

Silviculture and Multi-Resource Management Case Studies for 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 are heterogeneous, consisting of numerous combinations of tree, shrub, and herbaceous species and stand densities that are representative of the wide range of sites and habitat types they occupy. Silvicultural methods can be employed on better sites to meet multi-resource objectives and maintain the health and sustainability of the woodlands. Even-aged, uneven-aged, and coppice regeneration methods can be used in pinyon-juniper woodlands. Thinning operations may have a variety of objectives. Silvicultural prescriptions cannot be applied blindly, but must be based on stand conditions, an understanding of the silvics of the woodlands and their major species, and the biological and economic goals of land managers and owners. Several case studies of silvicultural prescriptions are discussed in detail in this document. These include the single-tree selection and diameter-limit regeneration methods and thinning (an intermediate method). Thinning is used where regeneration is not a primary objective. It is applied to reduce stand cover to improve understory development, improve wildlife habitats, and reduce fuels in wildland-urban-interface areas. Silvopastoral prescriptions, common in agroforestry, are designed to maintain the tree component and provide for increased forage production and improved wildlife habitats, are also discussed in this document.

Introduction

The concept of applying silviculture techniques to southwestern pinyon-juniper (*Pinus edulis-Juniperus* spp.) woodlands to accomplish multi-resource objectives and maintain the health and sustainability of stands is foreign to many managers. Woodlands have a long history of being ignored or receiving a minimum of active management. Large acreages of pinyon-juniper and juniper woodlands were destroyed in the period following World War II in an attempt to improve forage production for livestock, increase water yields, and improve wildlife habitats. Treatments were applied indiscriminately to old-growth stands and to stands of more recent origin.

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. Silviculture was considered a way to accomplish this goal. More recent concerns include fire suppression and reducing fuel concentrations, especially near towns and exurban developments; improving wildlife habitats by increasing the production of browse and herbaceous species while maintaining sufficient cover; and improving watershed condition. Silviculture can be used to meet these objectives while maintaining healthy and sustainable woodland ecosystems that produce commercial products where markets exist.

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However, not all sites can produce the full range of resource benefits, and this must be considered in land management planning. Silviculture is most successful on highly 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). Eighty-six percent of the pinyon-juniper woodlands in New Mexico and 89 percent of these lands in Arizona have been classified as productive sites using this definition (Conner and others 1990, Van Hooser and others 1993). This paper will provide a general discussion of silviculture and of several regeneration methods, intermediate treatments, and silvopastoral prescriptions that are appropriate to southwestern pinyon-juniper woodlands.

A Review of Silviculture

The Society of American Foresters (1958, p. 77) defines silviculture as “The art of producing and tending a forest; the application of the knowledge of silvics in the treatment of a forest; the theory and practice of controlling forest establishment, composition, and growth.” Silviculture is directed at creating or maintaining a forest or woodland that meets the objectives of the owner (Smith 1962). Silviculture is divided into two main systems: even-aged and uneven-aged. A system is a comprehensive planned program of silvicultural treatments during the life of a stand (Smith 1962).

In an even-aged stand, the age difference among individual trees is usually between 10 and 20 years, although a difference of 25 percent of rotation age can be applied to a stand with long rotations of 100 to 200 years. Uneven-aged stands contain trees of considerable age differences, where three or more age classes are present. An uneven-aged stand will have a decrease in the number of trees per unit area as the diameter increases. There are progressively fewer trees in the larger size classes than in the smaller size classes. The characteristics of the trees and other vegetation and the site characteristics determine the system and regeneration cutting methods used. Pre- and post-treatment inventories are essential for developing a sound prescription and determining the success of the treatment and any necessary modifications. Seed production, seed dispersal, and seed bed requirements are important if stand sustainability is desired. The coppice-forest method is applied if regeneration of sprouting species, such as alligator juniper (*Juniperus deppeana*) or associated oaks (such as Emory [*Quercus emoryi*] or Gambel oak [*Q. gambelii*]), is important. Light requirements affect tree establishment and initial growth of regeneration and young trees. Although most pinyon seedlings seem to benefit from moderate microclimatic conditions under the shade of nurse trees or inanimate objects, they are shade-intolerant and eventually need light to grow successfully (Gottfried and others 1995). Spacing among residual trees will affect future growth and resistance to damaging agents. Insects and diseases, including dwarf (*Arceuthobium* spp.) and true mistletoes (*Phoradendron* spp.), fire, and wildlife herbivory are important considerations. Prescriptions designed to enhance understory shrubs and herbaceous vegetation must also consider their requirements for establishment and growth.

