Expo / Desktop Rainfall Simulator Lesson Plan

> *"We know more about the movement of celestial bodies than about the soil underfoot."* - *Leonardo Da Vinci, circa 1500's*

> *"Essentially, all life depends upon the soil ... There can be no life without soil and no soil without life; they have evolved together."*
> - *Charles E. Kellogg, USDA Yearbook of Agriculture, 1938*

Topic: Teaching soil health principles using a bench-top rainfall simulator

Life Skills:

- Teamwork
- Record Keeping
- Critical Thinking
- Problem Solving
- Communication

Skill Level: Advanced; ages 15-19/grades 9-12

Next Generation Science Standards:

Human Impacts on Earth Systems (HS-ESS3-1): Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Earth and Human Activity (HS-ESS 3-2.): Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

Human Sustainability (HS-ESS3-4): Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Engineering Design (HS-ETS1-3.): Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Time Needed:

- Three hours prep time
- One 60-90 minute class period for lesson

Materials:

- Expo/Desktop Rainfall Simulator Instructor Guide
- Introductory PowerPoint presentation
- Desktop rainfall simulator and associated materials (see Expo/Desktop Rainfall Simulator Instructor Guide)
- Access to sites for soil sampling, including land use/management information (school grounds, gardens, parks, farms)
- Copies of student Rainfall Simulator Demonstration Worksheet

Desired Impact/Goal: Educational commitment and application of learning (Head). Students will understand how soil health, as affected by environmental conditions and human activity, influences the capacity of natural ecosystems to sustain plants, animals, and humans.

Key Soil Health Concepts

Soil Health:

- Soil health is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.
- A healthy soil sustains plant, animal and human life by providing a stable foundation for plant roots and human structures, regulating water, cycling nutrients, filtering, buffering and degrading pollutants.
- Soil health takes into account the integrated physical, chemical and biological components of soil ecosystems, whereas traditional soil fertility views soil as a non-living chemical system.
- Both environmental conditions (parent material, climate, topography) and human activities (soil disturbance, cropping, fertilization) can degrade or improve soil health.
- In highlighting the link between functioning soil ecosystems and the productivity or resiliency of human systems, soil health represents a new way of thinking about soil management and conservation.

Soil Minerals and Texture:

- Soil consists of four major components: mineral material (~45%), organic matter (~5%), water (~25%) and air (~25%).
- The mineral component of soil is the remnants of weathered rocks and can be classified into three categories by particle size: sand (2.0-0.05 mm), silt (0.05-0.002 mm) and clay (<0.002mm).
- Clay is the only chemically active texture class with the ability to adsorb plant nutrients.
- The proportion of different mineral particle sizes in a soil determines its texture, within twelve recognized classes.
- Soil texture is important to soil health as a determinant of surface area and pore space available in a soil for holding nutrients, air and water.
- Soil texture is primarily determined by geology and climate, and cannot be easily changed by human activity. That is except in the case of disturbed (i.e. urban) soil where large amounts of soil are imported into or removed from an area.

Soil Biology and Organic Matter:

- Soil ecosystems support a great diversity of organisms, rivaling the above-ground diversity in tropical rainforests or coral reefs.
- Soil biota range from microscopic bacteria to vertebrates that coexist in complex food webs.
- Soil life is often concentrated in areas with more organic matter including near plant roots (rhizosphere exudates), close to surface litter and in sites with incorporated organic matter like crop residues, cover crops, or manure.

- The organic matter component of soil is the remnants of plant and animal tissue in various states of decomposition by soil organisms, a valuable source of nutrients for all members of the soil food web, plants and people, as well as a reservoir for water storage in soils.
- Agricultural production depends on soil biology to cycle vital nutrients like nitrogen from organic to mineral forms that are available to support plant growth.

Soil Aggregation and Aggregate Stability:

- The four components of soil often stick together in units called aggregates that include both solid (mineral and organic) materials and pore space (air and water) held together by physical and chemical forces.
- Several natural processes contribute to soil aggregation through the physical movement and adhesion of soil particles including:
    - wetting and drying
    - freezing and thawing
    - microbial activity that aids in the decay of organic matter (glomalin produced by fungi)
    - activity of roots and soil animals (root sugar exudates)
    - soil chemical charges (adsorbed cations)
- Aggregates vary in their size, shape and stability. Patterns of soil aggregation determine soil structure within nine categories (i.e. crumb, blocky, single grain), that along with texture, is used to describe a particular soil type.
- Soil aggregation is important to soil health as a determinant of pore space available in a soil for holding air, water and nutrients, as well as the growth of plant roots and soil biology. Aggregates include micropore spaces within their structure, but also form macropores between aggregate units.
- A well aggregated soil resists wind and water erosion that can degrade environmental quality through sedimentation and nutrient loading.
- Soil aggregation is sensitive to environmental conditions and human activities. The impact of raindrops, tillage and wheel traffic destroy aggregates. Aggregation is encouraged by practices such as reduced tillage, and organic matter additions from crop residue, cover crops or manure.

