Prescribed Burning on Arizona Watersheds[1]

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THE IMPORTANCE of prescribed burning in land management is becoming obvious to more people each year. Numerous publications, including the past proceedings of the Tall Timbers Fire Ecology Conferences, have shown that fire, if properly applied and controlled, can be used to effectively accomplish many management objectives. It is also recognized, however, that fire is not and should not be regarded as the ultimate or universal management tool. The present intensive research program on fire effects and burning prescriptions needs to be continued and increased to delineate the conditions under which fire can be used effectively.

Watershed management is one area in which fire is becoming increasingly important. In Arizona, prescribed burning has been used in all phases of watershed management with a considerable amount of success.

However, before examining these uses, it might be well to take a brief look at some of the fundamental concepts of watershed management and what these concepts imply in terms of management and

[1]Arizona Agricultural Experiment Station Journal Article No. 1368.

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research objectives. Watershed management is based on the premise that a land area, that is the rock mantle, the soil, and the plant cover, is a reservoir which receives, stores and discharges water. It further assumes that the hydrologic behavior of this reservoir is subject to change and regulation through vegetation manipulation and other land management practices. Proper watershed management then, first, must develop and maintain watershed conditions which produce and put to beneficial use the maximum amount of water; and, secondly, it must do this in a manner which ensures the satisfactory control of erosion and sedimentation. These objectives must also be integrated with a program providing for the optimum production and utilization of all the resources on the watershed.

Professor Percy B. Rowe, a former member of our faculty at Arizona and a pioneer in watershed management, had stated that a successful watershed manager must be able to predict the quantitative effects of his management actions on the hydrologic regime for a particular watershed. The information necessary to make this prediction must come from basic, sound research. However, much of the available information on the effects of burning on soil properties, in particular, the physical properties associated with hydrologic characteristics, is, in many cases, quite contradictory. Some researchers have published results showing that soil water infiltration, for example, is decreased following burning; others have shown that it is increased. Diverging information can also be found concerning the effects of burning on soil bulk density, soil texture and structure, and soil porosity.

Several reasons for these diversified findings can be postulated. Most research on this subject has, in the past, been devoted to an examination of the extremes; to a comparison between severe fires and no fires or to annual burns with no burn. Results from these investigations will certainly show wide treatment variation. More recently, with the promotion of fire as a management tool, low or moderate intensity fires of less frequent occurrence have been studied. In most cases, these burns have shown an amelioration of the detrimental and beneficial effects reported in investigations of extreme situations. It is evident, therefore, that greater consideration must be given to the varying and interrelated direct and indirect effects of

such factors as fire frequency, intensity, and duration; to fuel characteristics such as moisture, continuity, and quantity; and to variable soil conditions themselves.

A new watershed research tool which may answer many of the questions concerning the use of fire in watershed management is the hydrologic simulation model. These analytical models are essentially computer programs in which the components of the hydrologic cycle are used as inputs. By changing various components of this cycle and applying simulated treatments a model can be developed which would characterize the hydrologic behavior of a watershed.

To quantify some of the effects of fire intensity and duration on hydrologic properties of soils and to obtain some base-point information necessary for the simulation model approach, Zwolinski (1966) investigated the changes in water infiltration capacities following summer burning of a ponderosa pine forest floor on four representative sites. A light burn and a heavy burn treatment, which approximated prescribed burning and wildfire conditions, respectively, were conducted on each of the four sites. Base-point measurements of most factors known to influence the effect of fire on components of the hydrologic cycle were taken, such as fire intensity, duration, and fuel characteristics. A modified North Fork infiltrometer with constant head tank was utilized to conduct infiltration measurements before and at various intervals for three consecutive summers following the fires. Physical and chemical characteristics of the environment, and particularly the soil, which would influence infiltration were also measured before and after the fire.

The results of this study indicate that both light and heavy burns produced highly significant decreases in infiltration capacities immediately following burning. No significant differences were detected, however, between the burning treatments and controls during the second and third summers. As would be expected, the degree of effect on infiltration capacities was related to fire intensity with the hotter burns showing the greatest influence. It was concluded from the study that burning programs conducted in late fall on this research area, when followed by an overwintering period with freezing and thawing conditions, would cause no appreciable effect on watershed conditions. These basic data can now be used to

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The remainder of this paper will be devoted to a brief discussion of the major vegetative types found on Arizona watersheds and how prescribed burning has been used in each type to obtain watershed management objectives. Wherever appropriate recent research results will be mentioned.

