1. Determining Soil Quality

Driving Questions

Determining the quality of soils, particularly top soil, and suggesting remedies for soil problems are important tasks for agricultural outreach agents worldwide.

- ♦ What can you find out about the capacity of soil to support plant growth by examining its physical, chemical, and biological characteristics?
- ♦ How is this information about soil quality useful?

Background

Soils are complex combinations of inorganic materials, organic materials, and living organisms. (*Organic* means carbon-based. *Inorganic* means not carbon-based.) Some combinations of materials yield soils that provide good support for plant growth. Others do not, or they only support certain types of plant growth.

Ideal soils for plant growth include the following characteristics:

- ♦ Being porous, to allow air and water to filter through them
- ♦ Being able to retain moisture
- ♦ Containing a substantial amount of humus (dead plant material)
- ♦ Having a pH in the neutral range from 6.0 to 7.5 and the ability to resist changes in pH
- ♦ Not containing too much salt or sodium
- ♦ Having a thriving population of decomposers

Decomposers, such as earthworms, ants, beetles, fungi, and bacteria, break down materials to the smallest building blocks that can be used by plants for growth.

Soils are a vital part of the ecosystem, providing the support for terrestrial plant growth. Terrestrial plants comprise an important segment of primary productivity on which all living beings ultimately depend for food. Plants and decomposers are vital links in the global cycles of water, carbon, oxygen, nitrogen, sulfur, phosphorous, potassium, calcium, and other elements that are required for growth of living things. Being able to analyze soils and determine potential remedies for poor soils are important skills for the good of humanity.

Materials and Equipment

For each student or group:

- ♦ Carbon dioxide gas sensor and sampling bottle
- ♦ pH sensor
- ♦ Conductivity sensor
- ♦ Stirring rod
- ♦ Beaker (4), 100-mL
- ♦ Beaker, 50-mL
- ♦ Graduated cylinder, 100-mL
- ♦ Microscope with magnification up to 400x
- ♦ Dissecting microscope
- ♦ Microscope slides and cover slips (3)
- ♦ Microwave oven (1 per class)
- ♦ Pipet, disposable
- ♦ Digging tool
- ♦ Soil samples (from 3 different locations)
- ♦ pH calibration standard solution, pH 4
- ♦ pH calibration standard solution, pH 7 or 10
- ♦ White household vinegar, 4 mL
- ♦ Distilled or deionized water, 300 mL
- ♦ Wash bottle containing distilled or deionized water
- ♦ Plastic bags (4), sealable, about 1-L
- ♦ Waste container
- ♦ Permanent marker
- ♦ Labeling tape

Safety

Follow all standard laboratory procedures.

Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Part 1 – Obtain samples (day before lab)

Strive for consistency in the collecting technique for each soil sample collected. Strive to collect samples of obviously different types.

1. ☐ Collect a soil sample by doing the following:
   a. Clean the digging device.
   b. Clear away leaves and any other contaminating debris.
   c. With the digging device, loosen the soil as deep as 8 centimeters.
   d. Place at least 200 mL (about 3/4 cup) of soil into a plastic bag.
   e. Seal the bag to preserve moisture.
   f. Label the sample (for instance:, "Vacant lot" or "Hiking trail").

2. ☐ Collect two more soil samples using the same technique.

3. ☐ Why must you maintain the same technique when collecting the three different soil samples?

____

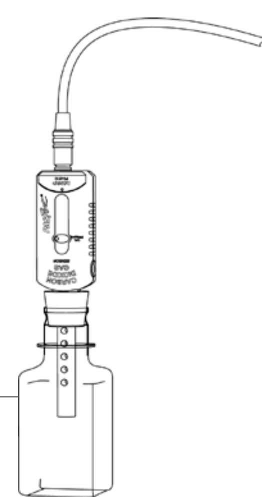
____

4. ☐ In the Data Analysis section, complete the steps for recording soil information for all 3 samples.

You will set up and start "Part 2 – Soil respiration assessment." While you are collecting data for that part, you will complete Parts 3, 4, 5, and 6.

