OAK REGENERATION RESPONSE TO MODERATE AND HEAVY TRAFFIC UNDER MECHANICAL HARVESTING IN AN OAK-HICKORY FOREST ON THE CUMBERLAND PLATEAU

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Abstract—Forest harvest operations can cause ground disturbances that negatively impact regeneration. On the Cumberland Plateau, managers must often rely on very small (less than a foot in height) oak advanced reproduction that is susceptible to disturbance by harvesting equipment. Furthermore, sites on the plateau top are often harvested when conditions are too wet to permit operations elsewhere, and the potential for small seedlings to be pulled from the ground may be heightened because of greater soil moisture. This study was designed to assess the effect of heavy and moderate equipment traffic on small oak advance reproduction under a clearcutting prescription. A feller-buncher and grapple skidding were used to harvest sites under "free access," resulting in heavy traffic on the sites, or under "strip access," with moderate site traffic. Five hundred oak seedlings were permanently tagged preharvest; species, height, and basal diameter were recorded and have been remeasured 3 years postharvest. Fifty-three percent of the tagged seedlings survived, and the survival rate for seedlings exposed to moderate traffic did not differ from that for seedlings exposed to heavy traffic. No evidence of seedlings being pulled out of the ground was observed. After three growing seasons, there is no significant difference in site disturbance between the two treatments. Initial assessment of the impact to the regeneration suggests that little damage was incurred under heavy equipment traffic.

INTRODUCTION

Forest harvest operations usually result in ground disturbances that may negatively impact regeneration. Because many stands located on the Cumberland Plateau have been degraded by generations of selective logging, clearcutting is often the only viable management option. Clearcutting on the plateau is most economical when implemented by mechanical harvesting, using a feller-buncher and grapple skidding. There are concerns that because of the topography and species composition, heavy traffic by such equipment may negatively impact desirable regeneration and small seedlings of the oak species in particular.

Advance reproduction of oak is the key to obtaining oak as a component of the future overstory in upland hardwood systems. Many studies have shown that the size of this advance reproduction before the final harvest is positively related to the growth of the reproduction after the overstory removal. However, on Cumberland Plateau sites, managers must often rely on very small advanced reproduction as the larger size classes are nonexistent. Therefore, the physical effect of harvesting practices on these small seedlings is very important.

Current forest conditions on the Cumberland Plateau vary greatly. Both site characteristics and past disturbance history have contributed to stands that are considered to be of low to medium quality. The most viable management option is often to clearcut to minimize costs and to aid in regeneration of a better quality stand.

Regeneration of hardwood stands in these systems has been documented in key studies by Loftis (1983, 1985, 1990), McGee (1967, 1975), McGee and Hooper (1970), Sander (1971, 1972), Sander and Clark (1971), and Sander and others (1976). These studies have shown that growth of oak reproduction following a harvest is a function of the size of advance reproduction and the pre-existing vegetative structure. Stump sprouts and advance reproduction must both be considered when evaluating the

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regeneration potential. However, managers often do not have the time and resources it takes to promote small advance reproduction into larger size classes. As a result, they rely on the small reproduction (< 1 foot in height) whose fate becomes of paramount importance to successful regeneration.

Assessments of ground disturbances that result from silvicultural operations in the Cumberland Plateau region have focused on physical site characteristics. Soil and litter displacement studies have described the surface soil conditions associated with forest operations conducted with the appropriate equipment (Aust and others 1993, Dyrness 1965, Greacen and Sands 1980, Green and Stuart 1985, Incerti and others 1987, Miller and Sirois 1986, Reisinger and others 1988). Few studies in the Cumberland Plateau region have focused on the impacts of harvesting traffic on small oak reproduction (Shostak and others 2002).

This study was designed to assess the effect of moderate and heavy traffic by equipment on small oak advance reproduction following clearcutting. Because of the nature of sites on the Plateau top, clearcutting operations with a feller-buncher and grapple skidding usually allow the feller-buncher free access to all trees on the site and result in heavy traffic throughout the site. An alternative to this free access technique is to designate strips of access and allow the feller-buncher to pick only trees that can be reached from these strips. Trees are then bunched and placed on the strip for skidding. Current management objectives include increasing the oak component while maintaining a complex and diverse species mix that will compliment wildlife habitat requirements and objectives. We planned to assess the disturbance by examining preharvest and postharvest conditions, tagging individual oak seedlings, and quantifying the physical soil characteristics before and after harvesting.

