

**A COMPUTER-SIMULATED EVALUATION OF
THREE SILVICULTURAL PRACTICES FOR
REDUCING HAZARDOUS FUEL CONDITIONS
AND EXTREME FIRE BEHAVIOR IN PINE
FLATWOOD FORESTS**

**A Final Report for
Dale Wade and Susan Grace
1998 Florida Wildfires Project**



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Abstract

Because of excellent growing conditions, pine flatwood forests in the coastal plain region of the southeastern United States can develop tremendous amounts of highly flammable undergrowth (rough) in only a few years, necessitating intervention to reduce hazardous fuels and prevent catastrophic wildfires. A computer modeling study was initiated in 1998 to determine the potential fire behavior in pine flatwood forests following partial timber harvest, prescribed fire, and understory herbicide application to reduce hazardous fuels. Three sites were selected, each representing one of the treatments, and at each site 15 stands covering a range of rough ages, time since the last silvicultural treatment, were chosen. The stands were inventoried for height, fuel load, and percent cover of the rough and these data were used to develop a custom fuel model for each treatment / rough age combination. These models were then used in the BEHAVE fire prediction system to estimate fire behavior and probability of overstory pine mortality under drought and normal weather conditions for each treatment / rough age combination. In all untreated stands (rough age > 10 years), BEHAVE predicted extreme fire behavior, making any fire control operation very difficult and probably ineffective, and 100% mortality of overstory pines. Prescribed burning provided immediate protection for the pines by reducing fire behavior under both weather conditions. However, this protection quickly disappeared as the rough aged and the shrubs recovered following the prescribed fire. Partial harvest impacted fire behavior in much the same manner and for a similar length of time as prescribed fire. Understory herbicides showed little immediate reduction in fire danger. However, beginning in second year after treatment, fire behavior decreased, a condition that lasted at least until year 6, making survival of overstory pines and successful fire suppression more likely. Under some circumstances, partial harvests and understory herbicides can substitute for fire to reduce fire behavior in pine flatwood forests but forest managers must be aware of each alternative's strengths and weaknesses. Combining treatments may provide immediate and long-term fire protection but these combinations need more research.

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Introduction

In 1998, Florida experienced one of its most active wildfire seasons ever (Karels 1998). From mid-May to mid-July, over 2000 wildfires occurred in central and northern Florida. Over 500,000 acres of forest burned, most of them by high-intensity/high-severity, stand-replacing fires. Over 10,000 firefighters, many of them from other states, fought the fires. Property losses included the destruction or damage of 370 businesses and residences. Commercial timber losses exceeded \$300 million and suppression costs topped \$130 million. The magnitude and severity of the wildfires prompted several land management agencies, including the USDA Forest Service and the USDI Biological Resources Division, to combine resources to study the ecological and economic impacts of the wildfires on Florida's forest ecosystems. Part of the USDA / USDI study addressed the issue of what can be done to reduce the hazardous fuel loadings in commercial pine stands before a wildfire occurs.

Historically, prescribed fire has been the means of controlling hazardous fuel throughout the southern United States (Pyne 1982). Generally, prescribed burning for hazardous fuel reduction in commercial pine stands was done on a 4- to 6-year rotation during the dormant season. Now with new techniques, the 3-year return interval recommended by Sackett (1975) is the goal for most forest managers. The frequent use of fire was necessary because redevelopment of the rough was rapid with fire hazard returning to its preburn level in less than 5 years on most sites (Davis and Cooper 1963). This use of prescribed fire has become controversial in recent years because of smoke management concerns, liability issues, and misconceptions about the ecological ramifications of fire among the region's sizeable population of out-of-state retirees (Wade 1993), resulting in longer burning rotations or attempted fire exclusion.

The continued need for hazardous fuel reduction and the social limitations of prescribed fire have prompted interest in identifying and developing other hazardous fuel management strategies. Two potential treatments are partial timber harvests and application of understory herbicides. Partial timber harvests, usually a deferred shelterwood or diameter limit cut, are sometimes used by public land management agencies to meet widely diverse resource goals while maintaining a continuous forest cover (Smith 1996). Herbicides are often used as a mid-rotation treatment in commercial pine plantations to boost growth (Oppenheimer et al. 1989). Both reduce the highly flammable shrub layer although the degree and longevity of hazardous fuel control is not well defined.

The effectiveness of different fuel reduction techniques for modifying fire behavior can be tested with computer models. Stephens (1998) used FARSITE (Finney 1996), a GIS-based fire prediction system to evaluate silvicultural treatment effects on fire behavior and tree mortality for a watershed in Yosemite National Park. BEHAVE is another fire prediction system and consists of two subsystems, five programs, and 13 modules (Burgan and Rothermel 1984; Andrews 1986; Andrews and Chase 1989). It utilizes existing fuel models (Anderson 1982) or custom-designed ones to predict the behavior of head fires for a given set of environmental conditions.

This report consists of two parts. In the first, I describe fuelbed characteristics of pine flatwood forests treated with one of three silvicultural techniques (prescribed fire, partial timber harvest and understory herbicide application) at 5 different ages of rough (time since treatment). In the second part, I use the fuels data from Part I and BEHAVE to create custom fuel models, simulate fire behavior (flame length and rate-of-spread), and predict overstory pine mortality for each treatment/rough age combination. Because the 1998 wildfires occurred during a severe drought, I conduct each simulation under drought and normal weather conditions. Finally, I discuss the advantages and disadvantages of each silvicultural practice as a fuel reduction technique from a resource protection and fire danger perspective. If alternatives to prescribed fire for reducing hazardous fuels can be found, resource managers will have a wider choice of methods to reduce damaging fires in commercial pine forests - in Florida and elsewhere.

Part I – Methods

Study Sites

Part I of this study was conducted during winter 1998-1999 at three sites located in the Coastal Plain Physiographic Province of northern Florida (Figure 1). Site 1 was north of Olustee on the Osceola National Forest (ONF) in Baker and Columbia counties (30°30'N, 82°30'W). Site 2 was on forest industry (Georgia-Pacific and ITT Rayonier) land located between Lake Butler and Starke in Bradford and Union counties (30°15'N, 82°15'W). Site 3 was on land owned by the St. Johns River Water Management District (SJRWMD) located between Lake George and Daytona Beach in Putnam and Volusia counties (29°15'N, 81°15'W).



Figure 1

The study sites consisted of nearly flat terrain intermixed with slight depressions at elevations of 80 – 160 ft above mean sea level. Mean annual precipitation for these sites was 55 in. with half occurring between May and August and the remainder being distributed evenly throughout the other months. Mean annual temperature for the study sites was 66°F with a January mean minimum of 41°F and an August mean maximum of 92°C. The average growing season was 286 days (Baldwin et al. 1980; Watts 1996).

All study sites were within the North Florida flatwoods ecological community and were dominated by longleaf pine (*Pinus palustris*) and/or slash pine (*P. elliottii*) in the canopy. Gallberry (*Ilex glabra*) and/or saw palmetto (*Serenoa repens*) dominated the understory, but were usually accompanied by various grasses, hardwoods, shrubs, and vines, depending on soil drainage and past land use history. Some sites were slash pine plantations and others were naturally regenerated mixtures of slash and longleaf pines.

General soil characteristics were rather uniform among and within the three study sites. All soils were of the Mascotte, Myakka, Pelham, Pomona, and Sapelo series, which are deep somewhat poorly drained fine sands formed from thick deposits of sandy and loamy marine deposits (Baldwin et al. 1980; Howell 1984; Readie 1990; Dearstyne et al. 1991a, 1991b; Watts 1996). According to land management records, site index varied considerably among and within the study sites. At the ONF, site index for longleaf pine at age 50 ranged from 70 – 75 ft while on SJRWMD lands it was 85 – 100 ft. For the forest industry lands, site index for slash pine at age 25 was 60 – 70 ft.

Study design and measurements

Each site represented a different silvicultural practice due to varying management objectives with prescribed fire at ONF, understory herbicide on forest industry lands, and partial harvest on SJRWMD lands. Hereafter, sites are referred to by their particular silvicultural practice. Prescribed fire was a dormant season burn on a 3 to 5 year rotation. Generally, this type of fire was low to moderate intensity and caused little, if any, mortality to the canopy dominants. The understory herbicide treatment was a mid-rotation application of Garlon 4 applied in autumn by a skidder-pulled mistblower at a rate of 2.0 qts/ac. The partial harvest treatment was a merchantable cut that generally left 50 - 90 ft²/ac of basal area.

At each site, 12 stands varying from 4 to 35 ac were chosen based on the age of rough, i.e., number of years (1, 2, 3, or 5) since last application of the silvicultural practice. The 5-yr-old rough class consisted of 4-yr-old rough at the prescribed fire site, 5-yr-old rough at the partial harvest site, and 6-yr-old rough in the understory herbicide stands. Also at each site, three unmanaged stands, no silvicultural treatment for the past 10 to 40 years, were chosen and included in the study as controls. All sites had 3 or more stands in each of the five age classes. The combining of these five age classes with the three silvicultural treatments created a 3x5 factorial with 3 replications.

For the most part, treatments were exclusive from one another. An exception to that was at the partial harvest site where a few stands had received some low-intensity, dormant-season prescribed fires either immediately before or after the logging operation.

Stands with obvious signs of past fires were excluded and selected stands showed no evidence of recent fire. Even if fire was used early in the life of these stands, its effects were judged minimal relative to the impact of the partial harvest. Also, several stands were found at the understory herbicide site where Garlon 4 had been used as a follow-up treatment to a commercial thinning. Three of these stands were selected and included in the study as a fourth treatment within the rough age 3 category.

Percent cover was determined for all stands using line transects. Near the center of each stand, three 425 ft-long transects were systematically located parallel to one another at distances of 75 ft. Along each transect at 25-ft intervals, vegetation was sampled by holding a 10-ft tall range pole perpendicular to the ground and recording each plant species touching the range pole and the height of the tallest plant. Percent cover and height to the nearest 0.5 ft were determined for five categories; grass, pine litter, saw palmetto, small shrub, and tall shrub. Grass included all graminoid species, i.e., *Andropogon* spp., *Aristata* spp., and *Panicum* spp., while saw palmetto was species specific. Tall shrub was primarily gallberry but also included all other woody shrubs \geq 1.0 ft tall while small shrub included all $<$ 1.0 ft tall, i.e., blueberry (*Vaccinium* spp.) and runner oak (*Quercus pumila*). Pine litter was open areas devoid of vegetation but usually blanketed by pine needles. Because sampling was done in January and February, no forbs were found.

At every fifth sampling point, basal area was determined using a 10-factor prism. The nearest dominant tree was identified to species and measured for diameter at 4.5 ft above the ground, bark thickness at 1.0 ft above the ground, height to base of crown, and total height. Percent cover of saw palmetto and basal area were used in existing equations to estimate fuel loadings for the partial harvest and prescribed fire treatments as per McNab et al. (1978).

In all herbicide-treated stands, the clip-bag-dry (CBD) method was used to determine loadings of shrub and litter fuels because the equations were unsuitable for this treatment. In this method, six 3.3 ft² quadrats were located on a 100x100 ft grid near the center of the stand. Quadrats were delineated by a 3.3x3.3 ft sampling frame and all vegetation, living and dead, within the frame and between 0.5 and 10.0 ft tall was designated as shrub fuels and was clipped, bagged, and taken to the lab for drying. All live and dead plant material $<$ 0.5 ft tall, on or in the forest floor (O_i and O_e horizons) was likewise collected and designated as litter fuels.

To verify the accuracy of the fuel loading equations for the partial harvest and prescribed fire treatments, shrub and litter samples were also collected from one stand for each age-of-rough class using the CBD method.

The shrub and litter samples were dried at 195°F to a constant weight in a wood-drying oven. Fuels were then separated by type (grasses, pine litter including dead downed woody material, and shrubs) and by size class ($<$ 0.25 in dia., 0.25-1.00 in dia., and $>$ 1.00 in dia.). These size classes correspond to the time-lag fuel classes of 1-hr, 10-hr, and 100-hr, respectively (Fosberg 1970). After separation, fuels were weighed on an electronic scale and weight recorded to the nearest 0.357 oz.

