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# Vegetation Strips Control Erosion in Watersheds

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Natural vegetation buffer strips were found to act as barriers for reducing soil movement. In ponderosa pine in Arizona, buffer strips up to 20 m wide withheld practically all of the sediment delivered from nonwooded areas that had slope lengths of up to 130 m. While the buffer strips delivered an average of 0.85 kg ha$^{-1}$ yr$^{-1}$ of sediment, similar nonwooded areas without buffer strips averaged 51.60 kg ha$^{-1}$ yr$^{-1}$, or 61 times more sediment. Buffer strips in other southwestern vegetation types (pinyon-juniper and chaparral) similarly restrained sediment delivery, as did buffer strips of willows and poplars on a large disturbed site in the Idaho batholith. Erosion control efforts in mountain areas should thus utilize vegetation buffer strips for relatively fast stabilization of disturbed hillslopes and for gaining time for large-area control applications. Furthermore, timber and other vegetation could be harvested in a manner that would leave appropriately located buffer strips.

**Keywords:** Erosion control, overland flow, sediment delivery, ponderosa pine, pinyon-juniper, chaparral

Western mountain watersheds are usually less susceptible to erosion, compared with lower elevation zones. Generally, moisture availability is sufficient for healthy plant growth, which minimizes surface soil movement. Compared with lowlands, however, lower temperatures in mountain watersheds mean shorter growing seasons and longer periods of recovery once disturbance has occurred. Thus, recovery of disturbed sites should proceed as fast as possible, because the control of soil movement becomes progressively more difficult with time. Rapid stabilization of erosional conditions saves soils and money and therefore should receive priority in any erosion control treatment design. The ultimate goal should be vegetation rehabilitation, unless plant growth potential has been totally lost, because it is the vegetation that perpetuates itself and guarantees a certain degree of stability. In contrast, structures not supplemented by vegetation may halt erosion nearly instantaneously, but require maintenance.

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Pilot field research reported here demonstrated the importance of vegetation strips in arresting surface soil movement. The data vary among different vegetation types, however, and are not precise enough to warrant specific, how-to-do-it recommendations due to complex interactions among soils, climate, vegetation, topography, and storm characteristics. So far, however, all vegetation types have in common an overwhelming effectiveness of natural vegetation buffer strips. The objective of this paper is to raise interest in natural plant arrangements that proved to be effective barriers against surface soil movement, and to use them for erosion control. Based on the pilot study, we plan an additional experimental design to identify variables responsible for the processes.

## Past Work

Much has been written about vegetation as an effective erosion control agent, but little is known of the effects of vegetation strips for erosion control. I investigated distribution aspects in ponderosa pine forests (Heede 1984), pinyon-juniper (Heede 1988) and chaparral (Heede et al. 1988). Results of these studies, both published and unpublished, form the basis for this report.

## Study Areas and Methods

Physical characteristics, management practices, and vegetation distribution for each study area are described in table 1. In the White Mountains and on the Colorado Plateau, both in Arizona, ponderosa pine appears as a subalpine species, although generally in the West, it is not always so considered.

Microwatersheds were randomly selected on hillslopes, ranging in gradient between 0.10 m/m and 0.56 m/m, and instrumented for the collection of overland flow and sediment. Sample sites were selected on the basis of average site conditions with regard to percent of area with erosion pavement. The term microwatershed implies that the sizes are larger than those used in so-called plot studies, and that natural topographic divides were used as much as possible to delineate the boundaries. Where divides were not sufficiently pronounced so that intense overland flows could breach them, sheet-metal borders were used. These penetrated about 10 cm into the ground. On the downslope border of the microwatersheds, prefabricated 4-m-long sheet metal troughs were installed that conveyed the water-sediment mixture into tanks. Sheet metal borders, installed at each end of the troughs, assured conveyance of overland flow into the collectors. Collector tanks were serviced, if possible, after each rainstorm and samples collected for analysis.

In the two ponderosa pine forests, erosion pavements developed where individual large trees had been cut by the single-tree selection method 42 years earlier (fig. 1). The term erosion pavement refers to a matrix of different rock sizes on the ground surface (Heede 1983). This term, first described by Shaw (1929) is somewhat misleading because it implies an armor layer; in nondesert areas, however, the term has become synonymous with bare ground and is in common usage.

