Impacts of Pinyon-Juniper Treatments on Water Yields: A Historical Perspective

Peter F. Ffolliott[1] and Cody Stropki[1]

Abstract—*Pinyon-juniper woodlands are not normally considered a high water-yielding type largely because of the low precipitation amounts and high evapotranspiration rates encountered. Nevertheless, a recommendation was made in the 1950s to evaluate the effectiveness of increasing water yields by converting pinyon-juniper overstories to herbaceous covers. A series of process and plot studies and watershed-level experiments were carried out in acting upon this recommendation. It was concluded, however, that the potentials for increasing water yields through conversion treatments is "poor" in the region. A summary of these research findings is presented in this paper.*

Introduction

Pinyon-juniper woodlands, the largest "forest type" in the southwestern United States, lie adjacent to and surround the montane forests in the region. Occurring at lower elevation and generally with less annual precipitation than the forests, these woodlands possess a lower water-yield improvement potential compared to these forests. Because of their extensive distribution, however, early investigators felt that water-yield improvement practices in pinyon-juniper woodlands could conceivably affect the availability of water supplies (Barr 1956, Dortignac 1960). The water-yield improvement practices to be implemented were conversions of comparatively high water-demanding pinyon-juniper overstories to lower water-demanding herbaceous covers by mechanical, chemical, and burning treatments. It was anticipated that the reductions in water consumption by plants might become recoverable water. A historical summary of the effects of these treatments on water yields is presented in this paper.

Hydrologic Characteristics

Pinyon-juniper woodlands are not normally considered a high water-yielding type largely because of the low precipitation amounts and high evapotranspiration rates encountered. Streamflow is largely ephemeral, with no permanent streams originating in the area. While runoff events can coincide with the two seasonal precipitation patterns encountered, most of the annual water flows are associated with the winter period, primarily the result of heavy rainfall, rapid snowmelt-runoff, or rain-on-snow events. Over 70 percent of the annual streamflow originating in the pinyon-juniper woodlands on the Beaver Creek watersheds in north-central Arizona occurs in this winter period (Clary and others 1974, Baker 1984). When they occur, runoff events in the summer are low, variable, and short-lived events following torrential summer thunderstorms.

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[1]Watershed Resources Program, School of Natural Resources, University of Arizona, Tucson, AZ.

Water Yield Improvement Potentials

While there was some evidence in the literature (prior to 1956) that removal of pinyon-juniper overstories with the replacement of a herbaceous cover might not produce additional water, a recommendation of Barr (1956) and others was that evaluations of alternative conversion treatments to achieve water-yield improvement in the type should be made by watershed-level experiments. Before this recommendations could be implemented, however, a justification for considering water-yield improvement in pinyon-juniper woodlands was deemed necessary. This justification was largely attained through process and plot studies.

Process and Plot Studies

In a study of interception, throughfall, and stemflow, Skau (1964a) reported that between 10 to 20 percent of the precipitation falling on pinyon-juniper woodlands on the Beaver Creek watersheds was intercepted by the tree crowns. He felt that these interception losses might be (at least partially) reduced by conversion treatments. A somewhat similar conclusion was also reached by Collings (1966) on the Fort Apache Indian Reservation.

Researchers believed that an increase in soil moisture storage might occur following the removal of pinyon-juniper overstories, reducing infiltration losses and (possibly) increasing water yields. Skau (1964b), in another study, found two percent more soil moisture in the upper two feet of the soil on sites cleared of pinyon-juniper overstories than on uncleared sites at the beginning of the summer and winter precipitation seasons. He implied that this difference might have been greater if it was not for the dense herbaceous vegetation that had invaded the cleared sites.

Decker and Skau (1964) measured transpiration rates of Utah and alligator juniper trees by enclosing sample trees in a ventilated tent of transparent plastic film. Increased humidity of the ventilation stream was a direct index of vapor production and, therefore, transpiration rates through conversion. They observed transpiration rates increasing through the morning, peaking at noon, and remaining at this high rate until the middle of the afternoon when transpiration rapidly decreased into early night. By coupling their results with knowledge of the frequencies of occurrences of trees similar to those sampled, the researchers were able to estimate water losses to the hydrologic cycle by transpiration in woodland communities where juniper trees tend to dominate.

