Runoff and Erosion Following Mechanical and Chemical Control of Creosotebush (*Larrea tridentata*)[1]

M. KARL WOOD, EDDIE L. GARCIA, and JOHN M. TROMBLE[2]

Abstract. Runoff and sediment yield were monitored from 1983 through 1986 on a range site dominated by creosotebush. The site was rootplowed and seeded, treated with tebuthiuron at 36 kg ai ha^{-1}, or left untreated. Runoff from rootplowed and herbicide-treated plots was no different from untreated plots for 1 yr, but sediment yield from treated plots was lower than that from the untreated plots. Rootplowing and seeding increased sediment yield in the second year (1984), whereas treating with herbicide decreased sediment yield. Runoff and sediment yield during 1985 and 1986 were greatest from the untreated areas and least from the rootplowed and herbicide-treated areas. Total cover was nearly the same for each treatment. The untreated plots had 13% shrub cover; the others had none. Between shrubs in untreated plots, bare ground occupied large interconnected areas that contributed to the higher runoff and erosion rates. **Nomenclature:** Tebuthiuron, *N*-[5-1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-*N,N*-dimethylurea; creosotebush, *Larrea tridentata* (Sesse & Moc. ex. DC.) Coville #[3] LARTR.

Additional index words: Chihuahuan desert, phytomass, rainfall, root plow, sediment yield, water stage.

INTRODUCTION

The Chihuahuan desert is characterized by precipitation that is highly variable in amount, duration, intensity, and form. Runoff studies are complicated because of infrequent runoff events. Runoff varies with soil type and kind and quantity of vegetation. In the Chihuahuan desert runoff is a low percentage of precipitation compared to other plant communities in more moist zones. For example, in the Rio Grande basin of New Mexico, Dortignac (3) showed that at least 250 mm of precipitation must occur before there is a marked amount of runoff. A marked amount was considered to be 2% or 5 mm. Much of the Chihuahuan desert receives below 250 mm. Because of differences in vegetation and soils, runoff tends to be spatially variable in lower precipitation zones. However, Tromble (unpublished data)[4] found several runoff events occurred each year on a site of gravelly, loamy sand dominated by creosote.

Erosion usually accompanies runoff in the Chihuahuan desert. Most precipitation events that result in runoff are high-intensity thunderstorms with high erosive energy from raindrop impact. Many land management activities cause perturbations of the hydrologic cycle. Attempts to control brush and increase forage for livestock and wildlife often result in excessive sheet, rill, and gully erosion before desired plants can adequately stabilize the soil.

Rootplowing has been widely used in Texas on mesquite [*Prosopis juliflora* (Sw.) DC] and associated mixed brush (12). The rootplow is mounted behind a heavy-duty crawler tractor which pulls the 3 to 5-m long, V-shaped blade usually 20 to 40 cm below the soil surface. Rootplowing in southern Arizona killed 95% of sand-dune mesquite and creosotebush when properly applied during drought (8). Herbicides are continually being developed for rangelands. Tebuthiuron effectively controls creosotebush (7), but its hydrologic consequences are not known. Richardson et al. (9) found controlling honey mesquite (*Prosopis glandulosa* Torr.) on the Blackland Prairie of Texas increased runoff by about 10%. Spraying a pinyon-juniper watershed increased streamflow by 157% over an 8-yr period in Arizona (1).

The purpose of this research was to compare runoff and erosion on a creosote-dominated range site that was rootplowed and seeded, treated with herbicide, with an untreated site in a native condition.

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[2]Authors are Prof. Watershed Manage., Dep. Anim. Range Sci., New Mexico State Univ.; Range Tech. and retired Range Hydrologist, U.S. Dep. Agric./Agric. Res. Serv., Jornada Experimental Range, P.O. Box 30003, Dep. 3-I, Las Cruces, NM 88003.

[3]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.

[4]Tromble, J. M. 1975 through 1983.

