2A.5 INVENTORY AND CLASSIFICATION OF WILDLAND FIRE EFFECTS IN SILVICULTURALLY TREATED VS. UNTREATED FOREST STANDS OF NEW MEXICO AND ARIZONA

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1. INTRODUCTION

Southwestern forests, particularly those dominated by ponderosa pine (*Pinus ponderosa* var. *scopulorum* Engel.), developed under the influence of frequent fire (Sackett et al. 1993). Reported mean fire intervals for southwestern ponderosa pine forests range between 2–12 years (Weaver 1951, Cooper 1960, Dieterich 1980). Over the last 10,000 years, frequent fire shaped vegetation composition, succession, and structure in pine-grassland communities (Biswell 1959, 1972, Cooper 1960, 1961, Pyne 1982, Covington and Moore 1994). Frequent fires, characterized as light to moderately severe, were largely understory fires and killed few overstory pines. Fire acted as a natural thinning agent by reducing litter build-up, burning small trees, and thinning ladder fuels. Resulting forests were open and park-like with invigorated herbaceous understories providing the fuel for the fire cycle to repeat itself (Ahlgren and Ahlgren 1960, Moir et al. 1997). Due to their open nature and lack of ladder fuels, stand replacement fires were historically uncommon in southwestern ponderosa pine forests (Woolsey 1911, Cooper 1960, Pyne 1996). However, a number of factors combined to change forest structure, understory and overstory composition, fuel biomass conditions, and the historic natural fire regime in southwestern forests over the last 120 years. Early contributing factors around the turn of the 20th century included logging practices (Habeck 1990) that removed overstory trees allowing for prolific conifer regeneration (Cooper 1960, Schubert 1974), and heavy grazing by sheep and cattle, which removed fine fuels necessary for fire spread.

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Moreover, within the last 80 years aggressive fire suppression efforts and exclusion policies contributed significantly to the changes in these forests. As a result, high-intensity crown fires have replaced low-intensity fires in southwestern pine-grassland stands threatening not only those communities at the wildland-urban interface, but also the ecological integrity of vast areas throughout the west.

The purpose of this study was two-fold; first, to document and delineate the occurrence of wildland fire in the southwestern National Forest system and delineate within that boundary where various silvicultural treatments have taken place within the last 25 (approximate) years; and second, to increase our understanding of fire behavior and post-fire ecology in southwestern forests having received silvicultural treatments versus untreated stands. In this forum we will report only on the latter. Until recently, information comparing fire behavior and fire effects on treated versus untreated forest stands following wildland fire remained largely anecdotal. We hypothesized forest stands treated recently (<20 years) using silvicultural practices were less likely to experience crown fire compared to untreated stands. Potential silvicultural practices we considered included: commercial timber, individual tree, and group selection harvests; pre-commercial thinning; forest health or aesthetic treatments; prescribed burning treatments, or some combination of above mentioned treatments. This report details the first of two data collection seasons. As such, results should be considered preliminary until the conclusion of the second data-collection season.

2. METHODS

Study Area

Study areas were located in three National Forests across Arizona and New Mexico. Within Arizona, we studied the Rodeo-Chediski fire in the Apache-Sitgreaves National Forest (NF). Within New Mexico, we studied the Oso fire in the Santa Fe NF, and the Penasco and Scott Able fires in the Lincoln NF. Study sites within the Rodeo-Chediski fire were lower (1,960 m) montane coniferous stands composed of ponderosa pine and gambel's oak (*Quercus gambelii*). The Oso fire burned in upper (2,475 m) montane coniferous stands composed of ponderosa pine with some Douglas fir (*Pseudotsuga menziesii*), and white fir (*Abies concolor*). The Penasco fire burned in upper (2,315 m) montane coniferous stands. However, the two study sites within the Penasco fire differed in species composition and canopy cover (%) and were examined separately as Coleman one and Coleman two; Coleman one was composed predominately of Douglas fir and had a closed canopy, while Coleman two was similar in composition to the Oso fire study sites, but had an open canopy. The Scott Able fire burned at a higher elevation (2,792 m) within the upper montane coniferous forest and was composed of white fir, Douglas fir, and spruce (*Picea* spp.) species.

Fire and Management Treatment History

Weather and fuel condition data for the four fires studied were obtained through archives taken from the nearest weather station on the day the fire passed through the study sites (Table 1). Timelag fuel moistures were obtained to provide an indicator of fuel conditions leading up to the fire (Table 1). Energy release component was also obtained as it provides good insight into conditions primed for extreme fire behavior. Energy release component is a measure of the heat released per unit area in the flaming zone of the fire and is affected by varying fuel moistures in the fuel bed. It is the least variable index on a day-to-day basis.

