



Raindrops And Bombs: The Erosion Process

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Useful Trouble

The role of raindrops in the erosion process can easily be envisioned as being similar to bombs. A raindrop and a bomb may strike some as an exaggerated comparison. After all from our perspective, a typical rainfall seems innocent enough. However, from the perspective of a soil particle, there is not a better analogy than a bomb. During a rainfall, millions of drops fall at velocities reaching 30 feet per second. They explode against the ground, splashing soil as high as 3 feet in the air and as far as 5 feet from where they hit.

Without raindrops, there would be little soil erosion caused by water. But, of course, without raindrops there also would be no crops. As one person put it, rain is a "useful trouble."

Geologic Violence

To understand how soil loss can be controlled, the first step is to understand how erosion occurs and what role raindrops play in the process.

Soil erosion has always taken place and it always will. It is a natural process. The surface of the earth is continually undergoing what might be called a "face lift in slow motion." Slowly, the coastline is receding, the hills and mountaintops are being carried down to the valleys, and the river deltas are being enlarged.

The form of erosion that occurs naturally, without man's influence, is called *geologic* erosion. Some of the best examples of geologic erosion are the Grand Canyon, the Badlands of South Dakota, the canyons of Utah, and many great river valleys.

If conditions in Oklahoma today were pristine, geologic erosion would occur at a low rate on level land; and on gentle slopes, erosion would only be a minor problem. With the state's humid conditions and ideal environment for plant growth, there would be a protective cover for most of the soil.

But needless to say, conditions today are not pristine. Agriculture has replaced some of the protective cover with plants that are more valuable to man – plants that do not cover the soil as effectively as the natural prairie does. Some farmers leave the soil totally bare during fallow periods between crops.

The result? Erosion has increased to destructive proportions on some soils, carrying away topsoil and nutrients, washing pollutants into streams, filling waterways with sediment, and reducing the natural productivity of the land (Table 1).

Although wind has caused significant erosion in the past in Oklahoma, water causes most of the problem today. And here is where raindrops come into the picture.

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Splash Erosion

Erosion caused by water can be broken into four categories—*splash* erosion, *sheet* erosion, *rill* erosion, and *gully* erosion. The first part, splash erosion, is the stage when raindrops strike the soil surface as shown below.

When rain falls vertically on a flat surface, splash erosion is equal in all directions. On a slope, more of the soil is splashed downhill than uphill; and in a wind-driven rainfall, splash movement depends on wind direction and slope steepness.

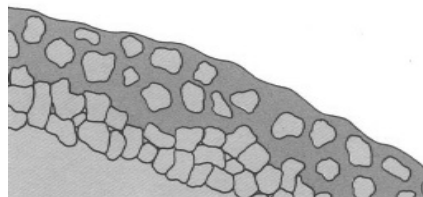
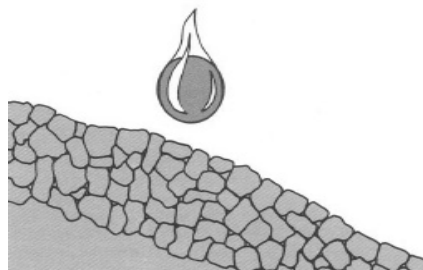


Table 1. Expected yields (percentage of normal yields under various erosion conditions and under high management for common slope groups)

Slope (percent)	High management, favorable subsoil			High management, unfavorable subsoils		
	Uneroded	Moderate Erosion (percent)	Severe Erosion	Uneroded	Moderate Erosion (percent)	Severe Erosion
0-2	100	97	90	100	95	80
2-5	99	96	89	99	94	79
5-10	97	94	87	96	91	76
10-15	93	90	83	91	86	71
15-20	87	84	77	85	80	65
20-25	80	77	70	78	73	58

This table, which is based on studies of Illinois soil types, shows the estimated percentage of normal yields you can expect under certain conditions. For example, if your land has a 2 to 5 percent slope, favorable subsoil and is suffering from moderate erosion, you should receive an estimated 96 percent of normal yields.

Here are definitions of the terms used:

- **High Management** assumes that drainage, nutrients, plant population, tillage, planting, and harvesting are optimal. Also, weed and insect control is adequate and timely.
- **Uneroded** includes a range from no to slight erosion.
- **Moderate** is significant erosion. Subsoil is evident in the plow layer of areas that have been freshly plowed.
- **Severe erosion** is extreme erosion; a condition in which all or nearly all of the surface soil (or A horizon) and probably some of the subsoil has been lost.

To observe the effects of splash erosion, look at a white fence or building by tilled soil just after a rain. Most likely, rain will have splashed soil up several feet on the fence or building.

Other visual indicators of splash erosion are soil pedestals, which are created with the Oklahoma State University rain simulator, or during a heavy rainstorm. When the simulator applies 2-inches of rain per hour on bare soil, the particles underneath a stone or piece of residue remain protected. Meanwhile, erosion batters and washes away unprotected soil from around the object, sculpting a soil pedestal that conforms to the shape of the stone or residue.