Silvicultural Methods for Pinyon-Juniper Woodlands

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. Most pinyon-juniper stands are uneven-aged.

Single-tree selection, designed to maintain uneven-aged stands, has a number of advantages since it favors the establishment of natural regeneration of the main tree species, protects the site from wind and water erosion, can maximize vertical diversity important for wildlife, manipulates composition easier, and is esthetically pleasing (Bassett 1987). There are also disadvantages to single-tree selection, as it is more difficult to plan and administer wood sales, can result in damage to residual trees, may reduce horizontal diversity over large areas, does not allow for prescribed burning, and will make dwarf mistletoe control difficult. Group selection, another variant where small openings are created in the stand, is designed to maintain an uneven-aged stand.

Other prescriptions designed to create even-aged stands, such as two-step or three-step shelterwood, are used in the Southwest. These shelterwood methods remove the overstory over a short period and are designed to encourage regeneration under the partial shade of the residual trees. Some advantages of these shelterwood methods are that they allow control over site conditions for regeneration, protect the site from erosion, can control dwarf mistletoe, create horizontal diversity, and are esthetically pleasing (Bassett 1987). The disadvantages are similar to those for single-tree selection. 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 control dwarf mistletoe (*Arceuthobium divaricatum*). Clearcuts are difficult to regenerate because of poor seed dispersal, except where alligator juniper, which sprouts, is a major stand component. Clearcuts are also the least esthetically pleasing. However, harvesting narrow strips of woodland trees or small openings is beneficial to deer (*Odocoileus* spp.) and elk (*Cervus elaphus*), as large homogeneous landscapes are broken up. This provides food and adjacent hiding-thermal cover. A series of small clearcuts about 2 acres in size, distributed across the landscape, should provide both temporal and spatial diversity. While some private landowners may continue to remove the tree cover, many have recognized the values to their lands and livestock operations of creating mosaics of openings mixed with woodlands, or creating savannas by retaining larger trees or groups of trees.

Artificial regeneration is uncommon in woodlands because of the high expense, but is used to reclaim mining sites and 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.

Thinning is classified as an intermediate cutting made in immature stands to stimulate the growth of remaining trees and increase the total yield of useful material (Smith 1962). The traditional objective is to redistribute stand growth to the remaining trees and to use all of the merchantable material produced by the stand during the rotation. The term thinning is also commonly used to describe cutting that reduces stand densities when wood production is not a goal. For example, thinning may be used to improve understory herbaceous and shrub production, alternate tree resources (such as production of pinyon nuts), and watershed condition. It is also used to reduce fuel loadings.

Slash is a by-product of silvicultural operations. At least some of the slash should be scattered throughout the site to provide protected regeneration niches for trees and herbaceous species, provide habitats for small mammals, and slow surface runoff and sedimentation. In some rural areas, it is also an important source for firewood (Gottfried and others 1995). An administrative study on an alligator juniper site in central Arizona estimated that forage production increased to 809 lb per acre in openings where harvesting slash had been treated and to 1,366 lb per acre under untreated slash (Soeth and Gottfried 2000). Adjacent untreated openings contained an average of 252 lb per acre and unharvested juniper stands contained an average of 138 lb per acre of forage. Concentrations of slash require

treatment. Large piles are not recommended because of damage to soil resources caused if they are burned (Teidemann 1987). Small piles can be burned or left to provide habitats for small mammals that are part of the prey base for some of the Southwest's threatened or endangered avian species. Green slash can attract *Ips*, especially in the spring or summer, and operations may have to be delayed until fall or winter to reduce insect activity.