Statistical analysis

The fuels data were analyzed as a 3x5 factorial with three treatments (partial harvest, prescribed fire, and understory herbicide) and 5 ages of rough (1, 2, 3, and 5 yrs and untreated). Analysis of variance with Student-Newman-Keul's mean separation test were used to determine differences in fuel loading (tons/ac) for all possible combinations of fuel type (grass, litter, and shrub) and size class (1-hr, 10-hr, and 100-hr) among the treatments for each age-of-rough and among the ages-of-rough for each treatment (SAS 1993). Analysis of variance and Student-Newman-Keul's mean separation test were also used to determine differences in stand characteristics, i.e., basal area (ft²/ac), tree height (ft), crown height (ft), and bark thickness (in.) among the sites and stands. All percent data were arcsine transformed before analysis to correct for unequal variances. In all tests, alpha was 0.05.

Part I – Results

In nearly all treatments, stand characteristics and trends through time in cover, height, and fuel loading of the rough were consistent among replications (Appendix Tables 1 - 14). A few differences in these variables were detected among replications of the individual treatments and these were attributed to site and stand history variation. These differences were judged to be unimportant for the purposes of this study and data were pooled within each treatment / age-of-rough combination to simplify reporting.

Comparison of Site Characteristics

The controls were analyzed to detect underlying differences among the three study sites (Table 1). They differed from each other in several aspects. Slash pine was the only canopy species at partial harvest and understory herbicide sites and co-existed with longleaf pine at prescribed fire site. The oldest trees, about 85-90 years old, were found at the prescribed fire site while trees at the partial harvest and understory herbicide sites were considerably younger, 31-40 and 17 years, respectively. Basal areas were nearly identical at the herbicide and partial harvest sites ($\cong 121$ ft²/ac) while the basal area

Table 1. Characteristics (mean \pm 1 se) of the dominant vegetation at the study sites*.

Characteristic	[----- Sites -----]		
	Partial Harvest	Prescribed Fire	Understory Herbicide
Species [•]	Slash pine	Slash & Longleaf pine	Slash pine
Tree age [†] (yrs)	31-40	85-90	17
Stand Origin [‡]	Planted	Natural	Planted
Basal area (ft ² /ac)	121 \pm 8a ¹	78 \pm 6b	122 \pm 6a
Tree height (ft)	79.0 \pm 4.3a	67.5 \pm 5.6a	37.1 \pm 1.5b
Crown height [¶] (ft)	64.1 \pm 4.2a	49.4 \pm 4.3a	28.6 \pm 1.3c
Bark thickness (in.)	0.70 \pm 0.1a	0.70 \pm 0.2a	0.50 \pm 0.1b
Gallberry Cover [#] (%)	45-65	17-27	70-75

Saw Palmetto Cover[#] (%) 35-45 60-75 5-10

* – 3 control stands per site with rough > 10 years old.

• – n = 45 trees.

τ – Determined from land management records.

1 – Means followed by different letters are different within that row ($\alpha = 0.05$).

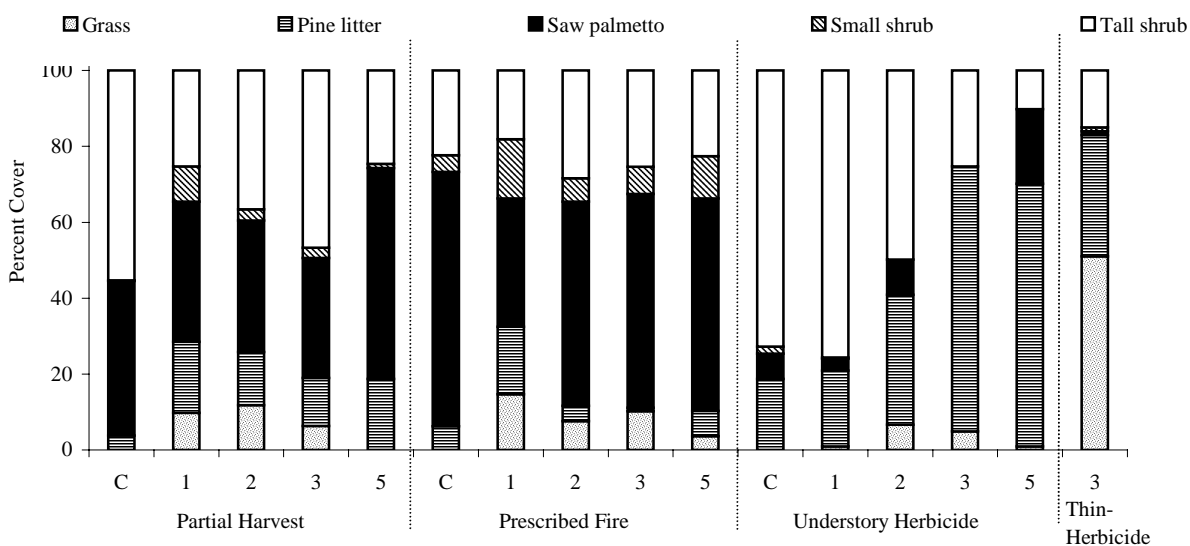
ψ - Height to base of crown.

– The range of data collected.

at the prescribed fire site was substantially less (78 ft²/ac). Trees were tallest and had the highest crowns at the partial harvest site, shortest with the lowest crowns at the herbicide site, and intermediate at the prescribed fire site. Bark thickness of the dominant canopy trees was nearly equal at the partial harvest and prescribed fire sites but was less at the herbicide site.

Within each site, little variation was found among the stands (Table 2). Basal areas at the partial harvest and prescribed fire sites were greatest in the control stands and

Figure 2. Percent cover of the rough in untreated (C) pine flatwood forests and for 1-5 years after treatment by different fuel reduction techniques.



least in partial harvest-age 1, and prescribed fire-age 5 stands. Bark thickness, crown height, and tree height did not differ among rough ages within the partial harvest and prescribed fire treatments but did differ in the herbicide site with the oldest trees having the thickest bark and the youngest trees having the shortest tree and crown heights.

Comparison of Treatments - Percent Cover and Height

Hazardous fuel characteristics varied among the treatments at the different ages of rough (Figure 2). In the control stands, gallberry was most common in the understory herbicide treatment (73% coverage), least common in the prescribed fire treatment (22%) and intermediate in the partial harvest treatment (55%). Saw palmetto was most common in

the prescribed fire treatment (67% coverage), least common in the understory herbicide treatment (7%) and intermediate in the partial harvest treatment (41%). Grass was absent and small shrubs were scarce in all treatments. Pine litter was more common in the understory herbicide treatment (19%) than it was in the other two treatments. Gallberry and saw palmetto were tallest in the partial harvest treatment, averaging 6.1 ft, and of equal height (4.8 – 5.0 ft) in the other two treatments (Figure 3).

Figure 3. Height of the dominant shrubs in untreated (C) pine flatwood forests and for 1-5 years after treatment by different fuel reduction techniques.

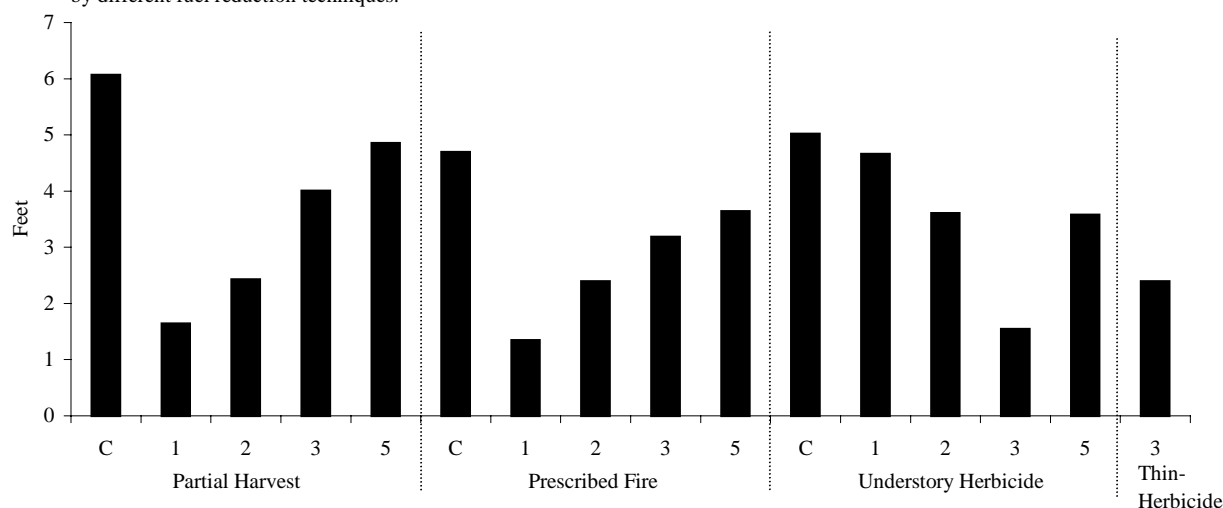


Table 2. Characteristics (mean \pm 1 se) of the study sites.

Age of Rough (yrs#)	Basal Area (ft ² /ac)	Tree Height (ft)	Crown Height* (ft)	Bark Thickness (in.)	Age of Trees (range in yrs)
----- Partial Harvest -----					
C ^r	121 \pm 8a ¹	79.0 \pm 4.3a	64.1 \pm 4.2a	0.70 \pm 0.1a	31-40
1	55 \pm 5b	70.0 \pm 6.2a	57.9 \pm 5.9a	0.72 \pm 0.1a	28-36
2	73 \pm 5b	64.9 \pm 6.2a	50.6 \pm 5.9a	0.68 \pm 0.1a	28-34
3	63 \pm 7b	72.2 \pm 4.3a	55.1 \pm 4.3a	0.72 \pm 0.2a	33-38
5	63 \pm 8b	78.1 \pm 5.7a	63.4 \pm 5.7a	0.71 \pm 0.1a	30-36
----- Prescribed Fire -----					
C	78 \pm 6a	67.5 \pm 5.6a	49.4 \pm 4.3a	0.70 \pm 0.2a	85-90
1	66 \pm 6ab	69.4 \pm 5.4a	51.0 \pm 4.7a	0.67 \pm 0.2a	58-63
2	64 \pm 6ab	69.4 \pm 5.4a	51.5 \pm 4.6a	0.66 \pm 0.1a	58-60
3	65 \pm 6ab	66.7 \pm 6.5a	50.0 \pm 4.3a	0.68 \pm 0.1a	55-60
5	59 \pm 4b	68.4 \pm 6.3a	50.7 \pm 5.1a	0.66 \pm 0.2a	84-86

Table 2. Characteristics (mean \pm 1 se) of the study sites.

Age of Rough (yrs#)	Basal Area (ft ² /ac)	Tree Height (ft)	Crown Height* (ft)	Bark Thickness (in.)	Age of Trees (range in yrs)
----- Understory Herbicide -----					
C	122 \pm 6a	37.1 \pm 1.5a	28.6 \pm 1.3a	0.50 \pm 0.1b	17
1	119 \pm 13a	30.5 \pm 1.3b	21.1 \pm 1.3b	0.44 \pm 0.1b	14
2	129 \pm 8a	33.5 \pm 1.3ab	24.1 \pm 1.2a	0.46 \pm 0.1b	15
3	128 \pm 9a	33.1 \pm 1.3ab	22.0 \pm 1.2a	0.45 \pm 0.1b	16
5	112 \pm 9a	42.0 \pm 1.3a	28.2 \pm 1.3a	0.62 \pm 0.1a	22
----- Thin/Herbicide -----					
3	63 \pm 5b	41.0 \pm 1.4	8.8 \pm 0.3	0.52 \pm 0.1	17

– Time since most recent application of the treatment.

* – Height to the base of the crown.

Y – Control (untreated) stands with rough being 10 – 40+ years old.

1 – Means followed by different letters are different within that treatment and column

($\alpha = 0.05$), 3 stands per each treatment / age-of-rough combination.

