of human influence on soil health and carbon dynamics. Consider factors such as land use history, deforestation, or other anthropogenic activities.
 - ▶ Analyze the data from the Southwest (Sonoran Desert) and the Southeast (Okefenokee Swamp) to compare the role of wetlands in carbon sequestration. How do the waterlogged conditions in the swamp contribute to organic carbon storage compared to the arid conditions in the desert?
6. Guide students in identifying patterns and relationships between soil properties and carbon sequestration potential. Discuss how certain soil characteristics contribute to the stability or change in carbon storage.
7. Ask students to consider the broader implications of their findings and how understanding soil properties contributes to sustainable land management.

Climate-related Natural Hazards

Climate-related natural hazards are extreme events or processes that occur or are exacerbated due to climate conditions and can have significant impacts on ecosystems and human communities. These hazards, such as floods, hurricanes, droughts, and wildfires, are influenced by changes in temperature, precipitation patterns, and other climate-related factors. Soil plays a crucial role in the response and impact of these hazards. For instance, in floods, the type of soil and its condition determines its ability to absorb and retain water, affecting the extent of flooding. In droughts, soil moisture levels influence water availability for plants and contribute to the severity of the drought's impact on agriculture. Understanding the interplay between climate-related natural hazards and soil conditions is essential for developing effective strategies to manage and mitigate the consequences of these events on both natural and human systems.

This guide will cover select interpretations related to natural hazards that are affected by climate. Visit the *Web Soil Survey Teachers Guide – Natural Hazards* for more information and interpretations related to natural hazards.

Soil properties to examine related to climate-related natural hazards

- ◆ Hydrologic soil group
- ◆ Slope
- ◆ Organic matter
- ◆ Drought vulnerable soils

NGSS Alignment

MS-ESS3-2 focuses on analyzing and interpreting data on natural hazards to forecast future catastrophic events and mitigate their impacts. Students can explore how soil composition, moisture content, and slope influence the likelihood and severity of hazards like landslides, floods, and erosion. By examining soil data in the context of climate-related events, students can discern patterns and make predictions about the vulnerability of different areas to these hazards.

HS-ESS3-1 emphasizes using geoscience data to forecast the effects of climate change on Earth's systems. Soil's role in climate regulation and its response to changing climatic conditions are integral components of this standard.

Students can investigate how soil moisture, temperature, and organic matter content impact climate feedback mechanisms, such as the release of greenhouse gases. By studying soil data in conjunction with climate models, students can develop a deeper understanding of how soil processes can either exacerbate or mitigate climate and its effects on the environment.

Sustainable Development Goals

11: Sustainable Cities and Communities: Soil management practices are essential for building climate-resilient cities and communities. Proper soil management can mitigate the impacts of climate change-related hazards such as flooding, erosion, and landslides, thereby enhancing the sustainability and resilience of urban areas.

13: Climate Action: SDG 13 directly addresses climate change and its impacts. Soil management practices can contribute to climate change mitigation and adaptation efforts by enhancing carbon sequestration, reducing greenhouse gas emissions, and improving soil resilience to extreme weather events.

15: Life on Land: Emphasizing the importance of protecting, restoring, and promoting the sustainable use of terrestrial ecosystems, SDG 15 highlights the pivotal role of healthy soils in mitigating climate change impacts, preserving biodiversity, and reducing the vulnerability of ecosystems to climate-related hazards.

Hydrologic Soil Group

The classification of soils into different Hydrologic Soil Group (HSG) categories is based on their infiltration and water transmission characteristics, providing valuable insights into their behavior during various climatic events. High SDG soils, often characterized by their sandy or coarse-textured compositions, exhibit rapid infiltration rates and efficient water transmission. In contrast, low HSG soils, typically comprised of clayey or fine-textured materials, have limited infiltration capacities and slower water movement. A soil's HSG is intricately linked to climate-related natural hazards, serving as a key determinant in how soils respond to water movement and drainage.

One significant implication of HSG is its role in flooding scenarios. Soils with poor infiltration rates are more susceptible to surface runoff, contributing to flash floods during intense rainfall or storms. This understanding aids in predicting flood-prone areas. Urban flooding, a growing concern in the face of climate change, is also linked to HSG. Urban areas with significant impervious surfaces and compacted soils may exhibit characteristics akin to higher HSG soils, contributing to urban flooding during extreme weather events. Understanding the HSG of urban soils is essential for sustainable urban planning, stormwater management, and infrastructure resilience, ensuring cities can withstand the challenges posed by a changing climate.

The susceptibility of soils to drought conditions is another aspect related to HSG. Some soils possess better infiltration and water retention capacities, which may make them more susceptible to drought due to faster drainage. This knowledge becomes vital in regions experiencing prolonged droughts or water scarcity, helping to assess soil water availability and anticipate potential impacts on agriculture, water resources, and ecosystems.

Landslides, exacerbated by climate-related events, are influenced by Hydrologic Soil Group (HSG) classifications. Soils characterized by poor drainage and reduced stability are more prone to landslides, especially during intense rainfall, a common consequence of climate change, which can saturate these soils and elevate the risk. Recognizing the HSG of soils allows for the identification of regions

vulnerable to landslides, enabling proactive measures for hazard mitigation and risk reduction. Similarly, erosion risk, particularly during extreme weather events, is influenced by HSG. Soils with poor infiltration rates are prone to surface runoff and erosion, with increased rainfall intensity leading to elevated erosion rates in areas with higher HSG soils. This has broader implications for soil health, sediment transport in water bodies, and ecosystem stability.

► *How to Get there on WSS*

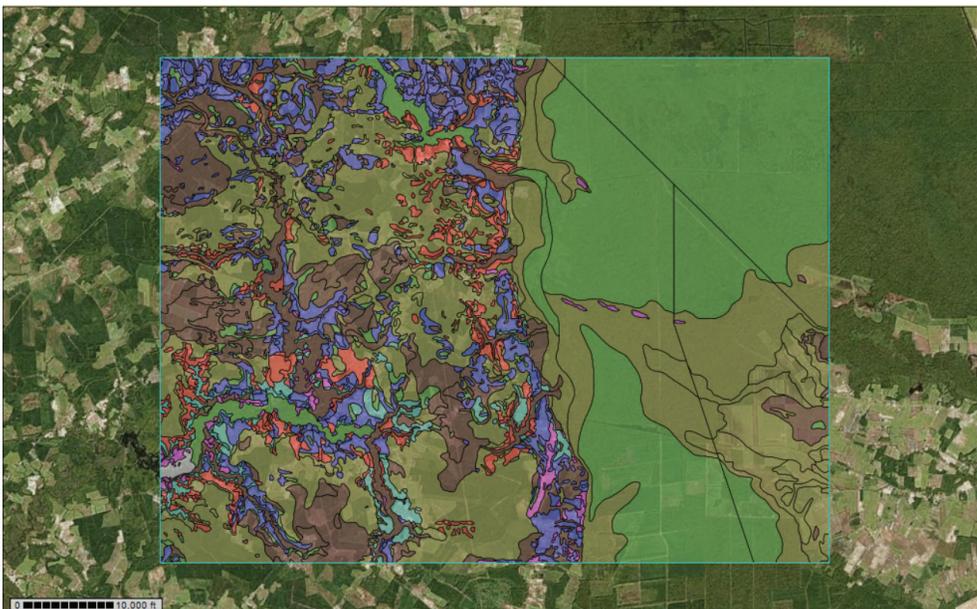
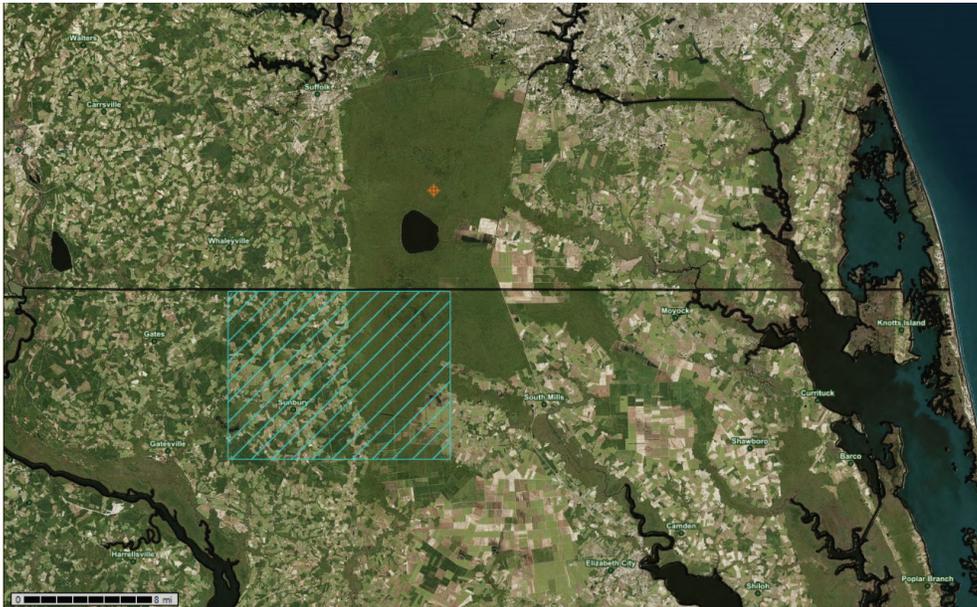
Soil Data Explorer > Soil Properties and Qualities > Soil Qualities and Features > **Hydrologic Soil Group**

