ARIZONA CHAPARRAL: A REVIEW AND RESEARCH DATABASE

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Chaparral is a shrub-dominated vegetation type typically found worldwide growing under Mediterranean climates. It has many different names—mallee in Australia, garrigue in France, tomillares in Spain, phrygana in the Balkans, mattoral in Chile, and fynbos in South Africa. "Heath" is another term used for a similar vegetation type in South Africa and southeast France. In the United States, the term "chaparral" was initially coined to describe dense brush fields made up of broadly distributed sclerophyll vegetation located in the Upper Sonoran life zone of southern California. "Chaparral" evolved from "chabarra," the Basque word for a scrub oak of the Pyrenees (Cronemiller 1942), and the Spanish in California used the term "chamiso" (or "chamisal") to designate open brush areas composed of small shrubs. To early Spaniards, chaparral was the kind of brush field one could not ride a horse through, whereas chamiso or chamisal (or later just chamise) referred to more open brush stands dominated mainly by chamise (*Adenostoma fasiculatum*). Arizona chaparral has been termed "mock " or "interior" chaparral because it does not grow in a characteristic Mediterranean climate.

Chaparral in Arizona largely occurs on rough, discontinuous mountainous terrain south of the Mogollon Rim, extending approximately from Seligman in the northwest to the Chiricahua Mountains in the southeast. Most of the chaparral type in the southern Rocky Mountains is located in Arizona. Estimates of chaparral acreage in Arizona vary from about 3 million acres (1.2 million hectares; Cable 1973) to 4 million acres (1.5 million hectares; Hibbert and Ingebo 1971) to nearly 6 million acres (2.4 million hectares; Nichol 1952). Approximately 2.2 million acres (0.9 million hectares) of chaparral in Arizona are found within the National Forest system, mainly the Prescott and Tonto National Forests, and more than 60 percent is under federal ownership or management (Cable 1957).

Chaparral makes up a significant part of Arizona's wildlands, where it provides watershed protection, wildlife habitat, recreational opportunities, and forage for livestock production. The importance of the chaparral vegetation type in Arizona has led to its inclusion in long-term research and management programs of natural ecosystems throughout the state. One such program (called the Arizona Watershed Program) was initiated in the 1950s to study the effect of vegetation manipulations on streamflow (Fox et al. 2000). This program included designating watersheds in all major vegetation types in Arizona, including mixed conifer and ponderosa pine forests, pinyon-juniper woodlands, and chaparral, as long-term research sites. Much has been learned through this long-term program about the chaparral vegetation type. Although a large amount of data and information has been collected on chaparral, it is not as widely available for use by interested parties as is the information about ponderosa pine forests.

The overview of Arizona chaparral provided here also outlines the activities underway to incorporate this body of information into a computer database to make it widely available. This database will provide present-day managers with a source of information useful for evaluating the role of chaparral management on streamflow augmentation. The increasing need to provide additional water for rapidly growing metropolitan areas in Arizona and the Southwest has prompted a renewed interest by water managers on the effect of vegetation management on streamflow.

CHARACTERISTICS

Historical Development

Although Arizona and California chaparral are similar in many respects, important differences in the vegetation characteristics of the two have evolved due to the differences in the historical

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climatic regimes of these two vegetation types. Initially, chaparral did not expand as a regional vegetation type, but instead it was an understory in woodlands (Rundel and Vankat 1989). These woodlands developed as part of a large vegetation complex found in southwestern North America during the late Paleocene to early Neogene, when the areas were subjected to a subhumid climate having summer rainfall conditions. The ancestral taxa were derived mainly from laurophyllous forests and woodlands as a result of basic adaptations of thick evergreen leaves, stump sprouting, and deep root systems. These taxa had therefore preadapted to the increasingly more stressful environments of the later Paleogene, when secondary drought-resistant adaptations such as villous leaf covering, deep crypts, thicker leaves, and a deciduous habit were important. However, these shrubs formed only small seral communities on drier sites during the later Tertiary period. The increasing aridity favored the spread of desert and other semiarid vegetation, which divided and restricted the chaparral vegetation complex to certain areas in California, Arizona, and northeastern Mexico. The development of drought throughout the summer occurred during the Tertiary period in California, which caused a shift in plant activity from summer to spring. In contrast, plants in Arizona and northeastern Mexico remained active during the summer rainy periods (Axelrod 1989). Chaparral became a regional vegetation type only in historical times as human-caused ignitions increased fire sequences, which regularly removed the tree layer and increased shrub density on many of the former woodland types.

