Chapter 4

Managing Chaparral in Yavapai County

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Introduction

Yavapai County in central Arizona supports extensive stands of chaparral in the Bradshaw Mountains, Mingus Mountain, and the Santa Maria Range. Chaparral occupies about 400,300 acres of the Prescott National Forest (Anderson 1986). These chaparral communities provide a wide range of benefits including watershed protection, grazing for wildlife and domestic animals, recreational opportunities, and wildlife habitat. As in other chaparral areas in Arizona and California, these shrublands are subject to regular wildfires that can destroy the protective shrub canopy and leave the burned areas susceptible to runoff and erosion, normally for 3 to 4 following fire.

Mining and cattle ranching are important activities in these chaparral areas (Bolander 1986). Cattle grazing of chaparral stands began in central Arizona around 1874 and within a single decade the vegetation type was almost entirely stocked or overstocked (Croxen 1926). Almost every acre of Yavapai County was occupied by cattle or sheep by 1890. Because of these early extremely high stocking rates, by 1926 grasses in many chaparral stands had disappeared and the cover and density of shrubs had increased (Cable 1975).

The extensive stands of chaparral in Yavapai County provided the setting for further refinement of research evaluations and management techniques that started earlier in the Salt-Verde Basin (see DeBano et al., Chapter 4 of this publication). Consequently, experimental watersheds (Whitespar and Mingus), experimental grazing areas (Tonto Springs), and a pilot application area (Battle Flat) were established in Yavapai County. Satellite research studies were also implemented on fire effects and designing prescriptions for prescribed burning in chaparral.

Experimental Watersheds

Three experimental watersheds, the Whitespar, Mingus, and Battle Flat, were established in Yavapai County to study chaparral management (figure 9). The Whitespar watersheds played an important role in assessing the potential water yield increases that could be obtained by chaparral conversion practices in areas of moderately dense chaparral (40% to 60% cover density). This information extended the research results obtained from the Three-Bar watersheds, which were covered with a dense stand of chaparral (see DeBano et al., Chapter 3 of this publication). The Mingus watersheds contained a sparse cover of chaparral and were similar to the Natural Drainages watersheds on the Sierra Ancha Experimental Forest (see Gottfried et al., Chapter 2 of this publication).

Whitespar Watersheds

A pair of watersheds located about 8 mi southwest of Prescott, on the Prescott National Forest, were gaged in 1958. One watershed designated as Whitespar A was

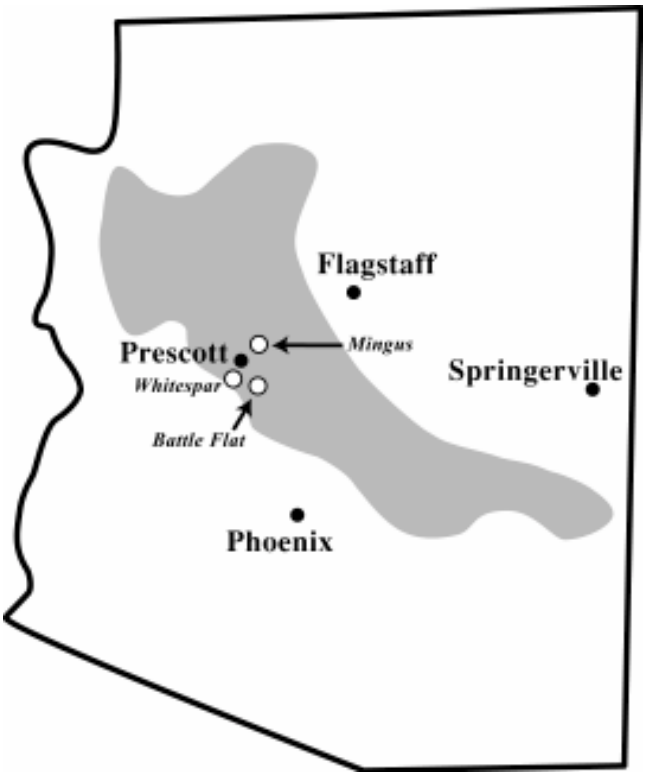

Figure 9. Watersheds in Yavapai County in the Central Arizona Highlands.

about 300 acres in size and an adjacent watershed designated as Whitespar B was 250 acres. The elevations of Whitespar A and B range from 5,900 to 7,200 ft (Davis 1993). The climate is semi-arid with 26 inches of annual precipitation over 30 yr. About 90% of the streamflow from the untreated watershed occurred between December and April. Medium-dense chaparral composed of shrub live oak/hairy mountainmahogany (*Quercus turbinella/Cercocarpus breviflorus*) habitat type provided a crown cover of about 50% (Hibbert and Davis 1986). Whitespar A was dominated by chaparral with isolated areas of Gambel oak and ponderosa pine along the upper ridges and north-facing slopes. Whitespar B was totally covered with chaparral.

