Mechanical Methods for Restoration and Fuels Reduction in Longleaf Pine Flatwoods

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Mowing has been used to create fuel breaks and buffers for as long as machines existed.

Before that, the original “mastication” machines...

- Both nationally and regionally, the scale and extent of their use is increasing greatly, which changes the scale and extent of their effects.
- New quantification of mechanical treatment effects on fuelbeds and whether they mitigate wildfire risk.
Mechanical in lieu of / before fire

Increasing Populations = Increasing WUI

Liability concerns

Rx Fire and Smoke Issues

Initial stage of restoration pursuits (long unburned areas)

Ideally, followed by fire

Increasingly conducted in Florida’s National Forests and private lands in the future?
Reduce vertical fuel continuity and height
  - Convert into horizontal fuelbeds
  - Reduce small diameter trees
Reduce wildfire risk and mitigate behavior
Initiate restoration in long unburned locations
  - Reduce fire behavior when reintroduced
What we already know

- Lack of or infrequent (>4 yr FRI) fire will lead to litter and duff fuel build-up (Osceola Long-Term Rx Fire Demonstration Plots, Outcalt and Wade, 2004)

- Mechanical methods vary greatly, but most cost between $150-$350/acre, vs. prescribed fire ~$15-$100/acre

- Restoration of native ground cover (e.g. forbs, grasses) requires successive treatments, or additive treatments (mech. + fire; Rummer, Outcalt, Brockway 2002)

- Regrowth following mech. treatments can double understory cover (e.g. oaks, vines, shrubs) if not re-treated within 2 growing seasons in longleaf pine stands (Brockway et al. 2009) (? True elsewhere?)
How can mechanical and fire treatments be used to meet management objectives?

Do treatments reduce wildfire risk?
- Potential (predicted) and actual (prescribed) fire behavior
- Are combined treatments most effective?
- How long do effects last?

Other effects of mechanical and combined treatments
- Reductions in tree mortality where fire is being reintroduced?
- Impacts on understory composition (restoration)?
- Impacts on growth rates of remaining trees (2015)
- C budget/ soil nutrients, fertility
- Spread of invasive species from WUI into forest
Osceola National Forest

Repeat photos taken before (left) and after (right) mechanical mastication in pine flatwoods.
Study locations - three areas

113 Total plots
Buffer (2009), Areal Treatment (2010)
Split block demonstration sites

- 2 ha units
- 3 replicates per treatment, 3 plots per rep. = 9 per treatment
- Soil Respiration study sites (D. Godwin)
- Long term monitoring
- Remeasuring 2014-2015
Key issues addressed

- **Efficacy of Treatments**
  - Fire hazard reduction
  - Longevity
  - Restoration
  - Reducing palmetto/increasing grasses
  - **Restoring frequent fire without damaging overstory**
  - Soil impacts?
  - Understanding what drives treatment effects
  - Shrubs? Downed woody debris? Litter?

Treatment prescriptions included mowing all shrubs and small-diameter trees (<20 cm) and the resulting debris to be left on site.
Within 8 m area, all trees measured.

Forest Floor Biomass Plots

Measurements
- Litter depth
- Duff depth

Woody debris, litter, and duff collected oven-dried and weighed DECOMPOSITION plots.

Plot Center
- Fuel Transects (4)
- Groundcover Plots (4)
- Forest Floor Biomass Plots (2)
- Shrub Plots (2)
Immediate Effects of Mowing on trees, shrubs, fuels

Overstory, understory, and surface fuel characteristics of a 500 ha mowing treatment in palmetto/gallberry pine flatwoods of north-central Florida, USA. Surface fuels sampled non-destructively (planar intercept method). Values in parentheses are standard errors.