Study Design

Due to the unpredictability of how, when, and where wildland fires will burn, setting up elegant experimental studies is impractical. Replicated silvicultural treatments may exist on the landscape, but irregular burn patterns and heterogeneous fire behavior often complicate establishment of study sites. Once potential study sites were identified on paper, site visits were initiated to verify that treatments were within the fire boundary, and further, to verify that treatment sites and adjacent untreated sites had similar slopes and aspects.

Study stands, defined entirely by management treatment and wildland fire boundaries, were > 16 ha. Stands had similar slope, aspect, and overstory composition (Table 2). On the Rodeo-Chediski fire we located three replicates of three treatments in the summer of 2002: (1) lop, pile, burn (n = 15); (2) lop and scatter (n = 15); (3) untreated (n = 15). On the Oso fire we found two replicates of two treatments in the summer of 2002: (1) harvest and burn (n = 10); (2) untreated (n = 10). On the Penasco fire two study sites, Coleman one and Coleman two were located, but because of different species composition and percent canopy cover between the two sites replication was not possible. Treated sites were on private property and compared to untreated sites on adjacent US Forest Service land. Treatments included: (1) commercial thinning (Coleman 1, n = 4; Coleman 2, n = 3); (2) untreated (Coleman 1, n = 4; Coleman 2, n = 3). The Scott Able fire produced only one suitable study site; treatments included (1) shelterwood (n = 5); (2) untreated (n = 5).

Fire Behavior and Fire Ecology Indices

Within five variable radius plots per treatment, determined by using a 10-factor prism, we measured stand characteristics important to understanding fire behavior including tree height (m), crown length and width (m), height to pre-fire live crown (m), diameter (cm) at breast height (1.37 m), bole char height (m), scorch height (m), consumption height (m), percent crown scorch (%), and percent crown consumption (%). A clinometer was used to estimate heights, and % crown scorch and consumption were ocular estimates. Canopy weight was estimated using Brown's (1978) tree canopy weight equations. Canopy weights were based on all foliage plus 50% of the one-hour branchwood fuel (Agee 1996). Because equations for all tree species present on our study sites were not available, we used the closest species with regards to tree habit. We used whitebark pine (*Pinus albicaulis*) to estimate limber pine (*P. flexilis*), western redcedar (*Thuja plicata*) to estimate alligator (*Juniperus deppeana*) and one-seeded juniper (*J. monosperma*), and grand fir (*Abies grandis*) to estimate white fir. Stem density (stems/ha) was calculated following Avery and Burkhart (1994), and then used with tree canopy weights to calculate canopy weight per area (kg/m^2). Actual crown length (m) was the criterion for crown volume and used to determine canopy bulk density (kg/m^3).

Ground char was estimated following Ryan and Noste (1985), fire damage was estimated following Omi and Kalabokidis (1991), and fireline intensity was estimated using scorch height and Van Wagner's (1973) equations. Because scorch height underestimates fireline intensity on unscorched or completely scorched trees we followed Omi and Martinson's (2002) formula for calculating average scorch height. Independent estimates of fire severity and ground char were made within the immediate vicinity of the plot.

To characterize forest structure post-wildland fire we estimated percent cover in four 0.3 x 0.6-m^2 plots in the following categories; grass-like, forb, shrub (0–1 and >1–2 m height classes), litter, rock, bare soil, woody live stem, and woody dead stem (shrub >1–2 m, woody live stem, and woody dead stem were omitted from table 5). Percent cover for categories was estimated using Brown et al.'s (1982) cover value scale. Dead and down fuel loading and depth was estimated following Brown et al. (1982). To estimate conifer basal area (Avery and Burkhart 1994) and percent canopy cover (Lemmon 1957), a 10-factor prism and a spherical densiometer were used, respectively. Basal area (m^2/ha) estimates in treated and untreated sites provide an indication of the specific treatment prescription (Table 2).

Fire damage, ground char, fuel loading, basal area, litter and duff depth, and percent cover were estimated at four 8-m-radius subplots on 1–2 randomly spaced parallel lines perpendicular to the contour. The first sub-point was the plot center. The second sub-point was located in a random direction 10 m from the plot center. The remaining 2 sub-points were 120 and 240° from the second, and 10 m from the plot center. To avoid bias from surrounding stands and an edge effect, no sampling was conducted within 75 m of stand edge (Mueller-Dombois and Ellenberg 1974:123). All data were collected post wildland fire.