In the first year after treatment, percent cover differed from the untreated stands with all species groups now being present in all treatments (Figure 2). Percent cover for species in the understory herbicide treatment did not differ between the controls and year 1. Gallberry continued dominating with >75% cover, although nearly all of it was dead, pine litter space was 20%, and the three other groups made up the remainder. None of the species groups dominated the other two treatments. Cover at the partial harvest treatment consisted of 25% gallberry (a decrease relative to the untreated stands), 37% saw palmetto, 19% pine litter (an increase), 10% grass (an increase), and 9% small shrub. The prescribe-burned stands were similar to the partial harvest treatment with 34% saw palmetto and 18% pine litter space but had less gallberry (18%), more small shrub (16%), and more grass (14%). Relative to the unburned stands, saw palmetto coverage decreased while grass, pine litter, and small shrub cover increased. Rough height was unchanged in the herbicide treatment (4.7 ft) relative to its untreated stands but was greater than that of the partial harvest and prescribed fire treatments where rough height had dropped to 1.6 and 1.3 ft, respectively (Figure 3).

By year 2, gallberry had become less abundant in the understory herbicide treatment (50% coverage), relative to its percent cover in the control and year 1 (Figure 2). This amount was equal to gallberry coverage in the partial harvest treatment (37%) which had increased from year 1 but had not yet returned to its pretreatment coverage. The percent cover of gallberry in the prescribed fire treatment was 28%, less than that of the other two treatments but slightly higher than year 1 and the control. Saw palmetto increased in the prescribed fire treatment to 54% coverage and was more abundant than that of the understory herbicide and partial harvest treatments, 9% and 35%, respectively. Pine litter increased in the understory herbicide treatment to 34% and was greater than the decreasing amount of pine litter in the partial harvest and prescribed fire treatments (14% and 4%, respectively). Grass and small shrub cover declined in the prescribed fire treatment while grass cover increased in the understory herbicide treatment. All three treatments had comparable coverage of grass (7-12%) and small shrubs (0-6%). Shrub height increased in the partial harvest and prescribed fire treatments to 2.4 ft each which

was shorter than the 3.6 ft shrub height (a decrease from year 1) in the understory herbicide treatment (Figure 3).

At rough age 3, gallberry had the greatest coverage (47%) in the partial harvest treatment, equal coverage (25%) in the prescribed fire and understory herbicide treatments, and was least common (15%) in the thin – herbicide stands (Figure 2). Relative to the previous year, this was a decrease for gallberry cover in the understory herbicide treatment. Saw palmetto coverage was greatest in the prescribed fire treatment (56%), intermediate in the partial harvest stands (32%), and least in the understory herbicide and thin – herbicide sites (0-1%). Only in the understory herbicide treatment did the percent cover of saw palmetto decrease relative to the previous year. Open space was 70% in the understory herbicide treatment (an increase from the previous year), followed by thin – herbicide (32%), partial harvest (13%), and prescribed fire (1%). Grass occupied 51% of the thin – herbicide treatment, significantly more than the 5-10% coverage for the other three treatments (all unchanged from year 2). Cover of small shrubs was unchanged for all treatments relative to year 2 with prescribed fire having more (7%) than the others (0-3%). Shrub height was greatest in the partial harvest treatment (4.0 ft, an increase), followed by prescribed fire (3.2 ft, an increase), thin – herbicide (2.4 ft), and understory herbicide (1.5 ft, a decrease) (Figure 3).

In year 5, gallberry cover was greater in the partial harvest treatment (25%, a decline from the previous year) and the prescribed fire stands (23%) than it was in the understory herbicide treatment (10%, a decline from the previous year) (Figure 2). Percent cover of saw palmetto was similarly distributed among treatments; 56% in the partial harvest and prescribed fire stands and 20% in the understory herbicide site. For the partial harvest and understory herbicide treatments, these percents were increases relative to the previous year. Pine litter changed little in all three treatments relative to year 3 with the understory herbicide treatment having more (69%) than the others (7-18%). Grass and small shrubs also reunchanged from year 3 and did not differ among treatments (0-6%). Shrub height in years 5 was greatest in the partial harvest treatment (4.9 ft, an increase from year 3) and equal in the other two treatments (3.6 ft, increases for both from the previous year) (Figure 3).

Comparison of Treatments - Fuel Loading

No differences were found between the fuel weights estimated by the equations and those determined by the CBD method for any ages of rough (Table 3). Therefore, it was felt that the equations provided reasonable estimates and were used to determine fuel loadings in all partial harvest and prescribed fire stands with rough < 26 yrs old. Also, 100-hr fuels were extremely scarce and were dropped from the study. Both of these findings were similar to results of previous research in Florida (McNab et al. 1978).

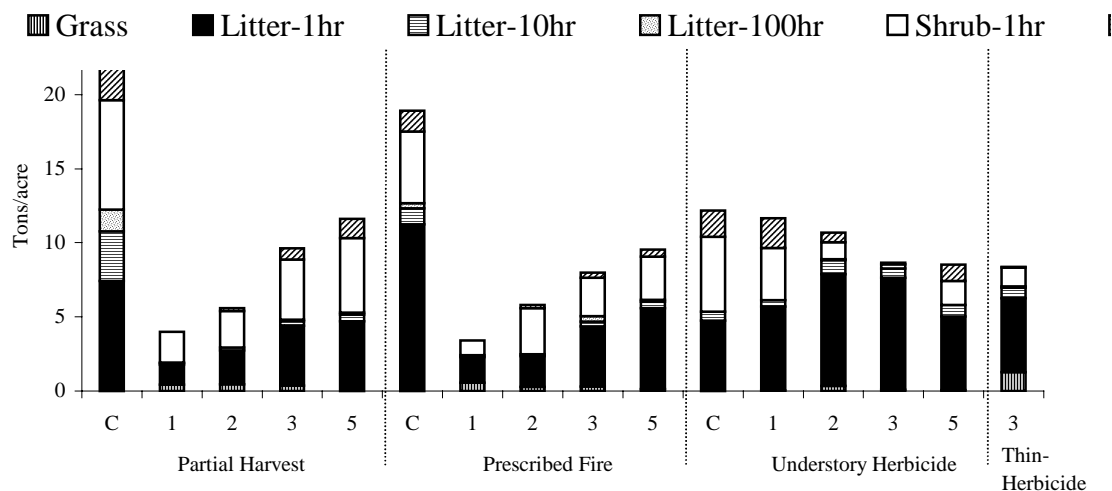
Table 3. Comparison of fuel loadings (tons/ac, mean \pm 1 se) for pine flatwood forests as determined by the CBD method and those estimated from McNab's 1978 equations.

Treatment	Age of Rough (years)	CBD Method*	McNab's Equations
----- 1-hr Litter Fuels -----			
Prescribed Fire	1	1.7 \pm 0.2	1.9
Prescribed Fire	2	2.1 \pm 0.4	2.0
Partial Harvest	3	4.0 \pm 0.4	3.8
Partial Harvest	5	4.7 \pm 0.5	4.4
Partial Harvest	20	7.4 \pm 0.5	7.1
----- 1-hr Shrub Fuels -----			
Prescribed Fire	1	1.0 \pm 0.2	0.8
Prescribed Fire	2	2.9 \pm 0.4	2.6
Partial Harvest	3	4.1 \pm 0.4	4.2
Partial Harvest	5	5.0 \pm 0.5	5.8
Partial Harvest	20	7.4 \pm 0.5	7.4
----- Total Fuels -----			
Prescribed Fire	1	3.1 \pm 0.2	3.0
Prescribed Fire	2	5.6 \pm 0.3	5.7
Partial Harvest	3	9.3 \pm 0.7	9.4
Partial Harvest	5	11.6 \pm 0.8	11.8
Partial Harvest	20	17.9 \pm 1.7	19.1

* - n = 6 for each row.

In the control stands, total fuel loading was greatest (21.8 tons/ac) in the partial harvest area, least in the understory herbicide stands (12.2 tons/ac), and intermediate (18.9 tons/ac) at the prescribed fire site (Figure 4). Regardless of fuel type or size class, the partial harvest treatment generally had fuel loadings greater than or equal to those of the other two treatments. Depending on treatment, from 70-80% of the total fuel loading was in 1-hr fuels with 57-63% of the 1-hr fuels being in the litter layer. Ten-hr fuels comprised the remainder of the loading with 55-75% of this amount occurring in the shrub layer.

Figure 4. Distribution of fuel loading (tons/acre) by type and size class in untreated (C) pine flatwood forests and for 1-5 years after treatment by different fuel reduction techniques.



In year 1, total fuel loadings in the understory herbicide treatment (11.7 tons/ac) were greater than that of the partial harvest (4.0 tons/ac) and prescribed fire treatments (3.4 tons/ac) (Figure 4). Relative to their respective controls, total fuel loadings were less in the partial harvest and prescribed fire treatments and unchanged in the understory herbicide treatment. In the 1-hr and 10-hr litter and shrub fuels, the understory herbicide treatment had greater loadings than the other two treatments. Regardless of treatment, 1-hr fuels constituted from 70-90% of the total loading and the 1-hr fuel loading was generally distributed evenly between the litter and shrub layers. Ten-hr litter and shrub fuels were absent or rare (0-0.2 tons/ac) in the partial harvest and prescribed fire treatments but more abundant in the understory herbicide treatment (0.4 tons/ac in litter, 2.1 tons/ac in shrub). Grass loading was higher in the prescribed fire treatment (0.6 tons/ac) than in the partial harvest site (0.4 tons/ac) and both had more grass than the herbicide area (0.1 tons/ac).

In year 2, total fuel loading in the partial harvest treatment was 5.6 tons/ac and was equivalent to that of the prescribed fire treatment (5.8 tons/ac) (Figure 4). Both of these were about half the total fuel loading found in the understory herbicide treatment (10.7 tons/ac). Regardless of treatment, 82-89% of the total fuel loading was in the 1-hr size class. In the understory herbicide treatment, nearly all the 1-hr fuels were in the litter layer while the other two treatments had 38-50% of their 1-hr fuels in the shrub layer. The understory herbicide treatment had more 10-hr fuels in the litter and shrub layers than the other two treatments, 0.6-0.9 tons/ac versus 0.2-0.3 tons/ac, and all three treatments had equivalent loadings of grass (0.3-0.5 tons/ac).

In year 3, total fuel loading for the understory herbicide treatment was 8.6 tons/ac with most (88%) of this weight being found in the litter layer as 1-hr fuels (Figure 4). The thin – herbicide treatment was quite similar in total fuel loading (8.4 tons/ac) but had only 60% of its total in the 1-hr litter class. The prescribed fire treatment had the least amount of fuel (8.0 tons/ac) but that loading was greater than that of year 2 and 39% of the fuel weight was in the shrub layer, most of it as 1-hr fuel. The partial harvest

treatment had the most fuel, 9.6 tons/ac, with this amount evenly distributed between the litter and shrub layers. Only the thin – herbicide treatment had a noticeable grass component (1.3 tons/ac).

In year 5, total fuel loading was greatest in the partial harvest treatment (11.6 tons/ac), least in the understory herbicide treatment (8.5 tons/ac), and intermediate in the prescribed fire treatment (9.5 tons/ac) (Figure 4). For all treatments, these loadings were greater relative to year 3 except for the understory herbicide which was equivalent. Regardless of treatment, from 80-89% of the total fuel loading was in the 1-hr size class. However, treatments differed in distribution of the 1-hr fuel loading with 78% of it being in the litter layer for the understory herbicide treatment while partial harvest and prescribed fire had 42 and 65%, respectively, in the same layer. The partial harvest treatment had more 10-hr fuels in the litter and shrub layers than the other two treatments and no treatment had much grass loading, 0-0.2 tons/ac.

Part II - Methods

Fire simulations

All fuels data from both inventory methods were used in the NEWMDL program (Burgan and Rothermel 1984) of BEHAVE to create a custom fuel model (Table 4) for each treatment / age-of-rough combination. The models were used with landform and weather data in the SITE module of the FIRE1 program to develop treatment / age-of-rough specific fire behavior and overstory pine mortality estimates (Andrews 1986). Weather data were provided by the Osceola National Forest for June 1997 (normal) and June 1998 (drought). Cloud cover, ambient air temperature, relative humidity, 20-ft windspeed, precipitation, and fuel moistures were averaged for the entire month (Table 5). Each simulation was of a summer fire (June 15th) burning at 1300 hours under normal and drought weather conditions. Outputs were flame length (ft), rate-of-spread (ft/min), and mortality (%) of pines for a head fire for each treatment / age-of-rough combination.

