SOIL WATER IMPACTS FROM FOREST TREATMENT TO PREVENT CATASTROPHIC WILDFIRES IN A PONDEROSA PINE FOREST ECOSYSTEM

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Research on the various aspects of the southwestern ponderosa pine (*Pinus ponderosa* Laws.) forest ecosystem has been going on for almost a century (Moore et al. 1999). Some of the early research works include experiments on the forest components' responses to natural and anthropogenic changes at the Fort Valley Experimental Station in northern Arizona and in the Beaver Creek Experimental Watershed in central Arizona. The latter has provided information on how various forest management efforts affect ecosystem functions, such as run-off and streamflow. The motivation initiating the research on Beaver Creek was to explore ways to increase water yield while also considering other resource conditions in the watershed (Brown et al. 1974; Tecle 1991). The purpose of the present study is to determine whether restoration treatments have any effects on soil infiltration rates and soil moisture conditions, and if so what those effects are. Our hypothesis is that removal of trees will increase the level of soil moisture, while decreasing soil infiltration rates in the treated watersheds.

STUDY SITE

The study sites are located in the Fort Valley restoration treatment area, within the Rio de Flag watershed, just north of the city of Flagstaff, in northern Arizona. The Rio de Flag drains the southern portion of the San Francisco Mountains. The vegetation cover in the watershed consists mainly of a ponderosa pine forest, with a relatively sparse understory of native grasses.

There are three study sites within the Rio de Flag watershed (Figure 1). The first site is labeled ERI Treatments 97/98. Here, Northern Arizona University's Ecological Restoration Institute (ERI) has been conducting various experimental restoration treatments since 1997. This study is done on plots treated in 1997, 1998, 2001, and 2002. Treatments consisted of thinning the forest to a variety of stand density levels. We chose three test locations within the ERI study sites. The first test location is situated within a heavy restoration treatment site, the second lies within a light restoration treatment site, and the third is a control in an untreated part of the watershed, but adjacent to the other two sites (Figures 1 and 2). The other two test locations were thinned in 2001 and 2002, respectively, with adjacent untreated areas. These test locations are labeled Summer 2001 and Summer 2002 in Figure 1.

METHODS

Data Collection

After selecting a treatment area, we chose a relatively central location within that treatment area for the infiltration rate and soil moisture condition measurements. In this preliminary study, we performed only one infiltration test per treatment, and another one in an adjacent untreated area for a control. For the ERI plots, however, we performed one infiltration test in the selected untreated area as a control for both ERI prescriptions, due to its proximity to both sites.

We conducted the infiltration tests using a double ring infiltrometer. We took infiltration measurements until we had established an infiltration rate ± 5 ml per 3 min interval for at least 5 consecutive measurements and for a total observation time of at least 60 min. However, if we had 10 infiltration readings (30 min) ± 5 ml per 3 min interval prior to the minimum length of 60 min, we discontinued the test. We recorded the results by hand and later transcribed the data into an MS Excel spreadsheet.

We used a 6050X1 Trase System 1 TDR (Time Domain Reflectometry), manufactured by Soilmoisture Equipment Corporation, for the soil moisture measurements. We took a maximum of 16 TDR readings within a treatment area. We selected the soil moisture test locations in a cross