HSG Group Descriptions

- ◆ **Group A** soils have a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.
- ◆ **Group B** soils have a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.
- ◆ **Group C** soils have a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.
- ◆ **Group D** soils have a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.
- ◆ **If a soil** is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas. The second letter is always a D, representing the soils in their natural, undrained state.

Hydrologic Soil Group (Great Dismal Swamp, North Carolina)

The first image shows the selected AOI in North Carolina, which includes a portion of the Great Dismal Swamp. The second image is the hydrologic soil group map of the same AOI. Examine the group descriptions and the map. How might the HSG group in the swamp be beneficial for the surrounding areas? Explore the soils of different areas around the swamp and make comparisons to other wetland areas such as the Everglades National Park in Florida, the Atchafalaya Basin in Louisiana, or the Sacramento-San Joaquin Delta in California.



Soil Rating Polygons

-  A
-  A/D
-  B
-  B/D
-  C
-  C/D
-  D
-  Not rated or not available

Quick Review of Hydrologic Soil Groups

Definition: Hydrologic Soil Groups (HSG) classify soils based on their infiltration and water transmission properties. HSG soils are categorized from A to D, with A representing soils with the highest infiltration rates and D representing soils with the lowest infiltration rates.

Significance:

- ◆ **Water Runoff and Infiltration:** HSG determines soil's capacity for water runoff and infiltration, influencing flood risk and informing land use decisions.
- ◆ **Flood Risk Assessment:** HSG is critical for assessing flood susceptibility. Soils with higher runoff potential, such as soils in HSG D, contribute to increased flash flood risks, impacting communities and infrastructure.
- ◆ **Drought Susceptibility:** Relevant to drought conditions, HSG helps identify soils that may mitigate or exacerbate drought impact, informing water management strategies. For example, soils categorized as HSG A may mitigate the impact of drought by efficiently retaining moisture and supporting plant growth during periods of water scarcity. Conversely, soils classified as HSG D may exacerbate drought impact by limiting water availability for vegetation and contributing to soil moisture deficits.
- ◆ **Land Management:** HSG guides decisions on water conservation, irrigation, and erosion control, impacting sustainable land use and stormwater management. For example, urban development projects in regions with HSG D soils may necessitate careful planning to mitigate the risk of flooding and soil erosion, especially during heavy rainfall events.

◆ **Environmental Impact:** HSG contributes to assessing the environmental impact of land use changes affecting flood risk and the broader water cycle. For example, deforestation activities in regions characterized by HSG A soils may exacerbate soil erosion and sedimentation in water bodies, impacting aquatic ecosystems and water quality.

Extension Questions

1. What factors determine the classification of soils into high and low Hydrologic Soil Groups?
2. How does the classification of soils into Hydrologic Soil Groups influence their response to climate-related hazards?
3. How does climate change affect the behavior of soils classified into different HSG categories?
4. What strategies can be employed to mitigate erosion and landslide risks in regions with high HSG soils?
5. What are the socio-economic impacts of climate-related hazards associated with Hydrologic Soil Groups?

ACTIVITY: Exploring Hydrologic Soil Groups

Objective: Students explore Hydrologic Soil Group (HSG) interpretations to analyze implications for climate-related natural hazards.

1. Divide students into groups and assign each group a specific area. Assign one group a local area, and other groups different areas such as areas in coastal regions, mountainous terrain, agricultural landscapes, urban environments, and/or wetland ecosystems.
2. Guide students to WSS and demonstrate how to navigate through the system.
3. Provide time for each group to explore HSG interpretations for their assigned area and create soil maps.
4. Instruct each group to add their maps to a shared class document or folder for display and discussion, including information about the region they examined.
5. Facilitate a class discussion using the following prompts:
 - a. How do HSG classifications vary across different areas?
 - b. Identify areas on the maps with high and low HSG classifications. What factors might contribute to these variations?
 - c. How might changes in HSG influence climate-related hazards such as erosion, flooding, and landslides?
 - d. What are the potential impacts of HSG on local communities, infrastructure, and ecosystems?
6. Conclude the discussion with each group sharing insights on:
 - a. Potential human activities that may influence HSG, such as urban development, agricultural practices, or deforestation.
 - b. Strategies for integrating HSG considerations into land use planning, conservation efforts, and climate resilience initiatives.

Slope

The slope of the terrain plays a significant role in the susceptibility of an area to various hazards associated with climate change. In regions with steep slopes, the risk of landslides and soil erosion is heightened, particularly during extreme weather events such as heavy rainfall or storms. Steeper slopes are more prone to surface runoff, even during non-extreme weather events, which can lead to flash floods and increased erosion rates. With climate change contributing to more intense and frequent precipitation, areas with steep slopes become more vulnerable to these hazards.

