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Harvesting Productivity and Disturbance Estimates of Three Silvicultural Prescriptions in an Eastern Kentucky Hardwood Forest

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Abstract:

A large scale silvicultural assessment designed to examine the effectiveness of four treatments in reducing the impacts of gypsy moth infestation and oak decline was implemented on the Daniel Boone National Forest in eastern Kentucky. The study was funded through the Healthy Forests Restoration Act of 2003. The goal of the treatments was to improve the health and vigor of the stands through four different thinning prescriptions. Three of the treatments required mechanized harvesting to achieve the desired stand condition, while the fourth treatment utilized herbicides to treat the stand.

This paper discusses the productivity of the mechanized harvesting systems and their estimated soil disturbance for each of the three treatments. The harvesting system consisted of a swing-to-tree feller buncher, chainsaw limbing and topping in the woods and skidding with a grappler skidder. Products removed from the stands include a variety of hardwood logs and biomass logs. Harvesting began on the approximately 500 acres of mechanical treatment area in May 2007 and is scheduled to conclude in June of 2009.

Keywords: Kentucky, Feller Buncher, Grapple Skidder, Thinning, Hardwood, Site Disturbance

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Introduction

A large scale research study was implemented on the Daniel Boone National Forest in south eastern Kentucky under Title IV of the 2003 Healthy Forest Restoration Act (HFRA). The study was titled, "Maintaining Habitat Diversity, Sustaining Oak Systems, and Reducing Risk of Mortality from Gypsy Moth and Oak Decline on the Daniel Boone National Forest: Silvicultural Approaches and Their Operational Dimensions". The goal of the study, as stated in the title, is to assess the effectiveness of 4 different silvicultural treatments in limiting the impacts of gypsy moth and oak decline on the Daniel Boone National Forest.

Oak decline is a naturally occurring condition attributed to advance tree age, and adverse climate and site conditions. The combination of these stresses with the effects of forest pests can lead to the premature death of oak dominated forest stands. Occurrences of oak decline have been recorded since the early 1900's throughout New England, the Middle Atlantic, and Southeastern United States. Symptoms of oak decline include a progressive dying back from the tips of the branches and dwarfed or sparse foliage and premature autumn leaf color and leaf drop (Wargo, et. al., 1983).

The gypsy moth is a nonnative pest first introduced to the United States in 1869. Over the past 140 years the moth has slowly spread from its introduction point in Boston, MA to include the entire North East and now the Southern Appalachians. The gypsy moth feeds on the tree's foliage. Cyclic outbreaks of the insect can lead to the defoliation of entire stands. It is the combined stresses of gypsy moth and other pests such as shoestring root rot and the twolined chestnut borer along with oak decline that can lead to mass mortality of oak dominant forests (Hoyle, 2007).

Previous research suggests that oak decline and gypsy moth infestations can be limited by preparing the forest before arrival. Silvicultural treatments aimed at decreasing competition and increasing regeneration and tree vigor have been shown to lesson the impacts of oak decline and gypsy moth infestations. This study implements four silvicultural treatments and a control to test their effectiveness against oak decline and the gypsy moth. The study is being conducted by a multidisciplinary research team composed of USDA Forest Service and university researchers. Table 1 provides a list of all collaborators. Research will include studies of not only the silvicultural affects, but also the effects on wildlife, soils, and the harvesting methods and equipment. This paper focuses on the production, efficiency, and impacts of the harvesting systems used to implement the silvicultural prescriptions.

Table 1: Partners in the research study looking at sustaining oak systems amid threat of gypsy moth infestation and oak decline on the Daniel Boone National Forest.

COOPERATOR	PROJECT ASPECT
USDA Forest Service, Daniel Boone National Forest	Treatment Implementation & Administration
USDA Forest Service, Southern Research Station	Regeneration, Harvest Impacts, Soils, Biomass, Dendroecology /American Chestnut, Bat Habitat
USDA Forest Service, Northern Research Station	Overstory
University of Kentucky	Vegetation Response
Eastern Kentucky University	Dendroecology, Bat Habitat
University of Tennessee	Light & Canopy, LIDAR, American Chestnut

Study Details

The study design was a randomized complete block design. There were two site types (dry-mesic and dry-xeric) and five treatments (Table 2): shelterwood with reserves, oak shelterwood, B-line thinning, oak woodland, and a control (Schweitzer, 2008). There were three replicates for a total of 30 units equaling almost 600 acres. Eighteen of the 30 units are to be mechanically harvested. Six of the units are to be treated chemically and the remaining six are to remain undisturbed as controls. Harvesting began in May 2007 and was scheduled to be completed by the winter of 2008, with the goal of having all treatments implemented by the end of the second growing season. Harvesting limitations mainly due to adverse weather conditions has extended the implementation of all treatments into the third growing season.

