Influence of Site Manipulation on Infiltration Rates o a Depleted West Texas Range Site

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Abstract

Infiltration rates significantly increased each year of the 3-year study on a deteriorated site heavily infested with mesquite *(Prosopis glandulosa).* Vibratilling resulted in the highest infiltration rates of all treatments by increasing soil roughness and porosity. Shredding mesquite increased infiltration compared to no treatment. The shredding of mesquite increased the amount of soil cover by increasing litter and standing crop. Removal of mesquite by foliar spraying with 2,4,5-T + picloram, mechanical grubbing, or mechanical grubbing and planting to kleingrass *(Panicum coloratum)* did not increase infiltration. Plant cover and herbaceous standing crop were the most important factors affecting infiltration for treatments without mechanical soil disturbance. Soil variables such as surface roughness, organic carbon and porosity affected infiltration rates on treatments receiving mechanical disturbance. However, interactions between soil and plant variables were important in controlling infiltration on mechanically disturbed and mechanically undisturbed sites.

Desertification by man or his grazing animals is a major resource problem. For much of west Texas, overgrazing, short-term droughts, and brush invasion have resulted in depleted ranges with reduced infiltration rates and increased runoff. Without range improvements many of these areas will continue to decrease in productivity. Since range deterioration results in increased water loss, range renovation practices should be directed toward increasing vegetation cover, decreasing transpiration to precipitation ratios, and decreasing surface evaporation and runoff (Simanton et al. 1977).

In west Texas, herbicides, mechanical grubbing, shredding, and root plowing are often used to control brush. Many researchers have reported that mechanical treatments have increased infiltration by creating macroporous surface and by providing additional surface storage of water (Branson et al. 1966, Wight and Siddoway 1972, Neff 1973, Soiseth et al. 1974, Dixon 1974, Wight 1976, Tromble 1976, Neff and Wight 1977, Gonzales and Dodd 1979). However, others found no benefit or reduced infiltration rates in conversion of brush-dominated areas to grass stands (Williams et al. 1969, Gifford 1972, Blackburn and Skau 1974, Gifford and Busby 1974, Tromble et al. 1974, Brock et al. 1982). The contradiction of these studies regarding the influence of brush control on infiltration suggests site specific results. In areas of west Texas where forage production has been reduced because of brush invasion and water lost as runoff, more site specific data are needed to determine the influence of brush control on infiltration rates.

Gifford (1975) stated that since the life of most mechanical treatments is relatively short, it is imperative that a desirable vegetation cover be established and maintained. Plant cover is important in maintaining high infiltration rates on range areas which have received any type of vegetation manipulation. A 65 to 70% vegetative cover has been estimated as necessary to prevent excessive runoff (Packer 1951, Marston 1952, Osborn 1953, Wright et al. 1976). Others have found the relationship between plant cover and infiltration was not as well correlated for more xeric plant communities where plant cover was naturally limite (Gifford 1968, Williams and Gifford 1969, Blackburn 1975).

The effects of brush control on infiltration have been studied i many areas; however, more information is needed on the influenc of different vegetation manipulation practices on west Texas range land because of the increased emphasis on increasing range pro ductivity and the need to halt increasing aridity of these areas Therefore, the purpose of this study was to evaluate the effect o commonly used vegetation manipulation practices on infiltratio rates of a brush-infested range site in low fair range condition.

Study Area

A mesquite *(Prosopis glandulosa)*-buffalograss *(Buchloe dacty loides)* community on the Post-Montgomery Estate Ranch locate 7 km north of Post, Texas, was chosen for the study. The area is semiarid transition zone from the southern short grass plains of th Llano Estacado to the Red Rolling Plains of Texas. Averag precipitation is 47.8 cm and average growing season is 216 days Winds are a critical factor influencing evapotranspiration. Fre pan evaporation averages 264.5 cm/year (USDA 1965).

