Strategies for Establishing Ponderosa Pine Seedlings in a Repeatedly Grazed Area of the Navajo Forest in Arizona—20-Year Results

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Abstract

Reforestation in some areas of the Navajo forest is challenging because of intense grazing and vegetative competition. A study was initiated in 1989 to determine if disking the site to alleviate competition, planting ponderosa pine seedlings, and installing fencing for 10 years to exclude livestock would result in acceptable stocking. After 20 years, 36 percent of trees had survived and were growing at an acceptable rate for the low-moisture site conditions. This approach met the goal of establishing an understory stand before harvesting the overmature overstory trees. Furthermore, exclusion of livestock allowed for seedlings to become tall enough to reduce the risk of grazing damage when the area was reopened to grazing. In fact, reintroduction of livestock after 10 years resulted in reduced vegetative competition with no apparent effect on seedling growth or survival.

Introduction

The Navajo forest is located in the Chuska Mountains and on the Defiance Plateau of the Navajo Nation along the Arizona—New Mexico border (Navajo Forestry Department 2005). Nearly all (95 percent) of the Navajo forest is ponderosa pine (*Pinus ponderosa* Lawson & C. Lawson). Annual precipitation averages 20 to 25 in (50 to 64 cm) and occurs as rain in July, August, and September and snow from December through March (Navajo Forestry Department 1982).

Forest regeneration on the Navajo forest can be severely hampered by grazing. Grazing, particularly by sheep, leaves a near continuous impact on the landscape (Shepperd and others 2006). Sheep husbandry is a means of subsistence for some local people who are granted grazing permits by the U.S. Department of the Interior, Bureau of Indian Affairs (Weisiger and Cronon 2011). The permit holder is thus entitled to the grazing use of a certain area. The boundaries of the use area, however, are not always rigidly regulated or adhered to; as a result, more livestock are often grazing in some forested areas than were originally permitted, making the grazing pressure on the land very severe.

Grazing damage to planted and naturally regenerated seedlings can be reduced if reductions are made both in the number of sheep and in the length of the grazing season (Pearson 1933); but the pattern of relentless grazing in some areas of the Navajo forest has led to destruction of natural regeneration for decades. Conifer seedlings can be frail, brittle, and watery after germination (Baker 1950). Even if an occasional seedling starts to get established in a favorable spot, the sheep and goats graze it to the ground in its most vulnerable stage after germination.

Sheep should be excluded from areas on which it is desired to secure reproduction until the seedlings have become firmly established and are out of danger from browsing (Pearson 1910). Mexal and others (2008) recorded the major cause of mortality to conifer seedlings to be goats in unprotected plantations. Removing sheep from the area, however, does not set well with the people, and attempts at livestock reduction on the Navajo Reservation have always met with resistance (Roessel and Johnson 1974). Livestock operations particularly those of sheep in the Navajo forest will continue. Both market and subsistence value are involved in these operations; sheep are used for food, for ceremonies, to pay healers, and for wool (Iverson 2002).

In addition to grazing pressure, competing vegetation is a challenge to successful forest regeneration (Pearson 1942, Heidmann 2008). In many areas, seed from overstory trees cannot reach mineral soil to get established because of a thick cover of Mountain muhly (*Muhlenbergia montana* [Nutt.] Hitchc.), a grass with low palatability that develops into a sod-like mat. We have observed germinated seedlings with long exposed roots lying in the grass and ultimately drying in place. Macdonald and Fiddler (1989) point out that, competing vegetation causes a lack of initial resources available to conifer seedlings, low food production, decreased exploitation of soil, poor growth and, in many cases, death. Proper site preparation can increase the success of direct seeding and planting (Shepperd and Battaglia 2002). Planting success has been best on areas receiving complete site preparation

(Schubert and Adams 1971). Tree planting on sites where competing vegetation has not been killed or removed is not recommended (Heidmann 2008). Several researchers have noted increased survival and growth of pine following control of plant competition (Derr and Mann 1971, Malac and Brightwell 1973).

Because of grazing and competing vegetation, foresters are concerned that some stands in the Navajo forest might not regenerate in the foreseeable future. This condition has been observed elsewhere, where cutover stands failed to restock adequately after 50 or more years (Schubert and Adams 1971). The goal of our project was to restock the understory of a particularly vulnerable stand with ponderosa pine seedlings by planting and fencing the area off for 10 years, after which the plantation would be reopened to grazing by removing the fence.