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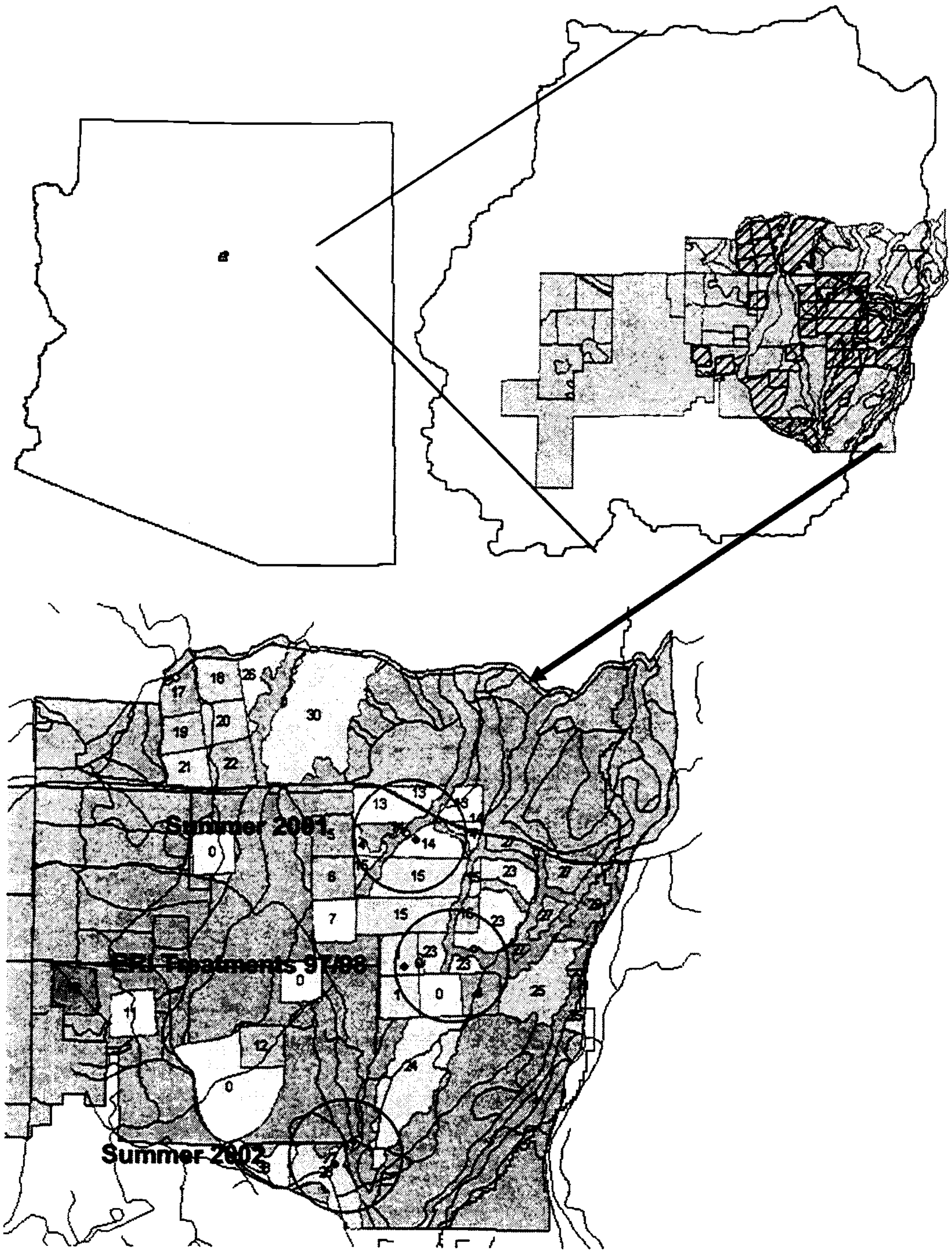

Figure 1. Location of the Rio de Flag Watershed in Arizona (top left) and its scheduled restoration treatment units (top right). Units in phase one of the restoration efforts are displayed by hatch marks. Location of the three study sites within the Rio de Flag restoration treatments (bottom). (The numbers within the treatment blocks indicate different harvesting units of phase one.) Unlabeled polygons represent either areas that have not yet been scheduled for treatment, or areas that will not be thinned at all because of special uses, such as wildlife corridors.

