16. Soil Erosion and Conservation

It takes up to 2,000 years to form one inch of soil. Under the right conditions, that inch of soil can be eroded by wind or water in a single storm. Thus, if not conserved, soil that developed over millennia can be lost within a single human generation. However, soils can be used over and over again using appropriate conservation practices. In this lab, several videos will be used to demonstrate the mechanics underlying soil erosion. In addition, a model will be used to estimate the impact of common soil conservation practices on soil erosion.

**Learning Objectives**

- Identify conditions under which soil is most susceptible to erosion by water.
- Utilize the RUSLE equation to estimate the erosion rates of a given hillslope.
- Compare estimated erosion rates to “tolerable” rates of erosion, commonly known as T values.
- Name and describe conservation practices that reduce water and wind erosion.
- Become familiar with the federal, state, and local agencies associated with soil and water conservation.

**Materials**

- Computer with internet access and a projector

**Note**

For this lab you will need to bring your textbook for lecture, and a laptop or tablet. If you do not have a laptop or tablet, please share with a partner.

**Recommended Reading**
Prelab Assignment

Using the recommended reading and the introduction to this lab, consider the questions listed below. These definitions/questions will provide a concise summary of the major concepts to be addressed in the lab. They will also serve as the basis for the post-lab quiz and are useful study notes for exams.

1. Describe the difference between geologic erosion rates, and erosion rates exhibited by managed soils.
2. Identify the soil particle size most susceptible to erosion by wind.
3. Identify the soil texture class size is most susceptible to erosion by water.
4. Identify and describe the three methods of sediment transport by wind.
5. Define sheet, rill, and gully erosion by water.
6. Name the factors included in RUSLE.
7. Identify and describe three conservation practices used to reduce water erosion.
8. Identify and describe two conservation practices used to reduce wind erosion.

Introduction

Worldwide there are approximately five billion hectares of degraded land, which is approximately 43% of the Earth’s land surface. Of those five billion hectares, the most common cause of degraded land (two billion hectares) is soil degradation due to erosion, compaction, surface crusting, acidification, or salt accumulation. Most of that degradation (85%) comes from water and wind erosion.

However, erosion is a natural process. Geologic erosion is a process that transforms soil into sediment. It takes place naturally without the influence of any human activities. Geologic erosion rates are what has carved and shaped all of the landscapes that we inhabit today. Typical geologic erosion rates are approximately 1 ton/ac annually.

Accelerated erosion occurs when human activities increase the rates of erosion to well above the rates of geologic erosion. It occurs when people disturb the soil, or the vegetation covering the soil. Such practices include overgrazing livestock, cutting forests, plowing hillsides, or tearing up land for construction projects. Accelerated erosion can be 10 to 1000 times as destructive as geologic erosion.

Soil erosion includes two separate processes – soil erosion by water, and soil erosion by wind. Water erosion begins with detachment as rain drops bombard soil aggregates, separating some of them from the aggregate. These stand-alone soil particles are much smaller, and are more easily transported. The transported particles are eventually deposited in a low-lying area, completing the three part process of detachment–transport–deposition. Transport can happen due to splashes from the raindrop, or from running water carrying sediment downhill.
Water erosion begins with sheet erosion where splashed soil is moved uniformly, but some columns of soil that were protected by pebbles may remain. When the water gathers into small channels due to irregularities in the landscape, those channels incise into the soil surface forming a rill. Rills can be smoothed by tillage equipment. If enough water gathers, a gully can form, which is essentially a large rill that is so deep that it cannot be smoothed by tillage equipment. Interill erosion is sheet erosion that occurs between rills. The majority of soil erosion is due to sheet and rill erosion.

Wind erosion is greatest in arid and semiarid regions, such as Kansas, though it can occur to some extent in humid regions. Similarly to water erosion, wind erosion involves three processes – detachment, transportation, and deposition. Detachment occurs as heavy winds push and bounce heavy particles along the surface. As this happens, silt and clay particles can be broken away from aggregates, and can become airborne and transported for great distances. The sediment is transported by three methods – saltation, soil creep, and suspension. Saltation occurs when soil particles move by short bounces, and happens with medium sized particles of 0.1 to 0.5 mm diameter. Soil creep occurs with larger particles, >1.0 mm in diameter, and involves these large particles rolling along the surface. Suspension occurs when particles are suspended in the air for several meters to many kilometers. Only the smallest particles (<0.1 mm diameter) are transported by suspension.