Data Analysis

Reported means and standard errors for dependent and independent variables were summarized by treatment. Null hypothesis testing of stand means was omitted in order to focus on magnitude of effect (Cherry 1998, Johnson 1999, Anderson et al. 2000). Statistical Analysis System version 8 (SAS Institute 1985) was used for statistical analysis. Pearson product-moment correlation analysis (SAS Institute 1985) was used as a starting point to index relationships between fire behavior and stand structure characteristics. Regression analysis (SAS Institute 1985) was used to model relationships between fire damage and stand characteristics. Mallows' C_p statistic was used as criterion for model selection (Mallow 1964, Daniel and Wood 1980).

3. RESULTS

Fire Behavior

Every treated stand experienced less severe canopy and ground char damage as compared to the adjacent untreated stand (Table 3, Figure 1). Further, as would be expected based on canopy and ground damage, estimates of fireline intensity (kcal/s/m) were lower in treated than untreated stands. Fireline intensity was underestimated on every untreated stand because accurate measures of scorch height were limited by tree height, i.e., flame height and scorch height exceeded the tallest tree. Height of bole char was also less on all treated stands as compared to untreated stands. Untreated stands were more susceptible to complete crown scorch and consumption than treated stands (Figure 2). Correlation analysis provided clues as to why treated stands experienced less fire damage compared to untreated stands. Basal area (m^2/ha) and density (stems/ha) were positively related to stand damage and ground char, whereas average tree diameter (cm) was negatively related to stand damage and ground char (Table 4). Basal area (m^2/ha), diameter at breast height (cm), and density (stems/ha) best explained stand damage (y = 2.07 + 0.08 [basal area] – 0.03 [diameter] + 0.002 [density]) ($P < 0.001$, $r^2 = 0.72$). Stands with canopy bulk densities >0.100 kg/m^3 appeared to be susceptible to crown fires (Figure 3).

Ecological Effects

Following the Rodeo-Chediski fire, treated stands had greater grass, forb and litter cover and less bare ground than untreated stands (Table 5). Differences were most evident between lop, pile, burn treatment stands and untreated stands. Four years following the Oso fire, grass cover remained greater in treated stands than untreated stands, while bare ground remained higher in untreated stands. In similar fashion to the Rodeo-Chediski and Oso fires, grass cover following the Scott Able fire was greater in treated stands than untreated stands, and bare ground remained higher in untreated stands. Differences in understory characteristics between treated and untreated stands following the Penasco fire were less evident.

Comparisons between herbaceous and litter fuel loads and fuel depths in treated and untreated stands showed similar patterns to understory cover; treated stands experienced less severe fire resulting in greater residual fuel loads and depths post-fire (Table 6). Differences between fine dead and down fuel loads (1 and 10 hour fuels) on treated and untreated stands were negligible across all fires. Differences in large dead and down fuel loads (100 and 1000 hour fuels) between treated and untreated stands immediately following fire were also negligible (e.g., Rodeo-Chediski and Penasco fire). However, four years following the Oso fire heavy fuels were greater on untreated stands as charred boles began to rot and fall.

4. DISCUSSION

Fire Behavior

The fire environment triangle states fuel, weather, and topography combine to determine fire behavior. Preliminary results indicate fire severity in middle elevation (circa 2,350 m) montane coniferous forests is allayed when the fuel leg of the fire behavior triangle is reduced. Under extreme conditions created by drought, high winds, and suitable topographical conditions, we observed treated forest stands that, although suffering less severe fire and ground char damage than adjacent untreated stands, were still subjected to near stand replacement type damage. However, this illustrates that even under extreme conditions, fire severity can be mitigated by fuel reduction. Furthermore, one could hypothesize a more aggressive silvicultural treatment would likely have experienced still less ground and stand damage. In particular, we observed prescribed fire in combination with mechanical thinning had the greatest impact toward mitigating fire severity. Silvicultural prescriptions designed to reduce stand susceptibility to crown wildfire must consider slope and aspect, slash treatment, and residual tree and stand characteristics. Specifically, as density (stems/ha) and basal area (m^2/ha) decrease and mean diameter at breast height (cm) increase, fire severity and ground char decrease. Further, a threshold in canopy bulk density (kg/m^3) on stands with 0–5 % slope was observed beyond which initiation of a crown fire was possible and below which it did not occur.

Ecological Implications

The ecological implications of different fire severities on natural processes are boundless: wildlife behavior, wildlife habitat, hydrologic processes, nutrient cycling, carbon release, global warming, etcetera. These are just a smidgen of the complex issues potentially affected by differing fire regimes, frequencies, and intensities. As such, the following terse discussion seeks only to stimulate thought as well as highlight one basic ecological implication above and below which rest many more.

