Influence of a Soil Microfloral Crust on Hydrologic and Chemical Properties of Soils in Southeastern Utah

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INFLUENCE OF A SOIL MICROFLORAL CRUST ON HYDROLOGIC AND CHEMICAL PROPERTIES OF SOILS IN SOUTHEASTERN UTAH

by

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Influence of a Soil Microfloral Crust on Hydrologic and Chemical Properties of Soils in Southeastern Utah

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Abstract

Cryptogamic soil crusts within the Colorado Plateau were studied to determine their effect on infiltration rates, potential sediment production, permeability, and several chemical properties of the soil. Six different crust stages were identified. Undisturbed soil cores were used to determine intrinsic permeability under three treatments and disturbed soil samples were analyzed for pH, percent organic matter, soil texture, Ca+Mg content and total conductivity.

It was found that the cryptogamic crust had little effect on soil chemical properties. Analysis of undisturbed soil core data indicates that high cryptogamic cover tends to decrease intrinsic permeability; this effect was reinforced when cores were irrigated. Data obtained with the Rocky Mountain infiltrometer indicated that sites with any degree of cryptogamic cover had significantly higher infiltration rates than chained areas (no lichen cover). Patterns of sediment production indicate a potential for increased sediment once the crust has been disturbed. (14 pages)
Introduction

Research has shown that soil crusts formed by algae and other microflora influence infiltration and soil stability. Fletcher and Martin (6) found that crusts of molds and algae increase tensile strength of soil, reduce erosion, and increase organic matter. Booth (2) reported that algal crusts resist drought, prevent wind erosion, and serve to break the force of falling raindrops. Cameron and Blank (4) point out the importance of soil crusts in preventing erosion and in colonizing bare areas. Soil microflora can have effects on soil aggregation according to Bond (1).

The objective of this study was to evaluate the influence of a soil crust composed of crustose lichens on infiltration rates, potential sediment production, and several additional soil properties.

The lichen crust, as found in the Colorado Plateau, is almost continuous in its undisturbed condition. Many small lichen 'pedestals' about 7.6 centimeters across characterize the crust; Lichen species found in the crust include Collema coccophorum Tuck., Dermatocarpon hepaticum Ach., Fulgensia fulgens Sw., Lecidea decipiens Ehrh., Peccania kansasa Tuck. Lichen identifications were made by C. W. Wetmore. These species are predominately black in color giving the crust a dark, 'bumpy' appearance.

 Procedures

The study area is located 72.5 kilometers west of Blanding in San Juan County, Utah in the vicinity of Natural Bridges National Monument. All work was done on a 48.5 hectare site, 14.5 kilometers

1/ Authorities for lichen plant names are as in Wetmore (1967).
south of the junction of Utah routes 261 and 95. Six conditions of
the crust were sampled (see Fig. 1):

A. relict areas; crust undisturbed

B. grazed areas within the pinyon (Pinus edulis Engelm.) -
   juniper (Juniperus spp.) where the crust was still intact
   (near relict)

C. grazed areas within the pinyon-juniper woodland (protected
   since 1967) where the crust was in an intermediate stage
   of breakdown

D. grazed areas within the pinyon-juniper woodland (protected
   since 1967) where the crust had been severely disturbed
   (animal pathways and waterways)

E. crust mechanically disturbed by double chaining (a large
   anchor chain is pulled behind two tractors, first in one
   direction and then in the opposite direction) pinyon-juniper
   and leaving the debris in place. The chaining treatment
   was applied in the fall of 1967.

F. crust mechanically disturbed by chaining the pinyon-juniper
   woodland and windrowing the debris. (This is a common
   range improvement technique used in the area.) The chaining
   treatment was applied in the fall of 1967.

Soil samples from three depths (0-1.3 cm, 1.3-2.5 cm, 2.5-5.1 cm)
were taken from sites representing each crust condition. Soil samples
were analyzed for the following factors at each depth; texture (3),
degree of aggregation (Bouyoucos (3), with Calgon omitted), Ca+Mg
present, conductivity, pH and organic matter (7).

