Probable Impacts of Various Range Improvement Practices on Diffuse Salt Production

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Abstract

During 1976 a study of soil profile salt concentrations and probable salt loading by surface runoff was made on 73 range improvement sites in Utah, Colorado, New Mexico, and Arizona. The range improvement practices studied included gully plugs, contour furrowing, pitting, pinyon-juniper chaining, and various sagebrush-control treatments. Results of these studies indicated that the impact of gully plugs and contour furrows on potential diffuse salt production is somewhat variable and may in fact indicate that these treatments have only a minor potential impact, probably because the overland flow route is not a major source of diffuse salt movement, at least on lands sampled in this study. On pinyon-juniper sites and the various sagebrush treatments, the lack of difference in salt concentrations between treated and untreated sites was the only consistent trend. In general the measured salt concentrations in surface soils of either pinyon-juniper or sagebrush sites present a problem of little concern as related to salt production within the major river basins.

Salinity in the Colorado River is of major national concern, for not only has it resulted in losses to the regional economy, but also high salinity levels have aggravated relations with the Republic of Mexico. Even in its virgin state, the salt load of the Colorado River in its lower reaches was about 600-700 ppm. However, man's development of water resources has affected both the quantity and quality of water supplies. Salinity levels in the lower reaches of the river now average 850 ppm with a predicted concentration of 1,300 ppm by the year 2000.

The sources and causes of dissolved solids within the Colorado River are of importance; for if they can be identified, strategies may be developed for effective management and control. In addition, this information would allow estimates to be made of downstream costs associated with upstream salt production, thus facilitating the development of economic trade-offs on a basin-wide level.

Recent estimates suggest that the largest single man-caused source of salinity is irrigation return flow, amounting to about a third of the total salt load. Natural sources such as salt wells and springs, plus concentration by evaporation, account for another third. The remaining salt load is attributed to diffuse sources originating on immense areas of wildland watersheds, and particularly rangeland watersheds.

This study deals with the application of various range improvement practices for eventual formulation of land management programs that may influence diffuse salt production from rangelands. Data on these aspects are sparse. For example, Soiseth et al. (1974), in southeastern Montana, found that soil salinity in upper soil depths was not reduced in comparison to the check on any of several panspot range sites that had been contour furrowed. Contour furrowing did, however, affect movement of salts (through increased infiltration) in the 0- to 10-cm depth in the furrows. Branson et al. (1966) near Fort Peck, Montana, found that 10 years after furrowing and seeding there was a decrease in salts (Ca, Mg, Na) in the upper 60 cm of the treated soils and an increase in salts below 60 cm. This leaching was assumed to have taken place during the years immediately after treatment because above-ground water storage in furrows decreases with time. Wein and West (1973), near Cisco, Utah, on Chipeta series, a member of the clayey mixed calcareous mesic typic torriorthents soil family, found no accumulation of salt in contour furrows or gully plugs 5 to 6 years following construction. Their data suggested some initial early leaching of salts due to treatments, while the present trend, as evidenced by infiltration measures, suggested a possible accumulation of salts.

The specific objective of this study was to determine the effects of existing land treatments on soil profile salt concentrations and probable salt loading by surface runoff.

General Description of Study Area

Seventy-three study sites located primarily in Utah, Colorado, New Mexico, and Arizona (one site) were included in this study. The range improvement practices studied include contour furrowing (11) sites, pitting (2 sites), pinyon-juniper chaining (14 sites), gully plugs (6 sites), and various sagebrush control treatments (40 sites). The sites in Utah (32 sites) lie primarily in Grand, Emergy, Carbon, and San Juan counties; in Colorado (12 sites), Montrose, Gunnison, Dolores, and San Miguel counties; in New Mexico (28 sites), Valencia, Sandoval, Rio Arriba, and San Juan counties; and Maricopa county in Arizona (1 site). General topographical, soils, and vegetation descriptions of the sites have been given previously by Hessary and Gifford (1979). More specific information is given in Table 1.

