

Soil Erosion and Management Activities on Forested Slopes

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Some of the most productive forests in the Western United States grow on marginally stable mountainous slopes, where disturbance increases the likelihood of erosion. Much of the public's concern about, and, consequently, most of the research on, erosion from these forested areas is related more to the degradation of stream resources by eroded material than to the loss of soil and nutrients from hillslopes. Erosion from these upper watersheds is a composite of surface, channel, and mass erosion processes. The relative importance of each process is determined by interactions among climate, soil, geology, topography, and vegetation and is the subject of much of the current research on erosion. A change in any of these elements can increase or decrease the rate of erosion.

Predicting Erosion

The best-known method for predicting erosion is the Universal Soil Loss Equation developed for agricultural lands in the Midwest by the U.S. Department of Agriculture's Agricultural Research Service. Attempts to apply the equation to steep-land forest areas generally have been unsuccessful—mainly because of inappropriate basic

assumptions. Most erosion from forests is not the result of sheet overland flow. In undisturbed forested steep-lands, mass erosion is the dominant mechanism by which soil is transported from hillslopes to stream channels. In mountainous areas, the erosion research most needed is on the causes of natural and human-induced landslides and subsequent sediment transport.

Under natural conditions, as the amount of stress on a site increases, the amount of erosion also increases. A major source of stress is increased rainfall, which can be expressed in terms of storm return period—the frequency with which a storm of a particular magnitude is expected to occur. Increased stress also could be caused by soil water pressures, seismic loading during earthquakes, or other factors.

Erosion can be expressed as the amount of river sediment, or surface erosion, or frequency of landslides. Disturbance by land-management activities, such as logging, road construction, and burning, generally increases erosion rates. The location and magnitude of the effects of land management on erosion rates, however, cannot be predicted accurately.

Human activities have their greatest relative effect on erosion rates during periods of low stress. Research is beginning to suggest that management-induced erosion rates tend to converge on natural erosion rates as the magnitude of the stress increases, but the relationships are not yet understood. Similarly, erosion-control activities are most effective during low stress conditions and become relatively less effective as the magnitude of stress increases.

The natural condition often represents the minimum erosion rate, and attempts to further reduce erosion are generally ineffective. But there are exceptions. During low stress, effective erosion control activities can re-

duce or even eliminate erosion. For example, control structures in stream channels can reduce sediment transport to below the natural rate until their storage capacity is exceeded; hillside buttresses and check dams on recent natural landslides can reduce slope movement and surface erosion from the landslide scar; horizontal drains and vertical wells, which remove ground water, can reduce the natural landslide erosion rate. Usually, however, erosion-control activities are used to bring an accelerated erosion rate down near the natural rate.

Erosion Control

In general, preventing erosion is more effective than controlling it. Also, the potential for increasing erosion rates by land-management activities is greater than that for reducing erosion by using erosion-control techniques. Although these principles are well documented, virtually no research on the effectiveness of erosion control over the long term has been done.

If control activities reduce erosion during low stress periods, under some conditions that stored or controlled material may be available to be eroded during high stress periods. For example, when small check dams in steep streams are effective in controlling sediment transport during small runoff events, sediment accumulates in the channel. During large runoff events, the material stored behind unstable check dams can be mobilized, leading to a debris torrent—a much larger and more destructive erosional event than if that material had been transported during less stressful events. Permitting small, sustained transport of debris during normal events is believed to lessen the probability of a major debris torrent. Future research is needed to verify this potentially important theory.

Under such circumstances, erosion-control activities might simply shift the stress-erosion relationship so that less erosion occurs during small events and more erosion occurs during large, infrequent events. This may be an acceptable alternative because people and property could be protected during small events with expected frequencies of perhaps once in 1 to 10 years. Loss of lives and property are inevitable in a large erosional event, but society may be able to tolerate this amount of damage providing such events occur only infrequently, perhaps once every 100 to 200 years. Also, the relative increase in erosion rate during a large event might not cause significantly increased destruction.