MATERIALS AND METHODS

The study site was on the eastern side of the USDA's[5] 77 700-ha Jornada Experimental Range. The soil was a gravelly, loamy sand of the Nickel series in the loamy-skeletal, mixed, thermic family of Typic Calciorthids. The plots were on a northwestern exposure with 6% slope. The site was dominated by creosotebush with small amounts of fluffgrass (*Erioneuron pulchellum* (H.B.K.]Tateoka), black grama [*Bouteloua eriopoda* (Torr.]Torr.], bush muhly (*Muhlenbergia porteri* Scribn.), Arizona cottontop (*Digitaria californica* (Benth]Henr.), cane beardgrass (*Bothriochloa barbinodis* (Lag.]Herter), slim tridens (*Tridens muticus* [Torr.]Nash), mesa dropseed (*Sporobolus flexuosus* [Thurb.]Rydb.), tarbush (*Flourensia cernua* DC.), little leaf sumac (*Rhus microphylla* Engelm. ex Gray), mariola (*Parthenium incanum* H.B.K.), and winterfat (*Ceratoides lanata* [Pursh.]Moq.). Mean yearly rainfall is 230 mm.

In 1983, 12 plots were established on a 7% slope with a northern exposure before summer and fall rains came in 1983. The plots were 23.2 m long and 3.7 m wide (0.0085 ha). This length of slope was used to develop the widely-used Universal Soil Loss Equation (13). The width is twice that used for the Universal Soil Loss Equation and was chosen to represent adequately the coppice dunes and dune interspaces. The plots were bordered with sheet metal buried 10 cm into the soil and rising 20 cm above the soil. Runoff was measured with an H-flume and continuous water stage recorder. Runoff water samples for sediment analysis were collected with a Coshocton wheel (2), and were diverted into collection tanks. The Coshocton wheel captured 1% of the total runoff. Aliquots of water containing sediment were evaporated in an oven at 104 C. The sediment was weighed to determine sediment yield per storm. Rainfall was measured with two weight recording rain gauges on the site.

Four plots were randomly chosen from the 12 total plots and mechanically treated in 1983 on the contour with a rootplow that severed the brush roots at a depth of 25 cm. Uprooted brush was left in place. A mixture of sideoats grama [*Bouteloua curtipendula* (Michx.)Torr.], and spike dropseed (*Sporobolus contractus* Hitchc.) was seeded at rates of 4.11 and 0.27 kg ha^{-1}, respectively. Four more plots were randomly chosen and treated with tebuthiuron pellets at 0.36 kg ai ha^{-1}. Four plots were left undisturbed for controls. Rainfall, runoff, and sediment yield were recorded after each storm in 1983 through 1986. In 1986, ground cover of litter, rock, gravel, grass, forbs, and shrubs was determined in each plot with the step-point method (4) (Table 1). Each plot is considered a spatial replication, with data collected for four years for replication through time.

[5]U.S. Dep. Agric./Agric. Res. Serv., Jornada Experimental Range, Las Cruces, NM 88003.

RESULTS AND DISCUSSION

Runoff. Runoff resulted from four storms between July and Dec., 1983 (Table 2). Total precipitation for these four storms was 108 mm or 46% of the yearly mean. The percentage of precipitation that became runoff for each date was 58, 82, 87, and 51%, respectively, with a mean of 70%. About 32% of the yearly mean precipitation was lost as runoff. This is much greater than the 2% reported by Dortignac (3) for regions receiving less than 250 mm. The highest percentage (87%) occurred on Sept. 12, only two days after the previous storm. High soil water content apparently increased runoff. During every storm, runoff was slightly greater from the herbicide-treated plots than from the control. Runoff from rootplowed plots and the control were similar during 1983. The rootplowed plots were treated on the contour, leaving distinct terracettes. Sanchez and Wood (10) found that terracettes were the dominant influence on runoff from bare soils during the first year after mining reclamation in west-central New Mexico. Richardson et al. (9) reported that rootplowing a honey mesquite stand near Sonora, Texas reduced runoff by about 20% over a 10-yr period. The reduction was attributed to the mechanical disturbance of the shallow soil, which created large depressions and encouraged rapid percolation into the fractured limestone substratum.