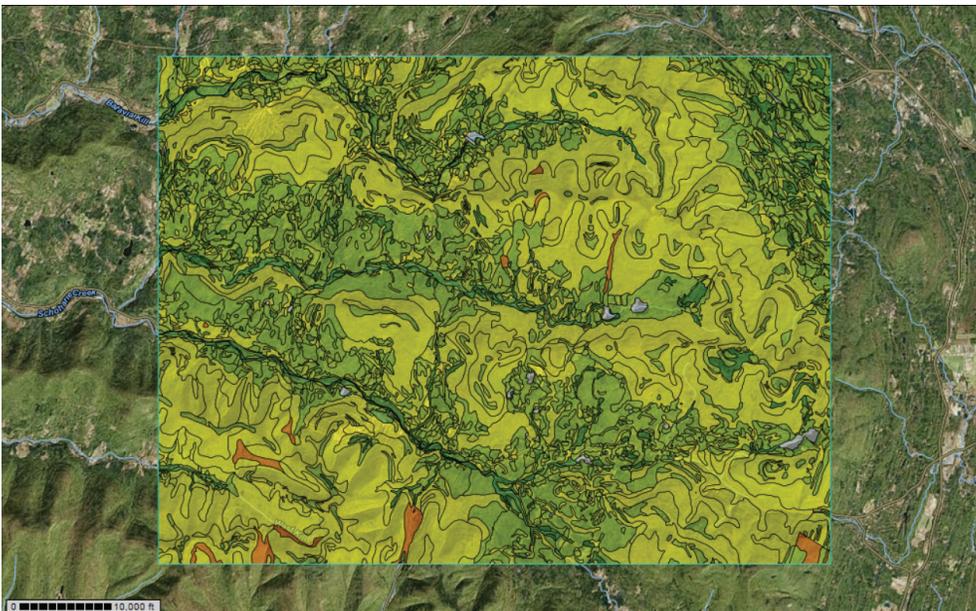
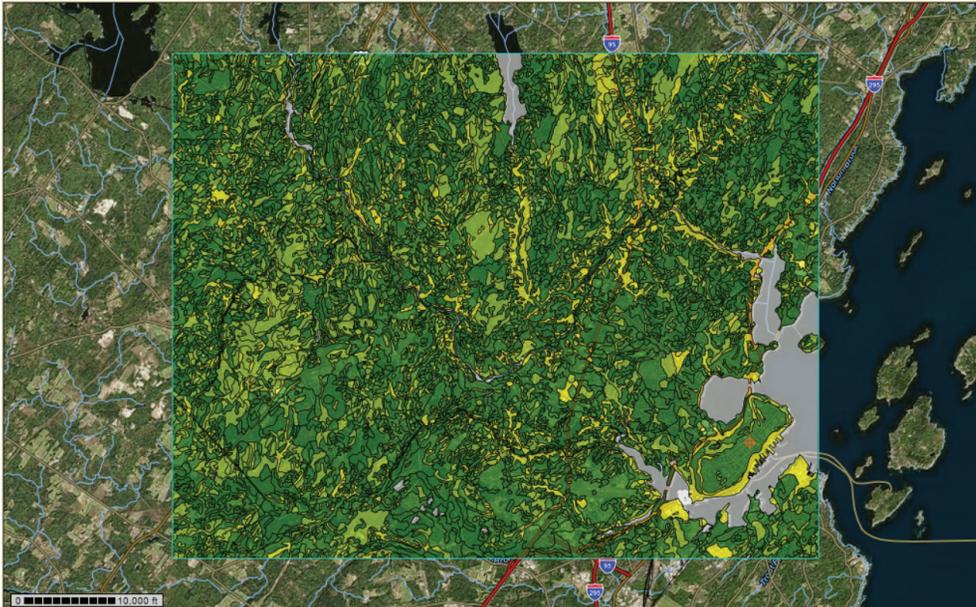
Conversely, flatter representative slopes may experience challenges related to drainage during periods of increased precipitation. Poor drainage on flat terrain can result in waterlogging, affecting soil health, agricultural productivity, and potentially causing urban flooding. Understanding the representative slope of an area is crucial for predicting and managing these climate-related natural hazards.

► ***How to Get there on WSS***

Soil Data Explorer > Soil Properties and Qualities > Soil Qualities and Features > **Representative Slope**

Slope (Portland, Maine and Albany, New York)

In the two maps of representative slope below, green areas are flatter areas with low to no slope, yellow and orange areas have moderate slopes, and red areas are steep areas with high slopes (not shown in either of the maps below). Compare the maps of Portland, Maine and southwest Albany, New York. How do the representative slope maps differ? What could you infer about the landscape in these areas? Neither location has areas of high slope; use your knowledge of U.S. landscape and topography to locate areas with high representative slope on WSS.



Quick Review of Slope

Definition: Slope gradient is the difference in elevation between two points, expressed as a percentage of the distance between those points. A higher percentage represents a steeper slope.

Significance:

◆ **Erosion Control:** Slope plays a crucial role in determining erosion susceptibility. Areas with steep slopes are more prone to soil erosion, especially during intense rainfall events or human activities such as deforestation and construction.

◆ **Landscape Stability:** The slope gradient affects land stability and the risk of mass movements such as landslides and debris flows. Steep slopes are inherently less stable and more susceptible to slope failure, posing hazards to infrastructure, property, and human safety.

◆ **Hydrological Dynamics:** Slope gradient significantly influences hydrological processes such as surface runoff, erosion, and infiltration. Steeper slopes tend to experience higher rates of runoff and erosion, leading to increased soil loss and reduced water retention capacity.

◆ **Soil Moisture Distribution:** Slope influences the distribution of soil moisture within a landscape. Higher slopes often experience rapid drainage, resulting in drier soil conditions, while lower slopes and valley bottoms may retain moisture for longer periods, supporting different vegetation communities and ecosystem functions.

◆ **Land Use Planning:** Understanding slope characteristics is essential for effective land use planning and sustainable development. Knowledge of slope gradients helps identify suitable areas for various activities such as agriculture, urbanization, and infrastructure development while minimizing environmental risks and optimizing resource management strategies.

Extension Questions

1. How might the steepness of a slope influence the susceptibility to climate-related hazards such as landslides and soil erosion?
2. What are some examples where human activities have exacerbated slope instability and increased the risk of natural hazards?
3. What role does vegetation play in stabilizing slopes and mitigating the impact of climate-related hazards?
4. How do variations in soil composition and moisture content affect the stability of slopes during extreme weather events?
5. In what ways can engineering solutions, such as terracing or slope stabilization structures, help mitigate the risks associated with sloping terrain and climate-related hazards?

ACTIVITY: Exploring Representative Slope Interpretations

Objective: Students will investigate representative slope interpretations in different regions using the Web Soil Survey (WSS) platform and analyze their implications for climate-related natural hazards.

1. Divide students into groups and assign each group a specific area. Assign one group a local area, and other groups different areas such as areas in coastal regions, mountainous terrain, agricultural landscapes, urban environments, and/or wetland ecosystems.
2. Guide students to WSS and demonstrate how to navigate through the system.
3. Provide time for each group to explore the WSS and locate representative slope interpretations for their assigned areas.
4. Instruct each group to add their maps to a shared class document or folder for display and discussion, including information about the region they examined.
5. Encourage students to discuss the potential climate-related natural hazards associated with the identified slope characteristics, such as landslides, soil erosion, and sedimentation.
6. Facilitate a class discussion based on the following prompts:
 - a. How do slope angles vary across different regions or landscapes?
 - b. What are the potential implications of steep slopes for soil stability and erosion during heavy rainfall or storms?
 - c. How might human activities, such as deforestation or urbanization, impact slope stability and increase the risk of natural hazards?
 - d. Discuss the importance of vegetation in stabilizing slopes and reducing the risk of erosion and landslides.
7. Conclude the discussion with each group sharing insights on:
 - a. Strategies for mitigating the impact of climate-related hazards on sloping terrain, such as erosion control measures and slope stabilization techniques.
 - b. How might landslides, erosion, or sedimentation affect local communities, infrastructure, and economies in regions with varied slope angles?

Organic Matter

Organic matter content in soil emerges as a pivotal factor in shaping the landscape's response to climate-related natural hazards. One of its primary roles lies in influencing water dynamics. Soils enriched with organic matter exhibit improved water retention, a quality that proves invaluable in mitigating the aftermath of flooding events. By enhancing soil structure and permeability, organic matter facilitates water infiltration, reducing surface runoff and lowering the risk of flash floods, particularly in regions vulnerable to intense and sudden rainfall.

