BC Agriculture in the Classroom Foundation

Lesson Plan

Investigating Topsoil

While this activity is designed to be an introduction to Grade 9 matter cycles, it can be adapted to fit the curricular competencies and content connections for the courses listed below. The objective of this activity is to help students establish the importance of topsoil conditions (nutrients, pH) on plant health in order to provide them with the relevance of studying matter cycles.

Suggested Grade/Subject Levels

Grade 9 Science – Matter Cycles

Science 7

Science 8

Environmental Science 11

Science for Citizens 11

Environmental Science 12

Teacher Guide – Investigating Soil

Curricular Competencies (Science 7-12)

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest
- Make observations aimed at identifying their own questions, including increasingly complex ones about the natural world
- Formulate multiple hypotheses and predict multiple outcomes
- Collaboratively and individually plan, select and use appropriate investigation methods, including field work and lab experiments, to collect reliable data (qualitative and quantitative)
- Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data
- Experience and interpret the local environment
- Seek and analyze patterns, trends and connections in data, including describing relationships between variables (dependent and independent) and identifying inconsistencies
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- Analyze cause-and-effect relationships
- Consider social, ethical and environmental implications of the findings from their own and others' investigations
- Transfer and apply learning to new situations

Content Connections

Science 7	• Survival needs: all organisms need space, food, water and access to resources in order to survive
Science 8	• Characteristics of Life: living things respire, grow, take in nutrients, produce waste, respond to stimuli and reproduce

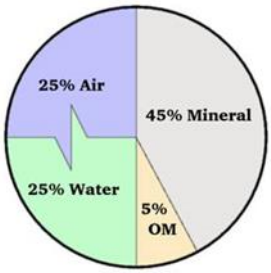
Science 9	• Sustainability of systems
	• Matter cycles within biotic and abiotic components of ecosystems:
	  ○ Eg. Water, nitrogen, carbon, phosphorus etc
	  ○ Human impacts on sources and sink (eg. Climate change, deforestation, agriculture etc.)

Environmental Science 11	• Diversity of local ecosystems: abiotic and biotic factors • Sustainability of local Ecosystems: Unsustainable and sustainable ecosystem practices • Conservation and Restoration of Ecosystems: Ecological restoration principles and practices
Science for Citizens 11	• Agriculture practices and processes: environmental impact
Environmental Science 12	• Soil quality • Land use practices

Teacher Background

Soil is one of British Columbia's most important resources. It supports the growth of fiber and food; acts as a filter for air and water; affects global climate through gas exchange and storage; contains a wide range of organisms (eg. Fungi, bacteria, insects and worms); and supports natural ecosystems and wildlife habitats (BC Ministry of Environment). Soil also plays an integral role in a variety of nutrient cycles (carbon, nitrogen, phosphorus, etc) and therefore provides a good starting point for student investigation of the nutrient cycles.

In this activity the focus will be on topsoil, the upper, outermost layer of soil which can be anywhere from 5 to 20cm in depth. It has the highest concentration of organic matter and microorganisms and it is where most of the Earth's biological soil activity happens. This is where plants typically obtain most of their vital nutrients.



Much of the time when people think of soil they just think of the dirt, but an average soil sample is 45% minerals (sand, clay, silt etc), 25% water, 25% air and 5% organic matter (living organisms, micro microorganisms, animal and plant residues, humus). Plant health depends on soil having the correct balance of each of these components.

Like all living thing, plants have requirements for growth, including space, water and food. While plants can produce their own food (glucose) through photosynthesis, they still require additional nutrients in order to be able to live, grow and reproduce. Macronutrients (nutrients required in large amounts) are carbon, oxygen, hydrogen, nitrogen, phosphorus and potassium. Carbon, oxygen and hydrogen are obtained from air (CO_2) and water (H_2O) so we will be focusing on nitrogen, phosphorus and potassium because plants have to be able to absorb them from the soil.

Nitrogen is needed to carry out photosynthesis and for the growth of leaves. Phosphorus is needed for energy transfer in photosynthesis and seed germination. Potassium plays an important role in catalyzing chemical reactions, controlling water loss and disease resistance.