During the period from 1945 to 1978, range improvement practices were attempted on the various study sites. The primary purpose of the improvement practices was to improve range condition through

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increasing soil moisture, grazing capacity, and nutritional value of forage. Crested wheatgrass (*Agropyron cristatum*), tall wheatgrass (*Agropyron elongatum*), western wheatgrass (*Agropyron smithii*), Russian wildrye (*Elymus juncus*), side-oats grama (*Bouteloua curtipendula*), alkali sacaton (*Sporobolus airoides*), sand dropseed (*Sporobolus cryptandrus*), sweet clover (*Mellilotous officinalis*), and fourwing saltbush (*Atriplex canescens*) are the main species which were seeded on the various sites.

Methods and Procedure

This study was carried out during 1976 in cooperation with various Bureau of Land Management districts. Age of treatment, acreage involved, geographic location, and methods of applying treatments were used for determining the approximate number of sites to be sampled. Topographical maps were used to determine the general location of various sites, while field studies established the exact location of sampling sites. Specific criteria such as how typical the site was of the general area and its predominant geologic type were considered in final site selections.

Field Methods

A "treated" and nearby similar "untreated" sampling site, each with an area of approximately 23,409 m^2 (2.3 ha), were selected for each treatment location. All on-site measures, including collection of soil samples (see below), were taken only once at each site. Statistical evaluations are therefore limited to treated vs. untreated comparisons within a given location rather than among all locations.

Soil Sampling

For the pitting treatments, pinyon-juniper chainings, and all sagebrush treatments, there were five replications (or sampling locations) for each treated and adjacent untreated site; one at each corner of the 2.3-ha sampling site and another in the middle. At each of the five sampling locations within a treatment, soil samples were collected at the 0–0.5, 0.5–1, 1–7.5, and 7.5–17.5 cm soil depths. When possible, at the middle location, soil samples were taken at depths beyond 17.5 cm (usually at 7.5-cm increments) to allow for a more complete characterization of soil particle size with depth.

On gully plug treatments there were three replications for each gully plug treatment site, and in each replication soils from nine positions were sampled at incremental depths indicated above. Within each gully plug replication there were two sampling positions termed "upper channel control," one position termed "lower channel control," two positions termed "upland control," and four positions inside the gully plug basin (Fig. 1).

On the contour furrowing treatments, four line transects were established on a representative sampling site across each contour furrow treatment. Four positions were selected on each line: the first was on the upland area between the furrows, the second at the bottom of the furrow, the third on the spoil (ridge), and the fourth on the lowland area between the furrows (Fig. 1). Soil samples were taken at depths indicated above.

Laboratory Methods

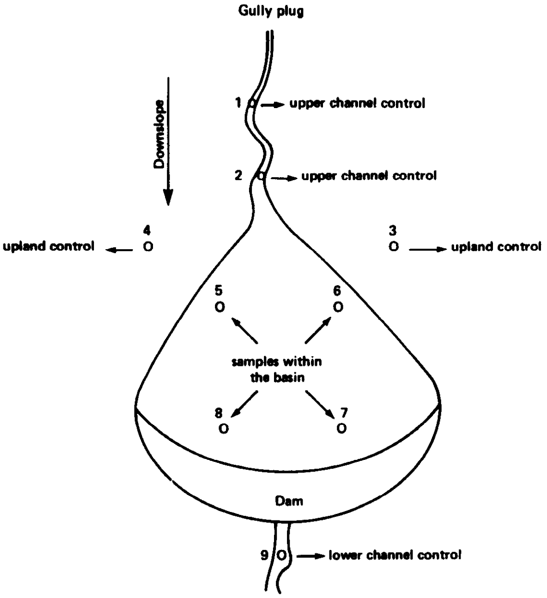
Soil Analysis

Electrical conductivity (EC) measurements and particle-size analyses were made in the laboratory. For the EC measures, extracts from a saturated soil paste (1:1 ratio; 100 g of soil and 100 cc water) were read using a Beckman Conductivity Bridge (Model RC-19). All conductivity data (in micromhos per centimeter) were converted to a standard reference temperature of 25°C (U.S.D.A., Handbook 60, 1954).

Particle-size distribution was determined from soil samples taken from a single representative position on each treated and untreated site using the hydrometer method (Bouyoucos 1962).

Statistical Analysis

All results from the field and laboratory analyses were analyzed using standard analysis of variance techniques on a per site basis.