Greater understory cover, particularly that of grasses two (Scott Able burn area) and four (Oso burn area) years following wildfire, suggests a difference in the ecological condition between treated and untreated forest stands. Further, because silviculturally treated stands experienced less severe fire damage and subsequently less loss of important litter and duff layers, stands were less susceptible to soil loss and more conducive to residual plant growth and recovery. This suggested difference in ecological "health" may best be illustrated by the continued high percent of bare soil in untreated stands two and four years following wildland fire. Extreme fireline intensities and high residual fire times can causes severe soil damage leading to loss of nutrient stores, loss of a viable seed bed, change in microclimates, and altered hydrologic soil behavior leading to rapid erosion events. This type of soil damage was most pronounced in the untreated Scott Able fire study sites due to moderate slopes and extreme fire intensities. For purposes of ecological comparison, the grass, forb, shrub, litter and duff cover in the understory as well as an intact soil profile characterize the adjacent treated shelterwood stand on the Scott Able study site.

5. MANAGEMENT IMPLICATIONS

Numerous stakeholders have reason to thoughtfully consider the implications of these preliminary results. Foremost in today's society includes urban and rural community leaders, planners, and citizens in considering how to reduce the threat of high-intensity wildland fire in the wildland-urban interface. Within the wildland-urban interface where the priority is elimination of crown fire potential and reduced fire severity, specific prescriptions should consider reducing ground fuel biomass, stem density and basal area. In particular, small diameter trees, particularly those with crowns in the midstory, should be removed. Specific target densities and basal areas will depend on management objectives, however as a general rule one can expect an inverse relationship between the degree of fuel reduction and the likelihood of crown fire initiation and propagation. Targeting specific canopy bulk densities may not be readily practical in the field because of the involved calculations required. However, depending on available time, size of the treatment area, and financial resources, post-treatment estimates of crown bulk density could be made and, if necessary, further reduced to minimize the potential for crown fire initiation and propagation.

In addition to reducing the threat of crown fire in the wildland-urban interface, city and community resource managers must also consider watersheds in their entirety. Ecologically functioning watersheds are vital not only to the sustainability of water supplies, but also to flood and erosion control. Natural resource management agencies, often required to manage for multiple resources such as wildlife habitat requirements, watershed hydrologic processes, and recreational opportunities, must also consider entire landscapes and watersheds when attempting to minimize the risk of crown fire. Past and present research results suggest mechanical fuel reduction followed by frequent prescribed fire is well suited as a management tool to restore and sustain entire watersheds and their ecological functions, particularly in pine-grassland forests.

It is noteworthy to mention the objective of fuel reduction in the wildland-urban interface or within a watershed is not to "fire proof" the environment, but rather to reduce the likelihood of stand-replacement crown fire. In fact, it was attempts at fire proofing western coniferous forests that largely lead to the unsustainable conditions of today's forest. Furthermore, when forest canopies are opened up via mechanical means, fine understory fuels can be expected to increase. The silver lining in increased fine fuels is the improved potential to use back-burns ahead of a wildland-head fire. Backfires burning through fine fuels are more effective and efficient in burning out understory fuels as compared to a closed canopy forest with a deep and compacted litter understory. Estimates of fireline intensity indicated that hand lines and dozer lines would have been effective containment techniques in treated stands (Andrews and Rothermel 1982).

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Table 1. Circumstance surrounding wildland fires studied in Arizona and New Mexico, summer 2002.

Circumstance	Fire			
	Rodeo-Chediski	Oso	Penasco	Scott Able
Date[a]	6/18/02 – 7/7/02	6/27/98 – 7/8/98	4/30/02 – 5/5/02	5/11/00 – 5/19/00
Hectares burned	189,015	2,171	6,232	6,677
Relative humidity (%)[b]	6	10	5	8
Wind speed (km/h)[b]	7.9	13.0	22.7	24.1
Temperature (Celsius)[b]	30	33	27	23
ERC (btu/ft^2)[b,c]	309	94	98	95
Timelag fuel moisture classes (%)				
10 hour	2	2	2	3
100 hour	2	4	3	3
1000 hour	3	6	6	5
Suppression cost (Million U.S. dollars)	43.0	3.5	5.7	3.6

[a] Ignition date to 100% containment date.
[b] Extreme fire weather conditions as reported from closest weather station from day fire burned through study sites.
[c] Energy release component.

Table 2. Study site characteristics in Arizona and New Mexico, summer 2002.