Figure 1.—Looking upslope at an erosion pavement in the ponderosa pine forest. Collector trough with sheet metal borders at each side is in the foreground.

Except for roads, erosion pavements were some of the highest sediment producers on the watershed. Collector troughs were installed downslope adjacent to the erosion pavements. Other microwatersheds were selected to evaluate a forest strip with litter-covered floor between trough and pavement (fig. 2). Forest and floor together formed the buffer strip. Another class of microwatersheds consisted of forest only with undisturbed floor.

In the pinyon-juniper forest, the typical wide tree spacings led to the formation of erosion pavements in most of the open areas between trees. In contrast with the ponderosa pine forest, some clusters of trees had grown close to the contour line. The latter were termed buffer strips and instrumented. Upslope from the strips, erosion pavements made up the area. The microwatersheds—buffer

Table 1.—Summary of physical characteristics, management practices, and vegetation distributions for each of the study areas.

| Vegetation type | Location | Elevation m | Precipitation mm | Geology | Soils | Management | Vegetation distribution |
|---|---|---|---|---|---|---|---|
| Ponderosa pine | Colorado Plateau N. Arizona | 2250 | 540–1100 20% in summer | Basalt & volcanic cinders | Cobbly montmorillonite clay loams | First and last timber harvest 42 yrs ago by single tree selection. Cattle grazing. | Most openings from selected tree cutting causing erosion pavements. |
| Pinyon-juniper | White Mtns. E. Arizona | 2500 | 395 66% in summer | Basalt | Sandy clay loam, very rocky | Overgrazed by 1900. Fuelwood cutting before study began. Cattle grazing. | Mosaic type. Erosion pavements in openings. Clusters of trees form strips on contour. |
| Chaparral | Mazatzal Mtns. E. Arizona | 1100 | 677 33% in summer | Granite, coarse textured | Sandy clay loam | Cattle grazing. Wildfire 28 yrs ago destroyed vegetation cover. | 95% of original canopy restored. Most remaining openings developed into erosion pavements often bordered downslope by vegetation strips. |

strips with pavements upslope, erosion pavements only, and wooded without buffer strips—were instrumented similar to those in ponderosa pine.

On the chaparral watershed, the tree canopy, nearly totally destroyed by a 1959 wildfire, was 95% restored in 1987. The remainder was erosion pavement. Clusters of trees had developed here also, often downslope from pavement areas. Heavy sediment depositions upslope from the clusters signified them readily as buffer strips. Thus, the three classes of microwatersheds could be established also in chaparral.

A network of standard and recording precipitation gages was used to measure precipitation at all study sites. Gages and collector tanks were serviced simultaneously.

## Results and Discussion

The results show a great variability in sediment delivery between the different vegetation types (fig. 3). Since only a few microwatersheds were available, characterized by nonwooded sites with and without buffer strips, the results have little statistical meaning. But the consistently overwhelming differences between both classes appear meaningful. In ponderosa pine, 61 times more sediment was delivered where buffer strips were missing. This factor was 18 and 277 for pinyon-juniper and chaparral, respectively. Thus, regardless of vegetation type, nearly all sediment was withheld by the strips, if we accept the assumption that the nonwooded areas above the strips produced similar volumes of sediment as the nonwooded areas without the strips. Unfortunately, we did not find a system to measure both sediment delivery to the strips and release by the strips. Instead, we inspected the strips closely and found concentrated sediment depositions upslope. These decreased rapidly on entering the strips.

