# Silvics and Silviculture in the Southwestern Pinyon-Juniper Woodlands

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***Abstract***—*Southwestern pinyon-juniper and juniper woodlands cover large areas of the western United States. The woodlands have been viewed as places of beauty and sources of valuable resource products or as weed-dominated landscapes that hinder the production of forage for livestock. They are special places because of the emotions and controversies that encircle their management. Silvicultural methods can be employed on better sites to meet multiresource objectives and to maintain the health and sustainability of the woodlands. Silviculture must be based on an understanding of the silvics of the woodlands and their major species. Single-tree selection and diameter-limit prescriptions are being evaluated in central Arizona. Silvopastoral prescriptions that can maintain the tree component and provide for increased forage production and improved wildlife habitat are being tested in New Mexico.*

## Introduction

Why are pinyon-juniper and juniper woodlands special places? Is it because they are uncommon? There are more than 47 million acres of coniferous woodlands within the western states and they are important landscape components in seven states (Evans 1988). The woodlands are divided into the Great Basin and southwestern woodlands. Pinyon-juniper woodlands cover approximately 7.7 million acres and associated juniper woodlands cover an additional 3.1 million acres in Arizona. Together the two woodland types, which will be considered together for this paper, comprise 56 percent of the forestland within the state (O'Brien 2002). The woodland types also are important in New Mexico, where they cover about 56% of the forestland or 8.5 million acres (Van Hooser et al. 1993). The woodlands are special places because of the emotions and controversies that their management generates among the diverse human populations of the Western United States. Some people view them as areas of natural beauty, an integral part of many southwestern national parks such as the Grand Canyon, Mesa Verde, or Zion. The woodlands are important to the cultural traditions and activities of the region's American Indian and Spanish people, some of whom depend on the woodlands for fuelwood, timber, and pinyon nuts; for habitats for game and species with ceremonial importance; and for medicinal crops and for grazing livestock. They provide a source of employment in areas where jobs are often scarce. The woodlands provide important watershed cover and are of increasing importance for recreation by the region's growing urban populations. On the other side are some interests who hold that the trees are weeds that are invading natural grasslands and that the best management is to remove them so that more forage can be produced for livestock. There are, of course, large ranges of opinions that fall between the two extremes.

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Pinyon-juniper woodlands produce a large variety of natural resource products and amenities. Silvicultural prescriptions can be used to sustain productivity of these lands for multiple resources and to maintain stand health. Silvicultural activities have the best chance of ecological and economic success on better sites. Approximately 88 percent of the pinyon-juniper and juniper woodlands have been classified as "high-site" indicating that they have the potential for growing wood products on a sustainable basis (Conner and others 1990). Silvicultural prescriptions can be formulated to enhance other resources such as wildlife habitat or forage for livestock.

The objectives of this paper are to review the silvics of southwestern pinyon-juniper woodlands and their component species and the relative merits of silvicultural options that have been applied to or proposed for woodland stands. The paper will then describe preliminary results from two ongoing silvicultural case studies. The first study involves an evaluation of single-tree selection and diameter-limit prescriptions in northern Arizona. Silvicultural prescriptions often are prepared to primarily benefit other resources such as wildlife habitat or forage production where the impacts on the tree products are secondary. The second case study describes three silvopastoral treatments that recently have been completed in central New Mexico to demonstrate that tree management and forage or wildlife habitat management can be compatible.

## Pinyon-Juniper Woodland Silvics For Silviculturists

### *Tree and Stand Characteristics*

The southwestern pinyon-juniper woodlands vary in species composition, density, and physiographic characteristics. At least 70 plant associations have been recognized in Arizona and New Mexico (Moir and Carleton 1987). Colorado pinyon (*Pinus edulis*), which has two-needles on a fascicle, is the most common pine within the type. Pinyon grows to between 9 and 35 ft in height and 5 to 18 inches in diameter. These slow growing trees may attain ages of 300 years or older on some sites in Arizona and New Mexico. Stands may contain one or several species of junipers; the four main species are oneseed juniper (*Juniperus monosperma*), Utah juniper (*J. osteosperma*), alligator juniper (*J. deppeana*), and Rocky Mountain juniper (*J. scopulorum*). Junipers usually are less than 40 ft tall. They can attain great age, but it is difficult to age most juniper trees because of the large number of false or missing rings. The floristic diversity in the woodlands is reflected in their herbaceous components rather than in the tree cover. While the total understory biomass may be small, the total number of species associated with the widely distributed woodlands is large (Gottfried and others 1995).

Most natural stands have an uneven-aged structure. In Arizona, total tree volume per acre averages 698 $ft^3$ in the pinyon-juniper type; net annual volume growth averages 6.4 $ft^3$/yr (Conner and others 1990). Clary (1987) reported that herbaceous understory plant biomass ranged from 78 to 1,042 lb/acre on seven sites in Arizona and New Mexico.