Characteristic	Fire and Study Site								
	Rodeo-Chediski			Rodeo-Chediski			Rodeo-Chediski		
	Bagnal			Caballos			Hop		
Treatment[a]	LPB	L&S	UT	LPB	L&S	UT	LPB	L&S	UT
Trt. Year	1999	1999	NA	1999	1999	NA	1998	1998	NA
BA (m^2/ha)	9.9	10.3	22.3	19.5	24.3	31.0	14.9	17.9	22.3
Elevation (m)	1,967	1,967	1,967	2,051	2,051	2,051	2,027	2,027	2,027
Slope (%)	1.1	1.1	0	1.6	2.9	3.8	5.6	5.6	4.4
Aspect	NE	NE	NA	NE	NE	NE	NW	NW	NE

Characteristic	Oso				Penasco				Scott Able	
	Ojito	Santa	Terrero	Posos	Coleman 1		Coleman 2		Wayland	
Treatment[a]	H&B	UT	H&B	UT	THIN	UT	THIN	UT	Shelterwood	UT
Trt. Year	1994	NA	1995	NA	1992	NA	1992	NA	1988	NA
BA (m^2/ha)	11.0	26.2	12.6	24.3	13.8	29.3	3.1	29.1	6.9	30.8
Elevation (m)	2,475	2,475	2,506	2,469	2,317	2,317	2,317	2,317	2,792	2,792
Slope (%)	3.3	1.3	2.0	4.4	1.7	1.1	3.0	4.4	15.3	13.3
Aspect	N	S	N	NW	S	S	E	E	N	N

[a] LPB = lop, pile, burn; L&S = lop and scatter; UT = untreated; H&B = harvest and burn; THIN = commercial thin.

Table 3. Forest stand characteristics and measured fire behavior indices important to understanding fire behavior in New Mexico and Arizona National Forests, June – August, 2002.

Treatment	Average diameter (cm)		Basal area (m^2/ha)		Density (stems/ha)		Ground char (0–3)		Fire severity (0–4)		Height to live crown (m)		Height bole char (m)		Fireline intensity (kcal/s/m)		Canopy bulk density (kg/m^3)	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Rodeo-Chediski Fire, Apache – Sitgreaves National Forest																		
Lop, Pile, Burn	34.4	4.8	14.8	2.8	294	35	1.4	0.1	2.0	0.4	6.1	1.7	2.5	1.2	115	51	0.078	0.008
Lop & Scatter	26.3	1.2	17.5	4.1	470	119	2.2	0.1	3.0	0.2	6.6	0.9	8.9	1.1	238	24	0.092	0.009
Untreated	23.1	2.9	25.2	2.9	2,054	1,138	3.0	<0.1	4.0	<0.1	6.2	0.9	10.9	1.7	414+	38	0.155	0.033
Oso Fire, Santa Fe National Forest																		
Harvest & burn	45.2	3.2	11.8	0.8	111	24	1.2	0.1	1.1	0.1	7.2	0.5	3.2	0.3	44	9	0.048	0.007
Untreated	22.6	1.3	25.1	2.5	1,213	220	2.2	0.1	4.0	0.1	5.4	0.4	10.9	0.3	485+	23	0.169	0.010
Penasco Fire, Lincoln National Forest : Coleman 1																		
Commercial thin	34.3	3.1	3.8	5.3	269	166	2.2	0.1	2.9	0.2	4.2	1.6	7.7	2.9	380	0	0.072	0.044
Untreated	32.6	2.5	29.3	3.5	625	169	3.0	0.0	4.0	0.0	11.7	0.4	19.3	0.9	555+	0	0.259	0.078
Penasco Fire, Lincoln National Forest : Coleman 2																		
Commercial thin	50.5	2.8	3.1	0.8	15	3	1.0	0.0	2.0	0.0	12.7	1.9	6.4	0.6	258	0	0.006	0.002
Untreated	39.3	1.7	29.1	5.4	450	114	3.0	0.0	3.4	0.2	14.5	0.8	20.9	1.5	527+	0	0.090	0.023
Scott Able Fire, Lincoln National Forest																		
Shelterwood	40.0	7.3	6.9	3.0	40	10	1.0	0.0	1.8	0.2	2.7	1.6	2.4	0.7	73	0	0.018	0.004
Untreated	44.4	2.2	30.8	3.3	367	72	2.3	0.2	4.0	0.1	9.1	1.1	16.2	1.3	654+	0	0.196	0.055

'+' Indicates underestimated fireline intensity.

Table 4. Pearson correlation coefficients between stand conditions and wildfire severity across all stands in New Mexico and Arizona National Forests, June – August, 2002.