Case Studies of Silviculture Prescriptions

The following case studies are examples of viable silvicultural methods. It is difficult to say that one method or another should be applied since silvicultural prescriptions must consider the existing stand and physical site characteristics and desired conditions for the future. There are at least 70 pinyon-juniper and juniper plant associations in the Southwest (Moir and Carleton 1987, USDA Forest Service 1997), each with unique features that must be considered. One treatment will not fit all situations and several may be valid within a landscape. Case studies are valuable since they provide information about new or different techniques and allow managers to compare results with their procedures or learn methods that could be appropriate to their situations. New ecological knowledge and management techniques will contribute to future activities within the southwestern pinyon-juniper woodlands.

Regeneration Method Case Studies

An Experimental Single-Tree Selection Prescription—The Rocky Mountain Research Station, in cooperation with the Black Mesa Ranger District of the Apache-Sitgreaves National Forests, Arizona, has been studying several silvicultural treatments for woodlands, including single-tree selection and diameter-limit prescriptions. Results are compared to changes in unharvested control plots. The diameter-limit prescription could also 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 being considered for future management. The objectives of the study were to evaluate the effects of treatment on overstory characteristics and tree regeneration and to demonstrate the feasibility of these prescriptions for woodland management.

This case study provides results from one of the single-tree selection plots and one of the diameter-limit plots that are part of a larger silvicultural experiment. Prescription planning was coordinated with the forest managers who administered the treatments as commercial fuelwood sales. Considering time and money constraints, treatments had to be practical to be accepted by managers and fuelwood contractors.

The long-term study is located on the Black Mesa Ranger District of the Apache-Sitgreaves National Forest. The study site is northeast of the town of Heber, Arizona. Topography on the study site is relatively flat. Elevation is approximately 6,600 to 6,800 ft. Precipitation occurs during two seasons. Winter precipitation, usually snow, produces 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. The soils are derived from undivided Cretaceous sedimentary rocks, mostly limestone, shale, and sandstone, and most are classified as Lithic Ustochrepts or Udic Haplustalfs and have fine loams in the surface horizon (Laing and others 1987).

The woodlands in the study area consist of Colorado pinyon (*Pinus edulis*), oneseed juniper (*J. monosperma*), alligator juniper, and occasional ponderosa pine (*P. ponderosa*). Pinyon is the most common tree species. Stand conditions in the general area showed an average basal area of 101 ± 23.5 ft² per 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.

Preliminary results reported for the single-tree selection and diameter-limit silvicultural treatment are from two 10-acre plots, which are part of a larger replicated study. Each treatment plot contains 12 permanent circular 0.05-acre inventory plots that 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 past wood utilization. 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. Gottfried (2004) discusses the study in more detail. 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).

Prescription and Sale Administration—The single-tree selection prescription was based on the 1989 pre-treatment inventory that measured a total of 456 trees per acre and 150 ft² per acre of basal area. 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. 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.

Another 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, and a basal area target of 60 ft² per 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 desired distribution of size classes is at a stand density index (SDI) of 25 percent of the maximum for pinyon-juniper woodlands (Ellenwood 1995). SDI is the number of trees per acre that a stand would contain at an average basal area as indicated by average diameter (Husch and others 1972). The maximum SDI varies for each species and is measured at a reference diameter (Page, this proceeding). The maximum SDI for pinyon-juniper stands is still being refined; however, values of 240 and 416 can be inferred from the literature (Ellenwood 1995, Page, this proceedings). The advantage of SDI is that it is a measure of use of a site that is unrelated to age and site (Spurr 1952).

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 ft² per acre, and they were within 0.9 ft² per acre of the target.

Results—The block was harvested in December 1992. Approximately 3 cords per acre were removed. Although the diameter distribution for larger trees was achieved, 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 ft² per acre. Figure 1 shows the post-harvest and present stand, including movement of trees among the diameter classes. A future solution 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 per acre in the regeneration classes (trees less than or equal to 4.5 ft in height), or 85 percent, survived the harvest. This should be more than sufficient to restock the stand. The treatment did achieve the overall goal of retaining tree productivity, wildlife habitats, and aesthetics. The effects of treatment on individual residual tree growth relative to growth on similar sized trees in the control block are being analyzed, as are the impacts of treatment on tree regeneration. However, the number of trees per acre increased in many size classes indicating increased growth of residual trees from 1993 through 2000.