Table 4. Key characteristics* of the custom fuel models for the partial harvest (PH), prescribed fire (RxF), understory herbicide (UH), and thin-herbicide (TUH) treatments at rough age 1-10+ years.

Treatment- Age-of-rough	-- Fuel Loading#-----			Height (ft)	Surface-to- Volume ratio (in ² /in ³)	Moisture of Extinction (%)
	1-hr (tons/ac)	10-hr (tons/ac)	Live Woody (tons/ac)			
PH-C [†]	14.94	6.45	5.76	2.56	2171	42
RxF-C	12.76	3.19	3.92	2.20	2112	41
UH-C	9.48	2.54	2.96	2.26	2116	35
PH-1	4.37	0.16	1.82	0.72	2188	34
RxF-1	1.37	0.13	0.47	0.39	2161	27
UH-1	8.55	2.06	0.08	1.71	2100	34
PH-2	8.21	0.62	3.10	1.05	2162	33
RxF-2	4.17	0.36	1.20	1.02	2097	28
UH-2	8.38	1.25	0.06	0.43	1896	40
PH-3	6.85	1.60	2.84	1.90	2205	32
RxF-3	6.25	0.55	1.89	1.38	2108	31
UH-3	7.88	0.72	0.03	0.20	1816	41
TUH-3	5.55	0.72	0.18	0.33	1899	30
PH-5	8.56	1.63	4.05	2.66	2238	33
RxF-5	7.79	0.80	2.05	1.41	2069	34
UH-5	5.32	0.98	0.36	0.33	1883	32

* - Other key characteristics were the same for all fuel models, i.e., live herbaceous S/V ratio (2000), live woody S/V ratio (2322), and heat content (8320 Btu/lb).

- Live herbaceous fuel load was 0.02 tons/acre for all fuel models except for TUH-3 which was 0.34 tons/acre. No 100-hr fuels were included in any of the fuel models because of their scarcity.

† - Control (untreated) stands with rough ranging in age from 10 – 40+ years.

Table 5. Drought, normal weather, and environmental conditions* used in the fire simulations.

Characteristic	Drought	Normal
Drought Index (KBDI#)	731	293
Ambient Air Temperature (°F)	97	84
Relative Humidity (%)	42	65
Windspeed (mi/hr)	7	4.5
Cloud Cover (%)	10	40
1-hr fuel moisture (%)	5	15
10-hr fuel moisture (%)	6	13
Live Woody fuel moisture (%)	104	166
Days w/o rain	25	15
30-day rainfall total (in)	2.1	5.2
Slope (%)	0	0
Elevation above sea level (ft)	100	100
Latitude	30°N	30°N

* - Data are from the Osceola National Forest as recorded daily at the Olustee Lookout Tower at 1300 hours during June 1997 (normal) and June 1998 (drought). N = 30 for all characteristics except for the last 5 which are totals or descriptive.

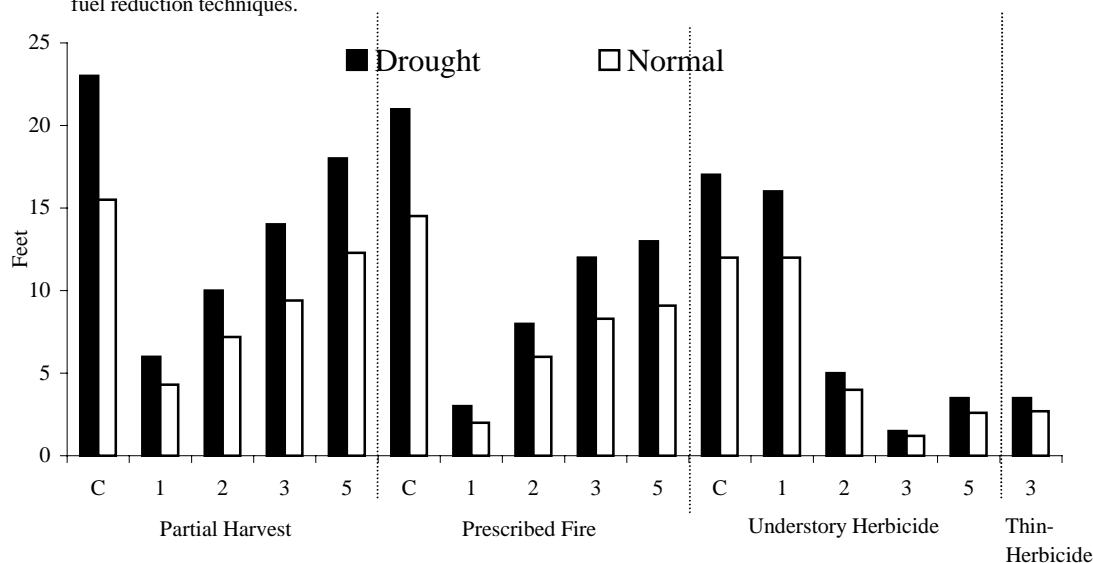
- Keetch-Byram Drought Index is a scale of 0 – 800 with 800 representing desert conditions.

Part II – Results

Fire Behavior Estimates

Predictions of flame length followed two distinct patterns in the treatments as the rough changed from untreated control to recently treated (year 1) and subsequently aged (year 1) and subsequently aged to year 5 (Figure 5). Under drought conditions in the partial harvest and prescribed fire treatments, flame length predictions showed a U-shaped distribution. BEHAVE predicted the longest flame lengths (16 – 23 ft) for the untreated control stands. In the first year after treatment, flame length dropped to 6 and 3 ft, respectively, but increased steadily each year thereafter. By age 5, flame length estimates were 18 ft for partial harvest and 13 ft for prescribed fire, 80 and 63% of the predictions for their respective untreated simulations. Generally, normal weather reduced the drought flame lengths by about 30%, regardless of the age of the rough.

Figure 5. BEHAVE-generated prediction of flame length for a wildfire burning under drought and normal weather conditions in untreated (C) pine flatwood forests and for 1-5 years after treatment by different fuel reduction techniques.

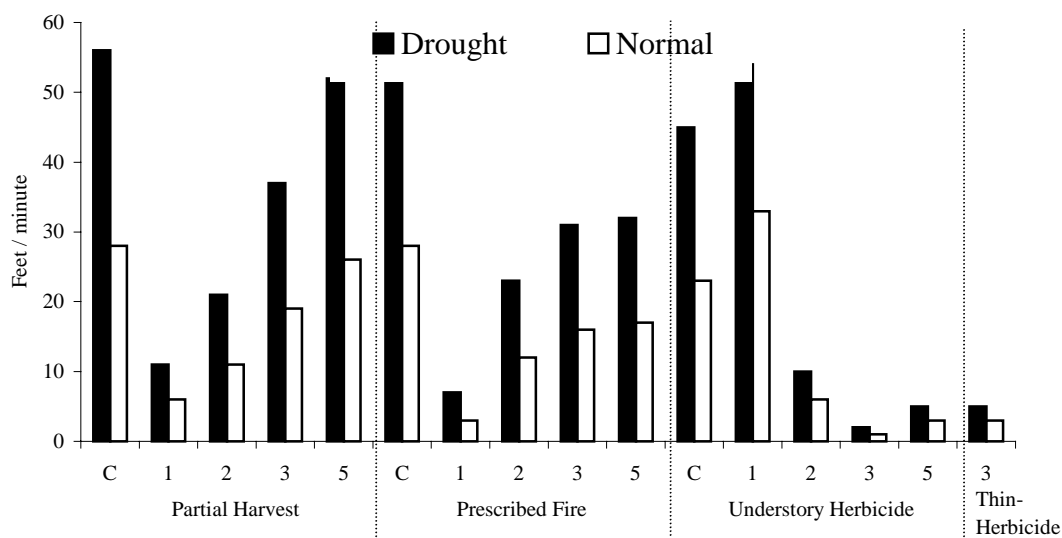


In the understory herbicide treatment, the flame length pattern as rough age increased resembled an inverse J (Figure 5). Under drought conditions in the untreated control stands, flame length estimate was 17 ft and declined only slightly at age 1 to 16 ft. However at age 2, flame length dropped precipitously to 7.9 ft and continued downward to 1.3 ft at age 3 before slightly rebounding to 3.3 ft at age 5. Flame length estimates for normal weather conditions followed this same pattern but were reduced by about 30% relative to drought conditions. The thin-herbicide treatment (age 3 only) produced flame length estimates similar to the understory herbicide treatment at age 5.

Rate-of-spread predictions followed a similar pattern to flame length estimations as the rough aged for the partial harvest and prescribed fire treatments (Figure 6). In the untreated control stands under drought conditions, BEHAVE predicted a head fire to

move at more than 59 ft/min when pushed by a 7 mi/hr wind. The partial harvest and prescribed fire techniques reduced rate-of-spread to 22 and 7.5 ft/min respectively in the first year following treatment. In subsequent years, rate-of-spread in the partial harvest treatment rapidly increased and at rough age 5, it was nearly the same as it was for the untreated stands. In the prescribed fire treatment, rate-of-spread also increased as the rough aged, but not as rapidly as it had done in the partial harvest stands. Simulations done under the normal weather conditions reduced rate-of-spread estimates by 45-60%.

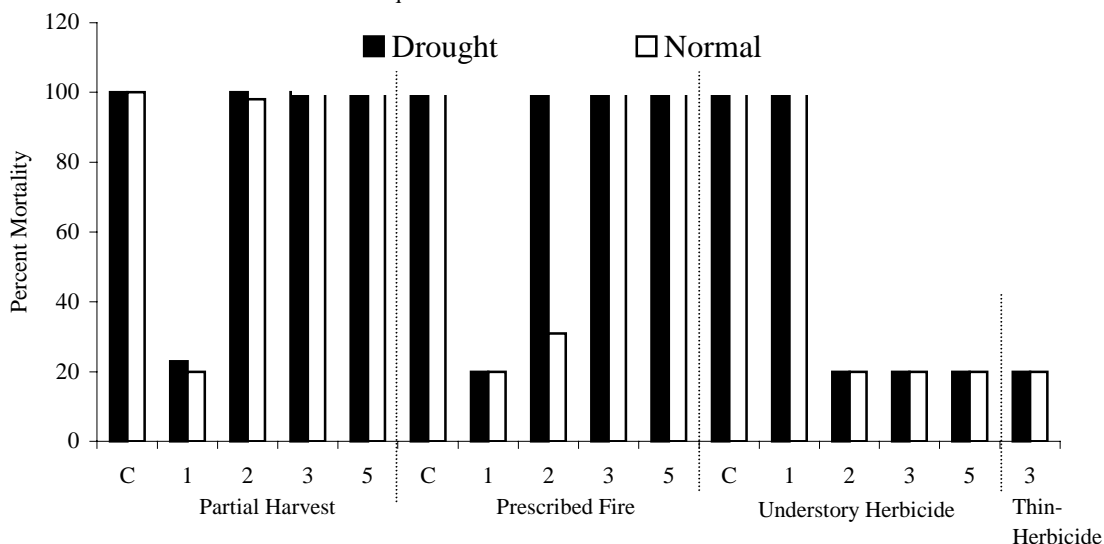
Figure 6. BEHAVE-generated prediction of rate-of-spread for a wildfire burning under drought and normal weather conditions in untreated (C) pine flatwood forests and for 1-5 years after treatment by different fuel reduction techniques.



Rate-of-spread estimates in the understory herbicide treatment for drought conditions started off high (49 ft/min) and increased slightly at age 1 to 59 ft/min (Figure 6). From that point, rate-of-spread dropped rapidly to 10 ft/min at age 2, 2.5 ft/min at age 3, and 5.5 ft/min at age 5. Normal weather conditions reduced all of these rate-of-spread estimates by another 45-60%. Again, the thin-herbicide treatment produced rate-of-spread estimates similar to the age 5 stands of the understory herbicide treatment.