A sagerton clay loam in the fine, mixed, thermic family of Typi Paleustolls typifies the study area. The soil is a deep, moderatel slowly permeable soil that formed in calcareous clays, and loam sediments on nearly level to gently sloping uplands. Climax vegeta tion of this clay loam range site was primarily a shortgrass com munity with a few midgrasses (USDA 1965). Range condition wa determined from Range Site Guides developed by the Soil Conser vation Service (USDA 1965). At the initiation of the study, the sit was in low fair range condition and the trend was downward Mesquite density averaged 919 trees/ha and foliar cover of mes quite was 19%. Historically, the area has been grazed year-long b cattle.

Methods

The study area was fenced in August 1977 and protected fron grazing by large herbivores for the duration of the study. Twenty one 0.4-ha plots were located in a completely randomized desig with 3 replications/treatment. The 7 range rehabilitation treat ments were: (1) shredding mesquite with a Service shredder an farm tractor; (2) foliar spraying mesquite with 2,4,5-T + picloran (0.6 kg a.i./ha); (3) mechanical grubbing mesquite with a farn tractor and rear mounted grubber; (4) mechanical grubbin between mesquite trees, but not disturbing the trees; (5) vibratil ling, with rippers set for a 76-cm row spacing and a 45-cm depth after mesquite trees were removed by mechanical grubbing; (6 kleingrass *(Panicum coloratum)* seeded after plots were plowe and disked; and (7) check or no range rehabilitation treatment. Al treatments were completed by 1 June 1 1978, except for the vibratil and kleingrass treatments, which were not completed until Ma 1979 because of problems in employing a contractor.

Infiltration

A sprinkling-type infiltrometer similar to the one described b Blackburn et al. (1974) was used to simulate rainfall on 0.64-m plots. Each plot was pre-wet 24 hr prior to infiltration measure ments to assure similar antecedent moisture conditions. Plots wer pre-wet using a fine mist spray for a 25-min period and the

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Table 1. Infiltration equations for site manipulation treatments combined for 1979 and 1980.

Treatment	Regression equation[1]	Coefficient of determination (R^2)	Standard error of estimate (S.E.E.)
Foliar spray	Y = –2.44 + 0.139(HC)(RC) + 0.086(P2)	0.75	0.86
Shred	Y = 1.15 + 0.092(TC)(OC) + 0.084(FC)(RC)	0.74	0.89
Check	Y = 0.40 + 0.0007(HC)(PI) + 4.830(RC)(OC)	0.73	0.76
Grub trees	Y = 1.19 + 0.058(P2)(RC) + 0.031(TC)	0.70	0.90
Grub between trees	Y = 2.57 + 0.018(FP)(RC) + 0.045(FC)	0.67	0.86
Kleingrass	Y = –5.9 + 7.650(OC) + 0.200(HC)	0.55	1.01
Vibratill	Y = 1.3 + 0.101(PI) + 0.027 (SG)	0.55	0.98

[1]Variables are arranged in the sequence of their entry into the stepwise regression. All regression equations are significant at the 0.01 level of probability.

Key to Symbols used:
Y = Predicted infiltration (cm/0.5 hr)
HC = Herbaceous plant cover (%)
RC = Roughness coefficient (standard deviation from a flat surface)
P2 = Total porosity at 1.3 to 2.5 cm depth (%)
TC = Total plant cover (%)
FC = Forb cover (%)
PI = Total porosity at 0 to 1.3 cm depth (%)
FP = Forb production (g/m²)
SG = Shortgrass production (g/m²)
OC = Organic carbon (%)

covered with clear polyethylene plastic to reduce evaporation and to maintain a uniform soil surface water content. A simulated rainfall rate of 14 cm/hr was chosen to ensure runoff on all plots.

Infiltration was considered as the amount of water applied minus the amount of runoff from the plot. Runoff (liters/m²), infiltration (cm), and infiltration rates (cm/hr) were determined at 5-min intervals for 0.5 hr. The amount of water infiltrated for the 30-min period was considered cumulative infiltration (cm/0.5 hr). Infiltration rates (cm/hr) were calculated from each 5-min sampling period. No attempt was made to estimate surface water storage on the soil surface, interception by plant material, or evaporation from the plot when calculating infiltration; however, interception and evaporation would have had only negligible effects and most soil surface storage was filled within the first 5 min. Simulated rainfall plots were randomly located within each treatment. In 1978 we measured 6 simulated rainfall plots/treatment. In 1979 and 1980 we measured 18 and 15 simulated rainfall plots/treatment, respectively.