Table 2: Treatments on the research study looking at sustaining oak systems amid threat of gypsy moth infestation and oak decline research study on the Daniel Boone National Forest.

STUDY TREATMENTS
-Control (No Burn, No Disturbance)
-Shelterwood w/ Reserves (10-15 ft^2/ac residual BA)
-Oak Shelterwood (60-75 ft^2/ac residual BA) Chemical Treatment
-Thinning to B-line (Gingrich's Stocking Chart)
-Woodland Thinning (30-50 ft^2/ac residual BA)

The study was implemented on the London Ranger District of the Daniel Boone National Forest (Figure 1). The harvesting units are located in the Cold Hill area with oak and hickory dominated stands ranging in age from 70 to 150 years. The units are generally located on broad ridges with some moderate side slopes (up to 30%). Stand density before harvest ranged from 70 to150 ft^2/ac.

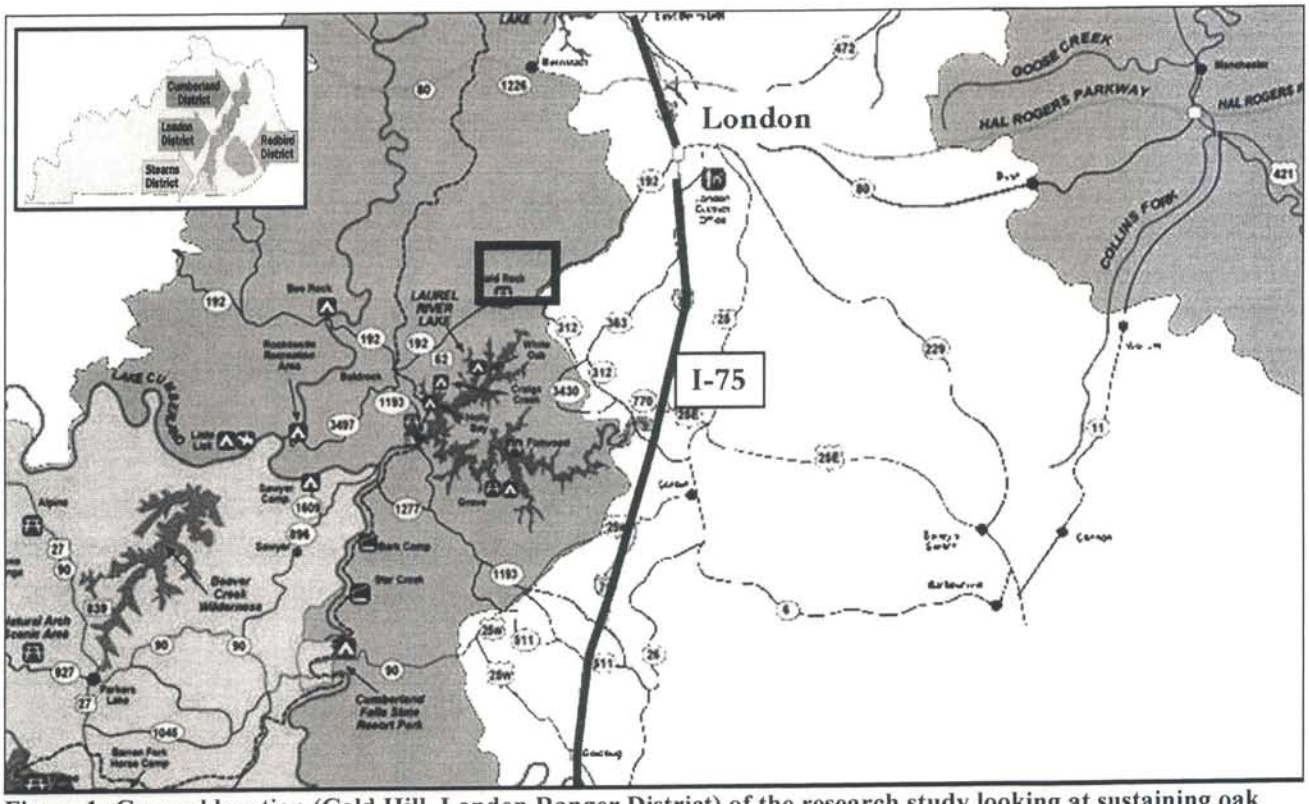

Figure 1: General location (Cold Hill, London Ranger District) of the research study looking at sustaining oak systems amid threat of gypsy moth infestation and oak decline on the Daniel Boone National Forest.

A mechanical tree length harvesting system was used to harvest all units. The system consisted of a feller buncher, grapple skidder and a knuckleboom loader. Trees larger than 23 inches DBH were felled with a chainsaw. All limbing and topping was performed with a chainsaw in the stand. Products removed from the units included hardwood sawtimber and biomass logs. A biomass log was any material greater than 3 inches in diameter, reasonably straight, at least 10 feet long and does not qualify as a saw log.

Methods

The Forest Harvesting and Operations Research Unit with the USDA Forest Service in Auburn, Alabama measured the productivity and efficiency of the harvesting system and its impact on the stand. Due to the number of acres to be treated and the long time frame to complete the harvesting, data recorders were used to capture gross harvesting data. The goal was to measure the productive time required for the harvesting system to harvest each unit of each treatment. This data along with the amount of timber removed from each unit allowed for the calculation of unit productivity and an estimate of cost and efficiency. Additionally, site impacts following the harvesting were also measured with a soil disturbance survey.

A data recorder was fitted to each machine in the harvesting system. Yellow Activity Monitoring System (YAMS) Activity Recorders were used to capture productive machine hours for each machine. The YAMS Activity Recorders are capable of recording 114 hours of productive machine before requiring a download. Assuming 8 productive hours a day, the Activity recorders would only have to be downloaded approximately every 14 working days or every 3 weeks (Thompson, 2002). The feller buncher was also equipped with a Multidat Junior data recorder/GPS unit in order to provide spatial data regarding the cutting pattern and acreage cut per day.