BEHAVE-generated mortality predictions for the overstory pines followed the same patterns of flame length and rate-of-spread estimates as the rough responded to the different treatments (Figure 7). Without any treatment, 100% mortality would occur, regardless of weather conditions. Mortality predictions under both weather regimes dropped to 20% for the first year following the partial harvest and prescribed fire treatments. In the second year after treatment, mortality estimates returned to 100% for partial harvest, regardless of weather conditions, and for prescribed fire under a drought

Figure 7. BEHAVE-generated prediction of overstory mortality caused by a wildfire burning under drought and normal weather conditions in untreated (C) pine flatwood forests and for 1-5 years after treatment by different fuel reduction techniques.



scenario and stayed there through year 5. Prescribed fire-treated stands under normal weather conditions produced 30% mortality estimates in year 2 and 100% for year 3 and beyond. In the understory herbicide stands, overstory pine mortality was initially predicted to be 100% for the first year after treatment and 20% for all years thereafter. The thin-herbicide stand also had a 20% mortality estimate.

Discussion

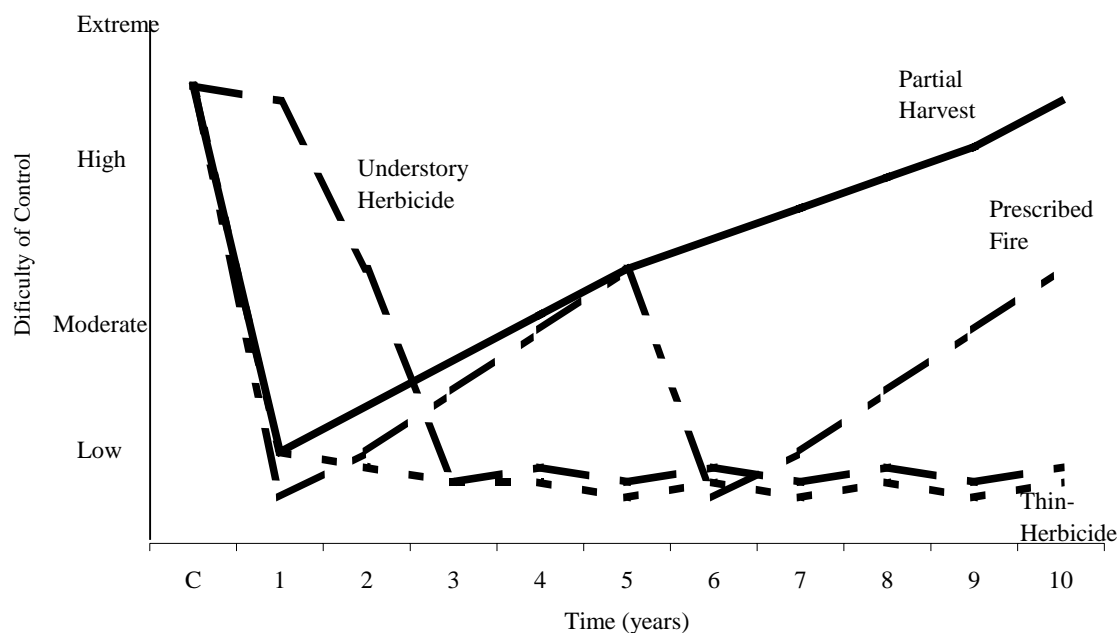
This study demonstrates the effectiveness and limitations of three different fuel reduction techniques for protecting pine flatwoods forests from stand-replacing wildfires. In the untreated stands, the rough was nearly impenetrable, consisting of almost complete coverage of highly flammable gallberry and saw palmetto that ranged from 3 – 12 ft tall. A wildfire in such a setting, regardless of whether during drought-enhanced or normal summer weather conditions, would be extremely dangerous, difficult to suppress (Figure 8), and would kill all overstory pines. Any of the three fuel reduction treatments included in this study could be used to reduce hazardous fuels but each has its own strengths and weaknesses that must be considered.

For immediate protection from a stand-replacing wildfire, prescribed fire is the best choice as it creates a fuel bed and structure that cannot support a conflagration (Figure 8 – following page). Under the normal or drought conditions used in these simulations, a wildfire in a recently burned (rough age ≤ 1 year) stand would have flame lengths < 3 ft long and rates-of-spread between 3 – 6 ft/min. Such behavior is calm enough to allow direct suppression with relative ease and safety. Initial pine mortality

would be reduced relative to untreated stands (Outcalt and Wade 2000) but subsequent infestations of southern pine bark beetle (*Dendroctonus frontalis*) may greatly increase mortality.

If prescribed fire is not chosen, a partial timber harvest is the next best approach to immediately protect against catastrophic wildfire (Figure 8). Whole-tree harvesting disrupts the continuity of the rough, reduces its height, and decreases the fuel loading, creating fuel conditions less suitable for an intense wildfire. Consequently, the site is accessible for an easy, safe direct attack with equipment and the wildfire probably would not kill a substantial proportion of the remaining overstory trees.

Figure 8. Probable difficulty of controlling wildfires burning in untreated (C) pine flatwood forest for 1-10 years after treatment by different fuel reduction techniques.



Unfortunately, the immediate fire protection provided by a partial timber harvest or prescribed fire is relatively short-lived. Gallberry and saw palmetto are well adapted to disturbance and readily sprout following topkill. Consequently, fuels rapidly redevelop after a prescribed burn or logging operation and fire danger quickly increases. In this study under normal weather conditions, flame lengths in 2-year-old rough were estimated at 10 and 8 ft for the partial harvest and prescribed fire treatments, respectively. Such fire behavior is within the capability of most tractor plows to directly fight a fire but difficulty of control is increased relative to 1-year-old rough (Figure 8). However under drought conditions, firefighting efforts would probably shift somewhat from direct to indirect to allow for more safety. This is the same case for 3-year-old rough under normal weather conditions. By age 5, flame lengths increased to 18 and 13 ft for the partial harvest and prescribed fire, making difficulty of control high due to the threat of extreme fire behavior, i.e., crowning, spotting, and rapid runs. Suppression tactics would

have to include indirect line construction, natural barriers, and air support to control a wildfire. The entire pine overstory would be killed.

Pine flatwood ecosystems evolved with frequent (3-5 year rotation) fire and, consequently, fire provides various benefits (some general and some unique) to this forest type, two of which are hazardous fuel reduction and protection against stand-replacing wildfires. However, rapid redevelopment of the rough and the necessity of re-treating it pose a major disadvantage to prescribed fire as a fuel reduction technique. Frequent prescribed fire is difficult to practice due to reduced personnel and operating budgets among land management agencies, smoke management considerations in populated areas, liability concerns, and misunderstanding about fire's role in the environment by urban dwellers (Wade 1993).

Partial timber harvests are plagued with this same rapid rough redevelopment problem. However, commercial entries can probably only occur every 15-20 years (Figure 8), meaning an extended period of time of heightened fire danger between treatments unless other, noncommercial, techniques are used in the interim.

Understory herbicide application takes the opposite approach to reducing fire behavior relative to the other two treatments. For the first year after treatment, fuel characteristics changed little. The shrubs were dead but still standing, densely spaced, and retaining fallen needles (Figures 2-4). Consequently, BEHAVE predicted 13 – 16 ft flame length, 23 – 59 ft/min rate-of-spread, and 100% overstory pine mortality (Figures 5-7), depending on drought or normal weather conditions. Difficulty of control would be high to extreme (Figure 8) and suppression strategy would be the same as if the fire was burning in an unmanaged stand, indirect attack, aerial support, and use of natural barriers.

However, fire danger and control difficulties decrease dramatically beginning in year 2 (Figure 8). Shrub fuels almost disappear and the only 1-hr fuel is the blanket of pine needles on the ground. The herbicide stands become quite open beginning in year 2. These favorable conditions exist at least until year 6 and quite possibly until final harvest in plantations managed for pulpwood. Under the same weather conditions, fires in such environments would be much less intense than in more recently herbicided stands. Direct attack would be relatively safe and easy.

The combination of treatments may be a way of capturing the strengths of the different practices while avoiding some of their weaknesses. In year 3, a fourth treatment was possible, a thin-herbicide combination. This consisted of a commercial thinning that removed about 50% of the basal area and undoubtedly reduced and disrupted the rough. Two years later, Garlon 4 was applied in the autumn at a rate of 2.0 qts/ac, killing the sprouting gallberry. Three years later when the stands were studied, they were quite open with a minimal amount of shrub fuel. Under drought conditions, predicted fire behaviors were flame length 3.5 ft and rate-of-spread 6 ft/min (Figures 5-6). Under normal weather conditions, fire behavior was 25-50% lower, depending on the specific parameter. In either scenario, fire suppression would be relatively easy. By combining techniques, a forest could conceivably be protected from catastrophic wildfire from treatment

application to final harvest (Figure 8). This combining of treatments warrants more study as do other treatment combinations, i.e., harvest-mowing, fire-herbicide, that may yield similar results.

Caution must be exercised in interpreting these results. Because of the limitations of the experimental design, I could not control for site quality or past stand history. Consequently, inherent differences among sites may be confounding the results. For example, the rough redeveloped much quicker and to a greater extent in the partial harvest treatment than it did in the prescribed fire treatment. Those results may be due to treatment, site quality differences, past stand history, or combinations of these factors.

Also, the limitations of BEHAVE must be kept in mind. It is designed to predict average fire behavior at the flaming front of a head fire for a given set of environmental parameters. In this study, I used fuel and weather conditions that I considered typical for early summer in northern Florida and consistent with a near-worse-case scenario. Changing location on the fire (flanks or rear) or one or more of the parameters, i.e., windspeed, fuel moisture, relative humidity, will alter the outputs. Also, the outputs are for relative comparison among the treatments. Validation of BEHAVE-generated fire predictions to actual fire behavior for these custom fuel models is still needed for the gallberry-saw palmetto fuel complex, especially under drought conditions. Likewise, comparison of actual fire behavior to BEHAVE-generated estimates for the applicable standard fuel models under drought conditions is another topic awaiting research.

BEHAVE's predictions of overstory pine mortality (Figure 7) must also be interpreted with caution because they are based primarily upon crown scorch. Wildfires in pine flatwood forests also kill trees by girdling roots and stems, especially where a deep duff layer has developed due to past exclusion of fire (such as in understory herbicide treated stands). Delayed overstory mortality can also occur due to feeding and nesting activity of pine bark beetles. Thus, when BEHAVE predicts low to moderate mortality (20 – 50%), actual mortality may be substantially higher as shown by Outcalt and Wade (2000).

Conclusions

Fire has been a long-time component of Florida's pine flatwoods forests and will continue to be because of the prevalence of lightning and a growing human population. Because of excellent growing conditions, the rough can quickly become a hazardous fuel problem and when combined with ignition sources and dry weather, extreme fire seasons, e.g., 1998, can occur.

Active fuels management is essential to reduce the size and intensity of chance wildfires. A passive do-nothing approach to hazardous fuel reduction can result in a catastrophic wildfire and exacerbates its damage and control difficulties.

For immediate fuel reduction, prescribed fire is the best technique. However, it requires reapplication at 3-5 year intervals to maintain tolerable levels of hazardous fuels. In natural stands where fire provides many benefits, resource managers should promote its expanded use. On sites where recurrent fire is not a viable option, partial harvesting offers some of the same fuel reduction benefits. However, time between harvests is probably too long to prevent development of hazardous fuels that would create conditions conducive to catastrophic wildfire under many fire weather conditions.

Understory herbicide application can also be used as an alternative to fire. It provides a longer-term reduction of the rough relative to partial harvest and prescribed fire but does not provide immediate fire protection nor many of the other benefits of fire (duff reduction) necessary to maintain the health of natural ecosystems.

Combining treatments may be the best approach to managing hazardous fuels because the strengths of one treatment offsets the weaknesses of the other. This aspect of fuels management needs more research.

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APPENDIX**Percent Cover, Height and Fuel Loading Data for each Stand**Table 1. Cover and height (mean \pm 1 se) of major vegetation groups in slash pine plantations at one, two, and three years after an application of a mid-rotation understory herbicide.

