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[So]il erosion

[Rece]nt research in soil erosion has involved the to[pogr]aphic parameters associated with the ephemeral [eros]ion, the effects of wind erosion on cropland and [m]easures for control, and the use of windbreaks [in r]educing erosion.

Parameters of Ephemeral Erosion

[E]phemeral gullies are channels that form in culti[vate]d fields when precipitation exceeds soil infiltra[tion] rates. Excess water moves downslope as thin[-shee]t flow but eventually coalesces into small streams. [Incr]eased scouring occurs in these concentrated flows [bec]ause water velocity is greater. Small channels, or [rills], subsequently develop on upper slopes; larger [cha]nnels form on lower slopes in concave swales that [serv]e as surface drains for relatively larger watersheds. [The]se larger gullies are called ephemeral gullies when [they] are small enough to permit passage of tillage [imp]lements.

[E]phemeral channels tend to form in the same loca[tion] each season, primarily because gully location is [stro]ngly controlled by landscape configuration. Unlike [eph]emeral channels, rills occur at random locations on [the] slope each season; thus soil is removed from the [enti]re slope, although the magnitude of erosion varies [wit]h slope position. Tillage acts as a cut-and-fill pro[ces]s, extending the impact of the gully several meters [bey]ond the ephemeral channel on both sides. Repeated [cyc]les of channel formation and tillage-filling remove [a g]reater volume of topsoil from these areas and can [qui]ckly reduce crop yields. Adjacent slopes become [ste]eper, hastening processes of rill and interrill ero[sio]n.

[F]actors influencing gully formation are those that [det]ermine (1) precipitation rates, (2) infiltration and [wa]ter-retaining capacities of the soil, (3) resistivity of [the] soil to detachment and transport, and (4) trans[por]t capacity of overland flow. Recent research has [det]ermined how landscape topography influences the [occ]urrence and severity of ephemeral gullies in a given [wat]ershed. This dependence occurs over a range of [lan]dscape scales.

[T]opography external to watershed. [To]pographic features occurring beyond the watershed [bou]ndary influence ephemeral erosion via impacts on [the] patterns of watershed precipitation and temperature [tran]sitions. The potential for erosion becomes greater [as n]umber and intensity of rainstorms increase. Occur[ren]ce of temperature transitions can increase erosion, [par]ticularly in early spring when soil frost just below [the] surface prevents infiltration of warm rainwater. [Th]e thawed surface layer becomes saturated, and soil [par]ticles are easily dislodged by concentrated flow. [Bo]th regional and local physiography may influence [eph]emeral erosion.

Regional influence. At the regional scale, the impact of orography on precipitation patterns is well known. Topographic barriers may decrease cyclonic precipitation on the leeward side, owing to drying associated with descending air. A reverse effect can occur when convectional storms develop over mountains and drift over leeward valleys. (Convectional storms are created when air that is warmed at the Earth's surface rises into the cooler upper atmosphere and, upon cooling, forms clouds and precipitation.) For example, a watershed separated from moist, temperate marine air by a mountain barrier will be subject to less severe ephemeral erosion than an identical watershed not so separated. Not only will the number of annual storms be reduced at the drier location, but the climate of the location may also be more continental; winters may be colder, perhaps cold enough that precipitation may fall in frozen form, eliminating the erosion potential in that season entirely.

The position of the watershed with respect to a topographic barrier may also determine whether storms are dominantly cyclonic or convectional in character. Rainfall from convectional storms is of higher intensity than that from cyclonic systems. High-intensity rains generally produce more runoff, because higher rates of precipitation commonly exceed capacities for soil infiltration. In addition, the kinetic energy of larger raindrops is greater, possibly leading to rapid formation of a surface seal that can reduce infiltration by as much as 80%. Watersheds in convectional rainfall areas may experience erosion throughout the warm season. Even when crop cover reaches its maximum, runoff and erosion may result from convectional storms because of high precipitation rates.