Plant cover and standing crop were recorded for each simulated rainfall plot within 24 hr after rainfall simulation. Plant foliar cover was determined by species and as herbaceous or woody litter by using a tenpoint frame (50 points/plot). Standing crop was clipped at ground level, separated by grass species, broomweed species (*Xanthocephalum* sp.), and forbs. Litter collected from the simulated rainfall plots was designated herbaceous, woody, or standing litter (herbaceous growth of a previous growing season that had not fallen to the ground). Standing crop samples were oven dried at 50°C for at least 7 days and then weighed and recorded as g/m².

Soil measurements such as slope, organic carbon, particle size distribution (texture), bulk density, total porosity, and microrelief were measured for each simulated rainfall plot after all vegetative measurements were completed. Soil samples for particle size distribution and organic carbon analyses were collected from the soil surface (0 to 2 cm) after all other soil measurements were completed. Particle size distribution was measured by the hydrometer method (Bouyoucos 1962). Organic carbon, total porosity, and bulk density were determined by procedures of Allison (1965), Hillel (1971), and Blake (1965), respectively. Antecedent soil moisture was determined gravimetrically (Hillel 1971) from soil samples at depths of 0 to 5 cm.

A modified microrelief (soil roughness) meter was constructed according to procedures of Kuipers (1957). Soil roughness (roughness coefficient) was calculated as the standard deviation of the pens from a zero point (flat surface). The soil roughness was measured across the slope using 50 points. Slope was measured with the microrelief meter with a standard carpenter's level attached.

Statistical Analyses

Analysis of variance was used to test for differences in treatment means at the 0.05 level of probability. If the analysis of variance test showed a significant treatment effect, treatment means were separated at the 0.05 level of probability using the Duncan's new multiple range test (Steel and Torrie 1960).

The effects of soil and plant variables on infiltration were tested

Table 2. Mean soil site characteristics and cumulative infiltration associated with range rehabilitation treatments.

	Rehabilitation treatments						
Site characteristic	Foliar spray	Shred	Check	Grub between tree	Kleingrass	Kleingrass	Vibratill
Biomass (standing crop + litter)	274c[1]	521a	165d	172cd	379b	297bc	266c
Plant cover (%)	58a	54ab	45b	48ab	45 45b	54ab	44b
Total porosity (%) (0 to 1.3 cm depth)	58ab	60a	58ab	60a	59ab	56b	59ab
Total porosity (%) (2.5 to 12.7 cm depth)	47bc	47bc	46c	48b	47bc	51a	50ab
Organic carbon (%)	1.4b	1.6a	1.5ab	1.4b	1.5ab	1.2c	1.3bc
Roughness coefficient[2]	23d	24d	19d	44b	38bc	34c	58a
Cumulative infiltration cm (0.5 hr)	4.1bc	4.5b	3.5c	4.3bc	4.3bc	4.1bc	5.5a

[1]Means followed by a similar letter within the same row and grouping of treatments are not different at the 0.05 level of probability.
[2]The roughness coefficient units were the standard deviation of a flat surface × 100.

Table 3. Comparison of mechanically grubbed and mechanically undisturbed simulated rainfall plots for the grub treatments.

Site characteristic	Mechanically disturbed	Mechanically undisturbed
Biomass (standing crop + litter) (g/m²)	343a[1]	181b
Plant cover (%)	31a	34a
Total porosity (%) (0 to 2.5 cm depth)	57.4a	53.5b
Total porosity (%) (2.5 to 12.5 cm depth)	49.5a	45.4b
Organic carbon (%)	1.41a	1.44a
Roughness coefficient[2]	0.58a	0.19b
Cumulative infiltration (cm/0.5 hr)	4.51a	2.98b

[1]Means followed by a similar letter in the same row are not different at the 0.05 level of probability.
[2]The roughness coefficient units were the standard deviation of a flat surface × 100.

by simple and multiple regression (Kerlinger and Pedhazur 1973). Linear and curvilinear regression were used to determine significant correlations between infiltration and 30 soil and vegetation measurements. Following simple regression and a correlation matrix of independent variables, 15 variables were chosen to develop predictive equations for infiltration. The multiple regression analyses employed a maximum R^2 procedure (Helwig and Council 1979). All variables remaining in the models were significant at the 0.10 level of probability.