Age-of-Rough (years)	Stand	Vegetation Group	Coverage (%)	Height (ft)	# of plots per stand
1	1	Grass	1.3 \pm 0.0	1.00 \pm 0.00	1
1	1	Pine litter	18.7 \pm 9.4	0.19 \pm 0.05	14
1	1	Saw palmetto	1.3 \pm 0.0	3.50 \pm 0.00	1
1	1	Tall shrub	78.7 \pm 8.3	4.79 \pm 0.13	59
1	2	Pine litter	18.7 \pm 5.5	0.44 \pm 0.04	14
1	2	Saw palmetto	5.3 \pm 3.5	3.63 \pm 0.13	4
1	2	Small shrub	1.3 \pm 0.0	0.50 \pm 0.00	1
1	2	Tall Shrub	74.7 \pm 5.7	4.98 \pm 0.18	56
1	3	Grass	1.3 \pm 0.0	1.00 \pm 0.00	1
1	3	Pine litter	22.7 \pm 8.8	0.15 \pm 0.03	17
1	3	Saw palmetto	2.7 \pm 1.6	3.50 \pm 0.00	2
1	3	Tall shrub	73.3 \pm 6.7	4.42 \pm 0.10	55
2	1	Grass	8.0 \pm 3.2	1.08 \pm 0.15	6
2	1	Pine litter	34.7 \pm 4.4	0.14 \pm 0.03	26
2	1	Saw palmetto	8.0 \pm 1.1	3.75 \pm 0.44	6
2	1	Tall shrub	49.3 \pm 6.2	3.43 \pm 0.22	37
2	2	Grass	8.0 \pm 3.9	1.17 \pm 0.17	6
2	2	Pine litter	33.3 \pm 7.1	0.14 \pm 0.03	25
2	2	Saw palmetto	8.0 \pm 5.0	3.55 \pm 0.32	6
2	2	Tall shrub	50.7 \pm 6.3	3.43 \pm 0.21	38
2	3	Grass	4.0 \pm 0.5	0.83 \pm 0.33	3
2	3	Pine litter	34.7 \pm 8.3	0.17 \pm 0.02	26
2	3	Saw palmetto	12.0 \pm 5.1	3.67 \pm 0.28	9
2	3	Tall shrub	49.3 \pm 3.5	3.96 \pm 0.25	37
3	1	Grass	6.7 \pm 1.5	1.00 \pm 0.50	5
3	1	Pine litter	69.3 \pm 5.3	0.10 \pm 0.10	52
3	1	Tall shrub	24.0 \pm 3.1	1.47 \pm 0.13	18
3	2	Grass	2.7 \pm 0.0	1.00 \pm 0.00	2
3	2	Pine litter	70.7 \pm 4.1	0.15 \pm 0.04	53
3	2	Tall shrub	26.7 \pm 4.1	1.60 \pm 0.11	20
3	3	Grass	5.3 \pm 2.2	1.00 \pm 0.50	4
3	3	Pine litter	69.3 \pm 5.9	0.14 \pm 0.06	52
3	3	Tall shrub	25.3 \pm 2.7	1.58 \pm 0.12	19

Table 2. Loading (tons/acre, mean \pm 1 se) of forest fuels by type and size class in slash pine plantations at one, two, and three years after an application of a mid-rotation understory herbicide.

Age-of-Rough (years)	Stand	Fuel Type	Fuel Size	Tons/acre	# of plots/stand
1	1	Litter	1-hr	5.25 \pm 0.26	6
1	1	Litter	10-hr	0.65 \pm 0.20	6
1	1	Shrub	1-hr	3.84 \pm 0.69	6
1	1	Shrub	10-hr	1.78 \pm 0.34	6
1	2	Grass	1-hr	0.16 \pm 0.10	2
1	2	Litter	1-hr	5.39 \pm 0.30	6
1	2	Litter	10-hr	0.19 \pm 0.08	6
1	2	Shrub	1-hr	3.43 \pm 0.78	6
1	2	Shrub	10-hr	3.13 \pm 2.06	6
1	3	Litter	1-hr	6.30 \pm 0.97	6
1	3	Litter	10-hr	0.44 \pm 0.10	6
1	3	Shrub	1-hr	3.26 \pm 0.54	5
1	3	Shrub	10-hr	1.18 \pm 0.41	5
2	1	Litter	1-hr	6.80 \pm 1.00	6
2	1	Litter	10-hr	1.10 \pm 0.19	6
2	1	Litter	100-hr	0.20 \pm 0.20	6
2	1	Shrub	1-hr	1.26 \pm 0.64	5
2	1	Shrub	10-hr	0.57 \pm 0.32	5
2	2	Litter	1-hr	9.14 \pm 0.69	6
2	2	Litter	10-hr	1.08 \pm 0.14	6
2	2	Shrub	1-hr	1.02 \pm 0.26	6
2	2	Shrub	10-hr	0.44 \pm 0.18	6
2	3	Grass	1-hr	0.47 \pm 0.19	5
2	3	Litter	1-hr	6.66 \pm 0.61	6
2	3	Litter	10-hr	0.65 \pm 0.16	6
2	3	Shrub	1-hr	1.11 \pm 0.47	5
2	3	Shrub	10-hr	0.94 \pm 0.50	5
3	1	Litter	1-hr	6.66 \pm 0.35	6
3	1	Litter	10-hr	0.72 \pm 0.18	6
3	2	Litter	1-hr	6.62 \pm 0.20	6
3	2	Litter	10-hr	0.68 \pm 0.16	6
3	2	Shrub	1-hr	0.11 \pm 0.07	2
3	3	Litter	1-hr	8.83 \pm 0.92	6
3	3	Litter	10-hr	0.63 \pm 0.18	6
3	3	Shrub	1-hr	0.49 \pm 0.29	3
3	3	Shrub	10-hr	0.12 \pm 0.06	3

Table 3. Cover and height (mean \pm 1 se) of major vegetation groups in slash pine plantations at five and more than ten years after an application of a mid-rotation understory herbicide.

Age-of-Rough (years)	Stand	Vegetation Group	Coverage	Height (%)	# of plots (ft)	per stand
5	1	Pine litter	66.7 \pm 3.4	0.20 \pm 0.10	50	
5	1	Saw palmetto	21.3 \pm 4.9	3.19 \pm 0.22	16	
5	1	Tall shrub	12.0 \pm 1.5	2.22 \pm 0.34	9	
5	2	Grass	2.7 \pm 1.0	1.25 \pm 0.25	2	
5	2	Pine litter	68.0 \pm 4.8	0.20 \pm 0.10	51	
5	2	Saw palmetto	21.3 \pm 3.5	4.19 \pm 0.20	16	
5	2	Tall shrub	8.0 \pm 2.0	4.33 \pm 1.05	6	
5	3	Pine litter	73.3 \pm 6.3	0.18 \pm 0.08	55	
5	3	Saw palmetto	16.0 \pm 2.6	3.83 \pm 0.22	12	
5	3	Tall shrub	10.7 \pm 4.1	3.56 \pm 0.92	8	
10	1	Pine litter	21.3 \pm 5.0	0.29 \pm 0.08	16	
10	1	Saw palmetto	6.7 \pm 2.9	3.81 \pm 0.12	5	
10	1	Small shrub	1.3 \pm 0.0	0.50 \pm 0.00	1	
10	1	Tall shrub	70.7 \pm 8.5	5.18 \pm 0.11	53	
10	2	Pine litter	20.0 \pm 4.2	0.25 \pm 0.08	15	
10	2	Saw palmetto	6.7 \pm 2.5	3.80 \pm 0.12	5	
10	2	Small shrub	1.3 \pm 0.0	0.50 \pm 0.00	1	
10	2	Tall shrub	72.0 \pm 9.3	5.19 \pm 0.11	54	
10	3	Pine litter	14.7 \pm 3.2	0.38 \pm 0.13	11	
10	3	Saw palmetto	6.7 \pm 2.1	3.60 \pm 0.10	5	
10	3	Small shrub	2.7 \pm 1.0	0.50 \pm 0.00	1	
10	3	Tall shrub	76.0 \pm 5.3	5.02 \pm 0.11	57	

Table 4. Loading (tons/acre, mean \pm 1 se) of forest fuels by type and size class in slash pine plantations at five and more than ten years after an application of a mid-rotation understory herbicide.

Age-of-Rough (years)	Stand	Fuel Type	Fuel Size	Tons/acre	# of plots/stand
5	1	Litter	1-hr	5.55 \pm 0.62	6
5	1	Litter	10-hr	0.67 \pm 0.18	6
5	1	Shrub	1-hr	1.65 \pm 0.20	3
5	1	Shrub	10-hr	0.32 \pm 0.17	3
5	2	Grass	1-hr	0.19 \pm 0.00	1
5	2	Litter	1-hr	4.76 \pm 0.59	6
5	2	Litter	10-hr	1.16 \pm 0.39	6
5	2	Shrub	1-hr	1.36 \pm 0.17	2
5	2	Shrub	10-hr	0.43 \pm 0.11	2
5	3	Litter	1-hr	4.58 \pm 0.56	2
5	3	Litter	10-hr	0.51 \pm 0.33	2
5	3	Shrub	1-hr	1.89 \pm 0.00	1
5	3	Shrub	10-hr	2.56 \pm 0.00	1
10	1	Litter	1-hr	6.18 \pm 0.88	6
10	1	Litter	10-hr	0.82 \pm 0.18	6
10	1	Shrub	1-hr	5.41 \pm 0.18	6
10	1	Shrub	10-hr	1.43 \pm 0.19	6
10	2	Litter	1-hr	4.72 \pm 0.61	6
10	2	Litter	10-hr	0.69 \pm 0.30	6
10	2	Litter	100-hr	0.02 \pm 0.02	2
10	2	Shrub	1-hr	5.62 \pm 0.65	6
10	2	Shrub	10-hr	1.97 \pm 0.32	6
10	2	Shrub	100-hr	0.10 \pm 0.10	2
10	3	Litter	1-hr	4.51 \pm 0.55	6
10	3	Litter	10-hr	0.34 \pm 0.06	6
10	3	Shrub	1-hr	4.55 \pm 0.49	6
10	3	Shrub	10-hr	1.98 \pm 0.33	6

Table 5. Cover and height (mean \pm 1 se) of major vegetation groups in pine flatwood forests at one, two, and three years after a partial timber harvest.

Age-of-Rough (years)	Stand	Vegetation Group	Coverage (%)	Height (ft)	# of plots per stand
1	1	Grass	12.7 \pm 3.5	0.95 \pm 0.13	9
1	1	Pine litter	19.3 \pm 4.1	0.11 \pm 0.01	15
1	1	Saw palmetto	34.0 \pm 6.6	2.23 \pm 0.89	26
1	1	Small shrub	10.7 \pm 2.8	0.84 \pm 0.06	8
1	1	Tall shrub	23.3 \pm 5.1	1.60 \pm 0.91	17
1	2	Grass	8.7 \pm 3.3	1.04 \pm 0.09	6
1	2	Pine litter	20.0 \pm 4.5	0.10 \pm 0.10	15
1	2	Saw palmetto	39.3 \pm 3.1	2.30 \pm 0.98	30
1	2	Small shrub	7.3 \pm 1.4	0.77 \pm 0.08	5
1	2	Tall shrub	24.7 \pm 2.2	1.72 \pm 0.67	19
1	3	Grass	8.0 \pm 2.0	1.04 \pm 0.07	6
1	3	Pine litter	16.7 \pm 3.9	0.11 \pm 0.05	12
1	3	Saw palmetto	37.3 \pm 7.1	2.24 \pm 0.88	28
1	3	Small shrub	10.0 \pm 5.0	0.93 \pm 0.05	7
1	3	Tall shrub	28.0 \pm 4.4	1.73 \pm 0.76	21
2	1	Grass	12.7 \pm 3.6	1.05 \pm 0.08	10
2	1	Pine litter	15.3 \pm 4.1	0.08 \pm 0.03	11
2	1	Saw palmetto	32.0 \pm 5.5	3.05 \pm 1.10	24
2	1	Small shrub	4.0 \pm 1.0	0.67 \pm 0.11	3
2	1	Tall shrub	36.0 \pm 6.5	2.64 \pm 0.80	27
2	2	Grass	12.7 \pm 7.1	1.13 \pm 0.05	10
2	2	Pine litter	14.0 \pm 2.5	0.09 \pm 0.04	10
2	2	Saw palmetto	34.7 \pm 7.2	3.28 \pm 1.06	26
2	2	Small shrub	2.0 \pm 1.0	1.00 \pm 0.00	1
2	2	Tall shrub	36.7 \pm 6.6	2.67 \pm 0.96	28
2	3	Grass	10.0 \pm 2.0	1.10 \pm 0.05	8
2	3	Pine litter	12.7 \pm 3.5	0.10 \pm 0.05	10
2	3	Saw palmetto	37.3 \pm 8.1	3.15 \pm 0.77	28
2	3	Small shrub	2.7 \pm 1.8	0.75 \pm 0.14	2
2	3	Tall shrub	37.3 \pm 5.9	2.62 \pm 0.72	28
3	1	Grass	5.3 \pm 2.3	2.06 \pm 0.63	4
3	1	Pine litter	14.0 \pm 3.0	0.10 \pm 0.10	11
3	1	Saw palmetto	34.7 \pm 3.9	4.11 \pm 0.72	25
3	1	Small shrub	4.7 \pm 2.8	0.93 \pm 0.07	4
3	1	Tall shrub	41.3 \pm 6.8	3.96 \pm 0.73	31

Table 6. Loading (tons/acre, mean \pm 1 se) of forest fuels by type and size class in pine flatwood forests at one, two, and three years after a partial timber harvest.

