# Sediment Production as Influenced by Livestock Grazing in the Texas Rolling Plains

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## Abstract

**The influence of livestock on sediment production was evaluated on a Clay Flat range site with shrub canopy areas, and midgrass and shortgrass interspace areas in the Rolling Plains near Throckmorton, Texas. Sediment production in the shrub canopy areas was similar across grazing treatments of heavy and moderate stocking, continuous grazing; rested and grazed deferred-rotation; rested and grazed high intensity, low frequency (HILF); and two livestock exclosures which had not been grazed for 20 years. Sediment production from the shortgrass interspace area was similar for all grazing treatments except from the heavily stocked, continuously grazed pasture, where sediment production exceeded that of the rested HILF treatment. The midgrass interspace sediment production for the heavily stocked, continuously grazed treatment exceeded that of the deferred-rotation treatments and the exclosures. Likewise, sediment production for the grazed HILF treatment was greater than that for the rested deferred-rotation treatment and exclosure. Soil and vegetation variables which significantly influenced sediment production included aggregate stability, organic matter content, mulch, standing crop, bulk density, and ground cover.**


Some of the earliest erosion problems in the West developed on rangelands. Many of these problems resulted from the combined influence of improper stocking rate, poor distribution of animals, the wrong kind or class of livestock, and improper season of use. Unfortunately, accelerated erosion still occurs on many rangelands because of mismanagement of grazing animals.

Sediment resulting from geologic erosion is a natural component of rangelands and their fresh water streams, and high sediment concentrations may occur naturally from phenomena such as wildfires. Blackburn et al. (1978) stated that sediment is not necessarily a pollutant and only becomes one when it exceeds natural levels and is interfering with the beneficial use of water. A certain amount of sediment and attached nutrients are needed in many waters to maintain their productivity. However, the Federal Water Pollution Control Act Amendments of 1972 (Public Law No. 92-500 Sec. 208) establish a need for control of nonpoint sources of pollution, which includes sediment production from all public and private rangelands in the United States. Range managers are required to implement "Best Management Practices," which eliminate the discharge of pollutants into navigable waters by 1985. This requirement places range managers in a difficult position because the relative effects on water quality from most management practices, including grazing on rangelands, are not well known.

Some researchers have measured erosion and sediment production resulting from grazing at different stocking rates with several kinds and classes of livestock on a continuous or seasonal basis. Very few studies have investigated sediment production from grazing systems with some sequence of grazing and resting periods. Renner (1936) found that the degree of erosion on the Boise River watershed was correlated with grazing intensity, with low intensity having some effect on erosion. Dunford (1949) concluded that erosion from a pine (*Pinus* spp.)-bunchgrass region of Colorado was not significantly changed by moderate grazing, but heavy grazing doubled the normal amount of erosion, compared to that from no grazing. On fescue (*Festuca* spp.) rangeland in Saskatchewan, Johnston (1962) found soil losses were not serious under light, moderate, or heavy rates of grazing.

Aldon and Garcia (1973) indicated that the Rio Puerco drainage in New Mexico was infamous for contributing only 8% of the water yield of the upper Rio Grande Basin, but almost half of the sediment load. After years of continuous yearlong grazing, the watersheds were fenced to obtain 55% utilization with summer-deferred grazing. Under this grazing treatment, sediment production decreased from 1.72 to 0.54 metric tons/ha. Buckhouse and Gifford (1976) found that grazing chained pinyon (*Pinus edulis* Engelm.)-juniper (*Juniperus* spp. L.) sites in southeastern Utah caused no changes in sediment production.

McGinty et al. (1979) measured sediment losses of 211, 134, and 160 kg/ha from a heavily stocked, continuously grazed treatment; a four-pasture, three-herd deferred-rotation treatment; and a 30-year-old livestock exclosure, respectively. Sediment production increased with decreasing standing phytomass and soil depth of range sites.

Objectives of this study were to determine: (1) sediment production from a Clay Flat range site under deferred-rotation; high intensity, low frequency (HILF); and continuous grazing; and grazing exclusion, and (2) the impact of grazing on variables which influence sediment production.

## Study Area

Field research was conducted on the Texas Experimental Ranch, between Throckmorton and Seymour, Texas. The ranch is part of the Rolling Plains land resource area which comprises approximately 6.32 million ha of rolling topography in northwest Texas. Soils on the Texas Experimental Ranch are mostly clays and clay loams. Limestone parent materials are of the Admiral formation. Annual precipitation for Throckmorton County has average 62.4 cm over the past 40 years. The average frost-free period is 200 days. Peak periods for forage production are April, May, June, and September; however, if adequate rainfall occurs during July and August, forage production will continue at a high level throughout the summer.