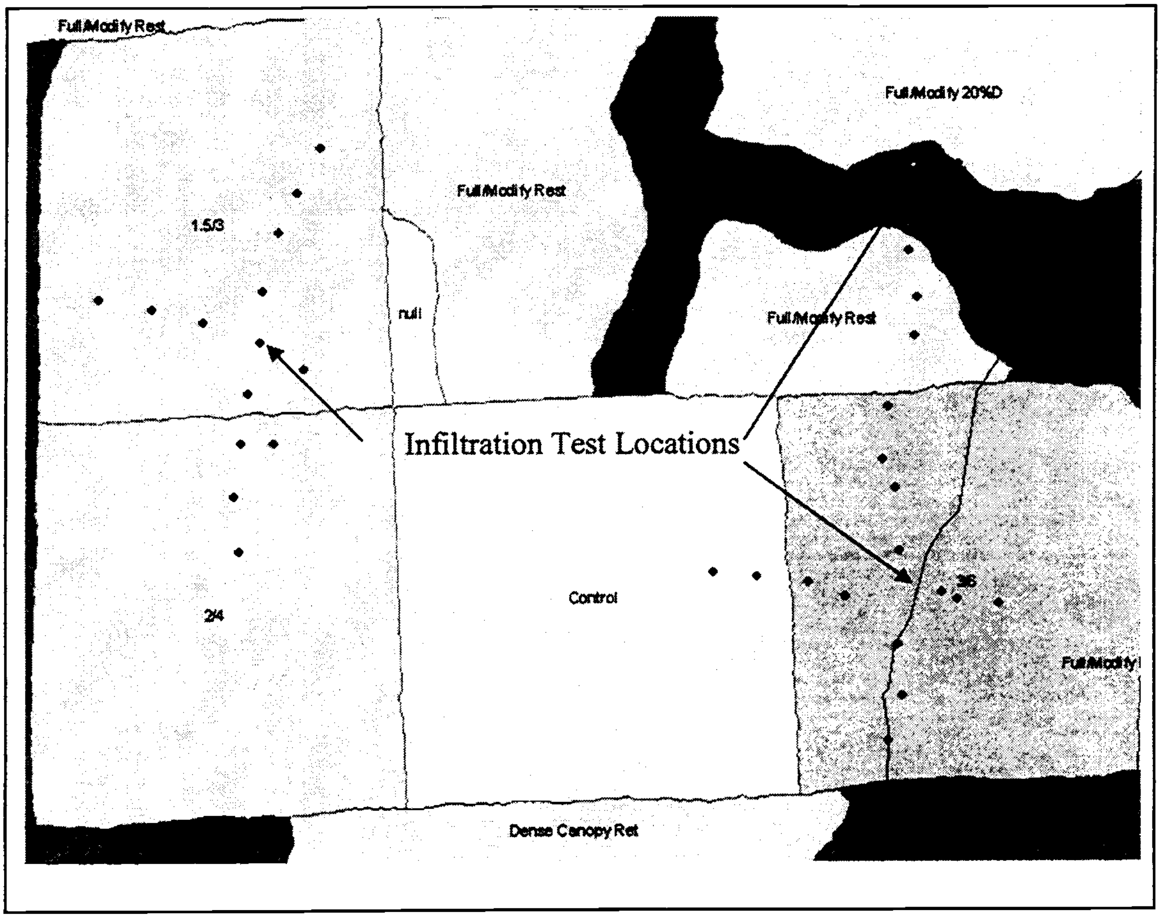

Figure 2. Location of the three measurement sites within the ERI restoration treatments (heavy treatment on left, light treatment at lower right, and the control at the upper right). Notice the cross-like pattern of the TDR measurements approximately around the infiltration tests. (The full/modify restoration treatment below the control site had not been conducted at the time of the TDR measurements.)

pattern around each infiltration test site; this is one of the reasons for locating the infiltration test sites approximately in the center of a treated area. We took a maximum of four readings, each 50 m apart, in approximately all four cardinal directions up to a maximum distance of 200 m from the infiltration test sites. If the shape of the treated or untreated site did not allow for the cross-shape pattern, we did not take a measurement (Figures 2–4).

At each infiltration as well as soil moisture test measurement site, we recorded the current basal area in sq ft/acre using a BA20 prism, which was later converted to sq m/ha. We did not include snags in the basal area estimation. Further, we captured the location of each test site (Figures 2–4) using a Trimble GeoExplorer 3 Global Positioning System (GPS) to facilitate mapping of the test sites.

Data Analysis

In this preliminary study only bar graphs were used to compare the responses of the soil infiltration rates under different forest treatments. We had to download the soil moisture measurements from the TDR into MS Excel files to analyze and compare the soil moisture conditions in the different treatment sites. However, because the number of soil moisture measurements, n, varied from site to site (n ranged from 7 to 15 with an average of 11), we used the mean soil moisture condition values to compare the effects of the different restoration treatments on soil moisture conditions. We surveyed the basal area to determine the stand density across treatments and the control plots. These data were also entered into MS Excel files and graphed for comparison purposes.

