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Stripcut-Thinning of Ponderosa Pine Stands: An Arizona Case Study

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Abstract

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Growth and structural changes in ponderosa pine (*Pinus ponderosa*) stands were studied over a 25-year posttreatment period to determine the impacts of a combined stripcut-thinning treatment. Trees on one-third of a watershed in north-central Arizona had been removed in clear-cut strips. Trees in the "leave" strips were thinned. Number of trees, basal area, and volume growth have increased since the leave strips were thinned and will likely continue to increase as the residual trees increase in size. Integrity of these stands should be maintained in the future, although it might be necessary to plant ponderosa pine seedlings to reestablish a forest cover in the cut strips for timber production. A more likely scenario is to manage the watershed for other multiple-use values obtainable from ponderosa pine stands.

Keywords: stripcuts, thinning treatments, ponderosa pine, stand integrity, basal area

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Introduction

Extensive studies in many regions of the United States have demonstrated that removing forest overstories generally increases water yields (Baker 1986; Douglass 1983; Harr 1983; Hibbert 1983; Kattelmann and others 1983; Troendle 1983). Where a major portion of the water yield comes from melting snow, the effect of forest removal on streamflow depends on how the removal influences snowpack accumulation and melt patterns. Clearing the forest overstory in strips, patches, or blocks can increase snow accumulation and, therefore, increase the amount of water available for streamflow (Baker 1999; Ffolliott and others 1989; Gary 1975; Leaf 1975).

Water-yield improvement treatments involving complete overstory removals, thinning treatments, and combined stripcuts with thinnings were tested on the Beaver Creek watersheds in north-central Arizona in the late 1960s and early 1970s (Baker 1999). This research was part of an interdisciplinary research effort of the USDA Forest Service and its cooperators to evaluate the effects of vegetation management practices on water, timber, forage, and other multiple-use values on ponderosa pine (*Pinus ponderosa*) forest lands (Brown and others 1974). While the effects of the treatments on water yields have been documented (Baker 1986; Baker and Ffolliott 1999), the long-term response of ponderosa pine stands to the treatments has not. Therefore, stand growth and structural changes over a 25-year posttreatment period are reported here to document the impacts of a combined stripcut-thinning treatment on one of the Beaver Creek watersheds.

Methods

Study Area

Strips were cut on a 1,350-acre watershed about 45 miles south of Flagstaff, AZ. The area is located within the cutover, uneven-aged ponderosa pine forests of the Colorado Plateau physiographic province above the Mogollon Rim. The watershed (Watershed 14) was established by the USDA Forest Service on the Coconino National Forest as part of the Beaver Creek research program (Baker 1999). One of the management practices evaluated was cutting strips in the stands and thinning the leave strips to increase the growth of the residual trees. Water-yield improvement, an original objective of the stripcut-thinning treatment, was significant for only the first 3 years posttreatment (1971 through 1973) (Baker 1986). The effect of this treatment on the residual stands in terms of density, structure, and stocking is reported here.

The stands studied are representative of those found in the *Pinus ponderosa/Quercus gambelii* habitat type (Muldavin and others 1996). Their site index, based on age at breast height of 100 years (Minor 1964), ranged from 56 to 70 feet. Nearly 80 percent of these stands occurred on Productivity Class 6 sites with a productivity potential of about 30 ft^3 per acre per year. Scattered Gambel oak (*Quercus gambelii*) and alligator juniper (*Juniper deppeana*) trees were intermingled with ponderosa pine trees before thinning.

Soils were derived from volcanic basalt and cinder parent materials. (Soils are classified as fine, smectitic Typic Argiborolls; clayey-skeletal, smectitic Mollic Eutroboralfs; clayey-skeletal, smectitic Lithic Eutroboralfs; and fine, smectitic Mollic Eutroboralfs.) Elevations range from 6,900 to 7,300 feet. Slopes vary from 5 to 35 percent on terrain with a southwardly orientation. Annual precipitation of 20 to 25 inches falls mostly in two distinct seasons; 65 percent falls as rain and snow in winter (Baker 1986; Brown and others 1974), while most of the reminder falls from July through September.

Treatment Prescription

One-third of the watershed was cleared of ponderosa pine trees in irregular strips averaging 60 feet wide (but varying by 50 percent) and generally oriented in the direction of the land slope (uphill-downhill). This orientation was prescribed to facilitate the direct movement of snowmelt water to the stream channels (fig. 1). The alignment and dimensions of the cut strips were varied as necessary to reduce the symmetry and uniformity of the pattern and take advantage of natural

Figure 1—Stripcut-thinning treatment in ponderosa pine stands on Beaver Creek Watershed 14.

opening in the forest overstory and local topography. "Spacers" of uncut trees were left in the cut strips to break up the continuity of the strips. If there were sufficient Gambel oak trees to break up the continuity of the strips, ponderosa pine "spacers" were not necessary.