Local influence. Local features influence rainfall and temperature regimes between different watersheds. Certain landscape configurations can channel airflow, producing zones of low-level moisture convergence. In these zones, a relatively warm, moist airflow collides with another airmass flowing from a different

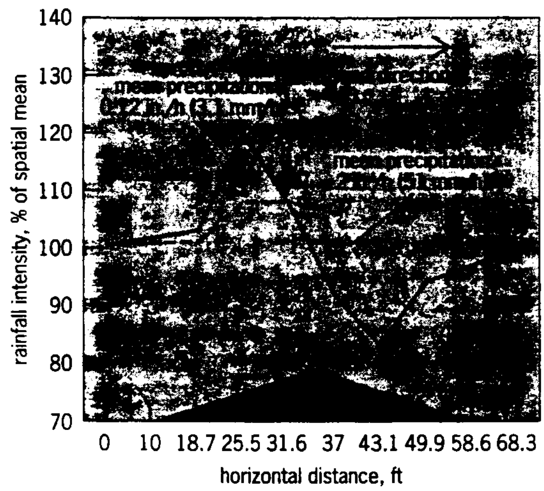

Fig. 1. Pattern of rainfall occurring across a 3-ft (0.9-m) ridge, along the wind path, when wind speed is 14 mi/h (6 m/s) and meteorological rainfall intensity is either 2 in./h (51 mm/h) or 0.12 in./h (3.1 mm/h). 1 ft = 0.3 m.

Table 1. Topographic indices commonly computed by digital terrain models

Code	Name	Definition
S	Slope	Maximum rate of change of elevation of the surface (m/m)
ASP	Aspect	Compass bearing of the maximum downward slope (degrees clockwise from north)
P_F	Profile curvature	Second derivative of arc defined by the intersection of the surface with a vertical plane that passes through slope vector and node (m/m^2; positive → convex)
P_L	Planform curvature	Second derivative of arc formed at the surface by a vertical plane perpendicular to slope vector and passing through node (m/m^2, positive → concave)
A	Upstream contributing area	Upstream area (m^2) that contributes flow to the surface point corresponding to each node
A_U	Unit area	Area/unit contour length (m^2/m; unit contour length is the size of land surface appraisal unit)

direction and from a different source area, so that locally higher mean rainfall results. Complex relief is thought to reduce the efficiency with which developing storms assimilate latent energy from the atmosphere. As a result, convectional storm activity in complex physiography consists of numerous small raincells that produce less intense rainfall. In smooth terrain, raincells can grow larger and produce more intense precipitation of longer duration. A watershed positioned in depressions or near the lower terminus of canyons or drainages experiences more temperature transitions than one not exposed to drainage of cold air; as a result, incidents of rain on frozen soil increase in the former.

Internal topography of watershed. The physiography of the watershed itself can affect runoff, and hence ephemeral erosion, by influencing spatial distribution of precipitation and infiltration, and by playing a role in controlling runoff or subsurface flow. Within the watershed, microclimates associated with surfaces of different slope and aspect create variable temperature patterns, crop production, and soil properties. Hydrologic response varies accordingly. For example, greater crop or residue cover or greater soil organic matter impedes the formation of surface seals due to raindrop impact; thus infiltration is better maintained, and runoff is reduced. Evidence indicates that interaction between wind and ridge-shaped relief causes unequal distribution of precipitation at the surface. The effect of wind on the pattern of rainfall intensity received over a hill, where rainfall is converted to an equivalent depth received on a level surface is shown in **Fig. 1**. Thus, the configuration and orientation of divides or included ridges within watersheds determine surface precipitation inputs under a given wind regime, and these inputs influence the location and severity of ephemeral channel development. Internal topography primarily controls ephemeral erosion by determining the distribution of soil moisture in the watershed and the erosive power of emergent streams of concentrated flow. An understanding of these processes is essential in order to evaluate the erosion potential inherent in different landscapes.

Digital terrain models. In order to examine spatially dependent processes in landscapes and to develop predictive relationships that are applicable in diverse environments, researchers require a nonpositional method of relating spatial properties within landscapes. In other words, the location in a landscape associated with ephemeral gully formation must not be defined in terms of fixed coordinates, but by parameters that describe erosion potential inherent at the location. Because ephemeral erosion processes are very sensitive to landscape configuration, parameters have been derived from topographic attributes.

Topographic parameters describing each location in a watershed are calculated by using a three-dimensional numerical representation of the watershed surface, the digital elevation model. Commonly, the digital elevation model is given as a series of elevations (Z values) for X and Y coordinates, as defined by the nodes of a uniform grid. A computer program analyzes the digital elevation model and outputs a digital terrain model; it models surface configuration by using topographic indices computed for surface points corresponding to all nonperipheral grid nodes in the digital elevation model. The indices commonly computed for each grid node are listed in **Table 1**. The relationship between curvature parameters and surface configuration is illustrated in **Fig. 2**.