Stand Condition	Fire Severity Index: Ground Char	Stand Damage	Bole Char
Basal Area (m^2/ha)	0.82**	0.81**	0.75**
Density (stems/ha)	0.66*	0.72**	0.32
Diameter (cm) at 1.37 m	–0.57*	–0.57*	–0.15
Canopy Bulk Density (kg/m^3)	0.71**	0.77**	0.63*

* $P \leq 0.01$
** $P < 0.001$

Table 5. Understory cover (%) response after wildland fire in New Mexico and Arizona National Forests, June – August, 2002.

Treatment	Grass $\bar{x}$	Grass SE	Forb $\bar{x}$	Forb SE	Shrub <1 m $\bar{x}$	Shrub <1 m SE	Soil $\bar{x}$	Soil SE	Litter $\bar{x}$	Litter SE
Rodeo-Chediski Fire, Apache – Sitgreaves National Forest										
Lop, Pile, Burn	2.0	0.9	1.4	0.9	0.4	0.1	52.5	5.8	44.1	0.4
Lop & Scatter	0.5	0.1	0.5	0.2	0.1	<0.1	69.0	3.4	24.0	4.1
Untreated	0.2	<0.1	0.2	0.1	0.1	<0.1	86.8	2.8	1.6	0.3
Oso Fire, Santa Fe National Forest										
Harvest & Burn	34.7	3.7	6.4	1.0	1.0	0.3	8.1	1.5	33.7	4.3
Untreated	4.1	1.3	10.7	1.8	4.0	0.7	34.3	5.5	20.7	2.7
Penasco Fire, Lincoln National Forest : Coleman 1										
Commercial thin	0.1	0.1	0.0	0.0	<0.1	<0.1	81.9	2.5	19.2	2.1
Untreated	0.0	0.0	0.0	0.0	0.0	0.0	90.5	1.1	3.1	0.3
Penasco Fire, Lincoln National Forest : Coleman 2										
Commercial thin	1.8	0.7	0.7	0.2	0.0	0.0	66.1	4.8	26.5	4.6
Untreated	0.2	0.1	0.0	0.0	0.0	0.0	78.2	8.2	19.7	8.8
Scott Able Fire, Lincoln National Forest										
Shelterwood	29.4	2.3	5.0	1.1	3.8	1.8	41.6	2.3	15.0	2.6
Untreated	0.3	0.3	2.8	0.9	0.6	0.2	70.4	3.1	13.8	2.3

Table 6. Fuel loading and depth in treated and untreated forest stands following wildland fire in New Mexico and Arizona National Forests, June – August, 2002.

Treatment	Herb loading (kg/ha)		Litter loading (kg/ha)		1 hr fuel loading (t/ha)		10 hr fuel loading (t/ha)		100 hr loading (t/ha)		1000 hr loading (t/ha)		Litter depth (cm)		Duff depth (cm)	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Rodeo-Chediski Fire, Apache – Sitgreaves National Forest																
Lop, pile, burn	13.1	1.0	1,833.3	204.5	<0.1	<0.1	0.2	0.1	1.0	0.3	0.9	0.4	0.4	0.1	0.2	0.1
Lop & scatter	5.0	0.6	789.9	343.0	<0.1	<0.1	0.1	<0.1	0.5	0.2	2.9	0.3	0.2	<0.1	0.1	0.1
Untreated	1.6	1.0	18.2	2.8	0.0	0.0	<0.1	<0.1	0.6	0.3	0.8	0.2	<0.1	<0.1	<0.1	<0.1
Oso Fire, Santa Fe National Forest																
Harvest & burn	389.5	47.5	1,679.2	184.9	0.1	<0.1	0.7	0.2	1.4	0.4	3.5	1.3	0.9	0.1	0.3	0.1
Untreated	192.3	23.9	893.5	205.0	0.1	<0.1	1.5	0.3	3.3	0.8	17.6	4.0	0.6	0.1	0.1	<0.1
Penasco Fire, Lincoln National Forest : Coleman 1																
Commercial thin	<0.1	<0.1	941.8	221.5	NA		NA		NA		NA		0.2	<0.1	0.0	0.0
Untreated	0.0	0.0	82.5	43.8	NA		NA		NA		NA		<0.1	<0.1	0.0	0.0
Penasco Fire, Lincoln National Forest : Coleman 2																
Commercial thin	25.4	12.1	1,179.4	267.1	<0.1	<0.1	0.9	0.1	0.6	0.6	0.9	0.5	0.4	0.1	0.1	<0.1
Untreated	0.0	0.0	504.9	209.0	<0.1	<0.1	0.2	0.2	0.6	0.4	4.9	2.3	0.2	0.1	0.0	0.0
Scott Able Fire, Lincoln National Forest																
Shelterwood	204.8	35.7	932.6	305.0	0.3	0.1	1.4	0.3	4.3	1.0	27.2	9.3	0.8	0.1	0.5	0.2
Untreated	32.9	10.7	761.5	174.5	0.2	<0.1	0.9	0.1	0.9	0.4	17.6	10.2	0.3	0.1	0.3	0.1

