

Ecology and Management of Oak Woodlands and Savannas in the Southwestern Borderlands Region

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Abstract—Management of the Madrean oak woodlands and the less dense and ecologically different oak savannas must be based on sound ecological information. However, relatively little is known about the Madrean oak ecosystems in spite of the fact that they cover about 80,000 km² in the southwestern United States and northern Mexico. Emory oak (*Quercus emoryi*), the dominant tree in most stands, is usually associated with other oak and juniper species. Trees are utilized for firewood, fence posts, and construction materials and oak acorns are gathered as food by local inhabitants. The woodlands and savannas provide important habitat for listed and sensitive wildlife species and forage for livestock grazing. Tree regeneration and water consumption are important considerations. Tree harvesting has been restricted because of heavy utilization in the past but coppice management could ease the supply situation. Recreational demands and fire management concerns in the woodlands are increasing as human populations grow in southern Arizona. This manuscript reviews the ecology and management of the overstory component of oak woodlands and savannas based on relevant literature from the southwestern United States and northern Mexico.

Introduction

The Madrean woodlands and less dense savannas are characterized by mild winters and wet summers. Brown (1982) classified them as belonging to the warm-temperate forests and woodlands biotic community and lists them as Madrean Evergreen Woodlands. There is a long history of human occupation in the woodlands but management of the Madrean oak ecosystems has become more complicated in recent years because of the increasing human populations in the region and societal demands. The woodlands and savannas are noted for their beauty and biological diversity, containing representative plants and animals from the Rocky Mountains to the north and the Sierra Madre of Mexico to the south. The ecosystems provide important wildlife habitat for federally listed and sensitive and more common species in the United States. The region supports viable ranching communities and is a recreational destination for people from urban areas. Trees are utilized for fuelwood, fence posts, charcoal, and construction materials (Ffolliott and Gottfried 1992) and oak acorns and pinyon seeds are gathered as food by local inhabitants. Woodland health and local water supplies are important considerations.

The exclusion of wildfires since the late 1800s because of overgrazing and fire suppression activities has resulted in increases in

woody vegetation and fuels and a decline in herbaceous resources. Large wildfires such as the Horseshoe 2 and Monument Fires in 2011 have become common. Private and public land managers are attempting to reverse this trend by using prescribed and managed fires (Gottfried and others 2007a). Management must be based on sound ecological information. However, relatively little is known about the Madrean oak ecosystems in spite of the fact that they cover about 80,000 km² in the southwestern United States and northern Mexico. This presentation focuses mainly on the ecology and management of the tree overstory component of Madrean woodland and savanna ecosystems based on research findings and relevant literature from the southwestern United States and northern Mexico.

Description of the Woodlands and Savannas

Emory oak (*Quercus emoryi*) is the dominant tree in most stands and is usually associated with other oaks, junipers and conifer species. The biological center for the ecosystems is in the Sierra Madre of Mexico but they extend northward into the Southwestern Borderlands Region and central Arizona (Brown 1982). The Madrean oak ecosystems are representative of arid and semi-arid dryland forests and woodlands of the world (McPherson 1992). The oak woodlands and savannas reach their best development in Arizona on the foothills of higher mountains, including the Pinalenos, Peloncillos, Santa Catalinas, Huachucas, and Chiricahuas (Ffolliott and Gottfried 2008a) and are found from 1219 to 1981 m in elevation. They grade into oak-pine and pine forests at the higher elevations and grasslands or desert shrub at the lower extreme. Temperatures range from summer highs in or above 32 °C to freezing in the winter. Average annual precipitation is

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between 254 to 508 mm, depending on elevation, with approximately half occurring during the summer monsoon period.