METHODS

Study Area

The study site is located in Jackson County, Alabama. The study was concentrated on a 20-acre area on the strongly dissected southern portion of the mid-Cumberland Plateau (Smalley 1982). The soils are moderately deep to deep, loamy, and clayey. The slope does not exceed 10 percent. The soil is well drained and low in fertility. Site index is 60 (base age 50) for the upland oaks (*Quercus alba* L., *Q. coccinea* Muench., *Q. montana* L., and *Q. velutina* Lamarck) and 85 (base age 50) for yellow-poplar (*Liriodendron tulipifera* L.). The yellow-poplar typically occurs on concave surfaces on the plateau (Smalley Land Type 1, broad, undulating sandstone uplands (Smalley 1982)). Oak reproduction is usually prolific on these sites, although seedling height is often < 2 feet. Clearcutting is commonly used for regenerating these sites because competition is sparse and oak advance reproduction numbers are high.

Study Design

Two disturbance treatments were tested. Treatments are adjacent 1-acre units with 10 replications per treatment. Treatment units were strips 66 feet wide by 660 feet long. Treatments were assigned systematically, alternating free access by the equipment (heavy traffic) with strip-only access (moderate traffic). In the heavy traffic treatment, the operator of the feller-buncher was allowed to choose the shortest route when approaching the trees. When possible, the trees were skidded after bunching. However, many were skidded from the fell point. In the moderate traffic treatment, the operator of the feller-buncher was allowed to select, cut, and bunch trees only from an access trail. This trail was then used for skidding. The entire 20-acre area was clearcut harvested in the fall of 2001 and winter of 2002.

Data Collection and Analysis

We systematically established 5 measurement plots per treatment unit prior to treatment application. We permanently marked the plot centers with rebar and captured their GPS coordinates. Regeneration was sampled on 0.01-acre circular plots. Seedlings were tallied by species in 1-foot height classes, up to 4.0 feet tall, and then by diameter. Using the same plot center, we established a 0.025-acre plot and recorded species and diameter at breast height (d.b.h.) for all trees with a d.b.h. > 1.6 inches.

We selected five oak seedlings that were representative of the plot species and permanently tagged them with a brass tag. Data collected about these tagged oaks included species, distance and azimuth from plot center, height, and basal diameter. We remeasured all regeneration plots in 2004.

We assessed and recorded soil and litter displacement (disturbance) on the regeneration plots immediately after harvesting in March 2002 and in the fall of 2003 and fall of 2004. We recorded the soil disturbance class (defined in Kluender and Stokes 1992) as untrafficked, trafficked with litter in place, trafficked with litter removed, trafficked with mineral soil exposed, or trafficked with mineral soil displaced to top of litter. Additionally, we recorded the number and depth of soil depressions.

Analysis of variance according to a randomized block design was used to quantify the significance of treatment differences; t-tests and Duncan's new multiple range test in SAS version 8.1 were used to separate means at an alpha level of 0.05 (SAS Institute 1990).

RESULTS AND DISCUSSION

Preharvest Tree Composition

Units averaged 130.3 square feet of basal area per acre (BA/A) and had 554 stems per acre (SPA). The dominant species in the stands were the oaks (black oak, chestnut oak, scarlet oak, and white oak). They represented 79 percent of the total BA/A. Other common mid- and overstory species included sourwood (*Oxydendrum arboreum* DC.), red maple (*Acer rubrum* L.), and hickories (*Carya glabra* Sweet, *C. ovata* K., *C. glabra* var. *odorata* (Marsh. Little), *Carya ovalis* [Wangenh.] Sarg.), representing 7, 6, and 4 percent of the total BA/A, respectively.

Regeneration plots averaged 9,698 stems per acre (SPA). There was a total of 28 different species. Sixty-seven percent of the reproduction was < 1 foot in height and 28 percent were small oak stems. The majority of these small size-class stems was in the other species category (*Diospyros virginiana* L., *Magnolia acuminata* L., *Ulmus* spp., *Cercis canadensis* L., *Ostrya* spp., *Ilex* spp., *Vaccinium* spp., and others). Five percent of the reproduction, 468 SPA, was > 1.5 inches in d.b.h. Species distribution in this size class was 31 percent white oaks, 21 percent sourwood, 14 percent blackgum, and 13 percent red maple.

Soil Disturbance

In March 2002, immediately after harvest, there was significantly more logging disturbance (rutting and bare soil exposure) in the heavy traffic units than in the moderate traffic units. However, in 2003 and 2004 the treatment-to-treatment difference in disturbance was no longer significant. Within each treatment, the measured disturbance decreased significantly with time. There was significantly less disturbance in 2003 than 2001, and significantly less in 2004 than 2003.