Climax vegetation of the Rolling Plains included tall and midgrasses (Kothmann et al. 1970) but continuous heavy utilization by livestock and exclusion of natural wildfires has reduced the vegetation to primarily short and midgrasses with varying densities of woody plants. When this study was conducted in 1977, over 70% of

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the ranch's herbaceous vegetation was comprised of Texas wintergrass (*Stipa leucotricha* Trin. & Rupr.), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), and buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.). Honey mesquite (*Prosopis glandulosa* Torr.) and lotebush (*Ziziphus obtusifolia* (T. & G.) Gray) were the dominant woody species.

The ranch was established in 1957 for the purpose of investigating methods of improving the efficiency of cow-calf operations on native rangeland. Initially, three grazing systems were employed; (1) the two-pasture, one-herd South African switchback [2-1, 3:3, 6:3, 3:6 mo] (nomenclature and notation follow Kothmann 1974); (2) a four-pasture, three-herd deferred-rotation grazing system [4-3; 12:4 mo]; and (3) a continuous grazing system with heavily stocked, moderately stocked, and lightly stocked pastures. Several pastures were designated as exclosures and have not been grazed by livestock since 1957. Comparisons of these grazing systems indicated that livestock production was greatest from the deferred-rotation system (Kothmann et al. 1970). In the fall of 1973, an eight-pasture, one-herd high intensity, low frequency (HILF) grazing system was employed [8-1; 17:119 da]. It was compared with the deferred-rotation system and the continuous system with stocking at moderate and heavy rates.

During this study, stocking rates for the deferred-rotation system; HILF system; moderately stocked, continuously grazed systems; and heavily stocked, continuously grazed system were 6.2, 6.5, 6.5, and 4.6 ha/au, respectively. The pasture which was evaluated in the HILF system was in a lightly stocked, continuously grazed system prior to 1973.

The soil series studied was a Leeray clay. This series is in the fine, montmorillonitic, thermic family of Typic Chromusterts. Leeray clay is a soil series of the Clay Flat range site. This series was chosen because it occurs in all the grazing treatments, and accounted for 60.4% of the Clay Flat range site and 23.3% of the ranch's total area. The Leeray clay series and Clay Flat site occur extensively throughout the Rolling Plains.

The mean percentage cover of shrub canopy, midgrass and shortgrass interspace areas on the Leeray clay series for the various grazing treatments is shown in Table 1 (Wood 1979). The largest occurrence of midgrass interspace was in the exclosures followed in decreasing order by the deferred-rotation; moderately stocked, continuously grazed; HILF; and heavily stocked, continuously grazed pastures. The shortgrass interspace was found most often in the heavily stocked, continuously grazed pastures and least in the exclosures. This seral stage of the exclosures was high enough that shortgrass interspace was not present. The differences observed in shrub canopy between grazing treatments were probably the result of original brush control efficiency.

Where the range was in good to excellent condition, shrub canopy areas occurred in a midgrass interspace matrix. Shrub canopy areas and patches of shortgrass interspace were located in a midgrass matrix where the range was in good to fair condition. Where the range was in fair to poor condition, shrub canopy areas and midgrass interspaces patches occurred in a shortgrass matrix (Wood 1979).

**Table 1. Mean percentage cover of shrub canopy area, midgrass interspace, and shortgrass interspace for various exclosures and grazing treatments.**

| Grazing treatment | Vegetation area: Shrub canopy | Midgrass interspace | Shortgrass interspace |
|---|---|---|---|
| Exclosure 1 (southern) | 16.8 | 83.2 | [1] |
| Exclosure 2 (northern) | 8.4 | 91.6 | [1] |
| Deferred-rotation | 10.2 | 60.4 | 29.4 |
| HILF system | 7.6 | 48.0 | 44.4 |
| Moderately stocked, continuous system | 8.9 | 60.2 | 30.9 |
| Heavily stocked, continuous system | 9.8 | 23.2 | 67.0 |

[1]No shortgrass interspace was found in the exclosures.