Runoff resulted from nine storms in 1984 (Table 3). The percentage of precipitation that became runoff was 65% for the controls, 32% for the rootplowed plots, and 46% for the herbicide-treated plots when totaled across the whole year. However, in at least one storm (July 20), no runoff resulted from the rootplowed plots. The range then was from zero (July 20) to very high (95% on May 15). Runoff from the rootplowed plots was less than that from the controls during six storms, but there

Table 1. Plant, rock, and gravel cover (%) plus bare ground for each treatment in 1986.

	Ground composition						
Treatment	Grasses	Forbs	Shrubs	Litter	Rock	Gravel	Bare ground[a]
	%						
Untreated	6	8	13	9	29	16	20
Rootplowed	10	8	<1	16	26	17	23
Tebuthiuron	7	6	<1	17	24	22	24

[a]Bare ground is calculated by subtracting the sum of total of all plant parts, rock, and gravel from 100%.

Table 2. Total precipitation and mean depth of runoff with their standard errors for untreated, rootplowed, and tebuthiuron-treated plots, 1983.

	Date of storm				
	July 25	Sept 10	Sept 12	Nov 2	Total
	Precipitation (mm)				
	39	28	19	22	108
Treatment	Mean depth of runoff				
	mm				
Untreated	20 ± 12	22 ± <1	16 ± <1	14 ± <1	73
Rootplowed	26 ± 2	21 ± <1	17 ± <1	13 ± 8	77
Tebuthiuron	21 ± 13	25 ± <1	17 ± <1	13 ± 3	76

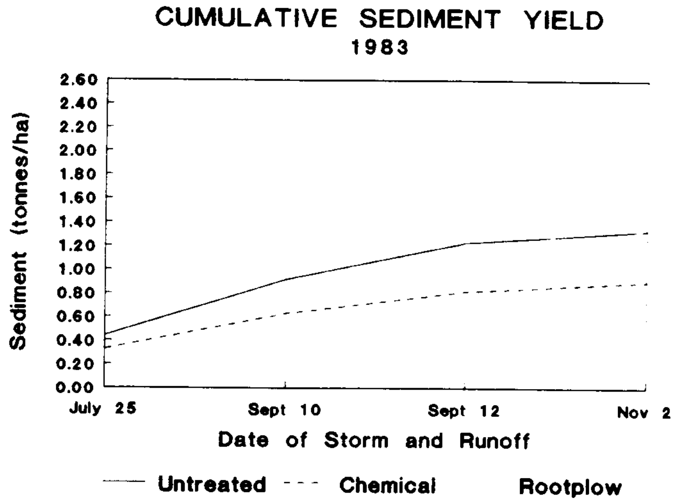


Figure 1. Cumulative sediment yield for rootplowed, chemical treated, and untreated plots in 1983.

was no consistent pattern during the year. In those six storms, runoff averaged 27% less than the controls. For the other three storms, runoff was 69% less from the control plots than the rootplowed plots. Runoff from the herbicide-treated plots was also less than that of the controls in six storms, with no apparent pattern, from May 15 through Aug. 6. After Aug. 6, the tebuthiuron-treated plots always yielded less runoff than the control plots. Neither the rootplowed plots nor the herbicide-treated plots responded to the high precipitation (47 mm) on Aug. 7, whereas runoff from the untreated plots was 31 mm.