Figure 1. Ground damage (ranges from 0–3) and stand damage (ranges from 0–4) index for treated and untreated stands (Ryan and Noste 1985, Omi and Kalabokidis 1991). Data summarized for New Mexico and Arizona study sites, June–August, 2002. (LBP = lop, pile, burn; L&S = lop and scatter; UT = untreated)

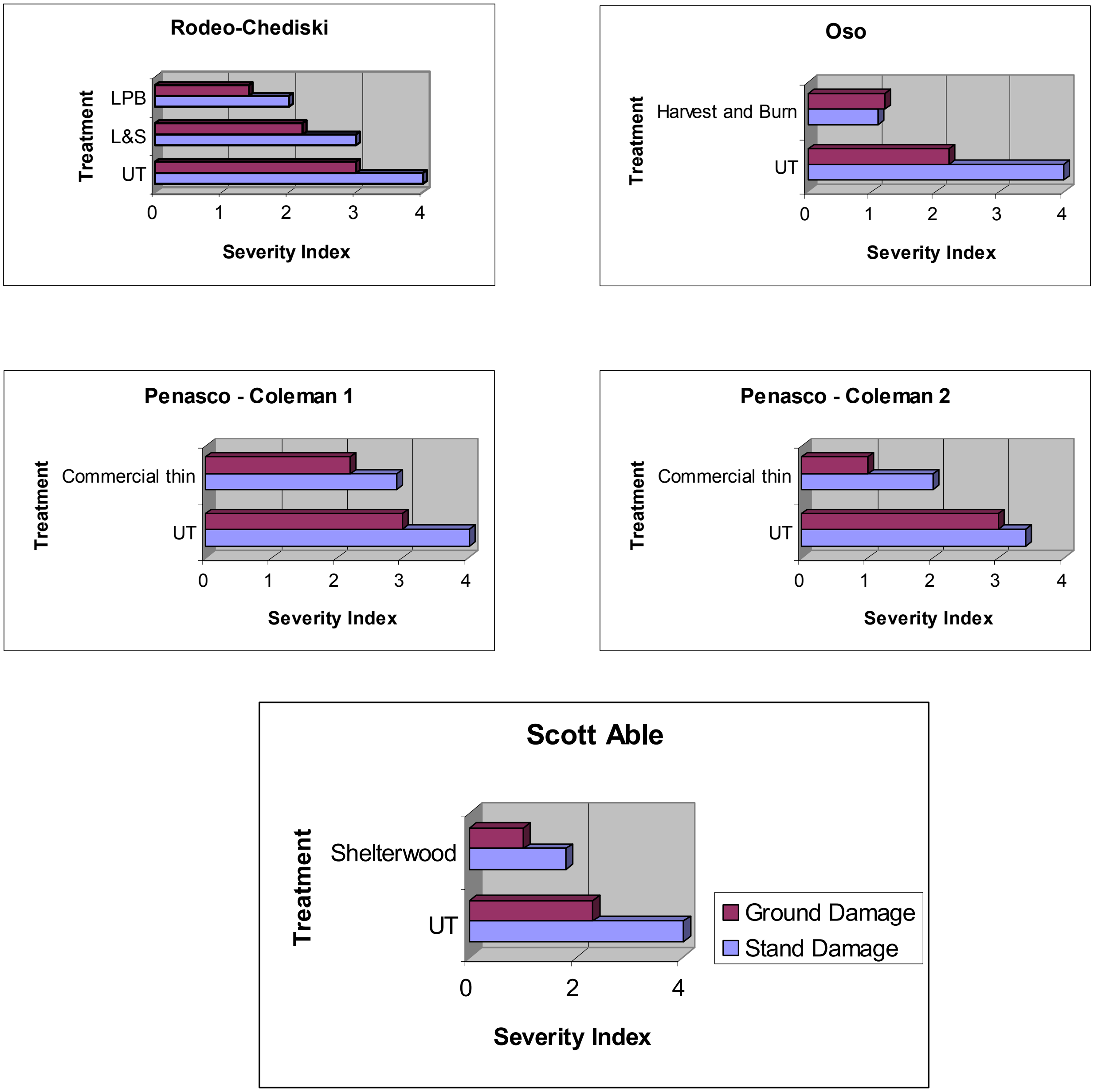

Figure 2. Percent (%) of treated and untreated tree canopies scorched and consumed by wildland fire. Data summarized for New Mexico and Arizona study sites, June–August, 2002. (LBP = lop, pile, burn; L&S = lop and scatter; UT = untreated)

