# EROSION EQUATIONS PREDICT LAND SLOPE DEVELOPMENT

L. Donald Meyer
Member ASAE

Larry A. Kramer
Assoc. Member ASAE

*How does slope shape affect sediment load and erosion depth? What changes occur in slope shape as erosion progresses? Which slope shapes are effective in reducing erosion and sediment problems?*

THE SHAPE of a hillside may not only affect the rate of erosion at different locations along its slope, but different erosion rates along a slope may appreciably change its shape as erosion progresses. In this research slope shape change, eroded depth and sediment load along slopes of various shapes were computed. This approach may be applied to farm fields and construction sites for predicting locations of critical erosion, rates of sediment movement, and expected slope shape changes.

Present methods for predicting soil loss use the average slope steepness plus other factors to describe expected erosion rates. Thus a relatively uniform slope is assumed, but Nature and man often leave sloping land in shapes that are quite nonuniform. Recent studies of field slope conditions plus research on areas mechanically shaped to more characteristic forms show that slope shape—particularly the steep- of the bottom portion of a slope — is a major factor determining the relative erosion.

In this project four slope shapes — uniform, concave, convex and complex (upper half convex, lower half concave) — were studied at mean slope steepnesses of 5 and 10 percent. All slopes had a 20-ft elevation difference between top and bottom (Fig. 1).

soil-loss prediction equations relating slope steepness and length to total erosion were studied using a digital computer. The coefficient in each was selected so that one erosion period (one iterative solution of the total erosion equation) predicted a soil loss of about 40 tons per acre from a 5 percent slope 400 ft long. This is the average annual soil loss on a Southern Indiana silt loam cropped to continuous corn.

Elevations at 10-ft intervals along each slope were used by the computer program to determine the total erosion or sediment load at the end of each 10-ft increment based on the steepness at and the length from the top of slope to that point. The net erosion or deposition between successive increments was the difference in the sediment load at these points. Erosion depth at each location was determined as the sum of the net erosion for the two adjacent increments divided by their total lengths. New elevations and steepnesses were computed at all points for each successive erosion period. The computer program also produced the input data for an electronic plotter to graph sediment loads and resulting slope profiles.

Both authors are agricultural engineers with SWCRD, ARS, USDA — L. Donald Meyer at Lafayette, Ind., Larry A. Kramer at Columbia, Mo. This is a contribution of the Corn Belt Branch, SWCRD, in cooperation with Purdue Agricultural Experiment Station (Purdue Journal Series Paper No. 3529).

This is a condensation. The full-length report includes a reference list and the analytical methods used in establishing a computer program to describe erosion as a function of slope shape. It also includes samples of program output, including computer-plotted profiles. To order that report, request Paper 1-749 from ASAE, St. Joseph, Mich. 49085. Cost is 50¢ per copy — or your ASAE Member Order Form.

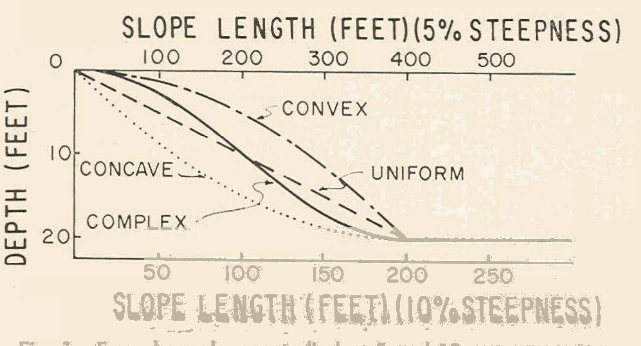


Fig. 1 Four slope shapes studied at 5 and 10 percent steepness, vertical scale is expanded. A flat area was assumed beyond the toe of the slopes

## Effect of Slope Shape

Slope profiles of the different shapes develop differently because erosion depth along each varies considerably. The sediment loads during the first erosion period along the four shapes at 5 percent steepness are given in Fig. 2. The relative depth of erosion or deposition is indicated by the difference between the load at successive locations. Where the slope of the curve is positive, erosion is occurring; where negative, deposition is occurring.