The initial research emphasis on the Whitespar watersheds was on water yield responses, with sediment production as a secondary hydrological evaluation. The major input and output measurements were precipitation, stream discharge, and sediment production. There was also emphasis on developing methods for controlling chaparral and converting a shrub cover to grass. As the research program evolved, environmental and ecological issues became increasingly important. One of these issues was increased nitrate concentrations that had been detected earlier on the Three-Bar experimental watersheds (Davis 1984). The need to convert chaparral in a mosaic pattern to enhance wildlife, reduce fire danger and nitrate release resulting from brush control, and improve esthetics strongly influenced later treatments.

The Whitespar watersheds were treated in 3 phases reflecting the changing emphasis on chaparral management over time. Each treatment phase required a pretreatment stream discharge calibration period lasting several years to establish the annual runoff relationship between the control and the treated watershed. The 3 treatment phases on Whitespar A and B were experiments designed to address emerging questions.

The Phase 1 experiments were applied to Whitespar B in the 1960s to determine whether annual streamflow could be increased by killing the chaparral brush and trees in and along the main channel (essentially a riparian treatment). Previous studies in California indicated that clearing trees along channels would substantially decrease evapotranspiration and increase streamflow (Rowe 1963). The main emphasis in the 1950s and early 1960s was managing chaparral vegetation to produce water yield increases. The riparian areas throughout the Central Arizona Highlands were viewed as major consumers of available water, causing reduced streamflow. Conversion of these woody riparian species to grass or other species that use less water was promoted. A decade later, these riparian systems were recognized as important recreation sites and wildlife habitats that required preservation and enhancement to maintain their sustainability (see Baker et al., Chapter 7 of this publication).

Within the context of earlier research emphasis on riparian treatment, 37 acres (about 15% of the watershed) of the channel area were treated with soil-applied herbicides that was hand applied underneath shrubs and small junipers in March 1967 (Hibbert et al. 1974). Intershrub spaces were not treated to avoid killing grasses and forbs. Larger junipers were either cut or girdled. The single application of the soil-applied herbicide gave 80% to 90%

Figure 10. Vegetation treatment in the Phase 2 experiment on Whitespar B.

control of the shrubs and made a follow-up treatment unnecessary. The channel treatment effect was evaluated for 7 yr, after which the Phase 2 experiment was initiated.

The Phase 2 experiment began in 1973 with a second treatment on Whitespar B. This experiment was started after the effect of the channel treatment on streamflow had stabilized and been evaluated. The objective of the Phase 2 experiment was to determine whether ridgeline brush-control would affect annual streamflow volume. The treatment consisted of treating the boundary ridges and a main centrally-located ridge with soil-applied herbicides broadcast aerially (figure 10). A follow-up treatment was necessary in 1976 because of uneven chemical distribution and poor shrub control after the aerial application. The overall shrub reduction on the areas treated was about 85% (Hibbert et al. 1986). The combined area was about 20% of the watershed (49 acres). The evaluation was for 7 yr.

The Phase 3 experiment was the last applied on the Whitespar watersheds. In February 1981, soil-applied herbicides were applied by helicopter in a mosaic pattern on Whitespar A. The treatment was applied to about 55% of the watershed (168 acres). This treatment pattern was designed to incorporate what had been learned from previous experiments into a design that would increase water yield without degrading wildlife habitat or other watershed resource values. Hydrology, soil-plant water relations, and wildlife habitat improvement were considered in designing a mosaic conversion pattern on Whitespar A that was aesthetically pleasing and technically feasible to implement by applying herbicide with a helicopter (Hibbert and Davis 1986). Because of esthetics and wildlife values, all ponderosa pine and Gambel oak stands were excluded from treatment. The ponderosa pine sites were used extensively for roosting doves and pigeons and contained big game trails leading into the watershed. Gambel oak sites along stream channels are valuable javelina (*Tayassu tajacu*) and deer habitat.