The intervening leave strips, which averaged 120 feet wide, were thinned to a prescribed basal area level of 80 ft^2 per acre by a silvicultural cut favoring tree diameter classes in short supply on the Coconino National Forest at the time of treatment. The thinning treatment was based on individual groups of ponderosa pine trees. All trees 25 inches and larger in a group were cut. It was then decided which of the remaining size classes dominated. Dominance was determined by the size class with crowns occupying the greatest portion of the area. All ponderosa pine trees in nondominant size classes were marked for cutting except in those cases where the basal area of the predominant class was less than 80 ft^2 per acre. If two size classes appeared to have similar proportions of dominance, the size classes in short supply (12 to 24 inches diameter at breast height—d.b.h.) were retained and the excess classes (4 to 12 inches d.b.h.) were cut.

Poor-risk trees and trees with heavy mistletoe infection or poor form were also cut in the leave strips if their removal did not significantly reduce the basal area of the ponderosa pine trees to less than the target level. Gambel oak trees less than 15 inches d.b.h. were left in both the cut and leave strips to benefit wildlife and retain aesthetic values. All alligator juniper trees were cut regardless of their size. The heavy concentrations of slash resulting from thinning in the leave strips were pushed into the cut strips and burned. Ponderosa pine seedlings were then planted in cut strips on the better sites to supplement the natural seedlings and advanced reproduction surviving the thinning.

Inventory Methods

A systematic sampling design with multiple random starts (Ffolliott 1965; Shiue 1960) was the original inventory design placed on the watershed to measure changes in stand structure. Permanently established sampling points were located at regular intervals along a series of 16 transect lines. These transect lines were oriented to maximize the variability in measurements on the sampling points along the lines, while minimizing the variability between the lines. There were four random starts and four strata (replications) placed on the watershed. The interval between sampling points along the transect lines was 330 feet (five chains), providing a total of 195 sample points on the watershed. It was subsequently decided that this sampling intensity was sufficient and well enough distributed on the watershed to consider each sample point as a primary sampling unit in a simple random sample.

Point sampling techniques (Avery and Burkhart 1994; Husch and others 1982) with a basal area factor (BAF) of 25 were used to select tally trees for measurement. The d.b.h. of all tally trees 7 inches and larger was measured and the total height of a subsample of trees was obtained to localize a standard volume table (Myers 1963) to estimate cubic-foot volumes. Stocking of ponderosa pine seedlings (less than 1 foot tall) was tallied on 0.005-acre sample plots centered over the sample points in the initial inventory. A sample plot was classified as stocked if at least one seedling was tallied; otherwise, the plot was not stocked.

Four inventories were made. The first inventory (1965) represented conditions before the stripcut-thinning treatment was applied to provide a point of reference for posttreatment evaluations. A second inventory was conducted in 1971, the year that the treatment was completed, to ascertain the proximity of the actual treatment to its prescription and provide a starting point for the posttreatment inventories. Two other inventories were made to determine the changes in stand structure 5 (1976) and 25 (1996) years following the stripcut-thinning treatment.

Analysis

Estimates of growth are important to managers of forest stands, but they are often viewed in isolation rather than being but one of a number of factors potentially affecting changes in stand structure. More critical questions to ask when considering changes in stand structure are, "What is the present stand density and how has it changed in time?" Silviculturally, the question often is, "What is the response of a stand to a treatment?" People's interest in growth usually initiates this question, but change in stand structure is often the answer (Teply 1985). The inventory data collected in this study were analyzed to answer this latter question.

One problem in estimating changes in stand structures from repeated inventories of forest stands based on point sampling techniques is what to do about *on-growth trees*. On-growth trees are not included in one inventory but are included in a subsequent inventory because they grew enough (regardless of their size) to be tallied with an angle gauge or prism (Chambers 1985). A change in density caused by a large on-growth tree in a tally often results in a large variance in growth estimates. A solution to this problem is to recalibrate the sample points for the successive inventories (Beers and Miller 1964; Chambers 1985). This approach was used in this study as it had been in an earlier study on the effects of heavy thinning of ponderosa pine stands on another Beaver Creek watershed (Ffolliott and others 2000). Therefore, the data collected in the four inventories were summarized to represent the stand conditions, including on-growth, at the time of the inventories. Stand densities were expressed in number of trees, basal area, and cubic-foot volume per acre. These densities are presented in table 1 in terms of averages and corresponding

Table 1—Means and 95 percent confidence limits for densities of ponderosa pine trees 7 inches and larger on Beaver Creek Watershed 14.