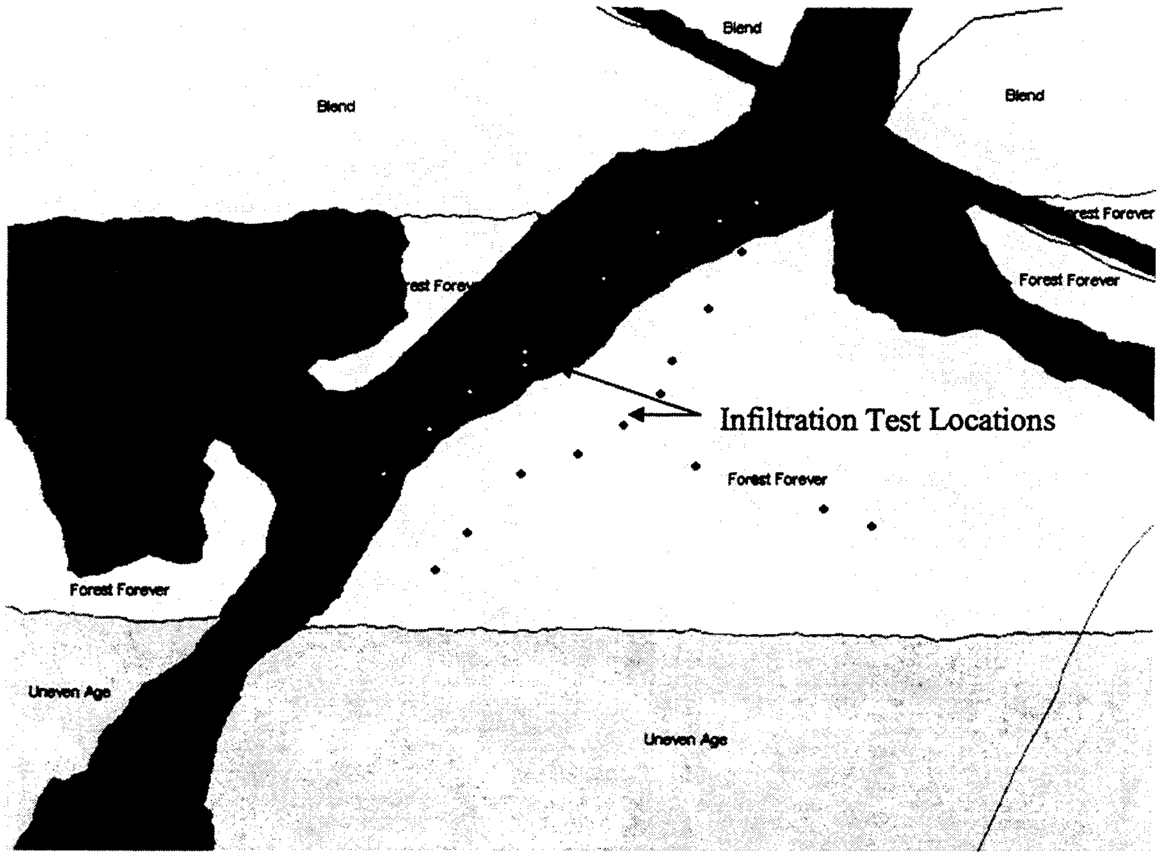

Figure 3. Location of the infiltration and soil moisture measurement sites within the Summer 2001 restoration treatments. The shape of the untreated site dictated the locations of the infiltration and TDR measurements along its small corridor.

RESULTS

Our basal area measurements revealed that the 2001 and 2002 treatments reduced stand density of live trees by 45 percent, compared to the densities in the control sites. In the ERI heavy treatment site overstory vegetation is reduced by 85 percent, whereas it was decreased by approximately 35 percent in the ERI light treatment site (Figure 5).

