Soil Water Infiltration

The infiltration rate refers to how fast water soaks into the soil. This turns out to be a very important property of soils that affects vegetation growth, recharge of aquifers, stream flow, and soil erosion.

Purpose: Introduce the concepts of soil water infiltration and the soil water balance. Study the factors that affect infiltration, practice taking environmental measurements, understand effect of land use practices on recharge and runoff.

In this lab you will determine the approximate infiltration rate of water into soils under various conditions, determine how surface conditions affect the infiltration rate, and speculate how change in surface conditions might affect other hydrologic variables.

Background

The infiltration rate is an important component of the hydrologic cycle of watersheds. It helps determine how rainfall is divided between recharging the groundwater and running off over the surface as sheetwash and in streams. The following relationships apply:

At the surface: Water In = Water Out

In general (simplified): Rainfall = Runoff + Recharge + Evaporation

In general, High Infiltration is good because it reduces runoff and increases recharge, and Low Infiltration is bad because it increases runoff (and erosion) and decreases recharge.

In general, lower infiltration rates cause greater surface runoff and more soil erosion. A high infiltration rate lets most of the rain water soak into the soil and make its way downward to the aquifer. So, typically, a low infiltration rate is bad and a high infiltration rate is good.

Many things can affect the infiltration rate, including soil grain size, vegetation cover, air voids, biotic activity (like worms), and mulching. One of the greatest environmental problems resulting from deforestation has been a huge increase in soil erosion: not only do plants slow down runoff so that it has more time to soak into the soil, but the roots aerate the soil, giving water tiny tube pathways as infiltration channels. When the plants are gone, there is little to slow the water from flowing over the surface and carrying soil with it. Other problems include increased flash flood hazard, increased sediment in rivers, and reduced river flow during dry seasons.
Materials needed:

1. tin can with both top and bottom removed
2. bucket of water
3. watch or cell phone to measure time in seconds
4. digging tool, like a trowel, old knife, or screwdriver
5. ruler to measure water depth

Procedure for determining the Infiltration Rate

Record the time in seconds required for one cup of water to soak into the ground through the bottom of the can at each location.

1. Embed the rim of the open can to a depth of about 1 cm (about 1/2 inch) by pushing and digging as required. Try not to disturb the soil in the center of the area, only dig the area where the rim will be embedded as needed. After embedding, pack soil around the buried part of the can so that water does not leak out around the rim, and restore any disturbed soil inside the can to its original state. If more than a small amount of water leaks out the side, the test is ruined and you will have to repeat it.
2. Pour one cup of water into the embedded, open can.
3. Use your stop watch or cell phone to measure the time in seconds required for the water to completely soak into the ground. Enter this value under column 1, Time, in Table 1 below. Note: if the trial takes more than two (2) minutes, you can stop and estimate the depth that the water level dropped during the 2 minutes. Measure the remaining depth, subtract it from the initial 60 mm and enter this value under column 2, Water Depth.
4. Calculate the infiltration rates in mm/sec by dividing column 2 by column 1 and enter in column3.

CAREFUL! Do not let the water seep out from the rim of the can; try to ensure that it soaks into the ground. If you are only recording a few seconds for the water to infiltrate into anything but gravel, water is leaking out - hold down firmly on the can and try again.
Measurement

One cup of water will fill a closed can to a depth of about 60 mm, the value shown in Column 2. Fill in the remaining blanks in the table.

TABLE 1: Infiltration Rate Measurement

<table>
<thead>
<tr>
<th>Surface (simulates)</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time (seconds)</td>
<td>Water Depth (mm)</td>
<td>Infiltration Rate (mm/second)</td>
</tr>
<tr>
<td>Gravel (lava rock)</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural area (forest)</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loose soil (farm land)</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compacted soil (urban)</td>
<td>120</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Concrete and asphalt</td>
<td>120</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- For gravel or lava rock, use the gravel under the building windows.
- For loose soil, you should be able to push in can fairly easily.
- For compact soil, use a well worn path. You may have to dig around the edge a bit to embed the can. Press hard on the can so that water does not leak around the rim.
- For natural area under trees, use an undisturbed area of small trees or bushes.

Analysis

1. Compare infiltration rates.

Grain Size: What are the infiltration rates for gravel (large grain size) and loose soil (medium grain size)?