Predicting ephemeral gullies. The associations between simple and combination indices and the occurrence and severity of ephemeral gullies in water-

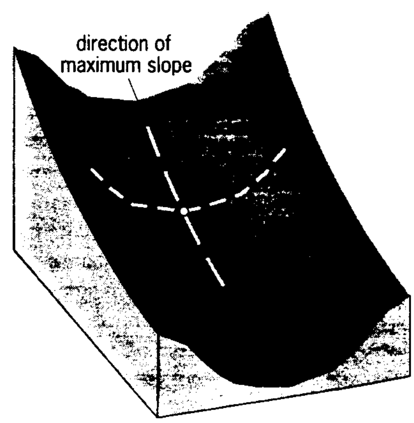

Fig. 2. Relationship between digital-terrain-model curvature indices and surface configuration.

Simple and combination topographic parameters and associated indicator or predictive potential

Name/definition†	Hydrologic indicator‡: Channel occurrence (high soil moisture)	Hydrologic indicator‡: Channel severity (erosive power)
Slope		+
Planform curvature	+	+
Profile curvature	−	
Upstream contributing area	+	+
Unit area	+	
P_L*A*S		+
P_L*S	−/+§	
$Log(A_U/S)$	+	−§
A_U*S	−	−

…isks indicate that the term in the first column is derived from the product of the indices given, that is, $P_L*A*S = P_L \times A \times S$.
…s and minus signs indicate the sign of the correlation.
…ationship may vary depending on watershed character.

…a are presented in **Table 2**. Recent studies have …n that the presence of ephemeral channels is … strongly related to the topographic parameter …lanform curvature (the curvature of the Earth's …ce as measured along the contour). Once this …r is accounted for, indices coded as PFS, LNAS, …ABS (see Table 2) provide further explanation …e variability observed with regard to gully posi… in watersheds. The severity, or size of ephemeral …nels, was also found to be primarily related to …form curvature. Secondary relationships with the …es LNAS, ABS, and CTI have been observed. …nature of the relationships observed between the …rrence and severity of ephemeral gullies and to…aphic parameters appears to differ between wa…eds having contrasting soil properties or other …rences. The suggestion is that one, two, or three …graphic parameters may not adequately describe …meral erosion hazards in various landscapes, and …topographic parameters alone are not adequate to …ict the pattern of the erosion that may develop … given site. Current approaches used to evaluate …phemeral erosion potential in landscapes have …loyed topographic parameters or have endeavored …evelop physically based mathematical models. The …ences of internal topography on the patterns of …all, temperature transitions, and soil properties … not been addressed in these efforts, and they need … included in future designs. *Rodrick D. Lentz*

Parameters of Wind Erosion

…he erosion of soils by wind has always presented a …rd to society. Many human activities can acceler… this basic geomorphological process, but erosion …be controlled with some basic practices. Wind …ion can render land almost useless for traditional …culture. Only the most rudimentary agricultural …tems can operate in a severely eroded region. In …tion to damaging the land, wind erosion degrades …environment by generating large dust clouds that …cure the Sun, render traffic extremely hazardous, …riorate painted surfaces, and damage or destroy …t seedlings and any moving mechanical device. …aging and using available resources is the key to effective and efficient control of wind erosion.

Soil erosion by wind is a subtle process, but the damage to plants can be dramatic. The impact on the soil may not be apparent until irreparable damage has already been done. Damage to plants is immediately apparent, because plants may be cut off at the soil surface; in addition, plants may be sufficiently damaged that the seedlings will die later, or the damage is such that crop quality and yields are severely reduced. Wind erosion has been studied for many years, but only recently have workers begun to understand the complete process and the complexity of trying to accurately measure and model wind erosion in the field. To describe the impact of wind erosion on the soil's ability to produce crops will require many years of additional research, because the impact depends on depth of the soil profile, the crop being grown, and the climate.

Effects on soil. Wind can detach soil particles, roll them along the soil surface, or inject them into the wind stream. Small particles become suspended in the air stream and may be transported hundreds to thousands of kilometers. In the detachment and transport process, the fine material is sorted in a manner similar to the winnowing of grain. The finest particles, 2–100 micrometers in diameter, are suspended in the air stream; the intermediate-size particles, 100–500 μm, are bounced along the soil surface in a process known as saltation; and the largest particles, 500–1000 μm, are moved along at the surface in a process known as soil creep.

As the soil surface continues to erode, it may be subjected to additional abrasion such that nonerodible aggregates are broken into erodible fractions. The fine material and soil organic matter that is lost represents the most productive portion of the soil profile.

In many areas of the United States, wind erosion is most prevalent at the time that crops are established. Most plant seedlings are very susceptible to damage by wind-blown soil particles. In fact, crops such as peppers and carrots can be destroyed when exposed to a 10-min windstorm. Yields of major cash crops like cotton can be reduced 50–75% by a 15-min exposure to blowing sand. The quality of horticultural crops and