

Chapter 7

Effects of Rock Fragments on Erosion of Semiarid Rangeland Soils¹

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Semiarid rangelands exhibit extreme variability in their hydrologic processes affecting erosion and sedimentation. The surface of these rangeland areas is usually sparsely vegetated, low in litter cover, and moderately covered with rock fragments larger than 5 mm. Rock fragments of rangeland soils are usually found throughout the soil profile, and are most abundant at, or near, the soil surface, especially where excessive erosion has occurred to form an erosion pavement. This erosion pavement formation is the result of finer soil particles being moved or eroded away by water (Anderson, 1974). Desert pavement and erosion pavement are different; desert pavement is the erosion response to an arid climate supporting intermittent and sparse vegetative cover, whereas erosion pavement is the erosion response to the exposure rock fragment containing soils that were once protected by complete vegetative cover (Shaw, 1929). Erosion pavement is found in regions where erosion has been accelerated beyond geologic norms, and is extensive on overgrazed rangelands in the West and Southwest (Lowdermilk and Sundling, 1950). Because of the dominance of this erosion pavement, an understanding of its role in

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runoff production, soil detachment, and sediment transport can be very useful in estimating rangeland hydrologic and erodibility behavior. Also, because of the vast areas of western rangeland influenced by this erosion pavement, relationships between erosion pavement and erosion rates need to be determined before erosion-estimating models, such as the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978), can be used.

Lowdermilk and Sundling (1950), using natural and artificial rainfall on lysimeter-type plots, showed that as a rocky soil eroded, the rate of erosion decreased as the finer soil particles were lost, leaving a partial cover of rock fragments larger than 5 mm in diameter. Meyer et al. (1972) found that erosion rates decreased with increasing applications of stone mulch to large plots under simulated rainfall, and that the erosion reduction effect was noticed in both sheet and rill erosion. Simanton et al. (1980), in their application of the USLE to semiarid rangelands, indicated an erosion reducing effect of erosion pavement. They combined the percent rock fragment on the soil surface with the vegetative basal cover to determine the values for the cover and management factor (C) of the USLE. Good correspondence between actual and calculated soil losses from small watersheds was obtained, but no definitive erosion pavement-erosion rate relationships were developed. Box (1981), in an experimental study using simulated rainfall on Carolina Slate Belt soils of the Southeast, concluded that the effect on soil erosion of surface slaty fragments 2 to 40 mm in size was much the same as that of a litter mulch.

The objective of this study was to develop a quantitative relationship between rangeland rock fragment cover and erosion. Rainfall simulation on field plots of two soil surface treatments and a naturally-occurring soil surface was used to produce data necessary to develop this relationship.

The study was conducted on the 150 km² Walnut Gulch experimental watershed in southeastern Arizona. This watershed, operated by the Agricultural Research Service, USDA, is representative of millions of hectares of brush and grass rangeland found throughout the semiarid Southwest. Watershed soils are generally well drained, calcareous, gravelly loams with large percentages of rock and gravel on the soil surface. Average annual precipitation is about 300 mm, with about 70% occurring during the summer thunderstorm season of July to mid-September.

EXPERIMENTAL BACKGROUND

The experimental plan included simulated rainfall on three antecedent soil moisture conditions of two treatments and a control replicated twice on two soils.

Soils

Two soils, Hathaway and Bernardino gravelly loams, commonly found on the rounded ridges, the sideslopes, and terraces were chosen for this study. These two soils are USDA-Soil Conservation Service bench-

mark soils for Arizona, and occupy about 45% of the Walnut Gulch watershed. The Hathaway soil is a thermic Aridic Calcicustoll formed from gravelly, or very gravelly, calcareous old alluvium, and can have up to 70%, by volume, of gravel and occasional cobbles in the surface 10 cm and usually less than 50% in the remainder of the profile. The Bernardino soil is a thermic Ustollic Haplargid formed in old calcareous alluvium, and can have up to 50%, by volume, gravel and cobbles in the surface 10 cm, and less than 35% in the remainder of the profile. The Bernardino soil has an argillic horizon from the 10 to 30 cm depth.