## Methods

### Sediment Production

Simulated rainfall was applied to 0.5 m² plots with an infiltrometer similar to the one described by Blackburn et al. (1974). Ten samples were randomly located within each vegetation area in the different grazing treatments. Water was applied at a rate of 17.7 cm/hr for 0.5 hr on soil initially dry and then on the same area 24 hours later when the soil was at or near field capacity. Only the results with the soil at field capacity are reported. The simulated rainfall rate of 17.7 cm/hr has a natural storm return period of more than 100 years and was chosen to ensure runoff from all sites. Immediately after the first wetting, the plots were covered with a clear polyethylene plastic to reduce evaporation and maintain a uniform soil surface water content. Simulated rainfall was used for convenience. Young and Burwell (1972) found no significant difference in runoff and erosion between simulated rainfall and natural rainfall on loamy soils in Wisconsin.

The area of accumulation of mulch and soil under woody plants was defined as the shrub canopy area, and interspace as the area between shrub canopy areas (Blackburn and Skau 1974).

Runoff from each plot was collected and, upon termination of the simulated rainfall application, was thoroughly agitated and a 1-liter subsample was taken. The sediment of each subsample was filtered off, dried at 105° C for 24 hours, weighed, converted to sediment yield in kg/ha, and used as an index of sheet erosion.

### Vegetation Cover and Standing Crop

The percentage foliage cover of shrubs, grasses, forbs and ground cover were determined by ocular estimate on each plot from gridded sampling quadrats. Grasses, forbs, and standing dead material were harvested to a 2-cm stubble height, and mulch was collected from each plot. The material was dried at 60° C for 1 week and weighed.

### Soils

Soil moisture by the gravimetric method (Gardner 1965) and bulk density by the core method (Blake 1965) were determined for areas adjacent to each runoff plot at depths of 0 to 3 and 5 to 8 cm before each simulated rainfall application.

Soil was collected to 3 cm deep within each plot after the final simulated rainfall event. Particle size distribution of the soil was measured by the hydrometer method (Bouyoucos 1962), aggregate stability by the wet sieve method (Kemper 1965), and organic-matter content by the Walkley-Black method (Allison 1965). Microrelief within each plot was measured along three different lines with a relief meter consisting of 10 pins spaced 6 cm apart (Kincaid and Williams 1966).

### Analysis

Skewness and kurtosis tests were applied to each variable to determine the normality of data (Snedecor and Cochran 1971). If the data were not normally distributed, the common logarithmic transformation was applied before conducting analysis of variance. Mean separation between grazing treatments and between vegetation areas was accomplished with Duncan's multiple range test (Steel and Torrie 1960). Simple linear correlation and stepwise multiple regression and correlation analysis (0.1 level of probability) determined the amount of variation in production attributable to selected parameters (Table 2) (Draper and Smith 1966).

## Results and Discussion

### Sediment Production

Sediment production averaged across all grazing treatments was significantly higher on shortgrass interspaces (94.7 kg/ha) than shrub canopy zones (14.4 kg/ha) but similar to the midgrass

**Table 2. Dependent and independent variables used in regression and correlation analysis.**

| Number | Variable | Units |
|---|---|---|
| Ŷ | Sediment production | kg/ha |
| X1 | Ground cover | % |
| X2 | Perennial grass cover | % |
| X3 | Total grass cover | % |
| X4 | Standing crop | $g/0.5\ m^2$ |
| X5 | Mulch | $g/0.5\ m^2$ |
| X6 | Bulk density, 0-3 cm depth | $g/cm^3$ |
| X7 | Organic matter content | % |
| X8 | Aggregate stability | % |

interspace (31.9 kg/ha). On this range site, brush control or conversion from a shrub area to a midgrass interspace would not significantly increase sediment production unless the soil was mechanically disturbed.

In the shrub canopy areas, sediment production was similar among all grazing treatments. However, there was a trend for higher losses from the continuously grazed treatments and lower sediment losses from the exclosures (Table 3).

Sediment production in the shortgrass interspaces was highest from the heavily stocked, continuously grazed treatment, and lowest from the rested HILF treatment. The heavily stocked, continuously grazed treatment was similar to all other treatments except the rested HILF treatment which was significantly lower. Although sediment production is similar in the deferred-rotation and HILF treatments, the HILF grazed range site had a greater proportion of shortgrass interspace area than the deferred-rotation. Consequently, more sediment production would be expected from the HILF treatments than from the deferred-rotation.

In the midgrass interspace, sediment production was greatest from the heavily stocked, continuously grazed treatment (114.6 kg/ha) which was nearly three times greater than the second highest sediment production value of 39.2 kg/ha from the grazed HILF treatment. Sediment production from the heavily stocked, continuously grazed treatment was significantly greater than that for the rested and grazed deferred-rotation treatments and the exclosures. The grazed HILF treatment produced more sediment than the rested deferred-rotation treatment and exclosure 1. Sediment production from the deferred-rotation treatments was closely related to the exclosure values.