**Figure 2.—The low part of a buffer strip, located uphill from the collector trough in the ponderosa pine forest.**

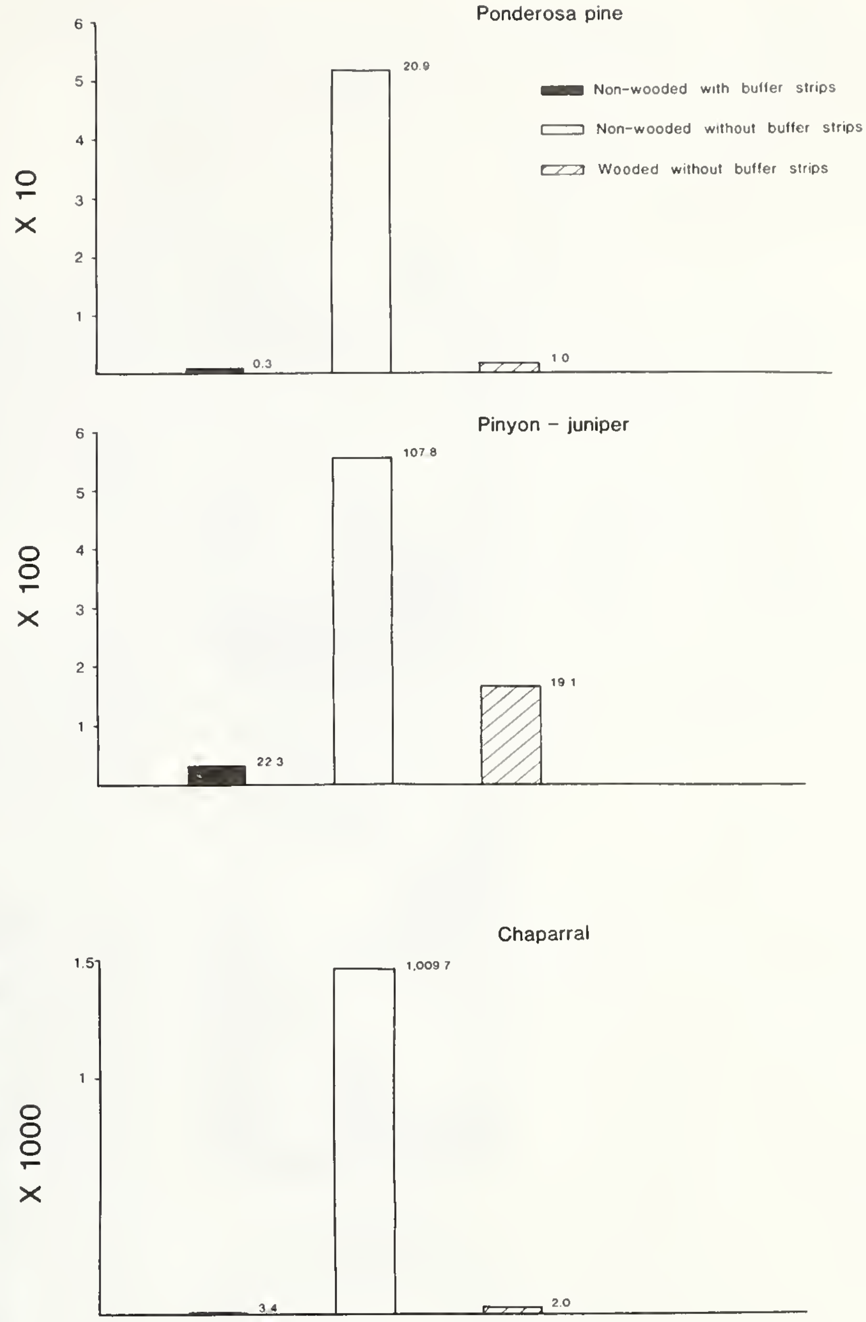


**Figure 3.—Average annual sediment delivery in kg ha$^{-1}$ for the three different vegetation types and vegetation cover. The data given at the columns are standard errors. Note the different scales applied to the vertical axes of the graphs.**

Comparison of overland flow volumes showed a similar large difference between the nonwooded sites with and without buffer strips. Thus, overland flow leaving the buffer strips was 2% of that of the nonwooded sites without buffer strips. In pinyon-juniper and chaparral it was 6% and 0.4%, respectively. Hence, practically all overland flow was arrested in the strips. Litter, mull, and soil layers, practically absent on erosion pavements, indicated increased infiltration rates were responsible for the water withdrawal.

In all vegetation types, wooded microwatersheds without buffer strips had more sediment delivery than "nonwooded with buffer strip," but less than "nonwooded without buffer strip." In ponderosa pine, the difference between wooded microwatersheds and those with buffer strips possibly was not significant.

It is believed that the concentrated sediment deposits, accumulated by the buffer strips, added to overland flow reduction by organic and soil layers. Permeameter observations in chaparral revealed consistently higher conductivity of the deposits than wooded areas without buffer strips or erosion pavements. Only one replication was made, however, which precluded testing of the data. Certainly, this aspect must be further investigated during the ongoing study.

