EFFECTS OF FIRE ON WATER INFILTRATION RATES IN A PONDEROSA PINE STAND

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INTRODUCTION

One of the more important ways in which water supplies can be maintained and, in some cases increased substantially, is through the proper management of watersheds or land areas producing water. Attention is being focused, in particular, on land areas supporting forest vegetation, and, specifically in Arizona, on the ponderosa pine type. Watershed studies have shown that these forested areas, which are normally limited to regions of high rain and snow fall, are best suited for intensive water yield management.

There are, however, some forest management practices which may affect the water yield from a forested watershed. The importance of the pine forest as a timber and water producing area has led to increased protection from wildfire. This has resulted in dense stand growth with increased destructive fire potential and transpirational water loss. In Arizona, as in many areas of the South and West, prescribed burning has been used to effectively reduce these fuel hazards in the forest. For example, 400,000 acres of ponderosa pine on the Fort Apache Indian Reservation, all of which lie in the Salt River Watershed, are being prescribed burned periodically to reduce surface fuels and raise crown levels. With periodic treatment by fire in this manner, a forest stand becomes open and parklike with a much reduced fuel volume.

Although these prescribed burns frequently accomplish their management objectives, concern has been expressed about the possible side effects of such treatments. Specifically, questions have been raised relating to atmospheric pollution by smoke particles and to the effects on water infiltration and water yield. The brief discussion in this paper will be limited to the effects on water infiltration rates.

FIELD PROCEDURES

A study was conducted on the Fort Apache Indian Reservation in east central Arizona at an elevation of approximately 7,600 feet above sea level. Research sites were located within a half square mile area 5 1/2 miles east of McNary on the south side of State Highway 73. Although the study sites and surrounding area were relatively flat there was an overall exposure to the south and southwest toward the North Fork of the White River.

Ponderosa pine (*Pinus ponderosa* Laws.) was the dominant tree species in the study area with some occasional deciduous white oak (Gambel oak - *Quercus gambelii* Nutt.). Average stocking density was found to be about 1,500 trees per acre with a mean basal area of nearly 160 square feet per acre.

Soils in this region are silt loam in texture derived from a mixture of volcanic cinders and basalt slag. Examination of profiles exposed in the study area provided enough evidence to classify the soils in the Sponseller series.

The study was designed to evaluate the influence of burning treatments on water infiltration capacities. These treatments (control, light burn, and heavy burn) were replicated on four sites. Light burn treatments were made on areas approximately 10 feet square by igniting an edge of the plot and allowing the fire to move across against the wind. This light intensity burn closely approximated a typical prescribed burn. A heavy burn treatment plot of similar size was ignited simultaneously from all sides and the fire allowed to reach maximum intensity in the plot center.

Seven fusion pyrometers were used to measure the heat generated by each burning treatment. These pyrometers consisted of pure organic compounds, which had definite melting points, painted on small sheets of mica. When inserted vertically into the soil with a flat putty knife, the temperature distribution of the top few inches of soil during burning could be determined by observing the extent of melting of each compound. Surface soil temperatures for the light burn treatments did not exceed 200° F. Maximum temperature at the soil surface for heavy burns ranged from 350° F. to 550° F.

After burning, an infiltrometer plot, one by 2 1/2 feet in size, was installed in the center of each treatment area on each site. A modified North Fork sprinkling type infiltrometer with constant head tank was utilized to conduct infiltration measurements. The twelve infiltrometer plots remained in place for over two years through two overwintering periods. Two infiltration runs were conducted on each plot in the late summer of 1963, and three series of runs were made in both the summers of 1964 and 1965. Infiltration curves were plotted for each run from runoff data programmed into a computer and an incremental digital plotter. Infiltration capacity values were obtained directly from these curves.

RESULTS AND CONCLUSION

Results showed light and heavy burns produced highly significant decreases in infiltration capacities immediately following burning. However, no statistically significant differences due to burning were detected between heavy burn and light burn treatments and controls during the second and third summers.

The restoration of infiltration capacities to nearly normal conditions after an overwintering period can be attributed to freezing and thawing conditions. It was noted in the early spring of 1964 and again in 1965 that the soils on the study area were more loosely textured and porous indicating the effects of frost action. Minimum temperatures during the winter months in this area are sufficiently low to cause freezing and thawing.

Increases in soil pH, carbon, and total nitrogen percentages for the surface two inches of soil were detected immediately following both light and heavy burning treatments. A slight increase in cation exchange capacity was also noted. These increases were still evident two years after treatment but to a lesser extent.

A significant increase in soil bulk density was obtained following heavy burning treatment but not following light burning. This increase, however, was not detected after the first overwintering period. Surface temperatures indicated that the heat generated by the heavy burn treatment was adequate to consume the organic material incorporated in the surface few millimeters of soil. This removal of organic material probably caused a breakdown in soil structure resulting in a more compacted surface soil. Consequently, bulk density samples of the surface one inch of soil would actually include more mineral soil, resulting in a higher bulk density value.

Late fall prescribed burning programs conducted on the Fort Apache Indian Reservation, when followed by an overwintering period with freezing and thawing conditions, therefore, seem to have little or no detrimental effect on infiltration rates.

Another interesting facet of water infiltration into Arizona forest soils was detected during the analyses of study data. Examination of the 96 infiltration curves plotted from the field data showed that 74 had a prominent depression approximately 5 to 15 minutes after the start of water application. This indicated that the infiltration rate reached a minimum value and then increased before a constant capacity was maintained.

The best explanation for this dip in the infiltration curve is soil non-wettability, sometimes known as a water-repellent or hydrophobic soil condition. It has been commonly observed that extremely dry surface soils will temporarily resist wetting at the start of rainfall but will transmit water normally after being moistened. This initial resistance to wetting may be caused by the formation of impenetrable air films at the water-soil interface (Krammes and DeBano, 1965).

Water-repellent soils have received increasing attention in recent years, particularly since they seem to be much more widespread than originally suspected. These soils may have widespread implications for watershed management. They can be a serious problem on steep slopes, where they reduce infiltration of rainwater and cause erosion. But they may also be an asset, for example, in arid regions, where soils might be artifically waterproofed to obtain more water (DeBano, 1969).

The identity of hydrophobic substances in soils responsible for water repellancy have not been established conclusively. It is suspected that oils and resins from organic plant remains may play an important role. The coniferous litter cover and acidic surface soil found in the study area could promote such a condition. Some research has also been published indicating that fire may accentuate a hydrophobic soil condition.

During the past two summers infiltration determinations have been made on ponderosa pine soils near Flagstaff and in the Santa Catalina Mountains northeast of Tucson. Preliminary results show the presence of a dip in the infiltration curves for these two locations which strongly indicates a water repellent-soil condition. Additional field infiltration studies are planned to investigate further the hydrologic importance of this phenomenon.

DeBano, Leonard F. 1969. Water repellent soils: a worldwide concern in management of soil and vegetation. Agric. Sci. Rev. 7(2): 11-18.

Krammes, J.S., and L. F. DeBano. 1965. Soil wettability: a neglected factor in watershed management. Water Resources Res. 1(2): 283-286.