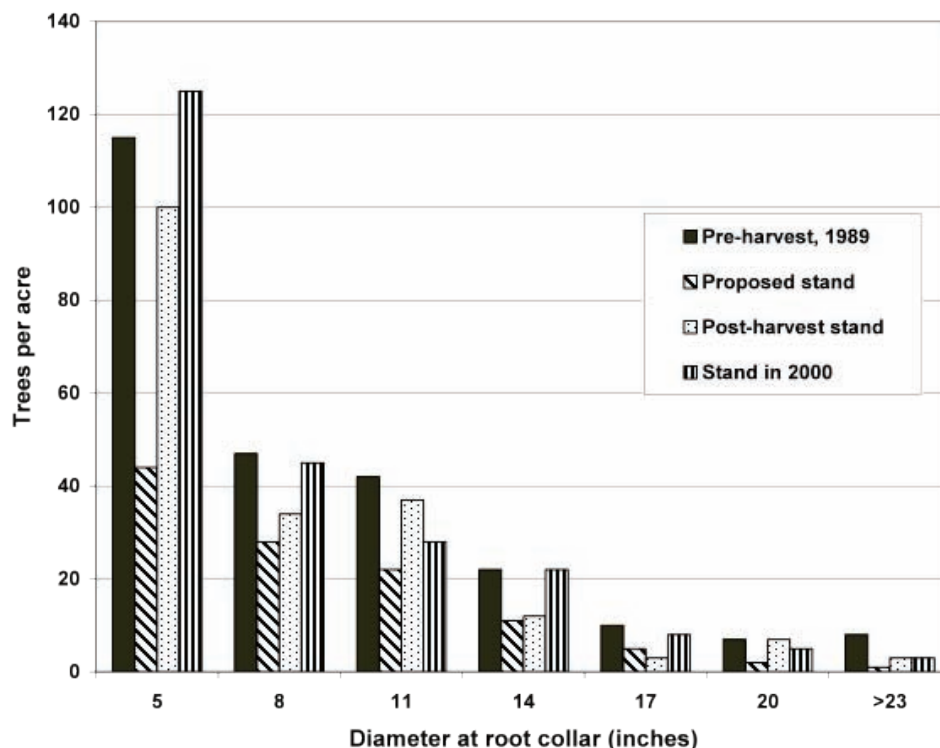


Figure 1—Initial, proposed, and post-harvest stand conditions in 1993 and 2000 for the single-tree selection block (Gottfried 2004). The graph shows the changes related to the treatment and to growth and mortality among the trees. Diameter is measured at the root collar (d.r.c.).

Another Case Study of a Single-Tree Selection Prescription—Other prescriptions are being evaluated in southwestern pinyon-juniper woodlands. The Bureau of Indian Affairs, Southern Pueblo Agency in New Mexico and southwestern Colorado is testing the impacts of different residual basal areas on tree growth at sites on four pueblos (Schwab 1993). They are evaluating an uneven-aged prescription based on a *q-value* of 1.0 that leaves an equal number of trees in each size class. The *q-value* was selected to concentrate growth on the larger trees. The prescription indicated about 320 residual trees per acre with the largest diameter at 12.9 inches. Each study site has at least four to five plots with residual densities ranging from 20 to 70 square feet of basal area per acre, depending on the site, and a control. The treatment is designed to support a 30-year cutting cycle. Current growth of residual trees is being evaluated.

An Experimental Diameter-Limit Prescription—

Prescription—The diameter-limit prescription was applied to another 10-acre plot at Heber. The stand on an average acre in the block had 438 trees and 142 ft² 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 had not been previously and carefully evaluated. The logging debris was not burned, but left in place or scattered in the interspaces.

Results—The diameter-limit harvest, without debris burning, removed 112 ft² per acre of basal area (or 79 percent of the initial overstory cover), retaining 30 ft² per acre, and removed 37 percent of the trees per acre, leaving 275 overstory trees per acre. The harvest removed about 5 cords per acre of volume. Approximately 89 percent of the tree seedlings survived harvesting (515 trees per acre). Stand density in the diameter-limit block was similar in 1993 and 2000.

