Historical Review of Fort Valley Studies on Stand Management

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Abstract*—One hundred years ago, the U.S. Forest Service launched a research program on the Fort Valley Experimental Forest to enhance the management of southwestern ponderosa pine (*Pinus ponderosa*) forests. This research program was the first scientific venture of its kind in the United States at the time it was initiated in 1908—and it is now the oldest in the country. Much of the early research was undertaken by G. A. "Gus" Pearson, who established the experimental forest in 1908 and guided its research program until his retirement in 1945. Research conducted at Fort Valley can be grouped into the general categories of ecology and silvical characteristics to provide a foundation for management; obtaining successful regeneration, which was a main reason for beginning research at Fort Valley; stand management including conversion of the original (virgin) stands to a condition of improved growth and quality; and control of damaging agents to maintain stands in a healthy and productive status (Gaines and Kotok 1954, Pearson 1942, 1950, Schubert 1974, and others). This historical review focuses mainly on the research efforts aimed at stand management with a lesser emphasis on the control of damaging agents.*

Introduction

Early Cutting Experiments

Early cutting experiments at Fort Valley were largely partial timber harvests aimed at initiating the conversion of virgin stands to managed stands. Three timber management objectives were the primary underpinnings in planning these cuttings—harvesting a crop of merchantable timber for sale; retaining growing stock capable of providing "satisfactory" future crops of timber; and encouraging natural regeneration on sites where growing stocking was deficient (Gaines and Shaw 1958, Pearson 1950). Intermingling sapling and pole stands received less attention than sawtimber stands, because of the pressing need to obtain better silvicultural information on sawtimber and a lack of market outlets for the smaller materials. The five cutting methods tested in these early experiments spanning the period from 1919 to 1945 were group selection, favoring dominants, favoring subordinates, salvage, and improvement selection (Pearson and Wadsworth 1941, Pearson 1944, 1950). An unharvested stand (the present G.A. Pearson Natural Area) was included for comparison purposes.

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Descriptions of Cutting Methods

Cutting of larger sawtimber trees for railroad construction at the time removed nearly 65 percent of the merchantable sawtimber volume in the group selection method of cutting. Intermingling groups of smaller sawtimber trees were mostly undisturbed. A partial harvest of trees in lower crown classes provided growing space for selected dominant trees in the cutting experiment favoring the dominants. Most of the trees larger than 75 cm (30 inches) in diameter (dbh) and smaller trees of poor-form and high-risk of not surviving were also cut. Dominants were cut where "good subordinates" could be liberated in the cutting experiment favoring subordinates. Additionally, most of the trees larger than 65 cm (26 inches) in dbh were cut. Harvesting of larger trees not expected to live 30 years into the future removed about 35 percent of the merchantable sawtimber volume in the salvage cutting. Subordinate trees were not intentionally released.

Improvement selection was developed at Fort Valley because the other cuttings tested were "silviculturally deficient" according to Pearson (1942, 1950) and Gaines and Shaw (1958). Improvement selection was aimed at placing a stand in a "vigorous growing condition" and building up effective growing stock by improving the spacing of trees in sawtimber groups to increase their growth; retaining the best quality trees for future growth; and removing poor-form and high-risk trees. These intentions took precedence over immediate timber sales and planning for future timber yields.

Timber Yields Following the Cuttings

Pearson (1950) and other silviculturalists working at Fort Valley anticipated that timber yields following the cuttings would be reflected by the subsequent growth, mortality, and replacement of trees in the treated stands. Growth would manifest itself by increased diameter and height increments that (in turn) could be translated into volume. Mortality would eliminate trees and, in doing so, lower aggregate increments of the stands. It was felt, however, that replacement by regeneration and the movement of smaller trees into merchantable size classes would balance mortality to some extent. Therefore, measurements of growth, mortality, and replacement were taken following the cuttings to evaluate the "effectiveness" of each of the experiments in satisfying the timber management objectives (Gaines and Kotok 1954, Pearson 1950). Similar measurements were also made in the virgin stand.

Analyses and summaries of the growth, mortality, and replacement measurements obtained are too extensive to present in this paper. However, in addition to the publications cited above, information on the progression of growth, mortality, and replacement patterns in the cut stands in comparison to the virgin stand are found in early papers by Krauch (1926, 1930, 1937), Lexen (1935, 1939), Pearson (1940, 1942), and others.