This brings us to the second component of the soil erosion process, which is readily observed as transport of soil particles in runoff. If water did not accumulate on the soil surface and generate runoff, the splashing of soil particles would not be a major concern with respect to erosion. When particles are splashed, they are not moved far enough to greatly disturb the soil surface, they are simply redistributed.

But water *does* accumulate on the soil surface. If rain falls hard enough and long enough, the soil eventually will become saturated and runoff will occur. Initially, low spots will collect water and form small ponds. If rain continues, these ponds ultimately will overflow and water will pour downhill.

At this point, the concern about splashed soil becomes clearer. Because raindrops have dislodged particles from the soil mass, runoff water can transport soil for great distances.

So unless there is runoff water, raindrops cannot do much damage. But by the same token, unless raindrops are hitting the ground, runoff water cannot do much damage. (One exception is when runoff moves in a concentrated flow.)

A thin sheet of water flowing across the land does not easily break apart soil particles on its own. This can be demonstrated by running a stream of water down a bare soil surface. The water will look relatively clear because it will only be carrying away soil particles that were already loose. However, if you send a stream of water across a soil surface while raindrops are striking the ground, the water will quickly become muddied with dislodged particles.

Rain and runoff water work together like a pair of thieves. In a bank robbery, one crook performs the actual hold-up while another prepares the getaway car. In a soil robbery, raindrops dislodge soil particles and runoff water carries them away.

In addition, wet soil particles are more easily broken apart. Therefore, as the rainfall persists and the soil becomes saturated the erosive power of raindrops is magnified.



Table 2. Mean composition of surface soil and eroded material.

	Organic Matter	Nitrogen (N)	Phosphorous (P ₂ O ₅) % by weight	Potassium (K ₂ O)	Limestone (CaCO ₃ and MgCO ₃)
Surface Soil	3.33	0.158	0.051	0.01	1.02
Eroded material	4.13	0.275	0.093	0.73	1.52

This table shows the composition of the surface horizon—the soil that has not been eroded away—and compares it to the composition of material that has eroded away.

Notice that there is a greater percentage of organic matter and nutrients in the eroded material than in the remaining soil. These figures, which show how erosion steals the most valuable part of the soil, come from a study on six watersheds in Indiana. The watersheds averaged a soil loss of 8.8 tons per acre per year.

Sheet Erosion

The stage of erosion when runoff water begins to move is called the sheet erosion stage. However, water does not really flow downhill in a smooth, level “sheet” as the name might imply—unless the soil surface is extremely smooth. Water detours around clods and spills out of small depressions. In general, it is a slow, but irregular flow.

Sheet erosion is difficult to see, but its damage can be great. The destruction is more obvious when a plow turns up light-colored or clayey subsoil on sloping land. That means much of the topsoil has been scoured away.

A typical silt loam soil is made up of clay, silt, and sand particles. Erosion has a greater tendency to carry away the finest material (colloidal clay) than it does the coarsest material (the sand particles). But the problem is that most plant nutrients are attached to the fine, clay particles. So erosion, a selective process, steals the most valuable part of the soil, as well as important organic matter (Table 2).

Rill Erosion

When the thin layer of water moves downhill, it tends to concentrate in tiny channels called “rills.” These rills look like miniature rivers, bending and cutting through the soil.

At this point, raindrops continue to break apart the soil, but runoff also has built up enough momentum to break loose soil particles. In addition, rills have an excellent ability to transport soil particles.

The amount of destruction done by moving water depends on the length and steepness of slope. The longer and steeper

the slope, the more momentum water builds. And as water builds momentum, it gains greater power to erode.

Gully Erosion

Eventually, the rills in a field will merge to form larger channels. These may form even larger channels and can become deep enough to be labeled, “gullies.”

Channels are defined as gullies when they cannot be obliterated with normal tillage operations. They are large, noticeable scars on the land. In many areas of the Midwest, gully erosion has even divided fields into small parcels that are inefficient to farm.

Deep gullies with vertical sidewalls are a phenomenon found in some deep river terrace soils along the Cimarron, and North and South Canadian Rivers. Some can reach depths of 20 feet or more.

But gully erosion can be deceiving. Although it is the most obvious form of erosion, it does not remove nearly as much soil in Oklahoma as the other, more invisible forms of erosion.

Splash, sheet, and rill erosion are the forces behind the loss of an estimated 50 million tons of soil each year from Oklahoma’s agricultural land. In comparison, gully erosion accounts for the loss of only about 10 million tons of soil each year on all land in the state. The reason for splash, sheet, and rill erosion’s impact is that they occur on all unprotected surfaces, while gully erosion is a problem mainly on steep or long slopes.

Erosion does the most damage downslope where all forms of erosion are at work. At the top of the slope, splash and sheet erosion are the major forces doing harm.

Sedimentation

So far, this outline of the erosion process has described how soil is detached and transported, but has said nothing about the destination for all of this mobile mud. The question remains, “Where are the soil particles carried?”