Mingus Watersheds

Three Mingus experimental watersheds, located about 23 mi northeast of Prescott, Arizona, were established in 1958 and equipped with stream gaging stations in 1960 (Ffolliott and Thorud 1974, Hibbert 1986). Watershed A is about 96 acres, Watershed B is 67 acres, and Watershed C is 44 acres. The mid-area elevation ranges from 6,200 to 6,560 ft and the mean annual precipitation over 12 yr averages 17 to 19 inches. The chaparral cover consisted of a low density stand of shrub live oak-mountainmahogany brush. The density was less than 40% crown cover. The mean annual streamflow on the untreated watersheds was 0.04 to 0.19 inch and was ephemeral.

The treatment plan called for Watershed A to be burned and Watershed B to be treated with chemicals (figure 11). Watershed C was the control. Chemicals, fire, or a combination, were to be used to maintain the brush cover below 10% crown density (Ffolliott and Thorud 1974). The upper halves of Watersheds A and B were treated in 1974 and the lower halves in 1975 to minimize any treatment-induced erosion (Hibbert 1986).

Figure 11. Burning treatment applied on Mingus Mountain Watershed A.

Battle Flat Pilot Application Program

Following 20 yr of research on small experimental watersheds in the chaparral shrublands, planning began for a joint pilot application project in 1976 between the Southwestern Region of the USDA Forest Service and the Rocky Mountain Forest and Range Experiment Station (Bolander 1986, Hassel 1976, Krebill and Tackle 1978). The objective of this pilot application program was to test the state-of-the art technology on a larger, operational-scale chaparral watershed. Management techniques aimed at improving the production of water, maintaining water quality, increasing livestock and wildlife forage, enhancing wildlife habitat, reducing fire hazard and erosion, and determining the economic feasibility of chaparral management was to be evaluated and refined. This program also provided research opportunities to study fire effects on nutrients, erosion and sedimentation rates, plant productivity and growth, and fire history.

Study Area

A 3,780-acre watershed (Battle Flat) on the Prescott National Forest in central Arizona was designated as a pilot application area in chaparral shrublands in July 1977 (Hassell 1976). The Battle Flat Demonstration Area in the Bradshaw Mountains was chosen to test the current knowledge of managing chaparral shrublands on an operational-size watershed (Bolander 1986). The results of all information gained on experimental chaparral watersheds (both in Arizona and in California) were used to design treatments.

The demonstration area consists of 2 adjacent watersheds. The southern-most watershed (1,600 acres) is drained by the northeast trending Tuscumbia Creek; the northern-most watershed (2,174 acres) is drained by the east-southeast trending Battle Flat Creek. Elevation at the junction point of the 2 stream channels is 4,969 ft.

The topography is highly dissected and rugged. Most of the watershed faces southeast with slopes ranging from 8 to 30 degrees. Parent rock materials in the study area consist of granitics, volcanics, and alluvium. The Battle Flat watershed contains 11 different soil-map units (Humbert et al., 1981) whose texture range from sandy loams to very gravelly coarse loams. These soils are located on slopes from 0% to 60% and are all less than 16 inches deep. Runoff on these slopes is rapid, and erosion hazard is moderate to high.

Annual precipitation averaged 27 inches over 10 yr. The watersheds were dominated by shrub live oak (48%), birchleaf mountainmahogany (27%), and pointleaf manzanita (19%). The remaining 6% cover was a combination of several other species.

Project Planning, Inventories, and Research

Before treatment, several inventories were done on the control (Tuscumbia) and treated (Battle Flat) watersheds in addition to hydrologic instrumentation. These inventories included archaeologic, geologic, vegetation, soils, hydrologic, and wildlife habitat. The vegetation and wildlife inventory was done jointly by the Prescott National Forest, Southwestern Region of the Forest Service, and the Rocky Mountain Forest and Range Experiment Station in coordination with the Arizona Game and Fish Department.

Once the inventory data were obtained, it was possible to specify the mosaic treatment pattern. This effort included modeling chaparral conversion for water augmentation based on social, economic, and ecological parameters (Hodge et al. 1985). The purpose of the model was to maximize water yield, while constraining the anticipated effects of conversion within selected boundaries. Upper limit constraints were based on nitrate and herbicide contamination of water and soil erosion due to conversion. Lower limit constraints were based on economic benefits associated with increased water yield to ensure cost-effectiveness. This research was used to decide which soil-mapping units were appropriate for treatment based on the model. According to this model, about 50% to 55% of the watershed was to be treated in a mosaic pattern similar to that developed for Whitespar A, which was described earlier.