**Table 3. Mean sediment production (kg/ha) for each vegetation area in each grazing treatment on the Rolling Plains, Texas.**

| Grazing treatment | Shrub canopy area | Midgrass interspace | Shorgrass interspace |
|---|---|---|---|
| Heavily stocked, continuously grazed | 22.3 a (y)[1] | 114.6 a (z) | 192.6 a (z) |
| Moderately stocked, continuously grazed | 22.6 a (y) | 27.9 abc (y) | 143.6 ab (z) |
| Rested deferred-rotation | 13.4 a (z) | 9.5 c (z) | 56.1 ab (z) |
| Grazed deferred-rotation | 9.7 a (z) | 14.4 bc (z) | 62.9 ab (z) |
| Rested HILF | 17.7 a (z) | 27.8 abc (z) | 35.6 b (z) |
| Grazed HILF | 19.4 a (z) | 39.2 ab (z) | 77.7 ab (z) |
| Exclosure 1 | 2.3 a (z) | 4.4 c (z) | — |
| Exclosure 2 | 7.5 a (z) | 17.1 bc (z) | — |

[1]Means followed by the same letter within each column or in parentheses within each row are not significantly different at the 95% level.

Variability within each grazing treatment was so large that the standard deviations almost equalled the mean values. Sediment production among these grazing treatments was extremely small when the values were compared to annual tolerance levels or to sediment produced from croplands as measured by other authors. The grazing treatment with the highest sediment production, the heavily stocked, continuously grazed, would have a value of about 400 kg/ha on an annual basis. The annual soil loss tolerance for the Leeray clay series has been set at 11,000 kg/ha (USDA 1978), which is far greater than losses from the heavily stocked, continuously grazed treatment. Wischmeier and Smith (1978) consider sediment production values between 4,500 and 11,000 kg/ha/yr to be within the environmentally acceptable range from cropland. An annual cropland sediment production value of 6,000 to 9,000 kg/ha was often considered acceptable, with some cropland soil losses exceeding 90,000 kg/ha (Wischmeier 1976).

## Factors Influencing Sediment Production

The predictive equation for each of the dependent variables resulting from selecting and weighing independent variables, is of the general form:

**Table 4. Sediment production predictive equations for each grazing treatment within each vegetation area.**

| Vegetation area | Grazing treatment | Predictive equations | Coefficient of determination $R^2$ |
|---|---|---|---|
| Shrub canopy area | Heavily stock, continuously grazed | $\hat{Y} = 131.051 - 1.624(X8) - 14.005(X7)$ | 0.443 |
| | Moderately stocked, continuously grazed | $\hat{Y} = 166.632 - 2.570(X8) - 0.013(X5)$ | 0.610 |
| | Rested deferred-rotation | $\hat{Y} = 116.526 - 0.562(X2) - 1.370(X8)$ | 0.404 |
| | Grazed deferred-rotation | $\hat{Y} = 25.547 - 0.016(X5)$ | 0.323 |
| | Rested HILF | $\hat{Y} = 182.343 - 1.660(X3) - 0.276(X8)$ | 0.866 |
| | Grazed HILF | $\hat{Y} = 56.587 - 6.661(X7) - 0.076(X4)$ | 0.728 |
| | Exclosure 1 | $\hat{Y} = 22.944 - 0.664(X8) + 17.715(X6)$ | 0.547 |
| | Exclosure 2 | $\hat{Y} = 38.795 - 5.743(X7) - 0.010(X5) - 0.063(X8)$ | 0.745 |
| Midgrass interspace | Heavily stocked, continuously grazed | $\hat{Y} = 682.120 - 5.878(X8) - 37.65(X2) - 34.280(X7)$ | 0.767 |
| | Moderately stocked, continuously grazed | $\hat{Y} = 216.886 - 30.756(X7) - 1.632(X8)$ | 0.790 |
| | Rested deferred-rotation | $\hat{Y} = 108.496 - 12.348(X7) - 0.618(X8)$ | 0.768 |
| | Grazed deferred-rotation | $\hat{Y} = 215.904 - 2.327(X3)$ | 0.813 |
| | Rested HILF | $\hat{Y} = 56.012 - 0.760(X8) + 0.526(X1)$ | 0.532 |
| | Grazed HILF | $\hat{Y} = 128.778 - 0.883(X2) - 9.191(X7)$ | 0.941 |
| | Exclosure 1 | $\hat{Y} = 20.617 - 0.257(X8) - 0.004(X5)$ | 0.871 |
| | Exclosure 2 | $\hat{Y} = 61.450 - 0.296(X8) - 14.561(X7)$ | 0.412 |
| Shortgrass interspace | Heavily stocked, continuously grazed | $\hat{Y} = 343.272 - 2.770(X4)$ | 0.347 |
| | Moderately stocked, continuously grazed | $\hat{Y} = 125.908 - 2.885(X8) + 222.753(X6)$ | 0.840 |
| | Rested deferred-rotation | $\hat{Y} = 194.431 - 55.535(X7) + 98.141(X6)$ | 0.745 |
| | Grazed deferred-rotation | $\hat{Y} = 337.174 - 49.715(X7) - 2.177(X8)$ | 0.566 |
| | Rested HILF | $\hat{Y} = 47.066 + 1.639(X1) - 0.770(X8)$ | 0.863 |
| | Grazed HILF | $\hat{Y} = 273.805 - 35.392(X7) - 1.850(X8)$ | 0.509 |

