Nebraska Soil Science Curriculum

Soil Electrical Conductivity

Approximately 180 minutes

Content and lab derived from the USDA-NRCS Guides for Educators. Please see the Guides for additional helpful pictures and diagrams.

Objectives

By the end of the lesson, students will know or be able to:

- Define: electrical conductivity, cation-exchange-capacity, dS/m, EC_e method, $EC_{1:1}$ method, saline soil, sodic soil, anion, cation, nitrification, denitrification
- Explain the role of electrical conductivity in soil health
- List and describe inherent factors that affect soil electrical conductivity
- Describe the necessity and factors of salinity management
- List and describe problems related to electrical conductivity
- Describe how electrical conductivity affects soil function
- Measure soil electrical conductivity and interpret results

Materials

- Guided notes (one per student)
- Small sample of salt
- 8 ½ x 11" paper stating "Climate"
- 8 ½ x 11" paper stating "Soil Texture"
- 8 ½ x 11" paper stating "Soil Minerals"
- Land to take soil samples
- All laboratory supplies (See Lab Guided Notes)

Preparatory Work

- Print all necessary copies
- Secure permission to collect soil samples from the land owner

Enroll the Participants – Approximately 4 minutes

Show students a container of table salt.

Facilitate a discussion with the students using the following questions as a guide.

Where do we typically see and use salt?
How might salt affect plant and soils?

Preview that during this lesson the class will explore how salts affect a soil's ability to grow productive plants.

Provide the Experience – Defining Key Terms and Explaining the Role of EC in Soil Health – Approximately 5 minutes

Direct students to their guided notes and instruct them to work in pairs to define the terms they may know from another science class.

After a short time, elicit definitions from students and fill in with additional information where needed.

Label the Information – Approximately 10 minutes

Review the terms and definitions using the accompanying PowerPoint or the information found here:

Anion: A negatively charged ion.

Cation: A positively charged ion.

Cation-Exchange Capacity (CEC): Capacity of soil to exchange cations. Soils with high clay or organic matter content have a higher CEC than those soils low in clay and organic matter.

Denitrification: Conversion and loss of nitrate nitrogen to atmosphere in various gas forms, due to lack of oxygen when soil becomes saturated with water.

dS/m: Unit of measurement for electrical conductivity of soil in deciSiemens per meter.

EC_e Method: Standard accepted laboratory method for soil EC testing using a saturated paste extract.

$EC_{1:1}$ Method: Soil EC testing method using a 1:1 soil-water mixture that must be adjusted for soil texture.

Nitrification: Conversion of ammonium compounds in organic material, or fertilizer into nitrites and nitrates by soil bacteria, making nitrogen available to plants.

Nitrogen Oxides: Family of nitrogen gases that can be generated by human activities and released to the atmosphere.

Saline Soil: Soil with a high content of soluble salts and negatively affect soil processes, productivity and overall soil health.

Sodic Soil: Soil with a high content of salt and poor structure. Water infiltration and drainage is prevented.

Soil Electrical Conductivity: A measure of the amount of salts in soil.

Demonstrate the Relevance – Approximately 4 minutes

Instruct students to add the following points to their notes:

1. Soil electrical conductivity affects yields, crop suitability, plant nutrient availability and soil microorganism activity such as emission of greenhouse gases and respiration.
2. Excess salts hinder plant growth by affecting the soil-water balance.
3. Arid and semi-arid climates naturally have a higher salt content.
4. Salinity is influenced by humans through cropping, irrigation and land management practices.

Provide the Experience – Inherent Factors Affecting Soil EC – Approximately 5 minutes

Divide the class into three small groups. Provide each group one of the 8 ½ x 11 papers with one of the following words on it:

Climate
Mineral Content
Soil Texture

Instruct the small groups to write on the papers how they believe each of the factors affect soil electrical conductivity.

After a short amount of time, ask groups to rotate to a new factor and add their thoughts to that paper.

Rotate a second time so all groups discuss all three factors.

Ask the groups that started at each factor to review for the class all of the ideas that were added to the paper.

Label the Information – Approximately 7 minutes

Inform students that there three inherent factors that affect soil electrical conductivity; these factors cannot be changed.

Direct students to their guided notes and add the following information about each inherent factor:

- Climate
    - Salts are more easily flushed through soil located in areas of high rainfall
    - Salts are flushed below the root zone into groundwater or streams
    - Salts accumulate in soils found in dry areas
- Mineral Content
    - Salts come from the weathering of minerals and rocks found in soil
- Soil Texture
    - Clay with high cation-exchange capacities have high electrical conductivity
    - Clay with lower cation-exchange capacities have low electrical conductivity
    - Salts can't leach through restrictive layers and therefore accumulate

Demonstrate the Relevance – Approximately 4 minutes

Ask students to make some predictions about the electrical conductivity (salinity) of the soil in your area based on the climate and soil texture of the area.

Encourage curiosity and inform students that they will be testing salinity soon.