Soil Porosity/Compaction:

- To maximize soil health and plant growth, a soil should ideally consist of 50% solid (mineral and organic) materials and 50% pore space (air and water).
- Soil bulk density is a measure of soil porosity/compaction expressed as soil weight per unit volume (g/cm3).

- In general, low bulk density (< 1.50 g/cm3) is associated with a healthy, porous soil with plenty of room for air, water and biology (plant and animal), while a higher bulk density (>1.50 g/cm3) can limit movement of air and water through soil and restrict root growth.
- Practices that destroy soil aggregates, like tillage and wheel traffic, increase bulk density over time. This is somewhat counterintuitive since tillage is designed to temporarily loosen soil for planting and crop establishment. However, fractured aggregates settle and compact over time. Practices that increase aggregation, such as reduced tillage, reduced wheel traffic and organic matter additions from crop residue, cover crops or manure tend to decrease soil bulk density.

Life Skill Objectives

Teamwork

Teams of students will share responsibility for observations before and during the rainfall simulator demonstration, development and testing of hypotheses and communication of results

Keeping Records

Students will accurately record observations relevant to soil properties, land use/management, and their effect on the movement of water over and through soils during the demonstration

Critical Thinking

Students will reflect on their observations to hypothesize about the inherent soil properties and land use/management differences that may have contributed to their findings

Problem Solving

Teams of students will develop a plan to change land use/management on the site(s) of interest in an effort to reduce runoff/erosion and improve infiltration

Communication

Teams of students will present their proposed changes in land use/management to the class, compare to the proposals of other teams and evaluate similarities/differences

Rainfall Simulator Instructional Plan

Background

- The instructor will first ask students to read and reflect on the two quotations from Leonardo Da Vinci and Charles Kellogg listed at the top of this lesson plan
    - What might limit human understanding of soil?
    - In what ways does life on earth depend on soil?
    - How do these quotations reflect the historical perspective of their authors?
- Through an introductory PowerPoint presented by the instructor, students will:
    - Be introduced to the concept of soil health, its definition and importance to life on earth (i.e. agriculture, water quality, urban development).
    - Become familiar with the four major components of soil and their relative abundance in a healthy soil (mineral material (~45%), organic matter (~5%), water (~25%) and air (~25%)).
    - Learn that soil texture is important to soil health as a determinant of surface area and pore space available in a soil for holding nutrients, air, water and biology.
    - Understand that the organic matter component of soil is the remnants of plant and animal tissue in various states of decomposition by soil microorganisms, an important source of nutrients and water holding capacity.
    - Realize that the four components of soil tend to stick together in units called aggregates that include both solid (mineral and organic) materials and pore space (air and water) held together by physical and chemical forces.
    - Discover that a healthy , well aggregated soil should ideally consist of 50% solid (mineral and organic) materials and 50% pore space (air and water), and become familiar with soil bulk density as a measure of soil porosity/compaction expressed as soil weight per unit volume (g/cm3).
    - Learn that human activities can degrade soil health and environmental quality by destroying soil aggregates, increasing bulk density and contributing to erosion (i.e. tillage, compaction, residue removal) or improve soil health by encouraging soil aggregation, lowering bulk density and preventing erosion (i.e. reduced tillage, residue retention, cover crops, manure application)