Rainfall Simulator

The rainfall simulator used was a trailer-mounted rotating-boom simulator capable of applying either 60 or 120 mm/h rainfall rates (Swanson, 1965). This simulator produces drop-size distributions similar to those of natural rainfall and energies of about 80%. The area covered by the simulator is large enough so that two plots can receive uniform rainfall applications simultaneously. The coefficient of variation of this application was less than 10% over both plots, and rainfall distribution studies indicated that an integrating raingage, located near each corner of each plot, was adequate to determine plot rainfall distribution.

Plots

The plots used in this study were 10.7 m long \times 3.1 m wide on slopes that ranged from 9 to 12%. Runoff from these plots was continuously measured by water-stage recorders mounted on flumes, and sediment samples were taken periodically throughout the hydrograph.

Treatments

A control and two treatments, replicated twice, were imposed on the two soils. The control (Fig. 1) was an undisturbed or naturally-occurring condition, and the treatments were: (1) bare surface (Fig. 2)—vegetation clipped at soil surface, and all litter and rock fragments greater than 5 mm removed; (2) clipped (Fig. 3)—vegetation clipped at soil surface and litter removed. After treatment, each plot was subjected to an initial 60-min rainfall simulation (dry) followed 24 h later by a 30-min run (wet), which was followed 30 min later by another 30-min run (very wet). The rainfall rate for each of these runs was about 60 mm/h.

Field Measurements

Rock fragment cover (fragments larger than 5 mm) on each plot was measured after treatment by using a 3.05 m long pin-point meter with holes spaced at 60 mm intervals. The meter was placed perpendicular to

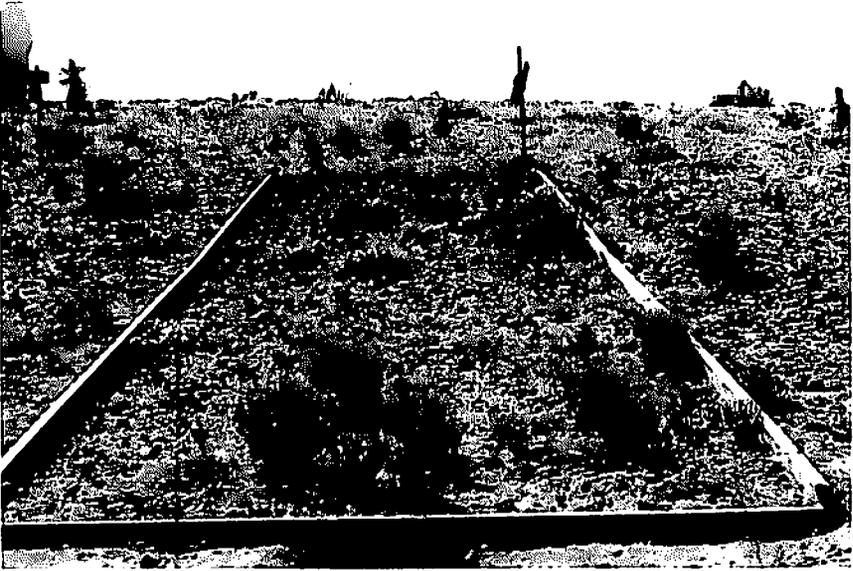


Fig. 1. Simulator control plot.



Fig. 2. Simulator bare plot.

the plot slope at 10 positions evenly spaced along the plot. At each position, 49 pin-point surface measurements were made by dropping a pin through each pin hole. This procedure produced 490 point measurements for each plot (Simanton and Renard, 1982). The same meter was used to measure the rock fragment, litter, and vegetative canopy of the control plots. Vegetative canopy included grass, forb, and shrub vegetation.