Part 2 – Soil respiration assessment

Set Up



5. ☐ Start a new experiment on the data collection system.

6. ☐ Connect the CO_2 gas sensor to the data collection system using a sensor extension cable.

7. ☐ Display a graph of CO_2 gas versus Time in seconds (s).

Soil respiration of Soil Sample 1

8. ☐ Using the 50-mL beaker, add approximately 50 mL (4 tablespoons) of soil from Soil Sample 1 to the sampling bottle.

9. ☐ Lower the CO_2 gas sensor into the bottle and cork it tightly using the attached stopper.

10. ☐ Why are you tightly corking the bottle?

____

11. ☐ Predict which soil sample will have the highest rate of cellular respiration as indicated by the rate of increase in CO_2? Why?

____

____

Collect Data

12. ☐ Start recording data.

13. ☐ Adjust the scale of the graph to show all data.

Note: While recording this data, proceed to "Part 3 – Examine the physical characteristics of the soil" and complete that investigation.

14. ☐ After 600 seconds (10 minutes), stop recording data and save your experiment.

15. ☐ Find the value for the CO_2 gas concentration at 600 seconds, and record it in Table 2 in the Data Analysis section.

16. ☐ Carefully remove the stopper.

17. ☐ Vigorously shake the bottle upside down to empty all soil and excess CO_2 gas.

Soil Samples 2 and 3

Note: During the 600-second data recording periods for the second and third soil samples, prepare the soil samples for Part 4, Part 5, and Part 6. You can use the same soil sample preparations to conduct all three of these analyses. Take the readings for Parts 4 through 6 at convenient times (such as after beginning the 600-second CO_2 data recording) during Part 2.

18. ☐ For Soil Sample 2 and then for Soil Sample 3, repeat the steps of the "Soil respiration of Soil Sample 1" subsection.

Choose the Sample to Microwave

19. ☐ Identify the soil sample with the highest increase in CO_2 concentration. Place a 50-mL aliquot of this soil sample in a paper or plastic container and put it into a microwave oven.

20. ☐ Expose the sample to a high level of microwaves for 120 seconds.

21. ☐ What happens to the living organisms in the soil sample when you microwave it?

____

22. ☐ For the microwaved sample, repeat the steps applied to the first sample ("Soil respiration of Soil Sample 1")

23. ☐ What important scientific process is being conducted in this step?

____

____

____

Part 3 – Examine the physical characteristics of the soil

24. ☐ Place a small sample of soil (no larger than a penny) from each soil sample on a sheet of white paper (you can use the back of the previous page).

25. ☐ Spread the small amount of each of the soil samples into its own thin layer.

26. ☐ Compare the soil color, texture, structure, and apparent moisture level of each sample, and enter your observations in Table 1 in the Data Analysis section.

    Note: You may need to update some of the information you entered when you initially collected the samples.

27. ☐ Sprinkle a small amount of each soil sample on a microscope slide and label the slides using a marker. Look at each slide under a dissecting microscope.

28. ☐ Enter new observations about soil composition in Table 1 in the Data Analysis section, considering the following:

    a. Particle size and characteristics like sand, silt, or clay

    b. Plant material such as root or leaf parts

    c. Animal parts such as an insect leg or wing

29. ☐ Use the pipet to add a drop of water to the soil on each slide and cover each one with a cover slip.

30. ☐ Look at each slide using a microscope that magnifies the sample 400 times.

31. ☐ Enter new observations to Table 1 about the type of live organisms you observe.

32. ☐ In which sample did you find the most living organisms?

____

Part 4 – Determine the soil salinity

Set Up

Preparing the soil

33. ☐ Remove any rocks and sticks. Crush Soil Sample 1 into a fine dust with the end of the handle of your digging tool or other suitable instrument.

34. ☐ Why do you need to pulverize the soil?

____

____

35. ☐ Place 50 mL of Soil Sample 1 into a 100-mL beaker. Label the beaker "#1".

36. ☐ Add an equal volume of distilled water.