Runoff occurred in five storms in 1985 (Table 4). For all four years of the study, the first storm of the season that resulted in runoff was latest in the year in 1985. For that storm (Aug. 12), runoff occurred only on plots of the untreated natural rangeland. Runoff from the rootplowed and herbicide-treated plots was lower than the controls in four of the five storms in 1985. By this time (three growing seasons after treatment), seeded grass species were established and native species had increased on the rootplowed plots. Simanton et al. (11) found a similar situation in Arizona. In their study, surface runoff increased after a mixed stand of shrub species was rootplowed, but decreased again after grass establishment. Shrubs in the herbicide-treated plots had been completely defoliated, and foliar cover of understory plants (mainly fluffgrass) had increased. The percentage of precipitation that became runoff was 25% for rootplowed plots, 21% for herbicide-treated plots, and 33% for untreated plots. For 1985, 62% of the runoff came from the last storm on Oct. 15. The soils were apparently quite dry before the Oct. 15

Table 3. Total precipitation and mean depth of runoff with their standard errors for untreated, rootplowed, and tebuthiuron-treated plots, 1984.

	Date of storm									
	May 15	June 14	July 20	Aug 5	Aug 6	Aug 7	Aug 23	Aug 26	Oct 3	Total
	Precipitation (mm)									
	22	13	5	11	11	47	15	14	11	149
Treatment	Mean depth of runoff									
	mm									
Untreated	20 ± 10	8 ± <1	4 ± <1	4 ± <1	3 ± <1	31 ± 51	14 ± 3	6 ± 1	7 ± <1	97
Rootplowed	13 ± 14	4 ± 2	0 ± 0	9 ± 38	3 ± <1	6 ± 13	1 ± 3	1 ± <1	10 ± 7	47
Tebuthiuron	20 ± <1	5 ± 2	4 ± 4	2 ± <1	3 ± <1	15 ± 1	8 ± <1	6 ± 1	5 ± <1	69

Table 4. Total precipitation and mean depth of runoff with their standard errors for untreated, rootplowed, and tebuthiuron-treated plots, 1985.

	Date of storm					
	Aug 12	Aug 18	Sept 19	Oct 8	Oct 15	Total
	Precipitation (mm)					
	20	26	6	24	43	119
Treatment	Mean depth of runoff					
	mm					
Untreated	5 ± <1	6 ± 4	3 ± <1	7 ± 3	18 ± 17	39
Rootplowed	0 ± 0	2 ± 1	3 ± 4	1 ± <1	24 ± 31	30
Tebuthiuron	0 ± 0	5 ± 2	0 ± 0	5 ± 14	16 ± 41	25

Table 5. Total precipitation and mean depth of runoff with their standard errors for untreated, rootplowed, and tebuthiuron-treated plots, 1986.

	Date of storm					
	July 8	July 22	Aug 22	Sept 22	Nov 4	Total
	Precipitation (mm)					
	10	36	17	20	34	117
Treatment	Mean depth of runoff					
	mm					
Untreated	1 ± <1	15 ± 2	7 ± 2	3 ± 2	5 ± 5	31
Rootplowed	2 ± <1	22 ± 2	2 ± 2	0 ± 0	1 ± <1	26
Tebuthiuron	2 ± <1	8 ± 12	4 ± 2	2 ± 2	1 ± <1	16

storm, which resulted in little runoff before this storm.

Five storms generated runoff in 1986 (Table 5). Amounts of runoff from rootplowed and herbicide-treated plots exceeded those of the untreated plots only during one storm each (July 22 and July 8, respectively). The five storms totaled 117 mm of precipitation. The untreated plots had 31 mm (26%), the rootplowed plots had 26 mm (22%) runoff, and the herbicide-treated plots had 16 mm (14%). Plant cover reflected the effects of treatment (Table 1), although the total cover was nearly the same among treatments. An average of 13% of the untreated plots was covered by shrubs, but the rootplowed and herbicide-treated plots supported almost no shrubs. The untreated plots had only half as much litter as treated plots. Although untreated plots had slightly less bare ground (the reciprocal of total cover), the bare ground was found in large interconnected areas between shrubs. Nearly all the litter was under shrubs. In the rootplowed and herbicide-treated plots, bare ground was widely dispersed among the grasses, forbs and litter. These differences in cover between the untreated control plots and the treated plots (Table 1) help explain differences in runoff. Other variables, such as standing phytomass and animal activities, also have important influences on runoff (5, 13, 14, 15), but these were not measured in this study because it involves extensive or destructive sampling.