Second Cutting Experiments

Pearson and the other silviculturalists felt that the initial cutting experiments at Fort Valley often failed to place the treated stands in a "desired state" for future timber production. A predominance of older sawtimber trees remained and there was a deficiency in intermediate and smaller trees in many of the treated stands. Also, the advanced reproduction following the cuttings did not always bridge the gap of missing age classes. As a consequence, a second cycle of experimental cuttings, focusing mainly on salvage and improvement selection, were imposed to rectify these shortcomings. Measurements of growth, mortality, and replacement were again obtained (Gaines and Kotok 1954, Myers and Martin 1963a, 1963b, Pearson 1950, and others).

Treated stands were far from their virgin condition following these second cuttings. The numbers of high-risk trees were less; densities of immature groups of trees had been reduced; and thinned stands of saplings and poles had been established to provide growing stock for future timber harvests. Marking rules for the initial one or two cuttings in virgin stands and the first re-cutting in older cutover stands were obtained from the results of the second cutting experiments.

A process of converting virgin stands to managed stands evolved from the findings obtained from the assemblage Fort Valley cutting experiments (Myers and Martin 1963a, Pearson 1950). It was determined, for example, that initial cuttings should remove poor-quality and high-risk trees and reduce the densities of immature sawtimber groups where necessary. Dense sapling and pole stands should be thinned as soon as possible to increase the growth of this needed growing stock. Non-stocked sites should be planted where natural regeneration had failed or occurred at irregular and unpredictable intervals. Conventional cutting systems resulting in either uneven-aged or even-aged stands should be scheduled after a second or third cutting in previously unharvested stands.

Silvicultural Control of Dwarf Mistletoe

Dwarf mistletoe (*Arceuthobium vaginatum* var. *cryptopodum*), a destructive disease of southwestern ponderosa pine, often infects virgin stands with diseased groups of trees intermingling with healthy groups. The spread of dwarf mistletoe is typically from large sawtimber trees to smaller trees within the overstory. A number of silvicultural treatments to reduce or eliminate dwarf mistletoe had been tested for many years on the Fort Valley Experimental Forest (Herman 1961). Heidmann (1968) summarized the information obtained from a large-scale study on Fort Valley to silviculturally control dwarf mistletoe in heavily infected stands. Whether heavily infected stands can be controlled by harvest cuttings and stand improvement and what is the influence of stand improvement selection cuttings on the incidence of dwarf mistletoe were among the questions this study was designed to answer.

Study Design

A virgin stand of ponderosa pine trees that had been heavily infected with dwarf mistletoe was the study area. The control treatments were limited control by harvest cutting and stand improvement; complete control; and light stand-improvement selection cutting. Each of the three treatments was replicated three times on nine 10 ha (25 acre) plots. The objective of limited control was to reduce the intensity of dwarf mistletoe infection to a level considered by silviculturalists to be "unimportant" to timber management; the objective of complete control was to eliminate the infection to the extent possible; and the objective of the light stand-improvement selection was to establish a standard of control practices for comparative purposes. The initial harvest cuttings to remove infected sawtimber trees were completed in 1951. Follow-up silvicultural treatments to remove or reduce the level of infection in the smaller trees were carried out in 1953. The plots were re-treated in 1958 and marked for the second re-treatment in 1963 although the trees were not cut. It was assumed, however, that the marked trees mimicked the anticipated post-treatment stocking and infection.

Specifications of the harvest cuttings and the guidelines for the stand-improvement selection are too detailed to summarize in this paper. However, this information can be found in Herman (1961), Heidmann (1968), and others.

Results

Over 75 percent of the original sawtimber was removed by both the limited and complete control treatments in the study period. Infected stocking was reduced from 46 to 4 percent by limited control and from 52 to 3 percent by complete control (Heidmann 1968). The light stand-improvement treatment removed 35 percent of the sawtimber volume, but it did not reduce the proportion of infected stocking. Before re-treatment in 1958, the guidelines for cutting the limited control plots were modified to "widen" the difference in impact between the limited and complete control treatments. As a result, the stocking of infected trees was 17 percent higher on the limited control plots than the complete control plots in 1963. Stocking for all of the treatments increased between 1958 and 1963, with the greatest increase on the limited control plots.

Heidmann (1968) concluded that dwarf mistletoe in heavily infected ponderosa pine stands could be controlled by almost complete removal of the trees in the original stand. Because partial clearing of trees leaving a relatively "open stand" can cause windthrow of the residual trees, clearcutting was the treatment suggested. Limited control appeared impractical, while the light stand-improvement selection treatment had little effect on the occurrence of infected trees.

