Oak Savanna Restoration through Thinning and Prescribed Burning
on the Southern Cumberland Plateau, Sewanee, TN

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Introduction

Oak-hickory dominated forests typical of the Cumberland Plateau tablelands and much of the eastern United States are in a state of decline and are now becoming comprised of maple and other shade-tolerant species (Iverson et. al, 2008, Blankenship et. al, 2006). It is believed the shift in species composition in eastern forests is the product of fire suppression policy, though other theories like deer herbivory may be furthering this change (Songlin Fei et. al., 2005). Fire set both by lightning and Native Americans have historically maintained an oak-hickory composition and an open, savannah-like structure of eastern woodlands (Abrams 2005, Blankenship et. al, 2006). When this fire disturbance is altered, as in the case of eastern forests beginning with European settlement, forest composition shifts in favor of shade-tolerant species and forest structure becomes less stratified as the canopy closes and dense vegetation establishes in the under and midstories (Nowacki et. al, 2008). Forests undergoing these changes become darker and more mesic, a process called mesophication. Furthermore, alterations to natural disturbance regimes often increase the proliferation of invasive species.

Forests on the Cumberland Plateau are among the most diverse in the temperate region and thus any changes to these forested ecosystems may have profound ecological consequences on the flora and fauna populations that live there (Hinkle et al., 1993). Recent interest in restoring eastern forests back to their historical condition, or reference point, through the use of prescribed burning and/or silvicultural treatments have had some success in regenerating oak (Iverson et. al, 2008, Brose et. al, 1998). These restoration efforts will be replicated on Cumberland Plateau in Sewanee, TN where the forest is transitioning from dominance by oaks and hickory to maple due to fire exclusion. The specific objectives of this restoration effort involving prescribed burning and a midstory cut were to: (1) increase oak and hickory regeneration, (2) decrease basal area of forest by targeting shade tolerant species (3) increase forest heterogeneity by creating open, savannah-like habitats characterized by grasses and low tree density, (4) remove nonnative eastern white pine from forest, and (5) preserve and re-establish native shortleaf and virginia pine component of forest.

Materials and Methods

Site Description

This study was conducted in compartment 20 at Sewanee: The University of the South located atop the Cumberland Plateau at approximately 1900 ft in elevation (Figure 1). The 56-acre site is located at about 35°13'22" N and 85°55'58" W. The forest is an upland oak-hickory forest with a shortleaf and virginia pine component (Figure 2). Nonnative eastern white pine is also comprised of the forest, and is planted in plantations and along the adjoining fire lines. The reference condition in this restoration project is the year 1959 in which the forest was largely comprised of oak and other hardwoods interspersed with some shortleaf, had low tree density, and did not contain eastern white pine (Figure 3).

The climate in Sewanee is classified as humid mesothermal with long, moderately hot summers and short, mild winters (Thornthwaite, 1948). Mean annual temperature in Sewanee is 55° F, and yearly precipitation ranges 55-60" (Wolford 2010). There are typically ca. 200 frost-free days in a given year (PRISM Climate Group, 2011). The underlying geology is largely Pennsylavanian sandstone, and soils are described as sandy loam Ultisols (Miller, 1974; Wolford 2010). Average soil depth based on field observations was 1.87 ft.

Data Collection

A pre-treatment inventory was completed at eleven plots placed throughout the site to serve as a baseline following the restoration effort and for future monitoring of the location (Figure 2). To calculate basal area and trees per acre, 1/20th acre (r = 26.3 ft) plots were established using each plot center as a reference point. In each plot, trees at least 4.5 ft tall were measured for diameter and identified by species. All snags 4.5 ft tall or greater were tallied and their diameters at breast were recorded. $1/1000^{th}$ acre (r=3.72 ft.) plots were established at each plot center to quantify regeneration at the site and vegetative cover. All saplings were tallied and distinguished as being oak or non-oak. Percent cover was estimated for all saplings, woody shrubs, and herbaceous plants.

Fuel loads were determined at each plot by conducting Brown transects starting at plot center and heading north 75 feet. No woody debris was quantified for the first 15 feet. All fuel classes -- 1, 10, 100, 1000 hr. -- were measured from 15-21 ft. Only 100 and 1,000 hr. fuels were tallied from 21-27 ft. For the remainder of the transect, only 1,000 hr fuels were measured and their diameters recorded. A ruler was used to measure duff and litter depths at the 15 ft and 75 ft marks along each Brown transect to further estimate fuel loadings for the site. Soil depth for each plot was estimated by averaging three soil measurements recorded by a soil probe. Slope gradient for each plot was also estimated using a clinometer. Photographs were taken of each plot's pre-treatment conditions to later aid in visual comparison purposes of photos taken during the post-harvest inventory (Figure 4). The photos were taken standing at plot center and facing south.

After the pre-treatment data collection was complete, trees were marked for retention before the midstory cut became underway in the 20 acres that was slated for harvest. All large-diameter oak were marked, as well as all hickory, shortleaf, and large snags. Large-diameter black gum and yellow poplar were also designated for retention. Sassafras, maple, sourwood, eastern white pine, and loblolly were left to be harvested. Approximately 5,000 eastern white pines growing in the understory were manually removed from the site. The site was harvested beginning on October 12th. A processor was employed to harvest marked trees and distribute logging slash evenly across the site, and a forwarder was used to gather all logs and ready them for shipment (Figure 5). After harvesting was complete, inventory of plots 6, 7, 8, 9, & 11 was conducted again using the pre-treatment methods outlined above, fuel loads were recalculated, and photographs were taken to document post-harvest conditions. A prescribed burn will be scheduled for the 56-acre site in spring 2012. Following the burn, grass seed will be dispersed across to the site to establish native warm-season grasses in the understory.

Results

Pretreatment

The stand is uneven in age due to an inverse J-diameter distribution of canopy trees (Figure 6). *Quercus* species generally range ≤ 16 inches at dbh (Figure 7). Average diameter for *Pinus* species were also typically ≤ 16 inches at dbh though there was extremely low representation in the 2.1-4 and 4.1-6 inch diameter classes (Figure 8). The 0-2 inch diameter class is the largest among the pines whereas the 2.1-4 inch is the largest among the oaks (Figures 8 and 7). Basal area in compartment 20 averages 130.03 ft per acre for all species (Table 1). Hardwood basal area, 98.09 ft^2 per acre is three times that of 31.94 ft per acre estimated for softwoods. Basal area for *Quercus* species averages 78.70 ft per acre. Snag density was 9.09 across the site and average snag dbh was 1.75 inches (Table 2).