$$\hat{Y} = a + b_1X_1 + \ldots + b_nX_n$$

where $\hat{Y}$ is the predicted dependent variable sediment production, $a$ is the Y-intercept, $b$ is a weighting factor, and $X$ represents the independent variables. These equations can be used to give insight into probable causative and important relationships, and to predict sediment production on this range site under similar circumstances. The independent variables are listed in order of correlation with the highest correlated variable being listed first.

Specific sediment production equations for each vegetation area and treatment indicate that aggregate stability (X8) was the most important influential variable in 36% of the equations, while organic matter content (X7) was the most important in 32% of the equations (Table 4). More importantly, aggregate stability (X8) was a subdominant factor in 36% additional equations and organic matter content (X7) was subdominant in 18% additional equations. Perennial grass cover (X2) and total grass cover (X3) were each the most important variables in 9% of the equations. Ground cover (X1), standing crop (X4), and mulch (X5) were each the paramount variable in 4.5% of the equations. Organic matter influences the soil plasticity by increasing the cohesion of clay particles (Baver et al. 1972). The increased cohesive properties render the soil as being less erosive. This occurrence of organic matter content (X7) and aggregate stability (X8) was equal among plant communities. The equations for the continuously grazed treatments contained a larger variety of influencing variables than the equations for other treatments. This condition shows the dominance some factors receive from some or total rest from grazing.

Coefficient of determination values ($R^2$) ranged from 0.323 to 0.941. A majority of the values (53%) were between 0.600 and 1.000. Other researchers found similar relationships for $R^2$ between infiltration rates (a closely related hydrologic variable) and sediment production (Blackburn 1975; Roundy et al. 1978).

## Conclusions

Sediment production from the grazing treatments was extremely small when compared to sediment production from croplands. Sediment production averaged across all treatments was significantly higher from the shortgrass interspace communities than from the shrub canopy area, and was slightly lower than from the midgrass interspace.

Sediment production from shrub canopy areas was similar, regardless of grazing treatment. Sediment production from the deferred-rotation grazing treatments was most closely related to that from the exclosures. Sediment production from the HILF treatments was intermediate compared to the moderately stocked, continuously grazed treatment and the heavily stocked, continuously grazed treatment.

Sediment production from the shortgrass interspace was similar among grazing treatments except for a higher value from the heavily stocked, continuously grazed treatment and a lower value from the rested HILF treatment. Although not statistically different, all deferred-rotation and HILF sediment production values were lower than those from the moderately stocked continuously grazed treatment.

Midgrass interspace sediment production was significantly lower in the exclosures and deferred-rotation treatments than the heavily stocked continuously grazed treatment.

Components of this range site which were important influencing factors upon sediment production included: aggregate stability, organic matter content, mulch, standing crop, bulk density, initial soil moisture content (0–3 cm depth), ground cover, perennial grass cover, and total grass cover. The most important variable was aggregate stability followed closely by organic matter content. However, these two variables are influenced by the other independent variables. Decreased sediment production can be expected in ecosystems where more favorable vegetation and soil conditions can be obtained by implementing a grazing system. The deferred-rotation grazing system in this instance would be a better method to use in reaching that goal. In this ecosystem, the deferred-rotation grazing system would be an effective "Best Management Practice" to control nonpoint source pollution from rangelands. For this range site, a properly applied deferred-rotation grazing system could be expected to improve hydrologic conditions as well as exclusion from grazing.

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