Inventory date	Density measure[a] Number of trees (number/acre)	Basal area (ft^2/acre)	Volume (ft^3/acre)
Pretreatment			
1965	103.9 ± 18.5	80.3 ± 10.8	1,661.7 ± 234.2
Posttreatment			
1971	48.2 ± 10.5	34.3 ± 4.2	709.1 ± 98.6
1976	54.7 ± 11.2	42.5 ± 5.6	857.3 ± 111.3
1996	102.1 ± 21.5	90.7 ± 11.1	1,851.9 ± 249.1

[a]Pretreatment densities are based on the 1965 inventory of the entire watershed; posttreatment densities are based on the 1971, 1976, and 1996 inventories of the leave strips only.

95 percent confidence limits and frequency distributions (stand tables, stock tables, and so forth) to analyze structural stand differences.

Because only trees 7 inches d.b.h. and larger were sampled, it was impossible to isolate the effects of thinning on saplings (less than 4 inches d.b.h.) and smaller poles (4 to 6 inches d.b.h.) in the leave strips. The posttreatment results presented are a composite of all stands in the leave strips on the watershed studied.

Results and Discussion

The stripcut-thinning treatment resulted in the removal of all ponderosa pine trees on one-third of the watershed, and about a 40 percent (42.7 percent) reduction of the original basal area over the entire watershed in the leave strips. The posttreatment stands in the leave strips were dominated by trees in the pole and small timber size classes. The effects of thinning on the densities and stand structure, regeneration stocking, and residual stand integrity in the leave strips are discussed below.

Changes in Stand Densities

Stand densities on the entire watershed before treatment (1965) and the changes in stand densities in the leave strips in the 25 years (1971 through 1996) following treatment are shown in table 1. Although changes in the number of trees, basal area, and volume in the pretreatment years (1965 to 1970) are unknown, we estimated by a stand projection (Ffolliott 1965) that the pretreatment annual growth of ponderosa pine 7 inches and larger was 37.8 ± 3.1 ft^3 per acre. This growth estimate excludes annual mortality, which is generally less than 1 percent of the growing stock volume in Arizona's ponderosa pine forests (Conner and others 1990).

Earlier thinning studies in Arizona's ponderosa pine stands had shown that little or no increase in basal area and volume growth per acre can be expected as a result of most treatments, but that individual trees often grow faster once they are released (Gaines and Kotok 1954; Krauch 1949; Myers and Martin 1963; Pearson 1950). Similar trends were observed in the study of heavy thinning of ponderosa pine stands on another Beaver Creek watershed (Ffolliott and others 2000) and the first 5 years following treatment (1971 through 1976) in this study. However, increases in number of trees, basal area, and volume growth per acre were significantly greater by the end of the 25-year evaluation period than during the initial posttreatment evaluation period.

On a per-acre basis, periodic annual increments (PAIs) in the leave strips were 2.2 trees, 2.3 ft^2 of basal area, and 45.7 ft^3 of volume at the end of the 25-year posttreatment evaluation period. These increments were significantly larger than the PAIs at the end of the 25-year posttreatment period on the Beaver Creek watershed that was heavily thinned (Ffolliott and others 2000). This difference in PAIs was not surprising, however, as the residual growing stock of ponderosa pine trees 7 inches and larger in the leave strips was almost 2.5 times higher than on the heavily thinned watershed following the respective treatments.

Changes in Stand Structure

Arizona's cutover ponderosa pine forests, while typically uneven-aged in their overall structure, are generally a mosaic of even-aged stands (Cooper 1961; Pearson 1950; Schubert 1974). This was also the pretreatment structure of the composite of stands on the Beaver Creek watershed studied, which was then altered as a consequence of the stripcut-thinning treatment.

The pretreatment and posttreatment inventories reflect changes in the structure of ponderosa pine stands comprised of trees 7 inches d.b.h. and larger. Stand structure based on d.b.h. distributions (stand tables) before the stripcut-thinning treatment exhibited features associated with uneven-aged characteristics such as the classical backward J-shape of uneven-aged forest stands (fig. 2a). During the 25-year posttreatment period, however, the d.b.h. distribution on the leave strips changed to that generally observed in the early stages of converting uneven-aged ponderosa pine stands to even-aged stands. It is anticipated that this d.b.h. distribution will continue to become similar to even-aged stand structures in the future.