**Activity 1: Soil Erosion Videos**

Watch the following videos posted to K-State Online, answer the following questions.

**Video: Raindrop Impact on a Sandy Surface (Cheng et al., 2014)**

- Of the three rain drop impacts shown, which velocity seemed to have the largest impact, 1.0 m/s, 3.3 m/s, or 5.4 m/s? (They are shown in that order on the video)

- How might the velocity of the raindrop impact detachment? Explain.

- How might the velocity of the raindrop impact the distance that soil particles are moved due to splash? Explain.

**Video: Rainfall Slow Motion HD Heavy Rain Drops Falling in Slow Mo Video of Droplets Hitting Water (Travel Links Directory, 2013)**

- Turbulent (violent) flow of water is more erosive to soil particles than laminar (smooth) flow. In this video, is the water turbulent? Also, how might the erosivity of a rain storm change depending on how intense the rainfall is?
Video: Wind Erosion (officemmdivide, 2011)

What is the speed at which raindrops can “pound the ground”?

If the speed of the wind increases from 20 mph to 30 mph, how much does the rate of erosion increase?

Fill in the percentages of sediment transport by each of the three modes of transport by wind:

Table 16.1. Percentages of Sediment Transported by Each Mode of Transport

<table>
<thead>
<tr>
<th>Mode of Transport</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saltation</td>
<td></td>
</tr>
<tr>
<td>Suspension</td>
<td></td>
</tr>
<tr>
<td>Creep</td>
<td></td>
</tr>
</tbody>
</table>

Draw a diagram below that shows the three types of sediment transport by wind.

Activity 2: Estimating Soil Erosion by Water

In order to estimate current water erosion rates, and to prescribe best management practices (BMPs) that reduce erosion rates, an accurate method to estimate soil erosion was needed. The first model that was used to estimate erosion is known as the Universal Soil Loss Equation (USLE). It is an empirical model, meaning that it was developed from experimentation. It was later revised to form the Revised Universal Soil Loss Equation (RUSLE). For both models, the following equation was used:

\[ A = R \times K \times LS \times C \times P \]

Where \( A \) is the annual soil loss (tons/ac), \( R \) is the rainfall erosivity, \( K \) is the soil erodibility, \( LS \) is the combined factor of the length of slope and the slope gradient, \( C \) is for cover, and \( P \) is erosion control factors. The \( R \) and \( K \) factors cannot be
changed through management. The LS factor can be changed through terracing. The C factor can be changed with crop residue management, such as through conservation tillage or cover crops. The P factor can be changed through the use of strip-cropping, contour tillage, or terracing.

The information required for this calculation can be found from a variety of sources. The R factor can be found on maps made available from the Natural Resources Conservation Service (NRCS) or through the extension service. The K factor can be found in the Web Soil Survey. The LS factor is determined from a table of factors (assuming that you have collected the length of the slope and the slope gradient from your field site) or from a topo map. The C factor can be estimated using tables, often from the extension service. Lastly, P can be found from tables provided by the NRCS.

You are going to estimate the erosion rate for slope on the student learning farm, located at the Agronomy North Farm north of Bill Snyder Family Stadium, in Manhattan, KS, which is in Riley County. The erosivity factor (R) for Riley County is 175.