37. ☐ Mix the soil and water thoroughly with a stirring rod.

38. ☐ Allow the mixture to sit for at least 5 minutes.

39. ☐ Why are you adding water to the sample?

____

____

40. ☐ Repeat the steps for preparing the soil for the other two samples, rinsing the stirring rod after mixing each sample.

Measure the salinity

41. ☐ Connect the conductivity sensor to the data collection system and monitor live data without recording. If necessary, open a digits display of conductivity.

42. ☐ Rinse the conductivity probe with distilled or deionized water.

Collect Data

43. ☐ Lower the conductivity probe into the soil-water mixture. Gently stir the solution with the probe during data collection.

44. ☐ Wait for the measurement to stabilize (as long as 30 seconds).

45. ☐ If necessary, adjust the sensitivity of the conductivity sensor.

46. ☐ Wait for the measurement to stabilize.

47. ☐ Enter the soil salinity value in Table 2 in the Data Analysis section.

48. ☐ Repeat the steps for measuring the salinity for the other two samples.

Part 5 – Determining the pH of the soil

Use the soil-water mixtures you prepared in Part 4 of the lab.

Set Up

49. ☐ Calibrate the pH sensor

50. ☐ Why are you calibrating the pH sensor?

___

___

___

Collect Data

51. ☐ Rinse the pH probe with distilled or deionized water. Monitor live data without recording. If necessary, open a digits display of pH.

52. ☐ Lower the pH probe into the soil-water mixture, and gently stir the solution with the probe during data collection.

53. ☐ Wait for the measurement to stabilize (as long as 30 seconds).

54. ☐ Enter the pH value in the "Initial Soil pH" column of Table 2 in the Data Analysis section.

55. ☐ Repeat the steps for collecting data for the other two samples.

Part 6 - Explore the buffering capacity of the soil

Set Up

In this buffering part of the lab, use the soil-water mixtures you prepared in the soil salinity and soil pH sections of the lab.

56. ☐ Prepare 40 mL of a 10% vinegar solution.
    a. Pour 4 mL of vinegar into a graduated cylinder.
    b. Fill the cylinder to 40 mL with distilled water to make a 10% vinegar solution.
    c. Pour the solution into a 100 mL beaker.

57. ☐ Rinse the pH probe with distilled or deionized water.

Collect Data

58. ☐ Lower the pH probe into the vinegar solution and gently stir the solution with the sensor during data collection.

59. ☐ Determine the pH of the vinegar solution and record it here: ________________.

60. ☐ What does the pH of the 10% vinegar solution indicate?

---

61. ☐ If a soil sample has a high buffering capacity, what will happen to the pH when you add the acid?

Determine the buffering capacity

62. ☐ Add 10 mL of the 10% white vinegar solution to soil-water mixture number 1 and mix thoroughly.

63. ☐ Rinse the pH probe with distilled water.

64. ☐ Lower the pH probe into the soil-water mixture and gently stir the solution with the probe during data collection.

65. ☐ Wait for the measurement to stabilize (as long as 30 seconds).

66. ☐ Enter the pH value in Table 2 in the Data Analysis section.

67. ☐ Repeat the steps of the subsection "Determine the buffering capacity" for the other two soil-water mixtures.

68. ☐ Save your experiment and clean up according to your teacher's instructions.

Data Analysis

Record soil information

1. ☐ Record detailed observations for each soil sample and its environment in Tables 1a, 1b, and 1c, identified by the label on the sample. These should include, where applicable:
   a. The appearance of the soil and soil composition, including conditions such as arid or humid; clay, sandy, loamy, or rocky
   b. The appearance and types of plants and other organisms in the area from which the soil was collected, for example shrubs, conifers, fungus
   c. What you hear, smell, touch, or taste, as well as what you see
   d. Animal tracks and the appearance of animals
   e. The terrain, holes in the ground, and the geological features of rocks
   f. The type of habitat, such as grassland or urban, including any nearby buildings and whether nearby roads are asphalt, cement, gravel, or dirt

g. Anything unusual about the area, especially if it might be relevant to soil health, such as being next to an irrigated area, or a field with runoff from a roadway

Note: If the data is being collected during fall or winter months, it may not be possible to gather information such as yellowing of leaves or deformities on young leaves.