Results and Discussion

Infiltration data are presented by year and grouped across years. The influence of treatments over time (year) was considered important in determining the value of the treatments on the rehabilitation of this depleted range site. The kleingrass and vibratill treatments were not completed until 1979, thus could only be evaluated from 1979 and 1980. The foliar spray, shred, check, and grub treatments were evaluated for 1978, 1979, and 1980. For ease of discussion, the time influence is presented only for the foliar spray, shred, check and grub treatments. Treatment comparisons are presented for all treatments but for only 1979 and 1980.

Treatment Influence

A comparison of the range rehabilitation treatments showed higher infiltration rates for the vibratill treatment for all time periods (Fig 1). The shred treatment had intermediate infiltration

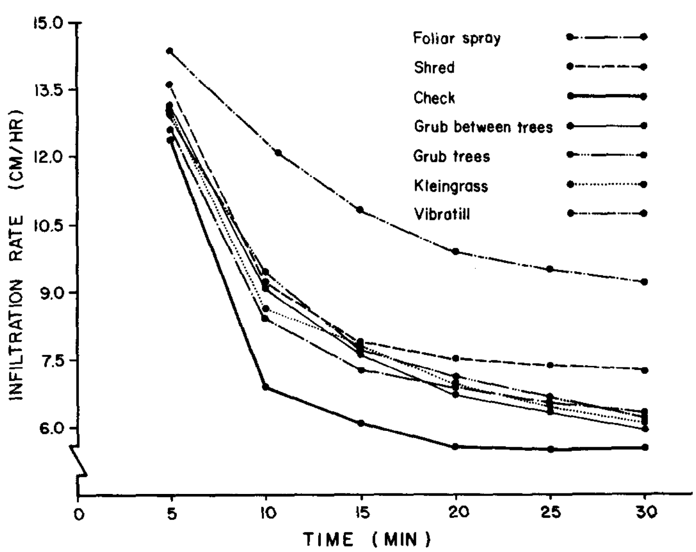

Fig. 1. *Infiltration rates for the foliar spray, shred, grub, kleingrass, and vibratill treatments during 1979 and 1980.*

rates compared to the vibratill and check plots. There was an apparent trend of increased infiltration rates for the foliar spray, kleingrass, and mechanical grub treatments compared to the check. However, infiltration rates for the 25- and 30-min time periods for the foliar spray, kleingrass, and mechanical grub treatments were not significantly different ($P \geq 0.05$) from the check or shred treatments. A treatment by year interaction was not found for any infiltration measurements.

The high infiltration of the vibratill treatment was most correlated with surface soil porosity at 0. to 2.5 cm depth ($R^2 = 0.48$), but no single measured site variable or combination of site variables accounted for more than 55% of the variability in infiltration (Table 1). Dixon (1975, 1978) reported improved infiltration on rough areas because of depression storage and improved air flow from the soil surface. He stated (1974, 1975, 1978) that the air-earth interface concept establishes the general principle that soil roughness and openness control infiltration by governing the flow of air and water in subsurface macropore and micropore systems. The roughness factor for the vibratill treatment was 130 to 305% higher than other treatments (Table 2) and contributed to water impoundment. The high infiltration rates from 10 to 30 min were true increases in infiltration probably because of large macropores.

The microhabitat near shredded mesquite was conducive to high infiltration because shredded mesquite areas had a trend of increased plant cover and increased biomass compared to the check (Table 2). Infiltration was most correlated with total cover ($R^2 = 0.39$). Herbaceous and woody little cover averaged 16% for the shred treatment compared to only 2% for other treatments one growing season after treatment. The increased vegetation cover on the shred areas protected the soil from the impact of raindrops and probably reduced soil temperature and evaporation, thereby resulting in increased herbage production and improved infiltration conditions during the first growing season.

