

Agronomic STEM

Water Management



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Objectives:

- Develop a technique to measure the porosity of soil.
- Explain how a high water table can reduce crop yields.
- Design and test a drainage tiling system.

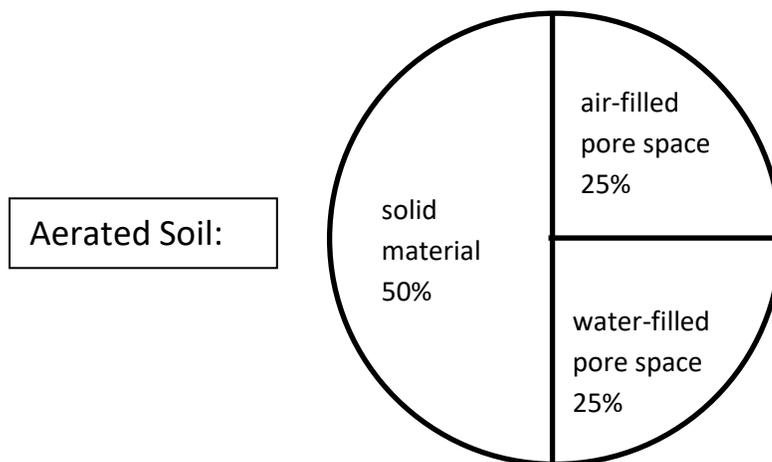
Background Information



The geologic and biologic history of Illinois has resulted in soils which are often poorly drained. Standing water in farm fields is a common sight. This unit examines the issue of poorly drained soils and some of the technologies used to analyze and resolve the problem.

Plant roots require oxygen for growth. The root cells need oxygen for respiration. Adjacent soil microbes, which provide the roots with necessary nutrients, also need oxygen. When soil becomes saturated with water, this oxygen is no longer available.

Ideally, agricultural soils have the following composition, shown as a circle graph:



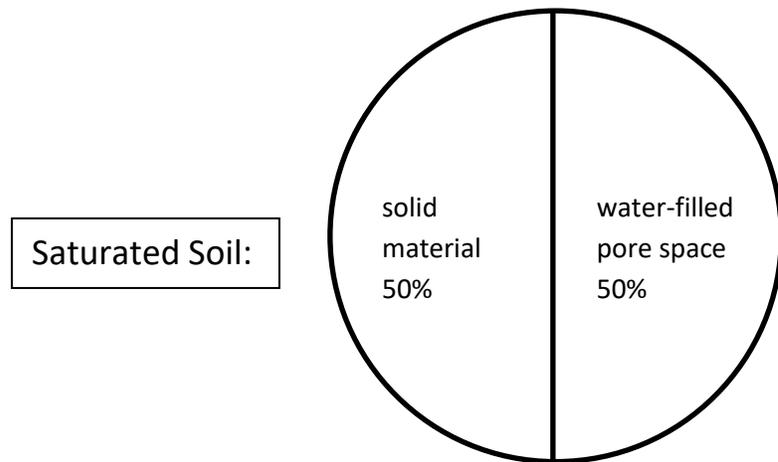
The amount of pore space which is filled by water will vary over time based on weather conditions and details of the soil composition.

After a heavy rain, a soil might be saturated with water as shown below:

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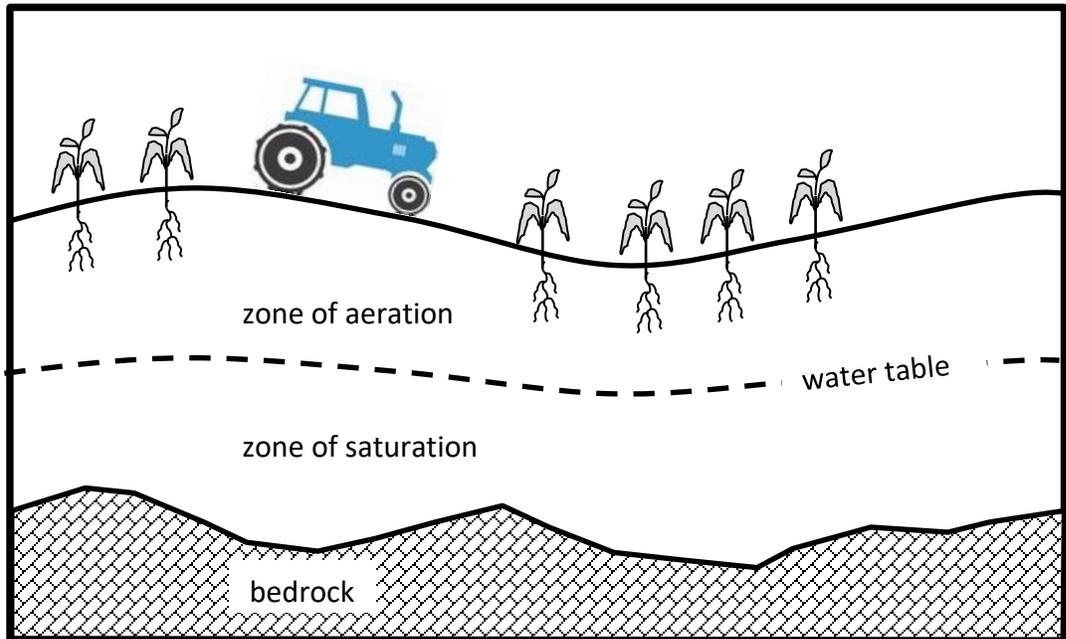
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If this soil is not able to drain within 48 hours, reduction to crop yields will result.

If one looks deep enough, there is generally a level below which the ground remains saturated with water. This level is the **water table** which can rise or fall through the year due to accumulated rainfall and other factors.



If the water table rises to within 50 cm of the surface, soils around the crop's roots will be unable to drain. Root growth will stop, plant development will be impacted, and yields will be reduced.

The depth of the water table can be measured in various locations and shown on a map. Such maps have been available for many years. Recent

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developments in technology, however, enable any farmer with access to the internet to match these maps with satellite photography of his own fields. Using this Geographic Information System (GIS) enables one to identify potential problem areas so farmers can make sound decisions about managing their operations.

A GIS includes a library of computerized maps, tied together with GPS coordinates, so that the maps may be superimposed upon each other in the same scale. This allows patterns and relationships to be identified. Maps may include aerial and satellite photography, or may be composed of any other type of data which can be tied to specific locations.

Farm fields which experience poor drainage can often be improved with the addition of drainage tiles. Drainage tiles are perforated plastic pipes, buried 90 to 130 centimeters below the surface. These tiles carry subsurface water away to drain into nearby ditches or streams. They can effectively lower the water table at their location.

A properly designed tile system can bring the water table down 30 cm from the surface within 24 hours after a heavy rain and down 50 cm within 48 hours. This allows healthy root growth and helps the surface dry, enabling farmers to get heavy equipment into the fields more quickly.

Drainage tiles help some nutrients, such as phosphorous, stay in the soil by preventing surface runoff. Unfortunately, water soluble nutrients such as nitrogen can exit the soil through the tiles and end up in local streams and rivers.

Inquiry Overview

In the first activity, students will develop a technique to measure the porosity of some gravel. This can be accomplished fairly easily, but the emphasis here is on writing a procedure with enough clarity and detail that others can use it. After exploring the concept of porosity, students will be better able to grasp water tables and soil drainage.

In the second activity, students will use the internet and GIS software to examine farm fields in Illinois. They will overlay several maps to identify which fields are over a water table which is frequently near the surface. They will select one field which they believe is likely to have drainage problems.

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In the final activity students will design a system of drainage tiles for the field identified in the previous activity. After building a model of the system, it will be evaluated by timing the duration required to drain excess water.

Activities

Activity 1: Porosity and the Water Table

Objectives:

- Develop a technique to calculate the porosity of soil.
- Explain why a high water table can reduce crop yields.