In 2002, 58 percent of the moderate traffic plots was characterized as trafficked with litter in place or litter disturbed, but without any mineral soil exposed, and 12 percent of the plots had traffic with mineral soil exposed. Sixty percent had at least one 6-inch deep depression. Forty-four percent of the heavy traffic plots had litter in place or slightly disturbed and 20 percent had exposed mineral soil. Fifty-four percent had at least one 6-inch deep depression. In 2003, 34 percent of the moderate traffic plots had traffic with litter in place or with litter disturbed, and 10 percent had mineral soil exposed. In 2003, 20 percent of the heavy traffic plots had litter disturbance, and 32 percent had mineral soil exposed. Twenty-two percent of both moderate and heavy traffic plots had depressions in 2003. By 2004, 2 percent of moderate traffic plots and 4 percent of heavy traffic plots had traffic with litter in place, and the remaining plots were all characterized as untrafficked. There were no depressions recorded in 2004.

Postharvest Oak Seedling Response

SPA of black oak, chestnut oak, scarlet oak, and white oak were reduced significantly in both treatments following harvest (table 1). Following harvest, total SPA of all species combined was significantly

Table 1—Average number of oak regeneration stems per acre from 2001 (preharvest) to 2004 for the two treatments

Species	Moderate traffic 2001	Heavy traffic 2001	Moderate traffic 2004	Heavy traffic 2004
	- - - - - - - - - -	- - - - - *stems per acre*	- - - - - - - - - -	- - - - - - - - - -
Black oak	757 (8)	540 (6)	288 (3)	459 (4)
Chestnut oak	743 (7)	968 (10)	378 (4)	450 (4)
Scarlet oak	855 (9)	686 (7)	490 (5)	478 (4)
White oak	338 (3)	437 (5)	384 (3)	241 (2)
All species	10,030	9,366	10,850	11,096
All oak species	2,693 (27)	2,631 (28)	1,540 (14)	1,628 (15)

Number in parenthesis is percent of all species tallied.
All differences between 2001 and 2004 by species and treatment were significantly different at $\alpha \leq 0.05$.

greater for the heavy traffic units than for the moderate traffic units. In the heavy traffic units there were significantly more black oak stems and fewer white oak stems than in the moderate traffic units.

Most of the oak advance regeneration was < 2 feet in height (table 2). The proportion of small oaks decreased significantly in both treatments following harvesting.

Survival of permanently tagged seedlings did not differ significantly from treatment to treatment (table 3). Fifty-three percent of all tagged oaks were alive following moderate traffic, and 38 percent were alive following heavy traffic. There was no clear evidence of seedlings being ripped from the ground. Nearly all of the dead seedlings had no visible signs of trauma, and some evidence (stem, roots, or both) of all but 10 seedlings was found.

The tagged seedlings averaged 0.7 feet in height and 0.1 inch in basal diameter. Three growing seasons after logging disturbance the seedling growth did not differ significantly between the two traffic treatments. An exception was chestnut oak, which grew 0.7 feet in the moderate traffic units and only 0.3 feet in the heavy traffic units.

CONCLUSION

Oak reproduction densities (1,540-1,628 SPA) and stocking levels (14 percent) after three growing seasons suggest that harvesting traffic had minimal impact on regenerative potential on these disturbed sites. Although the plateau tops are often harvested when conditions are too wet for machinery on the slopes, only minimal degradation to the site appears to occur. The disturbance seems to have been mitigated within just 3 growing seasons. None of the seedlings appeared to have been dragged or pulled from the ground. Current oak reproduction is small but has grown since the treatments were applied.

The harvesting methods used in this study did not result in severe soil disturbance or immediate impacts on the seedlings. The high competitiveness of oaks on these lower quality sites, the small amount of competition from other species, and the relatively high numbers of advance reproduction of oaks all contribute to a desirable species composition in these stands. Foresters and logging contractors have some control over the severity and extent of soil disturbance and should continue to take harvesting season into account, limiting operations during high soil moisture conditions and employing specific harvest planning techniques.

Table 2—Oak 2001 preharvest and 2004 postharvest regeneration average stems per acre for stems < 2 feet in height/total stems (percent of total), for moderate and heavy traffic harvesting treatments

Species	Moderate traffic 2001	Heavy traffic 2001	Moderate traffic 2004	Heavy traffic 2004
Black oak	668	486	247	354
	757 (88)	540 (90)	288 (86)	459 (77)
Chestnut oak	615	798	248	250
	743 (83)	968 (82)	378 (66)	450 (56)
Scarlet oak	763	650	414	354
	855 (89)	686 (95)	490 (84)	478 (74)
White oak	241	354	284	150
	338 (71)	437 (81)	384 (74)	241 (62)