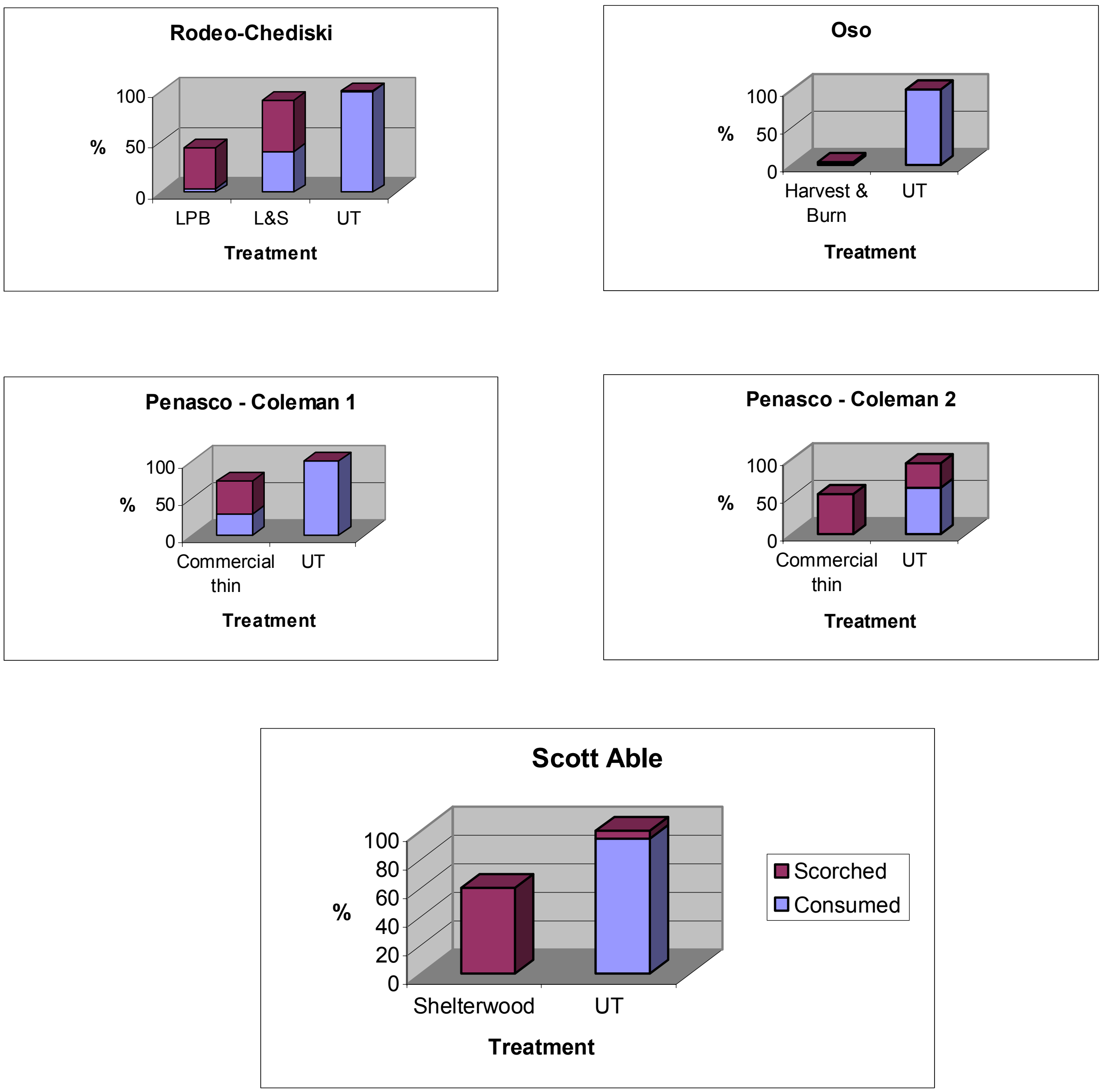

Figure 3. Canopy bulk density (kg/m3) for treated and untreated stands. Data summarized by fire for New Mexico and Arizona study sites, June–August, 2002. Untreated stands shown in red and treated stands shown in blue. Dashed red line indicates potential threshold for crown fire initiation. (LBP = lop, pile, burn; L&S = lop and scatter; UT = untreated)