### *Autecology*

Pinyon trees are generally monoecious, although dioeciousness may occur in trees stressed by drought or insect attack. The pine produces a relatively large, wingless seed, which weighs less than 0.01 oz (Ronco 1990). Seed crops are usually produced every four to seven years, depending on weather and site conditions. Cones mature in three growing seasons and seeds are released in mid-September and October. About 300 lbs of seed are produced on an acre in a good year (Ronco 1990). Seeds have a high nutritional value and are important food for wildlife. They are harvested by local human populations for personal consumption or sold commercially. Seed and cone insects sometimes reduce the amount of seed available for regeneration, wildlife, or human consumption.

Some of the southwestern junipers are monoecious, such as Utah juniper, and some are predominately dioecious, such as oneseed juniper (Johnsen and Alexander 1974). Seed-bearing age varies by species and by climatic conditions during seed development. Juniper "berries" contain one to four seeds depending on the species. The flowers of most southwestern junipers develop in the spring and the fruit ripens in the fall; some species require two years for the seeds to mature. Alligator juniper is the only major woodland tree that has the ability to regenerate vegetatively when the main trunk is injured.

The heavy mature seeds generally fall to the ground under or next to the tree crowns. Birds and small mammals are important for the wide dispersal of both pinyon and juniper seeds. Balda (1987) reported that four species of corvid birds, scrub jays (*Aphelocoma coerulescens*), pinyon jays (*Gymnorhinus cyanocephalus*), Clark's nutcracker (*Nucifraga columbiana*), and Steller's jay (*Cyanocitta stelleri*), are responsible for caching thousands of pinyon seeds during a year with a large crop. The birds cache the seeds in the ground and return in the spring to feed on the buried seeds. Seed that escapes the birds and rodents provide a main source for tree regeneration. Several birds, such as Townsend's solitaire (*Myadestes townsendi*), are important dispersal agents for juniper seed. Germination of oneseed juniper is enhanced after passing through a bird's digestive tract (Johnsen 1962).

Pinyon will germinate in the spring, but if conditions are not suitable, germination will be delayed until the summer monsoon period (Gottfried and others 1995). Most juniper seed germinates in the spring, but germination may be delayed because of embryo dormancy, chemical inhibitors, or impermeable seed coats. Juniper germination is generally less than 50 percent while pinyon germination is between 83 and 96 percent. Both trees are shade-intolerant, but germination and establishment is greater in the protection of mature trees, shrubs, and logging debris. Large cohorts of seedlings in the Southwest have been linked to the combination of bumper seed crops and favorable climatic conditions during the initial germination and establishment period. Seedling growth is slow, with root growth exceeding top growth in the early years. Growth of older trees of both genera also is relatively slow; a pinyon may grow to 12 inches in diameter in 150 years on a good site (Ronco 1990). However, pinyon grows at twice the rate of junipers (Conner and others 1990).

## *Synecology*

Pinyon-juniper woodlands occupy the warmest tree-dominated zone in the southwestern United States. They are found from about 4,500 to 7,500 ft in elevation where annual precipitation ranges from 12 to 22 inches. Precipitation is influenced by geography, topography, and elevation. Differences in species composition have been related to the proportion of winter and summer precipitation (Springfield 1976). Woodlands are found on soils derived from a variety of parent materials.

The woodlands grade into juniper savannas, grasslands, oak woodlands, and brush-dominated vegetation zones on drier sites and into ponderosa pine (*P. ponderosa*) forests on moister, higher elevation sites. Junipers, which are more drought-tolerant, dominate on drier sites but the proportion of pinyon increases with increased elevation and available water. The upper and lower ecotones have shifted over time because of wildfires and decade-level climate fluctuations. The extended drought of the 1950s caused extensive mortality of all woodland tree species and caused shifts in ecotonal areas throughout the region. The woodlands increased at higher elevations replacing ponderosa pine stands, and grasslands or shrub ecosystems became more common at the lower elevations. Several insects, diseases, and parasites attack the trees, and insect infestations during drought cycles can result in high mortality over relatively large areas. Outbreaks of a bark engraver beetle, the pinyon ips (*Ips confusus*), during the current period of drought, are causing heavy pinyon mortality in the Southwest and southwestern Colorado (USDA Forest Service 2004). The juniper bark beetle (*Phloeosinus christatus*) is contributing to the mortality of drought-stressed junipers in areas throughout the Southwest. Pinyon dwarf mistletoe (*Arceuthobium divaricatum*) is an important parasite that causes locally severe damage and mortality. True mistletoes (*Phorodendron* spp.) are common on junipers but generally do not cause heavy damage. Fire was the most common natural disturbance prior to the introduction of livestock by European-American settlers. Fires were uncommon in the recent past because of the loss of a healthy and continuous herbaceous understory that could carry fire through the stands. Fire exclusion has been linked to increases in tree stand densities in the forests, woodlands, and savannas of the Southwest. However, pinyon-juniper woodlands will burn under severe conditions, and one of the impacts of the recent drought and associated insect mortality has been an increase in the intensity and frequency of wildfires within the woodlands. Successional stages in the woodlands usually contain the same species but in differing densities and dominance (Evans 1988). Junipers are the first tree species to return to a site after a fire or other disturbance but are often followed and replaced by pinyon.