Erosion. Four of the several storms in 1983 resulted in sediment yield from the plots (Figure 1). About one-third (37, 33, and 32%) of the total sediment left the plots during the first storm. About another third (30, 36, and 40%) came off during the second storm. Only about a fifth (23, 19, and 21%) came off during the third storm. Finally, only a tenth (10, 12, and 7%) of the total sediment left the plots during the last storm. This trend shows a disproportionate amount of sediment

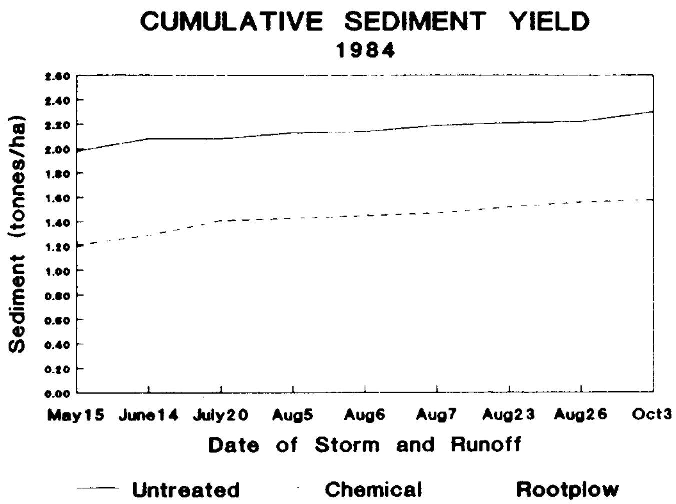
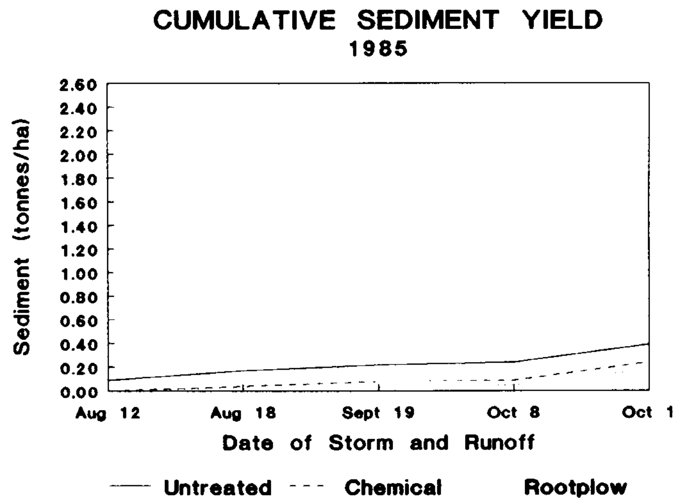


Figure 2. Cumulative sediment yield for rootplowed, chemical treated, and untreated plots in 1984.



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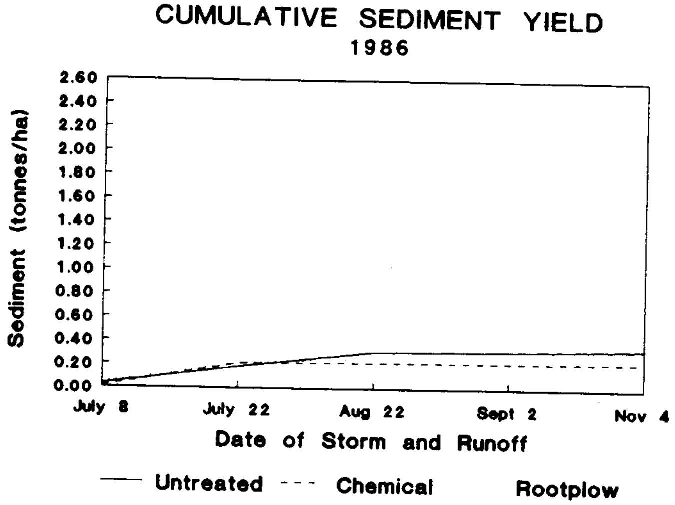

Figure 4. Cumulative sediment yield for rootplowed, chemical treated, and untreated plots in 1986.