The impact also extends to erosion control, offering a shield against the forces of weather. The stability and structure provided by organic matter make soils more resistant to erosion during extreme weather events. This safeguards the integrity of the soil and contributes to broader environmental goals by preventing sedimentation in bodies of water and maintaining ecosystem stability.

Organic matter's influence extends beyond wet conditions, proving vital in the face of drought-related challenges. Its ability to enhance soil water-holding capacity becomes a crucial asset during dry periods. Soils rich in organic content act as reservoirs, retaining moisture and providing a buffer against the adverse effects of water scarcity. This is particularly significant for sustaining agriculture, supporting plant growth, and preserving the overall health of ecosystems in regions susceptible to prolonged droughts.

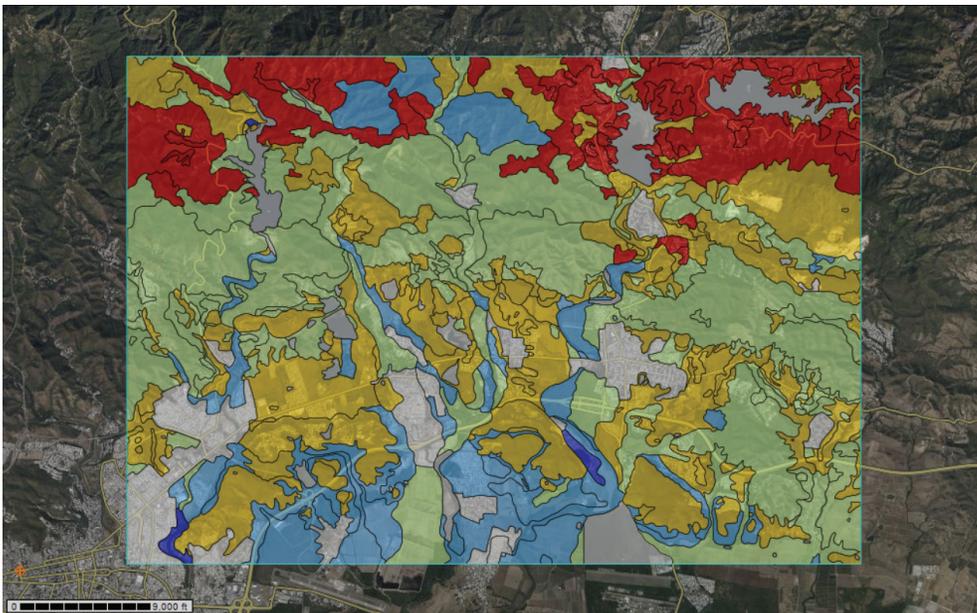
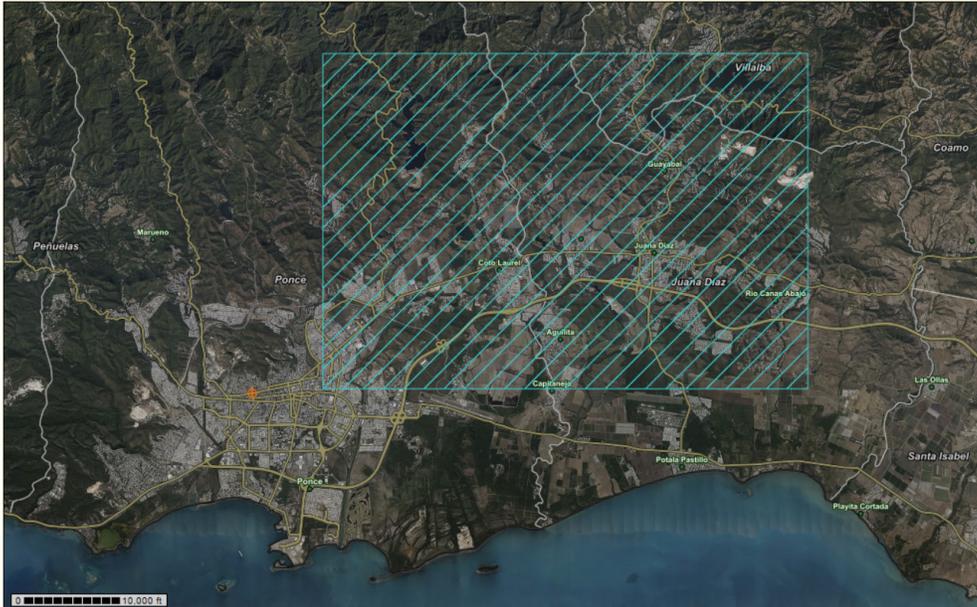
Additionally, the role of organic matter in regulating soil temperature underscores its importance in climate resilience. As an insulating layer, organic matter helps moderate soil temperatures, offering protection during extreme temperature events associated with climate change. This, in turn, ensures the well-being of plant roots and soil organisms, contributing to the overall resilience of ecosystems in the face of climatic uncertainties.

► *How to Get there on WSS*

Soil Data Explorer > Soil Properties and Qualities
> Soil Health Properties > **Soil Health –
Organic Matter**

Organic Matter (Ponce, Puerto Rico)

The first image displays the selected Area of Interest (AOI). Notice the city of Ponce, Puerto Rico is towards the southwest of the selected AOI. The second image is the Soil Health – Organic Matter soil map of the AOI. Areas in red and yellow have low amounts of organic matter, whereas areas in green and blue have higher amounts of organic matter. Consider what the Organic Matter map may look like in an area farther away from the city. Explore various regions across Puerto Rico and analyze the variations in organic matter content across different landscapes.



Quick Review of Organic Matter

Definition: Organic Matter is the weight of decomposed plant, animal, and microbial residues expressed as a percentage of soil material less than 2 mm in diameter.

Significance:

◆ **Erosion Control:** Organic matter plays a critical role in preventing soil erosion by enhancing soil structure and stability. Soils rich in organic matter are less susceptible to erosion during heavy rainfall or wind events, reducing the risk of sediment runoff and associated natural hazards such as landslides and flash floods.

◆ **Slope Stability:** Organic matter contributes to slope stability by promoting soil aggregation and root development. It helps bind soil particles together, reducing the likelihood of slope failures and landslides, particularly on steep terrain prone to mass movements.

◆ **Flood Mitigation:** Soils with higher organic matter content have better water infiltration rates, allowing them to absorb and retain excess rainfall during flood events. This reduces surface runoff and minimizes the risk of flash flooding in low-lying areas, contributing to natural hazard mitigation and improved flood resilience.

◆ **Drought Resilience:** Organic matter enhances soil water retention capacity, providing a buffer against drought conditions. Soils rich in organic matter can hold moisture for longer periods, supporting vegetation survival during extended dry spells and reducing the vulnerability of ecosystems to drought-related hazards such as wildfire and habitat degradation.

◆ **Climate Resilience:** Managing and preserving organic matter is vital for building climate-resilient ecosystems, fostering soil health, nutrient availability, and sustainable agricultural practices. Organic matter plays a crucial role in temperature stabilization within soils, helping to mitigate the impacts of extreme temperature fluctuations and maintaining a conducive environment for microbial activity and nutrient cycling.