The results of these and earlier process and plot studies formed a basis for subsequent experiments to evaluate the effectiveness of converting pinyon-juniper overstories to herbaceous covers to increase water yields on a watershed-level.

Treatment Methods

A variety of treatments had been used into the early 1960s to increase herbage (forage) production by clearing pinyon-juniper overstories. Researchers suggested that these treatment methods might also be implemented for water-yield improvement purposes. Extensive areas of pinyon-juniper woodlands had been cleared by chaining or cabling, in which a heavy anchor chain or cable was dragged between two tractors (Cotner 1963, Arnold and others 1964). Pushing (bulldozing) had been widely used to remove individual trees. These mechanical treatment methods of conversion pulled trees from the ground, leaving pits or depressions where the trees formerly stood. Parenthetically, Skau (1961) had determined that these pits reduced overland flow on the cleared landscapes. Nevertheless, at the time, these mechanical methods of conversion were considered to be a viable approach to implementing water-yield improvement treatments.

Another approach to clearing pinyon-juniper woodlands was hand-clearing with ax and (or) saw. This treatment method had been used to a lesser extent than chaining, cabling, or pushing treatments, however. Hydrologically speaking, this method of tree removal had a "minimal impact" on overland flow because pitting was eliminated. Recurring problems of increased soil erosion that occurred with chaining, cabling, or pushing were also minimized with hand-clearing treatments.

Broadcast burning was successful where the pinyon-juniper overstory was dense enough to carry a fire (Arnold and others 1964). Once again, pits were not created by this method and increased soil erosion was minimal when the burning treatment was properly prescribed and carefully implemented. Individual-tree burning was carried out on a mostly limited scale (Jameson 1966).

Killing trees with herbicides was also a possible option, but this kind of treatment had not been operationally applied at the time. Herbicidal treatments left the dead trees standing on the landscape, and the trees influenced less surface-area than if they were uprooted or felled by cutting and left on the ground.

Watershed-Level Experiments

An early test of the effects of pinyon-juniper conversion treatments on water yields was conducted on a large (operational) scale in the basin of the adjacent Corduroy and Carrizo Creeks in east-central Arizona in 1957-59. The pinyon-juniper overstory on Corduroy Creek was cleared on 34,000 acres (25 percent of the basin) by chaining, while the shrubs, litter, and duff beneath ponderosa pine stands on 18,000 acres (13 percent of the basin) were burned. Carrizo Creek was left undisturbed to serve as a control. Because the evaluation of these two treatments considered only their "total composite effect" on water yields (Collings and Myrick 1966), conversion of the pinyon-juniper overstory to a herbaceous cover on Corduroy Creek could not be isolated as the "sole influence" on subsequent water yields. Nevertheless, these differences were not important because it was concluded that this pinyon-juniper conversion treatment produced no significant changes in water yields in the post-treatment evaluation period.

Two small watersheds less than 100 acres in size were selected to investigate the effects converting pinyon-juniper overstories to herbaceous plants on a smaller-scale on Cibecue Ridge, in the same general area as Corduroy and Carrizo Creeks. Following a calibration period, the overstory on one of the watersheds was cleared by chaining in 1967, with the resulting slash burned and the watershed seeded with a mixture of perennial grasses and fenced to exclude livestock. The other watershed was the control. A "parameter model" to predict how components of the hydrologic cycle changed as a result of the treatment was used to evaluate this experiment (Robinson 1965, Myrick 1971). It was determined that water yields increased on the converted watershed in the initial two post-treatment years, but it then dropped below the expected water yields on the untreated watershed in the following two years. One reason for the subsequent decrease in water yields was the increase in transpiration by the perennial grasses seeded as part of the treatment prescription.

The effectiveness of converting pinyon-juniper overstories to herbaceous covers to increase water yields was also evaluated on three "experimental watersheds" as part of the Beaver Creek watershed program in north-central Arizona (Worley 1965, Price 1967). Varying conversion methods were imposed on the watersheds.