Timber volume removed from each unit was calculated from the load tickets. The load tickets for each unit were supplied by the timber purchaser to the Forest Service as part of the timber sale agreement. A portable digital video recorder (DVR) and small camera was also used during part of the study to help quantify the number and type of loads and the date and time of loads removed from the units. This data also allowed for the analysis of truck loading and turn times.

In order to measure the site disturbance caused by the harvesting operations each unit was accessed using the point transect method as described in McMahon (1995). A total of 9 classes and 12 subclasses were used to access site disturbance. Table 3 lists the disturbance classes and subclasses used.

Table 3: Disturbance classes used to access harvesting impacts on the Daniel Boone National Forest.

DISTURBANCE CLASS	LOCATION
-Undisturbed	-Landing
-Disturbed w/ litter in place	-Primary skid trail
-Litter removed & topsoil exposed	-Secondary skid trail
-Litter removed & mineral soil exposed	-Stand area
-Litter & soil mixed	-Road
-Soil exposed > 4 inches	-Other (stream bed, SMZ, etc.)
-Non-soil (stumps, rocks, logs, etc.)	
-Logging slash	
-Soil deposited on top of ground	

Results and Discussion

As of August 2009 seventeen of the 18 units scheduled to be harvested were completed. Twelve of the 17 completed units have been surveyed for site disturbance. The following results and discussion will focus on the 12 units that have had harvesting and the site disturbance surveys completed.

The research study required that the harvesting be completed with a mechanical harvesting system. The harvesting crew initially consisted of a rubber tired feller buncher, a tracked swing to tree feller buncher, two grapple skidders and a knuckleboom loader. The rubber tired feller buncher was fitted with a shear felling head, but after a few weeks this machine as well as the second grapple skidder was removed from the crew and the tracked swing to tree feller buncher with a bar saw was used to fell all trees 23 inches DBH and smaller. Later in 2007, the tracked feller buncher was replaced with a similar machine with a disc saw. This machine remained with the crew for the rest of the study. Adverse (wet) weather conditions resulted in the extension of the harvesting well beyond the desired completion date of the end of the second growing season (Winter 2008). The wet weather and the resulting slower harvesting productivity led to the decision to add a second harvesting crew in June 2008. The second harvesting contractor was similarly equipped as the first. The equipment models and operating cost for both crews are listed in Table 4. System costs were calculated using the machine rate method and include ownership, operating and labor costs, but do not include profit and overhead.

