Your ECOLOGICAL footprint

How Much Soil Do You Erode?

For many of you this seems like a silly question. On most days you hardly have any contact with the soil. Perhaps when you rake leaves or mow the lawn you increase the rate of soil erosion. More daring readers may increase soil erosion by riding a bike or driving a car off-road.

But like most of the other Your Ecological Footprint calculations, here we provide information that allows you to quantify the effects of your everyday activities on soil erosion. Some of these activities are fairly obvious. Growing your food increases the rate of soil erosion. But so do other activities, such as harvesting trees for use as paper or wood products. The effects are caused by a simple fact—harvesting environmental goods that are generated via net primary production usually changes land cover in a way that increases the rate of soil erosion.

We would like to provide a table here that shows the amount of soil eroded during each of these activities. Unfortunately we can't. One reason is that the soil loss equations described in this chapter require too much information. There is simply no way to know the slope, surface roughness, soil erodibility, and so on for each parcel of land that is used to grow your food and provide your wood and paper products. Even if we could know these factors, the equations are too imprecise. As was discussed in this chapter's case study, scientists who have detailed information about each of the independent variables in the soil loss equations produce estimates for soil erosion that don't match the quantities deposited in waterways.

To get around these difficulties, we use the approach developed by the International Geosphere–Biosphere Program, which is an international group of scientists whose mission is to deliver scientific knowledge to help human societies develop in harmony with Earth's environment. They calculate the relative rate of erosion with the following equation:

$$\text{Relative erosion rate} = \text{Slope}^{1.5} \times (\text{Precipitation}/1{,}000) \times \text{Biome factor}$$

in which slope is the slope of a parcel of land, precipitation is the mean monthly rainfall for the peak rainfall month (measured in millimeters), and biome factor is a parameter that represents the rate of erosion in various biomes. This equation does not calculate the quantity of soil eroded. Rather, it calculates the increase or decrease in erosion relative to erosion in a tropical rain forest.

When using this equation to calculate your effect on soil erosion, we do not expect you to include the effect of slope—there is little information about the slope of the land that you use in distant environments. Rather, we include the effect of slope to illustrate its importance. As slope steepens, its effect on soil erosion increases exponentially (it is raised to the 1.5 power). In contrast, the equation represents the effect of precipitation as linear: Doubling precipitation doubles erosion.

The biome factor represents the effect of plant cover on soil erosion. Notice that the values increase as you read down Table 1. This pattern should make intuitive sense. Because of their closed canopy and many layers of large leaves, tropical rain forests provide extensive protection for the underlying soil. Further down the table are biomes such as open savannas, where the lack of trees offers less protection, so soil erosion is greater than in a tropical rain forest. Even less protective are croplands and bare soils. Without plant cover during some or all of the year, soil is vulnerable to wind and rain.

TABLE 1 Relative Rates of Erosion

Land Cover	Maximum Monthly Precipitation (mm)	Biome Factor
Evergreen broadleaf forest	320	1.0
Evergreen needleleaf forest	42	1.5
Deciduous needleleaf forest	100	2.0
Closed shrubland	98	4.0
Open shrubland	58	5.0
Woody savanna	320	6.0
Savannas	85	8.0
Croplands, natural mix	100	12.0
Grasslands	100	12.5
Croplands	100	21
Urban and built up	100	21
Barren or sparse vegetation	10	21

Sources: Data for maximum rates of precipitation from M.C. Molles, Jr., Ecology: Concepts and Applications, McGraw-Hill; data from biome factor from the International Geosphere Biosphere Programme.

bounce, they may hit larger particles (up to 1 mm in diameter), which can cause the larger particles to **creep** along the surface. The most spectacular type of soil movement is **suspension,** in which soil particles may be lifted high into the air and carried long distances. This is the process that generated the dirt storms associated with the Dust Bowl.

The rate at which these three processes erode soil is represented by an equation that is similar to the universal soil loss equation. The **wind erosion equation** states that the rate of wind-driven soil erosion is determined by (1) soil erodibility, (2) climate, (3) roughness, and (4) vegetative cover. The interpretation of soil erodibility is similar

Because the biome factor represents relative rates of soil erosion, we need to make assumptions about how your use of net primary production changed land cover. For crops this transformation is relatively simple—the original biome was converted to croplands. If you think the pastureland used to support the livestock that provided your meat was overgrazed, perhaps the grassland was converted to the land cover "barren or sparse vegetation." For timber and paper products, we have to make some assumption about what happened to the forest. If the forest was allowed to regrow, the forces of succession changed the community from barren or sparse vegetation, to grasslands, to open shrublands, to closed shrublands, and back to forest. In other cases timber is harvested and the forest is converted to cropland or pastureland.