Regeneration plots reveal that oaks are regenerating twice as slow as to non-oak species (Figure 9). Plot 10, however, was anomalous to this trend. Four oak species-chestnut (*Quercus prinus*), white (*Quercus alba*), black (*Quercus velutina*), and scarlet (*Quercus coccinea*)-were found to be regenerating at compartment 20 (Figure 10). Chestnut oak seedlings, averaging at 5,364 per acre, were the most prolific oak species in the understory followed by white (2, 545 per acre), black (1,273 per acre), and scarlet (545 per acre). Understory percent cover typically comprised of seedlings, *Vaccinium*, and *Smilax* species, though other species were also found growing in the understory (Figure 11). Total percent cover of understory species and seedlings typically ranged above 20%; however, plots 6 and 9 were divergent to this trend.

Soil depth at compartment 20 averaged 1.87 feet (Table 3). Duff across the 11 sampling plots was estimated to be 4.08 tons per acre (Table 4) while mean leaf litter for the site was 1.77 tons per acre (Table 5). Course woody debris, or 1000 hour fuels, averaged 1.27 tons per acre (Table 6). Fine woody debris was estimated to be 0.09 tons per acre for 1 hour fuels, 0.8 tons per acre for 10 hour fuels, and 2.18 tons per acre for 100 hour fuels (Table 7). Total fuel load for compartment 20 including duff and leaf litter estimates is 10.19 tons per acre (Table 8).

Post-treatment

After harvest, the site retained an inverse J-diameter distribution of canopy trees; albeit densities (trees per acre) were much lower (Figure 12). *Quercus* species still dominated the 14.1-16 in. diameter class (Figure 13). The smallest diameter class (0-2 in dbh) was substantially reduced among the pines, dropping from approximately 18 to 2 trees per acre, thus reflecting the amount of regenerating eastern white pine that had been eradicated through mechanical means (Figure 14).

Basal area in compartment 20 was reduced from 130.03 ft per acre for all species to 101.45 ft per acre following harvest (Table 9). Basal area for *Pinus* species was reduced to 14.04 ft per acre, or a 66% reduction. Hardwood basal area decreased by 11% to 87.41 ft per acre, though most of this reduction was due to the removal non-oak species as indicated by the relatively unchanged estimate for oak basal area, which is 75.29 ft per acre following harvest. Snag density was left unchanged; however, the average snag dbh for the site increased from 6.4 inches to 7.23, though the estimates for snag density and average snag dbh are likely to be erroneous due to the incomplete inventory of plot data (Table 10).

Understory percent cover was dramatically reduced in plots that had been harvested (Figure 15). Plots 6, 7, and 9 were completely decimated of their understory vegetation, while Plots 8 and 11 still retained *Smilax* and *Vaccinium*, respectfully. Plots 1-5 and plot 10 were not inventoried for a second time since harvesting wasn't conducted in those portions of compartment 20, and thus their post-treatment understory cover were left unchanged.

Duff decreased slightly from 4.08 tons per acre to 3.76 tons per acre following treatment, while litter increased slightly from 1.77 tons per acre to 2.36 tons per acre (Table 11 & 12). Course woody debris increased nearly three-fold to 3.99 tons per acre (Table 13). One-hour fuels remained at 0.09 tons per acre; however, ten-hour fuels increased slightly to 1.33 tons per acre, while hundred-hour fuels experienced a 42% increase to 3.76 tons per acre (Table 14). Total fuel load for compartment 20 including duff and leaf litter estimates is 15.29 tons per acre, a 33% increase in fuel loadings following harvest (Table 15).

Discussion

Effects on Basal Area and Tree Density

Harvesting at compartment 20 was intended to increase openness to support the regeneration of oak species by decreasing the shade-tolerant tree species in the overstory and rid the site of planted eastern white pine plantations. The thinning operation resulted in a 41% overall density decrease across the site (Figure 12). Oak density decreased by 42% and pine density decreased by 67% (Figures 13 & 14). Basal area decreased overall by 29 ft per acre, with pines being the tree class experiencing the largest decline, an 18 ft per acre reduction (Table 9).

Thinning coupled with prescribed has been successfully used in establishing oak regeneration. A similar study conducted on the Alleghany Plateau in southern Ohio documented when basal area of upland, oak/hickory forest was reduced by approximately 30 ft2/acre through harvesting, the density of oak and hickory seedlings increased by 32% when the site was burned after thinning, and burned again four years of after harvest (Iverson et al. 2008). Compartment 20, having similar tree density and species composition as the site in southern Ohio, may benefit from prescribed burning to favor the establishment of a new cohort of oaks in the canopy.

Effects on Advanced Oak Regeneration

Oak regeneration prior to thinning operations was 9,727 seedlings per acre compared to 18,363 seedlings for non-oak species (Figure 9). The southern Ohio study concluded that a minimum of 2,000 seedlings/acre is needed to ascend oaks in the midstory (Iverson et al. 2008). Only six of the eleven plots at compartment 20 had ≥ 2,000 seedlings /acre; they were plots 1, 3, 5, 7, 10, and 11 (Figure 9). Although more than half of the plots met this threshold as indicated in the study, the amount of seedlings per plot varied greatly. Plot 10 had disproportionally higher oak seedling regeneration, 60,000 seedlings/acre, while plots 2, 6, and 8 had zero oak regeneration. Therefore, while some areas in compartment may experience some ascendency of oak species in the midstory, other portions of compartment 20 will continue to lack oak midstory component unless other management options are implemented in areas with no or low oak regeneration.

As the southern Ohio suggests, fire may be an effective management tool to establish oak seedlings. Oak regeneration may prove a viable option in compartment 20 due to the increased openness due to the thinning operation. In addition, fire would further aid in our efforts to decrease shade-tolerant species and eastern white pine since fire has been shown to negatively affect these types of trees, though stump sprouting of recently cut red maples may be a undesired consequence if compartment 20 were to be burned (Blankenship and Arthur 2005, Iverson et al. 2008). Therefore, these two studies suggest that oak species may initially respond well to fire, but may experience competition from other hardwoods, such as red maple, if prescribed burning does not cull out species that compete with oaks.

Change in Fuel Loading

The harvest operation conducted at compartment 20 increased total fuel loadings per acre by 33% (Table 15). This is consistent with findings of the Armfield Bluff study; however, the increase in fuel loadings there was only 9% (Wolford, 2010). Duff debris was on the only fuel type to decrease, but the reduction was only 8% compared to pre-treatment estimates; a decrease which may be explained due to sampling error and compaction of the soil (Tables 15 and 8). One-hour fuels remained exactly unchanged at 0.09 tons per acre while the other fine woody debris classes increased following the harvest, a trend inverse of the findings in the Armfield Bluff study. Litter debris increase from 1.77 to 2.36 tons per acre, an increase of 25%. The increase in leaf litter is likely attributed to the shedding of leaves by trees in preparation for winter. Both 10-hour and 100-hour fuels nearly doubled in weight, an increase of 40% and 42% respectively. Coarse woody debris (CWD) increased the most among fuel classes; the pre-treatment CWD estimate of 1.27 tons per acre increased to 3.99 tons per acre following the harvest, an increase of 68%.