Figure 6 shows the infiltration rates (in l/hr) in the different measurement sites. Note the difference between the treated and the untreated sites, especially when comparing the ERI plots to their control test site. The untreated control site has an infiltration rate of 4.85 l/hr, whereas the heavily treated site has an infiltration rate of 13.25 l/hr, which is about 15 times higher than the infiltration rate in the lightly thinned location (0.85 l/hr).

In Figure 7 we compare the soil moisture content (expressed in percent) in the different treatment sites. As expected, there is a distinct difference between treated and untreated sites; the treated sites have higher soil moisture contents than their untreated counterparts. It is interesting to note that the soil moisture content in all of the untreated sites remains very similar, even though the measurements (between the different sites) had been taken over the course of several months, with substantial precipitation events occurring between measurements.

DISCUSSION

The infiltration test results in this preliminary study did not show clearly what we had expected. The soil moisture content was considerably higher on the sites that were treated 5 years prior to the times of measurements than in the control site. However, the soil moisture content became only marginally higher at sites treated within a year prior to time of measurement than in the soils of the control sites. These findings suggest that it

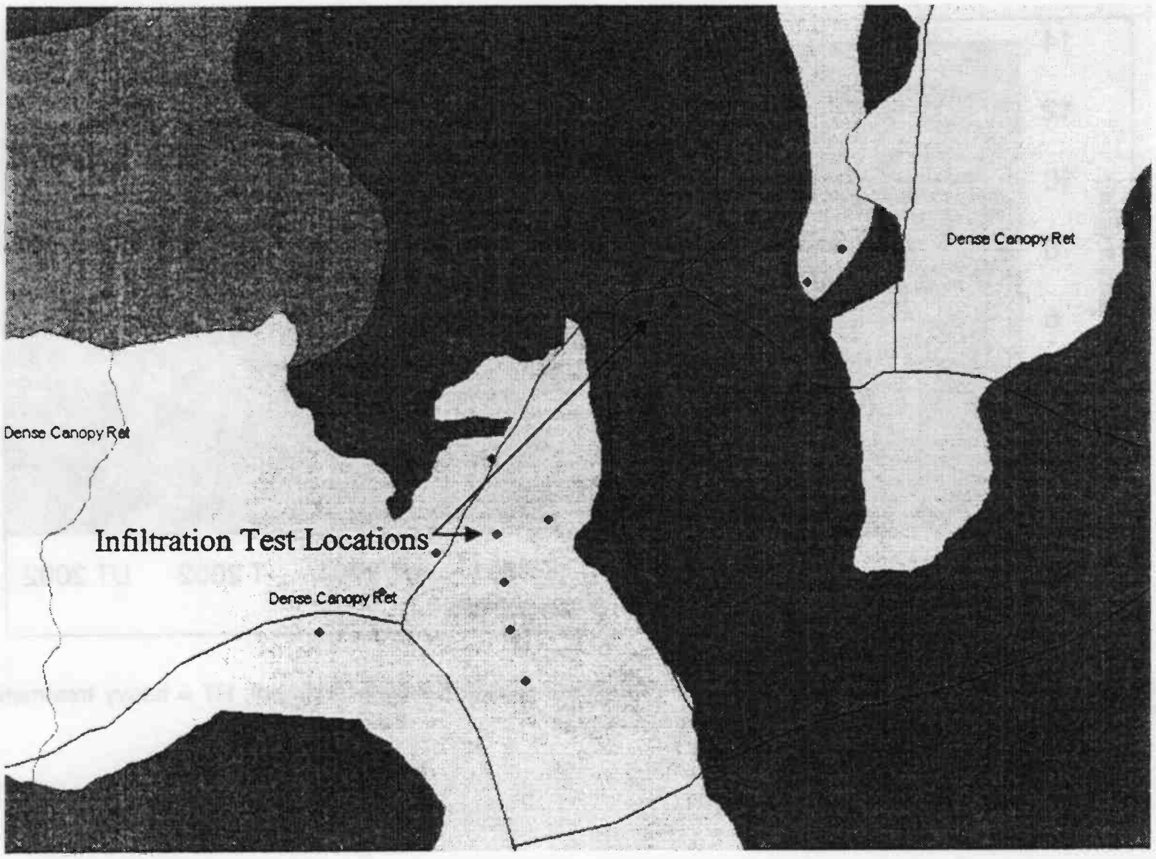

Figure 4. Location of the infiltration and soil moisture measurement sites within the Summer 2002 restoration treatments. The treated section is on the left. The untreated section is on the right.