In an effort to complete the harvesting by the end of the second growing season the harvesting crews were allowed to work through the normal winter shutdown period (December to April). The crews were closely monitored and not allowed to exceed site disturbance limits set by the Forest Service. Working through the winter months did speed up harvesting but included extended periods of idle time when conditions were too wet.

Table 4: Harvesting system machine type and costs for the research study looking at sustaining oak systems amid the treat of gypsy moth infestation and oak decline on the Daniel Boone National Forest.

MACHINE	CONTRACTOR 1		MACHINE	CONTRACTOR 2	
	SMH	PMH		SMH	PMH
1999 JD 648 G Skid	$40.71	$62.64	1998 JD 648 G Skid	$40.71	$62.64
1999 TJ 2618 FB	$49.71	$76.48	1998 TJ 608 FB	$49.56	$76.25
2007 JD 335 Loader	$54.07	$83.18	1985 Hawk Loader	$27.73	$42.65
System	$144.49	$222.30	**System**	$118.00	$181.54

In 2007 when harvesting began, measuring productivity was complicated by constantly changing personnel and equipment in the harvesting system. The addition of the second harvesting contractor also complicated the process of measuring productivity with the doubling of the number of machines to instrument and introducing an additional variable to account for differences in productivity and site disturbance among the treatments.

The 12 units considered in this paper represent 4 replicates of each of the 3 harvesting treatments. All units were harvested between May 2007 and December 2008. Seven of the units were harvested by the first contractor and the other 5 by the second contractor added in June 2008. Table 5 below lists the units harvested, acres, times to harvest each unit and the time and productivity for each unit.

Table 5: Harvesting data from 12 of 18 units of the research study looking at sustaining oak systems amid threat of gypsy moth infestation and oak decline on the Daniel Boone National Forest.

UNIT	TREATMENT	CREW	AREA (AC)	TIME (WKS)	TONS	TONS/AC	PMH	TONS/ PMH
2	Shelter	1	31	9	2136	68.9	321.5	6.65
12	Shelter	2	16	9	1523	95.2	277.9	5.48
29	Shelter	1	30	7	1510	50.3	215.9	6.99
35	Shelter	1	29	12	2865	98.8	400.6	7.15
18	Thin	2	21	4	526	25.1	116.7	4.51
21	Thin	1	27	4	409	15.2	113.4	3.61
25	Thin	2	17	4	540	31.8	83.8	6.45
33	Thin	1	26	5	593	22.8	211.5	2.8
4	WThin	1	20	5	1079	53.9	155.6	6.93
19	WThin	2	28	6	997	35.6	138.2	7.22
22	WThin	1	27	4	907	33.6	158.7	5.72
23	WThin	2	19	5	706	37.2	128	5.52

The shelterwood with reserves units average 27 acres in size and took and average of 9 weeks to harvest. The woodland thinning and thinning to B-line units averaged 23 and 24 acres in size and took an average of 4 and 5 weeks respectively to harvest. Figure 2 illustrates time to harvest by treatment. Shelterwood unit 35 took 3 months to harvest. This unit was the first unit of the study to be harvested and the long time to complete harvesting reflects contractor familiarization with the prescription as well as high personnel turnover.

Tons per acre removed varied, as expected, by treatment with an average of 78 tons/ac on the shelterwood units, 24 tons/ac on the thinning to B-line units and 40 tons/ac on the woodland thinning units. Figure 3 below illustrates tons/a/c removed for all three treatments. Overall productivity on all three treatments averaged 5.75 tons/Productive Machine Hours (PMH) with a range of 7.22 to 2.8 tons/PMH. Thinning to B-line unit 33 recorded the lowest productivity and this could be the result of another crew personnel shakeup and the replacement of the bar saw Timberjack feller buncher with the disc saw equipped Timberjack feller buncher.