You will find the K value using the Web Soil Survey. Using your computer, navigate to the Web Soil Survey. Navigate to Riley County, Kansas, then zoom in until the field north of the stadium fills most of your screen. The field is bordered by Marlatt Ave to the north, Denison Ave to the east, Kimball Ave to the south, and College Ave to the west. Using the rectangular AOI tool, draw rectangle over the field with those roads as the boundaries, then click on the “Soil Map” tab. Note that the 3919 Smolan silt loam, 1 to 3% slopes is the most prominent soil mapping unit, covering approximately 35% of the field (or approximately 150 ac). Click on the “Soil Data Explorer” tab, then click on the “Soil Properties and Qualities” sub-tab. Expand “Soil Erosion Factors, and click on “K Factor, Whole Soil”. Click on “View Rating” to load that data onto the map. Scroll down, and note the “Rating” for the 3919 Map Unit Symbol. Record it below.

Next you will determine the topographic (LS) factor. Navigate back to the “Soil Map” tab. You are going to estimate the erosion rate for the top terrace of the field along College Ave. Your instructor will show you where, precisely. Determine the length of the slope using the “Measure Distance” tool at the top of the map that looks like a lime green ruler. Click at the top of the hill near the ditch, then double-click at the first terrace. Scroll down to the bottom of the screen to determine the segment length. The percent slope is also needed. Typically this is measured in the field using a clinometer. However, today we will assume that it is a 2% slope (the middle of the soil mapping unit description of 1 to 3% slope). Using Table 16.2, determine the LS factor given the length of slope you measured combined with a 2% slope. Note that if your value falls between two listed values in the table, it is recommended that you use either the higher value for slope gradient and/or length of slope, so as to calculate a more conservative erosion estimation (i.e. higher erosion rate).
Table 16.2. Values for Topographic Factor (LS).

<table>
<thead>
<tr>
<th>Slope Gradient (%)</th>
<th>Slope Length (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>100 150 200</td>
</tr>
<tr>
<td>2</td>
<td>0.16 0.20 0.23</td>
</tr>
<tr>
<td>4</td>
<td>0.30 0.40 0.47</td>
</tr>
<tr>
<td>6</td>
<td>0.49 0.67 0.82</td>
</tr>
<tr>
<td>8</td>
<td>0.70 0.99 1.21</td>
</tr>
<tr>
<td>10</td>
<td>0.97 1.37 1.68</td>
</tr>
<tr>
<td>12</td>
<td>1.28 1.80 2.21</td>
</tr>
<tr>
<td>14</td>
<td>1.62 2.30 2.81</td>
</tr>
<tr>
<td>16</td>
<td>2.01 2.84 3.48</td>
</tr>
<tr>
<td>18</td>
<td>2.43 3.43 4.21</td>
</tr>
<tr>
<td>20</td>
<td>2.88 4.08 5.00</td>
</tr>
</tbody>
</table>

Next, determine the average annual soil loss in tons/acre, assuming that no conservation practices are being used, and that conventional tillage (straight up and down the hill) is being used:

\[ A1 = R \times K \times LS \]

To compare that erosion rate to the “tolerable rate”, commonly known as T, navigate to the “Soil Properties and Qualities” tab within the “Soil Data Explorer” tab in the Web Soil Survey. Click on “T Factor”, then click on “View Rating” to populate the map. Scroll down to the bottom of the page to see the rating in tons per acre per year.

How does the erosion rate under conventional tillage compare to the tolerable erosion rate?

The farmer wants to reduce the annual erosion rate from this slope, and needs your help to compare the impacts of potential conservation practices. One possibility is to switch to a conservation tillage practice in a wheat-on-wheat rotation that leaves at least 30% of the soil surface covered at the time of planting the next crop. Use Table 16.3 to determine the C factor for the wheat-on-wheat rotation if 30% of the soil surface is covered with residue at the time of planting the following crop under conservation tillage.
Table 16.3. Cover and management (C) values for combinations of tillage and residue cover after planting and crop sequence for wheat rotations.