Age-of-Rough (years)	Stand	Fuel Type	Fuel Size	Tons/acre	# of plots/stand
1	1	Litter	1-hr	1.32 \pm 0.28	3
1	1	Litter	10-hr	0.10 \pm 0.02	3
1	1	Litter	100-hr	0.03 \pm 0.01	3
1	1	Shrub	1-hr	2.80 \pm 0.80	3
1	2	Litter	1-hr	1.24 \pm 0.16	3
1	2	Litter	10-hr	0.10 \pm 0.01	3
1	2	Litter	100-hr	0.03 \pm 0.01	3
1	2	Shrub	1-hr	1.77 \pm 0.07	3
1	2	Shrub	10-hr	0.01 \pm 0.01	3
1	3	Litter	1-hr	1.57 \pm 0.14	3
1	3	Litter	10-hr	0.12 \pm 0.01	3
1	3	Litter	100-hr	0.04 \pm 0.03	3
1	3	Shrub	1-hr	1.68 \pm 0.05	3
2	1	Litter	1-hr	2.20 \pm 0.15	3
2	1	Litter	10-hr	0.17 \pm 0.11	3
2	1	Litter	100-hr	0.06 \pm 0.03	3
2	1	Shrub	1-hr	1.93 \pm 0.11	3
2	2	Litter	1-hr	2.62 \pm 0.03	3
2	2	Litter	10-hr	0.22 \pm 0.12	3
2	2	Litter	100-hr	0.53 \pm 0.22	3
2	2	Shrub	1-hr	2.83 \pm 0.18	3
2	2	Shrub	10-hr	0.30 \pm 0.05	3
2	3	Litter	1-hr	2.42 \pm 0.17	3
2	3	Litter	10-hr	0.30 \pm 0.13	3
2	3	Litter	100-hr	0.08 \pm 0.04	3
2	3	Shrub	1-hr	2.66 \pm 0.12	3
2	3	Shrub	10-hr	0.27 \pm 0.03	3
3	1	Litter	1-hr	3.97 \pm 0.15	6
3	1	Litter	10-hr	0.30 \pm 0.10	6
3	1	Litter	100-hr	0.12 \pm 0.03	6
3	1	Shrub	1-hr	4.36 \pm 0.09	6
3	1	Shrub	10-hr	0.56 \pm 0.10	6
3	1	Shrub	100-hr	0.06 \pm 0.03	6
3	2	Litter	1-hr	4.22 \pm 0.16	3
3	2	Litter	10-hr	0.33 \pm 0.12	3
3	2	Litter	100-hr	0.12 \pm 0.04	3
3	2	Shrub	1-hr	3.95 \pm 0.08	3
3	2	Shrub	10-hr	0.70 \pm 0.05	3

Table 7. Cover and height (mean \pm 1 se) of major vegetation groups in pine flatwood forests at three, five, and more than ten years after a partial timber harvest.

Age-of-Rough (years)	Stand	Vegetation Group	Coverage (%)	Height (ft)	# of plots per stand
3	2	Grass	7.3 \pm 3.1	1.95 \pm 0.13	5
3	2	Pine litter	11.3 \pm 4.2	0.08 \pm 0.05	7
3	2	Saw palmetto	28.7 \pm 0.5	4.16 \pm 1.17	22
3	2	Small shrub	2.0 \pm 1.0	0.83 \pm 0.17	2
3	2	Tall shrub	50.7 \pm 8.5	3.96 \pm 1.06	38
3	3	Grass	6.0 \pm 2.0	1.88 \pm 0.18	4
3	3	Pine litter	12.7 \pm 4.3	0.10 \pm 0.05	10
3	3	Saw palmetto	31.3 \pm 7.4	4.19 \pm 1.09	24
3	3	Small shrub	1.3 \pm 1.1	0.50 \pm 0.00	2
3	3	Tall shrub	48.7 \pm 9.6	3.90 \pm 1.07	36
5	1	Pine litter	20.7 \pm 4.8	0.10 \pm 0.05	15
5	1	Saw palmetto	55.3 \pm 9.5	4.81 \pm 1.06	42
5	1	Small shrub	0.7 \pm 0.0	1.00 \pm 0.00	1
5	1	Tall shrub	20.7 \pm 2.5	4.94 \pm 1.12	17
5	2	Pine litter	18.0 \pm 3.0	0.10 \pm 0.05	14
5	2	Saw palmetto	54.7 \pm 9.4	4.88 \pm 1.07	41
5	2	Small shrub	1.3 \pm 0.7	1.00 \pm 0.00	1
5	2	Tall shrub	26.0 \pm 4.0	4.78 \pm 1.12	20
5	3	Pine litter	17.3 \pm 2.9	0.10 \pm 0.10	13
5	3	Saw palmetto	56.7 \pm 8.8	4.82 \pm 1.06	44
5	3	Small shrub	1.3 \pm 0.7	1.00 \pm 0.00	1
5	3	Tall shrub	17.3 \pm 3.3	5.00 \pm 1.10	18
10	1	Pine litter	4.0 \pm 2.0	0.20 \pm 0.10	3
10	1	Saw palmetto	38.0 \pm 7.5	4.67 \pm 1.11	29
10	1	Small shrub	0.7 \pm 0.0	1.00 \pm 0.00	1
10	1	Tall shrub	57.3 \pm 7.9	5.48 \pm 1.09	43
10	2	Pine litter	4.7 \pm 2.5	0.20 \pm 0.13	4
10	2	Saw palmetto	45.3 \pm 7.2	4.99 \pm 1.08	34
10	2	Tall shrub	50.0 \pm 6.0	5.52 \pm 1.09	38
10	3	Pine litter	2.7 \pm 1.3	0.20 \pm 0.10	2
10	3	Saw palmetto	38.7 \pm 4.8	5.03 \pm 1.08	29
10	3	Tall shrub	58.7 \pm 4.5	5.55 \pm 1.08	44

Table 8. Loading (tons/acre, mean \pm 1 se) of forest fuels by type and size class in pine flatwood forests at three, five, and more than 10 years after a partial timber harvest.

Age-of-Rough (years)	Stand	Fuel Type	Fuel Size	Tons/acre	# of plots/stand
3	3	Litter	1-hr	4.06 \pm 0.18	3
3	3	Litter	10-hr	0.31 \pm 0.10	3
3	3	Litter	100-hr	0.13 \pm 0.03	3
3	3	Shrub	1-hr	4.15 \pm 0.07	3
3	3	Shrub	10-hr	0.74 \pm 0.02	3
5	1	Litter	1-hr	4.93 \pm 0.59	3
5	1	Litter	10-hr	0.43 \pm 0.13	3
5	1	Litter	100-hr	0.14 \pm 0.06	3
5	1	Shrub	1-hr	4.64 \pm 0.07	3
5	1	Shrub	10-hr	1.29 \pm 0.07	3
5	2	Litter	1-hr	5.38 \pm 0.25	6
5	2	Litter	10-hr	0.42 \pm 0.13	6
5	2	Litter	100-hr	0.14 \pm 0.04	6
5	2	Shrub	1-hr	6.16 \pm 0.37	6
5	2	Shrub	10-hr	0.90 \pm 0.21	6
5	2	Shrub	100-hr	0.09 \pm 0.04	6
5	3	Litter	1-hr	5.21 \pm 0.54	3
5	3	Litter	10-hr	0.49 \pm 0.03	3
5	3	Litter	100-hr	0.18 \pm 0.02	3
5	3	Shrub	1-hr	5.20 \pm 0.18	3
5	3	Shrub	10-hr	1.32 \pm 0.05	3
10	1	Litter	1-hr	12.23 \pm 0.82	3
10	1	Litter	10-hr	1.10 \pm 0.06	3
10	1	Litter	100-hr	0.39 \pm 0.04	3
10	1	Shrub	1-hr	4.09 \pm 0.28	3
10	1	Shrub	10-hr	1.49 \pm 0.07	3
10	2	Litter	1-hr	12.42 \pm 0.28	3
10	2	Litter	10-hr	1.29 \pm 0.17	3
10	2	Litter	100-hr	0.37 \pm 0.01	3
10	2	Shrub	1-hr	4.24 \pm 0.27	3
10	2	Shrub	10-hr	1.26 \pm 0.18	3
10	3	Litter	1-hr	14.95 \pm 0.28	6
10	3	Litter	10-hr	1.18 \pm 0.02	6
10	3	Litter	100-hr	0.58 \pm 0.07	6
10	3	Shrub	1-hr	7.20 \pm 0.48	6
10	3	Shrub	10-hr	1.43 \pm 0.05	6

Table 9. Percent cover and height (mean \pm 1 se) of major vegetation groups in pine flatwood forests at one, two, and three years after a dormant-season prescribed fire.

Age-of-Rough (years)	Stand	Vegetation Group	Coverage (%)	Height (ft)	# of plots per stand
1	1	Grass	14.7 \pm 5.5	0.68 \pm 0.08	11
1	1	Pine litter	12.0 \pm 4.0	0.03 \pm 0.01	9
1	1	Saw palmetto	36.0 \pm 8.5	1.30 \pm 0.05	27
1	1	Small shrub	14.7 \pm 3.2	0.59 \pm 0.06	11
1	1	Tall shrub	22.7 \pm 4.7	1.12 \pm 0.05	17
1	2	Grass	14.7 \pm 6.1	0.59 \pm 0.06	11
1	2	Pine litter	21.3 \pm 8.1	0.01 \pm 0.01	16
1	2	Saw palmetto	30.7 \pm 3.3	1.65 \pm 0.19	23
1	2	Small shrub	20.0 \pm 7.5	0.50 \pm 0.25	15
1	2	Tall shrub	13.3 \pm 2.8	0.90 \pm 0.07	10
1	3	Grass	14.7 \pm 4.1	0.86 \pm 0.10	11
1	3	Pine litter	20.0 \pm 6.0	0.02 \pm 0.01	15
1	3	Saw palmetto	34.7 \pm 8.3	1.50 \pm 0.08	26
1	3	Small shrub	12.0 \pm 3.0	0.55 \pm 0.06	9
1	3	Tall shrub	18.7 \pm 3.6	1.14 \pm 0.10	14
2	1	Grass	6.7 \pm 2.1	0.90 \pm 0.19	5
2	1	Saw palmetto	65.3 \pm 8.8	2.56 \pm 0.27	49
2	1	Small shrub	6.7 \pm 4.1	0.80 \pm 0.12	5
2	1	Tall shrub	21.3 \pm 7.2	2.06 \pm 0.14	16
2	2	Grass	6.7 \pm 2.2	0.60 \pm 0.10	5
2	2	Pine litter	6.7 \pm 4.3	0.02 \pm 0.01	5
2	2	Saw palmetto	48.0 \pm 9.5	2.38 \pm 0.12	36
2	2	Small shrub	6.7 \pm 3.9	0.50 \pm 0.20	5
2	2	Tall shrub	32.0 \pm 7.7	2.38 \pm 0.16	24
2	3	Grass	9.3 \pm 2.8	0.57 \pm 0.07	7
2	3	Pine litter	5.3 \pm 0.9	0.02 \pm 0.01	4
2	3	Saw palmetto	48.0 \pm 4.0	2.42 \pm 0.32	36
2	3	Small shrub	5.3 \pm 0.7	0.50 \pm 0.25	4
2	3	Tall shrub	32.0 \pm 5.9	2.35 \pm 0.16	24
3	1	Grass	10.7 \pm 9.4	1.00 \pm 0.50	8
3	1	Saw palmetto	61.3 \pm 3.2	3.21 \pm 0.57	46
3	1	Small shrub	6.7 \pm 0.5	0.80 \pm 0.13	5
3	1	Tall shrub	21.3 \pm 2.7	3.00 \pm 0.25	16
3	2	Grass	9.3 \pm 3.3	1.07 \pm 0.13	7
3	2	Pine litter	2.7 \pm 1.3	0.04 \pm 0.01	2
3	2	Saw palmetto	50.7 \pm 5.8	3.17 \pm 0.59	38
3	2	Small shrub	6.7 \pm 3.5	0.60 \pm 0.10	6
3	2	Tall shrub	30.7 \pm 7.1	3.00 \pm 0.66	23

Table 10. Loading (tons/acre, mean \pm 1 se) of forest fuels by type and size class in pine flatwood forests at one, two, and three years after a dormant-season prescribed fire.