Several nutrient cycling studies on shrubs and soils were accomplished as part of the overall research program. One study was designed to gather prefire data over several years, focusing on plant available nitrogen and phosphorus, and comparing immediate pre- and post-burn levels of available nitrogen and phosphorus (Overby and Perry 1996). This study was coordinated with one on the effect of aspect and shrub species on the availability and accumulation of nitrogen and phosphorus in soils (Klemmedson and Wienhold 1991a, 1991b). Nutrient and biomass studies were completed on shrub live oak and birchleaf mountainmahogany before and after fire (Whysong 1991, Whysong and Carr 1987).

Hydrologic research evaluations consisted of analyzing stream flow data from several permanent gaging stations located on the major drainages and on some of the smaller subdrainages in the Battle Flat and Tuscumbia watersheds. In addition, stock water tanks were established in 2 of the smaller watersheds to obtain annual measurements of sediment production. One of these watersheds was prescribe-burned in 1985 (figure 12). Nutri-

Figure 12. Igniting prescribed fire on Battle Flat with heliotorch.

ent changes and losses associated with increased erosion resulting from this prescribed burn were also studied (Overby and Baker 1995, Overby and Perry 1996, Hook and Hibbert 1979).

Relatively little was known about the fire history in the chaparral shrublands at the time, although fire suppression records indicated that large fires had been common. The Battle Flat area provided an opportunity to establish the fire history in chaparral stands because vegetation along the drainages contained ponderosa pine trees that could be dated by tree ring methodologies based on interpreting fire scars on the trunk of ponderosa pine trees (Dieterich and Hibbert 1990). Shrubs do not lend themselves to this analysis because the whole plant is often consumed during a fire. In contrast, during ground fires the basal area of some ponderosa pine trees may be scarred without significantly damaging the trees. Therefore, the close association of ponderosa pine trees with surrounding hillslopes covered with chaparral allowed fire frequencies to be estimated for both the pine and chaparral areas.

Cooperators

In collaboration with the pilot application program, several research studies were initiated by Rocky Mountain Forest and Range Experiment Station scientists and other scientists from Arizona State University and the University of Arizona. These studies included establishing baseline information on streamflow, erosion and sedimentation, shrub biomass, scenic beauty, effects of fire on nutrient cycling, fire history, and the effect of fire on erosion.

Streamflow, precipitation, and sediment measurements were a joint effort between the Rocky Mountain Research Station and the Prescott National Forest. Overall program management was jointly shared by a project leader for the Rocky Mountain Research Station, the supervisor of the Prescott National Forest, and the lead hydrologist for the Southwestern Region of the Forest Service.

Results

As previously stated, 2 status-of-knowledge publications presented the results of water yield improvement experiments and other research conducted on the watersheds in chaparral shrublands (Brown, T. C. et al 1974, Hibbert et al. 1974). These results have been refined and, in some cases, expanded in subsequent publications. A brief discussion of the results is presented below; details are in the cited literature.

Whitespar Watersheds

The channel treatment of trees and shrubs at Whitespar B (Phase 1) resulted in an increase in amount and duration of streamflow. Although only 15% of the watershed was treated, it produced perennial flow in previously ephemeral stream channels that was beneficial to wildlife and livestock (Hibbert et al. 1986). When the increases were prorated to the area treated, there was an annual increase

in streamflow of 4.2 inches. The increase in streamflow was short-lived as vegetation recovered after treatment and below normal precipitation occurred.

Ridgetop treatment of trees and shrubs at Whitespar B (Phase 2) resulted in no additional streamflow increases (Hibbert et al. 1986). It was concluded that any water saved by reducing the shrub cover along the ridgelines was used by the untreated downslope shrubs before it reached the channels.

The mosaic treatment of brush on Whitespar A (Phase 3) resulted in:

- Increased annual streamflow of 1.5 to 5.0 inches over a 7-year posttreatment evaluation period.
- A small, but statistically significant, increase in nitrate concentrations was attributed to the mosaic treatment (Davis 1993). Nitrate nitrogen released from converted areas was diluted by streamflow from untreated areas, which reduced nitrate concentrations in streamflow at the watershed outlet.