A gross system utilization rate of 25.7% was calculated for all units. This number was calculated using the number of weeks to harvest each unit, the productive machine hours for each unit and the assumption that a typical working year is 2000 hours. Therefore, the overall average utilization rate calculated is lower than the actual system utilization because it does not factor in days lost to weather delays and days not scheduled to work, but it still reflects a low utilization rate. Cost per ton was also calculated for each unit. The shelterwood with reserves and woodland thinning units both averaged $32/ton, while the thinning to B-line units averaged $52/ton. This additional $20 dollars per ton reflects the low average harvested tons per acre of 24 as compared to 78 tons/ac and 40 tons/ac for the shelterwood and woodland thinning treatments, respectively.

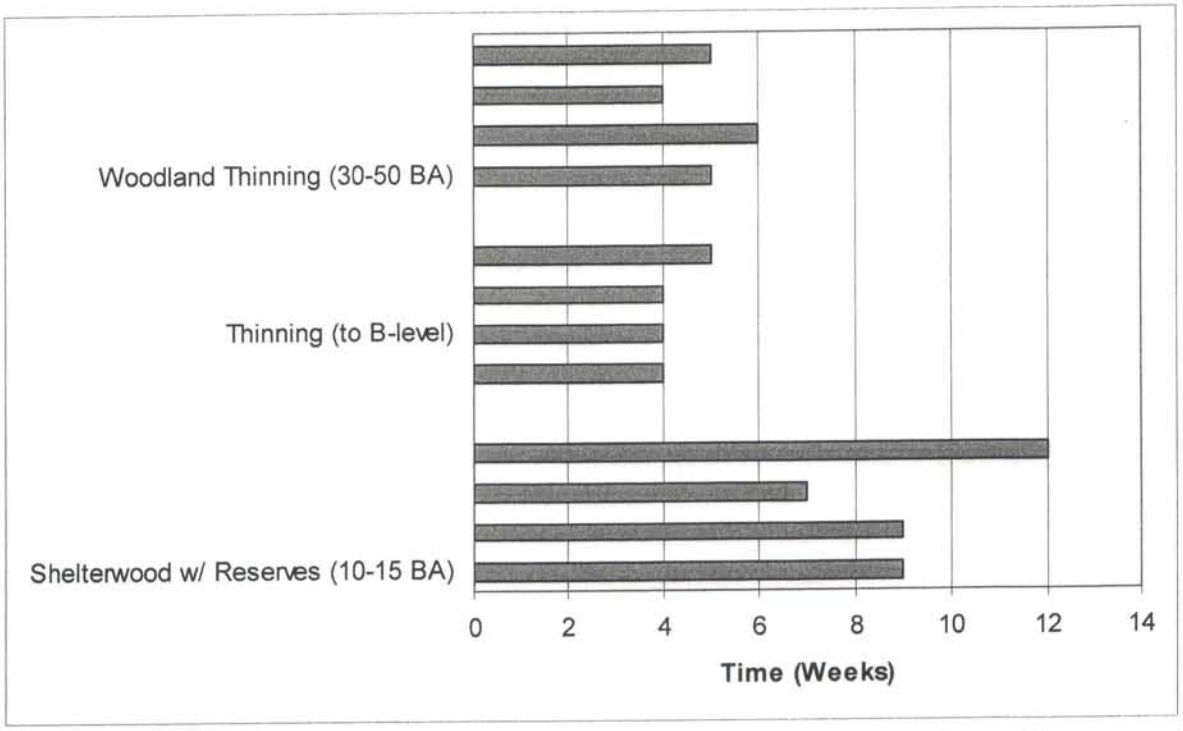

Figure 2: Time to harvest units by treatment of the research study looking at sustaining oak systems amid the threat of gypsy moth infestation and oak decline on the Daniel Boone National Forest.