Growing Stock Levels

The early cutting experiments conducted at Fort Valley did not provide all of the information required by managers to prescribe appropriate growing stock levels for even-aged stands, however. This deficiency of knowledge became increasingly apparent as the conversions to managed stands continued. There had been little attempt to evaluate the "low-reserve densities" that might be retained in thinned stands. Largely because of this lack of information, a large-scale study of growing stock levels in even-aged stands of western ponderosa pine was designed to obtain growth information over a range of stand and site conditions (Myers 1967). The Coconino Plateau of north-central Arizona was selected as one of the five provinces for this study, with Taylor Woods, part of the Fort Valley Experimental Forest, the site for this phase.

Study Design

Densities to be retained in thinned even-aged stands at Taylor Woods were specified in terms of growing stock levels that were defined by a series of relationships between basal area and average stand dbh. Numerical designation of the growing stock level for a stand represented the level of basal area per acre that should remain following thinning when the average diameter of trees in the stand is 25 cm (10 inches) in dbh or more (Myers 1967). The density of a stand less than 25 cm (10 inches) in dbh was a "perspective density level" that was designated by the relationship between basal area and stand diameter for the selected growing stock level. For example, a stand with an average dbh of 14 cm (5.5 inches) to be "managed" at a growing stock level of 18.3 m^2/ha (80 ft^2/acre) would have 11.8 m^2/ha (51.6 ft^2/acre) of basal area following a thinning treatment (fig. 1). The thinning schedule shown by the relationships in figure 1 for a growing stock level of 18.3 m^2/ha (80 ft^2/acre) specifies residual tree densities to be obtained through the thinning treatments. More than one thinning might be necessary to "keep" the stand on the prescribed path.

Six growing stock levels investigated at Taylor Woods were 6.9, 13.8, 18.3, 22.9, 27.5, and 34.4 m^2/ha (30, 60, 80, 100, 120, and 150 ft^2/ac). These growing stock levels were selected for study on the basis of earlier silvicultural experience; baseline information obtained from temporary growth plots; and the results from the

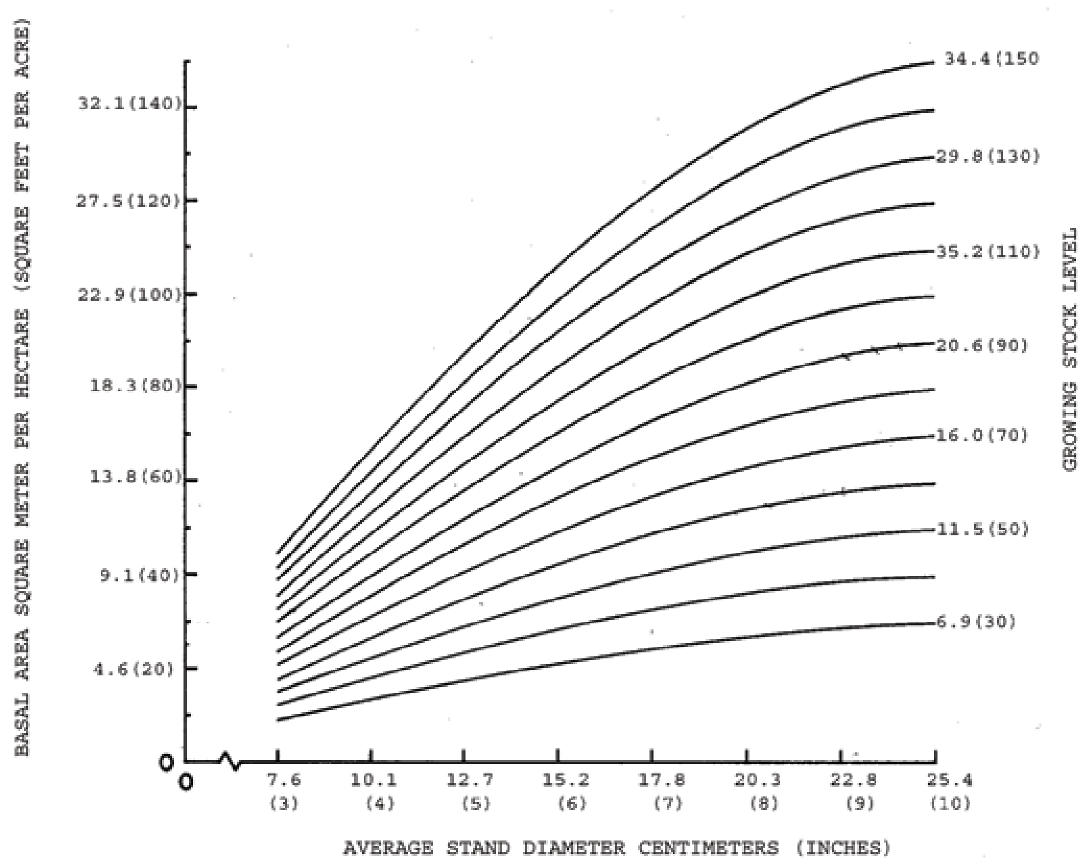

Figure 1. Residual basal area of a stand after thinning in relation to average stand diameter (from Myers 1967). The relationships shown are thinning schedules for selected growing stock levels in southwestern ponderosa pine stands.