2. ☐ Use the back side of the paper to sketch any site details that might be helpful with your soil analysis. Sketch at least 10 square meters.

3. ☐ Record the site with a digital camera, if possible.

Note: A digital camera is a great source of objective data. Still, include a sketch as part of the recorded observations.

Table 1a: Detailed observations of Soil Sample 1

Location Description	
Date and Time Collected	
Air Temperature and Weather Conditions	
Soil Color	
Soil Texture and Structure	
Soil Moisture	
Organisms Present	
Detailed Observations	

Table 1b: Detailed observations of Soil Sample 2

Location Description	
Date and Time Collected	
Air Temperature and Weather Conditions	
Soil Color	
Soil Texture and Structure	
Soil Moisture	
Organisms Present	
Other Observations	

Table 1c: Detailed observations of Soil Sample 3

Location Description	
Date and Time Collected	
Air Temperature and Weather Conditions	
Soil Color	
Soil Texture and Structure	
Soil Moisture	
Organisms Present	
Other Observations	

Record measured results

4. ☐ Display the graphs for each of your data runs. Adjust the scale of the graph to show all data.

5. ☐ Make a sketch of each run of data for CO_2 concentration in parts per million versus Time. Label the overall graph, the scale of the y-axis, and the individual data runs.

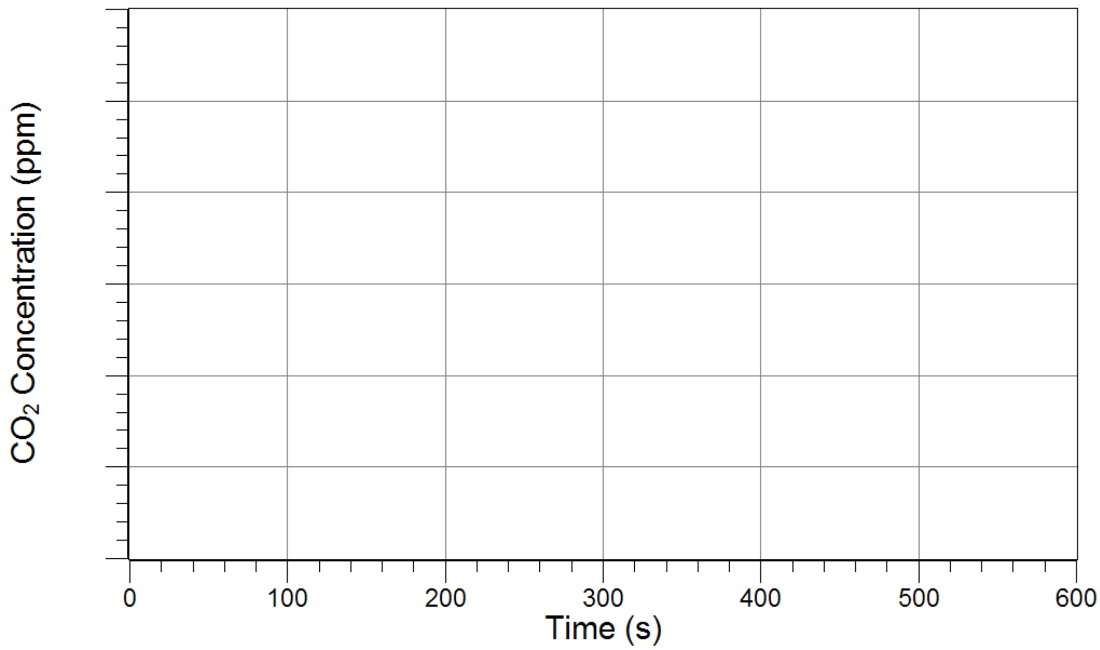


Table 2: Analysis of 3 soil samples

Soil Sample	Data Run	CO_2 Gas Generation (ppm)	Soil Salinity (conductivity) (µS/cm)	Initial Soil pH	Soil pH After Adding 10% Vinegar	Change in pH
1	1					
2	2					
3	3					
	4					