Materials and Methods

Site Description

This study was conducted on 140 ac (57 ha) in stand 31 of compartment 19 in the Navajo forest, located on the Defiance Plateau, near the community of Sawmill, AZ. Stand 31 is on the east side of the compartment and is part of a 2,200-ac (890-ha) area that has been regenerated by planting because of inadequate natural regeneration. The stand was park like with an overstory of ponderosa pine and no natural reproduction in the understory with the exception of three small (less than 1.0 ac [0.4 ha] each), widely dispersed patches of natural reproduction. The ponderosa pines, both overmature and younger trees, existed primarily as a single story (figure 1). Such park-like stands have been reported in the Southwestern United States by several authors (Woolsey 1911, Pearson 1950, Heidmann 2008). The site index of the stand is 82 (Minor 1964).

The stand was harvested in the 1950s and again in 1987 using the shelterwood seed-cut method. Sheep, goats, and other domestic livestock heavily grazed the stand for several decades. Several sheep camps and stock ponds are in compartment 19; grazing is continuous for 8 months of the year. Stand 31 is very close to the sheep camps and, like other adjacent stands, is consequently more heavily grazed by sheep and goats on their way to, and from, livestock corrals. One family had 300 sheep grazing the area in the 1960s (personal communication with local land users), although the numbers are considerably less at the present time. Natural regeneration has not occurred to restock the stand since the 1950s, in spite of several mild cone crops.

Figure 1. Overmature trees like those pictured here dominated the stand in a park-like setting before planting. (Photo by Amanullah K. Arbab and Leonard C. Lansing)

The predominant ground cover in the stand was Mountain muhly (figure 2). Livestock grazing tends to shift plant species composition in the understory to those of lower palatability (Houston 1954). The next grass of significant quantity is Arizona fescue (*Festuca arizonica* Vasey), which seems to be more palatable as evidenced by its heavier use by livestock. Other plants in the stand are big sagebrush (*Artemisia tridentata* Nutt.), blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag. ex Griffiths), pine dropseed (*Blepharoneuron tricholepis* [Torr.] Nash), paintbrush (*Castilleja austromontana* Standl. & Blumer), larkspur (*Delphinium nuttallianum* Pritz. ex Walp.), squirreltail (*Elymus elymoides* [Raf.] Swezey), wild buckwheat (*Eriogonum alatum* Torr.), snakeweed (*Gutierrezia sarothrae* [Pursh.] Britton & Rusby), pingue rubberweed (*Hymenoxys richardsonii* [Hook.] Cockerell), one-seeded juniper (*Juniperus monosperma* [Engelm.] Sarg.), lupine (*Lupinus argenteus* Pursh), aster (*Machaeranthera canescens* [Pursh] A. Gray), creeping barberry (*Mahonia repens* [Lindl.] G. Don), Navajo tea (*Thelesperma subnudum* A. Gray), owl's-clover (*Orthocarpus purpureoalbus A. Gray ex S. Watson*), pinyon pine (*Pinus edulis* Engelm.), muttongrass (*Poa fendleriana* [Steud.] Vasey), and deathcamas (*Zigadenus elegans* Pursh).

Site Preparation

Logging slash was piled and removed. In the fall of 1989, the entire stand was disked with a Towner off-set disk pulled by a D-7 Caterpillar crawler tractor. The disk had two rows of six notched blades, each 38.0 in (96.5 cm) in diameter and 0.63 in (1.6 cm) thick. Disking with the offset disk can control most grasses, forbs, and nonsprouting shrubs (Stevens and Monsen 2004). Mountain muhly and other vegetation were uprooted and the mineral soil was exposed. Disking penetrated the soil to a depth of 10 to 18 in (25 to 46 cm) resulting in most seed of competing vegetation buried too far below the surface to be available for immediate germination. Approximately 70 percent of the ground was disked at a cost of $34 per ac ($84 per ha).

Fencing To Protect Planted Seedlings

Fencing of the study area after planting seemed a desirable alternative provided that people using the area agreed to it. As Weisiger and Cronon (2011) caution: "Without listening to those who are most affected and live in intimate contact with the land, things can go wrong." The grazing permit holders

Figure 2. Mountain muhly forms a sod-like ground cover. (Photo by Amanullah K. Arbab and Leonard C. Lansing)

of stand 31 were contacted and the need for setting aside the land for reforestation was explained to them. Through this contact, we were able to obtain their written consent for the project. A five-strand, barbed wire fence was constructed around the stand at a cost of $1,800 per mi ($1,118 per km).

Livestock owners tend not to reduce herd size or discontinue grazing without compensation of some kind (Maroney 2006). An agreement was made with the land users that they would be compensated with hay for as long as the fence was up and livestock access to the stand disallowed. Compensation was based on one-half of the 176 lb per ac (197 kg per ha) of palatable forage that the land produced. Based on the proper use of "leave half, use half" for 6 months, livestock owners were compensated with 6,778 lb (3,070 kg) of hay per year for the entire stand. Compensation continued for 10 years, at which time the fence was dismantled and the area was reopened for livestock grazing.