To convert the relative rate of erosion to a quantity, you need an estimate for soil erosion on a flat hectare of tropical rain forest. Estimates for this rate of erosion indicate that about 0.2 kilograms of soil are lost per square meter per year. If you assume that all of your products of net primary production come from flat land, we can use this estimate to approximate the quantity of soil that is eroded due to the environmental goods you use.

Calculation and Example

The formula used to calculate the amount of soil eroded is based on the amount of net primary production you use, the biomes from which these environmental goods originate, and their rates of net primary production:

Soil eroded = [(__#1__ Good × __#2__ Grams carbon/good)/__#3__ Grams/m²]

*(__#4__ Converted biome factor/__#5__ Original biome factor) × 0.2 kg/m²/year

Notice that this calculation does not include the effects of slope because we could not determine the slope of the land from which you obtained your goods. Nor does it include the effect of precipitation—we assume that the change in ecosystem type does not change local precipitation. (For more about this assumption see Chapter 17.)

This equation seems complex, but it will seem simpler after we step through how the equation is used to calculate the quantity of soil eroded due to the trees harvested to provide the paper you use. Suppose that you use 10 kilograms of paper per year: Put a 10 in blank #1. According to Table 1 in Chapter 6's Your Ecological Footprint (page 106), each kilogram of paper requires 990.83 grams of carbon, so put 990.83 in blank #2. The product of these two numbers indicates that your use of paper represents net primary production of 9,908.3 grams of carbon. The area needed to generate this net primary production can be calculated by dividing 9,908.3 by the rate of net primary production in temperate forests, which can be obtained from Table 1 in Chapter 8's Your Ecological Footprint (page 148); put 702 grams of carbon per square meter in blank #3. This quotient indicates that you need 14.1 square meters of temperate forest to grow the trees that are harvested to make your paper.

Suppose that the trees used to produce your paper were grown in an evergreen needleleaf forest: Put a 1.5 in blank #5. After the trees were removed, the land becomes an open shrubland: Put a 5.0 in blank #4. This quotient (5/1.5) shows that converting the evergreen needleleaf forest to an open shrubland increased soil erosion by a factor of 3.33.

Now we can put all these numbers together to calculate the total quantity of soil eroded that is associated with your use of paper. The total area used to grow these trees is 14.1 m^2. The rate of erosion on these factors increases by a factor of 3.33 relative to a square meter of tropical rain forest, which loses 0.2 kg/m^2/year of soil. This product indicates that your use of paper increases soil erosion by 9.4 kilograms (14.1 m^2 × 3.33 × 0.2 kg/m^2/year). Now repeat these calculations with the other products of net primary production that you use (listed in Your Ecological Footprint in Chapters 6, 7, and 8) and sum them.

Interpreting Your Footprint

These calculations can be used to evaluate the importance of land degradation. Repeat your calculations by assuming that the original ecosystem is converted to barren land, which has an erosion factor of 21 relative to tropical rain forests. The difference between this total and your original represents the increase in soil erosion if the natural ecosystem is degraded after harvest.

We can also use these calculations to evaluate what happens when farmers are forced to grow food on land with ever-increasing slope. Repeat all of your calculations with a slope of 3° instead of 0°. By how much does soil erosion increase? How about when the slope rises from 3° to 6°? As you can see, the relationship is nonlinear: Moving to steeper slopes increases erosion at increasing rates.

STUDENT LEARNING OUTCOME

- Students will be able to explain the factors that determine how their activities affect the rate of soil erosion.

to that for the universal equation. Soil particles that stick together tend to be more resistant to wind erosion. (What types of soil tend to be "sticky"? Think back to the section about soil texture.)

Climate variables that affect wind erosion include precipitation. Wet soil is stickier than dry soil and therefore more resistant to wind; but high wind speeds, both average and maximum, tend nevertheless to increase soil erosion. Soil erosion also is increased by **turbulent** flow, which moves across the surface but also has an up-and-down component. These movements can pick up soil particles and move them over long distances.