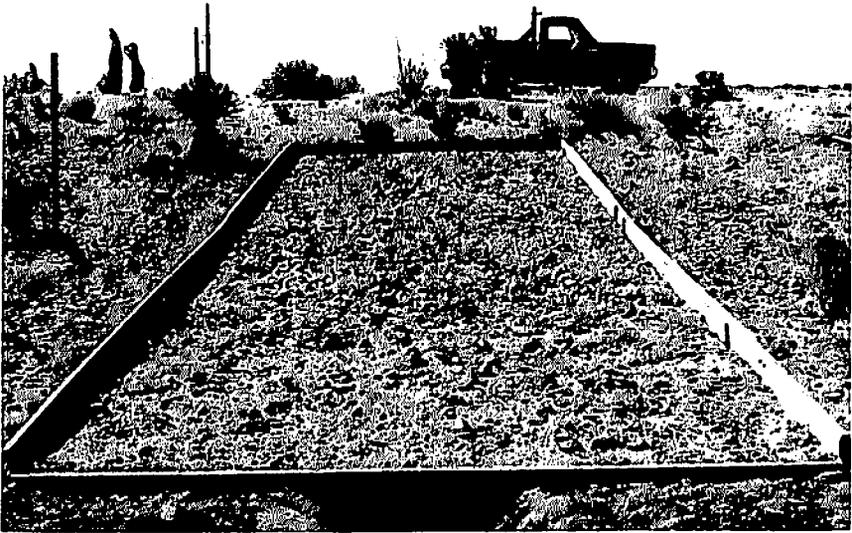


Fig. 3. Simulator clipped plot.

Overlap of canopy was not recorded so that, for each of the 490 surface cover points, there would be only one canopy point possible. Thus, if a grass canopy were under a shrub, only the shrub canopy would be recorded.

Simulated rainfall amount and rate were measured with a recording rain gage placed between each plot pair. Rainfall distribution on each plot was measured with integrating gages at each corner of the plot. The flumes used to measure plot runoff have a capacity of about 4 L/s, and have sloped floors to minimize sediment deposition. Sediment samples were periodically taken at the flume exit during the runoff event. Sampling intervals were dependent on changes in runoff rate, with more frequent sampling during rapid rate changes.

RESULTS AND DISCUSSION

Figure 4 shows the relationship between the percent rock fragment cover and erosion rate, per mm of rainfall (kg/ha/mm) from our Arizona plots. Because there was no significant difference among erosion rates of the three runs and two soils, the erosion rates shown are of the total plot sediment collected. Also shown in this figure are erosion rates obtained by Meyer et al. (1972) and Box (1981) for various percent covers of rock fragment mulch. These erosion rates were corrected to the standard USLE 9% slope using the USLE slope-length relationship (Wischmeier and Smith, 1978). As can be seen from the general shape of the curves and the r^2 of the fit, an exponential relationship between rock fragment cover and erosion rate fits the data well.