Although the sediment load was low at the upper portion of the convex slope where the steepness was small, it increased rapidly to a maximum of 0.92 units as slope steepness and slope length (quantity of runoff) increased. In contrast, the concave slope had its greatest steepness where the least runoff occurred — at the upper part of the slope. The steepness then decreased as the runoff increased so that that total sediment load at any point was low, with a maximum of only 0.14 units. Furthermore, the total sediment movement on the slope (indicated by the area beneath the curves) was much lower for the concave than for the convex slope. Thus, the concave shape not only had a lower sediment load, but also it was changed less rapidly than the convex.

The sediment load of the uniform slope increased steadily as length increased, reaching a maximum of 0.37 units — higher than the maximum for the concave slope but much lower than for the convex one. The sediment load of the complex slope reached a maximum of 0.32 units — nearly equal to the maximum of the uniform shape — about two-thirds the way downslope. Here the slope was still steep and the runoff large. The load then decreased as the slope steepness decreased, even though the runoff increased. For equal elevation changes, the sediment loads for these shapes were similar at 10 percent steepness.

If sediment is a problem, the load off the bottom of the slopes is significant. For the concave and complex slopes,

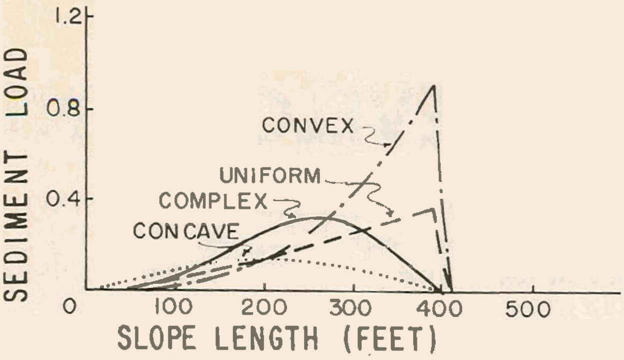


Fig. 2 Sediment load or total erosion (tons per foot of slope width) along the four original slope shapes of 5 percent steepness during their first erosion period. The sediment load was increasing and net erosion taking place where curves have positive slopes. Deposition occurred where curves have negative slopes. The steepness at any point along a curve indicates the depth of erosion or deposition

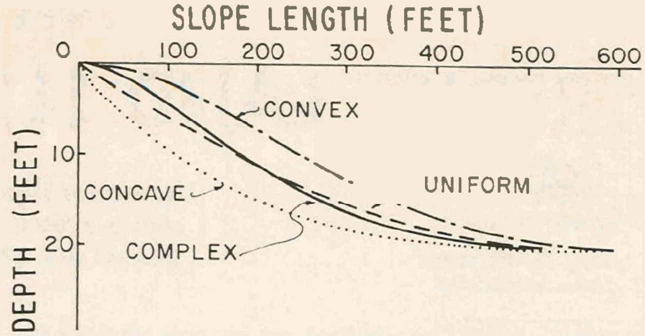


Fig. 3 Slope shapes that developed after 50 periods of erosion from the initial 5 percent slopes of Fig 1

most of the upper-slope sediment load was deposited along the lower one-third of the slope. Little soil movement was indicated beyond the slope base. Sediment load at the base of the uniform and particularly the convex slopes was high. Thus shaping at least the lower portions of long slopes to a concave shape can be quite helpful in reducing sediment losses.

The maximum eroded depths (based on uniform removal) occurred where the sediment load curves of Fig. 2 were of maximum positive slope. This maximum depth was least on the concave slope (0.019 ft) followed by the uniform slope (0.028 ft), the complex slope (0.044 ft) and the convex slope (0.129 ft). At 10 percent steepness, all depths were greater but in the same sequence.