Similar value justifications are commonly used for road drainage design. Road drainage is not designed to pass the largest imaginable event but is based upon economic and social costs. The selected moderate design allows the road to be used during all events except those exceeding some specified magnitude.

Researchers need more studies that address whether erosion controlled at one place or time can defer the problem to some later time. Not only are our models of the effectiveness of erosion control inadequate, but also the expected frequency of mass erosion events is not known.

For example, slope failures often originate in filled swales, and current research suggests that human activity accelerates the failure rate. If the swales are filled with periglacial deposits, then once the material is removed, subsequent failure would not be possible. Human activity would simply compress the time scale of failure, which would be followed by a reduction in failure rate to less than the expected long-term natural rate. If, however, the swales are filled with colluvial deposits and human activity increases the filling rate, then both

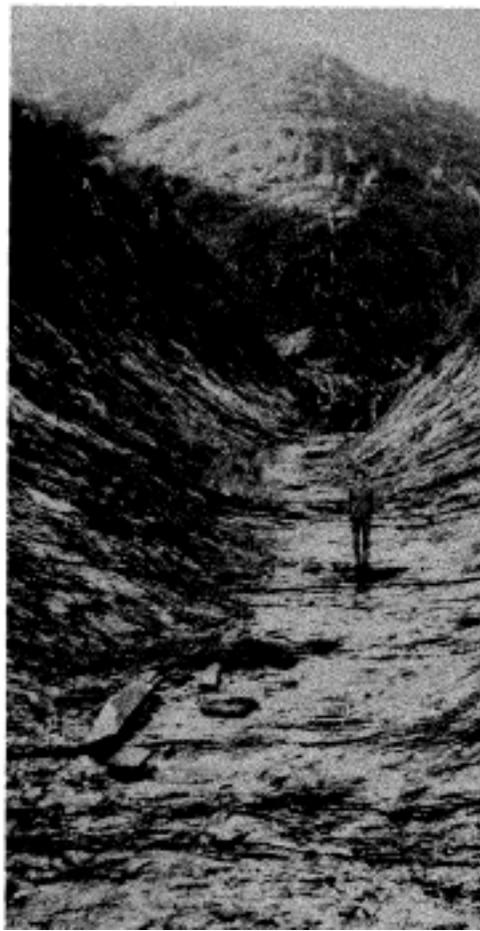
the short-term and long-term failure frequency would increase. The geomorphic denudation rate and the corresponding sediment transport rate also would increase. Without adequate knowledge of these erosional mechanisms, experts cannot devise appropriate management strategies.

Management of Erosion

The cumulative impact of management activities on erosion is a growing concern. A common assumption is that if a small proportion of an area is logged, the rest will buffer the effect of the logging on downstream values. But the proportion of a catchment that can be logged without undue degradation of the stream resource is a matter of conjecture and is based on the assumptions that erosion sources are uniformly distributed with an equal probability of erosion occurring at all locations. In fact, most upper watershed erosion occurs in a few areas, with the remaining area producing only a small amount of erosion. Studies suggest that to minimize erosion effectively in the upper watersheds, it is more important to specify where land is to be treated than to be concerned with how much land is to be treated.

In evaluating the cost effectiveness of erosion control, a longer time line should be used. In general, the current period of concern of land management-related erosion and its control is short-several years at most. This may be acceptable for surface erosion, but channel erosion and mass erosion can follow land treatment by decades. Understanding of the timing of erosion relative to land-management activities must be increased.

The key to successful management of erosion and sedimentation is to increase our ability to (1) identify potentially erodible sites, (2) correctly assess appropriate activities on those



A tributary to Cedar Creek on the Siuslaw National Forest near Mapleton, OR, experienced a debris flow in a clearcut, logged area that scoured the channel to bedrock.

sites, and (3) have a political or regulatory system that fosters the appropriate action. In some cases, the only appropriate action is to do nothing. The cost required to correct management-induced erosion is often far beyond the benefits obtained from the land-management activity or the costs required to follow a more sensitive alternative.