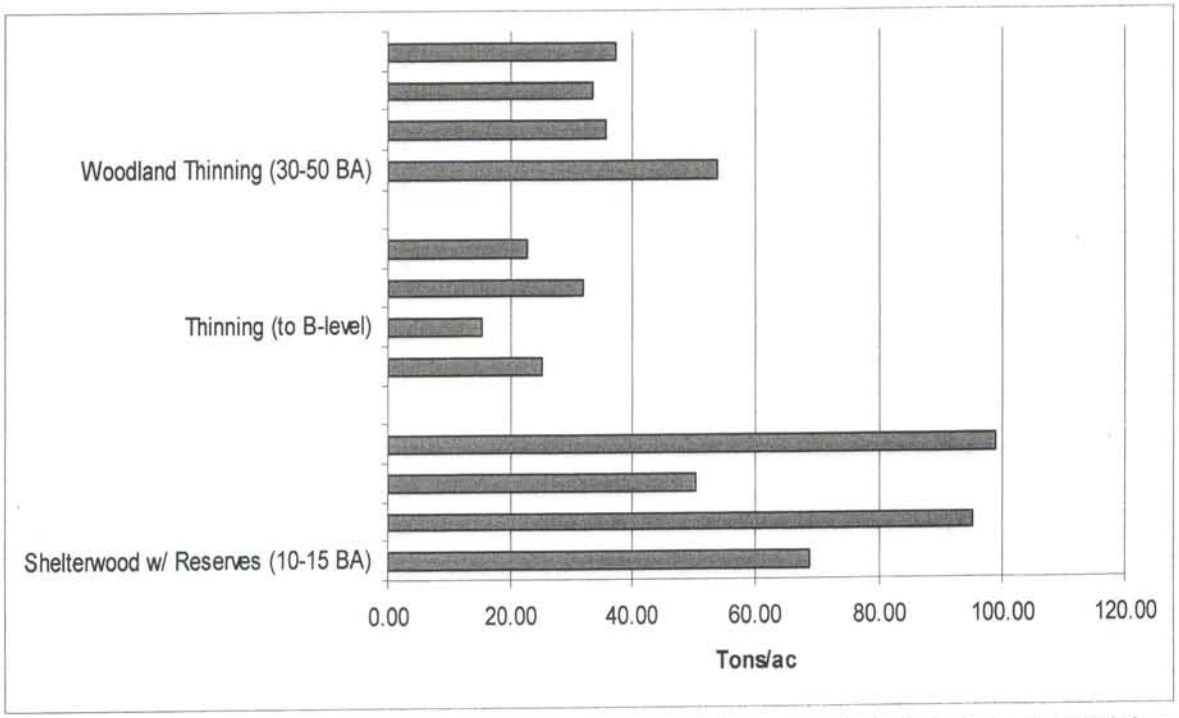

Figure 3: Tons/ac removed from harvest units by treatment of the research study looking at sustaining oak systems amid the threat of gypsy moth infestation and oak decline on the Daniel Boone National Forest.

Site disturbance sampling was performed on the 12 units. Table 6 below summarizes the 9 disturbance classes and 6 location classes into 5 disturbance classes and 2 location classes. The "Slash" disturbance class was included to illustrate the amount of biomass left in the units. Eighteen percent of the shelterwood with reserves units were classified as "Slash", while 9% and 12% of the thinning to B-line and woodland thinning units, respectively, were classified as "Slash". "Slash" was defined as any piled limbs and tops located at the survey point. Figure 4 averages the classes in Table 6 by treatment. "Soil Exposed" ranged from 27% on the thinning to B-line units to 35% on the

shelterwood with reserves units. "Litter in Place" and "Undisturbed" combined, accounted for 46%, 56%, and 63% in Shelterwood with reserves, woodland thinning and thinning to B-line, respectively. Thinning to B-line units had the highest percent area in undisturbed and litter in place which reflects the smaller average size (23 ac) and the least average volume of timber removed (24 tons).

Table 6: Site disturbance data for the research study looking at sustaining oak systems amid the threat of gypsy moth infestation and oak decline on the Daniel Boone National Forest.