A cabling treatment similar to that extensively used for rangeland improvement was applied to a 323-acre Beaver Creek watershed in 1963. The larger pinyon and juniper trees were uprooted by a cable pulled between two bulldozers and the smaller trees missed by the cable were felled by ax. These larger trees were then burned and the watershed was then seeded with a mixture of forage species.

A hand-clearing treatment with the trees felled by power saw was applied to a second Beaver Creek watershed 104 acres in size in 1965. It was hoped that the problems of pitting and other soil disturbances associated with uprooting trees would be eliminated with this method. Stumps of alligator juniper, the principal overstory species on the watershed, were treated with polychlorinated-benoic acid to reduce subsequent sprouting. Shrub live oak clumps were initially treated with fenuron and later with picloram and Gambel oak sprouts were sprayed with 2,4,5-T in the dormant season to control the occurrence of these species. No seeding of forage species was done.

A herbicidal treatment of a mixture of two and one-half pounds of picloram and five pounds of 2,4-D was applied to a third Beaver Creek watershed of 363 acres. An aerial application of the herbicide was sprayed on 281 acres of the watershed in 1968. The remaining 82 acres were either untreated or individual trees treated with the same herbicide using a backpack mist-blower. This treatment was intended to reduce transpiration losses by killing the trees, while leaving the dead trees standing to reduce windspeeds and solar radiation to control evaporation losses. The treatment also avoided trapping overland flow in pits formed by uprooting trees. A firewood sale removed all of the merchantable wood from the watershed in 1976, eight years after the herbicidal treatment. The resulting slash was piled and burned the following year.

Results of Watershed-Level Experiments

The results of the watershed-level experiments in the basin of Corduroy and Carrizo Creeks, at Cibecue Ridge, and on Beaver Creek indicated that conversions of pinyon-juniper woodlands to herbaceous covers by mechanical treatments has little effect on water yields for varying reasons. Reduced overland flows caused by pitting on the watersheds where chaining or cabling conversion methods were imposed likely compensated for any changes in water yields brought about by reductions in transpiration rates by the tree removals. Elimination of the trees in the largely open stands on the watershed converted to a herbaceous cover by hand-clearing was probably too little to significantly impact on the loss of water to the transpiration process.

Only killing trees with herbicide and leaving them in place to reduce evapotranspiration losses increased water yields on one of the Beaver Creek watersheds. While the increase averaged nearly 160 percent in the 8-year post-treatment period to the time that the dead trees were removed, it amounted to less than an inch in absolute terms (Baker 1984). Furthermore, the increase could only be expected about 1 out of every 2 years, when winter precipitation equals or exceeds the average. That landscapes treated with herbicides might not be aesthetically pleasing to much of the public was also a possible limitation to its widespread application. More importantly, the use of chemicals for natural resources management purposes is opposed by many people and their use limited by environmental regulations.

Conclusion

Overall, the potentials for increasing water yields through conversions of pinyon-juniper woodlands to herbaceous covers is considered "poor" in the region. While this general conclusion contradicted the earlier recommendation of Barr (1956) and others, it should not necessarily be surprising. Water-yield improvements in any vegetative type are largely based on the premise that streamflow and (or) groundwater regimes are increased by an amount that is equal to the net reduction in evapotranspiration (Hibbert 1979). However, there is little opportunity to reduce evapotranspiration on watersheds where precipitation is less than 18 inches and its total is exceeded by potential evapotranspiration (Thornthwaite and Mather 1957), because this amount of precipitation will not penetrate far enough into the soil to influence the storage of moisture in the soil. This latter situation exists throughout much of the pinyon-juniper woodlands in the region.

A similar conclusion that little, if any, increase in recoverable water should be expected through manipulations of pinyon-juniper overstories has also been reported by Ffolliott and Brooks (1988) in their summary of opportunities for enhancing water yields in the Mountain West, by Roundy and Vernon (1999) in their assessment of watershed values in pinyon-juniper woodlands of the Interior West, and by Baker and Ffolliott (2000) in their analysis of opportunities for increasing water yields through vegetative management in the Colorado River Basin.

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