Standards:

NGSS: SEP2, SEP3, SEP4, SEP5, SEP6, SEP7, SEP8

CCSS Mathematics: MP1, MP2, MP3, MP5, MP6

CCSS ELA/Literacy: 6-8.RST.3

Estimated Time:

- 50 Minutes

Suggested Inquiry Approach:

Arrange the students in groups of three.

Place materials in an accessible location.

Begin by asking students:

- **What do we mean when we say that something is porous?**
- **Is soil porous?**

Porosity Materials:

for the class:

- 1 bag of gravel
- water
- *paper towels*

for each team of 3:

- 1 plastic cup (30 ml)
- 1 graduated cylinder (100 ml)

for each student:

- Student Pages

Allow students to begin with observations of their small cup of gravel. They will estimate porosity and then write a procedure for measuring it. Encourage them to be as specific and detailed as possible while writing their procedure.

Don't let them actually start their measurements yet.

When all procedures are written, have students exchange papers and ask:

- **Can you actually follow the procedure as written?**
- **If not, return the procedure and ask for more details.**

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Once they have a procedure they can follow (however flawed it may be) students should conduct the procedure as written. After students have followed the procedures, have them share results and ideas about what worked and what did not.

Students can finish the remainder of the activity at their own pace.

Debrief Activity 1:

When students are finished, have the class share their answers and ideas in a group discussion.

EXTENSION

After students have measured the porosity of the gravel, ask them:

- **Which would be more porous, soil composed of large particles or soil composed of very fine particles?**

Most people will guess incorrectly, so this leads to a great experiment! Ask them to find the answer using only the materials they have already been using. It can begin with students sorting their gravel into two size ranges and testing as they did before.

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Activity 2: Geographic Information Systems

Objectives:

- Explore a range of features in GIS software which can help farmers make good water management decisions.

Standards:

NGSS: MS-ETS1-1, SEP1, SEP2, SEP3, SEP4, SEP5, SEP6, SEP7, SEP8

CCSS Mathematics: MP1, MP2, MP5, MP6

CCSS ELA/Literacy: 6-8.RST.3

Estimated Time:

- **5 Minutes – Introductory Discussion**
- **35 Minutes – Activity**
- **10 Minutes – Debrief**

GIS Materials:

for each partner team:

- Computer with internet access

for each student:

- Student Pages

Advanced Preparation:

Test to be sure your computers are able to reach the ArcGIS website and use the online application.

Suggested Inquiry Approach:

Begin by asking students:

- **How deep below ground is the water table?**
- **How could we find out how deep it is?**
- **Is the depth to the water table the same everywhere?**
- **What might cause the depth to change?**

Get students into pairs and have them go on the internet to:

<http://www.arcgis.com/home/>

The Student Pages have step-by-step instructions. Be prepared to go from group to group helping them find the appropriate buttons on their screen.

Students' selection of particular counties and farm fields is not critical. The idea is for them to feel some ownership of the field they will study, but don't let them spend too long looking for a "perfect" field. Any will do. Just be sure they haven't selected a football field or parking lot.

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In one step, students are asked to add a layer titled “World Hydro Reference Overlay”. The data for this layer is often hosted in several different online databases, so it may show up more than once. They may use any version. If students cannot find a version which is working, they can continue the activity without the World Hydro Reference Overlay displayed.

While they are looking at the fields, challenge students to find the home of the farmer who works that field. It is probably very close. 97% of all Illinois farms are family owned and operated. Remind students that they aren’t just looking at green rectangles on a map. Those fields are somebody’s life.

Debrief Activity 2:

Ask students the following:

- ***When water drains from a farm field, does that water carry anything else with it?***
- ***What might the consequences be, both for the farmer and for towns which get their water from rivers downstream?***
- ***The layers you added to your computer maps were all about water. Can you think of any other information a farmer might want to see on his computer maps?***

EXTENSION

Allow students to search for other layers to add to their computer maps.

Useful search terms include:

- Growing period
- Farmers markets
- Corn
- Soybean
- Nitrogen fertilizer
- Watershed

Remind students that layers are easiest to see when there is only one at a time being displayed over the basemap.

Students can also experiment with using other basemaps.