For the shred treatment the soil variables significantly correlated with infiltration were soil porosity at 0 to 1.3 cm ($R^2 = 0.32$), soil porosity at 1.3 to 2.5 cm ($R^2 = 0.23$), and organic carbon ($R^2 = 0.19$). Brock et al. (1982) stated that infiltration rates reflected variations in soil aggregate stability and impact of range improvement practices on increasing plant cover. For this study it was apparent that plant variables were positively correlated with organic carbon and porosity. Biomass was slightly more correlated with organic carbon ($R^2 = 0.41$) and soil porosity at 0 to 1.3 cm ($R^2 = 0.46$) than was plant cover to organic carbon and soil porosity ($R^2 = 0.21$ and 0.39, respectively) for the shred treatment. Thus, the interactions between site variables were important in influencing infiltration (Table 1). The interactions of plant and soil variables were also important in controlling infiltration of the check and foliar spray treatments (Table 1). For the check treatment the lower infiltration was a result of less plant material (biomass and cover) compared to the foliar spray and shred treatments, and to the influence of these plant variables on soil organic matter and porosity (Table 2). The mesquite on the check competed with herbaceous plants for water and the reduction in herbaceous plant material was important in reducing infiltration compared to other treatments.

Infiltration of the grub between tree and grub tree treatments was positively correlated with the roughness coefficient ($R^2 = 0.55$ and $R^2 = 0.30$, respectively). The intermediate infiltration rate of the mechanically grubbed treatment was a result of measuring simulated rainfall plots within grubbed pits and outside of the grubbed pits because of the random location of simulated rainfall plots. A comparison of mechanically grubbed areas and mechanically undisturbed areas within the grub between tree and grub tree treatments showed higher total infiltration (Table 3) and infiltration rates for the grubbed areas during all time periods except for the 5-min period. Soil porosity, roughness and biomass were greater on mechanically grubbed simulated rainfall plots, but there was no difference in plant cover (Table 3).

Infiltration for the kleingrass treatment was more correlated with organic carbon ($R^2 = 0.46$). The plowing and disking of the kleingrass plots decreased organic matter compared to mechanically undisturbed areas. The low organic carbon of the kleingrass treatment resulted in crusting and sealing of the soil surface by the second year after treatment. The surface crust could have been caused by the impact of raindrops before kleingrass became established, or as a result of slaking and breakdown of soil aggregates during wetting because of low organic matter. The importance of plant cover and organic carbon was very evident for the kleingrass treatment. Without adequate plant cover to protect the soil surface from raindrop impact, these kleingrass areas would have very reduced infiltration rates because of the low organic carbon.

Several studies have shown that infiltration rates were higher within the mesquite canopy zone (Knight et al. 1980, Wood and Blackburn 1981, Brock et al. 1982). For this site, however, infiltration measurements within the mesquite canopy zone were not different from infiltration outside the canopy zone. Also, no difference in infiltration of grubbed mesquite areas was found versus grubbed areas outside the canopy zone. Because of the heavily grazed depleted conditions of this area, it appeared that only large multi-stemmed mesquite trees were creating conditions which could offer protection from grazing and improve site conditions for increased infiltration rates.

Time Influence

Infiltration rates increased each year with the terminal infiltration rate (30 min) for 1980 and 1979 being 320% and 210% higher, respectively, than for 1978 (Fig. 2). In 1978 only 1.7 cm of water infiltrated compared to 3.2 and 4.2 cm for 1979 and 1980, respectively. The very low infiltration in 1978 was a result of the deteriorated site conditions and lack of vegetative cover to protect the soil surface and hold water on the site.