These high values of fuel loadings in is contrast to the Armfield Bluff site despite the site having more basal area removed than compartment 20, a reduction of 63.6 ft per acre compared to 28.58 ft per acre at compartment 20 (Wolford, 2010; Tables 1 and 9). However, this increase in fuel loadings may be explained by the spatial distribution of slash piles at the Armfield Bluff site. Instead of using a processor, a skidder was used to redistribute slash across the site. The skidder is not as effective in distributing slash evenly across the site, and it was noted that slash piles were highly concentrated (Wolford, 2010). Therefore, fuel transects may not have intersected this piles, and thus fuel loadings would be markedly reduced.

Effect on Understory Vegetation

Before harvest, *Vaccinium* and *Smilax* were the two dominant herbaceous plants growing in the understory at compartment 20 (Figure 11). Oak seedlings were generally outnumbered 2:1 to non-oak seedlings (Figure 9). Plots where harvesting took place, plots 6-9 and plot 11, showed complete loss of understory vegetation cover (Figure 15). Due to increase light conditions following the midstory thinning, *Smilax* will likely reestablish quickly, but *Vaccinium* will likely decrease in composition since it typically grows in the shade of the understory. If the proposed prescribed burn in spring 2012 occurs, eastern white pine remaining in the understory or midstory should be killed, but certain non-oak hardwood species, such as *Sassafras*, may not be affected (Blankenship and Arthur 2005, Iverson et al. 2008). Both the thinning and planned prescribed burns will change the understory composition in compartment 20; together they will likely favor a greater grass component especially if native seed is dispersed following the first burn.

Conclusion

The restoration project at compartment 20 at Sewanee: University of the South is nearing completion. A pre-treatment inventory was completed for the site, approximately 20 acres was harvested, a post-harvest inventory was completed for plots within the thinning area, and the site is being prepped to be burned in spring 2012. The success of this restoration effort on the oak regeneration will not be known until a prescribed burn is carried out for the entire 56-acre site. Studies suggest that the combination of thinning and prescribed burning is most effective for restoring oak in upland, oak/hickory forest types on the Cumberland Plateau. In addition to encouraging the establishment of *Quercus* species, the project also focused on removing the eastern white pine planted in plantations and along the fire lanes that form the boundary of southern and eastern edge of compartment 20. Furthermore, the study also sought to increase landscape heterogeneity by creating savannah-like areas of native grasses and maintaining its shortleaf pine component. Long-term monitoring of the site will provide direction for future restoration projects on the Domain, especially those that involve harvesting and prescribed burning.

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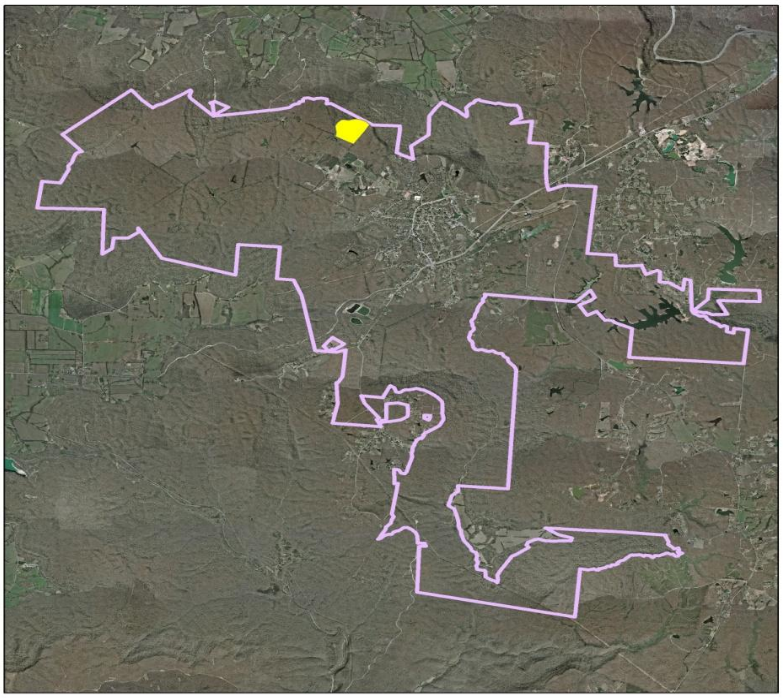

Figure 1: Map of the compartment 20 study site in relation to Sewanee: University of the South in Sewanee, TN. The bold line represents the boundary of the Domain, and the highlighted area indicates 56 acres that compartment 20 encompasses.

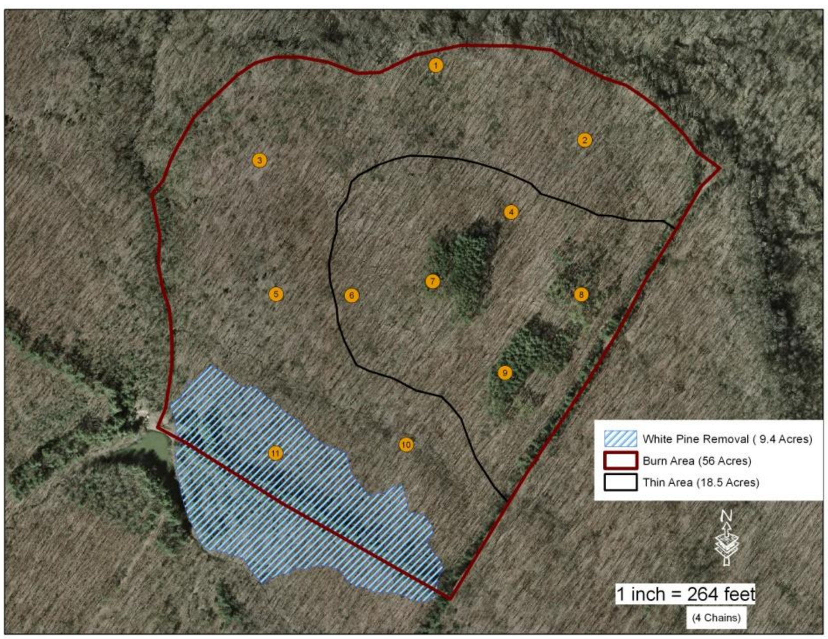

Figure 2: Map of the compartment 20 study site showing the spatial distribution of 11 plots represented by circles. The 56-acre proposed burn area is boldly outlined; the inner, black line represents the 18.5 acres that was thinned; and the highlighted section is the 9.4 acres of a eastern white pine stand that was removed. Please also note the eastern white pine planted along the fire lanes, cedar hollow lake, and in plantations near the compartment’s eastern border.