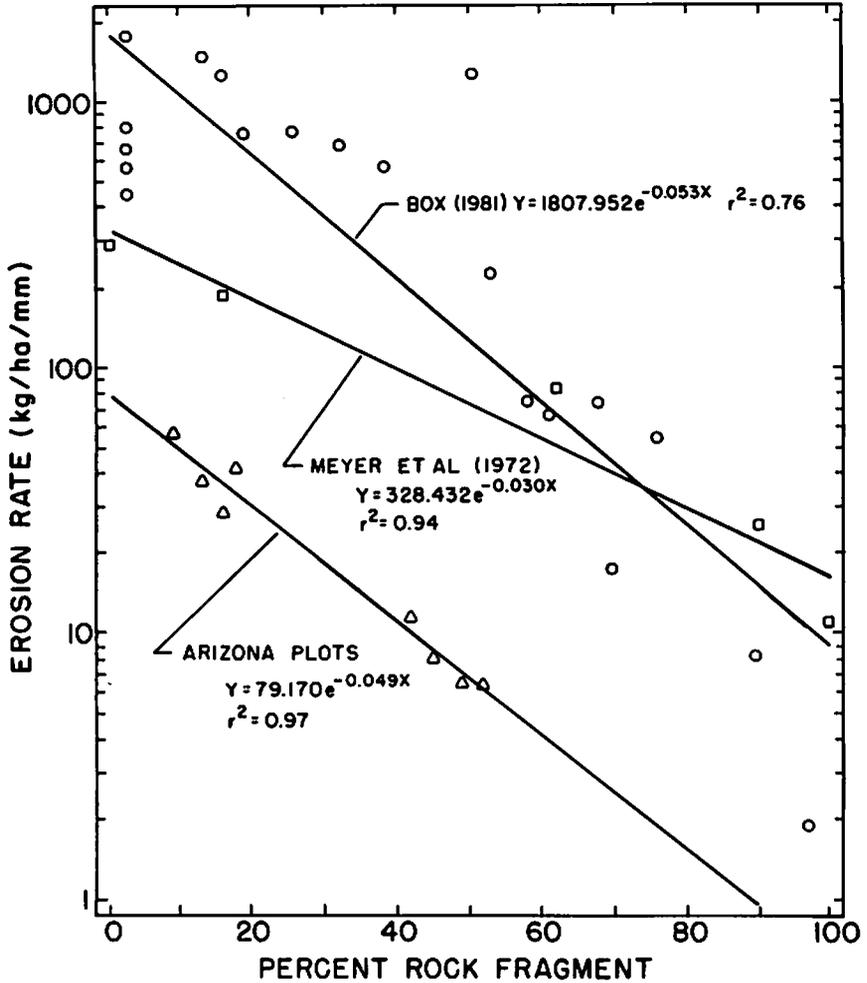


Fig. 4. Rock fragment cover vs. erosion rates from simulator plots for natural and mulched rock fragment cover.

Figure 5 shows the erosion ratio of the same data shown in Fig. 4. This erosion rate ratio was obtained by dividing all erosion rates by the coefficient of their respective curve fitting equation. Our erosion rates were divided by 79.2, those from Meyer et al. (1972) by 328, and those of Box (1981) by 1808. This normalization of the data eliminates differences caused by soil erodibility. Erosion rate ratios of these data sets show a similar decrease with increasing rock fragment cover. However, there is a much faster decrease in erosion rate with increasing cover on ours and Box's plots. This could be due to differences in simulator rainfall energies, or to the differences in infiltration and other soil properties found under natural and artificial rock fragment cover.

The erosion ratios of our control plots are listed in Table 1. This table also includes the control plot surface rock fragment cover, litter cover, and vegetative canopy. These data were used with Fig. 7, in *Agriculture*

