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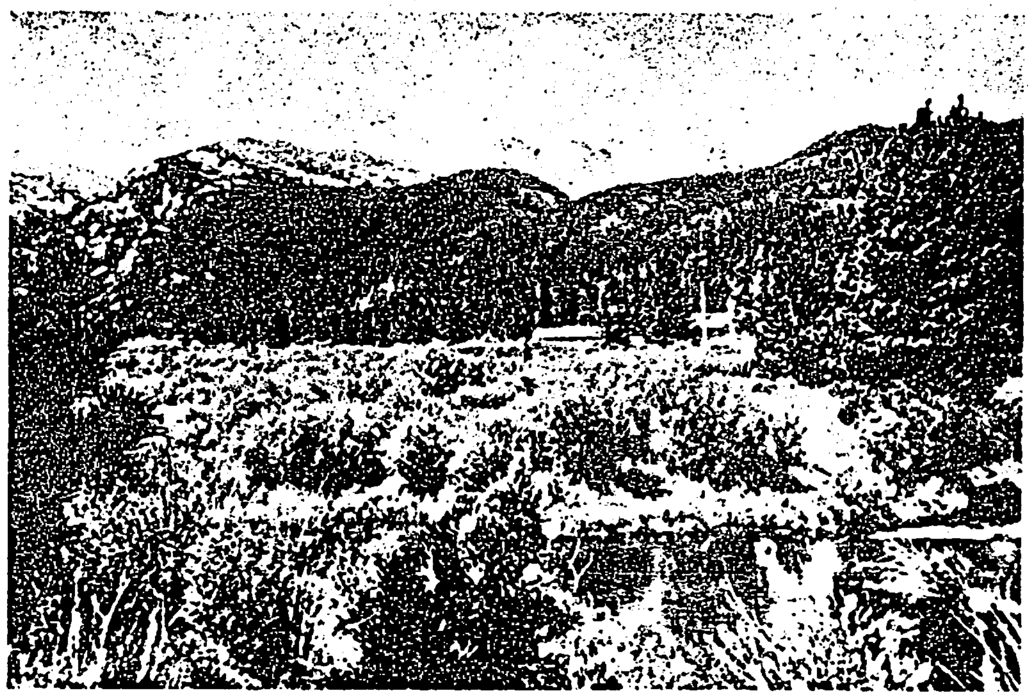

SEASONALLY EPHEMERAL CROPLAND GULLY EROSION

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WHAT IS AN EPHEMERAL CROPLAND GULLY?

Is it the same as an eroded concentrated flow channel? -- The topography of most fields causes overland flow to converge into a few major natural waterways (concentrated flow areas) before leaving the fields. These concentrated flow areas are tilled, leaving the soil highly susceptible to erosion. Most erosion in these channels is from storms soon after seedbed preparation (hence seasonal). After tillage, many soils reconsolidate, and these channels become much less erodible over time during the growing season. These eroded channels are much wider than rills (hence gullies), but unlike the traditional definition of a gully being an eroded channel too large to cross and obliterate with tillage equipment, concentrated flow areas are tilled annually on cropland and partially or completely filled in (hence emphemeral, transient, short lived). Flow in these channels is flashy and only occurs during and shortly after rain events (hence ephemeral flow).

Rills tend to be numerous, parallel, and narrow, while concentrated flow channels tend to be few and wide. Whereas the position of rills varies from year to year, concentrated flow erosion generally occurs in the same location each year. Concentrated flow areas slowly become incised over several years, steepening adjacent overland flow slopes and accelerating nearby sheet and rill erosion. In plan view, concentrated flow channels are usually dendritic, but sometimes tillage marks influence their pattern. The channels may be parallel where heavily influenced by tillage marks and may be difficult to distinguish from large rills.

On soils susceptible to erosion when tilled, concentrated flow erodes through the tilled surface soil. After reaching more resistant, untilled soil, downward erosion slows, the channels widen, and erosion decreases. On soils uniformly erodible with depth, eroded concentrated flow channels are narrower, deeper, and more incised than when the untilled soil beneath the tilled zone acts as a nonerodible layer. Definitions and characteristics of sheet and rill erosion, ephemeral cropland gully erosion, and gully erosion are given in table 1.