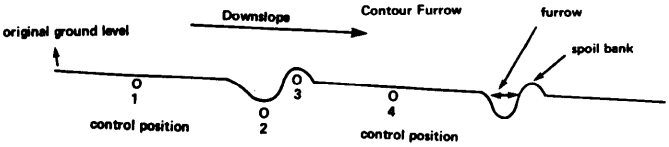


Fig. 1. *Plan view of gully plug and cross-section of contour furrow showing the sampling positions.*

When analyzing EC data from the contour furrow treatments, values for control positions No. 1 and 4 (Fig. 1) were combined at similar depths on each transect line. There were therefore three positions, each with four depth increments.

For the gully plug treatment (Fig. 1) EC values at similar depths at points 3 and 4 were pooled and EC measures inside the gully basin at sampling points No. 5, 6, 7, and 8 were also pooled for analysis. Data from the resulting five points were used in the statistical analysis. Significant differences among means for all analyses were determined using standard LSD procedures.

Results and Discussion

Gully Plugs

Salt accumulations in the soil profile were significantly different among sampling positions on three out of six gully plug treatments. However, the significant differences showed no consistent trend. For instance, one site indicated higher salt concentration in the upland control (position 3, Fig. 1) than in the other positions. In another case, higher salt concentrations were indicated inside the gully basins (position 5) than in positions, 1, 2, 3, and 9 (no significant differences existed among these latter positions). On a third gully plug treatment, lower salt concentrations were found inside the gully basin (position 5) than at positions 1, 2, 3, and 9 with no significant differences among the latter positions.

In four cases out of six, salt distribution within the soil profile was significantly different among the depth increments. In two cases the two surface soil increments (depth 1 and 2) showed higher salt concentrations than the lower depths. The other two gully plug treatments had higher salt concentrations in the lower depths. In only one case was there a significant depth × position interaction.

Variations in salt concentration with different positions and soil depths were never consistent among the gully plug treatments.

Table 1. Soil classification, approximate annual precipitation, and date of treatment for various range improvement practices sampled in this study.

