

MANAGEMENT NOTES

Indicators of Soil Movement on Range Watersheds

E. WILLIAM ANDERSON

Highlight: *Three agents of soil movement are discussed: wind, water, animal hoofs. Eight indicators of soil movement are described and their reliability for indicating soil movement is interpreted. The indicators are: trampling, soil remnants, erosion pavement, lichen lines, wind-scoured depressions, aeolian deposits, alluvial deposits, and gullies and rills. A simple field procedure for measuring gully and rill erosion is presented. This quantitative approximation of soil movement due to erosion by water has proved to be reasonably reliable.*

Abnormal soil movement on range watersheds is only a symptom. The real problem lies with the cause of the soil instability. Some factors influencing natural soil instability are (1) climate, including precipitation and frosts; (2) inherent character of the soil such as texture, structure, and permeability; (3) topography, mainly slope gradient; (4) retardants such as vegetation, litter and mulch, and stones. Disturbances by wildlife, livestock, machinery, and fire can accentuate the natural instability of soils. The cause of soil movement, however, usually is related to the quality and quantity of the vegetational cover on the watershed.

Soil movement is defined as the displacement of part of the soil mantle caused by wind, running water, or hoofs of animals. Soil movement in action may be observed during winds, heavy rainstorms, or when animals are traversing slopes having loose soil. Dust clouds and muddy streams are examples of displacement, but much displacement occurs without such obvious evidence.

A certain amount of bare ground is natural on most rangeland (Hugie and Passey, 1964). Rodent and ant activity and frost heaving exposes soil. Therefore, some soil movement, usually local, may be considered natural. If the surface is disturbed so that widespread soil movement may be detected, the probability is great that soil loss is abnormal. If such loss continues year after year, the probability becomes certainty.

Indicators

An indicator is a clue to events that have happened, are happening, or will happen on the range watershed (Ellison et al., 1951). Absence of an indicator may, in itself, have indicator value, but this usually is weak unless supported by independent, positive evidence. A single indicator alone seldom has absolute value; it must be supported by additional evidence. For example, soil movement alone is a poor indicator of trend in range condition. By the time erosion is apparent, profound changes usually have taken place already in the plant cover. Evidence of accelerated soil movement is good supporting evidence that the plant cover

is inadequate.

Gullied drainageways showing bank cutting and sediment deposits in ponds, lakes, and at the confluence of streams are among the more obvious indicators of unstable soils. On the other hand, mass movement downslope of saturated soils below snowdrift areas and seeps are more or less natural occurrences that take place even under good vegetational cover. They occur especially where clayey underlying material restricts water penetration, causing saturation to the point where the material flows, and the clay layer acts as a shear plane.

Subtle indicators of unstable soil conditions are important because they flag an early warning. The ability to discern and interpret such subtle indicators is an asset to the resource manager.

Trampling Displacement

Trampling displacement is evidence that surface soil has been moved downslope under the hoofs of grazing animals. Trampling on level terrain which results in churning the soil to dust or mud is not covered by this term, although churning changes the soil structure and contributes to subsequent displacement by wind or water.

Trampling displacement usually becomes more clearly marked as steepness increases. It occurs most readily when soil is very wet or very dry. Different soil textures respond to trampling in different ways.

Evidence of trampling displacement takes two forms. With excessive trailing, the surface is imprinted with nearly level terraces. The banks above these terraces are often steep, exposing soil to subsequent downward movement by water and gravitation. The displaced soil on the downward side of the terrace also is exposed and susceptible to subsequent movement by water. The terrace itself may become a watercourse during rain and serve to concentrate runoff into a flow of water with erosive force.

Trampling displacement, not concentrated in trails but more generally distributed over the slope, is marked by soil accumulations on the uphill side of peren-



Fig. 1. *Pedestals of soil formed during erosion by rainfall on a bare, clayey range soil that is low in organic matter content. Such pedestals usually disintegrate upon drying which obscures the evidence of soil movement.*

The author is state range specialist, U.S. Department of Agriculture, Soil Conservation Service, Portland, Oregon.