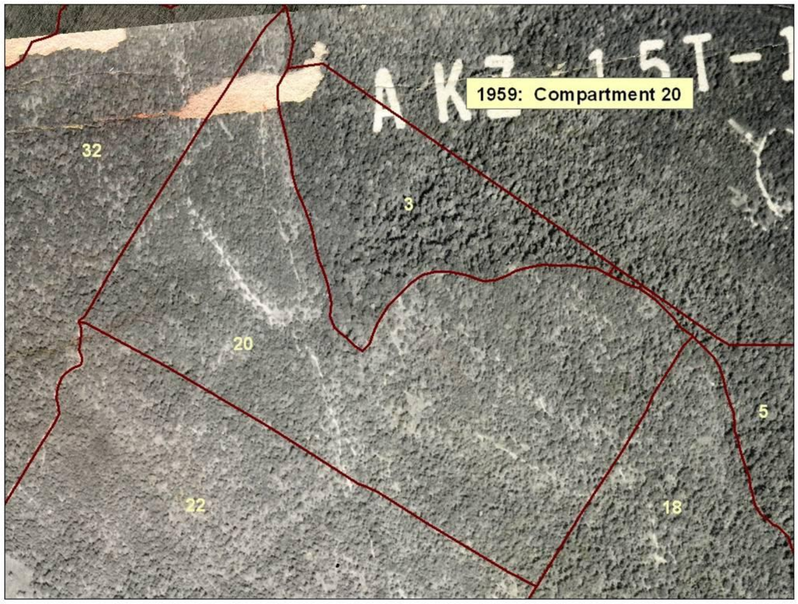

Figure 3: Aerial view of compartment 20 study site in 1959. Bold lines indicate the compartment's boundary.

Figure 4: Comparison of pre-harvest (left) and post-harvest (right) stand conditions at plot 9.

Figure 5: Photo of two forwarders (left) removing logs from the harvest area; and a photo of a processor head (right) that cuts each log to a desired size, delimbs it, and spreads out its logging slash evenly across harvest site.

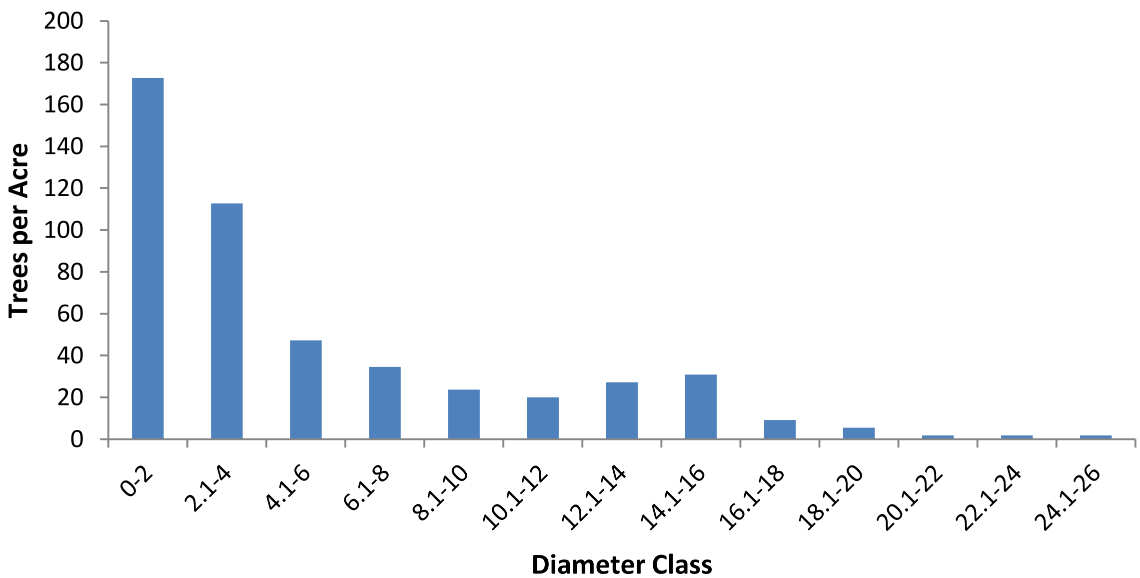

Figure 6: Number of trees per acre in 2” diameter class groups in compartment 20 at Sewanee: University of the South.

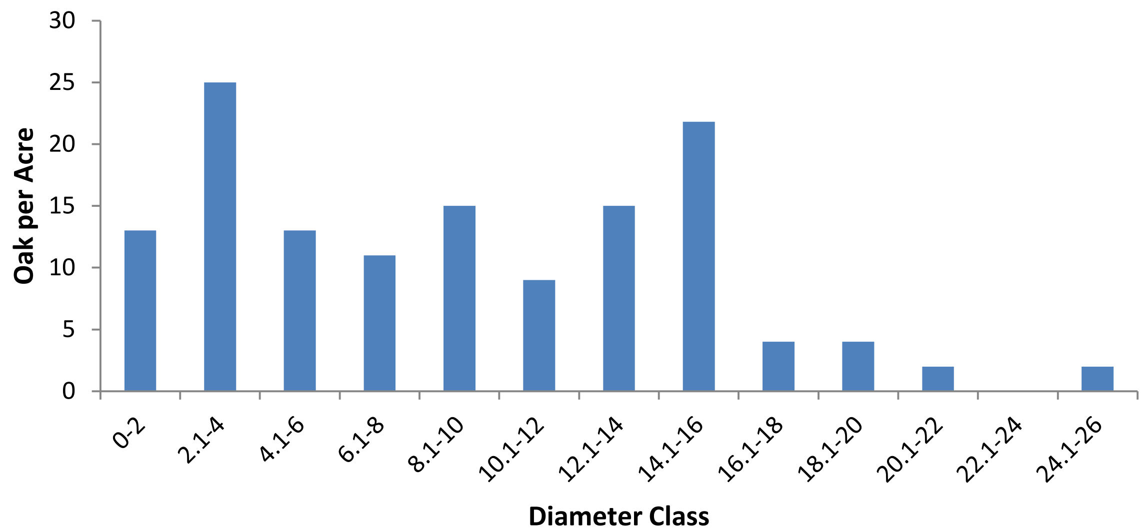

Figure 7: Number of *Quercus* species per acre in 2” diameter class groups in compartment 20 at Sewanee: University of the South.