Spruce-fir.—The spruce-fir type comprises only 110,000 acres of land area in Arizona (Shupe, 1965). This vegetation type has the highest potential for yielding water and under proper snow management this zone could provide water increases per unit area unrivaled by other types. The use of fire in the spruce-fir type has been mostly limited to the disposal of slash following block-cutting on watersheds. There are no plans at present to initiate a research or management program on the use of fire as a tool to increase water yields on these watersheds.

Ponderosa Pine.—The 3.7 million acres of ponderosa pine in Arizona are extremely valuable for their watershed functions. These pine-covered watersheds discharge a major portion of the water flowing in the Salt, Gila, and Verde River systems of the state.

Prescribed burning has been used on the Fort Apache Indian Reservation in east-central Arizona since 1948. Nearly one half of the 400,000 acres of ponderosa pine on the Reservation has received treatment by fire to date (Fig. 1). The main objective of the program is to reduce the flammability of this valuable forest. Successful broadcast burning in late fall has reduced the surface fuel volume, raised the crown levels of small saplings by scorch, and reduced the number of stems per acre (Fig. 2).

In the early 1960's, the U. S. Forest Service inaugurated a burning program for the disposal of slash following the harvest of ponderosa pine. The Apache and Sitgreaves National Forests have successfully machine-piled slash and burned it during the summer rainy season. Various harvesting systems to increase water yields on the Castle Creek watersheds in eastern Arizona have been supplemented by the use of fire in slash disposal (Fig. 3).

Although not a primary objective, additional benefits can be gained from burning in the pine type in the form of seedbed preparation and increased forage production for livestock.

Burning in this type for the primary purpose of increasing water

FIG. 1. A light prescribed burn on a ponderosa pine watershed (Fort Apache Indian Reservation).

yields has not yet received adequate attention. Burning prescriptions to achieve this objective still need to be developed. Even if a prescribed fire were to remove sufficient organic and surface material, the overstory vegetation with its high interception capacity may make any gains in water yields insignificant. Additional studies certainly are needed on this aspect of prescribed burning.

Pinyon-Juniper.—Many acres of pinyon-juniper watersheds in Arizona are being converted to grazing land by the use of fire. Protection from fire promoted the invasion of these species on former grasslands; now fire is being applied to change these brush areas back to grasses for grazing.

The Hualpai Indian Reservation in northwestern Arizona has nearly 550,000 acres of pinyon-juniper watersheds. Since 1956, 24,000 acres have been successfully treated with fire and reseeded. The burning prescription, in this case, calls for bulldozing fire lines

FIG. 2. Removal of heavy fuel hazards by a prescribed burn in ponderosa pine (Fort Apache Indian Reservation).

several months prior to treatment, then igniting the burn during peak burning conditions in late June and early July. A dense stand of vegetation, from 200 to 400 trees per acre, is needed to carry the fire effectively. Immediate seeding has resulted in 10-fold increases in forage production.

Similar treatment of pinyon-juniper watersheds has taken place on the western portion of the Fort Apache Indian Reservation. With fewer trees per acre, the approach has been modified to include chaining or pushing trees before applying the broadcast burn.

Water yield increases following these burning programs have not been adequately measured. It has, however, been widely accepted that a vegetation type conversion from brush to grass reduces the water losses from consumptive use and increases surface water infiltration. The Beaver Creek Watershed Project, south of Flagstaff, should yield some additional information on expected water yield

FIG. 3. Ponderosa pine slash ready for burning the summer rainy season (Castle Creek Watershed, Apache National Forest).

increases following treatment of pinyon-juniper watersheds by burning.

Chaparral.—Dr. Harold G. Wilm, in a recent report to the Arizona Watershed Symposium, stated that, "With careful application, the use of controlled fire in the Arizona zones of comparatively heavy chaparral seems a quite promising method of improving both grazing conditions and water yield." (Wilm, 1966). With approximately 4½-5 million acres of chaparral watersheds in Arizona, this potential for water and grazing cannot be overlooked.

Water yield increases following burning have, in fact, received more attention in the chaparral type than in any other vegetative zone in Arizona. Two studies on chaparral burning have received considerable attention. These are the Three-Bar Experimental Watersheds under investigation by the Rocky Mountain Forest and Range Experiment Station, and the Brushy Basin Project on the Tonto National Forest.