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cial plants and by hoofprints or ridges downslope from each hoofprint. Such displacement is less easily observed than terrace trails but probably is more serious. Terrace trails suggest a degree of stability, possibly only temporary, in which the surface has been reformed over time to accommodate a concentration of animals. In contrast, general trampling displacement over the slope suggests that there is no stability except where soil may accumulate on the uphill side of a fairly permanent obstruction.

Soil Remnants

Soil remnants are relics of surface soil, like miniature mesas, remaining in position after the soil between them has been eroded away. They are formed under the protection of stones or pebbles, residue, or vegetation that may consist of a single plant or a small island of a plant community. The latter are more positive than single-plant pedestals as indicators because, in certain soils, single plants often are elevated on a pedestal by frost heaving.

This indicator has value where a former soil surface can be established by the uniform height of pedestals or islands. Likenesses between cross sections of surface soils of pedestals and islands are excellent for establishing the reliability of this indicator. The reliability is good where the soil profile characteristics between the pedestals and islands resemble the soil profile characteristics at the same depth within the pedestals and islands.

Elevated islands and pedestals may be caused jointly by erosion and deposition, where a part of the eroded area in the locality may supply loose soil to be deposited by wind in clumps of vegetation. The identification of aeolian deposits is discussed later.

Soil pedestals under stones or litter are formed on some kinds of soil by the impact of raindrops and sheet flow of water over adjacent barren areas. Where a pebble or stick protects the soil from the impact of raindrops, the original soil under the protecting object is retained, whereas the soil in bare areas is churned by raindrop impacts and easily washes away. Pedestals also are formed on certain soils where the soil ped (a unit of soil structure) is resistant, whereas the soil material in the fracture between peds is less cohesive and susceptible to erosion as shown in Figure 1. Close observation soon after the storm usually is needed to denote these soil pedestals, because after a few hours or days of sunshine they may crumble. These pedestals formed during a known period are clues to the rate of sheet erosion that has occurred. This indicator is especially valuable as convincing evidence of current soil movement during storms of moderate intensity or

duration, which may not form gullies or alluvial deposits.

Frost heaving is common in many range soils. Care must be exercised to distinguish between soil remnants that are solely the result of erosion from those that are at least partially the result of frost heaving. Distinguishing precisely how much pedestal elevation is due to heaving and how much to erosion is difficult and probably impossible.

Frost heaving often occurs following decimation of the vegetational stand and organic ground cover between plants, which, in turn, bares and exposes the soil to the effects of periodic low air temperatures. With frost heaving, single plants elevated on pedestals usually characterize the vegetation. These plants commonly are tilted, the crown is not horizontal as it was when it grew as a part of a stable plant community. The probability that frost heaving has occurred also can be supported by the type of soil. For example, soils having clay subsoils fairly close to the surface commonly heave plants. Some pumicey soils are noted for their frost-heaving tendencies.

Frost heaving results not from the freezing of the soil itself but from the formation of ice lenses and crystals in the soil. In turn, the formation of ice depends on capacity of the soil to deliver water to a stationary or slowly moving freezing front. Almost every soil with more than 3% of material smaller than 0.02 mm has this capacity to some extent. Soils that are nearly clay free but are high in silt (0.05-0.002 mm) and very fine sand (0.10-0.05 mm) have this capacity to the greatest degree and, hence, have the highest potential for frost action if a supply of water is within reach. Also, other soils that have a large capillary water capacity have high potential, if water is available, to move to the freezing point (U.S. Dep. Agr., 1971).

Frost heaving usually is accompanied by accelerated erosion from around the crown and roots of the elevated plants. Exposed roots and raw vertical sides of the pedestal point this out.

Erosion Pavement

Erosion pavement, as used here, is an accumulation of gravel (2-76 mm diameter) and cobbles (7.7-25.4 cm diameter) at the soil surface due to blowing or washing away of finer soil particles that formerly surrounded them. An erosion pavement is underlain by a soil profile from which surface material apparently has been removed when compared to soil profiles normal to the vicinity. If there is no evidence of a truncated soil profile and the material beneath the surface consists of altered parent material and fragmented rocks, the pavement probably is normal. Pavement due to erosion normally is accompanied by substantiating erosional in-

dicators nearby. It should be noted that some soils naturally contain much gravel and cobbles in the surface layers.