EXTENT OF EPHEMERAL CROPLAND GULLY EROSION

When ephemeral gully erosion is severe, grassed waterways or terrace systems are installed to essentially eliminate it. Historically the issue of erosion by concentrated flow has been one of whether or not the channel is stable. In general, it was not a matter of estimating erosion under present conditions and estimating the reduction in erosion from control of concentrated flow erosion with installation of conservation practices. Since 1980, a need of quantitative estimates for this type of erosion has developed, prompting the USDA Soil Conservation Service (SCS) to initiate a field survey program in several States, including Alabama, Georgia, Maine, and Washington, to measure field erosion by concentrated flow. Preliminary results suggest that erosion by concentrated flow in some fields may be as great as sheet and rill erosion.

Ultimately, SCS needs a model to estimate this erosion for its assessment and planning programs and has contracted with USDA Agricultural Research Service (ARS) and others to collect field data needed to develop and validate a model and to develop and improve models for estimating erosion by concentrated flow. Organizations involved in this research include ARS locations at Oxford, MS; Ames, IA; and Watkinsville, GA; U.S. Army Corps of Engineers at Vicksburg, MS; Colorado State University; and University of Georgia. Additionally, rill and furrow erosion research at the ARS locations of Pullman, WA; Kimberly, ID; Columbia, MO; Lincoln, NE; and W. Lafayette, IN is also providing information.

MODELING RELATIONSHIPS

Erosion scientists planning CREAMS, a field scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems, in 1978 recognized the importance of concentrated flow erosion (USDA 1980). Consequently, CREAMS includes relationships for estimating this type of erosion for first- and second-order channel networks. CREAMS assumes steady state and peak runoff rate as a characteristic discharge rate to drive the equations.

The theory in CREAMS is based on the detachment equation

$$D = K(\tau - \tau_c), \qquad [1]$$

where D = detachment rate at a point on the channel boundary (mass/area · time),
K = a soil erodibility factor,
τ = shear stress at a point on the channel boundary,
and τ_c = critical shear stress for the soil.

A distribution for shear stress τ around the channel was assumed (Chow 1959) and combined with equation 1 in a detailed rill erosion model preliminary to CREAMS to compute change in the channel cross section for a steady discharge rate. The channel evolved to an equilibrium shape in a soil uniform with depth and eroded downward at a steady rate after an initial unsteady period as

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Table 1: Comparative Characteristics of Sheet and Rill Erosion, Ephemeral Cropland Gully Erosion, and Gully Erosion.

RILL EROSION	EPHEMERAL CROPLAND GULLY	GULLY EROSION
-Rills are normally erased by tillage; usually do not reoccur in the same place.	-Ephemeral cropland gullies are temporary features, usually obscured by tillage; reoccur in the same location.	-Gullies are not obscured by normal tillage operations.
-May be of any size but are usually smaller than ephemeral cropland gullies.	-May be of any size but are usually larger than rills and smaller than permanent gullies.	-Usually larger than ephemeral cropland gullies.
-Cross-sections tend to be narrow relative to depth.	-Cross-sections tend to be wide relative to depth. Sidewalls frequently are not well defined. Headcuts are usually not readily visible and are not prominent because of tillage.	-Cross-sections of many gullies tend to be narrow relative to depth. Sidewalls are steep. Headcut usually prominent.
-Flow pattern develops as many small disconnected parallel channels ending at ephemeral cropland gullies, terrace channels, or where deposition occurs. They are generally uniformly spaced and sized.	-Usually forms a dendritic pattern along depressional water courses, beginning where overland flow including rills, converge. Flow patterns may be influenced by tillage, crop rows, terraces, or other man-related features.	-Tend to form a dentritic pattern along natural water courses. Non dentritic patterns may occur in road ditches, terrace, or diversion channels.
-Occurs on smooth side slopes above drainageways.	-Occurs along shallow drainageways upstream from incised channels or gullies.	-Generally occurs in well defined drainageways.
-Soil is removed in shallow channels but annual tillage causes the soil profile to become thinner over the entire slope.	-Soil is removed along a narrow flow path, typically to the depth of the tillage layer where the untilled layer is resistant to erosion, or deeper where the untilled layer is less resistant. Soil is moved into the voided area from adjacent land by mechanical action (tillage) and sheet and rill erosion, damaging area wider than the eroded channel.	-Soil may be eroded to depth of the profile, and can erode into soft bedrock.

the channel adjusted from its initial shape to its equilibrium shape (Foster and Lane 1983).