Plant roots require specific conditions in order to be able to absorb these nutrients: sufficient moisture, optimal temperature, and the correct soil pH range. Much like humans, if plants don't have the right nutrients they start to get sick. The symptoms (in many cases the appearance of their leaves) are dependent on which nutrient they are deficient in.

Growing our food relies on farming, which depends on having good topsoil. Preservation and conservation is critical because once soil is damaged, it is very hard to replace.

Introducing students to soil and having them test for three of the major nutrients that determine plant growth and health, will provide them with tangible examples and relevance as they look more deeply into the matter cycles in future lessons.

Materials

- Class set of Student Activity booklet
- Cutting board (x15 if doing as an activity)
- Knife (x15 if doing as an activity)
- Apple (x15 if doing as an activity)
- Protractors for pie chart
- Class set of soil testing kits (or organize into groups of 2 or 4)
    - pH Testing tube (green cap)
    - N Testing tube (purple cap)
    - P Testing tube (blue cap)
    - K Testing tube (orange cap)
    - 3 green capsules
    - 3 purple capsules
    - 3 blue capsules
    - 3 orange capsules
    - 4 plastic droppers
- Distilled water
- 3 containers of soil from 3 different locations (taken from 2-3" below the surface for lawns, annuals and house plants and 4" deep from shrubs, vegetables and fruit). Prepare the samples 24 hours in advance:
    - Allow each soil sample to dry out naturally
    - For each of the soils put aside 100ml in a labelled jar
    - Fill a clean labelled container with 250ml of soil and 1250ml of distilled water (1:5 ratio). Thoroughly shake or stir the mixture for at least one minute then allow the mixture to stand undisturbed until it settles (30 minutes to 24 hours depending on the soil).
- Clock or stopwatch
- Class set of Natural Resources Fact Sheet
    - Nitrogen
    - Phosphorus
    - Potassium

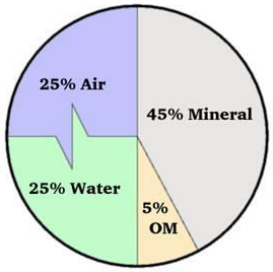
Activities

***a couple of days prior to this activity, give students the option of bringing a soil sample to test from home.

1. ***Importance of topsoil*** – Demo: The Earth as an Apple (depending on the age level, this can either be done in groups, or as a teacher demo)
    a. Have students watch the primer video https://www.soils.org/videos/play/psa/sssa-psa-002-food.flv
    b. Before starting the demo, have students define the term topsoil. Be sure to make the link that topsoil is the part of the earth's crust that produces our food. Ask them to predict what percentage of the earth's surface is covered by topsoil.
    c. Cut the apple into quarters. Set three quarters aside as these represent the oceans of the world. Land is represented by the fourth quarter.
    d. Slice the fourth quarter in half. Set aside one of the $1/8^{th}$ sections represents land inhospitable for humans (polar caps, deserts, swamps, high altitude, rock and mountainous areas). The second $1/8^{th}$ is the land where people live, but not necessarily where food is grown.
    e. Slice the second $1/8^{th}$ into 4 sections, to make four pieces representing $1/32^{nd}$ of the earth. Set aside three sections, as they are too rocky, wet, cold and/or steep, the soil is too poor to produce food, or they are buried under cities, highways, suburban development, shopping centers, etc.
    f. You are now left with $1/32^{nd}$ of the earth. Carefully peel this piece. The peel represents the earth's crust. This thin crust is less five feet deep and is what produces the food we eat.
    g. Questions:
        i. Consider the prediction you made at the beginning of this demo, were you surprised to see how much of the earth crust was topsoil? Why or why not.
        ii. Why is it important to make sure we protect the topsoil?
        iii. What will happen if we don't maintain the health of our topsoil?

2. ***So what is topsoil made of?***
    a. Ask students what things can be found in the soil. As they share their answers, write them on the board, keeping in mind as you organize them that the 4 main groups should end up being Air, Water, Minerals (includes sand, silt, clay, nutrients etc), Organic (microorganisms, plant and animal matter etc)

b. Use different color whiteboard markers to circle or group their answers into Air, Water, Minerals and Organic and then have the students predict what percentage of each can be found in the soil.
c. Have students compare their prediction with the correct percentages and then create a pie chart to represent the components of soil.
    i. Air = 20 – 30%
    ii. Water = 20 – 30%
    iii. Mineral = 45%
    iv. Organic = 5%
d. In the legend provided on their worksheet, have students write next to each component whether it is biotic or abiotic.