Table 3—Oak seedling survival and growth comparisons, by species, between moderate and heavy harvesting traffic treatments

Species	Traffic treatment	Pretreatment number	Number alive 2004	Number dead 2004	Alive 2004	Height growth	Diameter growth
					percent	*feet*	*inches*
Black oak	Moderate	63	29	34	46	0.6	0.17
	Heavy	62	21	41	34	0.4	0.13
Chestnut oak	Moderate	51	28	23	55	0.7[a]	0.14
	Heavy	72	27	45	38	0.3	0.10
Scarlet oak	Moderate	107	63	44	59	0.3	0.11
	Heavy	99	41	58	41	0.2	0.12
White oak	Moderate	29	13	16	45	0.4	0.11
	Heavy	17	7	10	41	0.5	0.10
All oaks	Moderate	250	133	117	53	0.5	0.13
	Heavy	250	96	154	38	0.3	0.11

[a] Indicates significant difference between traffic treatments at $\alpha \leq 0.05$.

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LITERATURE CITED

Aust, W.M.; Reisinger, T.W.; Burger, J.A. 1993. Soil physical and hydrological changes associated with logging a wet pine flat with wide-tired skidders. Southern Journal of Applied Forestry. 17(1): 22-25.

Dyrness, C.T. 1965. Soil surface condition following tractor and high-lead logging in the Oregon Cascades. Journal of Forestry. 8(1):1 5-17.

Greacen, E.L.; Sands, R. 1980. Compaction of forest soils: a review. Australian Journal of Soil Resources. 18: 163-189.

Green, W.D; Stuart, W.B. 1985. Skidder and tire size effects on soil compaction. Southern Journal of Applied Forestry. 9(3): 154-157.

Incerti, M.; Clinnick, P.F.; Willatt, S.T. 1987. Changes in the physical properties of a forest soil following logging. Australian Journal of Forest Resources. 17: 91-98.

Kluender, R.A.; Stokes, B.J. 1992. Harvesting productivity costs of three harvesting methods. In: Proceedings of the Council on Forest Engineering. Corvallis, OR: Council on Forest Engineering. 17 p.

Loftis, D.L. 1983. Regenerating Southern Appalachian mixed hardwoods with the shelterwood method. Southern Journal of Applied Forestry. 7(4): 212-217.

Loftis, D.L. 1985. Preharvest herbicide treatment improves regeneration in Southern Appalachian hardwoods. Southern Journal of Applied Forestry. 9(3): 177-180.

Loftis, D.L. 1990. A shelterwood method for regenerating red oak in the Southern Appalachians. Forest Science. 36(4): 917-929.

McGee, C.E. 1967. Regeneration in Southern Appalachian oak stands. Res. Note SE-72. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 6 p.

McGee, C.E. 1975. Regeneration alternatives in mixed oak stands. Res. Pap. SE-125. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 8 p.

McGee, C.E.; Hooper, R.M. 1970. Regeneration after clearcutting in the Southern Appalachians. Res. Pap. SE-70. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 12 p.

Miller, J.H.; Sirois, D.L. 1986. Soil disturbance by skyline yarding versus skidding in a loamy hill forest. Soil Science Society of America Journal. 50: 1579-1583.

Reisinger, T.W.; Simmons, G.L.; Pope, P.E. 1988. The impact of timber harvesting on soil properties and seedling growth in the South. Southern Journal of Applied Forestry. 12(1): 58-67.

Sander, I.L. 1971. Height growth of new oak sprouts depends on size of advance reproduction. Journal of Forestry. 69: 809-811.

Sander, I.L. 1972. Size of oak advance reproduction: key to growth following harvest cutting. Res. Pap. NC-79. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 6 p.

Sander, I.L.; Clark, F.B. 1971. Reproduction of upland hardwood forests in the Central States. Agric. Handb. 405. Washington, DC: U.S. Department of Agriculture. 25 p.

Sander, I.L.; Johnson, P.S.; Watt, R.F. 1976. A guide for evaluating the adequacy of oak advance reproduction. Gen. Tech. Rep. NC-23. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 7 p.

SAS Institute. 1990. SAS user's guide: statistics. Version 6 ed. Cary, NC: SAS Institute. 584 p.

Shostak, D.; Golden, M.S.; Dubois, M.R. 2002. Oak regeneration: 4 years after three harvesting treatments in a north Alabama upland hardwood stand. In: Outcalt, Kenneth W., ed. Proceedings of the 11th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-48. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 383-389.

Smalley, G.W. 1982. Classification and evaluation of forest sites on the Mid-Cumberland Plateau. Gen. Tech. Rep. SO-38. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 58 p.