Physical Setting

Arizona chaparral occurs mainly at elevations between 3000 and 6000 ft (about 900–1800 m), although it is found on some higher mountain peaks (Hibbert and Ingebo 1971; Pase 1966). Chaparral species can integrate with other vegetation zones, including ponderosa pine, pinyon-juniper, encinal woodland, and grassland. Factors determining which vegetation type will occur on particular sites within the overall chaparral zone are complex and involve many different combinations of topographic, geologic, climatic, and edaphic conditions.

The average annual precipitation in Arizona varies from about 15 inches (38 cm) at the lower elevations of the chaparral shrublands (3000 ft or 900 m) to over 25 inches (64 cm) at the higher elevations (6000 ft or 1800 m). Approximately 60 percent of the annual precipitation occurs as rain or snow between November and April. The summer rains fall in July and August, which are the wettest months of the year. Annual potential evapotranspiration rates can approach 35 inches (89 cm; Ffolliott and Throud 1974; Hibbert et al. 1974). The climate supporting Arizona chaparral is thus bimodal (i.e., both summer and winter precipitation occurs). Arizona chaparral is not found in the Mediterranean-type climate typical of the true chaparral found in California and elsewhere throughout the world, characterized by a lack of summer rainfall and a long period of moisture stress.

Chaparral soils are typically young, coarse-textured, deep, and poorly developed lithosols. Granites occur on more than half of the shrublands in Arizona, although some stands are found on schist, diabase, and sandstones (Hibbert et al. 1974). Despite having shallow A and B horizons, the C horizon can be deep and is hydrologically important, with total porosities of 20–25 percent. The topography is characterized by mountain ranges dissected by steep-walled gorges, and canyons with slopes of 60–70 percent are common. Chaparral vegetation can be found on all aspects.

Although some areas of Arizona chaparral receive over 25 inches of yearly precipitation, streamflow in most channels is ephemeral or intermittent. The high evapotranspiration rates associated with a deep-rooted shrub canopy usually deplete most of the available soil moisture, so little is usually available for streamflow. Streamflow typically occurs during intense summer rains or during periods of rapid snowmelt in the spring. The dense brush canopy of Arizona chaparral found in areas of higher precipitation usually provides excellent soil protection with little or no runoff; therefore, erosion is limited to moderate rates even on the steep, dissected topography. However, frequent wildfires during the spring, summer, and fall months can completely denude the watersheds of their protective cover and, in doing so, drastically change the hydrology of the affected watersheds. After fire, even small amounts of rainfall can cause large amounts of runoff and erosion to occur. The high runoff and erosion rates result from the loss of the protective plant cover and the production of a water-repellent soil condition during the fire. These high erosion rates usually persist until the native shrub cover becomes reestablished.

Vegetation

Chaparral communities typically consist of "moderate to deep-rooted" evergreen (sclerophyllous) shrubs that attain maximum development on deeply weathered or fractured rock mantles and deep soils (Hibbert et al. 1974). The density of the shrub canopy varies from very sparse, open stands of brush to dense, almost impenetrable stands, depending on local climate and site conditions. Sparse brush stands are commonly found on areas receiving lower amounts of precipitation and southern aspects, while the densest stands receiving 25 inches or more of annual precipitation are located on northern and eastern aspects.

An interior chaparral zone is located between the desert shrubs and high forest, where shrubby and stunted tree communities, dominated by many species of unrelated taxonomy, exist as a single ecological type (Cooper 1922). As a result, Arizona chaparral is sometimes called the "in-between" biome because it grows between desert and grassland, or forest and grassland, and shares certain characteristics with all these biomes (Ricciuti 1996). Chaparral and encinal woodlands occur in mixtures adjacent to ponderosa pine stands on the slopes of isolated mountain ranges.