3. **What are the main *elements* in the topsoil that are responsible for plant growth?**
    a. Explain to students that in order to grow, plants need the individual *elements* that can be found in soil components (air, water, mineral, organic) Give students this list (C,H,O,N, P, K) and then ask them which ones are readily available to plants from the air and water *They hopefully already know that water is H_2O and air is primarily CO_2 and O_2, (they should say H, O, C*). Make the connection, that while it's easy for plants to get those 3 nutrients, it's harder for plants to get N, P and K. This is why we sometimes use fertilizers to help replenish these in the soil.
    b. Have students complete Part 3 in the activity booklet.

4. **Testing for N, P, K and pH**
    a. Demonstrate to students how to use each of the soil tests. These instructions are for the McKenzie: soil test kit, so if you are using a different test kit you will need to adapt the directions.

pH

1. Remove the cap of the green capped tube and fill with soil sample 1 to the first line.
2. Carefully empty the contents of one green capsule into the test chamber. ****It may useful to have students do this over a piece of paper so that if they do spill the powder it can still be dumped into the container.*
3. Using a dropper, add distilled water to the fourth line.
4. Secure the lid tightly and then shake for 15 seconds.
5. Allow the soil to settle and the color to develop for 1 minute.
6. Compare the color of the solution against the pH chart.

****It is helpful to hold the samples against a piece of white paper when trying to determine the color.*

N, P and K

7. Remove the cap purple testing tube and using the dropper labelled soil 1, fill the tube with Soil Mixture 1 to the 4th line.
8. For the Nitrogen test, carefully pour the contents of one purple capsule into the test chamber.
9. Secure the lid tightly and then shake the sample thoroughly.
10. Allow the color to develop for 10 minutes and then record your results in the observation table.
    ***Tell students that while they wait for the color to develop, that they can use the same procedure for the P Test (blue tube and blue capsule) and the K Test (orange tube and orange capsule).
    *** They must repeat the steps for soil samples 2 and 3 and time permitting their own soil brought from home.

b. After the teacher demonstration have students work in pairs to conduct the soil tests, doing all four test for soil #1 before moving on to soil #2.
c. Have students record their results in the table provided.
d. If you have a limited number of soil test kits, considering having students work in groups of 4, with one set of partners doing the pH and nitrogen and the other set doing the phosphorus and potassium.
e. As students wait for the color to develop, they can work ahead on part 5 of the activity.

5. Nutrient Fact Sheets

a. Have students read the Natural Resources Fact Sheets for Nitrogen, Phosphorus and Potassium and complete the table provided.

6. What happens to plants if the soil conditions aren't right?

a. Ask students what would happen to them if they weren't getting enough nutrients. What are some of the signs that plants aren't healthy?
b. Have students read the information about plant deficiencies.
c. They should then look at the three pictures provided to determine the deficiency and make a suggestion as to how the soil could be remediated.

Plant deficiency images used:

Deficiency 1: ag.arizona.edu/pubs/garden/az1106.pdf

Deficiency 2: http://nosprayhawaii.com/education/

Deficiency 3: http://www.tomatodirt.com/phosphorus-deficiency.html

7. Have the students complete the conclusion questions for homework.

Extension Activities

- Use Activity 6 in The Real Dirt on Farming booklet to look at agricultural practices that demonstrate environmental sustainability
- Demonstrate erosion by wind and water using model systems (hair dryer to represent wind, watering can to represent water)
- Grade 7 – 9 Further investigate the living organisms found in soil For grade 7-9 http://archive.fieldmuseum.org/undergroundadventure/virtual_tour/index.shtml#
- research a career in soil science https://www.soils.org/discover-soils/soil-basics/archive
- Nitrogen cycle game http://www.windows2universe.org/teacher_resources/nitrogen_main.html
- Home soil testing kits are very simplified versions of the actual tests for N, P, and K. Have students research the research industrial soil testing techniques.