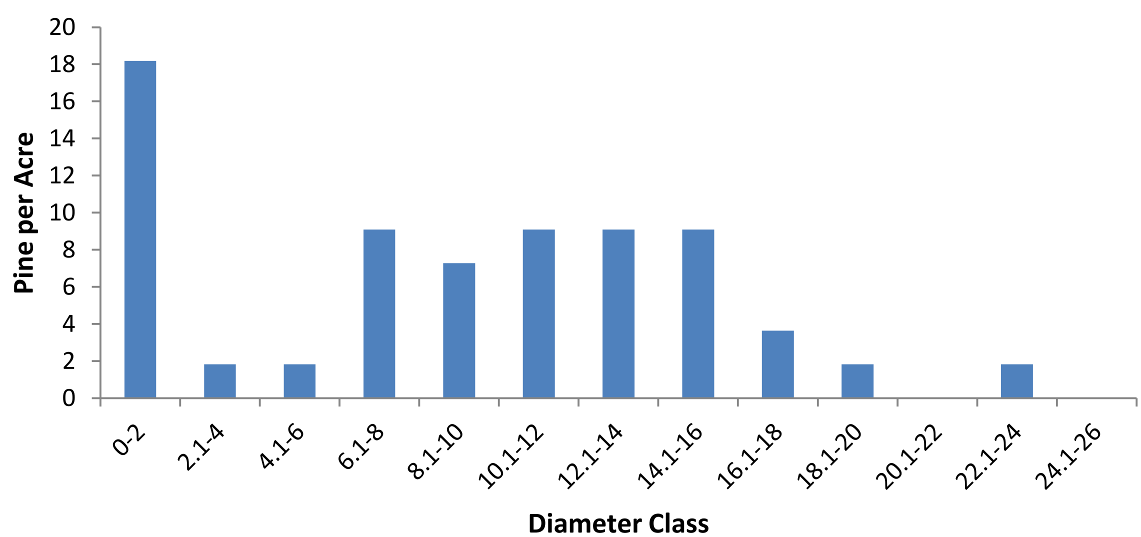

Figure 8: Number of *Pinus* species per acre in 2” diameter class groups in compartment 20 at Sewanee: University of the South.

Table 1: Basal area (ft² per acre) by forested plot (N=11) in compartment 20 at Sewanee: University of the South.

Plot	All Species	Hardwood	Oak	Pine
1	90.16	90.16	87.25	0
2	87.09	87.08	86.42	0.01
3	157.35	157.35	153.75	0
4	130.13	130.13	112.35	0
5	103.41	103.41	85.22	0
6	130.84	130.73	115.82	0.11
7	94.04	27.59	20.26	66.45
8	134.18	62.48	22.01	71.7
9	237.36	26.25	0	211.11
10	142.87	142.87	98.1	0
11	122.93	120.96	84.56	1.97
Average:	**130.03**	**98.09**	**78.70**	**31.94**

Table 2: Number of snags per acre and average snag diameter at breast height (dbh) by forested plot (N=11) in compartment 20 at Sewanee: University of the South.

Plot	Snags per Acre by Plot	Avg Snag dbh by Plot
1	0	0
2	0	0
3	0	0
4	20	6.7
5	0	0
6	20	4.5
7	0	0
8	0	0
9	0	0
10	0	0
11	60	8
Average:	**9.09**	**6.4**

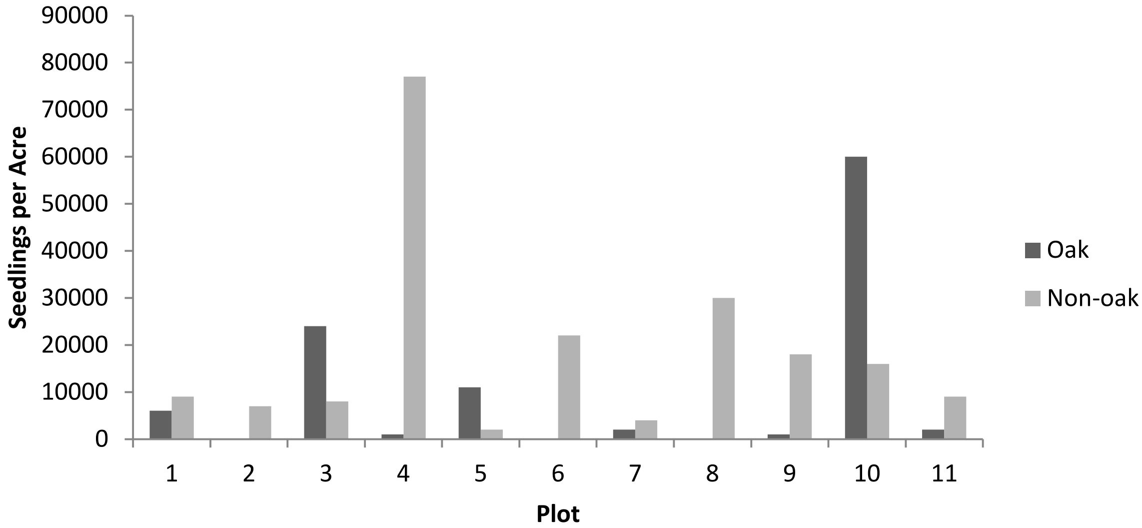

Figure 9: Number of oak and non-oak seedlings per acre by forested plot (N=11) in compartment 20 at Sewanee: University of the South. Oak averaged 9,727 seedlings per acre in compartment 20 compared to 18,363 seedlings per acre for non-oak species.

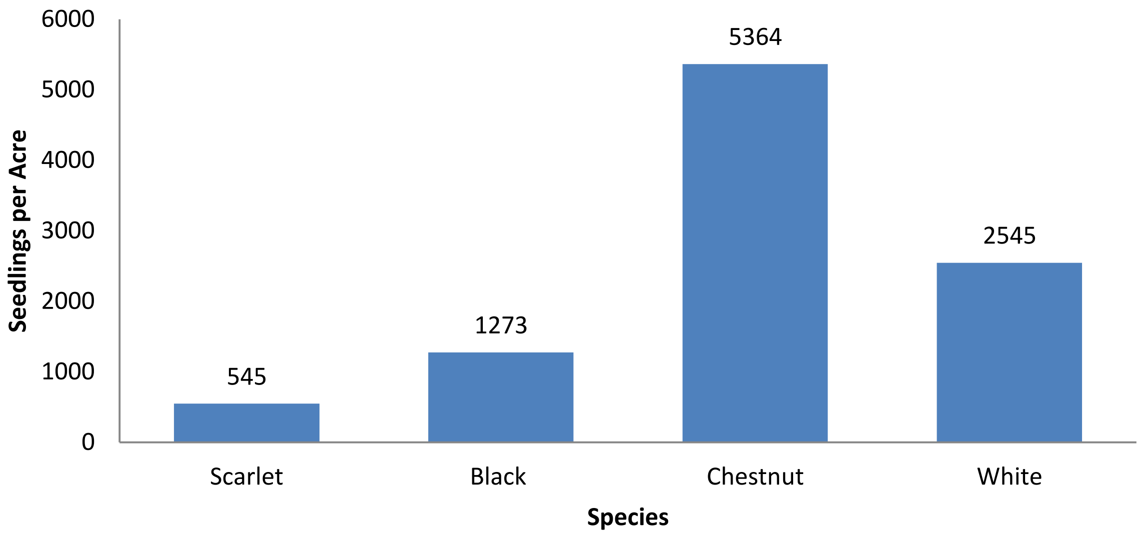

Figure 10: Number of seedlings per acre of four *Quercus* species in compartment 20 at Sewanee: University of the South.