The woodlands and savannas are characterized by evergreen oaks generally 6 to 15 m in height. Emory oak is often associated with Arizona white oak (*Q. arizonica*), and Mexican blue oak (*Q. oblongifolia*). Gray oak (*Q. grisea*), a generally small tree, might replace white oak in western New Mexico. Silverleaf oak (*Q. hypoleucoides*) and netleaf oak (*Q. rugosa*) are found at higher elevations in the Madrean oak ecosystems. A relatively large number of additional oak species including Chihuahua oak (*Q. chihuahuensis*) and *cusi* or *encino roble* (*Q. albocincta*) occur in Mexico (Brown 1982). On many sites, Emory oak is associated with conifers such as alligator juniper (*Juniperus deppeana*), redberry juniper (*J. coahuilensis*), border pinyon (*Pinus discolor*) or Mexican pinyon (*P. cembroides*). Chihuahua pine (*P. leiophylla*) often occurs in drainages. A number of pine species are found with oak at higher elevations throughout the border region and into the oak-pine communities of Mexico (Brown 1982). The density of shrubs varies by sites. Some shrub species are velvetpod mimosa (*Mimosa dysocarpa*), redbarberry (*Mahonia haematacarpa*), and alderleaf mountain mahogany (*Cercocarpus montanus*). Grasses include several species of grama (*Boutelous* spp.), bullgrass (*Muhlenbergia emersleyi*), and Texas bluestem (*Schizachyrium cirratum*). More complete lists of grasses, forbs, shrubs and half-shrubs are listed in Brown (1982) and Ffolliott and Gottfried (2008a).

Differences Between Woodlands and Savannas

Ffolliott and others (2008b) examined the differences between the woodlands in the San Rafael Valley on the south side of the Huachuca Mountains in Arizona and at the lower elevation, more open oak savannas at Cascabel on the east side of the Peloncillo Mountains in New Mexico. The oak savannas were more open and variable in the spatial distribution of overstory trees than the oak woodlands. These researchers tallied seven tree species at Cascabel but only four at the San Rafael site. Emory oak accounted for 60% of the overstory trees at Cascabel and junipers 15%. On the San Rafael site, Emory oak was 89% of the overstory species composition and junipers were 1%. Arizona white oak made up 12% of the overstory at Cascabel and 9% at San Rafael. There were about 445 trees/ha at San Rafael compared to 148 trees/ha at Cascabel. The number of small and large trees was greater at San Rafael but the number of saplings was similar for the two sites. Herbaceous plant species composition was similar on the two areas with most species of grasses and forbs being perennial.

Autecology

Oak trees regenerate from seed or vegetatively from root or stump sprouts. Borelli and others (1994) studied natural regeneration on six areas of the Coronado National Forest of Arizona that had been harvested for fuelwood and grazed by livestock. Emory oak, Arizona white oak and other tree species occurred on the study sites. Fifty-six percent of the regeneration was stump sprouts, 25% were root sprouts, and 19% were seedlings. Nearly 40% of the plantlets were less than 0.3 m in height, 35% were between 0.3 and 1.0 m, and 25% were greater than 1 m but less than 1.4 m. An average of 9.2 % of the sample plots was stocked with regeneration varying from 1.2 to 15.4% depending on area. The average number of plantlets on the six areas was 240 stems/ha with a range of 29.7 to 385.5 plantlets/ha. The authors caution that the relatively low number of seedlings could have been influenced by a local drought that could have influenced acorn production. Pase (1969) reported that conditions favorable for Emory

oak establishment only occurred once every 10 years in southeastern Arizona. However, large numbers of acorns probably are consumed by mammals and insects. The study by Borelli and others (1994) was conducted in one year; however, surveys over a number of years are necessary to get a true picture of regeneration in the oak woodlands.

Nyandiga and McPherson (1992) evaluated conditions needed for germination of Emory oak and Arizona white oak. Emory oak acorns mature in about a year and then fall and germinate in July through August. Arizona white oak acorns fall and germinate in November and December. Germination generally occurred within the first 30 days for both species. These researchers found buried acorns had a greater viability than acorns that remained on the soil surface or were under litter. However, seed viability generally declined the longer an acorn was buried. Acorn viability and germination was twice as high under tree canopies as in open grassland sites. Adequate soil moisture will enhance germination and emergence (Germaine and others 1996). Germination percentages were 21 and 73% for Emory and white oak, respectively. Emory oak acorn size is correlated positively with viability, germination, and seedling size (Germaine and others 1996).