<table>
<thead>
<tr>
<th>Residue</th>
<th>Tillage</th>
<th>Tillage</th>
<th>Tillage</th>
<th>Tillage</th>
<th>Tillage</th>
<th>No Tillage</th>
<th>No Tillage</th>
<th>No Tillage</th>
<th>No Tillage</th>
<th>No Tillage</th>
<th>No Tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20%</td>
<td>30%</td>
<td>40%</td>
<td>50%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>W-B</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.07</td>
<td>0.06</td>
<td>-</td>
</tr>
<tr>
<td>W-M</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>W-W</td>
<td>0.20</td>
<td>0.20</td>
<td>0.10</td>
<td>0.09</td>
<td>0.08</td>
<td>0.07</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>W-O</td>
<td>0.23</td>
<td>0.23</td>
<td>0.12</td>
<td>0.11</td>
<td>0.09</td>
<td>0.08</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.05</td>
</tr>
<tr>
<td>W-Co</td>
<td>0.16</td>
<td>0.16</td>
<td>0.13</td>
<td>0.11</td>
<td>0.10</td>
<td>0.08</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>Co-W</td>
<td>0.34</td>
<td>0.30</td>
<td>0.14</td>
<td>0.11</td>
<td>0.10</td>
<td>0.09</td>
<td>0.14</td>
<td>0.13</td>
<td>0.11</td>
<td>0.10</td>
<td>0.08</td>
</tr>
<tr>
<td>B-W</td>
<td>0.30</td>
<td>0.28</td>
<td>0.18</td>
<td>0.16</td>
<td>0.12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Table adapted from Jones et al. (1988) with permission.
† Sorghum (milo) may be substituted for corn; all C values are for wide row plantings.
‡ Crop abbreviations are as follows: Co, corn; B, soybeans; W, winter wheat; M, meadow (alfalfa, clover, grass, etc.); Fl, fallow.

Using the values from the previous RUSLE calculation (A1) above, incorporate the C factor to determine the resulting erosion rate after the implementation of conservation tillage.

\[
\text{A2} = R \times K \times LS \times C
\]

\[
\text{A2} = 
\]

How does the erosion rate under conservation tillage compare to the tolerable erosion rate?

How does the erosion rate under conservation tillage compare to the erosion rate under conventional tillage?

The farmer wants to know what options are available that don’t require the purchasing of new equipment (such as a planter or drill designed for planting through stubble). Determine the Pc factor for contour farming using Table 16.4 in the using the 2% slope for our field.

Assuming conventional tillage will still be used (no C factor), calculate the erosion rate if just contour tillage was used, using the same R, K, and LS values from the previous RUSLE calculation above (A2).

\[
\text{A3} = R \times K \times LS \times C \times Pc
\]

\[
\text{A3} = 
\]

Table 16.4. Conservation practice (P) values for contour farming and contour strip
cropping.

<table>
<thead>
<tr>
<th>Slope Gradient (°)</th>
<th>Contour Farming</th>
<th>Contour Farming</th>
<th>Contour Strip Cropping</th>
<th>Contour Strip Cropping</th>
<th>Contour Strip Cropping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Slope Length (ft)</td>
<td>P Value</td>
<td>Strip Width (ft)</td>
<td>P Value, RGMM</td>
<td>P Value, RRGM</td>
<td></td>
</tr>
<tr>
<td>1 - 2</td>
<td>400</td>
<td>0.6</td>
<td>130</td>
<td>0.30</td>
<td>0.45</td>
</tr>
<tr>
<td>3 - 5</td>
<td>300</td>
<td>0.5</td>
<td>100</td>
<td>0.25</td>
<td>0.38</td>
</tr>
<tr>
<td>6 - 8</td>
<td>200</td>
<td>0.5</td>
<td>100</td>
<td>0.25</td>
<td>0.38</td>
</tr>
<tr>
<td>9 - 12</td>
<td>120</td>
<td>0.6</td>
<td>80</td>
<td>0.30</td>
<td>0.45</td>
</tr>
<tr>
<td>13 - 16</td>
<td>100</td>
<td>0.7</td>
<td>80</td>
<td>0.35</td>
<td>0.52</td>
</tr>
<tr>
<td>17 - 20</td>
<td>100</td>
<td>0.8</td>
<td>60</td>
<td>0.40</td>
<td>0.60</td>
</tr>
</tbody>
</table>

Table adapted from Jones et al. (1988) with permission. †Strip cropping uses a four-year rotation of row crop followed by one year of a small grain and two years of meadow (forages) for RGMM, or uses two years of row crops followed by one year of small grain and one year of meadow for RRGM. Meadow includes alfalfa, clover, grass, etc.