Thirty-six 5.1 cm diameter soil cores were obtained from each
Figure 1. Cryptogamic crust conditions on southeastern Utah soils.
crust condition. These cores were used to determine intrinsic permeabilities (7). Water was ponded over each core and a constant head was maintained. Total percolation through each core was measured at 5 minute intervals for a period of forty-five minutes. Before permeability runs were made, one-third of the cores from each site were subjected to one of the following treatments:

1. cores air dry prior to the run
2. cores wet to saturation daily for a period of ten days prior to the run (cores air dry for 10 days prior to wetting treatment)
3. cores wet to saturation every five days for a period of two months prior to runs

Infiltration and sediment production measurements were made for each crust condition using a Rocky Mountain infiltrometer (5). Seventy-two infiltrometer runs, each 28 minutes in length, were made (12 replications per crust condition). Plots were prewet and soils allowed to drain to field capacity by waiting a minimum of 2 hours. Pooled sediment production samples were taken, i.e. turbidity of runoff was averaged over all time periods. Infiltrometer runs were made during the first 2 weeks of June, 1971.

Results and Discussion

Average values for all measurements regarding each crust condition are given in Table 1 and 2.

Soil Properties

Soil properties were not strongly influenced by the soil crust. Organic matter (overall average, .42%) and pH (overall average, 7.29)
Table 1. Average values\(^1\) for various physical, chemical and hydrologic properties of surface soils with varying degrees of cryptogamic cover.\(^2\)

Organic matter (overall average, 0.42%) and pH (overall average, 7.29) analyses showed no significant differences among crust conditions or soil depths.

<table>
<thead>
<tr>
<th>Site</th>
<th>% Sand</th>
<th>% Silt</th>
<th>% Clay</th>
<th>% Water Stable Aggregates(^3)</th>
<th>Ca + Mg(^4) (meq/50 gms)</th>
<th>Total Conductivity (mmohs)</th>
<th>Intrinsic Permeability (cm(^2)x10(^{-8}))</th>
<th>Infiltration Rate (cm/hour)</th>
<th>Sediment Production (kg/hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (relict)</td>
<td>48.7 bd</td>
<td>41.7 a</td>
<td>9.6 b</td>
<td>4.3 a</td>
<td>2.39 bc</td>
<td>836 bd</td>
<td>.64 bc</td>
<td>7.08 b</td>
<td>269 a</td>
</tr>
<tr>
<td>B (Near relict)</td>
<td>53.6 bc</td>
<td>38.7 bc</td>
<td>7.7 b</td>
<td>2.6 b</td>
<td>1.41 bd</td>
<td>701 bc</td>
<td>.44 bd</td>
<td>6.85 b</td>
<td>784 a</td>
</tr>
<tr>
<td>C (intermediate condition)</td>
<td>54.3 be</td>
<td>34.4 bde</td>
<td>11.3 a</td>
<td>3.3 a</td>
<td>1.76 bd</td>
<td>825 bd</td>
<td>.50 bd</td>
<td>7.13 b</td>
<td>538 a</td>
</tr>
<tr>
<td>D (waterways)</td>
<td>54.2 bc</td>
<td>35.0 bde</td>
<td>10.8 a</td>
<td>2.9 b</td>
<td>1.40 bd</td>
<td>841 bd</td>
<td>.98 ac</td>
<td>6.93 b</td>
<td>1053 a</td>
</tr>
<tr>
<td>E (chained-with-debris-in-place)</td>
<td>56.0 bc</td>
<td>33.6 bde</td>
<td>10.4 a</td>
<td>3.9 a</td>
<td>1.42 bd</td>
<td>875 bd</td>
<td>.63 bc</td>
<td>5.15 a</td>
<td>605 a</td>
</tr>
<tr>
<td>F (chained-with-windrowing)</td>
<td>61.9 a</td>
<td>26.6 bdf</td>
<td>11.5 a</td>
<td>5.9 a</td>
<td>2.99 a</td>
<td>1196 a</td>
<td>.80 ac</td>
<td>5.68 a</td>
<td>560 a</td>
</tr>
</tbody>
</table>

\(^1\) Averaged over the 0 to 1.3 cm, 1.3 to 2.5 cm, and 2.5 to 5.1 cm soil depths

\(^2\) Any two means in the same column with the same combination of letters are not significantly different at the .05 level of probability.