Sanchini (1981) studied growth and mortality of Emory oak and white oak in 1981 (cited in McPherson 1992; Touchan and Ffolliott 1999). He determined that mean annual diameter growth rate for Emory oak was 0.35 cm/yr and for Arizona white oak was 0.24 cm/yr. Growth-ring data, while difficult to measure in oak species, indicated that Emory oak reaches a maximum age at 200 years while white oak achieves this status in 250 years. The primary causes of death are fire, ice storms, and drought.

Ffolliott and others (2008b), in investigating the differences between woodlands and savannas confirmed that tree volumes per hectare were higher in the denser woodlands than in the savannas. Volumes of stem wood varied from less than 2 to more than 100 m³/ha. The average volumes for the two sites were about 15.86 m³/ha compared to 3.91 m³/ha. Annual volume growth rates in the dense stand at San Rafael were 0.0077 ± 0.0010 m³/ha while they were 0.0049 ± 0.0015 m³/ha at Cascabel. Growth was relatively rapid in the early and middle stages of development but declined in older trees.

Fire

Fire was the main disturbance in the Madrean oak woodlands and savannas prior to European settlement in the late 1800s. Fires probably occurred every 10-20 years at the lower end of the oak woodlands. These values were extrapolated from literature about forest fires in stands that are adjacent to semi-desert grasslands (McPherson 1992). Fire histories are difficult to determine for the oak woodlands since fire scars are not evident; however, conifers in the affected stands do display fire scars. Fire frequencies and extent have declined in the last century. The importance of fire for ecosystem health is just being recognized (Gottfried and others 2007a). Two prescribed fires and a wildfire in the savanna at Cascabel reduced overstory tree density of oaks and junipers by 21% (Ffolliott and others 2011) but resulted in significant increases in early-growing and late-growing grasses in the understory (Ffolliott and others 2012). Basal sprouting at Cascabel was observed on 37.4 % of the surviving oaks regardless of species. A wildfire in the Catalina Mountains, north of Tucson, resulted in 11.1% mortality of Emory oak and 14.2% mortality of Mexican blue oak. Emory oak produced more sprouts per tree after the fire than did Mexican blue oak (Caprio and Zwolinski 1992).

An inventory in six sites where Emory oak dominated found woody fuel loadings ranging from 0.36 to 7.82 tons/ha (Ottmar and others 2007). Measurements of litter and duff ranged from 3.26 to 10.72 tons/ha with soil surface cover of 40 to 82%. A study in pine-oak

woodlands in Arizona and northern Mexico found that sites with high fire frequencies accumulated less fuels than sites with low fire occurrences (Escobedo and others 2001). Sites in Mexico, which had 9 to 13 fires since 1900, had total fuel loadings of 11.22 tons/ha while sites in Arizona, that had from 0 to 5 fires during this period had total fuel loadings of between 22.19 and 48.43 tons/ha. Higher fuel loadings increase the potential for high-intensity stand-replacing fires.

Silviculture

The oak woodlands, and to a lesser extent savannas, were harvested heavily during the period of European settlement for mining and construction timbers, fuel for the smelters and stamp mills, fence posts, and for domestic uses by the miners and their families. The overharvesting did not eliminate the oak woodlands but resulted in a decrease in large trees and stand densities (Propper 1992). Interest in oak fuelwood increased in the 1970s and 1980s because of fuel shortages and increased oil prices. Federal lands provided 60% of the fuelwood in southeastern Arizona. Managers were forced to restrict harvesting during this period to guarantee sustainable fuelwood resources (Bennett 1992). Harvesting was limited to 3.62 m³ (1 cord)/household/year in 1992.