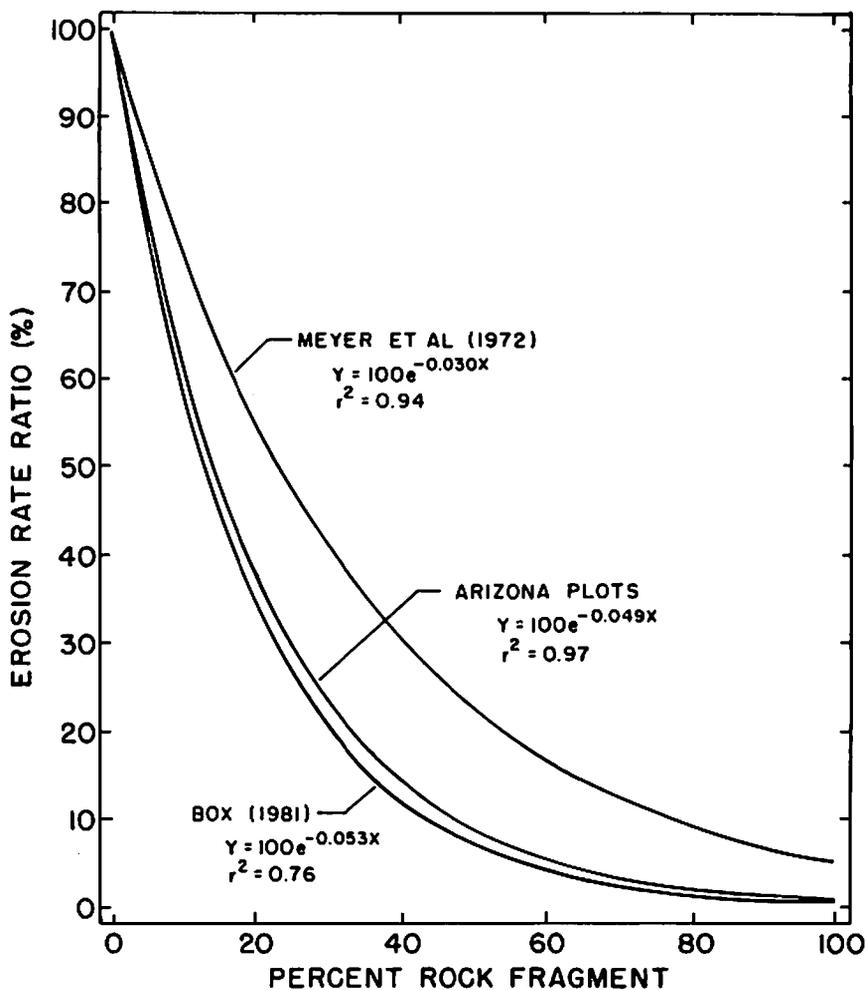


Fig. 5. Rock fragment cover and erosion rate ratios of simulator plots with natural and mulched rock fragment cover.

Table 1. Comparison between simulator Arizona plots erosion ratios and *Agriculture Handbook 537* erosion ratios.

ARIZONA PLOTS EROSION RATIOS
VS
AG. HANDBOOK 537 RATIOS

PLOT N*	VEGETATIVE CANOPY %	ROCK FRAGMENT COVER %	LITTER COVER %	TOTAL MULCH %	ACTUAL EROSION RATIO	HANDBOOK* EROSION RATIO
6	21	62	5	67	0.19	0.16
7	19	66	8	74	0.23	0.13
12	20	49	30	79	0.14	0.11
15	21	47	30	77	0.13	0.11

* AGRICULTURAL HANDBOOK 537, WISCHMEIER AND SMITH (1978)

Handbook 537, to determine how rock fragment cover might be incorporated into the USLE. The total surface or mulch cover of the plot is the sum of rock fragment and litter cover. We can sum our surface cover because, in our sampling technique, there was only one surface characteristic per point. In other situations where cover overlap is possible in the data, this summation of surface covers can be misleading. Our erosion ratios were determined by dividing each control plot erosion total by the average bare plot erosion of the respective soil type. Figure 7, in *Agriculture Handbook 537*, relates erosion ratios to percent surface mulch and vegetative canopy, and the comparison between actual erosion ratios and handbook erosion ratios is very good. This favorable comparison indicates that rock fragments can be incorporated in the USLE by considering their effect as that of a mulch, and be represented by the C, or cover-management, factor.

CONCLUSION

Rock fragment cover can dominate the surface conditions of semiarid rangeland to such an extent that an erosion pavement is formed. Erosion rates, from simulator plots with natural and artificial rock fragment cover, decreased exponentially with increasing percent cover. Erosion ratios of control plots, with varying amounts of vegetative crown cover, litter, and rock fragment cover compared favorably with published ratios of Fig. 7 in *Agriculture Handbook 537*. This comparable ratio for various covers indicates that the effect of rock fragment cover on rangeland erosion can be described by the C, or cover-management, factor of the USLE.

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