Additional Resources

BC Ministry of Environment: www.env.gov.bc.ca/soils/index.html

University of Hawaii Soil Nutrient Management http://www.ctahr.hawaii.edu/mauisoil/basics.aspx

Soil Science Society of America http://www.soils4teachers.org/soil-basics

Investigating Soil

Student Activity Sheet

Name: _____ Date: _____

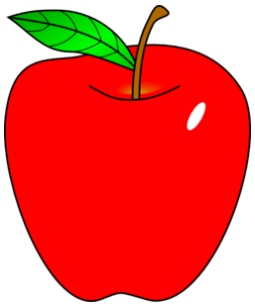
Part 1: The Importance of topsoil - Earth as an Apple

Define: Topsoil _____

Predict: What percentage of the earth's surface is covered by topsoil? _____%

Answer:

1. Consider the prediction you made at the beginning of this demo, were you surprised to see how much of the earth crust was topsoil? Why or why not.

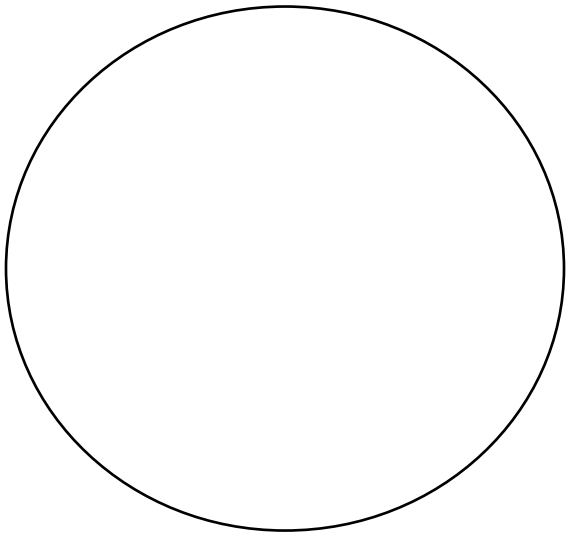


2. Why is it important to make sure we protect the topsoil?

3. What will happen if we don't maintain the health of our topsoil?

Part 2: So what is topsoil made of?

Create a pie chart to show the percentage of each component in healthy soil. Use the boxes to the right to create a legend.



☐ _____

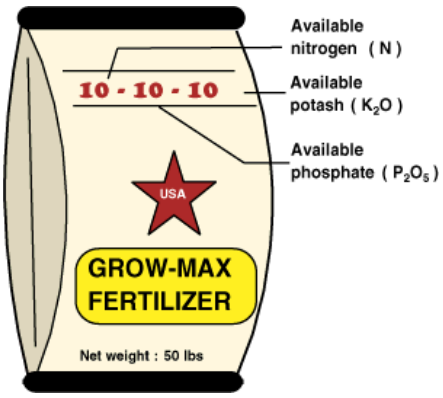
☐ _____

☐ _____

☐ _____

Part 3: What are the main *elements* in the topsoil that are responsible for plant growth?

When you are looking at a bag of fertilizer it lists the amount of Nitrogen, Phosphate and Potassium in that order. A bag of 10-10-10 fertilizer contains 10 percent Nitrogen, 10 percent Phosphate (phosphorus) and 10 percent Potash (potassium)



Because these are the three primary nutrients in soil, when you're buying potting soil you should also see them written on the bag. What percentage of each nutrient is found in this bag of potting mix?

_____ N _____ P _____ K

Part 4: Testing for N, P, K and pH

Materials

- p
- H Testing tube (green cap)
- N Testing tube (purple cap)
- P Testing tube (blue cap)
- K Testing tube (orange cap)
- 3 green capsules
- 3 purple capsules
- 3 blue capsules
- 3 orange capsules
- 4 plastic droppers
- Distilled water
- Soil 1
- Soil 2
- Soil 3
- Soil solution 1
- Soil solution 2
- Soil solution 3
- Stopwatch or some other time keeping device

Procedure:

11. Clear your table of everything except for this activity booklet and a pen or pencil.
12. Collect the testing tubes, the capsules and the droppers and bring them to your desk.
13. Label the droppers with H_2O, soil 1, soil 2 and soil 3. Be sure not to interchange them.

pH

14. Remove the cap of the green capped tube and fill with soil sample 1 to the first line.
15. Carefully empty the contents of one green capsule into the test chamber.
16. Using a dropper, add distilled water to the fourth line.
17. Secure the lid tightly and then shake for 15 seconds.
18. Allow the soil to settle and the color to develop for 1 minute.
19. Compare the color of the solution against the pH chart and record your results in the observation table.