Which had higher infiltration rates and by how much (either in mm/sec or as a multiple)?

Compaction: What are the infiltration rates for compact soil and loose soil?

Which had higher infiltration rates and by how much (either in mm/sec or as a multiple)?

Vegetation: What are the infiltration rates for natural area and loose soil?

Which had higher infiltration rates and by how much (either in mm/sec or as a multiple)?
2. What affects the infiltration rate? Name two factors that could affect the infiltration rate and explain how and why they would affect it. (This is easier than you think, just use common sense. What would cause more water to soak into the soil and why?)

1. 

2. 

3. Hawaii. List some locations in Hawaii that might be similar to the surfaces where you measured infiltration.

Gravel (lava rock):

Natural Area (forest):

Loose Soil (agriculture):

Compacted Soil:

Concrete and Asphalt:

4. Calculations. Assume that it rains 1 mm per second. Calculate the rate and amount of runoff for the following surfaces. NO NEGATIVE VALUES, if your calculation comes out negative, enter zero (0).

Rainfall is 1 mm/sec, Infiltration is from Table 1 above, calculate Runoff using:

\[ \text{Runoff} = \text{Rainfall} - \text{Infiltration} \]

Gravel, rate of Runoff (mm/sec) = _____________________________
Natural Area, rate of Runoff (mm/sec) = _____________________________
Loose Soil, rate of Runoff (mm/sec) = _____________________________
Compacted Soil, rate of Runoff (mm/sec) = _____________________________
Concrete and Asphalt, rate of Runoff (mm/sec) = _____________________________
If it rains steadily for 10 seconds, what will be the total runoff (in mm)? To answer, multiply the above runoff rates (in mm/sec) by 10. Again, the answer cannot be negative, nor can it be more than 10 mm.

Gravel, rate of Runoff (mm/sec) = _____________________________
Natural Area, rate of Runoff (mm/sec) = _______________________
Loose Soil, rate of Runoff (mm/sec) = _________________________
Compacted Soil, rate of Runoff (mm/sec) = _______________________
Concrete and Asphalt, rate of Runoff (mm/sec) = _______________________

(NOTE: this exercise is simplified, but helps to demonstrate the basic relationships between water balance variables.)

5. Water Balance. Determine the amount of recharge for each land use scenario in the table below. For the runoff, fill in the runoff column using values you calculated above for 10 seconds of rain. Again, No Negative Values, if your calculation comes out negative, enter zero (0).

Use the equation given at the beginning of this lab: Rainfall = Runoff + Recharge + Evaporation

Table 2: Water Balance of Different Land Use Areas

<table>
<thead>
<tr>
<th>Surface</th>
<th>Rainfall (mm)</th>
<th>Runoff</th>
<th>Recharge</th>
<th>Evaporation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lava rock (gravel)</td>
<td>10</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Forest (natural area)</td>
<td>10</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Farmland (loose soil)</td>
<td>10</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Compact Soil</td>
<td>10</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Urban (asphalt/concrete)</td>
<td>10</td>
<td></td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Based on the table above, suggest locations in Hawaii provide the MOST recharge to the groundwater aquifers (name specific places)?

Based on the table above, suggest locations that provide the LEAST recharge to groundwater aquifers (name specific areas)?
6. Land Use Scenarios. Based on your findings, speculate on how you think the following land use changes might affect the soil infiltration rate and the balance between runoff and recharge in Hawaii, and what environmental consequences there might be (once again, there are no wrong answers, use your imagination). Use the values you measured in Table 1 and calculated in Table 2 to explain your reasoning.

**Conversion of natural, forested land to farmland (loose soil)**

How would this affect infiltration rate, runoff and recharge (look at your tables)?

Environmental consequences (on whiteboard and page 1):

**Conversion of farmland (loose soil) to urban (housing, asphalt, concrete, compacted soil)**

How would this affect infiltration rate, runoff and recharge (look at your tables)?

Environmental consequences (on whiteboard and page 1):

These are relevant issues, especially on Oahu where the aquifer is being pumped at near its maximum sustainable capacity.

Suggest two ways to increase recharge on Oahu.

Why do you think that the forested mountain areas are protected from development in Hawaii?