earlier Fort Valley cutting experiments. The highest and lowest growing stock levels were considered to be beyond the "desirable range" of growing stock for timber production, but they were included in the study to provide a range of management alternatives (Myers 1967). Each of the growing stock levels studied was replicated three times. Stands were marked and thinned in late summer-early fall of 1962. Implementation of the study was largely a low thinning operation with the smallest trees and "rough dominants" removed.

Results

Initial results at Taylor Woods obtained five years after thinning indicated that periodic annual diameter, basal area, and volume growth of residual trees in the thinned stands increased in varying magnitudes throughout the range of growing stock levels (Schubert 1971). Furthermore, the increases in growth were concentrated in few and higher quality trees. However, stands with the higher growing stock levels remained understocked according to the designated basal area levels required for the average stand diameters measured. It was concluded, therefore, that slower growth at the higher levels had "prevented" these stands from overcoming their original understocked conditions.

The 20-year findings of the study reported by Ronco and others (1985) differed somewhat from the early results of Schubert (1971). With the exception of height growth, all averages of the other tree characteristics measured by Ronco and others exhibited a negative relationship with increasing stand densities. A two- to three-fold increase in periodic annual diameter growth and the two-thirds increase in the average stand diameter between the highest and lowest growing stock levels confirmed earlier observations of the growth potentials of ponderosa pine stands. In contrast to tree characteristics, however, stand characteristics such as basal area and volume increments showed a positive relationship with increasing stand densities. Intervening tree mortality had little effect on the overall results for the first 20 years of the study.

A 40-year update of the study of growing stock levels at Taylor Woods is presented by John Bailey elsewhere in the proceedings of this conference.

A Status-of-Knowledge Report

Technical information and observations on stand management that had accumulated through the early 1970s were summarized in a "status-of-knowledge report" on the silviculture of southwestern ponderosa pine forests prepared by Schubert (1974). This report brought together important timber-oriented facts to provide a reference for managers. Much of the knowledge presented had been gained from the findings from the Fort Valley cutting experiments. Included in the report was a review of silvicultural treatments to manipulate stands to create either even-aged or uneven-aged structures. Research at Fort Valley and elsewhere in the region suggested that depending on the management objectives, many stands could be managed as either one structure or the other. However, if the conversion from one structure to the other was deemed advisable, it was stressed that the conversion process should be made without destroying the residual growing stock. Furthermore, it was suggested that the conversion process be accomplished by combining groups of stands of similar condition classes. Also, retaining size classes of trees beyond their “normal rotation” or stimulating growth rates of smaller size classes to accelerate their entry into larger size classes might be required.

Intermediate cuts to be made following the establishment of a managed stand until it was time to replace it with a regeneration cut were outlined in the report. Among the intermediate cuttings were thinnings to improve tree spacing, release cuttings, improvement cuttings, sanitation cuttings, and salvage cuttings. Standard regeneration cuttings including the shelterwood, seed-tree, clearcutting, and selection methods were also reviewed with reference to their applications in southwestern ponderosa pine forests.

A Changing Situation

Following increases in allowable timber harvesting into the 1960s, when removals were generally one-third to two-thirds of the merchantable volume, the levels of harvesting in the region remained relatively flat into the 1980s. However, timber harvesting operations and silvicultural treatments to improve stand structures began to decline in the early 1990s after a number of lawsuits filed by environmental organizations challenged many of the sales. These challenges were based on a perceived failure—in the opinion of the environmental organizations—to adequately protect biological diversity and the habitats of rare, threatened, and endangered species. A lack of merchantable trees and unfavorable market conditions also contributed to this situation. With the curtailment in timber harvesting have been consequent alterations in the structure, stocking, and growth of the region’s forests. The earlier emphasis that managers often placed on obtaining and maintaining even-aged stand structures has been largely replaced with a gradual movement to more natural uneven-aged structures.

Increases in large wildfires have also altered the character of the region’s forests. Stands experiencing high severity fire have been damaged or destroyed or their ecological functioning has been disrupted, while the stands burned by lower severities fire are often impacted less. Such stand alterations occurred following the Rodeo-Chediski Wildfire of 2002, the largest known wildfire in Arizona’s history (Neary and others 2005). A mosaic of stands burned at varying fire severities with intermingling unburned stands was created following this fire.