## Silviculture For Multiple Resources

There was a shift in attitudes toward pinyon-juniper woodlands after the oil crisis of the mid-1970s when the demands for firewood increased dramatically throughout the Southwest. Managers began to consider woodland management that would sustain healthy stands that could be managed for multiple resources. However, not all sites can produce the full range of resource benefits, and this must be considered in land management planning. Silviculture has the best potential for success on the most productive sites that can sustain the production of tree products based on soil properties, slope, and the presence of regeneration (Van Hooser and others 1993). Most pinyon-juniper woodlands in the Southwest have been classified as high-sites. There is a renewed interest in silvicultural systems and methods for the woodlands, especially on the more productive high-sites.

A number of silvicultural regeneration methods can be prescribed for pinyon-juniper woodlands (Bassett 1987), depending on the land manager's desired biological and economic objectives. Single-tree selection has a number of advantages since it favors natural regeneration of the main tree species, protects the site from wind and water erosion, can maximize vertical diversity important for wildlife, is easier to manipulate composition, and is esthetically pleasing (Bassett 1987). There are disadvantages since it is more difficult to plan and administer wood sales, residual trees can be damaged, horizontal diversity may be reduced over large areas, prescribed burning is not possible, and dwarf mistletoe control is difficult.

Other prescriptions, such as two-step or three-step shelterwood and group selection, are used in the Southwest. Clearcutting, which is the easiest prescription to plan and administer, is discouraged unless the objective is to increase forage and browse for livestock and wildlife, or to control dwarf mistletoe. Clearcuts are difficult to regenerate because of poor seed dispersal, except where alligator juniper, which sprouts, is a major stand component. Clearcuts are the least esthetically pleasing. However, the harvesting of narrow stripes of woodland or small openings is beneficial for deer (*Odocoileus* spp.) and elk (*Cervus elaphus*) because large homogeneous landscapes are broken up, providing food and adjacent hiding-thermal cover. While some private landowners may continue to remove the tree cover, many have recognized the values for their lands and livestock operations of creating mosaics of openings and woodlands, or of attempting to create savannas by retaining larger trees or groups of trees. Artificial regeneration of woodland species is not common because of the high expense but is used to reclaim mining sites and to restore vegetation around recreational areas following wildfires. However, artificial regeneration may be necessary if pinyon is to be restored in drought and insect-impacted woodlands. One treatment will not fit all situations and several may be valid within a landscape. New ecological knowledge and management techniques will contribute to future activities within the southwestern pinyon-juniper woodlands.

# A Silviculture Experiment

The Rocky Mountain Research Station, in cooperation with the Black Mesa Ranger District of the Apache-Sitgreaves National Forests, Arizona, has completed the field phase of a study of several woodland silvicultural treatments, including single-tree selection and diameter-limit prescriptions, compared to changes in unharvested control plots. The diameter-limit prescription also could be characterized as the removal harvest of a one-cut shelterwood or an overstory removal, except that an upper diameter for residual trees was specified. The prescriptions were selected because they were being conducted by the District or were being considered for future management. The objectives of the treatments were to evaluate the effects of treatment on overstory characteristics and tree regeneration and to demonstrate the feasibility of these prescriptions for woodland management. A case study will be reported based on results from one of the single-tree selection plots and from one of the diameter-limit plots. Prescription planning was coordinated with the forest managers who administered the treatments as commercial fuelwood sales. Treatments had to be practical, considering the constraints of time and money, to be accepted by managers and fuelwood contractors.

## *The Study Area*

The long-term study is located on the Black Mesa Ranger District of the Apache-Sitgreaves National Forests. The study site is 7 miles northeast of the town of Heber, which is approximately 110 mi northeast of Phoenix. Topography on the study site is relatively flat. Ephemeral stream channels that drain the area were not included in the study plots to reduce variability. Elevation is approximately 6,600 to 6,800 ft. Precipitation occurs during two seasons. Winter precipitation, usually snow, is produced by frontal storms that originate in the Pacific Ocean while summer monsoon precipitation occurs as convectional rains from moisture from the Gulf of Mexico. Winter storms produce about 55 percent of the average annual precipitation (with standard deviation) of 19.0 ± 3.3 inches, as measured at the Ranger District office from 1981 through 2001. Precipitation for the 12-year study period was 18.5 ± 4.2 inches. The soils are derived from undivided Cretaceous sedimentary rocks, mostly limestone, shale, and sandstone; most are classified as Lithic Ustochrepts or Udic Haplustalfs and have fine loams in the surface horizon (Laing and others 1987).

The woodland in the study area consisted of Colorado pinyon, oneseed juniper sites, alligator juniper, and occasional ponderosa pine. Pinyon is the most common tree species. Stand conditions in the general area had an average basal area of 101 ± 23.5 ft$^2$/acre and average canopy cover of about 40 percent (Laing and others 1987). The primary plant association is *Pinus edulis/Bouteloua gracilis* (USDA Forest Service 1997), which is one of the most common associations in Arizona and New Mexico. Cattle grazed the area during part of the study period, but use was minimal. Local residents had removed some large trees over the years prior to the study.