Mingus Watersheds

As expected, only small increases in streamflow occurred as a result of treatment on the Mingus Watersheds. Annual streamflow from Watershed A (prescribed burn) increased 0.30 inch and Watershed B (chemical treatment) increased 0.22 inch (Hibbert et al. 1986). The magnitude of response was similar to that measured on the low-precipitation watersheds of the Natural Drainages watersheds study area on the Sierra Ancha Experimental Forest (Gottfried et al,. Chapter 2 of this publication).

Battle Flat Watershed

Although extensive instrumentation, inventories, and baseline research studies were performed on the Battle Flat Demonstration Area, treatment of the entire watershed was delayed because of the political and legal constraints surrounding the widespread use of soil-applied herbicides for treating watersheds. However, one small area on the Battle Flat watershed was prescribe burned in 1985. Measurements associated with this prescribed fire, along with other inventories and studies, added to our basic understanding of chaparral shrublands.

Sediment accumulations in the 2 stock tanks before treatment with prescribed fire, showed that sediment production from chaparral is primarily the result of winter periods of heavy precipitation and runoff and generally not from summer rainstorms (Hook and Hibbert 1979). The sediments came mostly from erosion of channel alluvium in upstream tributaries where the sediments accumulated from downslope creep, dry ravel, and overland flow produced during the typical, smaller, convective rainstorm events. The study further concluded that:

- The long-term sediment rate from the unburned watersheds was about 0.6 lb / acre annually, but increased to almost 2.7 lb / acre (about 4 times) during winters of heavy precipitation.
- After the prescribed burn, sediment yields increased to over 7 lb / acre (about 12 times) annually for 3 years following the fire (Overby and Baker 1995).
- The increased erosion resulting from the prescribed fire removed substantial amounts of nitrogen, phosphorus, and cations from the burned watershed (Overby and Baker 1995). Both concentrations and amounts of these nutrients increased in the sediment material that was eroded from the burned areas.

A separate study on the small watersheds within the Battle Flat Watershed showed that interactions between species composition and aspect have an effect on nutrient responses to prescribed fire. Higher preburn nutrient concentrations were found under shrub live oak than under mountainmahogany (Klemmedson and Wienhold 1991a). Phosphorus was also a limiting nutrient before burning, particularly on south aspects (Klemmedson and Wienhold 1991b).

The results after the prescribed burn indicate that:

- Ammonia and phosphorus were translocated downward in the soil as a result of fire (Overby and Perry 1996).
- Residual ash and underlying soil contained increased concentrations of available nitrogen and phosphorus. This temporarily increased soil fertility on the burned sites.

Fire history for the Battle Flat watershed was established from the mid 1800s (Dieterich and Hibbert 1990). Reconstruction of the history showed that:

- Fires burned at an average 2-yr interval within the 200 acre ponderosa pine stand and surrounding chaparral, before intensive mining activities began in the 1860s.
- Ponderosa pine and associated oak and juniper trees were heavily cut during expansion of local mining from 1863 to 1885, after which fire protection, low fuel loading, and grazing eliminated large fires for many years. This resulted in the current overmature chaparral stands that lack a natural mosaic appearance and contain heavy accumulations of dead material.

- Large wildfires have swept through continuous stands of dense chaparral since the 1900s due to the large fuel accumulation.

Implications

Research and management efforts in Yavapai County consisted primarily of testing previous research findings on experimental watersheds and on an operational scale. Studies at Whitespar and Mingus experimental watersheds extended the information gained from the Three-Bar watersheds and Natural Drainages watersheds in the Salt River Valley (DeBano et al. Chapter 3 of this publication). It was concluded from the investigative studies that:

- The mosaic pattern (where about 50% of the brush was treated with soil-applied herbicides and fire) was beneficial for increasing water yield, maintaining water quality, improving wildlife habitat, and reducing fire hazard.
- The availability of soil nitrogen and phosphorus increased as a result of the burning and these fire-related responses were affected by plant species and aspect. The increased nutrient availability disappeared after 2 yr.
- Sediment production and nutrient loss increased even after low-intensity prescribed burns.
- Long-term productivity and sustainability of chaparral ecosystems were enhanced by prescribed fire (Overby and Perry 1996).

Current Status

Evaluations on the Mingus experimental watersheds were discontinued in 1983 and on the Whitespar watersheds in 1986 as part of the change in emphasis of watershed research in the Central Arizona Highlands. Streamflow and precipitation measurements were continued at Battle Flat through 1989, then all data collection was terminated.