Planting Seedlings

Ponderosa pine seedlings were grown in the Navajo greenhouses from a local seed source for 14 weeks in 21.5-in^3 (350-cm^3) Spencer-Lemaire Rootrainer® containers and then moved to the lath house to harden off and overwinter. Seedlings were outplanted on the fenced and disked stand April 4 through May 7, 1990. At the time of planting, the average seedling was 5 in (13 cm) tall with a root collar diameter of 0.19 in (4.8 mm) and a dormant bud.

Seedlings were shovel planted at a density of 524 seedlings per ac (1,294 seedlings per ha). The planting cost was $135 per ac ($333 per ha), not including the cost of seedlings. Planting was accomplished by digging a 10-in (25-cm) deep hole, placing the seedling in the hole, putting moist soil back in the hole up to the root collar, and tamping the soil around the seedlings. Planters attempted to stay as close to 9 ft by 9 ft (2.7 m by 2.7 m) spacing as possible. Most of the uprooted and ripped vegetation was dead and dry at the time of planting.

Measurements

After planting, 140 permanent circular plots were installed for monitoring growth, survival, animal and insect damage, and causes of mortality. Each plot was 1/100 ac (40.5 m^2). Diagrams of permanent plots were drawn and locations of planted seedlings on each plot were marked on a plot sheet. Survival and growth measurements were conducted 8 times beginning in 1991 and ending in 2010. Heights were measured from ground level to the top of the uppermost bud. Root collar diameters were measured as close to the ground as possible. Height and diameter measurements were taken regardless of whether the seedlings were intact or damaged. Only seven survival data are reported here. Growth for the 10th year (after which fencing was removed) was not recorded but was estimated based on the average of the previous 9 years.

Results And Discussion

Competing Vegetation

Mountain muhly and other vegetation started colonizing the stand during the year after planting. Six years after planting, the Mountain muhly cover was nearly as thick as it had been before disking. Pinedrop seed, rarely observed before disking, became more prevalent. The squirreltail population also had a marked increase. Buckbrush (*Ceanothus fendleri* A. Gray), goldenrod (*Solidago* spp.), and stickseed (*Lappula* spp.) came into the site as new invaders in the flora and gradually declined with time.

After 10 years, during which time planted seedlings were not subject to damage by sheep, seedlings averaged 3.5-ft (1.1-m) tall and survival was 42 percent (table 1). When the fence was removed, the rest period had resulted in the volume of grass cover and other vegetation being greater than the adjoining untreated stands. The fence removal had the obvious effect of attracting more livestock to the plantation and resulted in reducing vegetative competition to the planted seedlings without any apparent harm to the reforestation effort.

Table 1. Percent survival of planted seedlings over time.

Year	Percent survival
1991	77
1992	63
1994	52
1999	42
2008	36
2009	36
2010	36

Seedling Survival

Survival after the first year was high, gradually declining until stabilizing at 36 percent when the seedlings were 18 years old (table 1). Because sheep, goats, and other livestock were completely excluded from the plantation for 10 years, the 64 percent mortality on the site was caused by other factors. Drought and unknown causes were the major factors (59.4 percent mortality). Drought has been recognized as the major cause of mortality of planted containerized ponderosa pine seedlings (Heidmann and Haase 1989). The unknown causes may include improper planting, planting on undisked sites, or planting where too much competition exists. Rabbits damaged 44 seedlings, 23 of which ultimately died (contributing 3.1 percent of the mortality). Rabbits cut the seedlings and left them in place without consuming them for food. Trees that were damaged by rabbits but survived were shorter and less vigorous. Porcupine damaged 42 seedlings, 12 of which died (accounting for 1.6 percent of the mortality). Porcupine-damaged trees that survived had various deformities (figure 3). Damage by porcupine occurred in the first 4 to 5 years when the understory of planted seedlings was getting established and ceased later on. No porcupine damage is currently reported.

No more trees were lost to drought or rodents after year 18, although minor tip moth damage was observed. In the stand are 187 surviving trees per acre in various stages of development. Visually the distribution of planted trees, interspersed between the overmature trees of the overstory looks relatively uniform (figure 4).

Seedling Growth

Average heights and root collar diameter of 265 surviving seedlings on 140 permanent plots are shown in figure 5. Considerable variation exists in the height and root collar diameter of individual trees on the plots (figure 6). Nearly 70 percent of the planted seedlings had root collar diameters between 1.8 and 4.8 in (4.5 and 12.1 cm) and heights between 3 and 16 ft (0.9 and 4.9 m), while 23 percent had root collar diameters between 5 and 7 in (12.7 and 17.8 cm) and heights between 9.0 and 17.7 ft (2.7 and 5.4 m) and 8 percent have root collar diameters between 0.5 and 1.5 in (1.3 and 3.8 cm) and heights between 1 and 4 ft (0.3 and 1.2 m). Overall