The preliminary results reported here for the single-tree selection and diameter-limit silvicultural treatment are from one replication (block) of a larger study. The prescriptions were applied to 10-acre plots. Each treatment plot contained 12 permanent circular 0.20-acre inventory plots. The treatments were randomly assigned among the four plots in the block, and inventory plots were located using a stratified random design. Measurements included species, diameter or equivalent diameter at root collar (d.r.c. or e.d.r.c.), height, disease or insect damage, crown characteristics, and tree defects or utilization. Equivalent diameter is necessary because most of the oneseed junipers are multi-stemmed with branching occurring at or near ground level. Tree seedlings were located within each inventory plot and pinned and numbered for re-identification. The blocks were measured in 1989; prior to treatment; in 1993; after harvesting; and in 2000. Changes in small mammal populations, understory responses, and soil-plant nutrient dynamics associated with the treatments were studied in some of the silvicultural treatment blocks (Kruse 1999, Kruse and Perry 1995).

## *Treatment Design and Administration*

### Single-Tree Selection

The single-tree selection prescription was based on the 1989 pre-treatment inventory that measured a total of 456 trees/acre and 150 ft$^2$/acre. The general objective was to sustain the production of tree products while maintaining the stand’s uneven-aged structure, provide micro-sites for tree regeneration, improve stand health, maintain hiding and thermal cover for wildlife, and produce an aesthetically acceptable landscape. The immediate objective was to reduce the basal area of trees greater than 4 inches in diameter by about 60 percent while maintaining the existing structure. The desired maximum diameter for crop trees was 13 to 14 inches; however, some larger junipers were retained for wildlife and aesthetic considerations.

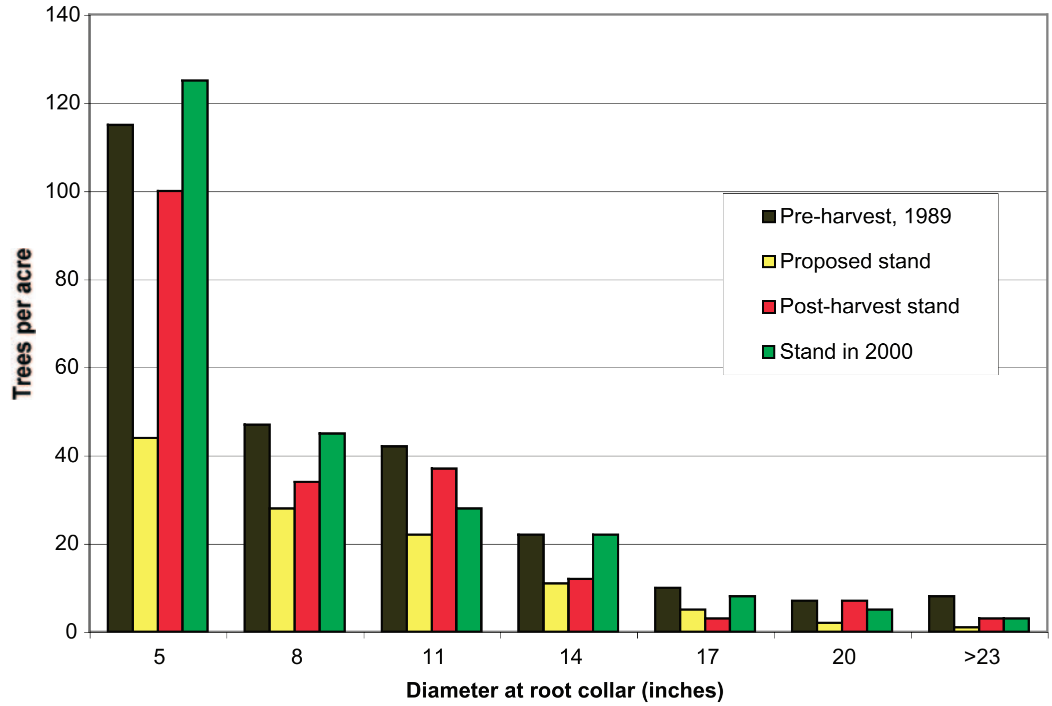


**Figure 1**—Initial, proposed, and post-harvest stand conditions in 1993 and 2000 for the single-tree selection block. The graph shows the changes related to the treatment and to growth and mortality among the trees. Diameter is measured at the root collar (d.r.c).

These large trees were considered when the inverse-J diameter distribution curve was defined. Regulation was directed to trees that were equal to or greater than 4 inch d.r.c., about 95 percent of the total basal area, because smaller trees do not have an economic value and it would be difficult to justify the tree marking costs to achieve the desired diameter distribution in these smaller trees. One objective was to keep the existing distribution of species in the stand. The desired number of trees in each diameter class was calculated using a "*q*-value" of 1.25 (figure 1), and a basal area target of 60 $ft^2$/acre. The *q* is the ratio of the geometric series that defines the number of trees in each successive diameter class (Husch and others 1972).

The Ranger District marked the residual trees within the harvesting block. The crew consisted of three people: a tally keeper and two measurers/markers. The crew was supplied with the desired stand structure and noted residual trees as they were measured and marked. Leave trees exhibited good vigor, had a potential for seed production, and were free of insect or disease problems. Higher basal areas were allowed in part of the area to keep high-quality trees. The guides also specified that cutting should not create new or enlarged openings of more than 0.25 acre. Markers used a 10 BAF wedge to maintain an average basal area of 60 $ft^2$/acre, and they were within 0.9 $ft^2$/acre of the target.