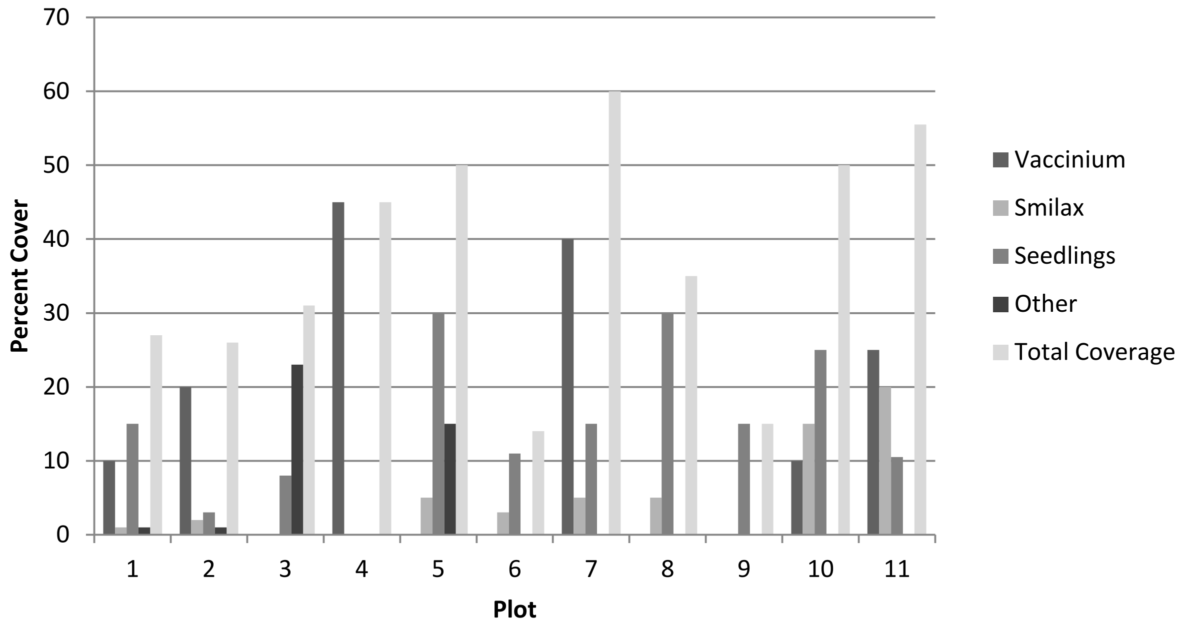

Figure 11: Estimated percent cover of Vaccinium, Smilax, seedlings, and other understory species in 1/1000th acre plots (N=11) in compartment 20 at Sewanee: University of the South.

Table 3: Average soil depth (ft) in 11 forested plots in compartment 20 at Sewanee: University of the South.

	Average Soil Depth (ft)
Plot 1	1.87
Plot 2	1.73
Plot 3	1.60
Plot 4	2.05
Plot 5	1.97
Plot 6	2.42
Plot 7	1.87
Plot 8	2
Plot 9	1.19
Plot 10	0.89
Plot 11	2.93
Compartment 20 Average:	**1.87**

Table 4: Duff estimates (tons per acre) derived from samples taken at the 15th and 75th foot-marks on a north-facing transect in 11 forested plots in compartment 20 at Sewanee: University of the South.

	Duff (tons per acre) at 15 (ft)	Duff (tons per acre) at 75 (ft)	Average (tons per acre) by Plot
Plot 1	4.36	4.79	4.58
Plot 2	3.48	4.36	3.92
Plot 3	2.61	3.48	3.05
Plot 4	2.72	3.63	3.18
Plot 5	3.63	0	1.82
Plot 6	5.45	4.54	5.00
Plot 7	10.89	4.54	7.72
Plot 8	12.71	0.91	6.81
Plot 9	0.91	5.45	3.18
Plot 10	4.36	3.48	3.92
Plot 11	1.74	1.74	1.74
Compartment 20 Average:			**4.08**

Table 5: Litter estimates (tons per acre) derived from samples taken at the 15th and 75th foot-marks on a north-facing transect in 11 forested plots in compartment 20 at Sewanee: University of the South.

	Litter (tons per acre) at 15 (ft)	Litter (tons per acre) at 75 (ft)	Average (tons per acre) by Plot
Plot 1	1.96	1.96	1.96
Plot 2	2.45	2.45	2.45
Plot 3	0.39	1.96	1.18
Plot 4	3.27	2.04	2.66
Plot 5	2.45	0.41	1.43
Plot 6	1.63	2.04	1.84
Plot 7	2.45	0.41	1.43
Plot 8	3.27	0.82	2.05
Plot 9	0.41	1.63	1.02
Plot 10	0.39	2.45	1.42
Plot 11	1.57	2.45	2.01
Compartment 20 Average:			**1.77**

Table 6: Coarse Woody Debris (1000 hour fuel) averages (tons per acre) for 11 forested plots in compartment 20 at Sewanee: University of the South.

	1000 Hr Fuel (Tons per Acre)
Plot 1	0.80
Plot 2	0
Plot 3	1.63
Plot 4	0.63
Plot 5	0
Plot 6	0
Plot 7	1.38
Plot 8	3.67
Plot 9	1.04
Plot 10	3.20
Plot 11	1.63
Compartment 20 Average:	**1.27**

Table 7: Fine Woody Debris (1, 10, & 100 hour fuel) averages (tons per acre) for 11 forested plots in compartment 20 at Sewanee: University of the South.

	1 Hr Fuel (Tons per Acre)	**10 Hr Fuel (Tons per Acre)**	**100 Hr Fuel (Tons per Acre)**
Plot 1	0.13	0.91	2.18
Plot 2	0.05	0.46	0
Plot 3	0.04	0.80	2.18
Plot 4	0.04	1.03	1.09
Plot 5	0.06	0.23	1.09
Plot 6	0.08	0.68	1.09
Plot 7	0.18	0.68	9.80
Plot 8	0.06	0.46	1.09
Plot 9	0.19	0.57	0
Plot 10	0.05	0.80	2.18
Plot 11	0.10	2.17	3.27
Compartment 20 Average:	**0.09**	**0.80**	**2.18**

Table 8: Total fuel load (tons per acre) by fuel type in Compartment 20 at Sewanee: University of the South.