Experience – Getting Started

- The instructor will group students into teams of 4-6 and distribute the Rainfall Simulator Demonstration Worksheet (RSDW)
- The instructor will introduce students to the components of the bench-top rainfall simulator and explain its use as a tool to compare how inherent soil properties and human land use/management influence the movement of water over and through different soils
- The instructor will describe to students the site(s) used for sample collection including geography, geology, land use/management history, disturbance and plant cover, withholding soil type/texture/ organic matter info for the time being
- Students will inspect and manipulate several soil aggregates collected with the demonstration samples to see how they vary in their size, shape, stability and density based on texture, organic matter concentration and field histories (i.e. tilled vs. no-till)
- Teams of students will use the Soil Texture by Feel test to estimate a soil's proportion of different mineral particle sizes by feel and identify soil texture within twelve recognized classes
- Teams of students will use the Color Chart for Estimating Organic Matter to estimate a soil's organic matter concentration by percentage
- Teams of students will record information about each site/soil sample on the RSDW, develop, record and report to the class hypotheses regarding how known soil properties and land use/management might affect how water runs-off or infiltrates through the soil during the demonstration (RSDW questions 1-3)

Experience – Going Further

- The instructor will conduct the rainfall simulator demonstration, pointing-out how water moves from the upper drip pan over and through the soil samples, noting key differences between the samples
- Teams of students will record their observations during the demonstration, noting which samples had the greatest run-off/infiltration and possible implications for agriculture, water quality, etc. (RSDW questions 4-5)

Think and Discuss

- Teams of students will discuss among themselves how the observed results of the demonstration either supported or contradicted their hypotheses regarding infiltration and run-off (RSDW question 6)
- Considering the sample with the greatest volume of run-off water caught in the front pan, teams of students will research and formulate a plan for how use/management of the site could be changed to decrease run-off and increase infiltration (RSDW question 7)
- Teams will present their proposed changes in land use/management to the class , compare and contrast

Rainfall Simulator Demonstration
Student Worksheet

"We know more about the movement of celestial bodies than about the soil underfoot." - *Leonardo Da Vinci, circa 1500's*

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Before the demonstration begins…

1. What do you know about the sites where soil samples were collected for the rainfall simulator demonstration? Describe each one including information about geography, geology, land use/ management, soil disturbance and plant cover.

2. Obtain soil samples from your teacher and conduct the Soil Texture By Feel test using the instructions on the third page of this worksheet. How do expect the physical properties of each soil sample (texture, aggregation, structure, pore space) to affect how water runs-off or infiltrates through the soil? Do you think that use/management of the site(s) each sample was collected from has affected the soil's physical condition? In what ways?

3. Using the same soil samples from your teacher, estimate the organic mater concentration of the soil(s) using the Color Chart for Estimating Organic Matter on the final page of this worksheet. How do expect the biological properties of each soil sample (organic matter, cover type, biota) to affect how water runs-off or infiltrates through the soil? Do you think that use/management of the site(s) each sample was collected from has affected the soil's biological condition? In what ways?

During the demonstration…

4. Observe how water runs-off and/or infiltrates through the soil sample(s). Which sample(s) had the greatest volume of water run-off the soil surface? What color was the water in the run-off catch pan(s)? What does the color of the run-off water tell you about the movement of soil and nutrients with rain water?