UNIT	TREAT-MENT	UN-DISTURBED	LIT. IN PLACE	SLASH	SOIL EXPOSED	SOIL ON TOP	STAND AREA	SKID TRAILS
2	Shelter	18	29	15	36	2	95	5
12	Shelter	12	31	18	36	2	91	9
29	Shelter	19	33	12	36	1	91	9
35	Shelter	17	24	25	34	0	73	27
18	Thin	35	24	10	30	0	89	11
21	Thin	35	28	4	31	1	85	15
25	Thin	15	47	10	27	1	89	11
33	Thin	32	36	12	20	1	81	19
4	WThin	30	23	7	36	3	72	28
19	WThin	19	39	17	25	0	80	20
22	WThin	31	25	7	37	0	81	19
23	WThin	24	32	15	28	0	92	8

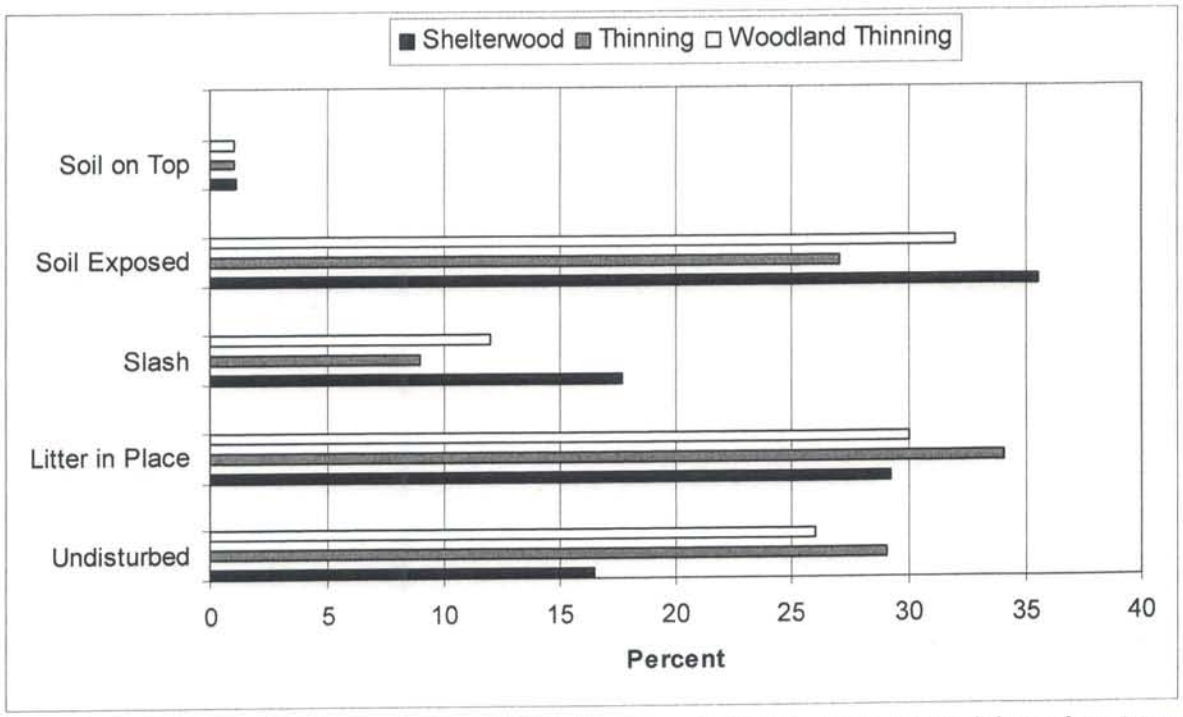

Figure 4: Average site disturbance class values for the research study looking at sustaining oak systems amid the threat of gypsy moth infestation and oak decline on the Daniel Boone National Forest.

The disturbance classes for location are summarized as "Stand Area" and "Skid Trails". Trails consists of all non "Stand Area" classes including; primary skid trails, secondary skid trails, landings, and roads. Shelterwood unit 35 has one of the highest percentages in Skid Trails at 27%. This number is again potentially explainable by the contractor becoming familiar with the prescription requirements and a high turnover in personnel. Woodland thinning unit 4 has the highest percent of area in Trails, 28%. This number is explainable by the topography of the unit. The unit

was aligned along a short ridge and consisted of step slopes on both sides and the end. The contractor was forced to winch timber from some sections of the unit. Figure 5 illustrates that on average all three treatments had average percent in Trails between 10% and 20%.