Distributions of basal area (fig. 2b) and volume per acre by d.b.h. classes (fig. 2c) (the latter being stock tables) also differed between the pretreatment and posttreatment inventories. These distributions also illustrate uneven-aged structures of ponderosa pine stands evolving into the early stages of even-aged stands. Additional thinnings would be required to complete this conversion process, however. Depending on the initial structure of the uneven-aged ponderosa pine stand to be converted, two or more thinning treatments are generally necessary to achieve the desired even-aged structure (Schubert 1974).

It is not surprising that the thinning treatment in the leave strips is encouraging a mosaic of even-aged stands. The original thinning prescription specified thinning to favor one of four size classes in the residual stands. Large sawtimber, the largest size class considered, was found in a limited number of residual stands on the watershed in 1996. Two other size classes, poles and small sawtimber, were the predominant size classes in the posttreatment d.b.h. distributions shown

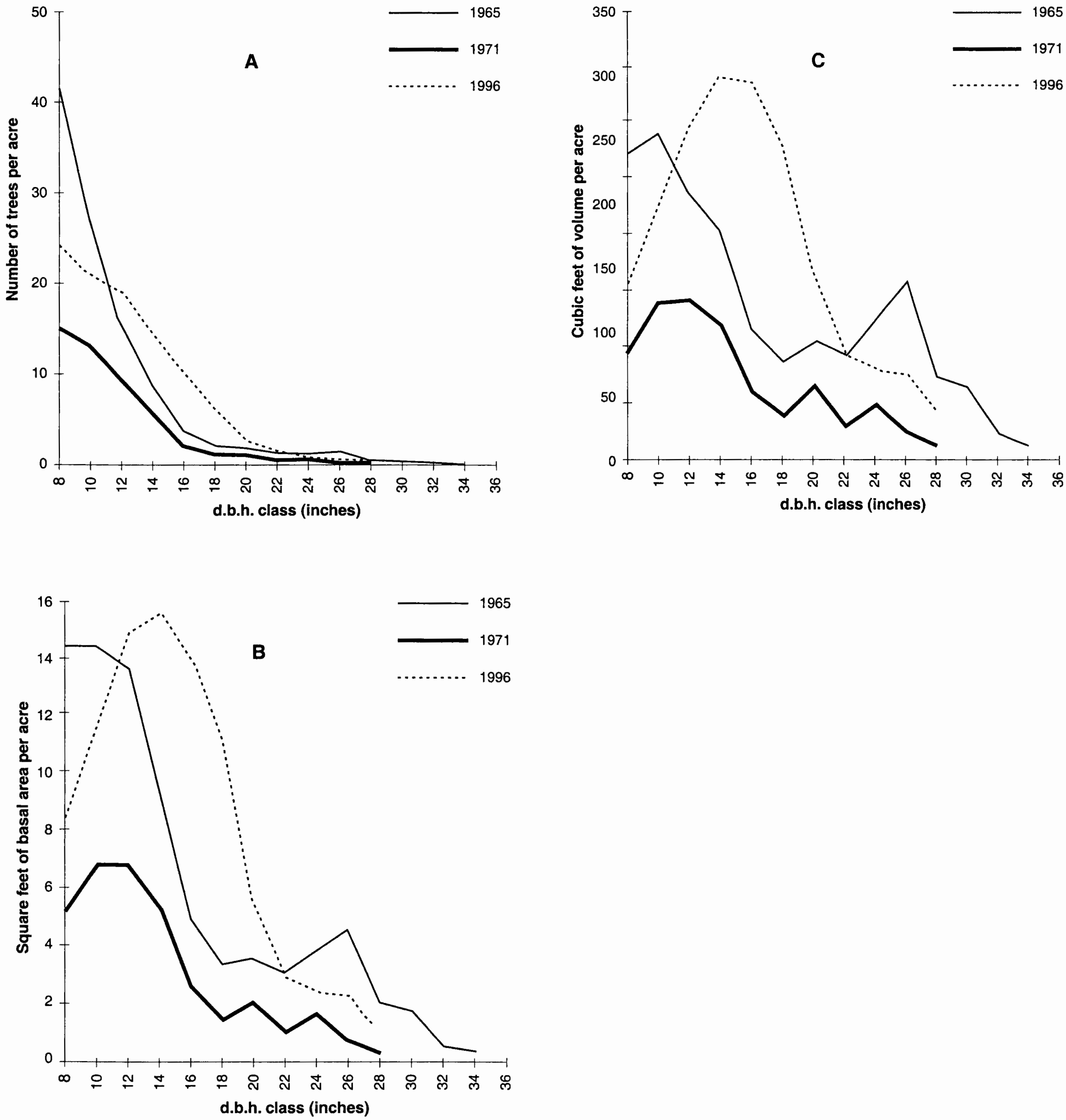

Figure 2—Distributions of: (a) number of trees, (b) basal area, and (c) volume per acre for ponderosa pine trees 7 inches d.b.h. and larger before (1965), immediately after (1971), and 25 years after (1996) the combined stripcut-thinning treatment on Beaver Creek Watershed 14. Densities in 1965 are based on the inventory of the entire watershed; densities in 1971 and 1996 are based on the inventories of the leave strips only.

(fig. 2a). The smallest size class (saplings) was not inventoried and, therefore, was not included in the analysis.

Stocking of Regeneration

Stocking of regeneration reflects the distribution of seedlings and small saplings over the watershed. The pretreatment inventory indicated that 18.5 percent of the 195 0.005-acre sample plots were stocked with ponderosa pine regeneration. This regeneration was distributed randomly. These stocking conditions were similar to or less than other observations of stocking in the cutover ponderosa pine stands on the Beaver Creek watersheds (Ffolliott and Gottfried 1991; Ffolliott and others 2000). Stocking on the watershed was reduced due to the thinning treatment. Less than 12 percent of the plots in the leave strips were stocked with seedlings immediately after treatment; residual stocking in the cut strips at that time (1971) was unknown. The loss in stocking in the leave strips was attributed to felling and skidding the trees marked for thinning. Stocking in these strips has remained largely unchanged since.

Stocking of reproduction in the cut strips that were planted with ponderosa pine seedlings to supplement the initial regeneration was almost 45 percent in 1996. This stocking included regeneration of natural origin that survived the thinning and the planted regeneration. Stocking in the cut strips that were not planted following the thinning (12 percent) was similar to the stocking in the leave strips at that time (1996).