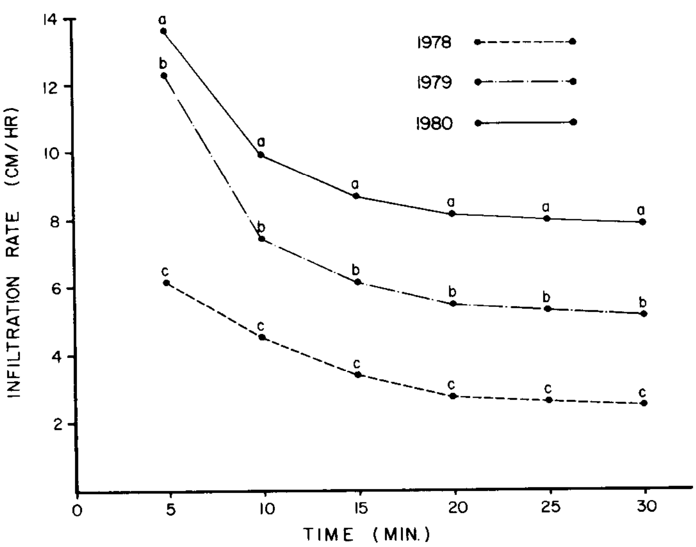

Fig. 2. *Infiltration rates for the foliar spray, shred, check and grub treatments combined for 1978, 1979, and 1980.*

[1]Means of the same time period followed by a similar letter are not statistically different at the 0.05 level of probability.

Grass standing crop, grass cover and herbaceous litter increased each year and there was an increase in total cover for 1979 and 1980 compared to 1978 (Table 4). The only soil factor to increase each year was total porosity at the 0 to 1.3 cm depth. Organic carbon, total porosity (2.5 to 12.7 cm), and soil roughness were higher in 1980 than in 1978 (Table 4). Monthly and total precipitation were similar for 1978 and 1980 (Fig. 3), but site conditions were much improved by 1980. We found that the range rehabilitation treatments influenced many of the measured plant and soil variables; however, the rest from grazing was also important in influencing the biohydrological condition of this site.

Table 4. Mean site characteristics for range rehabilitation treatments grouped by years.[1]

	Year		
Site variables	1978	1979	1980
Total porosity (%) (0 to 2.5 cm depth)	52b[2]	55b	59a
Total porosity (%) (2.5 to 12.7 cm depth)	45b	46b	48a
Organic carbon (%)	1.39b	1.41b	1.52a
Roughness coefficient[3]	22b	21b	39a
Grass standing crop (g/m²)	48c	81b	141a
Litter (g/m²)	81c	97b	178a
Phytomass standing crop (g/m²)	71b	158a	192a
Grass cover (%)	23c	33b	41a
Litter cover (%)	5b	4b	9a
Phytomass cover (%)	33b	48a	54a
Cumulative infiltration (cm)	1.7c	3.2b	4.2a

[1]Range rehabilitation treatment means compared for 1978-1980 were the foliar spray, shred, check, grub between tree, and grub tree treatments.
[2]Means followed by a similar letter in the same row are not different at the 0.05 level of probability.
[3]The roughness coefficient units were the standard deviation of a flat surface × 100.

Thus, plant cover, herbaceous biomass, porosity and organic carbon were increasing annually. The importance of these factors to infiltration has been shown by many researchers (Colman 1953, Dixon 1978, Wood and Blackburn 1981, Brock et al. 1982) and they were positively correlated with infiltration for this site. Wood and Blackburn (1981) found that aggregate stability and organic matter were the major factors controlling infiltration in the Rolling Plains of Texas. For this site, regression equations showed that plant cover and phytomass accounted for more variation in infiltration on mechanically undisturbed sites, whereas organic carbon and porosity were more related to infiltration on mechanically disturbed sites. However, interaction between vegetation measurements such as plant cover and standing crop, and soil factors such as organic carbon and porosity were evident. Plant cover was correlated with organic carbon ($R^2 = 0.31$) and porosity ($R^2 = 0.38$). Plant biomass was related with plant cover ($R^2 = 0.74$) and organic carbon was correlated to soil porosity ($R^2 = 0.61$). Therefore, the increased plant material protected the soil surface from raindrop impact and helped hold water until infiltration occurred. The plant material modified soil characteristics by increasing organic carbon which would improve aggregate stability of the soil, resulting in higher porosity and infiltration.