Extension Questions

1. How does the depletion of soil organic matter contribute to increased vulnerability to climate-related natural hazards such as erosion, landslides, and flooding?
2. Discuss the role of soil organic matter in regulating soil moisture levels and its implications for mitigating drought conditions and waterlogging during extreme weather events.
3. How do changes in soil organic matter content influence soil structure and stability, particularly in regions prone to landslides and soil subsidence?
4. Explore the relationship between soil organic matter and carbon sequestration potential. How can enhancing soil organic matter contribute to climate change mitigation and adaptation efforts?
5. Investigate the impact of agricultural practices, land-use changes, and deforestation on soil organic matter levels. How can sustainable land management practices help to preserve and enhance soil organic matter content, thus reducing the susceptibility of ecosystems to climate-related natural hazards?

ACTIVITY: Exploring Carbon Content and Climate-Related Natural Hazards

Objective: Students investigate variations in soil organic matter across diverse local areas using the Web Soil Survey (WSS) platform and discuss its implications for climate-related natural hazards.

1. Divide students into groups and ask each group to explore a specific local area (e.g., city, farmland, forest, riverbank, different socio-economic areas)
2. Guide students to the WSS and demonstrate how to navigate through the system.
3. Provide time for each group to use WSS to create soil maps, focusing on organic matter of their selected AOI.
4. Have each group add their maps to a shared class document or folder for display and discussion. Make sure that each group also includes information on where their AOI is located.
5. Facilitate a class discussion about the maps using the following prompts:
 - a. Identify areas with high or low levels of soil organic matter on the maps and discuss potential factors contributing to these patterns.
 - b. Discuss the variations in soil organic matter content across different locations and hypothesize reasons for these differences.
 - c. Analyze how land use patterns, such as agriculture and urbanization, influence soil organic matter content and its implications for climate-related natural hazards.
 - d. Explore the interplay between natural factors and human interventions in shaping soil organic matter content.
6. Conclude the discussion with each group sharing insights on:
 - a. Potential human impacts on soil health, and ideas for sustainable land management.
 - b. Ways in which local communities could be involved in soil conservation efforts.

Drought Vulnerable Soils

Drought-vulnerable soils are those that exhibit characteristics contributing to water stress in plants, particularly during periods of limited precipitation or high evapotranspiration. These characteristics include low water storage capacity, inherent inability to retain sufficient water for plant growth, and environmental factors such as low annual precipitation or high temperatures. The susceptibility of these soils to prolonged drought conditions is a key concern, as their poor water retention capacities can lead to decreased soil moisture levels. This, in turn, contributes to elevated risks of wildfires, particularly in regions experiencing dry climatic conditions. The lack of soil moisture makes vegetation more susceptible to ignition, fostering an environment in which wildfires can spread rapidly.

Moreover, drought-vulnerable soils pose additional hazards, such as the potential for land subsidence. In areas where soils shrink and swell with changes in moisture content, prolonged drought can trigger soil shrinkage, resulting in the settling or sinking of the land surface. This phenomenon can have detrimental effects on infrastructure, damaging buildings, roads, and pipelines. Additionally, because these soils often cannot support plant growth, their reduced ground cover makes them prone to erosion during extreme weather events, exacerbating sedimentation in bodies of water, which can negatively impact water quality.

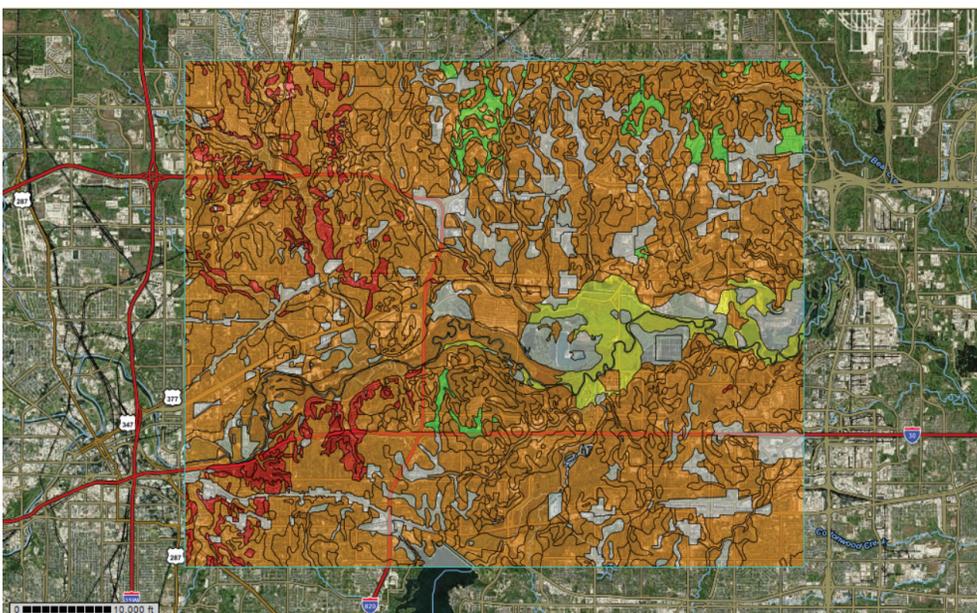
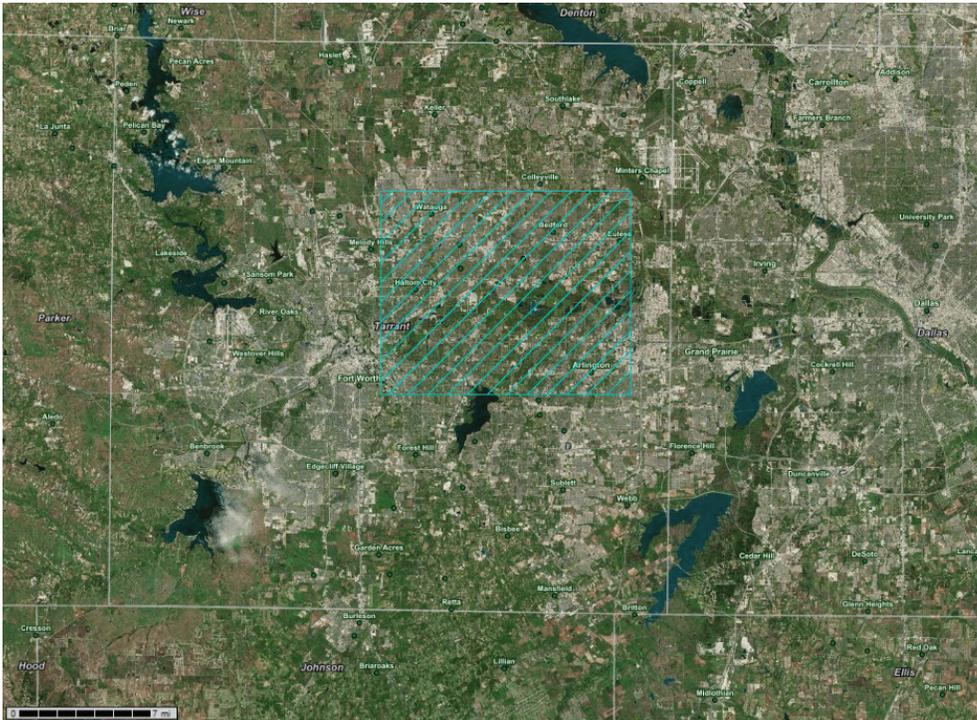
The agricultural sector is also significantly affected, as drought-vulnerable soils may not retain sufficient moisture for crops to thrive. Prolonged drought conditions can lead to diminished crop yields, soil degradation, and increased vulnerability to other climate-related hazards, such as heat stress on crops. Addressing the challenges posed by drought-vulnerable soils involves implementing mitigation and adaptation strategies, including sustainable land management practices, water conservation initiatives, and the development of drought-resistant crop varieties. This holistic understanding of the relationship between drought-vulnerable soils and climate-related hazards is vital for formulating resilient strategies to navigate the complex challenges posed by a changing climate.