## Management Implications

We could debate the value of the data because of the lack of sufficient replications. However, it is not the numerical value per se that is important for the context of this report, but the great difference in sediment delivery between buffered and nonbuffered areas.

For land managers, the term buffer strip has become synonymous with forest strips left for the protection of stream sites. I use the term reluctantly in this paper, because results of this pilot study indicate that vegetation buffer strips should not be restricted to streambanks, but can also be effectively applied wherever surface soil movement must be arrested.

The processes of sediment withholding by buffer strips, acting so similarly in three different vegetation types, may indicate phenomena characteristic for tree buffer strips per se. If we accept this postulate, then we can apply buffer strips throughout the mountain watersheds, regardless of tree species, wherever growing conditions allow tree establishment.

One of the main benefits of vegetation buffer strips is that revegetation efforts can be concentrated and therefore intensified on the relatively narrow areas. More plants could be introduced per unit area than required for the remaining acreage upslope. Where possible, artificial irrigation could be applied, as well as fertilizer to hasten plant establishment, and mulch to simulate litter. Plant spacing as well as fertilizer rates must be empirically determined according to moisture demand of the plant species and the expected moisture availability after fertilizer application.

If large disturbed areas must be controlled, buffer strips, aligned on the topographic contour, could be spaced over the area. In our study, this spacing reached 130 m in ponderosa pine. Unfortunately, our investigations were not designed to yield threshold values for spacing. The designer must therefore use an empirical approach. The best approach would be to find examples in the field with conditions similar to those of the project area.

For years, practitioners have applied forest buffer strips with success to protect streams from road or other

Figure 4.—This buffer strip of willows developed naturally at the toe of a cut slope. About 40 years ago, the slope was created by the excavation of borrow material near Anderson Ranch Reservoir in the Idaho batholith. Note the concave shape of the slope's toe that was formed of colluvial material by the buffer strip.

sediments. As a rule of thumb, usual strip width was 35 m. This value falls within the scope found by our study (high value 20 m). However, the designer should realize that the slope gradient may play a dominant role for effective strip width on steep slopes in a given vegetation type. Steep slopes may require larger widths. It is important to use examples from the same type, because, as our results indicated, required strip width may change with type. On the steep 0.56-m/m slope in chaparral, a strip width of only 2 m was effective, while this width ranged between 7 and 25 m on 0.23- and 0.25-m/m slopes in ponderosa pine.

Once buffer strips are in place, time has been bought for the rehabilitation of the remaining acreage, because the strips will retain nearly all sediment from the open areas. Certainly, control efforts should not be unreasonably postponed, since soil loss will continue on the areas located between the buffer strips.

On our research slopes, not one case was encountered where buffer strips were overrun by overland flow or sediment. An exceptional storm event may cause such flow, of course.

During summer of 1987, I was able to observe an example of buffer strip efficiency in a different physiographic province, with different growing conditions and different tree species than those of this study. I visited a large 40-year-old earth borrowing site in the Idaho batholith. Steep earth walls were between 5 and 25 m high and had slope gradients of more than 1.00 m/m. They formed sharp brinks where they intersected the undisturbed land, and also where they met the bottom of the excavation areas. But where willows and cottonwoods grew below these walls, forming chains of trees, sediment deposits reached 3/4-m depths at their upslope side. The transition from the bottom of the excavation to the wall was concavely shaped (fig. 4). This shape indicated that natural processes were at work to stabilize the scarred land. A stable hillslope, if not controlled by bedrock or other hard material, has an s-shaped cross section, concavely shaped at the bottom and convexly at the top. The convexity of former sharp brinks of the

walls can be obtained after the wall toe becomes stable (concave).

There are other management implications, especially in light of the growing concern for control of nonpoint source pollution (primarily sediment). For example, timber and other vegetation could be harvested in a manner that would take advantage of the study findings: leaving buffer strips. Or water quality enhancement projects, instead of using large planting areas, could apply vegetation strips only. Many situations exist for strip application, once we consider them a management option. The effectiveness of vegetation strips in ponderosa pine, pinyon-juniper, chaparral, willow, and cottonwood demonstrate that the strips behave very similarly regardless of vegetation type, which suggests that many tree species could be utilized for erosion control objectives.

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# Rocky Mountain Forest and Range Experiment Station

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