The slope shapes after 50 periods of erosion are shown in Fig. 3. The profile of the convex shape changed the most, the concave shape the least. The uniform slope developed a concave profile; the initially complex slope also developed a concave profile except at the very upper part of the slope. After several hundred periods of erosion, *all* slope shapes tended strongly toward *concave* profiles.

As erosion progressed over succeeding periods, erosion rates decreased because of slope shape changes during the intervening time. Thus erosion intensity tends to diminish with time if other conditions remain the same.

**Effect of Slope Steepness**

Steeper slopes change shape more rapidly because of their greater depth of erosion per unit of time. At steepnesses averaging 10 percent, shapes changed about twice as fast as the same shapes at 5 percent. However, the sediment loads for the 5 and 10 percent steepnesses were nearly the same at equivalent elevations downslope. The effect of increased steepness on erosion for the 10 percent slope was approximately compensated by the decreased length and consequent reduced runoff. Thus, sediment losses at the toe of slopes with different average steepnesses but the same characteristic shape will be similar for a given elevation change. A moderately steep slope with a flattened portion for deposition beyond the toe may therefore be preferable to a less steep, longer slope with no flattened portion at the end.

**To Apply Results**

Information on erosion rates along different slope shapes can be applied to various field conditions. Locations of critical erosion for installing terraces or other erosion control measures can be determined for areas with limited good soil. Major sediment sources can be identified so that reservoirs and water courses can be protected from excess sediment. For construction sites, these data indicate those shapes that will minimize sediment movement and slope shape changes.

Suppose a large commercial building is to be constructed on a hillside (Fig. 4). To keep the main floor level, the area will be reshaped so that the slope below the building will be 400 ft long with an average steepness of 5 percent from the building edge to a level residential area beyond the slope base. Runoff from the building area and above will be removed underground. The residential area itself has ditches and storm sewers for the runoff but can handle little eroded sediment.

With a uniform slope from the building to the toe of the hillside, up to 100 tons of sediment per hundred feet of slope width may be expected annually from this site until cover is established. The expected average erosion depth at the slope base will be about 1 in. annually. Rills may be much deeper. For a complex shape on this same area, the sediment loss will be low but the average erosion depth will exceed 1 in. per year near the center of the slope until cover is established. However with a concave slope, the sediment loss will be low *and* the erosion depth shallow. Thus a concave profile would erode less, produce less sediment, and change shape less than the more common uniform or complex slopes. However, any of these would be superior to a pronounced convex slope. ••

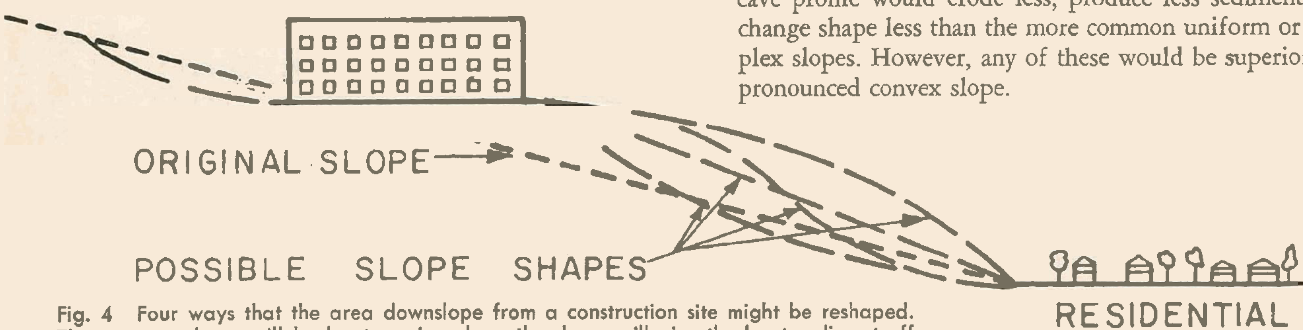


Fig. 4 Four ways that the area downslope from a construction site might be reshaped. The concave shape will be least erosive along the slope, will give the least sediment off the toe of the slope, and will change shape the least