Where gravel has washed downslope to spread over the surface of an area and sometimes over plants, soil loss is not a factor and an erosion pavement is not indicated.

It is important to note that a significant erosion pavement adds a limitation to that caused by loss of topsoil in terms of re-establishing a suitable stand of plants. The pavement may physically restrict seedling establishment by occupying space formerly occupied by plants. The summer microclimate on an exposed erosion pavement can be very hot, which also restricts seedling establishment. It is also important to note that an erosion pavement effectively protects the soil surface and slows soil movement. It curtails evaporation, promotes greater moisture holding capacity, and reduces plant competition per unit of soil surface. Soil movement will continue, however, where frost heaving or trampling by animals brings soil up between the pavement particles.

Lichen Lines

Lichens grow on the above-ground portions of stones and rocks, usually more abundant on the shaded side. They grow slowly. If the surface soil has been eroded away, its former level sometimes is indicated on the stones and rocks by an abrupt, more or less horizontal, break between the lichens that grew above ground and the rock area that originally was below the soil surface (Fig. 2). These breaks are known as lichen lines.

Growth of lichens probably keeps pace with normal geologic erosion and possibly even with slight or moderate accelerated erosion. Pronounced lichen lines repeated on a number of stones or rocks in the



Fig. 2. A lichen line on a rock is a reliable indicator of soil movement when supported by nearby pedestalled plants that show little or no evidence of having been heaved by frost.

area are reasonably reliable indicators of soil movement that has occurred or is progressing at an accelerated rate on that area. The distance between the lichen lines and the present soil surface indicates the amount of soil that has been moved.

Lichen lines are pronounced on elevated terrain such as ridges. They may not be pronounced on slopes where soil losses from alongside any particular rock may be replaced by soil deposits that were eroded from farther upslope.

It is important to note that stones and rocks, like plants, commonly are heaved upward by frost action, which could create lichen lines. Previous discussion of frost heaving of plants applies to judging lichen lines on stones and rocks.

Wind-Scoured Depressions

These are shallow basins a few inches or feet across in bare soil between patches of vegetation from which wind has carried away the fine soil particles. The action of wind may be recognized by a residue of small pebbles or sand particles, too large to blow away, resting on the scoured surface of the depression. Evidence of fresh scouring by wind on these depressions appears as lines etched in the soil surface paralleled by tiny streamlined ridges of fine soil in the lee of pebbles, vegetation, litter, or other obstructions.

Bare areas caused by ants, commonly called ant disks, on which collection of sand particles is common, should not be mistaken for wind-scoured depressions, although removal of fine soil material by wind from ant disks does occur. Ant disks usually can be identified by the aggregation of coarse sand particles near the center of the ant habitation, which is apparently caused by ants moving the particles, whereas particles of coarse sand and pebbles occur quite uniformly over a wind-scoured depression.

Aeolian Deposits

Aeolian deposits are soil material transported by wind after having been eroded from some other area. They usually occur adjacent to the eroded areas and often within the eroding area. They also occur on distant noneroding areas, such as on leeward slopes.

Aeolian deposits are usually developed within or to the leeward of plants or other obstructions. Such deposits consist of fine, well-sorted soil particles and normally contain no pebbles or cobbles. In some large deposits, however, coarse fragments sometimes are introduced from below by rodents.

The amount of deposit can be determined by cutting a vertical section through a mound and the obstructing material so as to expose the original soil surface. If a comparison is made between the mound and an adjacent scoured area, the difference represents both erosion



Fig. 3. A prominent alluvial deposit on the uphill side of a clump of grass.

and deposition. Relative age of the deposit may be judged by the degree of decomposition of buried plant parts where vegetation is the obstruction creating the mound. For example, plant parts are readily identifiable in recent deposits, whereas in older deposits buried vegetation is unidentifiable.