Integrity of Residual Stands

The integrity of the residual stands in the leave strips has been maintained in the 25 years since the stripcut-thinning treatment. A windstorm in early spring of 1975 following a wet winter uprooted a few isolated and mostly sawtimber-sized trees on scattered areas of the watershed. A salvage cut recovered approximately 3,400 ft^3 of merchantable blowdown volume from the watershed shortly after the storm. This blowdown, the only loss of its kind in the 25-year posttreatment period, was not a factor in maintaining the integrity of the residual stands.

Planting of ponderosa pine seedlings in leave strips might be necessary to ensure the growth of trees into the sapling and then larger d.b.h. classes necessary to sustain stands at prescribed stocking conditions. Additional plantings of ponderosa pine seedlings in the cut strips would also be needed if a forest cover is to be reestablished on these stripcuts or, alternatively, if other strips are cut to replace the original stripcuts in the rotational cycle of forest management envisioned for the watershed when the stripcut-thinning treatment was implemented (Brown and others 1974). This latter scenario appears unlikely at the present time, however.

Conclusions

The integrity of ponderosa pine stands in the leave strips on the Beaver Creek watershed studied should be sustained into the future. Furthermore, the periodic annual growth increments of stands in the leave strips should increase as the residual trees in these strips increase in basal area and volume. However, a question that a manager might ask at this time is, "How should these stands be managed in the future?" The emphasis of management in Arizona's ponderosa pine forests has changed since the combined stripcut-thinning treatment was imposed in 1970 from timber production to a holistic perspective of natural resources management.

Current management strategies for the watershed should consider other ecosystem-based, multiple-use values. Forage production in the leave strips is likely to increase in response to the reduction in original forest overstory densities (Bojorquez Tapia and others 1990). Increased forage production is also expected in the cut strips. Habitats for many wildlife species should be improved as a result of the combined stripcut-thinning treatment, largely because of the increase in forage, the retainment of sufficient protective cover in the leave strips, and the edge effect (ecotone) between the leave and cut strips (Ffolliott 1997; Larson and others 1986). Habitats for some wildlife will be enhanced by the mast provided by the Gambel oak trees retained in the cut strips and thinned leave strips, and the increased oak sprouts (browse) resulting from the combined treatment (Reynolds and others 1970).

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