Fuelwood harvesters were further restricted to leaving stumps less than 15-cm in height and slash accumulations of less than 46-cm in height (Bennett 1992). Trees designated for harvesting were marked by managers in what appeared to be either single-tree selection or thinning from below depending on stand conditions and objectives. On some Forest Service districts, fuelwood harvesting was limited to trees that were smaller than 23 cm at the base. Larger trees were maintained because of their importance to wildlife.

Vigorous sprouting of oak species after the removal of the tree indicates that coppicing might form a basis to obtain satisfactory regeneration since stump and root sprouts are more common than seedlings (Borelli and others 1994). Furthermore, Touchan and Ffolliott (1999) determined that the fuelwood rotation for Emory oak sprouts to reach a diameter at root collar of 15 to 20 cm can be reduced from 100 years to approximately 30 years by thinning sprouts on a stump. Growth of residual sprouts depends on the number of stems retained. Net growth/stump is lower if fewer stems are left. While there was no difference if 1, 2, or 3 stems remained compared to the control, which was not thinned, mean annual growth per sprout increased for the single stem after its eighth anniversary.

Farah and others (2003) found that stump diameter was not a consistent factor that affected growth and volume of the thinned coppice 10 years after the thinning treatments were applied. Average growth and volume was greater for the 1-stump sprout treatment than for the other options at that time. The researchers recommended that stump sprouts be thinned initially in years 6-8 after the top is removed. Another subsequent thinning in year 15-20 should retain one sprout. Three stump-sprouts can be retained if structural diversity to benefit wildlife is a management goal.

Water Use

Water use by Emory oak has been studied with the heat pulse velocity method in the San Rafael Valley (Ffolliott and Gottfried 2000; Gottfried and others 2007b; Shipek and others 2004). The study site included an unharvested stand and an area harvested by the coppice method that included sprouts and residual uncut trees (standards). Average daily water use by mature trees averaged 17.5 liters/day,

while water use by sprouts averaged 4.0 liters/day. These averages for standards and sprouts were then extrapolated to a stand basis. The harvested stand used more than 3,150 liters/ha/yr compared to 1,900 liters/ha/yr for the uncut stand (Ffolliott and Gottfried 2000). The harvested stand contained 430 standards and 927 sprouts per hectare, while the uncut area contained 452 mature trees and 27 sprouts per hectare. Water use by the harvested site with the large number of sprouts was equivalent to 80% and water use by the unharvested site was equivalent to 45% of the annual precipitation.

Shipek and others (2004) measured water use by oak sprouts that had been thinned to retain 1, 2, or 3 sprouts per stump or not thinned. Stumps with one sprout used an average of 7.48 ± 0.31 liters/day compared to the controls that used 35.3 ± 1.72 liters/day. The values for stumps thinned to two or three stems were intermediate. Transpiration for stands with standards and sprouts thinned to 1-sprout per stump and stands with unthinned stumps was equivalent to 34% and 80% of the annual precipitation, respectively.

Ffolliott (2004) developed an annual water balance for Emory oak in southeastern Arizona. The calculations assumed that annual precipitation averaged 450 mm. This amount was reduced by 45 mm for interception by tree crowns; the remaining water was partitioned mainly to infiltration into the soil (325-350 mm), and transpiration (155-345 mm). Approximately 20-45 mm, about 4 to 10% of the input, remained for streamflow. Thirty-four to 77% of the annual precipitation was lost through transpiration.

Management Implications

Management of the Madrean oak woodlands and savannas must be based on sound ecological information. Managers must understand tree regeneration requirements to develop silvicultural prescriptions that will maintain healthy oak woodlands and savanna ecosystems. Vegetative reproduction by oaks and some junipers gives managers options that are not available to those working with non-sprouting tree species. Thinning oak sprouts will shorten the cycle for tree products. Public and private land managers are attempting to reintroduce fire into the region but these efforts also are often hindered by incomplete ecological information about fire effects and fuel conditions. These data are currently being collected on the Cascabel Watersheds and elsewhere to support the fire programs. Research on tree and woodland water use and the impacts of silvicultural treatments such as coppicing, should provide a basis for management prescriptions in oak dominated watersheds.

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