Further analysis showed that relationships for the geometry of the equilibrium channel and its downward erosion rate could be analytically determined. These equations, functions of discharge rate, channel grade, hydraulic roughness, soil erodibility, and critical shear stress, are used in CREAMS to estimate concentrated flow erosion for the time before a channel erodes to a nonerodible layer. The equations were validated with data from rill erosion field experiments (Foster and Lane 1983). Rohlf and Meadows (1980) have also studied channel erosion with a model that calculates erosion at points around the channel's wetted perimeter.

As a channel having steady discharge rate widens after it reaches a nonerodible layer, erosion rate decreases. The rate of widening depends on the shear stress at the intersection of the sidewall and the nonerodible layer. Again the detailed model of rill erosion around the cross section was used to study the effect of the nonerodible layer. The results showed that the average erosion rate for time t could be computed from

$$E = \Delta W \, H_{sw} \, \rho_s / t, \tag{2}$$

where E = erosion rate per unit channel length,
ΔW = change in width,
H_{sw} = height of the channel sidewall,
and ρ_s = mass density of the soil.

The change in width is given by

$$\Delta W = W - W_i = W_*(W_f - W_i), \quad [3]$$

where $W_* = (W - W_i)/(W_f - W_i)$,
W = width at time t,
W_i = initial width,
and W_f = final width.

The normalized width changes according to

$$W_* = 1 - \exp(-t_*), \quad [4]$$

where $t_* = t(dW/dt)_i/(W_f - W_i)$
and $(dW/dt)_i$ == initial rate that channel widens.

Equations 2 through 4 are functions of discharge rate, channel grade, hydraulic roughness, soil erodibility, and critical shear stress. The exponential decay in erosion rate implied by equation 4 was validated with experimental data from a field rill erosion study (Foster and Lane 1983). Accurate estimates of total erosion depends on accurate estimates of final channel width W_f. Equations were derived for W_f and were validated with data from channels ranging in width from rills to rivers (Lane and Foster 1980). Furthermore, channel erosion equations and concepts used in CREAMS are being used to analytically describe stream channel morphology (Osterkamp et al. 1983).

FURTHER DEVELOPMENTS

CREAMS was a first step. Its theory and equations are a starting point for a simpler, applied model useable by field technicians for estimating erosion by concentrated flow. The equations in CREAMS were based on the assumptions of steady discharge and uniform soil that restrict their application. Research needs for development of a more generally applicable model include

1. Use a detailed rill erosion model that computes erosion at several points around a channel cross section to study how channel erosion and channel shape vary with unsteady flow and a nonuniform soil profile.

2. Develop simple methods to estimate concentrated flow erosion. Such methods could consider drainage pattern, base level controls, runoff hydrology and hydraulics, soil conditions, cover, tillage, and other management factors.

3. Study the basic mechanics of erosion by concentrated flow. Current theory ignores the nonuniformity, and often localized characteristics, of concentrated flow erosion. The influence of basic soil strength properties should be determined. Field research is needed to evaluate parameter values so that SCS can apply a model to a wide range of climatic, soil, cover, and management conditions.

4. Validation data and testing are needed to insure that the models are sufficiently accurate for their intended applications.

SUMMARY

Seasonally ephemeral cropland gully erosion occurs in many tilled fields in areas where overland flow has converged in concentrated flow areas in natural depressions. These channels are tilled, often leaving them highly susceptible to erosion soon after tillage. Preliminary results from a recently initiated field survey show that erosion in these channels can be as great as sheet and rill erosion on some fields.

The Soil Conservation Service and Agricultural Research Service of USDA and other agencies are cooperating in research to obtain data and to develop methods to estimate erosion in these concentrated flow areas. Equations in CREAMS are a basis for some of this research. Further developments will include a better understanding of the erosion processes in these channels, simpler methods to estimate this erosion, parameter values to allow application of the methods to a wide range of conditions, and data and testing to show that the methods perform satisfactorily.

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