N, P, and K Test

20. Remove the cap of the purple testing tube and using the dropper labelled soil 1, fill the tube with Soil Mixture 1 to the 4^{th} line.
21. For the Nitrogen test, carefully pour the contents of one purple capsule into the test chamber.
22. Secure the lid tightly and then shake them sample thoroughly.
23. Allow the color to develop for 10 minutes and then record your results in the observation table.
24. While you wait for the color to develop, use the same procedure for the P Test (blue tube and blue capsule) and the K Test (orange tube and orange capsule).

25. Repeat all 4 tests for soil samples 2 and 3. Record all of your results in the observation table.

*****while you wait for the color to develop, you can read the Natural Resources Fact Sheets for Nitrogen, Phosphorus and Potassium and fill in the table in Part 5.**

Observations:

Sample	Location	Soil Description	pH	Nitrogen	Phosphorus	Potassium
1						
2						
3						
bonus						

Describe the conditions (pH, N, P and K) for each of the soils that you tested:

Soil 1: _____
_____
_____

Soil 2: _____
_____
_____

Soil 3: _____
_____
_____

Bonus soil: _____
_____
_____

Part 5: Nutrient Facts

Read the Natural Resources Fact Sheets for Nitrogen, Phosphorus and Potassium and fill in the table below:

Nutrient	How is it used by the plant?	Where does it come from?	What forms can it be found in?	What are the main countries producing it?
Nitrogen				
Phosphorus				
Potassium				

Part 6: What happens to plants if the soil conditions aren't right?

As you saw in Part 4, sometimes there's not enough of a particular nutrient in the soil. This means that the plants become deficient and can't grow properly. The following table shows some of the symptoms you might notice. Use it to answer the questions below:

Nutrient	Deficiency	What to look for in a fertilizer?
Nitrogen	General yellowing of leaves, stunted growth, often the older (bottom of the plant) leaves are affected first. The rest of the plant is often light green.	Anything with the words "ammonium", "nitrate", "urea" or "manures".
Phosphorus	Difficult to visualize until severe. Dwarfed or stunted plants. Leaf tips look burnt, and older leaves turn dark green or reddish purple	Anything with the words "phosphate" or "bone".
Potassium	Older leaves may wilt or looked scorched. Yellowing between veins begins at the base of the leaf and goes inward from the leaf edges.	Anything with the words "potassium" or "potash".

*** Note: in this activity we are only looking at 3 of the nutrients that affect plant growth, there are many more macro and micronutrients that can cause deficiencies that may look similar!

1. Plants need the correct pH because it controls how well the plants use the nutrients in the soil. All plants have a pH preference, here are some examples:

Soil pH and Interpretation

5.0	5.5	6.0	6.5	7.0	7.5	8.0
Strongly Acid	Medium Acid	Slightly Acid	Neutral	Neutral	Mildly Alkaline	Moderately Alkaline

Best Range for Most Crops

Tomato: 5.5 - 7.5 Lettuce: 6.0 – 7.0 Onion: 6.0 – 7.0 Mint: 7.0 – 8.0

Which of the above plants would do well in:

Soil 1: _____

Soil 2: _____

Soil 3: _____

2. For each of the pictures below, identify the nutrient deficiency and make a recommendation of how to fix it:

Nutrient Deficiency 1: _____

Recommendations: _____
_____
_____
_____

Nutrient Deficiency 2: _____

Recommendations: _____
_____
_____
_____

Nutrient Deficiency 3: _____

Recommendations: _____
_____
_____
_____

Conclusion

Using all the information that you've learned in this activity, what recommendations would you make for the soils that were tested in Part 4 of this activity in order to avoid having these problems with plant growth?

Soil 1: _____
_____
_____

Soil 2: _____
_____
_____

Soil 3: _____
_____
_____

Bonus soil: _____
_____
_____