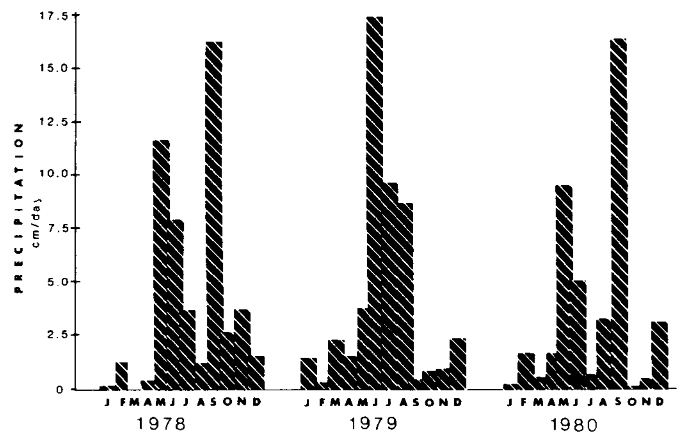

Fig. 3. *Monthly precipitation (cm) for the study site during 1978, 1979, and 1980.*

Summary and Conclusions

During this study it was evident that the biohydrological state of the controlled area was changing. Infiltration (cm/0.5 hr) for 1980 and 1979 was 320% and 210% higher, respectively, than for 1978. The increased infiltration was a result of the increased grass production and soil cover. Plant cover protected the soil surface from raindrop impact and impounded water until infiltration occurred. Plant material also modified soil characteristics such as organic carbon and porosity. Total soil porosity and organic carbon were higher in 1980 than in 1978. The increase in organic carbon was believed to increase aggregate stability which would increase macroporosity, thus increasing infiltration.

The effect of the vegetation manipulation treatments was to influence the rate of change of the biohydrological conditions of this site. Vibratilling improved infiltration immediately by increasing soil roughness and micro- and macroporosity. Grass revegetated disturbed areas and responded favorably to the moderately severe vibratill treatment. We believe that vibratilling offers a potentially valuable tool for increasing infiltration on extremely deteriorated hardland range sites in west Texas, especially where slopes are greater than 2%.

Mechanical grubbing also resulted in increased infiltration by increasing soil roughness and porosity. This increase, however, was only found within the mechanically disturbed areas. We found evidence of increased soil compaction and reduced plant production outside of the mechanically grubbed pits (Bedunah 1982). Therefore, the improvement in infiltration was only for a small part of the total treated area.

Shredding of mesquite had the immediate effect of returning nutrients to the soil and the litter protected the soil surface from raindrop impact. The litter also created a rougher surface which held water on the site. Dixon (1974) reported that plant litter used as a mulch greatly improved infiltration by shielding the soil surface from raindrops and feeding invertebrates, helping create a more macroporous system. For clay loam range sites with significant mesquite invasion and reduced plant cover shredding offers an excellent way to rapidly improve site conditions. However, since mesquite is a crown sprouter, a follow-up treatment would be necessary to control mesquite regrowth.

For mechanically undisturbed plots, plant cover and biomass were the most important single variables for predicting infiltration. On mechanically disturbed plots soil variables such as roughness, organic carbon and porosity were more highly correlated with infiltration than were plant measurements. It was apparent, however, that there were interactions between plant variables such as porosity and organic carbon. Thus, as plant material increased soil porosity and organic carbon also increased.

Regression equations were successful in accounting for 55 to 75% of the variability in infiltration. The low coefficient of determination of the infiltration equations may partially be a result of differences by year. However, other researchers have found that infiltration was difficult to predict because of the complex interactions of the hydrological process (Busby 1977, McGinty et al. 1979, Gifford 1979).

The rate of change in the biohydrological conditions of any site, following a range rehabilitation treatment, will depend upon adequate plant cover to protect the soil surface from raindrop impact of intense thunderstorms. Therefore, grazing management which allows for plant cover improvement on deteriorated sites would also be important in improving infiltration, decreasing runoff and improving forage plant production.

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