All the major shrub species are well adapted to periodic fires, meaning that they either sprout prolifically from the root or root crown and do not produce many seedlings (Pase 1969), or they produce abundant seed and do not sprout. Both mechanisms are used to quickly restore the shrub cover following fire. Depending on the site, the shrub species usually dominate within 30–40 years and are again subject to recurring fire. Chaparral stands consist of a heterogenous species mix in many locations, but often only one or two species dominate. Shrub live oak (*Quercus turbinella*) is the most prevalent species, with true (*Cercocarpus montanus*) and birchleaf (*C. betuloides*) mountain mahogany, Pringle (*Arctostaphylos pringlei*) and pointleaf (*A. pungens*) manzanita, yellowleaf (*Garrya flavescens*), hollyleaf buckthorn (*Rhamnus crocea*), desert ceanothus (*Ceanothus greggii*), and other shrub species also included in the chaparral mixture of shrub species. Annual and perennial grasses, forbs, and half-shrubs are present, particularly where the overstory canopy is open or only moderately dense. Stream channels often support a variety of oak trees (*Quercus* spp.) on the drier sites and can on occasion support true riparian vegetation in higher precipitation areas where near-perennial streamflow occurs (Brown 1978).

USES AND VALUES

In the past, Native Americans probably used plants and animals in chaparral areas for their sustenance. Later, mining and cattle ranching were important activities in chaparral areas for well over a century (Bolander 1986). Both silver and gold were mined throughout the chaparral areas in Arizona. Cattle grazing of chaparral stands was started in central Arizona around 1874 and within a single decade the vegetation type was almost entirely stocked or overstocked. Extremely high early stocking rates led to the disappearance of grasses in many chaparral stands, thereby increasing the cover and density of shrubs.

Chaparral continues to provide watershed protection on millions of acres of steep, deeply incised mountainous terrain in Arizona. In many cases these brush-clothed watersheds are immediately adjacent to urban development, and concerns about protecting the urban-wildland interface from wildfires have long been recognized and are continually increasing over time (Hickman 1987). Grazing is still important in some areas, and rangelands are often grazed year-long by livestock, because evergreen plants common to the shrublands provide a continuous forage supply in addition to understory grasses that remain or have been seeded. A variety of wildlife species (including some threatened and endangered species) are found in chaparral shrublands, with comparatively high populations often being concentrated in fringe areas. Although the recreational value (e.g., hiking, camping, and hunting) of chaparral may be considered lower than for the higher elevation vegetation types, the close proximity to major population centers insures heavy utilization for recreational purposes.

HYDROLOGIC RESEARCH AND APPLICATION

Research Activities

Long-term hydrologic research in the chaparral vegetation type was conducted as part of the Arizona Watershed Program, which evaluated the potential for augmenting streamflow by means of vegetation management (Fox et al. 2002). The research in chaparral was conducted throughout Arizona, but several specific studies were located on long-term experimental watersheds that represented environments extending from high precipitation sites near Lake Roosevelt on the Salt River north of Phoenix to drier sites located on Mingus

Mountain north of Prescott. These watersheds were instrumented for streamflow and climatic measurements, with data on some sites being collected for 30 years or longer. The effects of brush-to-grass conversions on streamflow response were investigated in depth because this treatment was shown during preliminary studies to potentially increase streamflow (Hibbert et al. 1974). In addition to the research conducted on permanent watershed sites, a large number of related studies were conducted on chaparral areas throughout Arizona.

To evaluate the effects on streamflow augmentation, brush control and conversion to grass were effected on the permanently established watersheds by the use of herbicides and prescribed fire, or combinations of the two. Additional studies of brush control on other sites included grazing by goats and mechanical methods, while numerous other studies on the chaparral type focused on wildlife, ecology, recreational aesthetics, postfire regeneration, and economic aspects of chaparral management. The research program ended with the results being applied to a large watershed demonstration project located on the Prescott National Forest.