Some of the density reductions in both the diameter-limit and single-tree selection plots 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 per acre in the treated blocks and 70 lb per acre in the un-harvested control blocks.

Thinning Method Case Studies

Thinning From Below—Thinning is classified as an intermediate treatment designed to stimulate the growth of residual trees where enhanced regeneration is not a consideration. Fuel managers with the Bureau of Land Management in southern Utah used diameter-limit prescriptions for thinning pinyon-juniper stands by setting a minimum diameter for residual trees (Page 2006). This qualifies as a “thinning from below” treatment. Page (2006) stresses that diameter-limit thinning does not produce sustainable stands since the smaller size classes are removed, and the replacement component is lost and species composition may be altered. Page (this proceedings) suggests using an uneven-aged thinning method based on the stand density index, which is an index of competitive interaction, to guide the prescription. The goal is to achieve an SDI of 5 to 25 percent of maximum SDI, which should provide for satisfactory residual tree growth and provide for the development of an understory herbaceous cover. The number of trees and basal area per acre remaining would depend on the diameter of residual trees. For

example, if an even-aged stand is the objective, and an SDI of 104 (25 percent of maximum SDI) is desired, the result would be 49 trees with an average diameter of 16 inches, or 104 trees with a diameter of 10 inches. The residual basal areas would be 68.5 and 56.7 ft² per acre, respectively. SDI is also used when multiple size classes are retained.

Nut Production—Another example of thinning from below is the Bureau of Indian Affairs effort to increase pinyon nut production on some of its better sites. Pinyon nuts are an important economic crop for many Native American communities. The prescription calls for the retention of superior nut producing trees while eliminating competition from neighboring trees. At the Southern Ute Reservation near Ignacio, Colorado, the harvest left a residual stand containing about 27 trees per acre with 16.8 ft² of basal area per acre. Superior trees are selected because of past evidence of good cone crops as judged by cones in the trees or on the ground surrounding the trees. Residual trees must have a full crown, be free of diseases, and show other signs of good vigor. Tree form is not a criterion for retention. The effects of the treatments have not been evaluated because the current 11-year drought has reduced cone production throughout much of the Southwest.

Wildland-Urban-Interface—Thinning is employed in wildland-urban-interface situations to reduce stand cover and fuel accumulations. Residual tree growth and regeneration are not the basic objectives. Thinning can be conducted by hand crews that often pile the slash for later burning or by mechanical equipment ranging from small vehicles with mounted shears to heavy mastication units. Hand thinning, although more expensive than machine thinning, is favored in visually sensitive areas around recreation areas and home sites and where archeological resources are to be protected. The Dolores Service Center of the San Juan National Forest, which administers woodlands on Forest Service and Bureau of Land Management lands in southwestern Colorado, and the Rocky Mountain Research Station are studying the effects of tree mastication with a hydro-mow machine, and the effects of hand thinning, piling, and burning on the overstory and understory and soil nutrient dynamics in woodlands north of Mesa Verde National Park. Most of the sites are in the wildland-urban-interface, adjacent to, or surrounding, expanding exurban developments. The area has been heavily damaged by the *Ips* infestation. One objective is to create mosaics of different stand conditions on the landscape. Treated plots are being compared to control plots. The invasion of cheatgrass (*Bromus tectorum*) into newly opened stands is a major concern.

Summit II, one of the study sites thinned with chainsaws, contained at least 389 trees per acre—60 percent were pinyon and 40 percent were Utah juniper (*J. osteosperma*)—prior to the infestation. At the time of treatment, 65 percent of the pinyon trees were dead, primarily due to the *Ips* infestation, and the surviving pinyon trees were mostly in the 1- to 6-inch d.r.c. classes. The stand contained junipers that were larger than 20 inches at d.r.c. The Service Center developed the prescription for the Summit Site. It called for cutting 50 percent of the canopy cover of trees up to 8 inches d.b.h. Dead pinyon trees and dense pockets of live pinyon and juniper trees were cut and live trees over 8 inches in diameter and healthy saplings, which were not under the canopy of larger trees, were left. Cutting resulted in mosaics of trees and openings of between one-quarter and two acres in size. Slash piles were restricted to between 6 and 10 ft wide and 4 and 6 ft high and had to be at least 15 ft from residual leave trees. The thinning was conducted in early winter 2005–2006 and the piles were burned in the spring of 2006.