## Diameter-Limit Prescription

The diameter-limit prescription was applied to another 10-acre plot. The stand on an average acre in the block had 438 trees and 142 $ft^2$ of basal area. The prescription called for the removal of all trees equal to or greater than 7 inches in diameter and the protection of remaining trees and regeneration classes. This prescription was similar to one of the common practices in the area, but one that has not previously been carefully evaluated. The logging debris was not burned on one block. Burning is a common practice but currently is questioned because of damage to residual trees, and because high-intensity fires can have a negative effect on soil nutrient dynamics (Teidemann 1987). Retaining the debris provides protected regeneration sites for trees and herbaceous plants, slows surface runoff and sedimentation, provides shelter for small mammals, and in some rural areas, is an important source for firewood (Gottfried and others 1995).

# Results and Discussion

## *Single-Tree Selection*

The block was harvested in December 1992; approximately 225 $ft^3$/acre were removed. Although the diameter distribution for larger trees was achieved (figure 1), stand density goals were not achieved because of the reluctance of the harvesters to cut smaller diameter trees. The post-harvest *q*-value met the goal of 1.20 but the harvesting did not achieve the basal area reduction goal for trees equal to or greater than 4 inches in diameter; only 36 percent of the stand basal area was removed leaving about 90 $ft^2$/ac. The graph shows the post-harvest and the present stand, including movement of trees among the diameter classes. One solution in the future is to give greater consideration to market preferences; it may be more realistic to regulate trees in the 7-inch and larger classes than to include the smaller sizes of trees. However, the impacts of dense groups of small trees on residual tree and stand growth still need to be determined. Approximately 678 trees/acre in the regeneration classes (85 percent) survived the harvest. The treatment did achieve the overall goals of retaining tree productivity, wildlife habitats, and of aesthetics. While an economic analysis was not part of the study, Ranger District personnel felt that they would recover the additional administrative costs from the amount received from a logging contractor for the wood. The effects of treatment on individual residual tree growth relative to growth on similar sized trees in the control block will be analyzed, as will the impacts of treatment on tree regeneration. However, the number of trees/acre increased in many size classes from 1993 through 2000, indicating increased growth of residual trees (figure 1).

## *Diameter-Limit Prescription*

The diameter-limit harvest, without debris burning, removed 112 $ft^2$ /acre of basal area or 79 percent of the initial overstory cover, retaining 30 $ft^2$/acre, and removed 37 percent of the trees per acre, leaving 275 trees/acre. The harvest removed about 375 $ft^3$ /acre of volume. Approximately 89 percent of the tree seedlings survived harvesting (515 trees/acre). Stand density in the diameter-limit block was similar in 1993 and 2000.

Some of the reductions in both blocks can be attributed to attacks and mortality by ips. The infestation that Wilson and Tkacz (1992) described occurred a short distance to the north of the study area. A 1993 inventory of herbaceous vegetation in harvested and un-harvested blocks indicated that harvesting increased the production of blue grama (*Bouteloua gracilis*) (the primary understory species), perennial forbs, and total herbaceous cover (Kruse and Perry 1995). Total production, for example, was 172 lb/acre in the treated blocks and 70 lb/acre in the un-harvested blocks.

# Silvopastoral Prescriptions

The lack of commercial markets for alternative, higher-value juniper wood products limits management practices (Ffolliott and others 1999). In February 1999, the USDA Forest Service's Forest Products Laboratory and Rocky Mountain Research Station received a CROPS (Creative Opportunities) grant for the restoration demonstrations and workshops for management of pinyon-juniper savannas in New Mexico. The grant is part of an effort to develop new products and markets for the juniper resource that could improve the economics of treating these woodlands, not only for range restoration but also for more intensive management for sustainable tree products. Ongoing research projects at the Forest Products Laboratory in Madison, Wisconsin, have demonstrated the potential of value-added products from the wood and fiber of oneseed juniper. P & M Signs, Inc. in Mountainair, New Mexico, is using extrusion and injection molding technologies in the manufacture of sign panels and sign posts. The use of wood chips and fiber would increase the economic potential of woodlands dominated by smaller trees that are difficult to harvest for traditional products. The proposed manufacturing facility could influence management on a large part of the 252,402 acres of woodlands in Torrance County with its net volume of about 102,579,000 $ft^3$ (Van Hooser and others 1993). The facility would have a positive effect on employment and the general economy of Mountainair and Torrance County and adjacent areas.

Approximately 61 percent of the woodland area and 57 percent of the woodland volume are on private land in Torrance County. The goal of the project is to demonstrate to the landowners several ecosystem restoration prescriptions with the potential for economic wood and range products recovery while resulting in sustainable management. The plan is to use different techniques on three areas and to compare results with an adjacent untreated control site. The activity has resulted in two field workshops to provide participants with overviews of restoration approaches and in an evaluation of the economics of restoration including the value of products compared to the cost of treatments. Although the prescriptions were designed to integrate range and tree production objectives, the prescriptions could also be useful for treatments in pinyon-juniper dominated wildland-urban-interface areas.