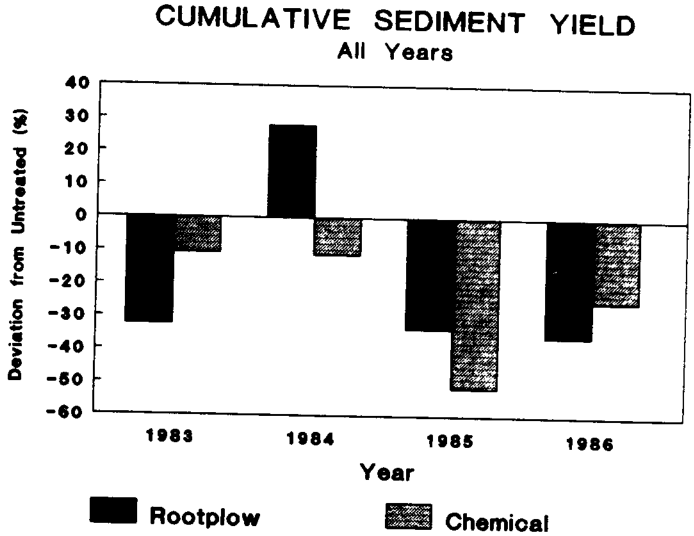

Figure 5. Cumulative sediment yield for rootplowed and chemical treated plots as departures from the untreated plots for all years.

early in the growing season and with the first few runoff events. Rootplowed and herbicide-treated plots yielded less sediment than the untreated plots in every storm in 1983.

Nine of the several storms in 1984 resulted in sediment yield from the plots (Figure 2). The first storms (May 15 and June 14), were unusual because they occurred in what is usually the driest period of the year. Sediment yields from all treatments were high compared to other years. In May, loose soil material is present on the soil surface from dust fallout as spring winds erode lower elevations to the west (6). Considerably more sediment left the rootplowed plots than the herbicide-treated and untreated plots. Most of the sediment yield for the year occurred during this first runoff event (86% in the rootplow, 69% in the untreated plots and 77% in the herbicide treatment). Later storms on three consecutive days (Aug. 5, 6, and 7) had low sediment yield. August is the middle of the growing season, which got an early start in 1984.

The first storm resulting in runoff and sediment yield occurred August 12 in 1985 (Figure 3). Untreated plots had the highest sediment yield; however, sediment losses from all treatments were low. This first event is near the middle of the period of highest rain and plant growth. Apparently, this is important for soil protection.

The first runoff event in 1986 occurred near the beginning of the rainy period (Figure 4). By the end of July, most of the sediment yield for the year had occurred. This is represented by 53% of the total in the untreated plots, 91% in the rootplowed plots, and 81% in the herbicide-treated plots. Differences among treatments were small. Apparently, differences in cover (Table 1) among treatments were not as important for sediment yield as for runoff.

Cumulative sediment yield from the treated plots was less than the untreated plots each year except for the rootplowed plots in 1984 (Figure 5). This was the second season after treatment, a critical year because terracettes caused by rootplowing had settled to a lower roughness, and herbaceous vegetation had not responded to treatment. Ridges from rootplowing were a temporary benefit and were effective long enough for establishment of vegetation. If the seeding had failed, sediment yields likely would have been greater in the treated plots than on the untreated rangeland.

Controlling creosote with tebuthiuron or rootplowing had no immediate increase in runoff and erosion. Erosion may be high in rootplowed areas one year after treatment because of decreasing soil surface roughness. Erosion in rootplowed areas was low the second year after treatment due to plant establishment. Runoff and erosion from tebuthiuron treatment was always lower than the control.

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