The preliminary post-treatment inventory indicates that the stand now contains 50 live and 38 dead standing pinyon trees per acre and 86 live and 6 dead

standing dead junipers per acre. The 136 live trees per acre are about 35 percent of the original density. Future analyses will examine other stand and tree attributes (percent cover, SDI, basal area), the impacts of stand reductions on tree regeneration, shrubs and herbaceous plants, and the effects of treatments on soil nutrient dynamics.

Silvopastoral Prescriptions

The lack of commercial markets for alternative and potentially higher-valued juniper wood products limits management practices (Ffolliott and others 1999). Harvested trees are generally used for firewood, fenceposts, latillas, and vigas, which have relatively low economic value. The Forest Products Laboratory in Madison, Wisconsin, has demonstrated the potential of value-added products from the wood and fiber of oneseed juniper. 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. In February 1999, the U.S. 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 (Gottfried 2004). 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.

A manufacturing facility in Mountainair, New Mexico, could influence management on a large part of the 252,402 acres of woodlands in Torrance County (Van Hooser and others 1993) and would have a positive effect on employment and the general economy of Mountainair and Torrance County. Approximately 61 percent of the woodland area and 57 percent of its 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 products recovery while sustaining livestock production. Silvopastoral prescriptions are common agroforestry practices that favor tree production for wood, nuts, berries, or fodder (coarse feed for livestock), and integrates tree benefits with livestock husbandry goals (Ffolliott and others 1995). Harvested trees provide an additional source of income to ranchers and residual trees left after treatment are a potential economic reserve that can provide funds in hard times. Trees also provide important thermal cover for livestock in the summer and winter. The plan was to use different silvopastoral techniques on three areas and to compare results with an adjacent untreated control site. Although the prescriptions were designed to integrate range and tree production objectives, they 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. 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 Quiviera Unit of the Salinas Missions National Monument and US Highway 55. 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. 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 and appears to have a good cover of grasses, including blue grama, side-oats grama (*B. curtipendula*), and sand bluestem (*Andropogon hallii*). 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 pre-harvest inventories practical for ranchers and small acreage landowners, it was decided to arbitrarily limit sampling to 10 randomly located, permanent 0.05-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 treatment block. 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. The permanent plots will be monitored to provide an indication of post-treatment growth. Range resources were sampled on four transects in each block using a double sampling procedure prior to treatment (Maynard, J. personal correspondence, 2002). The average forage for each plot was: Block I, 260.2 lb per acre; Block II, 373.3 lb per acre; Block III, 585.9 lb per acre; and Block IV, 589.2 lb per acre. Results from the treated blocks will be compared to conditions on a control block.

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 for wildlife cover. Trees that showed 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.

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 multi-resource 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 as there were concerns that the Bobcat would cause excessive damage to residual trees. At this time, all blocks have been harvested, but the wood has not been removed so only the results of the harvesting can be reported. An evaluation of the impacts on forage production will follow wood removal; however, the rancher recently noticed more cattle and deer use in the treated blocks.

Sustained Multi-Resource Production—The Sustained Multi-Resource Production prescription for the first treatment block (Block I) was designed to increase the herbaceous cover but retain sufficient trees of all size classes in order to sustain the tree production option on these productive sites. 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. The objective was not forcing the residual stand into either an even-aged or uneven-aged structure, although the

final result was a relatively all-aged stand with a *q-value* of 1.08. The marking favored healthy trees of all size classes in an attempt to retain younger trees for future harvests or to replace natural losses. Pinyon, which is a minor component of the block, and some snags were retained and protected for wildlife. Slash was left in the channels to slow water movement and trap soil. Groups of trees were retained for wildlife or for esthetic considerations. The final tally indicated that the residual stand contained 30 trees per acre and 29.4 ft² per acre of basal area. The residual volume was estimated at 2.9 cords per acre. Preliminary estimates are that about 7 to 10 cords per acre were harvested. Measurements of the inventory plots indicate that the residual basal area is 38 percent and the number of trees per acre is about 21 percent of the original amounts.