## *The Demonstration Site*

The demonstration was conducted within an area on the Greene Ranch in the Estancia Basin of Torrance County, New Mexico. New Mexico State University is studying the economics of the value of wood products relative to treatment costs in the same general area. It has six 1-acre plots that have been harvested by mechanized equipment (Bobcat) or by chainsaws (Maynard and others, unpublished report). Stand densities were reduced to 5-10 $ft^2$ /acre.

The site contains sandy soils that are 5 to 6 ft deep, and are representative of a band of soil that extends across the county. It is within a mile of the Gran Quivera Unit of the Salinas Missions National Monument and US Highway 54. The site is unique in the number of huge oneseed junipers that it supports; many have straight trunks with large diameters at breast height. This area is considered old-growth by local ecologists. The larger trees may date from the period when Gran Quivira was abandoned in the 1670s.

There is little surface erosion on the site that can be related to water movement probably because of high infiltration capacity of the sands. The area is grazed in winter but has a good cover of grasses, including blue grama (*B. gracilis*), side-oats grama (*B. curtipendula*), and sand bluestem (*Andropogon hallii*). Most grass is under the protection of larger junipers and there is less in interspaces. Larger natural openings within the area have a good cover of grass. This site is reserved for winter grazing partially because the tree cover provides thermal cover for the cattle. Average annual precipitation at the Gran Quivira National Monument was 15.4 inches between 1938 and 2001; most of the precipitation occurs during the summer.

### Monitoring and Marking

The site was divided into four 20.3-acre treatment blocks, and a tree inventory was conducted in each block prior to marking the residual trees or designating prescriptions. Since the hope was to make this practical for ranchers and small acreage landowners, it was decided to arbitrarily limit sampling to 10 randomly located, permanent 0.20-acre fixed plots within each block. It later was apparent that either larger plots or more numerous plots would have given us a better idea of stand conditions because of the variability in each plot. Often 30 percent of the plots were non-stocked and others contained more than 32 trees/plot. The crew measured species and d.r.c. or e.d.r.c.; on some plots, total height was measured so that volumes could be determined. However, the permanent plots will be measured to provide an indication of post-treatment growth. Harvested trees are utilized for firewood, fenceposts, latillas, and vigas. Range resources were sampled on four transects in each block using a double sampling procedure (Maynard, J. personal correspondence, 2002). The average forage for each plot was: Block I with 260.2 lb/acre; Block II with 373.3 lb/acre; Block III with 585.9 lb/acre; and Block IV with 589.2 lb/acre.

All residual trees were marked within the blocks to be harvested. The goal was to maintain a relatively uniform crown cover within the limitations of the existing stand; however, groups of trees were retained along water courses and to maintain wildlife cover. Trees that had signs of wildlife activity, such as bird or rodent nests, were retained. Diameters were measured on all residual trees. The crew consisted of three people: two diameter measurers and one person who calculated and recorded the e.d.r.c. values. Leave trees were flagged in all directions around the tree.

## *The Prescriptions and Results*

The specific prescriptions were designed to be general enough to be applied to juniper woodlands in a variety of different sites. The four treatments included a multiresource production block, a “savannarization” cut, a strip cut for wildlife, and an untreated control block.

The blocks were marked and harvested for firewood during the summer of 2002. A Bobcat equipped with a shear was used to fell trees in the savannarization and strip cut blocks. The trees were bucked for transportation and sale. The sustained multi-resource production block was harvested by chainsaw because there were concerns that the Bobcat would cause excessive damage to residual trees. At this time, not all of the wood has been removed from the site, so only the results of the harvesting can be reported. An evaluation of the impacts on forage production will wait until the wood is removed; however, the rancher recently has noticed more cattle and deer use in the treated blocks.

## Sustained Multi-Resource Production

The prescription for the first treatment block (Block I) was designed to increase the herbaceous cover but still retain sufficient trees of all size classes in order to sustain the tree production option on these productive sites. The denser stand could have wildlife benefits for some small mammal and bird species. The prescription was designed to remove approximately 50 percent of the initial basal area but retain the variety of size classes present on the site. However, at least 65 percent of the crown cover should be left. The objective was not to force the residual stand into either an even-aged or uneven-aged structure, although the final result (figure 2) was a relatively all-aged stand. The marking favored healthy trees of all size classes in an attempt to retain younger trees to replace natural losses or additional harvesting. (Slash can be chipped for fiber as long as it can be done without damaging the residual trees.) Pinyon, which is a minor component of the block, and some snags were retained and protected for wildlife. This block contains some channels and signs of erosion, and slash was left in the channels to slow water movement and to trap soil. Groups of trees were retained for wildlife or for esthetic considerations. The final tally indicated that the residual stand contained 30 trees/acre and 29.4 $ft^2$/acre of basal area. The residual volume was estimated at 2.9 cds/acre. Preliminary estimates are that about 7 to 10 cds/acre were harvested but a final tally had not been conducted. Measurements of the inventory plots indicate that the residual basal area is 38 percent and the density is about 21 percent, respectively, of the original amounts.