Stand-level experiments at Fort Valley and silvicultural research elsewhere in the southwestern region have been re-oriented (to some extent) in response to this changing situation brought about by the curtailment of timber harvesting and increases in large wildfires. Two efforts of note in this regard have been the initiation of restoration studies and fire and fire surrogate studies.

Restoration Studies

Concerns about the increasing fire danger to people's lives and property because of the increasingly larger fuel loads and (possible) changing climatic regimes led to the establishment of the Grand Canyon Forests Partnership in 1996 - renamed the Greater Flagstaff Forests Partnership in 2002. The aim of this partnership of public agencies and private organizations has been largely implementing (on a larger scale) the findings obtained from a keystone restoration experiment on the G.A. Pearson Natural Area at Fort Valley. These findings showed the response of trees, herbaceous plants, and soils to an array of thinning and burning treatments (Covington and others 1997). Ideals of ecology, community collaboration, and economy were the collective visions to be realized in these larger experiments to be placed on demonstration plots.

Study Design

Twelve blocks within Fort Valley were the demonstration areas for the studies. Nine of these blocks were thinned and/or burned to varying prescriptions, while the remaining blocks remained untreated controls. The idea was that the thinnings would create stand structures emulating those representative of presettlement conditions, allowing ecosystem processes including recurring "low-level" fire to be sustained (Covington and others 1997, Mast and others 1999, Moore and others 1999). Old-growth trees were considered to be largely of presettlement origin and, therefore, generally left standing. A specified number of younger trees were designated "replacement trees" to also be left following thinning. The thinning treatments were completed in 1998, with the slash piled and burned after which the treated blocks were broadcast burned in 2000 and 2001.

Initial Results

Initial results of the treatments studied revealed restoration opportunities. Tree densities of treated stands have been reduced by up to 85 percent. Blocks with old-growth trees are looking like the open forests of presettlement times. However, many of younger trees left in these blocks were small in size and surrounded by "fresh" stumps, bare soil, and invasive plant species (Friederici 2003, Fulé and others 2001). On a positive note, flammable fuels in tree canopies had been reduced by the thinning treatments and the burning of slash piles and the imposed broadcast burning reduced fuels on the forest floor. It has been generally concluded that it will likely take decades or even centuries before the stands attain a condition approximating the presettlement era.

Fire and Fire Surrogate Study

Even in the face of more frequent wildfires, many unburned stands have become increasingly dense over the last century, with excessive accumulations of flammable fuels. The escalating occurrences of catastrophic wildfires in the region have often been (at least partially) attributed to this condition. Managers, therefore, need better information on the appropriate stand management to avoid future wildfires and restore the densely stocked stands to a "more natural" state. A question asked by the managers is: Can "fire surrogates" such as varying combinations of tree cuttings and mechanical fuel treatments replace the ecological role of natural fire in retaining the health of these stands? In attempting to answer to this question, a set of interdisciplinary studies funded by the Joint Fire Sciences Program was initiated in 1999 to evaluate the ecological and economic consequences of the alternative fuel reduction treatments available to managers.

Seven of the 13 study sites are located in western coniferous forests where ponderosa pine is a main component (Edminster and others 2000). One of these sites is situated close to the Fort Valley Experimental Forest. Fuel reduction treatments on this site include mechanical only, prescribed fire only, mechanical and prescribed fire, and a (untreated) control. The response variables measured on the site reflect fuels and fire behavior, vegetative conditions, soils and forest floor characteristics, hydrologic processes, wildlife conditions, occurrences of insects and diseases, treatment costs, and social values. While the measurement of these variables continue, it is anticipated that the results obtained will lead to management prescriptions that will reduce the threat of devastating wildfire in the future and enhance the health of the managed stands.

Summary

Studies on stand management at the Fort Valley Experimental Forest and surrounding areas have largely paralleled management needs in southwestern ponderosa pine forests. Initial emphasis was placed on converting virgin stands to management stands through partial timber harvesting. Cuttings to sustain the conditions achieved in the managed stands were then tested. Insufficient knowledge of the low-reserve densities to retain in even-aged stands to be thinned led to a regional study of growing stock levels, with one of the study sites located at Fort Valley. More recently, studies on stand management have changed in their focus in response to the curtailment of timber harvesting and increasing occurrence of wildfires. Restoration studies and studies of fire and fire surrogates have been initiated as a result. A theme of the recent research has been to provide a better foundation to the planning for sustainable forest management practices to achieve ecosystem-based, and multiple-benefit goals in ponderosa pine forests.

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