\(^3\) Aggregates less than 2mm diameter.

\(^4\) Bulk density (gms/cc) of the surface 7.6 cm of soil ranged from 1.6 to 1.8.
Table 2. Average infiltration rates (cm/hr) during various time periods (minutes) for each cryptogamic crust condition.

<table>
<thead>
<tr>
<th>Site</th>
<th>Site 3-8</th>
<th>Site 8-13</th>
<th>Site 13-18</th>
<th>Site 18-23</th>
<th>Site 23-28</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (relict)</td>
<td>9.3 ac</td>
<td>8.1 a</td>
<td>7.2 ac</td>
<td>6.4 ac</td>
<td>6.3 ac</td>
</tr>
<tr>
<td>B (near relict)</td>
<td>10.5 a</td>
<td>8.1 a</td>
<td>6.8 ac</td>
<td>5.4 bc</td>
<td>5.2 ac</td>
</tr>
<tr>
<td>C (intermediate condition)</td>
<td>8.8 bc</td>
<td>8.2 a</td>
<td>7.6 a</td>
<td>7.6 a</td>
<td>6.7 a</td>
</tr>
<tr>
<td>D (waterways)</td>
<td>10.4 a</td>
<td>7.5 ac</td>
<td>7.5 a</td>
<td>6.2 ac</td>
<td>6.0 ac</td>
</tr>
<tr>
<td>E (chained-with-debris-in-place)</td>
<td>8.2 bd</td>
<td>6.3 bd</td>
<td>5.8 b</td>
<td>5.3 bc</td>
<td>5.0 bc</td>
</tr>
<tr>
<td>F (chained-with-windrowing)</td>
<td>8.3 bd</td>
<td>5.9 bd</td>
<td>4.7 b</td>
<td>4.6 bd</td>
<td>3.8 bd</td>
</tr>
</tbody>
</table>

1/ Any two means in the same column with the same combination of letters are not significantly different at the .05 level of probability.
analyses showed no significant differences among crust conditions or soil depths. Significant differences were found in analysis of particle size distribution, Ca+Mg content, total conductivity, and water stable aggregates less than 2 mm diameter. These differences can be attributed to differences caused by mechanical disturbance during chaining activities.

a. Texture

Averaged over all depths, sand percentages were significantly higher in the chained with windrowing treatment (see Table 1). Wind, as a sorting agent, is more effective in this area and as a result has probably deleted the silt fraction slightly. The remaining crust conditions did not show this effect since their surfaces were protected by cryptogamic cover and/or pinyon-juniper woodland or debris. Silt percentages, averaged over all depths, were likewise significantly different; sites A and B were significantly higher in silt than the remaining sites. Clay percentages, averaged over all depths, were significantly lower in sites A and B than the other sites.

The clay fraction was influenced somewhat by soil depth. Averaged over all crust conditions, the 2.5-5.1 cm depth showed significantly greater clay content than the other two depths (11.2% vs 10.8% and 8.6%, respectively). This may indicate some mobilization and translocation of clays to lower depths.

b. Physical and Chemical Properties:

Averaged over all depths (Table 1), Ca+Mg content was found to be significantly higher in the chain with windrowing treatment area and in the relict stand (Site A). Total conductivity (averaged over all depths) was also significantly higher in the chain and windrowed area than in the remaining sites.
The windrowing treatment involves disturbance and mixing of the soil to a depth of from 10 to 15 centimeters. The ion-rich caliche layer which is present at a shallow depth in this geographic region was disturbed and mixed with the surface soil during mechanical treatment; this probably accounts for the higher Ca+Mg content and higher total ion content found in this crust condition.