Research Results

Much has been learned about Arizona chaparral over the years, although little research is currently being conducted. The past research focused on hydrologic processes in chaparral areas, showing that chaparral is a major source of streamflow if brush control can be achieved. It was found that replacing deep-rooted shrub plants with shallower-rooted grasses resulted in substantial increases in streamflow, particularly if the treated areas were located on the lower slopes near the stream channels. Brush control research was conducted using mechanical, chemical, and biological methods, as well as prescribed fire. Chemical control was most effective, but environmentally least desirable. Mechanical control was limited to small areas on relatively gentle slopes. Biological control with goats was limited because of the lack of interest in meat and wool products. Prescribed fire was effective for maintaining existing brush-to-grass conversion, but was not too effective for the initial conversion. However, when brush fields were converted to brush-grass mosaic patterns where more than half of the brush cover had been converted to grass, water was increased, wildlife habitat was improved, and there was increased grazing for domestic livestock (Hibbert 1986).

The long-term research data collected on the experimental watersheds includes daily streamflow records, climatic data, and regular vegetation inventories. Much of this field data remains in summarized form as part of the Rocky Mountain Research Station's historic data files. Although the results from many of these studies were published in scientific outlets, some information still remains as project progress reports and other unpublished documents. State-of-the-art summaries for several major topics of the chaparral research program were published in 1974 and 1975. These include watershed management (Hibbert et al. 1974), economics (Brown et al. 1974), and range management (Cable 1975), and research accomplishments on individual research areas in chaparral and other vegetation types studied as a part of the Arizona Watershed Program have also been summarized (Baker 1999). A more comprehensive summary of the program (including an annotated bibliography, long-term data file system, and published monographs) is now being planned as described below.

DATABASE DEVELOPMENT AND AVAILABILITY

Although a wealth of information from field research on Arizona chaparral exists, much of this information is not readily available, nor are recent comprehensive summaries of this information available. Efforts are currently being focused on summarizing all research findings and data and integrating this information into the existing watershed database, "Watershed Management in the Southwest" (http://www.ag.arizona.edu/OALS/watershed). This database includes a variety of topics on watershed management practices, displays accessible baseline data sets, and provides an interactive learning package on watershed management practices (Baker and Young 2000; Haseltine et al. 2002). This website is an ongoing International Arid Lands Consortium demonstration project. Recent efforts include GIS applications to allow users to search, chart or graph, and compare precipitation, streamflow, vegetation, and other watershed-based resource characteristics through a dynamic interface.

The website has proven useful to many people desiring this kind of information. Watershed managers throughout the world are formulating and implementing actions that result in the manipulation of natural and human resources to satisfy specific goals and objectives. Watershed management in the southwestern United States is particularly challenging because water supplies and associated resource productivity levels are limited. In addressing this challenge, watershed management research has led to a better understanding of the hydrology, ecology, and land-use potentials of the region's watershed landscapes. This research has helped in the establishment of management guidelines to meet the needs of the growing population, but the findings obtained are not necessarily widely known or readily accessible.

Most of the bibliographic materials describing Arizona chaparral have been identified, collected, and referenced. Individual annotations of these publications are being prepared for incorporation into the Watershed Management in the Southwest database. This bibliographic information will be brought together to provide an up-to-date synthesis of our current knowledge about Arizona chaparral. This information will be presented both as a scientific review and in a management format. Other watershed data (including long-term hydrologic records collected on chaparral watersheds) will also be formatted and entered into the watershed information database in a form similar to that currently available for ponderosa pine forests (Haseltine et al. 2002).

SUMMARY

Evergreen (or sclerophyllus) brushlands occupy large areas in Mediterranean climates throughout the world. Chaparral in the Southwest is typically found in the Upper Sonoran life zones in southern California and Arizona. Chaparral vegetation in Arizona is found mainly on the rough, discontinuous mountainous terrain south of the Mogollon Rim where it covers 3–6.5 million acres (about 1.3–2.4 million hectares). Arizona chaparral provides a protective cover for steep, erodible topography and as such provides an important source of water for streamflow. Much has been learned about Arizona chaparral during the last half century. However, this information is widely spread throughout the literature. Current efforts to bring this published information into a computer database for interested users will greatly enhance not only management but future research efforts concerning interior chaparral ecosystems.

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