	Average Tons per Acre
Duff	4.08
Litter	1.77
1 Hr Fuels	0.09
10 Hr Fuels	0.80
100 Hr Fuels	2.18
CWD	1.27
Total Tons per Acre:	**10.19**

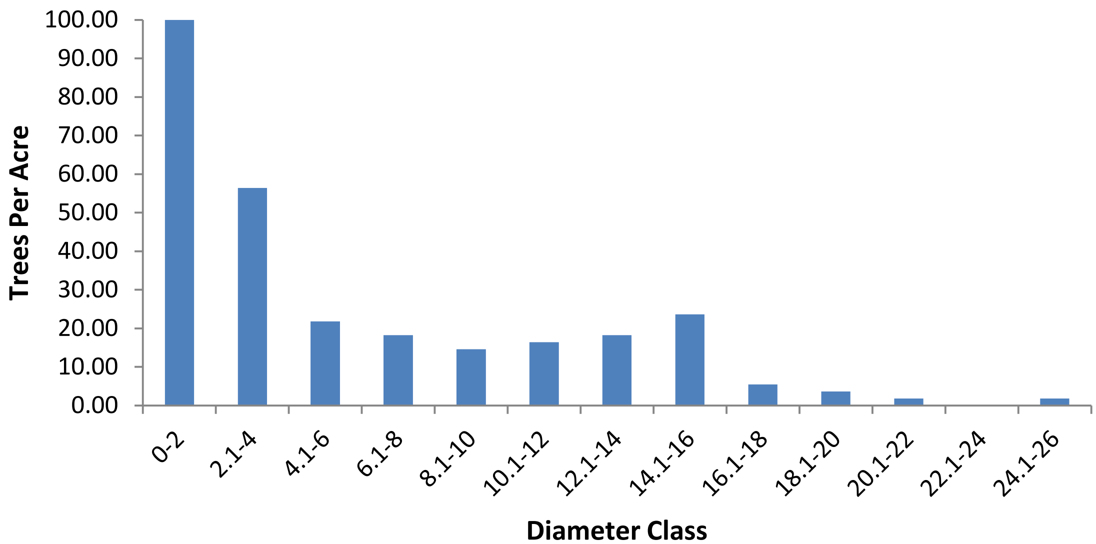

Figure 12: Number of trees per acre in 2" diameter class groups following harvest in compartment 20 at Sewanee: University of the South.

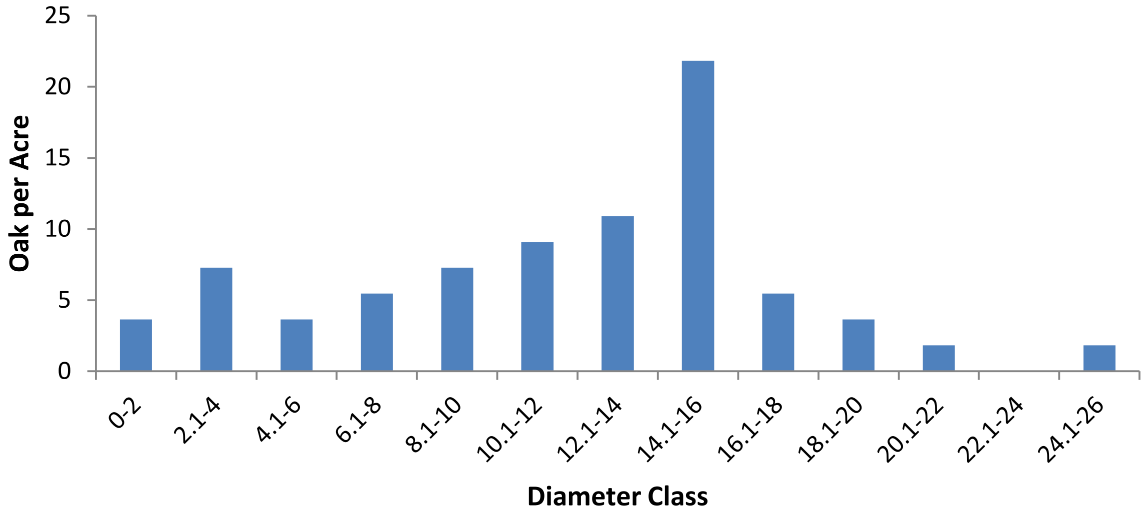

Figure 13: Number of oaks per acre in 2” diameter class groups following harvest in compartment 20 at Sewanee: University of the South.

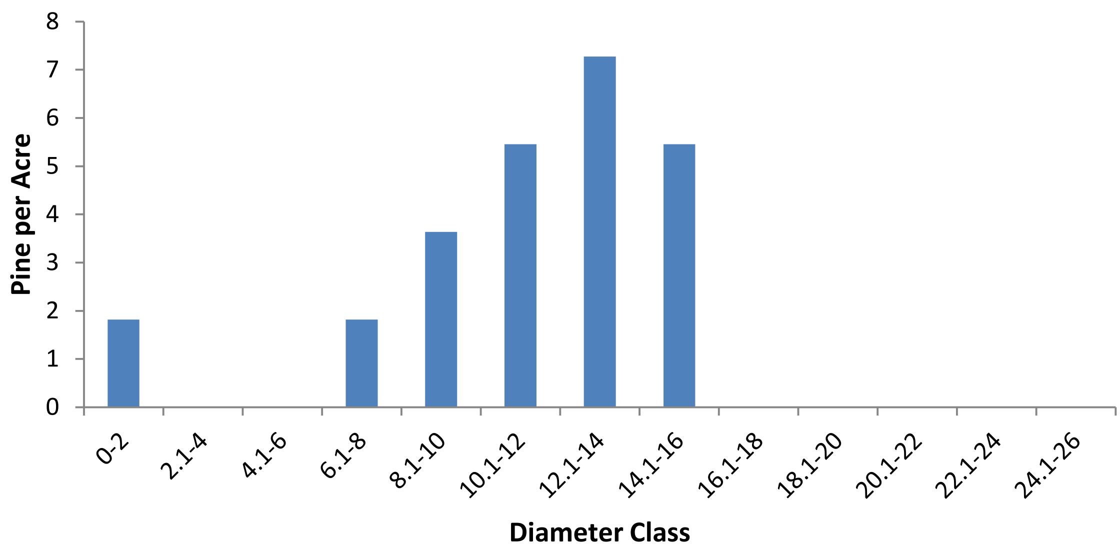

Figure 14: Number of pines per acre in 2” diameter class groups following harvest in compartment 20 at Sewanee: University of the South.

Table 9: Basal area (ft² per acre) by forested plot (N=11) following harvest in compartment 20 at Sewanee: University of the South.

	All Species	Hardwood	Oak	Pine
Plot 1	90.16	90.16	87.25	0
Plot 2	87.09	87.08	86.42	0.01
Plot 3	157.35	157.35	153.75	0
Plot 4	130.13	130.13	112.35	0
Plot 5	103.41	103.41	85.22	0
Plot 6	51.74	51.75	51.74	0
Plot 7	136.96	7.70	7.7	129.26
Plot 8	44.44	19.24	0	25.2
Plot 9	19.88	19.88	0	0
Plot 10	142.87	142.87	98.1	0
Plot 11	151.97	151.97	145.66	0
Post-harvest Average:	**101.45**	**87.41**	**75.29**	**14.04**

Table 10: Number of snags per acre and average snag diameter at breast height (dbh) by forested plot (N=11) following harvest in compartment 20 at Sewanee: University of the South.