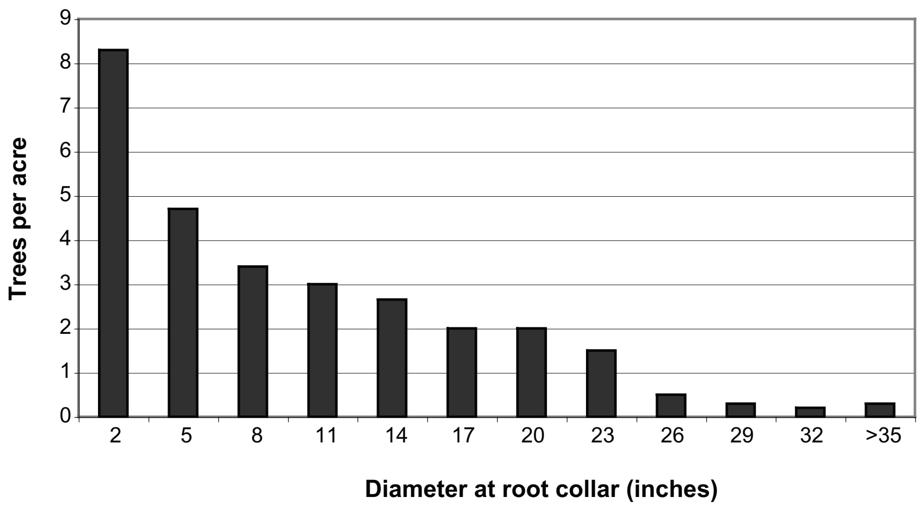


**Figure 2**—Residual stand on the multiresource silvopastoral treatment in New Mexico . The residual stand is uneven-aged and has a "q-value" of 1.08. Some of the largest trees are about 50 inches in d.r.c.

## Savannarization

The second block (Block II) was treated according to a savannarization prescription. The objective is to restore the range value of the landscape by returning it to the savanna condition that probably existed prior to European settlement. However, no one knows exactly what conditions existed during the period, so managers must select an option. One option of leaving six trees/acre had already been applied to an experimental site near the Abo Unit of the Salinas Missions National Monument in the Cibola National

Forest (Brockway and others 2002), and it would not be that useful to reproduce it here. The selected prescription on the demonstration site was designed to leave a larger number of individual large trees or groups of large, medium, and small trees throughout the 20-acre block. The distribution of trees would not be uniform and would consider scenic views. The selected option was to leave between 15 and 25 large trees or groups of smaller trees per acre. Some areas would have no trees and others had more than 25 trees. One recommendation is that large trees should be retained on 40 to 60 percent of the area (USDA Forest Service 1993). The larger slash elements would be chipped and smaller material would be lopped and left for soil cover and regeneration protection. Some snags were retained and protected but were not counted as part of the residual stand.

The final mark indicated that 14 trees/acre in a variety of size classes had been retained on the savanna block (figure 3); this was 34 percent of the amount indicated by the pre-harvest inventory. The residual basal area was 26.3 $ft^2$/acre and the residual trees contained about 1.2 cds/acre.

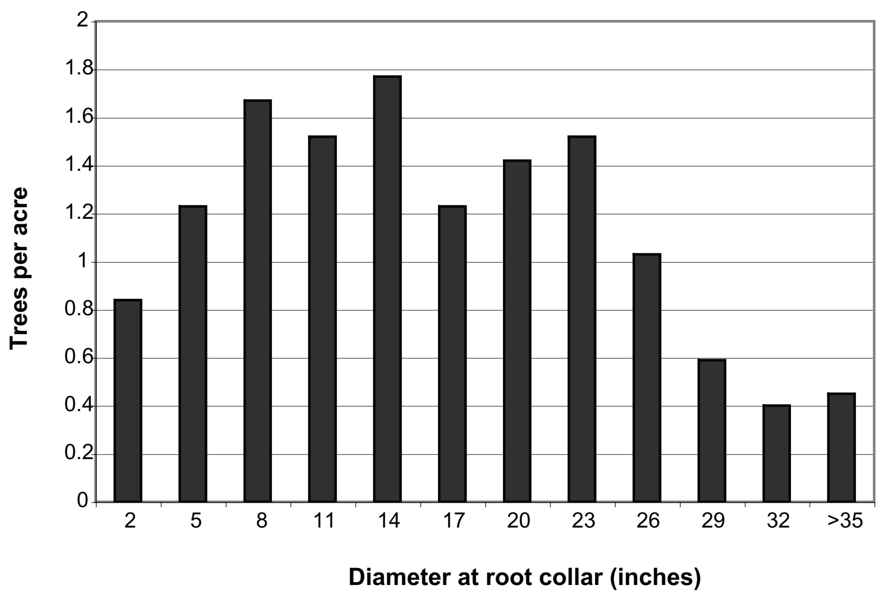


**Figure 3**—Residual stand for the savannaization silvopastoral treatment. The harvest left about 14 trees/acre. Approximately 1.2 cds/acre remain in the largest size classes.