Age-of-Rough (years)	Stand	Fuel Type	Fuel Size	Tons/acre	# of plots/stand
1	1	Grass	1-hr	0.55 \pm 0.04	6
1	1	Litter	1-hr	1.79 \pm 0.09	6
1	1	Litter	10-hr	0.15 \pm 0.01	6
1	1	Litter	100-hr	0.05 \pm 0.01	6
1	1	Shrub	1-hr	0.93 \pm 0.14	6
1	2	Litter	1-hr	1.62 \pm 0.06	3
1	2	Litter	10-hr	0.16 \pm 0.04	3
1	2	Shrub	1-hr	1.03 \pm 0.04	3
1	3	Litter	1-hr	1.57 \pm 0.12	3
1	3	Litter	10-hr	0.12 \pm 0.01	3
1	3	Shrub	1-hr	1.04 \pm 0.15	3
2	1	Litter	1-hr	2.82 \pm 0.17	6
2	1	Litter	10-hr	0.21 \pm 0.11	6
2	1	Litter	100-hr	0.07 \pm 0.03	6
2	1	Shrub	1-hr	1.92 \pm 0.06	6
2	2	Shrub	10-hr	0.23 \pm 0.04	3
2	2	Litter	1-hr	2.66 \pm 0.16	3
2	2	Litter	10-hr	0.20 \pm 0.12	3
2	2	Litter	100-hr	0.07 \pm 0.03	3
2	2	Shrub	1-hr	1.69 \pm 0.36	3
2	2	Shrub	10-hr	0.08 \pm 0.08	3
2	3	Litter	1-hr	3.05 \pm 0.15	3
2	3	Litter	10-hr	0.24 \pm 0.11	3
2	3	Litter	100-hr	0.08 \pm 0.03	3
2	3	Shrub	1-hr	1.78 \pm 0.26	3
2	3	Shrub	10-hr	0.06 \pm 0.03	3
3	1	Litter	1-hr	4.22 \pm 0.30	3
3	1	Litter	10-hr	0.33 \pm 0.03	3
3	1	Litter	100-hr	0.11 \pm 0.01	3
3	1	Shrub	1-hr	2.57 \pm 0.12	3
3	1	Shrub	10-hr	0.37 \pm 0.05	3
3	2	Litter	1-hr	3.71 \pm 0.23	3
3	2	Litter	10-hr	0.29 \pm 0.02	3
3	2	Litter	100-hr	0.09 \pm 0.05	3
3	2	Shrub	1-hr	2.54 \pm 0.12	3
3	2	Shrub	10-hr	0.29 \pm 0.04	3

Table 11. Cover and height (mean \pm 1 se) of major vegetation groups in pine flatwood forests at three, five, and more than ten years after a dormant-season prescribed fire.

Age-of-Rough (years)	Stand	Vegetation Group	Coverage (%)	Height (ft)	# of plots per stand
3	3	Grass	10.7 \pm 3.3	1.06 \pm 0.07	8
3	3	Saw palmetto	57.3 \pm 9.9	3.24 \pm 0.87	43
3	3	Small shrub	8.0 \pm 4.0	0.83 \pm 0.11	6
3	3	Tall shrub	24.0 \pm 6.1	3.22 \pm 0.78	18
5	1	Grass	1.3 \pm 0.0	1.00 \pm 0.00	1
5	1	Pine litter	5.3 \pm 2.8	0.10 \pm 0.00	4
5	1	Saw palmetto	66.7 \pm 7.1	3.73 \pm 0.98	50
5	1	Small shrub	9.3 \pm 4.4	0.93 \pm 0.07	7
5	1	Tall shrub	17.3 \pm 2.5	2.69 \pm 0.63	13
5	2	Grass	5.3 \pm 2.6	1.38 \pm 0.55	4
5	2	Pine litter	9.3 \pm 5.1	0.10 \pm 0.00	7
5	2	Saw palmetto	48.0 \pm 8.8	3.51 \pm 1.07	36
5	2	Small shrub	13.3 \pm 2.4	0.85 \pm 0.08	10
5	2	Tall shrub	24.0 \pm 6.4	2.83 \pm 0.51	18
5	3	Grass	4.0 \pm 2.0	1.67 \pm 0.67	3
5	3	Pine litter	5.3 \pm 1.4	0.10 \pm 0.00	4
5	3	Saw palmetto	53.3 \pm 6.8	3.25 \pm 1.06	40
5	3	Small shrub	10.7 \pm 6.1	0.81 \pm 0.09	8
5	3	Tall shrub	26.7 \pm 3.2	2.90 \pm 0.85	20
10	1	Pine litter	5.3 \pm 2.2	0.20 \pm 0.10	4
10	1	Saw palmetto	68.0 \pm 5.5	4.29 \pm 1.08	51
10	1	Small shrub	5.3 \pm 1.8	1.00 \pm 0.00	4
10	1	Tall shrub	21.3 \pm 7.4	5.09 \pm 1.21	16
10	2	Pine litter	9.3 \pm 2.6	0.19 \pm 0.06	7
10	2	Saw palmetto	58.7 \pm 9.6	4.13 \pm 1.07	44
10	2	Small shrub	2.7 \pm 1.3	1.00 \pm 0.00	4
10	2	Tall shrub	29.3 \pm 4.4	4.32 \pm 1.26	22
10	3	Pine litter	4.0 \pm 3.0	0.17 \pm 0.10	3
10	3	Saw palmetto	74.7 \pm 9.7	4.30 \pm 1.08	56
10	3	Small shrub	5.3 \pm 3.7	1.00 \pm 0.00	4
10	3	Tall shrub	16.0 \pm 5.2	4.63 \pm 1.18	12

Table 12. Loading (tons/acre, mean \pm 1 se) of forest fuels by type and size class in pine flatwood forests at three, five, and more than ten years after a dormant-season prescribed fire.

Age-of-Rough (years)	Stand	Fuel Type	Fuel Size	Tons/acre	# of plots/stand
3	3	Litter	1-hr	3.88 \pm 0.20	3
3	3	Litter	10-hr	0.30 \pm 0.15	3
3	3	Litter	100-hr	0.10 \pm 0.01	3
3	3	Shrub	1-hr	2.68 \pm 0.13	3
3	3	Shrub	10-hr	0.38 \pm 0.04	3
5	1	Litter	1-hr	6.32 \pm 0.42	3
5	1	Litter	10-hr	0.49 \pm 0.03	3
5	1	Litter	100-hr	0.16 \pm 0.10	3
5	1	Shrub	1-hr	3.16 \pm 0.38	3
5	1	Shrub	10-hr	0.64 \pm 0.14	3
5	2	Litter	1-hr	5.12 \pm 0.37	3
5	2	Litter	10-hr	0.39 \pm 0.03	3
5	2	Litter	100-hr	0.13 \pm 0.09	3
5	2	Shrub	1-hr	2.89 \pm 0.07	3
5	2	Shrub	10-hr	0.43 \pm 0.02	3
5	3	Litter	1-hr	4.88 \pm 0.32	3
5	3	Litter	10-hr	0.38 \pm 0.02	3
5	3	Litter	100-hr	0.12 \pm 0.08	3
5	3	Shrub	1-hr	2.64 \pm 0.11	3
5	3	Shrub	10-hr	0.38 \pm 0.06	3
10	1	Litter	1-hr	8.03 \pm 0.33	10
10	1	Litter	10-hr	1.44 \pm 0.06	10
10	1	Litter	100-hr	0.47 \pm 0.02	10
10	1	Shrub	1-hr	7.31 \pm 0.10	10
10	1	Shrub	10-hr	1.77 \pm 0.03	10
10	2	Litter	1-hr	6.15 \pm 0.36	10
10	2	Litter	10-hr	1.51 \pm 0.05	10
10	2	Litter	100-hr	0.48 \pm 0.01	10
10	2	Shrub	1-hr	5.63 \pm 0.39	10
10	2	Shrub	10-hr	1.71 \pm 0.10	10
10	3	Grass	1-hr	0.37 \pm 0.00	10
10	3	Litter	1-hr	5.98 \pm 0.70	10
10	3	Litter	10-hr	1.44 \pm 0.04	10
10	3	Litter	100-hr	0.47 \pm 0.01	10
10	3	Shrub	1-hr	5.58 \pm 0.78	10
10	3	Shrub	10-hr	1.77 \pm 0.06	10

Table 13. Cover and height (mean \pm 1 se) of major vegetation groups in slash pine plantations three years after a combination commercial thinning / understory herbicide treatment.

Age-of-Rough (years)	Stand	Vegetation Group	Coverage (%)	Height (ft)	# of plots per stand
3	1	Grass	50.7 \pm 7.5	1.67 \pm 0.15	38
3	1	Pine litter	32.0 \pm 6.3	0.11 \pm 0.01	24
3	1	Saw palmetto	1.3 \pm 0.0	3.00 \pm 0.00	1
3	1	Tall shrub	16.0 \pm 3.9	2.47 \pm 0.43	12
3	2	Grass	54.7 \pm 4.9	1.73 \pm 0.10	41
3	2	Pine litter	30.7 \pm 4.6	0.09 \pm 0.01	23
3	2	Saw palmetto	1.3 \pm 0.0	3.00 \pm 0.00	1
3	2	Tall shrub	13.3 \pm 2.1	2.10 \pm 0.42	10
3	3	Grass	48.0 \pm 5.2	1.68 \pm 0.15	36
3	3	Pine litter	34.7 \pm 5.4	0.11 \pm 0.02	26
3	3	Saw palmetto	1.3 \pm 0.0	3.00 \pm 0.00	1
3	3	Tall shrub	16.0 \pm 2.7	2.46 \pm 0.40	12

Table 14. Loading (tons/acre, mean \pm 1 se) of forest fuels by type and size class in slash pine plantations three years after a combination commercial thinning / understory herbicide treatment.

Age-of- Rough (years)	Stand	Fuel Type	Fuel Size	Tons/acre	# of plots/stand
3	1	Grass	1-hr	1.07 \pm 0.43	6
3	1	Litter	1-hr	4.53 \pm 0.60	6
3	1	Litter	10-hr	0.42 \pm 0.07	6
3	1	Shrub	1-hr	0.27 \pm 0.02	2
3	1	Shrub	10-hr	0.13 \pm 0.04	2
3	2	Grass	1-hr	1.72 \pm 0.45	6
3	2	Litter	1-hr	6.22 \pm 1.06	6
3	2	Litter	10-hr	1.14 \pm 0.40	6
3	2	Shrub	1-hr	0.25 \pm 0.08	2
3	2	Shrub	10-hr	0.09 \pm 0.03	2
3	3	Grass	1-hr	0.96 \pm 0.28	4
3	3	Litter	1-hr	4.19 \pm 0.66	6
3	3	Litter	10-hr	0.58 \pm 0.12	6
3	3	Shrub	1-hr	0.38 \pm 0.12	3
3	3	Shrub	10-hr	0.15 \pm 0.05	3