Analysis Questions

1. **The rate of change of CO_2 gas concentration is indicative of the rate of change in cellular respiration. What kind of soil would you expect to produce CO_2 gas at a faster rate—dark, moist soil or dry, clayey soil? Why?**

2. **What were the effects of microwaving the soil? What happened to the rate of CO_2 gas increase after you microwaved the soil sample? Explain.**

3. **In which sample did you find the most soil organisms? Is this also the sample that had the highest rate of increase in CO_2 concentration? Discuss the relationship between respiration rate of soil organisms and changes in CO_2 gas concentration within the sample bottle.**

4. **Which of the three soil solutions had the highest conductivity? Explain why it might be higher than the other two samples. Recall the location of the sample.**

5. **Which soil sample had the greatest buffering capacity? Did you see a relationship between buffering capacity and conductivity measurements? If so, explain why this relationship might exist.**

6. **Which of the soil samples would you predict would have the greatest capacity to support plant growth? Explain.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Based on your results, discuss the roles that soil plays in the carbon cycle.**

2. **What effects do soils of high salinity have on plant growth? Why?**

3. **Each plant type possesses an inherent tolerance level to salinity. In general, a crop should tolerate salinity levels up to 700 microsiemens per centimeter (μS/cm), without a decrease in yield; however, some plants tolerate even higher levels of salinity. If a soil contains more than this level of salt, what types of crops might be successfully grown in it?**

4. **It is best to avoid cultivation of highly saline and sodic (sodium-containing) soils because of the expense of reclaiming the soil. However, if it became imperative to salvage the land, how might you treat saline soil in order to harvest a crop with a high yield?**

5. **What effects do very acidic or very alkaline soils have on plant growth? Why?**

6. **Each plant type grows best within a certain range of pH values. What are some plants that will grow well in relatively acidic soils (pH 5.0 to 5.5)? What are some plants that will grow well in relatively alkaline soils (pH 7.5 to pH 8)?**

7. **Describe methods that may be used to adjust the pH of soil.**

8. **Which of the three soil types would be more efficient at neutralizing acid rain? Explain.**

9. **List some possible remedies for the soil samples that seem to be less capable of supporting plant growth.**

____

____

____

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. **In which of the following do soil bacteria play an important role?**

   A. The water cycle
   B. The carbon cycle
   C. The nitrogen cycle
   D. The phosphorous cycle
   E. All of the above

2. **To which of the following characteristics of soil does humus *not* contribute?**

   A. High water-holding capacity
   B. High nutrient-holding capacity
   C. Mineralization
   D. Aeration
   E. Water infiltration

3. **Soils high in salinity cause plant damage because of which of the following?**

   A. They are highly toxic to plants.
   B. They inhibit plant growth by preventing plant roots from taking in nutrients.
   C. They cause plants to wilt by creating osmotic pressure from roots to the soil.
   D. Only B and C are true.
   E. A, B, and C are true.

4. **What can be altered as the result of change in soil pH?**

   A. Growth of soil microorganisms
   B. Solubility of toxic substances in the soil
   C. Availability of mineral nutrients
   D. All of the above

5. **Increase in soil acidity can cause which of the following?**

   A. Release of toxic metals such as Al, Fe, Mn, and Ni
   B. Increase in alkalinity
   C. Release of calcium carbonate
   D. Increase in salts

6. **Which of the following can make soil too acidic?**

   A. Release of CO2 during soil respiration
   B. Release of calcium carbonate by parent rock
   C. Release of sulfur from burning of fossil fuels returning to the ground as acid rain
   D. Answers A and C

7. **The addition of which of the following can raise the pH of acidic soils?**

   A. Sulfur
   B. Salts
   C. Lime
   D. Compost or mulch
   E. Either C or D