Provide the Experience – Managing Soil Electrical Conductivity – Approximately 1 minutes

Write the following categories down on the white board or a location that is visible to all students:

Cropping   Irrigation   Land Use   Application of Fertilizer/Compost/Manure

Ask students to share their initial thoughts about how these items might relate to management of soil electrical conductivity.

Label the Information – Approximately 12 minutes

Share the following information with the students and encourage them to add it to their guided notes:

- Cropping
  - Leave crop residue to add organic matter and to limit evaporation
  - Low organic matter + poor infiltration + poor drainage + saturated soil + compaction = Increased EC and a decrease in the soil's ability to buffer
- Irrigation
  - The salinity of water affects the salinity of soil
  - Extra water can help flush salts from the soil
- Land Use
  - Ensuring that the least amount of compaction and erosion occur improves soil EC
- Application of Fertilizer/Manure/Compost
  - Monitoring of municipal waste is necessary
  - Nitrogen increases salinity

Demonstrate the Relevance – approximately 3 minutes

Share the following affects with students:

As EC increases, soil microorganism activity decreases, affecting respiration, residue decomposition, nitrification and denitrification

Sodic soils have poor soil structure and poor infiltration or drainage as well as increased toxicity

EC indirectly indicates the amount of water and water-soluble nutrients available for plant uptake

Provide the Experience – Measuring and Interpreting Soil Electrical Conductivity – Approximately 3 minutes

Review the laboratory scenario with students. Students can find the scenario in their guided notes.

Riley, an area agronomist was recently contacted by a farmer concerned about the performance of last fall's crop. Despite efforts made by the farmer, the crop yield decreased consistently over the past couple of years. Since the farmer has never tested the field's soil electrical conductivity and several surrounding farms have had problems with sodic soils, Riley recommends that the tests be run.

Label the Information – Approximately 15 minutes

Review and identify each of the supplies from the soil testing kit that will be used during the lab activity.

- Soil probe for gathering soil samples
- Plastic bucket for mixing soil samples
- 1/8-cup (29.5-mL) measuring scoop
- Calibrated 120-mL shaking vial with lid
- Squirt bottle
- Distilled water or rainwater

- Calibrated 120-mL shaking vial with lid
- EC probe (blue with black cap)
- Probe holder with field calibration resistor (470 ohm)
- 1.41-dS/m calibration solution
- Pen, field notebook, sharpie and zip-lock bags

Review the steps of the laboratory activity and provide any instructions specific to your classroom expectations and time.

Demonstrate the Relevance – approximately 120 minutes

See the attached laboratory guided notes for the steps to complete the laboratory. Review the results and analysis steps of the lab

Review the Content – Approximately 4 minutes

Instruct students to verbally review the steps used to complete the laboratory experience and to discuss the results observed in their particular group.

Celebrate Student Success – Approximately 2 minutes

Congratulate students on their discovery of EC level results for their tested soil. Encourage students to continue being curious.

Guided Notes: Soil Electrical Conductivity

Anion:

Cation:

Cation-Exchange Capacity (CEC):

Denitrification:

dS/m:

EC_e Method:

$EC_{1:1}$ Method:

Nitrification:

Nitrogen Oxides:

Saline Soil:

Sodic Soil:

Soil Electrical Conductivity:

Notes about Soil Electrical Conductivity:

Climate Soil Texture Mineral Content

Cropping

Irrigation

Land Use

Application of Fertilizer/Compost/Manure

Guided Notes: Soil Electrical Conductivity Laboratory

Soil pH Scenario

Riley, an area agronomist was recently contacted by a farmer concerned about the performance of last fall's crop. Despite efforts made by the farmer, the crop yield decreased consistently over the past couple of years. Since the farmer has never tested the field's soil electrical conductivity and several surrounding farms have had problems with sodic soils, Riley recommends that the tests be run.

Laboratory Supplies

- Soil probe for gathering soil samples
- Plastic bucket for mixing soil samples
- 1/8-cup (29.5-mL) measuring scoop
- Calibrated 120-mL shaking vial with lid
- Squirt bottle
- Distilled water or rainwater
- Calibrated 120-mL shaking vial with lid
- EC probe (blue with black cap)
- Probe holder with field calibration resistor (470 ohm)
- 1.41-dS/m calibration solution
- Pen, field notebook, sharpie and zip-lock bags

Laboratory Steps

Soil electrical conductivity is variable. Therefore, multiple samples should be taken from multiple locations. Look over sampling area for large bare spots, areas with short plants, areas where plants are growing better or other areas of possible salinity. These areas should be sampled separately.

1. Calibration: Ensure the electrical conductivity probe is calibrated before starting. Calibrate the probe by immersing it in a standard salt solution (1.41 dS/m) at 25 degrees Celsius (77 degrees Fahrenheit) and turning adjustment knob on probe with a screwdriver until the probe reads 1.4. Then insert the electrical conductivity probe into calibration resistor on the probe holder and record the reading for future use. Future readings are taken at the same temperature.
2. Soil Sampling: Gather a minimum of 10 small samples from an areas that represents the soil type and management history using the soil probe. Take the samples at a depth of 8 inches and place them in a small plastic bucket. Do not include large stones and residue in the sample. Repeat this step for each sampling area.
3. Tamp down one sampling scoop of mixed soil by striking the scoop carefully on a hard level surface and place soil in the plastic mixing vial. Add one scoop of distilled water to the same vial. The vial will contain a 1:1 ratio of soil to water, on a volume basis.