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Activity 1: Porosity and the Water Table Student Pages

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Problem:

- Calculate the porosity of a simulated soil sample.
- Explain why a high water table can reduce crop yields.

Procedure:

Take a small plastic cup and fill it to the rim with gravel. Do not pile any gravel up above the rim.

Look at the cup of gravel very closely. Record observations about everything you see in the cup, without emptying it.

The gravel is composed of rocks of various sizes. Is the volume of space occupied by the rocks equal to the entire volume of the cup? Explain your answer.

Estimate how much of the cup's volume is occupied by solid rock and how much is the empty space between the rocks (we call this "pore space" or "porosity").

Solid rock = _____ %

Pore space = _____ %

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Activity 1: Porosity and the Water Table Student Pages

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Would your estimates be any different if you had a larger cup, filled to the rim?
Explain your answer.

To test the accuracy of your estimates, you must find a way to measure the appropriate volumes. The following materials are available:

- Your cup of gravel
- One 100 ml graduated cylinder
- Water
- Paper towels

Write your procedure for how you would measure and calculate the two percentages. Be as neat, thorough, and detailed as possible.

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Activity 1: Porosity and the Water Table Student Pages

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When instructed to do so, exchange papers with another group. Read their procedure. Is there enough detail here for you to follow their procedure? If not, tell them what type of information they must add to their procedure. Once you have a procedure you can follow, use it to find the two percentages for your cup of gravel. Record your work and results below.

Do you think this procedure worked well? If not, explain how the procedure could be modified to be more successful.

Why do you think a farmer or an agronomist might care about the porosity of the soil in a field?

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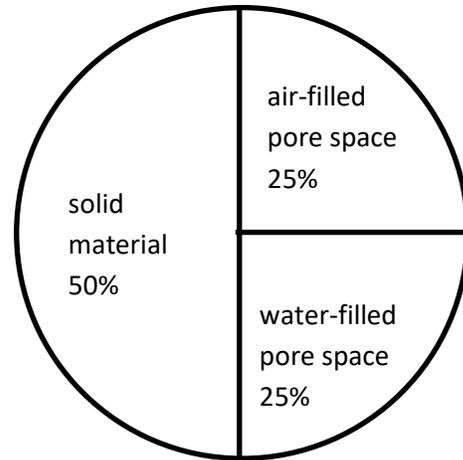
Activity 1: Porosity and the Water Table Student Pages

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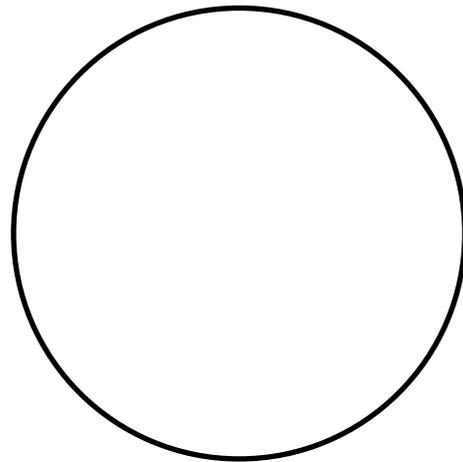
Plant roots require both moisture and oxygen for growth. Ideally, agricultural soils have the following composition, shown as a circle graph:

Aerated Soil:



If heavy rains fall, and the soil becomes saturated with water, what might the composition look like? Show your idea in the pie chart to the right:

Water Saturated Soil:



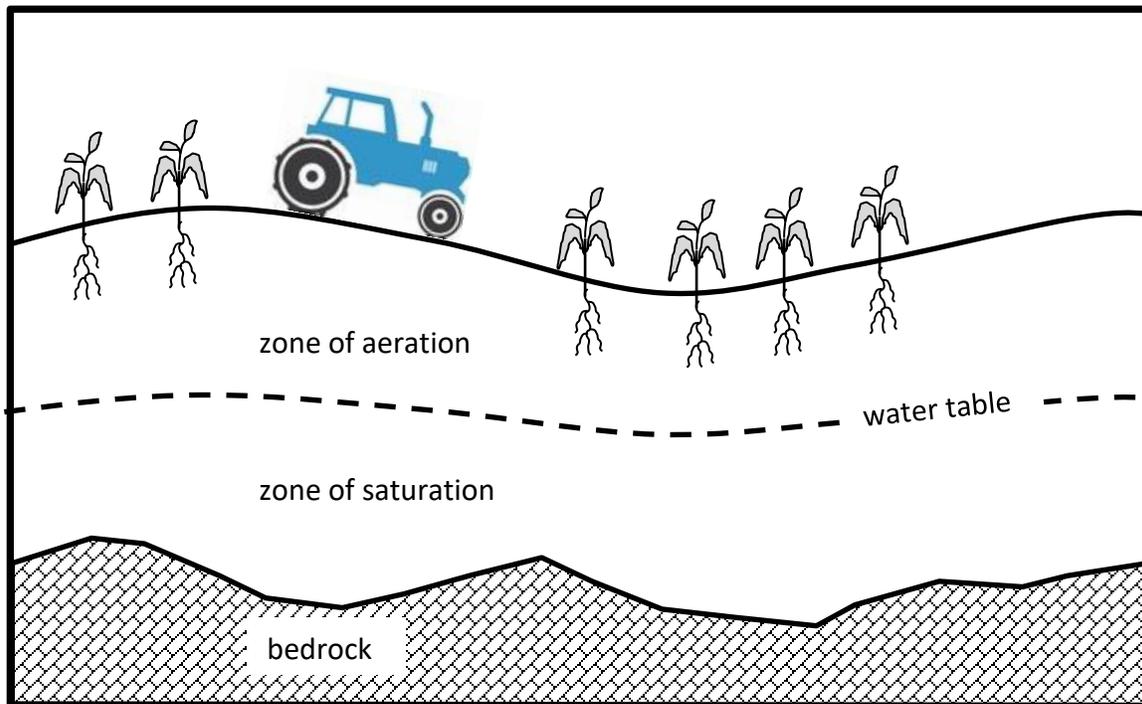
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Activity 1: Porosity and the Water Table Student Pages

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If you dig deeply into soil, as if you were digging a well, you will eventually reach a level below which the soil is completely saturated with water. That level is called the **water table**.



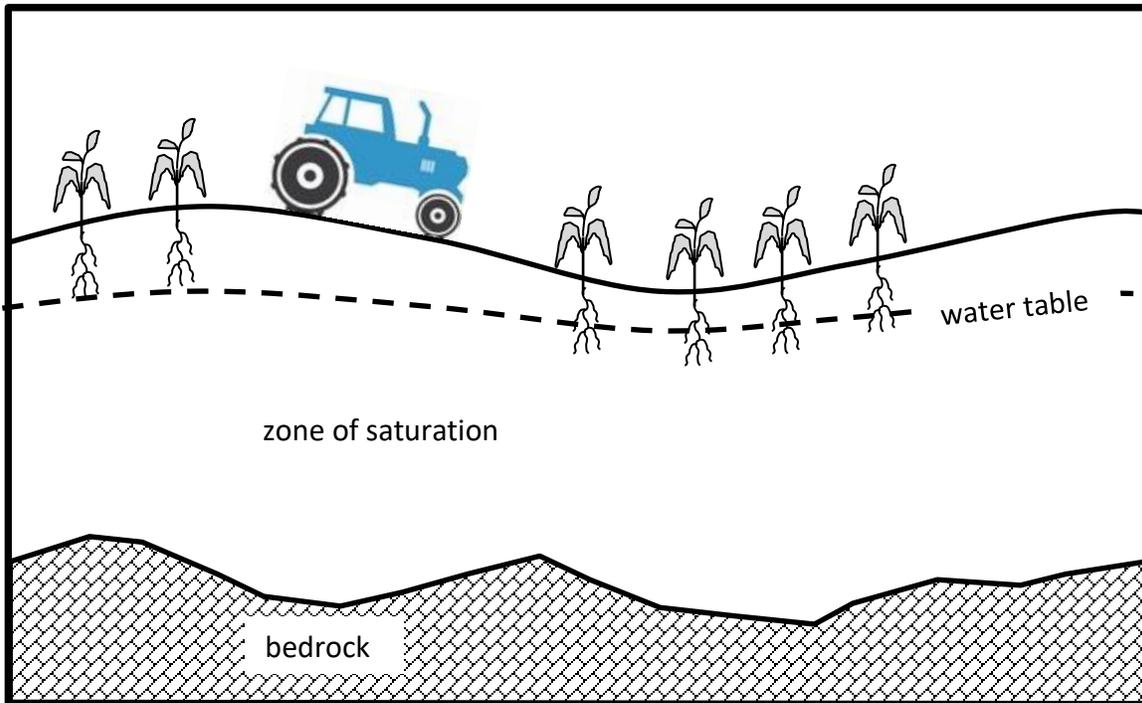
The depth of the water table can change over time. How might the weather influence the depth of the water table?