► *How to Get there on WSS*

Soil Data Explorer > Suitabilities and Limitations for Use > Land Management > **Drought Vulnerable Soils**

Drought Vulnerable Soils (Dallas, Texas)

The first image shows the selected AOI in Texas between Dallas and Fort Worth. The second image is the drought vulnerable soils map of the same AOI. Areas in orange and red are drought vulnerable and severely drought vulnerable, respectively. Areas in yellow and green are moderately to somewhat drought vulnerable. How might the drought vulnerability change further away from the cities? How might it vary in more southern cities or along the shoreline? Explore the drought vulnerability of different areas around Texas and consider why the drought vulnerability differs.



MAP LEGEND

Area of Interest (AOI)

-  Area of Interest (AOI)

Soils

Soil Rating Polygons

-  Severely drought vulnerable
-  Drought vulnerable
-  Moderately drought vulnerable
-  Somewhat drought vulnerable
-  Slightly drought vulnerable
-  Not rated or not available

Quick Review of Drought Vulnerable Soils

Definition: Soil types that are predisposed to experiencing water scarcity and moisture stress, particularly during periods of insufficient precipitation or increased evapotranspiration.

Significance:

◆ **Water Availability:** Drought-vulnerable soils exhibit reduced water availability, reducing plant hydration and growth. For example, soils classified as severely drought-vulnerable in the WSS interpretation have low water retention capacities, exacerbating water stress for vegetation during prolonged dry periods.

◆ **Erosion Risk:** Drought vulnerable soils are prone to erosion during drought conditions, leading to degradation, increased runoff, and potential for increased deposition in bodies of water, leading to downstream impacts.

◆ **Agricultural Productivity:** Drought-vulnerable soils pose challenges to agriculture by limiting crop yields and affecting overall productivity. For example, in regions classified as severely drought-vulnerable in the WSS interpretation, sandy soils struggle to retain moisture, leading to water stress in crops like maize and wheat.

◆ **Wildfire Risk:** Drought-vulnerable soils contribute to an increased risk of wildfires due to reduced moisture content, making vegetation more susceptible to ignition.

Extension Questions

1. How do drought-vulnerable soils contribute to the severity and frequency of drought-related natural hazards in different regions?
2. What are the socioeconomic implications of drought-vulnerable soils on agriculture, water resources, and local communities during prolonged drought periods?
3. Discuss potential adaptation strategies for mitigating the impacts of drought-vulnerable soils on water availability, soil erosion, and ecosystem health in arid and semi-arid regions.
4. How do land-use practices and urban development exacerbate or mitigate the effects of drought-vulnerable soils on climate-related natural hazards such as wildfires, land subsidence, and water scarcity?
5. Explore the role of government policies, community resilience initiatives, and technological innovations in addressing the challenges posed by drought-vulnerable soils and enhancing climate adaptation and mitigation efforts at the local, regional, and national levels.

ACTIVITY: Exploring Drought Vulnerability

Objective: Students investigate variations in drought vulnerability across diverse local areas and discuss its implications for climate-related natural hazards.

1. Divide students into groups and ask each group to explore a specific local area (e.g., city, farmland, forest, riverbank, different socio-economic areas)
2. Guide students to the WSS and demonstrate how to navigate through the system.
3. Provide time for each group to use WSS to create soil maps, focusing on organic matter of their selected AOI.
4. Have each group add their maps to a shared class document or folder for display and discussion. Make sure that each group also includes information on where their AOI is located.
5. Facilitate a class discussion about the maps using the following prompts:
 - a. Discuss the variations in drought vulnerability across different locations and hypothesize reasons for these differences.
 - b. Identify areas with high or low levels of drought vulnerability on the maps and discuss potential factors contributing to these patterns.
 - c. Analyze how land use patterns, such as agriculture and urbanization, influence drought vulnerability and its implications for climate-related natural hazards.
 - d. Explore the interplay between natural factors and human interventions in shaping drought vulnerability.
6. Conclude the discussion with each group sharing insights on:
 - a. Potential human impacts on soil health, and ideas for sustainable land management.
 - b. Ways in which local communities could be involved in soil conservation efforts.

Permafrost and Permafrost Sensitivity

Permafrost refers to soil, sediment, or rock that remains frozen for at least two consecutive years, typically found in regions where temperatures remain consistently below freezing for a significant portion of the year. Permafrost exists in polar and high-altitude regions and plays a crucial role in shaping the landscape and ecosystem dynamics. Permafrost contains varying amounts of ice, and can account for up to 90% of the soil volume.

Gelisols are a soil order defined by the presence of permafrost within the soil profile. They are characterized by the presence of permafrost within 100 centimeters of the soil surface and occur in areas with cold climates. Gelisols are found in polar regions, high mountain ranges, and other cold environments where temperatures remain below freezing for extended periods.

The presence of permafrost in Gelisols profoundly influences soil characteristics and ecosystem processes. It affects soil moisture, drainage patterns, and the types of vegetation that can thrive in these environments. Permafrost also contributes to landscape features such as patterned ground, frost boils, and ice wedges, which further shape the terrain and affect surface water flow. The sensitivity of permafrost to climate change is a growing concern, as rising temperatures can lead to its degradation and thawing. This process not only affects the stability of land surfaces but also influences hydrology, vegetation, and wildlife habitats in permafrost regions.

Thawing permafrost poses various climate-related natural hazards, including land subsidence, increased soil erosion, and changes in hydrological patterns. As permafrost thaws, the ground becomes less stable, leading to the sinking or settling of the land surface, which can damage infrastructure such as buildings, roads, and pipelines. Moreover, the release of stored organic matter in thawing permafrost (e.g., methane gas) can contribute to greenhouse gas emissions, further exacerbating climate change.

Understanding the dynamics of permafrost and its interactions with the climate system is crucial for developing effective mitigation and adaptation strategies. Monitoring permafrost conditions, studying its vulnerability to climate change, and implementing

sustainable land management practices are essential steps in addressing the challenges posed by thawing permafrost. By integrating permafrost considerations into climate resilience planning, communities can better prepare for and mitigate the impacts of permafrost thaw on landscapes, infrastructure, and ecosystems.