FIG. 4. Removal of chaparral by a high intensity fire (Brushy Basin Project, Tonto National Forest).

The Three-Bar watersheds are located on the east slopes of the Mazatzal Divide about 50 miles northeast of Phoenix. Four watersheds, in the dense, mixed chaparral zone ranging in size from 50 to 270 acres, were instrumented in 1956. In June, 1959, a hot wildfire swept over the experimental area and the watershed cover was largely destroyed. Research objectives were then realigned to measure sediment and water yields from denuded watersheds. Results have indicated some dramatic changes between two of the watersheds. One 95-acre watershed, which was seeded to grass and kept free of brush by herbicide treatment, has yielded about three inches more water annually for the last three years compared to an 80-acre control watershed with natural shrub recovery. Although sediment yield increased sharply on both watersheds following the fire, there was a rapid decline to near prefire levels. The control watershed, however, is still yielding more sediment than the watershed converted to grass (Pase and Ingebo, 1965).

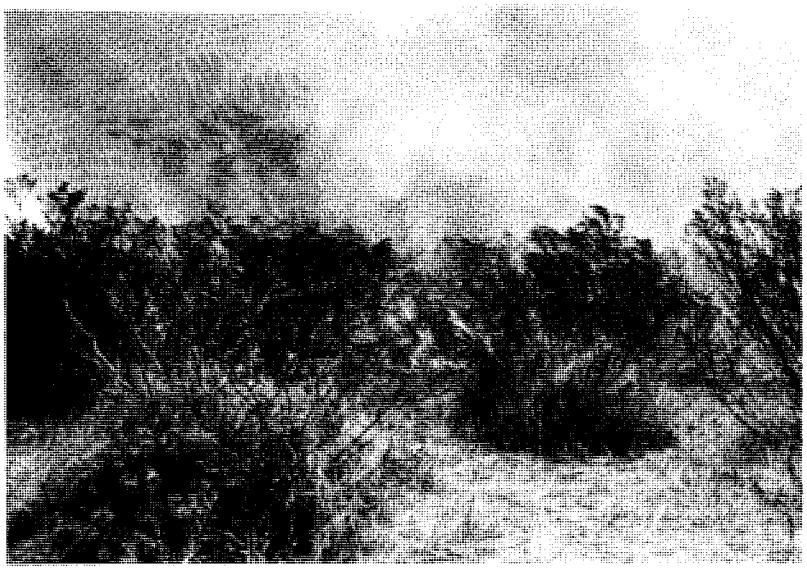

FIG. 5. Broadcast burning in the desert grassland (Bowie, Arizona).

Brushy Basin, an area of 8,100 acres, lies on the west slope of the Mazatzal Divide about 40 miles northeast of Phoenix. A hydrologic analysis of this chaparral-covered watershed indicated a good potential for increasing water yields. Consequently, over a three-year period (1962-65), 3,000 acres of the basin were broadcast burned to remove the existing shrub cover (Fig. 4). Burned areas were seeded immediately to grass and later, with the sprouting of shrubs, treated with herbicides by helicopter (Courtney and Baldwin, 1964).

Streamflow data for the last several years have indicated that this treatment resulted in a substantial increase in water yield. An increase of 440 acre-feet of water per year from the 3,000 acres treated by fire has been estimated. Sediment yields were increased substantially but have stabilized in recent years (Suhr, 1967).

These two studies on the effects of fire on the hydrologic properties of chaparral-covered watersheds are very encouraging. Continued research in this zone should result in a much wider application of fire as a watershed management practice.

Desert Grassland.—The use of fire in the desert grassland has been limited largely to the conversion of brush to grass watersheds. Broadcast burning is difficult at times because of the sparseness of vegetative cover and surface organic material (Fig. 5). Preliminary results from recent studies at the University of Arizona indicate that there are no changes in the erosion profile following broadcast burning.

Several factors have become apparent with this brief evaluation of prescribed burning on Arizona watersheds.

First, the role of prescribed fire in the management of Arizona watersheds is well established. Many objectives, from slash disposal and hazard reduction to type conversions in many different vegetative zones, have been attained successfully by the proper use of fire.

Secondly, the potential for increasing water yields through the use of prescribed fire has not yet been fully realized. As more information from basic and applied research programs becomes available, the watershed manager should find that fire, when properly applied and controlled, can, indeed, be an effective management tool.

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