How does the erosion rate under contour tillage compare to the tolerable erosion rate?

How does the erosion rate under contour tillage compare to the erosion rate under conservation tillage alone?

Next we will test the impact of installing terraces on the landscape. Using Table 16.5, determine the Pt factor. When terraces are installed, contour tillage is usually used as well. Also, note that installing a terrace results in a shorter length of the slope (because the terrace stops water from continuing to run down slope), so this calculation is performed for each terrace individually. Also note that the net P factor is determined by multiplying the Pc and Pt values together, or writing the RUSLE as follows:

\[ A4 = R \times K \times LS \times Pc \times Pt \]

Table 16.5. Conservation practice (P) values for terraces with underground outlets or waterways.

<table>
<thead>
<tr>
<th>Terrace Interval (ft)</th>
<th>Underground Outlets</th>
<th>Waterways with percent grade of:</th>
<th>Waterways with percent grade of:</th>
<th>Waterways with percent grade of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pt Values</td>
<td>0.1-0.3</td>
<td>0.4-0.7</td>
<td>0.8</td>
</tr>
<tr>
<td>&lt;110</td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
<td>1.0</td>
</tr>
<tr>
<td>110-140</td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>140-180</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
</tr>
<tr>
<td>180-225</td>
<td>0.8</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
</tr>
<tr>
<td>225-300</td>
<td>0.9</td>
<td>0.9</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>300+</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Assume that one terrace has a length of slope of 130 ft, has the same percent slope as above (2%), uses underground outlets to remove excess water, and that contour tillage practices are being used as described above, calculate the erosion rate for that single terrace.

$$A4 = \text{Erosion Rate}$$

How does that erosion rate compare to the tolerable erosion rate?

How does that erosion rate compare to the likely geologic erosion rate of 1 ton/ac/yr?

Now, calculate the erosion rate if conservation tillage, contour tillage, and terraces were all used together for soil conservation as they were described above.

$$A5 = R \times K \times LS \times C \times Pc \times Pt$$

$$A5 = \text{Erosion Rate}$$

How does that erosion rate compare to the tolerable erosion rate?

How does that erosion rate compare to the likely geologic erosion rate of 1 ton/ac/yr?

Considering your results, would installing terraces in addition to using contour tillage and conservation tillage make economic sense if the goal is to reduce erosion rates to near-geologic rates?

Describe how the USLE model could be used to make management decisions regarding tillage practices or terracing – specifically, how could a soil conservationist work with a farmer to reach a truly sustainable erosion rate in the easiest and most economically feasible way possible.

Activity 3: Preventing Wind Erosion

Early on, the estimation of wind erosion rates relied on the Wind Erosion Equation that was similar to RUSLE. It is as follows:

$$E = F \times I \times C \times K \times L \times V$$

Where $E$ is the annual wind erosion rate in tons/ac, $I$ is the soil erodibility factor, $C$ is the climate factor, $K$ is the soil-ridge-roughness factor, $L$ is the width of field factor, and $V$ is the vegetative cover factor. While this model does do a good job of visualizing the primary factors that control wind erosion, the accuracy of the prediction of wind erosion
rates has greatly increased through computer based models, such as the Revised Wind Erosion Equation (RWEQ) and the Wind Erosion Prediction System (WEPS). However, as you can see, vegetative cover, surface roughness, and length of the field are all factors that can be manipulated by the farmer to reduce wind erosion.

- Describe at least one way in which surface roughness can be managed to reduce wind speed, and thus wind erosion.

- Describe how windbreaks and shelterbelts work, and how they must be oriented relative to the prevailing wind.

- Strip-cropping is one conservation practice used to reduce water erosion. It is also used in reducing wind erosion. Describe strip cropping, and compare and contrast how the practice is utilized for reduction of wind erosion, and reduction of water erosion.

Assignment: Online Quiz

A quiz for this lab will be available online. Please access it as directed by your instructor.