► *How to Get there on WSS*

Soil Data Explorer > Suitabilities and Limitations for Use > Land Management > **Permafrost Sensitivity (AK)**

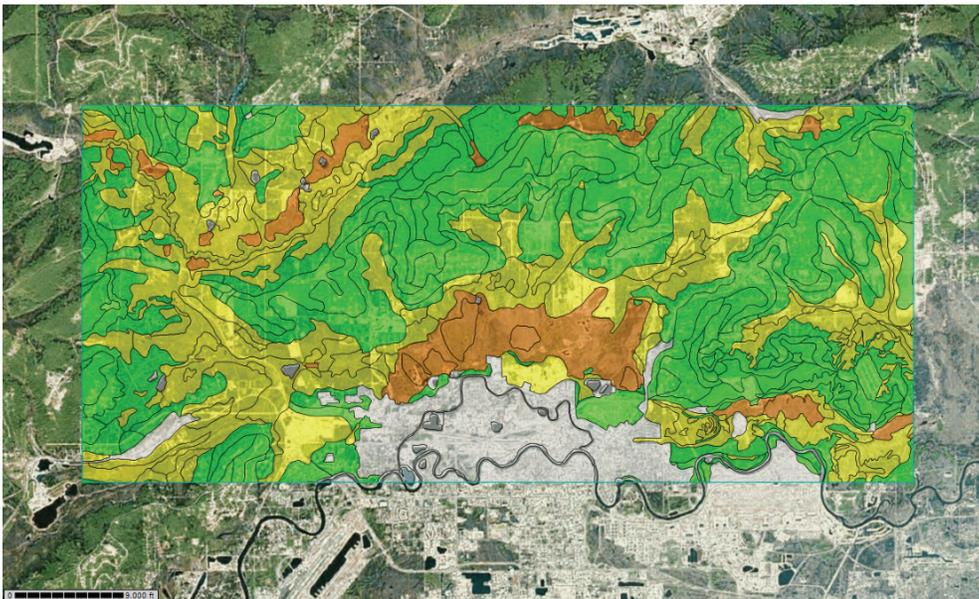
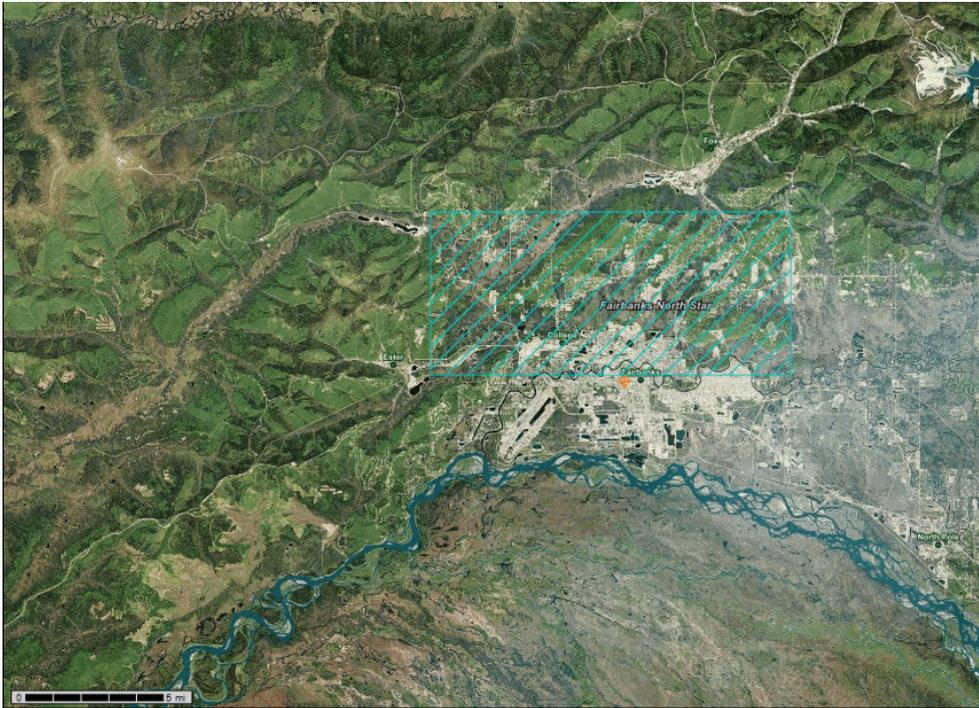
Although some regions in northern and high-elevation parts of states like Washington, Montana, Wyoming, Idaho, and Maine have permafrost, the WSS Permafrost Sensitivity interpretation is limited to Alaska.

Use the Soil Taxonomy Order interpretation to examine where permafrost is located. Soils that have permafrost are classified as Gelisols:

Soil Data Explorer > Suitabilities and Limitations for Use > Land Classifications > **Soil Taxonomy Order**

Permafrost Sensitivity (Fairbanks, Alaska)

The soil map below displays the permafrost sensitivity in an AOI around Fairbanks. Areas in green have no permafrost or low risk associated with thawing permafrost. Areas in yellow and orange have moderate to high amounts of risk associated with thawing permafrost. Consider how city planners in Fairbanks may use this map as the city is further developed.



MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

Soil Rating Polygons

-  Very high
-  High
-  Moderate
-  Low
-  None, no permafrost
-  Not rated or not available

Quick Review of Permafrost Sensitivity

Definition: This interpretation assesses the risk of permafrost thawing due to climate change or land use changes. Permafrost sensitivity ratings are determined by factors including soil order, temperature class, mean annual air temperature, soil thermal conductivity, landform, aspect, and frequency of ponding, all of which contribute to the likelihood of permafrost thawing and its associated impacts.

Significance:

- ◆ **Climate Change Indicator:** Permafrost sensitivity serves as an indicator of climate change impacts in regions where frozen ground exists. Monitoring changes in permafrost conditions provides insights into the rate and extent of climate warming and its effects on terrestrial environments.
- ◆ **Infrastructure Stability:** Thawing permafrost can destabilize infrastructure built on frozen ground, including buildings, roads, pipelines, and other critical facilities. Understanding permafrost sensitivity helps assess the vulnerability of infrastructure to ground subsidence and settlement, informing adaptation strategies and engineering solutions.
- ◆ **Carbon Release:** Permafrost contains vast stores of organic carbon accumulated over thousands of years. As permafrost thaws, organic matter decomposes, releasing potent greenhouse gases such as carbon dioxide and methane, into the atmosphere. Permafrost sensitivity informs estimates of carbon emissions from thawing permafrost and their contribution to global climate change.
- ◆ **Hydrological Changes:** Thawing permafrost alters hydrological patterns by affecting groundwater flow, river discharge, and lake dynamics. Changes in permafrost sensitivity influence water availability, habitat suitability, and ecosystem resilience in permafrost regions, with implications for human communities and wildlife.

◆ **Ecosystem Dynamics:** Permafrost sensitivity influences the structure and function of cold-region ecosystems, including vegetation composition, soil nutrient cycling, and wildlife habitat suitability. Understanding the sensitivity of permafrost helps predict ecosystem responses to climate warming and guide conservation efforts to protect vulnerable species and habitats.

◆ **Indigenous Communities:** Many indigenous communities rely on permafrost landscapes for traditional activities such as hunting, fishing, and reindeer herding. Changes in permafrost sensitivity can disrupt cultural practices and livelihoods, highlighting the importance of considering local knowledge and community perspectives in permafrost research and management.

Extension Questions

1. How does climate change impact permafrost stability, and what are the resulting hazards for communities in permafrost regions?
2. In what ways does permafrost thawing affect infrastructure resilience, and what challenges does it pose for urban and other developed environments?
3. What are the implications of permafrost degradation on greenhouse gas emissions, and how does this contribute to the feedback loop of climate change?
4. How does the thawing of permafrost influence wildlife habitats and biodiversity in cold regions, and what are the potential cascading effects on ecosystems?
5. What strategies can communities and policymakers implement to mitigate the impacts of thawing permafrost on landscapes, infrastructure, and ecosystem services, considering the long-term implications of climate change?

ACTIVITY: Exploring Permafrost Sensitivity around Alaska

Objective: Students explore permafrost sensitivity interpretations around Alaska and examine their implications for climate-related natural hazards.