A large, empty rounded rectangular box provided for the student to write their answer to the question above.

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Activity 1: Porosity and the Water Table Student Pages

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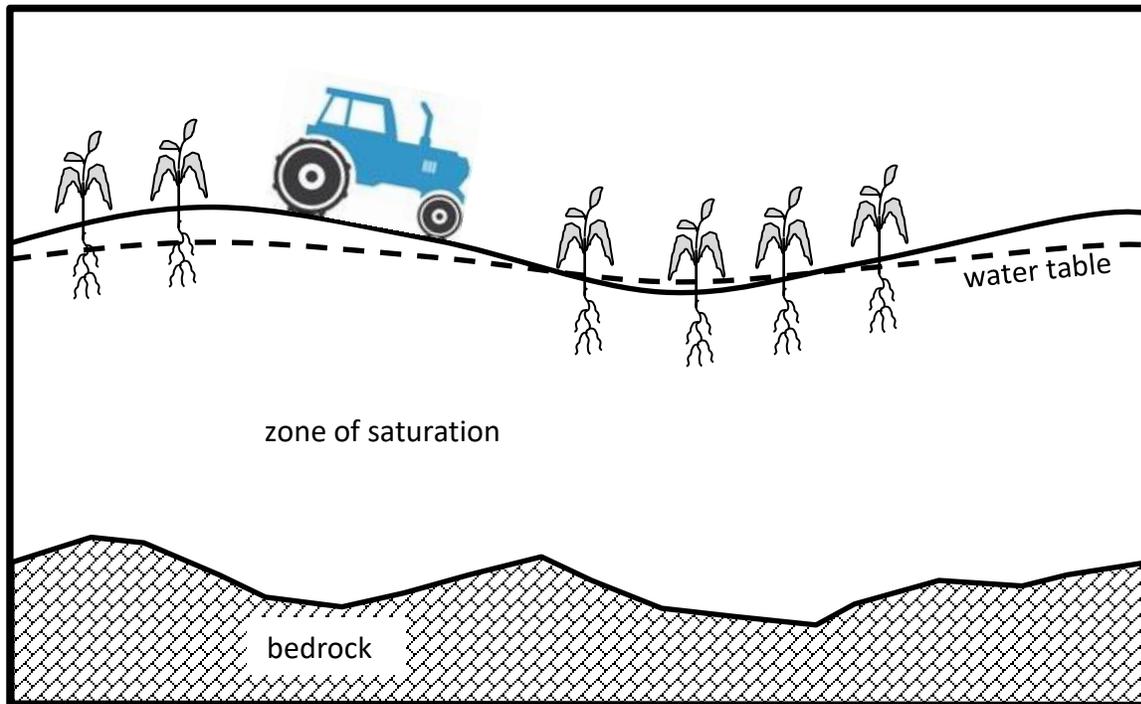
How is this diagram different from the first version? What problems might these crops experience?

Since a farmer can't see below the surface, what clues might alert him to the problem?

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Activity 1: Porosity and the Water Table Student Pages

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How is this third diagram different from the previous versions? What additional problems might the farmer face now?

A large, empty rounded rectangular box intended for student answers.