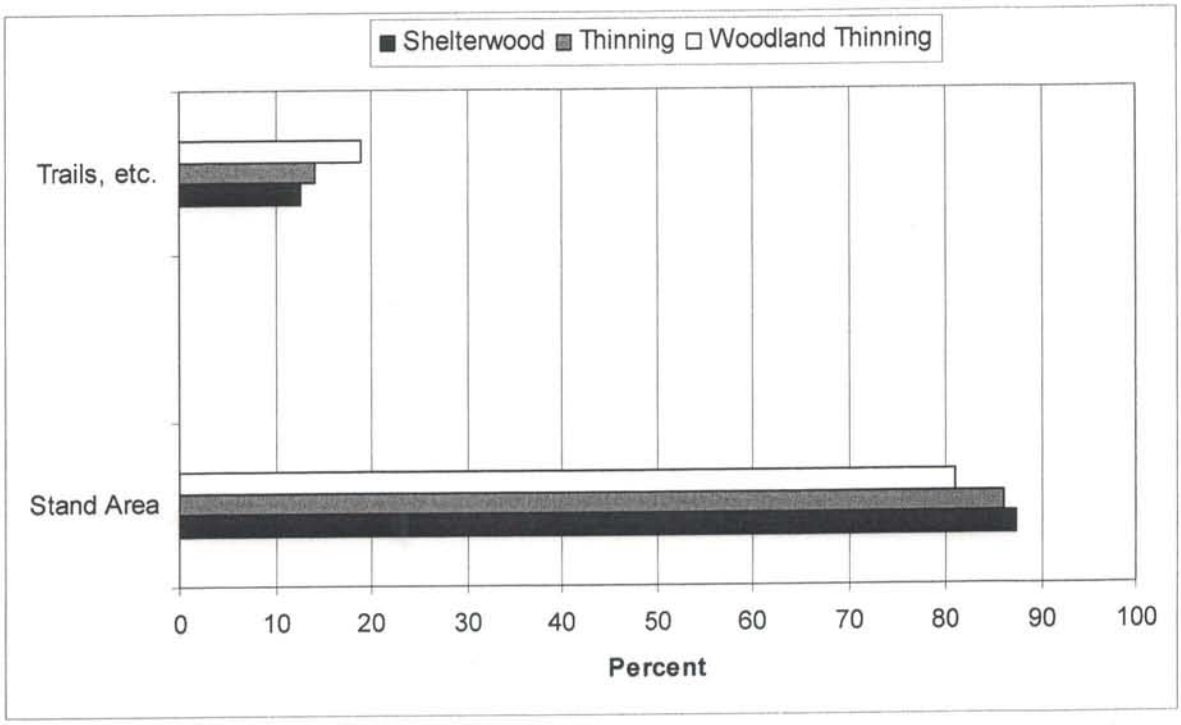

Figure 5: Site disturbance survey location data averaged by treatment for the research study looking at sustaining oak systems amid the threat of gypsy moth infestation and oak decline on the Daniel Boone National Forest.

Conclusions

This paper presents data from 12 of 18 harvest units that are part of a large scale multidisciplinary research study designed to evaluate the effectiveness of various silvicultural treatments at minimizing the impacts of gypsy moth and oak decline in oak stands of the Daniel Boone National Forest in Southeastern Kentucky. The harvesting crews were instrumented with data loggers to measure productive machine time. Load tickets and machine time was used to calculate gross production for each unit. Site disturbance resulting from the harvesting was also measured.

Overall productivity for the 12 units averaged 5.75 tons/PMH. Time to harvest ranged from 9 weeks for the shelterwood with reserves units to 4 and 5 weeks for the thinning to B-line and woodland thinning units, respectively. Over all system utilization was low at 25.7%, but this number did not reflect nonscheduled days and time lost to wet weather. Production costs were $32/ton for the shelterwood with reserves and woodland thinning units, but were $52/ton for the thinning to b-line units. This high figure resulted from the small volume of timber removed from the units and may indicate that this treatment is not economical to perform. Site disturbance data indicated that on average the percent of the units in landings, skid trails and roads was between 10 and 20% for all treatments.

Harvesting on the last unit should be completed by the end of August 2009. Once all harvesting and disturbance sampling is complete a more comprehensive statistical analysis and comparison between the treatments will be preformed. Productivity, cost and site impact data will be used along with the other silvicultural and stand data collected on the units to evaluate the effectiveness of the treatments at mitigating gypsy moth infestations and oak decline on the Daniel Boone National Forest.

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