4. Tightly cap the vial and shake 25 times.
5. Remove the cap, turn on the electrical conductivity probe and insert it into the soil-water mixture in the vial, keeping the probe tip well in the center area of the soil suspension. Take the reading while soil particles are still suspended in solution. To keep soil particles from settling, stir gently with the electrical conductivity probe. Do not immerse the probe above maximum immersion level.
6. After the reading stabilizes for about 10 seconds, record $EC_{1:1}$ in dS/m.
7. Save the soil-water mixture for measurement of pH, nitrate, nitrite and phosphorus if applicable.
8. Turn off and thoroughly rinse the electrical conductivity probe with distilled water and replace the cap.
9. Record the soil $EC_{1:1}$ reading(s) and complete the rest of Table 4 by comparing readings to values in Tables 1, 2 and 3.
10. Answer discussion questions.

Table 1. Soil EC influence on microbial processes and gaseous N production in soils amended with sodium chloride or nitrogen fertilizers (after Smith and Doran, 1996 (Tables 10-5 & 10-6) and Adviento-Borbe et al., 2006).

Process	**$EC_{1:1}$ Range (dS/m)**	**Relative Decrease/Increase (%)**	**Threshold $EC_{1:1}$**
Respiration	0.7 to 2.8	-17 to -47	0.7
Decomposition	0.7 to 2.9	-2 to -25	0.7
Nitrification	0.7 to 2.9	-10 to -37	0.7
Denitrification	1.0 to 1.8	+32 to +88	1.0
Anaerobic N_2O gas production (high nitrate)	0.02 to 2.8	+1500 to +31,500	1.0-1.5
Anaerobic N_2O gas production (low nitrate)	0.5 to 2.0	+200 to +90,000	0.7-1.0

Table 2. Salinity classes and relationship between $EC_{1:1}$ to EC_e values (Smith and Doran, 1996 adapted from Dahnke & Whitney, 1988).

Texture	**Degree of Salinity (Salinity Classes)**

	Non-Saline	**Slightly Saline**	**Moderately Saline**	**Strongly Saline**	**Very Saline**	**Ratio of $EC_{1:1}$ to EC_e**
$EC_{1:1}$ Method (dS/m)						
Coarse to loamy sand	0-1.1	1.2-2.4	2.5-4.4	4.5-8.9	9.0+	0.56
Loamy fine sand to loam	0-1.2	1.3-2.4	2.5-4.7	4.8-9.4	9.5+	0.59
Silt loam to clay loam	0-1.3	1.4-2.5	2.6-5.0	5.1-10.0	10.1+	0.63
Silty clay loam to clay	0-1.4	1.5-2.8	2.9-5.7	5.8-11.4	11.5+	0.71
EC_e Method (dS/m)						
All Textures	0-0.2	2.1-4.0	4.1-8.0	8.1-16.0	16.1+	NA

Table 3. Salt tolerance and yield decrease beyond EC threshold (Smith and Doran, 1996; $EC_{1:1}$ based on Hoffman & Maas 1977).

Crop(s)	**Threshold EC_e (dS/m)**	**Threshold $EC_{1:1}$ (dS/m)**	**Yield Decrease (%) per $EC_{1:1}$ Unit (dS/m) Beyond Threshold**
Barley	8.0	4.5 to 5.7	5.0
Cotton	7.7	4.3 to 5.5	5.2
Sugar beet	7.0	3.9 to 5.0	5.9
Wheat	6.0	3.4 to 4.3	7.1
Ryegrass, perennial	5.6	3.1 to 4.0	7.6
Soybean	5.0	2.8 to 3.6	20.0

Tall Fescue	3.9	2.2 to 2.8	5.3
Wheatgrass, crested	3.5	2.0 to 2.5	4.0
Peanut	3.2	1.8 to 2.3	29.0
Rice; Vetch, common	3.0	1.7 to 2.1	12.0
Tomato	2.5	1.4 to 1.8	9.9
Alfalfa	2.0	1.1 to 1.4	7.3
Corn & Potato	1.7	1.0 to 1.2	12.0
Clover, berseem; Orchardgrass; Grapes; Peppers	1.5	0.8 to 1.1	5.7
Lettuce & Cowpea	1.3	0.7 to 0.9	13.0
Green Bean	1.0	0.6 to 0.7	19.0

Table 4. Soil EC (salinity) in surface soil and interpretations.

Site	Soil $EC_{1:1}$ (dS/m)	Texture	Degree of Salinity	pH	Nitrate Estimate (ppm)	Microbial Processes Impacted	Crops Impacted

What about the soil EC test results differed from your expectations? How?

Compare soil EC results to values in Tables 1, 2 and 3. Are EC levels ideal for crops or forages grown and soil microbial processes? Why or why not?