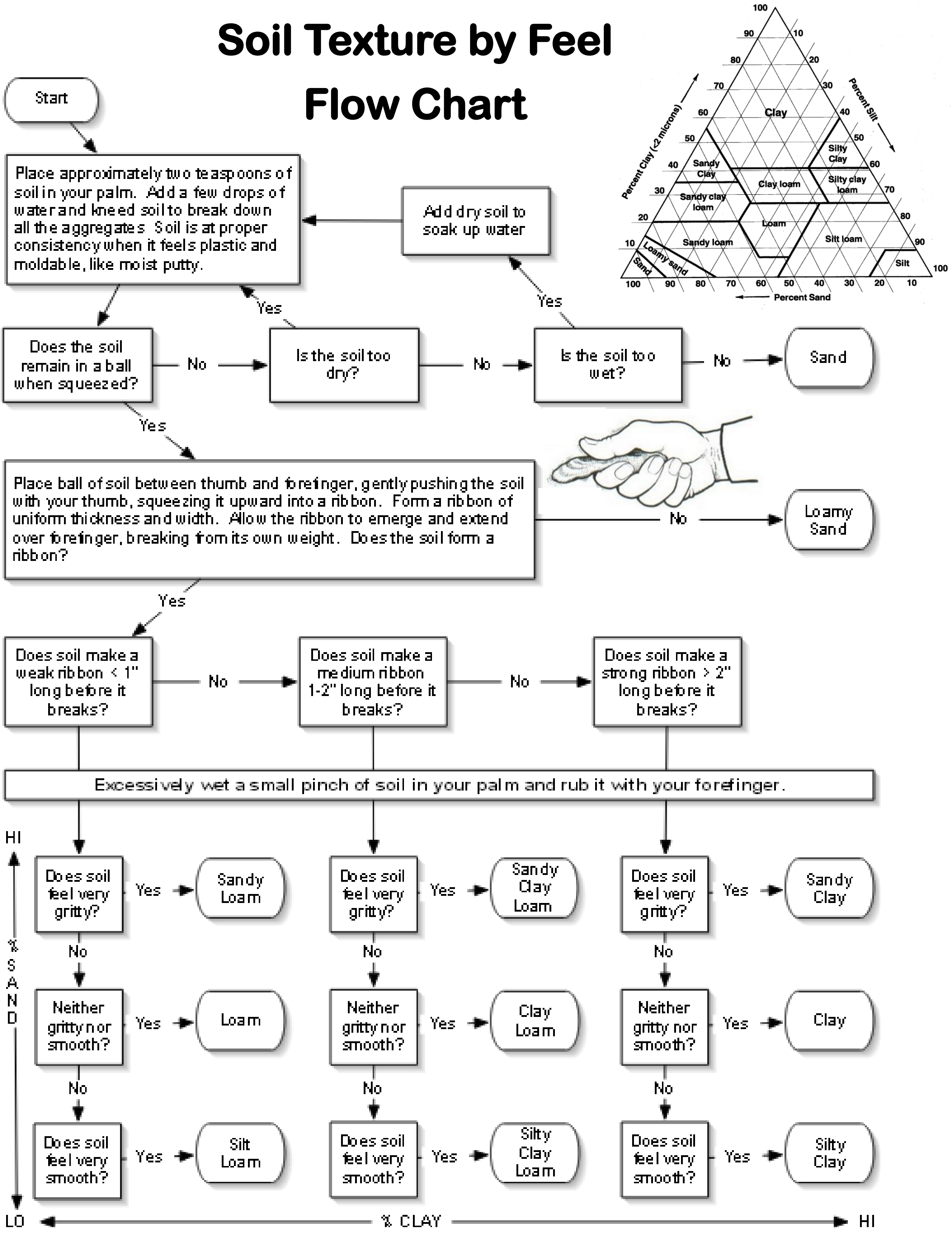
5. Which sample(s) had the greatest volume of water infiltrate through the soil? How quickly did infiltration water accumulate in the lower catch pans compared to run-off water? Why might greater infiltration be desirable for water quality/quantity, crop production, etc.

After the demonstration…

6. Did the demonstration support your hypotheses about how water would run-off vs. infiltrate through each soil sample? If so, which physical and biological soil properties or site use/management factors seemed to have the greatest effect on the movement of water? If not, what do think led to the unexpected result?

7. Considering the sample with the greatest volume of run-off water caught in the front pan, how could use/management of the site be changed to decrease run-off and increase infiltration? Use available resources (internet, soil survey books, etc.) to formulate a plan for changes in land use/management changes that could affect chemical, physical and biological soil properties for improved infiltration.

Soil Texture by Feel Flow Chart



Color Chart for Estimating Organic Matter

This chart is a guide for estimating the organic matter content of mineral soils in Illinois.

How to Use the Color Chart

1. Take a sample from the plow layer.
2. Use moist soil—neither wet nor dry. If the sample is dry, moisten it.
3. Find which chart color matches most closely the soil color.
4. Read the associated organic matter content.

The most accurate estimates are obtained with medium- and fine-textured soils. Soils containing high proportions of sand (more than 50 percent) and low proportions of clay (less than 10 percent) usually contain less organic matter than indicated by this chart.

Organic soils, such as mucks and peats, contain 20 to 90 percent organic matter. Mucks are normally black and soft, while peats tend to be brown and fibrous. This color chart is not intended to apply to organic soils.

More information about Illinois soils is given in *Soils of Illinois* and individual county soil reports, available from Extension offices. *Soils of Illinois* is also available from University of Illinois Information Technology and Communication Services; 800-345-6087; www.PublicationsPlus.uiuc.edu.

ORGANIC MATTER		COLOR
Average	Range	(moist soil)
5%	3½ to 7%	
3½%	2½ to 4%	
2½%	2 to 3%	
2%	1½ to 2½%	
1½%	1 to 2%	

(Strong sunlight may eventually cause these colors to fade slightly.)

University of Illinois Extension