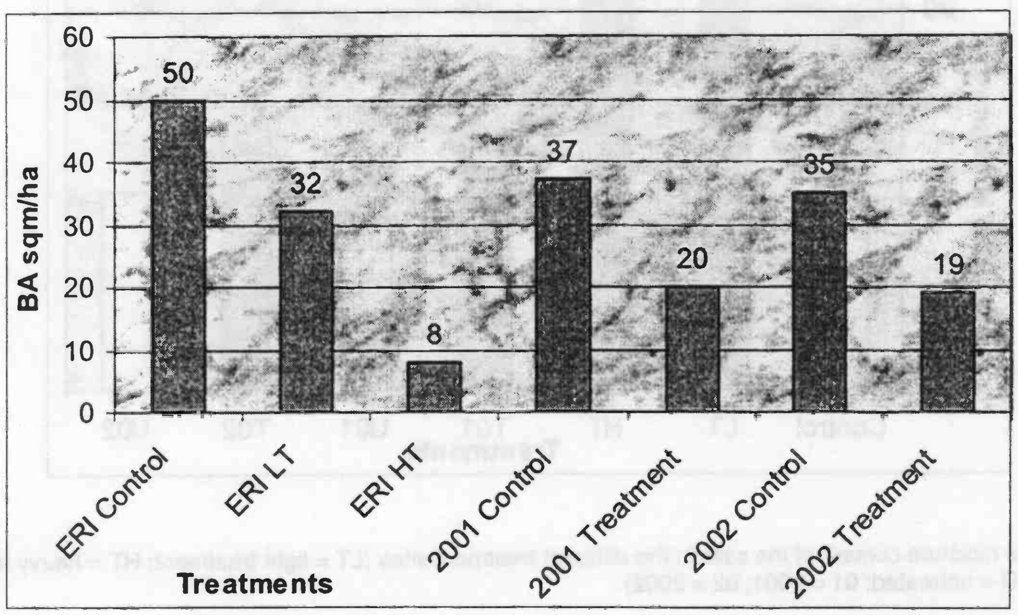

Figure 5. Basal area expressed in sq m/ha in the different treatment sites.