Soil is deposited in a process called “sedimentation.” Whenever the flow of runoff water is interrupted, ponds develop. And when ponds develop, soil particles in the water settle to the ground.

Sedimentation can occur in small depressions in the field; above contour furrows; above small debris dams that are formed when residue collects in rills and gullies; by terrace channels; or in lakes and streams.

While most soil may only travel from one part of the field to another, a significant amount of soil particles can eventually reach various waterways. In fact, the Oklahoma Environmental Protection Agency has identified sediment as the number one agricultural pollutant in the state’s waters.



Sediment can choke lakes and carry chemicals and nutrients into waterways, making them uninhabitable for game fish. Everyone, from the farmer and the fisherman to the recreational enthusiast and the taxpayer, must pay for the damage.

Absorb and Control

Erosion caused by people is not uncontrollable, though. The erosion process—from the time it begins with raindrops, all the way to the sedimentation state—suggests two principal ways to reduce this destruction. First, absorb the energy of the raindrop; and secondly, reduce the flow rate of runoff water.

Both of these goals can be met by covering the ground with a growing crop or leaving crop residue on the soil surface. The most effective way to minimize erosion is through the utilization of continuous no-till crop management practices that promote the accumulation and maintenance of crop residues on the soil surface. The establishment of sod-based pastures or other perennial crop production systems on highly erodible land will also minimize erosion. Conservation tillage practices that leave some residue on the soil surface, or maintain crop residue longer during fallow periods will reduce erosion compared to conventional clean till management. However, the fact remains that anytime the soil it tilled it is made more susceptible to erosion.

The flow of runoff can also be controlled with contour farming, grass waterways, or terraces. The key is finding out which combination of these and other conservation practices can be used on your land to minimize soil erosion. One way to evaluate different management options to control erosion is to utilize the Revised Universal Soil Loss Equation.

Revised Universal Soil Loss Equation 2 (RUSLE2):

The RUSLE2 equation provides a long-term average estimate of soil loss resulting from rill and sheet erosion on cropland. This estimate is based on soil type, rainfall patterns, topography, cropping system and management. These loss estimates can be compared to soil loss tolerance values (T Value), to provide guidance for effective control of erosion. Soil loss values calculated using RUSLE2 will also be used in all P-index calculations used to predict the potential for off-site transport of P to surface water bodies.

RUSLE2 is available as a software model to the public for use at the following website:
http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm

This software is designed to be utilized by NRCS staff and other technical service providers and therefore requires a level of expertise to provide sound estimates of erosional soil losses. However, the program uses the following basic equation to calculate erosion loss estimates.

A=RKLS²C_p

Where:

A=average annual soil loss from rill and interrill erosion

R=Rainfall-runoff erosivity factor

K=Soil erodibility measured under standard condition

L=Slope length

S=Slope Steepness

C=Cover Management

P=support practices.

The R factor is a function of the intensity and energy of rainfall in a given area. Therefore, this value is calculated based on the long-term average intensity and energy of rainfall measured in an area. The K factor is a function of soil type and is controlled by characteristics such as texture and structure. The K value for any soil can be found in the county soil survey manual. The RUSLE2 software program contains values for both the R and K factors, eliminating the need to look them up.

The S and L values can be measured in the field as the prevalent slope and slope length of the field. The C factor is calculated based on crop type, crop rotation, residue management, and tillage practices. The P factor accounts for the presence of terraces, and the effects of contour farming and/or strip cropping.

T Values

The T value is the maximum average annual rate of soil erosion that can occur and still permit a high level of crop productivity to be obtained indefinitely. In other words, this is the amount of erosion that can occur and not have a long lasting negative effect on the productivity of the land.

The T value will vary between 1 and 5 tons per acre per year according to soil type. T values of 1 will be assigned to shallow soils whereas T values of 5 will be assigned to deep soils that are least susceptible to the damaging effects of erosion.

When soil is disturbed—by tillage, for example—the rate of erosion increases; but at the same time, nature also is able to rebuild soil at a faster rate. Tillage mixes organic material and nutrients, speeding up the soil building process.

The rate of soil formation cannot be precisely measured, but the best estimate of soil scientists is that with undisturbed conditions, it takes nature about 300 years or more to form 1 inch of topsoil. However, when soil is disturbed by tillage, the length of time to build 1 inch of soil is reduced to about 30 years—assuming that ideal soil-building materials are at nature's disposal.

It should be noted, though, that tillage generally increases the rate of erosion significantly more than it increases the rate of soil formation. So in the long run, it still causes more soil loss. Much of this soil loss is hard to spot with the naked eye; but the erosive forces are at work all the same, washing away truck-loads of soil.

The next time rain is falling on exposed soil think about the image of a bomb. It will serve as a reminder of what is happening to the soil.

But also remember this: Raindrops are bombs that can be intercepted. With the proper mix of conservation practices, the benefits of rainfall in Oklahoma do not need to be associated with excessive soil erosion.

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