Figure 3. Most porcupine-damaged trees had a pronounced crook at the point of injury above which the tree ultimately resumed normal growth (top). Some porcupine damage resulted in two stems developing on the tree (bottom). (Photos by Amanullah K. Arbab and Leonard C. Lansing)

Figure 4. After 20 years, the plantation is evenly stocked with ponderosa pine saplings (top), some of which have established beneath overmature trees (bottom). (Photos by Amanullah K. Arbab and Leonard C. Lansing)

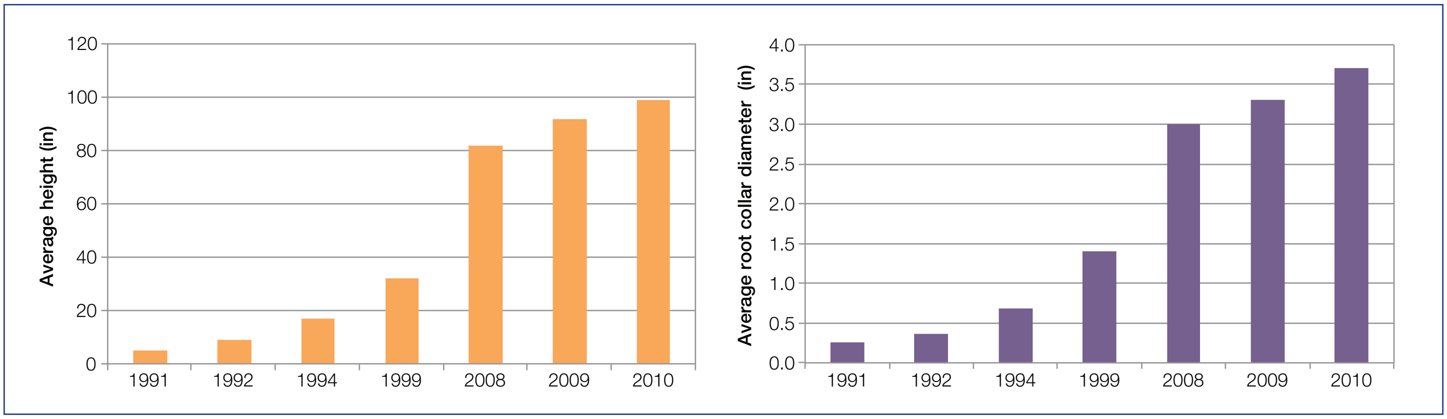

Figure 5. Average height (left) and root collar diameter (right) of surviving planted seedlings over time.

Figure 6. After 20 years, planted seedling height and diameter varied considerably. For example, the tree on the left is only 11 in (28 cm) tall with a 0.5 in (4.7 mm) root collar diameter, while the tree on the right is 17.7 ft (5.4 m) tall with a 7-in (18-cm) root collar diameter. (Photos by Amanullah K. Arbab and Leonard C. Lansing)

average after 20 years is 8.3 ft (2.5 m) in height and 4 in (10.2 cm) in diameter. This variation will have implications in the future management and harvest of the stand.

In an Arizona study of 45-year-old ponderosa pine trees, average diameter at breast height was 7.8 in (19.8 cm) with a range of values from 0.5 to 14.3 in (1.3 to 36.3 cm) (Ffolliott and others 2006). Root collar diameter measurements taken at the base of the tree and those taken at breast height cannot be compared, but the similarity in growth values between the two studies seems to be apparent.

Average root collar diameter in this study increased by 0.4 in (1 cm) and the average height increased by 7 in (17.8 cm) from 2009 to 2010. The growth rate is likely to be greater in the future. Even if the same growth rate continues, the average root collar diameter and average height in the stand will reach 5.6 in (14.2 cm) and 10.5 ft (3.2 m), respectively, in another 4 years when the trees are 24 years old.

Conclusions

Severely grazed, single-story, overmature ponderosa pine stands can be regenerated with containerized seedlings grown from locally collected seed. Fencing to exclude livestock, particularly sheep and goats, for a 10-year period is recommended. Because most grazing occurs at ground level, 10-year-old seedlings are sufficiently tall to be safe from grazing animals. On sites with low annual precipitation, such as the one described in this study, at least 500 seedlings need to be planted to get an appreciable number of surviving trees in the understory for future harvest.

Natural regeneration in normal years is a slow, sporadic process and its success depends on a number of favorable factors coming together at the same time. During the 20-year study period on this site, only 40 naturally regenerated seedlings were encountered on the 140 monitoring plots. This very small number is inadequate to restock the stand if natural regeneration is solely relied upon when prompt restocking is required. Adequate natural regeneration would have occurred ultimately at some distant future date, if time was of no consequence. By planting the stand, however, the goal of establishing an understory before the next harvest has been accomplished.

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