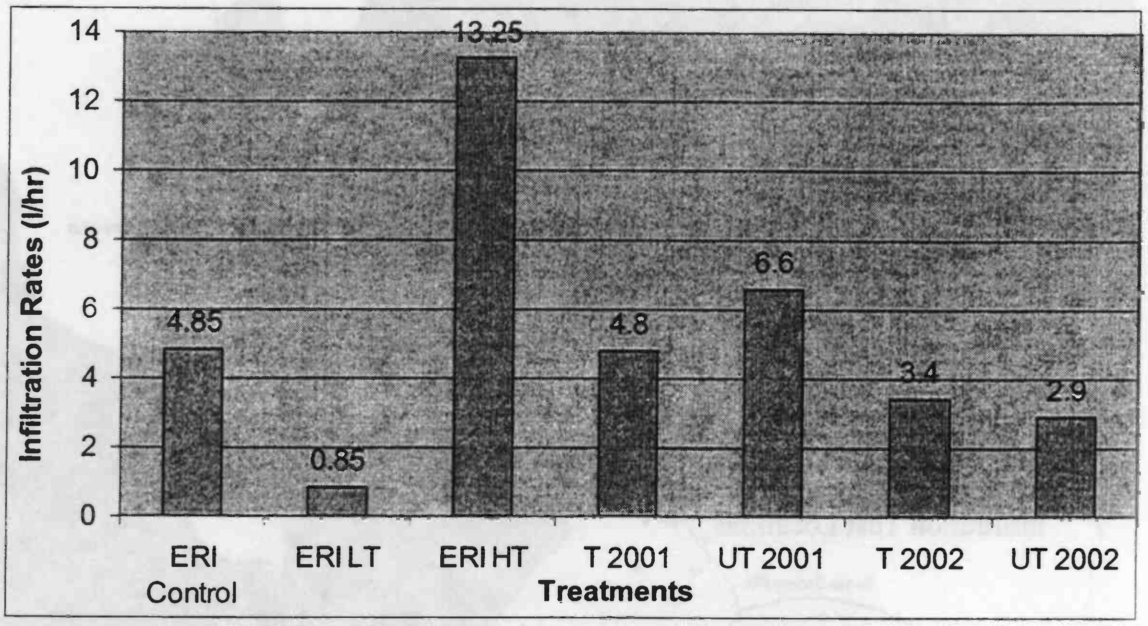

Figure 6. Infiltration rates (in l/hr) in the different treatment sites (LT = light treatment; HT = heavy treatment; T = treated; UT = untreated).

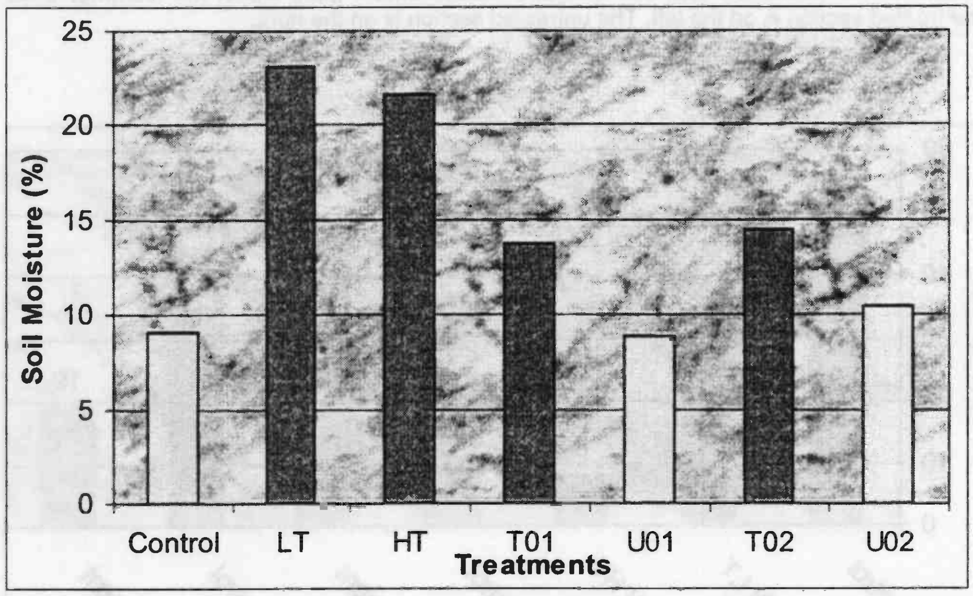

Figure 7. Soil moisture content of the soils in the different treatment sites (LT = light treatment; HT = heavy treatment; T = treated; U = untreated; 01 = 2001; 02 = 2002).

takes several years before the effects of restoration thinning treatments on soil moisture conditions become recognizable. However, we are not sure why there is such a great difference between the heavy and light treatment sites, especially considering that both sites have the same soil type. Our speculation is that in heavily thinned areas, infiltration rates are significantly higher with the help of well-established understory vegetation. The reestablishment of understory vegetation creates a network of roots and rhizomes, which make the soil more penetrable by water. Also, heavily thinned sites have fewer active tree roots taking up moisture than do lightly thinned sites. In lightly thinned areas, where the understory vegetation did not reestablish successfully, infiltration rates are even lower than in the control sites, because there is little or no network of fine roots. Further, traffic during the thinning operation itself could have compacted the soil even further, from which it has not yet recovered.

The soil moisture test results agreed with our hypothesis that thinning the forest increases soil moisture content, which is considerably higher in treated areas. This trend increases with time, as shown by the results from sites treated 4 or 5 years earlier. This is probably because treated sites have fewer trees that take up water from the soil through transpiration. However, to confirm any of the above findings further tests should be conducted, and more test sites should be selected in the future.

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