Savannarization—The second block (Block II) was treated according to a savannarization prescription. The objective was to restore the range value of the landscape by returning it to the savanna condition that probably existed prior to European settlement. However, the conditions that existed during the period are unknown, so managers must select an option. One option, leaving six trees per 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). The current prescription was designed to leave between 15 and 25 large trees or groups of smaller trees per acre. The distribution of trees was not uniform and was considered to have esthetic value. Some areas had no trees and others had more than 25 trees per acre. One recommendation was to retain large trees on 40 to 60 percent of the area (USDA Forest Service 1993). Although this did not occur, the plan was to chip larger slash elements and lop and leave smaller material 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 per acre in a variety of size classes had been retained on the savanna block. This was 34 percent of the amount indicated by the pre-harvest inventory. The residual basal area was 26.3 ft² per acre and the residual trees comprised about 1.2 cords per acre.

Strip Cut—Research and observations throughout the West have indicated that wildlife does not move into large openings 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” bordering the strip be at least 200 to 330 ft wide (Gottfried and Severson 1994, USDA Forest Service 1993). The leave areas can be thinned, but there should be sufficient residual density so that the animals are not able to see nearby openings through the stand. Very open stands are treated as extensions of the opening and lose their value as hiding and thermal cover.

The actual harvesting created a 13.1-acre strip in the middle of the treatment block; the base was 556 ft wide. The strip was oriented perpendicular to the direction of the prevailing winds to minimize erosion of the sandy soil. The edges were feathered and 3.9 trees per acre were left in the strip to provide additional hiding or thermal cover and to break up and raise the wind flow. Unmerchantable slash was also lopped and left on the ground to reduce wind erosion and provide protected regeneration sites for herbaceous generation. Some snags in the strip cut and borders were retained and protected for wildlife. Critical nesting or birthing sites were identified and not disturbed. An average of 2.9 trees per acre, or 14 percent of the basal area, was harvested in the border strips.

Conclusions

Silvicultural prescriptions can be employed on most productive pinyon-juniper sites to meet multi-resource objectives and to maintain and sustain woodlands. A variety of uneven-aged, even-aged, and coppice regeneration methods and intermediate thinning prescriptions are applicable depending on existing stand and site conditions and on the objectives of the land managers and owners. Several different prescriptions can be applied in a landscape to produce a mosaic of stand conditions. Silviculture can be used to regenerate existing stands for traditional tree products or to enhance other woodland resources such as browse and forage for livestock and wildlife, improve thermal and hiding cover for livestock, large game and other wildlife species, and improve watershed condition. Providing for adequate tree regeneration, whether by creating suitable conditions for new tree establishment and survival or by nurturing existing seedlings and saplings is necessary for sustained ecosystems. Compromises may be necessary among conflicting objectives, for example, near recreation areas and archeological sites, or adjacent to populated areas where aesthetics and fuel reduction objectives may conflict. Silvopastoral prescriptions provide land owners with a compromise between wood production, which can be a potential financial reserve, and traditional livestock production goals. Case studies provide a way for managers to compare their ideas with those of other practitioners.

Silviculture will become even more important as managers attempt to sustain and improve the health and productivity of the woodlands and their resources after suffering the impacts of the recent drought and insect infestations. Large areas of woodlands have lost their pinyon component and have shifted to a predominance of junipers or brushy species such as Gambel oak. The general public has noticed the changes and is concerned. Although it has not received much past attention, tree planting of pinyon may become necessary in some locations. More intensive, multi-resource management of the pinyon-juniper woodlands depends on the development of economically and technically viable products and markets (Ffolliott and others 1999). Increased demand for manufactured tree products might justify higher stumpage prices and investments in woodland silviculture and management. New silvicultural prescriptions will be developed and traditional ones will be modified over time to achieve the goals of sustainable and productive southwestern pinyon-juniper woodlands.

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