	Snags per Acre By Plot	Avg Snag dbh By Plot
Plot 1	0	0
Plot 2	0	0
Plot 3	0	0
Plot 4	20	6.7
Plot 5	0	0
Plot 6	0	0
Plot 7	0	0
Plot 8	0	0
Plot 9	0	0
Plot 10	0	0
Plot 11	80	7.75
Post-harvest Average:	**9.09**	**7.23**

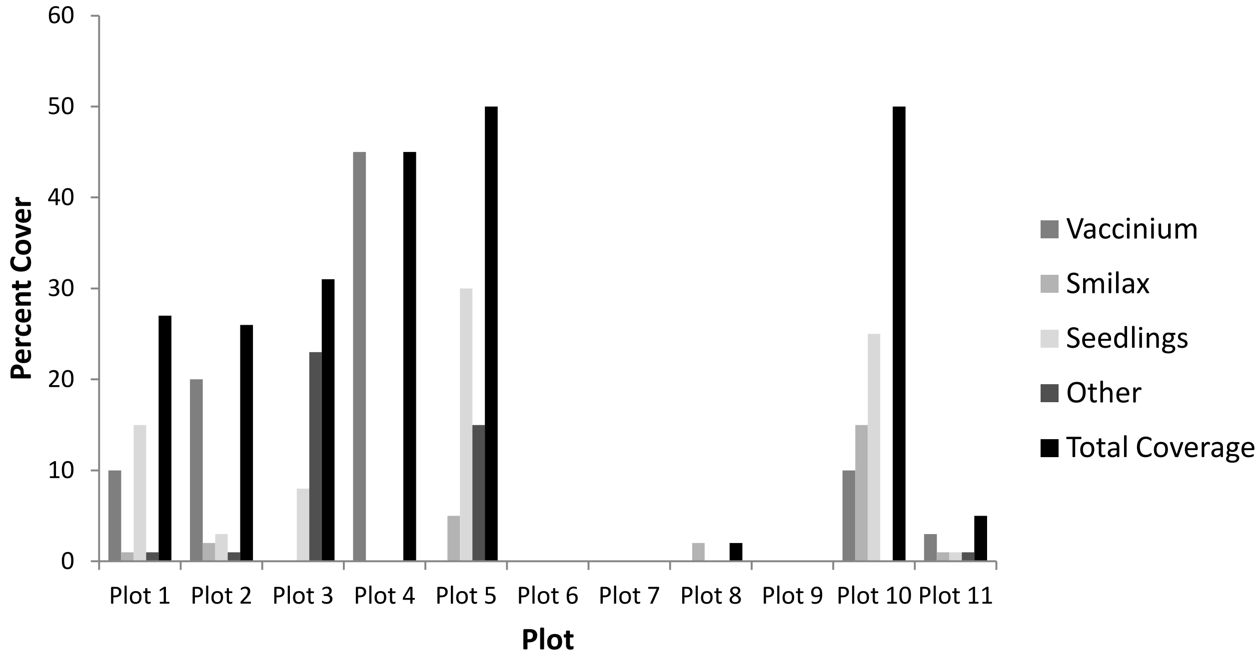

Figure 15: Estimated percent cover of *Vaccinium*, *Smilax*, seedlings, and other understory species in 1/1000th acre plots (N=11) following harvest in compartment 20 at Sewanee: University of the South.

Table 11: Duff estimates (tons per acre) derived from samples taken at the 15th and 75th foot-marks on a north-facing transect in 11 forested plots following harvest in compartment 20 at Sewanee: University of the South.

	Duff (Tons per Acre)at 15 (ft)	Duff (Tons per Acre) at 75 (ft)	Average (Tons per Acre) by Plot2
Plot 1	4.36	4.79	4.57
Plot 2	3.48	4.36	3.92
Plot 3	2.61	3.48	3.05
Plot 4	2.72	3.63	3.18
Plot 5	3.63	0.00	1.82
Plot 6	7.26	2.72	4.99
Plot 7	3.63	2.72	3.18
Plot 8	9.08	7.26	8.17
Plot 9	0.00	0.00	0.00
Plot 10	4.36	3.48	3.92
Plot 11	3.63	5.45	4.54
Post-harvest Average:			**3.76**

Table 12: Litter estimates (tons per acre) derived from samples taken at the 15th and 75th foot-marks on a north-facing transect in 11 forested plots following harvest in compartment 20 at Sewanee: University of the South.

	Litter (Tons per Acre) at 15 (ft)	Litter (Tons per Acre) at 75 (ft)	Average (Tons per Acre) by Plot
Plot 1	1.96	1.96	1.96
Plot 2	2.45	2.45	2.45
Plot 3	0.39	1.96	1.18
Plot 4	3.27	2.04	2.65
Plot 5	2.45	0.41	1.43
Plot 6	8.98	2.45	5.72
Plot 7	3.68	0.82	2.25
Plot 8	2.45	1.63	2.04
Plot 9	0.00	0.00	0.00
Plot 10	0.39	2.45	1.42
Plot 11	5.72	4.08	4.90
Post-harvest Average:			**2.36**

Table 13: Coarse Woody Debris (1000 hour fuel) averages (tons per acre) for 11 forested plots following harvest in compartment 20 at Sewanee: University of the South.

	1000 Hr Fuel (Tons per Acre)
Plot 1	0.80
Plot 2	0.00
Plot 3	1.63
Plot 4	0.63
Plot 5	0.00
Plot 6	19.85
Plot 7	3.23
Plot 8	7.67
Plot 9	3.58
Plot 10	3.20
Plot 11	3.29
Post-harvest Average:	**3.99**

Table 14: Fine Woody Debris (1, 10, & 100 hour fuel) averages (tons per acre) for 11 forested plots following harvest in compartment 20 at Sewanee: University of the South.

	1 Hr Fuels (Tons per Acre)	10 Hr Fuels (Tons per Acre)	100 Hour Fuels (Tons per Acre)
Plot 1	0.13	0.91	2.18
Plot 2	0.05	0.46	0.00
Plot 3	0.04	0.80	2.18
Plot 4	0.04	1.03	1.09
Plot 5	0.06	0.23	1.09
Plot 6	0.25	2.74	5.45
Plot 7	0.19	2.85	6.53
Plot 8	0.11	2.62	6.53
Plot 9	0.06	1.25	11.98
Plot 10	0.05	0.80	2.18
Plot 11	0.02	0.91	2.18
Post-harvest Average:	**0.09**	**1.33**	**3.76**

Table 15: Total fuel load (tons per acre) by fuel type following harvest in Compartment 20 at Sewanee: University of the South.

	Average Tons per Acre
Duff	3.76
Litter	2.36
1 Hr Fuels	0.09
10 Hr Fuels	1.33
100 Hr Fuels	3.76
CWD	3.99
Total Tons per Acre:	**15.29**