Treatment	Order	Subgroup	Family	Precipitation (mm)	Treatment year
Contour furrowing					
Site 1	Alfisols	Typic Cryoboralfs	Coarse-loamy, skeletal, mixed	305	1962
2	Entisols	Ustic Torriorthents	Fine, mixed, mesic	356	1963
3	Mollisols	Typic Argiborolls	Fine, mixed, frigid	762	1963
4	Entisols	Typic Ustifluvents	Fine, mixed, frigid	762	1948
5	Entisols	Ustic Torrifluvents	Fine-loamy, mixed, mesic	356	1965
6	Entisols	Ustic Torriorthents	Fine-loamy, mixed, mesic	356	1966
7	Aridisols	Typic Calciorthids	Coarse-loamy, mixed, thermic	178	1969
8	Aridisols	Ustollic Haplargids	Fine-loamy, mixed, mesic	229	1964
9	Entisols	Typic Torriorthents	Fine, mixed, mesic, shallow	203	1968
10	Entisols	Typic Torriorthents	Fine, mixed, mesic, shallow	203	1969
11	Entisols	Typic Torriorthents	Fine, mixed, mesic, shallow	229	1967
Pitting					
Site 1	Entisols	Typic Torriorthents	Fine, mixed, mesic	254	1958
2	Entisols	Typic Torrifluvents	Sandy, mixed, mesic	254	1975
Pinyon-juniper chaining					
Site 1	Mollisols	Typic Argiustolls	Fine-loamy, mixed, mesic	508	1961
2	Aridisols	Ustollic Haplargids	Fine-loamy, mixed, mesic	356	1960
3	Mollisols	Aridic Haplustolls	Fine-loamy, mixed, mesic	356	1960
4	Aridisols	Ustollic Haplargids	Fine-loamy, mixed, mesic	356	1961
5	Aridisols	Ustollic Haplargids	Fine-loamy, mixed, mesic	406	1962
6	Aridisols	Ustollic Haplargids	Fine-loamy, mixed, mesic	356	1962
7	Aridisols	Typic Calciorthids	Fine-loamy, mixed, mesic	330	1964
8	Aridisols	Ustollic Calciorthids	Loamy-skeletal, mixed, mesic	406	1964
9	Mollisols	Aridic Argiborolls	Fine-loamy, mixed, mesic	356	1965
10	Aridisols	Typic Calciorthids	Coarse-loamy, mixed, mesic	305	1968
11	Mollisols	Typic	Fine-loamy, mixed, mesic	356	1968
12	Mollisols	Typic Haplustolls	Fine-loamy, mixed, mesic	356	1969
13	Mollisols	Typic Argiustolls	Fine, mixed, mesic, shallow	203	1970
14	Aridisols	Ustollic Haplargids	Fine-loamy, mixed, mesic, shallow	279	1971
Gully plugs					
Site 1	Entisols	Typic Torriorthents	Fine, mixed, mesic, shallow	203	1960
2	Entisols	Typic Torriorthents	Fine-loamy, mixed, mesic, shallow	203	1963
3	Entisols	Ustic Torriorthents	Fine-loamy, mixed, mesic	356	1966
4	Entisols	Typic Torriorthents	Fine-loamy, mixed, mesic, shallow	203	1964
5	Entisols	Typic Torriorthents	Fine-loamy, mixed, mesic, shallow	203	1962
6	Entisols	Ustic Torrifluvents	Fine-loamy, mixed, mesic	254	1963
Sagebrush ripping					
Site 1	Entisols	Ustic Torriorthents	Fine, mixed, mesic	254	1957
2	Aridisols	Typic Camborthids	Fine-loamy, mixed, mesic	254	1958
3	Entisols	Ustic Torriorthents	Fine-loamy, mixed, mesic	406	1958
4	Entisols	Typic Torrifluvents	Coarse-loamy, montmorillonitic, mesic	254	1959
5	Aridisols	Typic Camborthids	Fine-loamy, mixed, mesic	254	1960
6	Entisols	Typic Torriorthents	Fine-loamy, mixed, mesic, shallow	279	1961
7	Aridisols	Ustic Haplargids	Fine-loamy, mixed, mesic	305	1963
8	Entisols	Ustic Torrifluvents	Fine-silty, mixed, mesic	406	1963
9	Aridisols	Ustollic Haplargids	Fine-loamy, mixed, mesic	254	1965
10	Entisols	Ustic Torriorthents	Fine, montmorillonitic, mesic	305	1965
11	Entisols	Typic Torrifluvents	Fine-loamy, mixed, mesic	203	1965
12	Entisols	Ustic Torriorthents	Fine, mixed, mesic	406	1967
13	Entisols	Ustic Torriorthents	Fine-loamy, mixed (calcareous), mesic, shallow	305	1969
Sagebrush plowing					
Site 1	Mollisols	Calcic Argiustolls	Fine-loamy, mixed, mesic	305	1945
2	Aridisols	Ustollic Haplargids	Fine-loamy, mixed, mesic	279	1954
3	Aridisols	Ustollic Haplargids	Coarse-loamy, mixed, mesic	279	1960
4	Mollisols	Typic Arguistolls	Fine-loamy, mixed, mesic	356	1961
5	Mollisols	Typic Haploborolls	Fine-loamy, mixed, mesic	305	1962
Sagebrush chaining					
Site 1	Aridisols	Ustollic Haplargids	Fine-loamy-skeletal, mixed, mesic	305	1948
2	Entisols	Ustic Torrifluvents	Sandy, mixed, mesic	356	1949
3	Mollisols	Lethic Arguistolls	Fine-loamy, mixed, mesic	330	1951
4	Aridisols	Typic Calciorthids	Fine-loamy, mixed, mesic	279	1956
5	Aridisols	Lithic Ustollic Haplargids	Fine-loamy-skeletal, mixed, mesic	203	1960