1. Divide students into groups and assign each group a specific area in Alaska.
2. Guide students to the WSS and demonstrate how to navigate through the system.
3. Provide time for each group to use WSS to create soil maps, focusing on the permafrost sensitivity interpretation for their selected AOI.
4. Have each group add their maps to a shared class document or folder for display and discussion. Make sure that each group also includes information on where their AOI is located.
5. Facilitate a class discussion about the map(s) using the following prompts:
 - a. Identify areas on the maps with high permafrost sensitivity. What factors might contribute to these patterns?
 - b. How do permafrost sensitivity ratings vary across different regions or local areas?
 - c. How might changes in permafrost sensitivity impact natural hazards such as soil erosion, coastal erosion, and infrastructure damage?
 - d. What are the potential implications of permafrost thawing for local communities and ecosystems?
6. Conclude the discussion with each group sharing insights on:
 - a. Potential human activities that may influence permafrost sensitivity, such as land development, resource extraction, or climate change mitigation efforts.
 - b. Strategies for involving local communities in permafrost conservation and adaptation initiatives to mitigate the impacts of climate change.

CULMINATING ACTIVITY: Exploring Climate-Related Natural Hazards using Web Soil Survey Maps

Objective: Students will analyze soil data to investigate the relationship between soil properties and climate-related natural hazards.

Connections

NGSS

DCI: Earth's Systems, Earth and Human Activity

SEP: Analyzing and Interpreting Data, Developing and Using Models, Obtaining, Evaluating, and Communicating Information

CCC: Patterns, Cause and Effect, Systems and System Models

SDGs

2: Zero Hunger

4: Quality Education

11: Sustainable Cities and Communities

12: Responsible Consumption and Production

13: Climate Action

15: Life on Land

Activity

1. Begin with a brief discussion about the significance of climate-related natural hazards, such as landslides, soil erosion, flooding, and drought, and their impact on ecosystems and communities. Emphasize the importance of understanding soil properties in mitigating and adapting to these hazards.
2. Guide students to the Web Soil Survey (WSS) platform and demonstrate how to navigate through the system to access soil data related to climate-related natural hazards.
3. Instruct students to choose different study areas on the WSS platform, considering regions prone to specific natural hazards. Encourage them to explore diverse locations, such as:
 - ▶ **Appalachian Mountains/ Asheville, North Carolina:** Investigate soils in this region known for landslides and soil erosion to understand soil stability and its implications for hazard mitigation.
 - ▶ **Mississippi Delta/ Baton Rouge, Louisiana:** Explore soils in this area prone to flooding to analyze water retention capabilities and flood risk assessment.
 - ▶ **Wildfire-Prone Areas/ South Lake Tahoe, California:** Study soils in regions susceptible to wildfires to examine soil moisture content and its relationship to fire risk.
 - ▶ **Midwest/ Tornado Alley/ Kansas City, Missouri:** Analyze soils in tornado-prone areas to assess soil erosion potential and its impact on infrastructure and agriculture.
 - ▶ **Arid Regions of the Southwest/ Albuquerque, New Mexico:** Explore soils in arid regions to understand soil moisture dynamics and drought vulnerability.
4. Have students create maps of the soil data for their chosen areas, focusing on soil properties relevant to climate-related natural hazards, such as soil stability, water retention, erosion potential, and drought vulnerability. Ask students to also note the dates when the data was collected for their AOI.
5. Facilitate a class discussion based on the students' findings, encouraging them to share observations and insights regarding soil properties and their relationship to climate-related natural hazards. Some discussion questions could include the following, which can be adapted based on the specific areas students choose to study:
 - ▶ How do soil characteristics in landslide-prone areas (e.g., Appalachian Mountains) differ from those in flood-prone areas (e.g., Mississippi Delta)? Discuss the implications of these differences for hazard mitigation strategies.

- ▶ Based on the soil data from wildfire-prone regions (e.g., California), how does soil moisture content influence fire risk? What measures can be taken to mitigate the impact of wildfires on soil health?
 - ▶ Explore the relationship between soil erosion potential and tornado activity in the Midwest. How do soil properties affect the resilience of ecosystems and agricultural lands to tornado-induced damage?
 - ▶ Analyze the soil moisture dynamics in arid regions of the Southwest. How does soil composition contribute to drought vulnerability, and what are the implications for water resource management and ecosystem resilience?
 - ▶ How may recent climate effects have intensified and exacerbated existing hazards in various regions? Consider the historical soil data in these areas. What specific mitigation strategies could be implemented to address the amplified impacts of climate-related hazards?
6. Reflection and Implications: Guide students in reflecting on the broader implications of their findings and how understanding soil properties can inform resilience-building strategies and sustainable land management practices in the face of climate-related natural hazards. Encourage students to consider the role of soil conservation, land use planning, and community engagement in mitigating the impacts of natural disasters on both human and environmental systems.

SOIL AND CLIMATE RESOURCES

Lessons

- ◆ [Module 4 – Soils and Climate Change | Soils 4 Teachers](#)
- ◆ [Know Soil Know Life Educator's Guide | Soils 4 Teachers](#)
- ◆ [Life in the Soil Educator's Guide | National Association of Conservation Districts](#)

Other Resources

- ◆ [Soils and Climate Introductory Video | Soils 4 Teachers](#)
- ◆ [What's soil got to do with climate change? | UC Merced & Bobcat Comics](#)
- ◆ [Animations, Interactives, and Videos | Science of Agriculture](#)
- ◆ [Soil, Climate, and Carbon Webinar | Illinois Extension UIUC](#)

Careers Related to Soil and Climate

Careers related to soil and climate are of paramount importance in addressing the pressing environmental issues of our time. Professionals such as soil scientists, environmental consultants, and climate analysts play a critical role in understanding and mitigating the impacts of climate change on soil and ecosystem health, as well as agricultural productivity. These careers encompass a wide range of responsibilities, including soil analysis, sustainable land management, climate modeling, and environmental policy development. Individuals in these roles contribute to enhancing soil fertility, promoting sustainable agriculture, and developing strategies to adapt to and mitigate the effects of climate change. They also engage in research, data analysis, and advocacy, working collaboratively to create resilient ecosystems and sustainable solutions for a changing climate.

Examples of Related Careers

- ◆ **Soil Scientist:** Specialists who study soil properties, composition, and behavior, often working on projects related to climate-change impacts on soil.
- ◆ **Climate Change Analyst:** Professionals assessing the effects of climate change on various environmental factors, including soil health and composition.
- ◆ **Agricultural Conservationist:** Experts working with farmers to implement sustainable practices, considering soil conservation and climate-resilient agriculture.
- ◆ **Environmental Consultant:** Individuals advising on the impacts of climate change on ecosystems, including soil health and management strategies.
- ◆ **Hydrologist:** Scientists studying water-related issues, such as the influence of climate change on soil moisture, groundwater, and water availability.
- ◆ **Ecologist:** Researchers examining the relationships between organisms and their environments, including how climate change affects soil ecosystems.
- ◆ **Soil Conservation Technician:** Professionals implementing soil conservation measures, especially those adapted to changing climate conditions.
- ◆ **Geospatial Analyst:** Experts using geographic information systems (GIS) to analyze and visualize spatial data, including soil and climate-related information.
- ◆ **Environmental Engineer:** Engineers designing solutions to environmental problems, such as developing systems to mitigate climate change impacts on soil quality.

Career Resources

- ◆ Learn about and browse potential careers at [My NRCS Career](#).
- ◆ Read about being a soil scientist with NRCS in the [Soil Scientist Career Group Guide](#).
- ◆ Visit the [GROW](#) website to explore geoscience resources on opportunities in the workforce.
- ◆ Explore AGI's [Geoscience Career Explorer](#) in which users select a [Sustainable Development Goal \(SDG\)](#) they would prefer working towards and related geoscience+ careers are provided. Select SDG 2 to include soil-related careers and/or SDG 13 for climate-related careers.