Alluvial Deposits

Alluvial deposits are soil material that has been dislodged, transported, and redeposited over the watershed surface by water. They form little fans at the end of small channels or behind obstructions in channels where the current is slack. They also appear as accumulations on the uphill side of clumps of vegetation, litter, logs, or other obstructions as shown in Figure 3. As used here, they refer to deposits on the range watershed and not to fans at the mouths of prominent channels.

Fine materials in alluvial deposits sug-



Fig. 4. A rangeland drainageway, previously a raw gully, now practically stabilized on the banks and bottom.

gests a gentle runoff, whereas coarse materials indicate a violent runoff.

Active Gullies and Rills

Gullies are channels cut into the soil mantle by running water and, as used here, do not pertain to main downstream channels but rather to channels on the watershed itself. Gullies are "active" if their sidewalls are unstable because of insufficient vegetation or if there is evidence of recent cutting in the bottom. Only when adequate vegetation covers the sidewalls and no cutting occurs in the bottom can the gully be considered as healed (Fig. 4).

Rills are small channels in the soil mantle, some of which may be so small as to be obliterated easily by trampling or slight soil movement associated with weathering; yet in the process, the soil profile is gradually truncated. The existence of rills usually indicates current soil movement. Following obliteration, a new set of rills is again formed by the next storm, and these in turn are obliterated. This process is unspectacular but it moves a lot of soil in a short time. Much of what is called "sheet erosion" actually is moved through the process of rilling.

When certain rills cut deeply and entrench themselves so that their channels are not filled or blocked by movement of soil, they become gullies.

Rills are particularly good indicators because they relate to current causes and results rather than to the past. Furthermore, they can be measured to produce a quantitative approximation of soil loss by using a method which was originated by A. N. Alutin, Soil Conservation Service, Newberg, Ore. in 1937 and described by Hill and Kaiser (1965).

Measuring Rill Erosion

The Alutin method provides a means of securing a quantitative approximation of soil movement due to erosion by water. It is useful in helping evaluate the effectiveness of treatments, practices, and management. It provides a means of checking judgment estimates of soil movement in broad-area land damage surveys and for watershed purposes.

This method is reasonably reliable as a field procedure. In tests at the Palouse Soil and Water Conservation Experiment Station at Pullman, Wash. in the late 1930's, the rill method of measuring soil movement on silt loam soil accounted for 75% of the total soil movement measured by lysimeters. The accuracy of this method varies for different soils according to the ease with which they can be transported. Normally, this will be somewhat less than 75% on sandy soils and somewhat greater on clayey soils.

Judgment in selecting representative locations on which to measure soil movement is essential for making a reliable



Fig. 5. *Measuring rills according to the Alutin method along a transect on severely eroded rangeland.*

appraisal.

Method

The movement of soil through erosion, expressed in tons/acre, equals the collective cross sectional area of the rills, expressed in square inches, when meas-

ured in a line 13.7 ft long (Fig. 5).

Step 1 — Choose a representative area at right angles to the direction of the rills (across slope).

Step 2 — Measure off a distance of 13.7 ft (or multiples thereof) and mark this line with tape or a piece of white cord.

Step 3 — Measure average width and depth of each discernible rill along the line and tabulate as illustrated below.

Size of rills (inches)		
Avg. width	Avg. depth	Area (inches ²)
3	3	9
2	4	8
1	1	1
6	1	6
6	2	12
Total *		36

*Inches² or tons per acre.

Step 4. — Compute the area of *each* rill in inches². Add the areas of all rills on the transect to obtain the total area of all rills in the sample. The total area represented by rills in a 13.7-ft transect equals tons/acre soil movement. If the transect used measures 27.4 ft (twice the length of the

unit transect), divide the total rill area by 2. For other multiples of the unit transect, divide by the appropriate number.

Step 5 — A number of transects may be located randomly or selected deliberately on an area to increase sampling reliability. Each transect should be computed separately.

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