Table 1. Continued

Treatment	Order	Subgroup	Family	Precipitation (mm)	Treatment year
6	Entisols	Ustic Torriorthents	Coarse-loamy, mixed, mesic	279	1961
7	Aridisols	Borollic Haplargids	Fine-loamy, mixed, mesic	406	1962
8	Aridisols	Typic Haplargids	Fine-loamy, mixed, mesic	279	1962
9	Entisols	Typic Ustifluvents	Fine-loamy, mixed, frigid	406	1964
10	Entisols	Ustic Torriorthents	Fine-loamy, mixed, frigid	305	1965
11	Aridisols	Typic Calciorthids	Fine-loamy, mixed, mesic	305	1966
12	Entisols	Ustic Torriorthents	Fine-loamy, mixed, mesic	35	1966
13	Entisols	Ustic Torriorthents	Fine-loamy, mixed, mesic	356	1966
14	Mollisols	Aridic Arguistolls	Coarse-loamy, fixed, frigid	305	1970
15	Entisols	Typic Ustifluvents	Coarse-loamy, mixed, mesic	356	1951
Sagebrush railing					
Site 1	Aridisols	Ustollic Haplargids	Coarse-loamy, mixed, mesic	305	1950
2	Mollisols	Typic Arguistolls	Coarse-loamy, mixed, mesic eroded	508	1952
3	Aridisols	Typic Calciorthids	Coarse-loamy, mixed mesic	305	1955
4	Aridisols	Ustollic Haplargids	Fine-loamy, mixed, mesic	305	1956
5	Aridisols	Ustollic Haplargids	Fine-loamy, mixed, mesic	330	1958
6	Aridisols	Ustollic Haplargids	Fine-loamy, mixed, mesic	356	1961
7	Aridisols	Ustollic Haplargids	Coarse-loamy, mixed, mesic	279	1962

Contour Furrows

In three out of 11 contour furrow treatments, salt concentrations were significantly different among the three sampling positions (Fig. 1). Two treatments had significantly higher salt concentrations inside the furrow (at position 2), while one treatment had significantly higher salt concentrations outside the furrow (at position 1). For the three treatments there were few significant differences between ridge (spoil) and control (position 1), or spoil and furrow.

There were significant differences in salt concentrations as a function of soil depth on eight of the eleven contour furrow treatments. The general trend indicated higher salt concentrations in the two surface layers in nonsaline soils, with almost equal quantities of salt at the third and fourth depth increments. On saline soils the lower depths had higher salt concentrations than the two surface layers. There were few significant differences between the third and fourth depths.

Pittings

Analysis of variance for the two pitting treatments showed no consistent trend in salt concentrations as a function of different soil depth increments.

Pinyon-Juniper Chainings

On three of 14 pinyon-juniper sites, salt accumulations were significantly lower in the surface 0.5 cm soil layer of treated sites. However, the only really consistent pattern at any soil depth was the lack of difference in salt concentrations between treated and untreated sites. Based on EC measures in surface soils (maximum EC values 675 mmhos/cm) and at greater depths (maximum EC value 445 mmhos/cm), salt concentrations should not be a major concern on pinyon-juniper sites similar to those sampled in this study.

Sagebrush Treatments

For the most part there were few differences between treated (chained, ripped, plowed, and railed) and untreated sites, regardless of soil texture. As with indicated salt concentrations on pinyon-juniper sites, EC values as measured on sagebrush sites in this study do not indicate a need for major concern as related to salt production within major river basins.

Conclusions

During 1976 various range improvement practices, including gully plugs, contour furrowing, pitting, pinyon-juniper chaining, and various sagebrush control treatments, were studied in Utah, Colorado, New Mexico, and Arizona. Emphasis was placed on probable salt loading as a function of the above treatments. The following represents the major findings.:

1. Salt accumulations in the soil profile were significantly different among sampling positions on three of six gully plug treatments. However, the significant differences showed no consistent trend. Likewise, significant differences in salt concentrations as a function of soil depth were never consistent among the gully plug treatments. The impacts of gully plugs on diffuse salt production therefore appears mixed, perhaps somewhat site specific, and perhaps a function of age and exposure to runoff producing storms. Lack of consistent results can also be interpreted as gully plugs having only minor potential impacts on diffuse salt production, probably because the overland flow route is not a major source of diffuse salt movement, at least on the lands sampled in this study. Studies by Ponce and Hawkins (1978) and White (1977) would seem to indicate this.
2. On contour furrowing treatments, salt concentrations on three of 11 sites were significantly different among sampling locations. Two treatments had significantly higher salt concentrations inside the furrow while one treatment had significantly higher salt concentrations outside the furrow. Based on this study it would appear that impacts of contour furrowing treatments on salt loading can be interpreted as similar to those for gully plugs. Evidence of salt accumulations within the furrows were absent on 73% of the sites sampled.
3. The only consistent pattern on pinyon-juniper chainings and the various sagebrush treatments was the general lack of difference in salt concentrations between treated and untreated sites. In general, the measured salt concentrations in surface soils of either pinyon-juniper or sagebrush sites present a problem of little concern related to salt production within major river basins.

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