### Strip Cut

Research and observations throughout the West have indicated that wildlife do not move into openings that are too large, even when sufficient forage or browse is available. Animals tend to remain near the edges to take advantage of hiding cover. The general recommendation is that openings be limited to about 600 ft in width (Gottfried and Severson 1994) and that "leave areas" that border the strip be at least 200 and 330 ft wide (USDA Forest Service 1993, Gottfried and Severson 1994). The leave areas can be harvested but there should be sufficient residual density so that the animals will not be able to see through the stand to other nearby openings. Very open stands are treated as extensions of the opening and lose their value as hiding and thermal cover.

The final prescription for Block IV was to harvest a strip of 500 to 600 ft in width to run through the block and to cover about 12 acre. The strip was to have "feathered" edges and not be a regular rectangle and be oriented perpendicular to the direction of the prevailing winds to minimize soil erosion because of wind action on the sandy soil. The border strips were to be harvested to reduce stand density by 20 percent but had to retain a mix of size classes. The actual width of the border was closer to 300 ft since areas immediately outside of the plot were included. Some trees or small groups of trees were retained in the strip to break up and raise the wind flow. Unmerchantable slash was to be lopped and left on the ground to keep the wind above the soil surface and to provide protected regeneration sites for herbaceous generation. An administrative study on an alligator juniper (*J. deppeana*) site in central Arizona estimated that forage production increased to 809 lb/acre in openings where harvesting slash had been treated and to 1,366 lb/acre under slash (Soeth and Gottfried 2000). Larger slash could be chipped for the P & M plant or left on the site. Some snags in the strip and borders were to be retained and protected for wildlife. Critical nesting or birthing sites were to be identified and the plan altered accordingly.

The actual harvesting created a 13.1 acre strip in the middle of the treatment block; the base was 556 ft wide. The edges were feathered and 3.9 trees/acre were left in the strip to provide additional hiding or thermal cover. In addition, an average of 2.9 trees/acre were harvested in the border strips; this accounted for 14 percent of the strip basal area.

### Control

The fourth block (Block III) was not treated and will be monitored to compare with the three treated units. The control is particularly important for herbaceous production and wildlife comparisons. It is anticipated that stand differences will not be great over the demonstration period.

## Conclusions

There is a growing recognition that the southwestern pinyon-juniper woodlands are valuable and should be managed for multiple resources. Silviculture, based on a sound knowledge of silvics, provides a tool for multiple resource management. Several silvicultural systems and methods are applicable to the southwestern pinyon-juniper and juniper woodlands, but the prescription must be matched to stand and site characteristics and to the landowner's objectives.

Most woodland silvicultural prescriptions have been developed through adaptive management procedures often with little post-treatment evaluation. A case study was initiated in Arizona to evaluate several prescriptions with the objectives of providing managers with information that could be used in evaluating and planning treatments. The results indicate that single-tree selection is feasible for high-quality sites. The selection treatment met the objectives of sustaining tree production and maintaining habitat for woodland dependent species but full regulation and targeted density reductions are difficult because of the lack of demand for small diameter wood products. However, attitudes should change if markets develop for pinyon and juniper fiber. The stand continues to be esthetically pleasing and can sustain future entries on a relatively short cycle. It appears that residual trees are growing but it is not yet known if post-harvest growth exceeds normal growth in non-treated stands. The need for growth and survival information for the advance regeneration and new regeneration is important to the question of long-term sustainability. The more dramatic diameter-limit prescription reduced stand densities but accelerated growth of residual trees, and the survival of most of the advance regeneration should allow a more rapid return to productivity for tree products relative to more severe stand reductions. However, the diameter-limit area has been removed from general tree product production for a long period. The observed increases in herbage production should benefit livestock and some wildlife species.

The three silvopastoral treatments in New Mexico should show that tree production is compatible with forage production for livestock and wildlife. However, it is too early to make this assessment until additional range inventories can be conducted. The characteristics of the residual stands will provide hiding and thermal cover for animals and are esthetically more pleasing to most observers than cleared areas. The trees also provide a financial reserve for the ranches. The trees continue to grow and add volume. In some years, ranchers may earn more from selling firewood and vigas than from calf crops. Silvopastoral treatments are a viable option to tree eradication programs and also are applicable for treating woodlands in wildland-urban-interface areas.

The pinyon-juniper woodlands are important to many of our constituents—they are special places. Even our urban neighbors are becoming aware and concerned about the woodlands and lower ponderosa pine forests as drought, fires, and insects take their toll. The current natural onslaught is creating challenges to foresters and other land managers. What are we going to do with the areas that have suffered extreme mortality? Do we take an active approach to rehabilitation or do we allow nature to take its course? The loss of large areas of woodlands will put addition pressures on the remaining lands; not just by humans but also by wildlife that depend on the woodlands for all or part of their habitat requirements. It is my opinion that silviculture will become more important in the pinyon-juniper woodlands as we try to manage them for sustain and improved health and productivity. We have seen that there are a large number of silvicultural options that are appropriate to the woodlands and are available to us. New or modified prescriptions will be developed to fit the variety of stand and site conditions and management objectives. New scientific knowledge will contribute to future silvicultural prescriptions and management activities. The pinyon-juniper woodlands are worthy of our attention—and they are special places.

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