Averaged over all crust conditions, soil depths 1.3-2.5 cm and 2.5-5.1 cm were significantly higher in Ca+Mg than was depth 0-1.3 cm (1.8 and 2.0 vs. 1.7 meq/50 gms). This indicates there has been some leaching of ions since treatments were applied.

Organic matter was not significantly different among sites or depths.

c. Water Stable Aggregates:

Water stable aggregates less than 2 mm diameter were found to be significantly higher in the chain with windrowing treatment (averaged over all depths). Averaged over all crust conditions, depth 1.3-2.5 cm and depth 2.5-5.1 cm also showed significant increases in stable aggregates (4.4% and 5.2% vs. 1.8% at depth 0-1.3 cm). This can be explained by the above-mentioned increase in total ions and Ca+Mg content due to mechanical mixing at site F and probably leaching phenomenon at this depth.

**Intrinsic Permeability**

Crust condition and treatment influenced intrinsic permeability. High lichen cover significantly impeded permeability; in general, the greater the lichen cover, the greater the resistance to percolation. Intrinsic permeability did not vary significantly between time periods. Significant differences were found among sites with
appreciable cryptogamic cover (Sites A, B, C) and those which were nearly bare of lichen cover (see Table 1). Highest percolation rates occurred within cores from sites with very low lichen cover; lowest values occurred in cores with greatest lichen cover.

The two irrigation treatments (see Procedures) significantly decreased intrinsic permeability of cores as compared with cores not irrigated. Addition of water simulates conditions of the lichen crust during favorable moisture periods. Irrigation reinforces the tendency of high lichen cover to impede percolation.

**Infiltration and Sediment Production**

Infiltrometer runs indicated that high cryptogamic cover significantly increases infiltration rates. Sites with any degree of crust cover (sites A, B, C) showed significantly higher infiltration rates as compared with both of the chained areas where cryptogamic cover has largely been destroyed. There were no significant differences among unchained sites (A, B, C, D), but all were significantly different from the chained sites (E, F). Cryptogam pedestals help prevent surface sealing of soil pores and they also create some detention and retention storage on the plots, thus increasing infiltration.

Site D (pathways and waterways) appears to be a special case in regard to infiltration rate. It is an apparent exception to the generalization that presence of any degree of cryptogamic lichen cover enhances infiltration. There are several plausible reasons for this inconsistency. Infiltration measurements were taken in the spring of 1971 when the frost heaving effects of the past winter were still
very much in evidence. In this arid region, soil moisture accumulates during the winter months and resultant frost heaving causes pronounced "fluffing-up" of the soil and thus increased friability and decreased bulk density. Past experience has shown that increased infiltration rates are to be expected in spring and early summer due to these effects. With this in mind, one could speculate that once summer thunderstorms cause flow in the waterways, the apparently high spring infiltration rate would be reduced.

Infiltration rates among the different crust conditions remained in the same positions relative to one another throughout the infiltrometer runs (e.g., a site with higher infiltration rate compared to another at the beginning of the infiltrometer run tended also to have a higher rate at the end of the run; see Fig. 2 and Table 2). Effect of very high cryptogam cover (sites A and B) on infiltration rates was greatest early in the infiltrometer runs.

Averaged over all sites, successive time periods all differed significantly; the first five-minute period showed highest infiltration rates and the rates decreased with each successive period.

Differences in sediment production among the crust conditions were not significant although a general pattern was indicated. The trend was toward increased sediment once the crust had been in any way disturbed. Degree of disturbance seemed to matter little in regard to sediment production (see Fig. 3).
Figure 2. Changes in infiltration rates with time on each of the crust conditions.
Figure 3. Sediment production (average values) for each crust condition.
Conclusions

1. The cryptogamic crust has little direct effect on the soil chemical and physical properties considered.

2. High cryptogam cover (sites A, B, C) caused a decrease in intrinsic permeability; this effect was reinforced when the cores were irrigated.

3. Appreciable cryptogamic cover promotes increased infiltration as compared with soil surface conditions that result from chaining.

4. Patterns of sediment production data indicate an increase in sediment production once the crust has been disturbed.
References Cited