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Activity 1: Porosity and the Water Table Student Pages



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Activity 2: GIS Student Pages

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Background Information: A Geographic Information System (GIS) includes a library of computerized maps, tied together with GPS coordinates, so that the maps may be superimposed upon each other in the same scale. This allows patterns and relationships to be identified. Maps may include aerial and satellite photography, or may be composed of any other type of data which can be tied to specific locations.

Problem:

- Use layers of data in Geographic Information System (GIS) software to investigate water tables in Illinois.
- Identify which farm fields are likely to have poorly drained soils.

Materials:

- Computer with internet access

Procedure:

1. Find a partner to work with. Direct your web browser to:
<http://www.arcgis.com/home/>
2. Below the pictures are four links. Click on the one called “Make a Map”.
3. In the upper left is a button called “Basemap”. Click the button and select “Imagery with Labels”.
4. Find Illinois and zoom in until Illinois fills most of your screen.
5. In the upper right is a link called “Modify Map”. Click it to access additional options.
6. In the upper left, a button labelled “Add” should now be visible. Click and drag down to “Search for Layers”.
7. There are over 200,000 data layers available. The one we want is called “World Hydro Reference Overlay”. Find it using the search function. Once you have found it, click “Add”.



8. What does this layer add to your map?

9. Very slowly, zoom in using the mouse wheel or +/- keys until county outlines become visible.

10. Select a county you would like to investigate. This may be the county in which you live, but any county will work as long as it has a lot of agricultural land. Since we will be looking for farm fields, Chicago or Cook County might not be best choice.

11. Zoom-in until the county fills most of your screen. Describe the appearance of the land.

12. List the named rivers and creeks in this county.

Note: If you zoom-in too far, you will lose the World Hydro Reference Overlay, and the labels for these waterways will disappear until you zoom out again.

13. All of the information currently shown on your map reflects what is above the surface. Next, we want to add information about what is underground. Search for the layer titled “Annual Minimum Soil Depth to Water Table” and

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Activity 2: GIS Student Pages

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add it to your map. Note: It may take your computer a minute or two to process this data and add it to your map. Be patient.

14. This layer tends to overwhelm the previous layers, making them difficult to see. To adjust your view, click the “Done Adding Layers” button. In the “Contents” pane, put your cursor over the Annual Minimum Soil Depth to Water Table link to highlight it. Three tiny blue dots will become visible beneath the link. Click on those blue dots. Drag down to “Transparency”. Adjust the slider to somewhere between 50% and 75% so that all layers are visible again. Adjust this whenever necessary to improve your view.
15. Click the “Legend” button to see what each of the colors of this layer represent.
16. Zoom in until you can easily see individual farm fields. Click on any farm field to get a pop-up showing information about that location.
17. Within your chosen county, select one particular farm field which has a significant amount of ground with a water table less than 50 cm deep. Explain why it might be difficult to grow crops in this field.

18. Now that you have selected a field, recording its location will help you find it again if you accidentally lose it. Click on the “Measure” button above the map. Then click the “Location” icon. Place the cursor in the approximate center of your field. Record the Longitude and Latitude below:

_____ , _____

If you get lost, enter the coordinates recorded above into the search bar labelled “Find address or place” which is just above your map.

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Activity 2: GIS Student Pages

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19. Turn off the “Annual Minimum Soil Depth to Water Table” layer and examine your adopted field as closely as possible. Zoom-in. Is there anything about your field which is interesting or sets it apart from surrounding fields?

20. In the next activity you will be designing a system of drainage pipes to remove excess water from beneath this field. It would be good to know the surface area of your field. Use the tools available to measure the area of your field in square meters.

Area = _____ m²

21. The excess water you remove from this field will be carried downhill in a pipe to the nearest creek or river. Find that body of water and record its name:

22. Use the tools available to measure the distance from the closest edge of your field to the stream or river.

Drainage Pipe Length = _____ m

23. The water you drain from your field will eventually end up in Lake Michigan or the Gulf of Mexico. Follow its path downstream, noting the names of each creek and river through which it flows, as well as the names of any cities it flows through or by.