<table>
<thead>
<tr>
<th></th>
<th>Trees</th>
<th>Shrubs(^a)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Density(^\text{b})</td>
<td>BA(^d)</td>
<td>QMD(^d)</td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>358 (39(^A))</td>
<td>18.8 (2.3)(^A)</td>
<td>25.8 (1.0)(^A)</td>
</tr>
<tr>
<td>Post-treatment(^b)</td>
<td>277 (38(^A))</td>
<td>18.6 (2.4)(^A)</td>
<td>29.8 (1.2)(^B)</td>
</tr>
</tbody>
</table>

Surface fuel loading

<table>
<thead>
<tr>
<th></th>
<th>1 h</th>
<th>10 h</th>
<th>100 h</th>
<th>1000 h-S</th>
<th>1000 h-R</th>
<th>Litter</th>
<th>Duff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Mg ha(^{-1}))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>1.7 (0.3)(^A)</td>
<td>1.4 (0.1)(^A)</td>
<td>0.3 (0.1)(^A)</td>
<td>0.3 (0.3)(^A)</td>
<td>0.2 (0.2)(^A)</td>
<td>9.0 (0.9)(^A)</td>
<td>42.0 (3.6)(^A)</td>
</tr>
<tr>
<td>Post-treatment(^b)</td>
<td>2.7 (0.5)(^B)</td>
<td>3.1 (0.5)(^B)</td>
<td>0.6 (0.3)(^A)</td>
<td>0.4 (0.2)(^A)</td>
<td>0.3 (0.2)(^A)</td>
<td>13.4 (1.2)(^B)</td>
<td>42.0 (4.3)(^A)</td>
</tr>
</tbody>
</table>

Fuel depth

<table>
<thead>
<tr>
<th></th>
<th>FWD(^c)</th>
<th>Litter</th>
<th>Duff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(cm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-treatment</td>
<td>7.2 (1.7)(^A)</td>
<td>7.8 (0.8)(^A)</td>
<td>5.8 (0.5)(^A)</td>
</tr>
<tr>
<td>Post-treatment(^b)</td>
<td>7.3 (0.9)(^A)</td>
<td>6.0 (0.5)(^B)</td>
<td>3.8 (0.4)(^B)</td>
</tr>
</tbody>
</table>

Note: Values sharing letters (superscripts A and B) within columns are not statistically different (\(\alpha = 0.05\)).

\(^a\) Shrubs >0.5 m in height.
\(^b\) ca. 2 mos following treatment.
\(^c\) Fine woody debris (1 h, 10 h, and 100 h fuels).
\(^d\) Basal area (BA), quadratic mean diameter (QMD), crown base height (CBH).

Post- Mowing: Percent Ground Cover: Major functional groups

Pre Treatment

Post Treatment

1Yr Post Treatment
Burned Feb 23, 2011
(Unmowed)

(6 Months Post-Mowing)

Mow + Burn

2 Days Post-Burn

Burn Only
Pre burn characteristics
Winter Burn: Feb 23, 2011
(6 mos post-mastication)
Wind: 1-5 km·h⁻¹
RH: 47-62%
Temp: 17-24 °C (63-75°F)

Fuel Moisture

10h:
- Burn: 28 (6)%
- Mow + Burn: 21 (7)%

Litter (1h):
- Burn: 18 (2)%
- Mow + Burn: 12 (1)%

Load (Mg/ha)
- Burn: 110 (3) %
- Mow + Burn: 117 (3)%
Demonstration Site Burning
Burn only vs. mow + burn
Burn Only

Burned Feb 23, 2011 (Unmowed)

(6 Months Post-Mowing)

Mow + Burn

2 Days Post-Burn
Fire Behavior

**Rate of Spread**
- Burn: 7.1 (2.1) m·min⁻¹
- Mow+burn: 3.5 (1.1) m·min⁻¹

**Flame Height**
- Burn: 3.3 (0.5) m
- Mow+burn: 1.1 (0.3) m

**Litter Consumption**
- Burn: 86 (8)%
- Mow+burn: 83 (4)%

**Duff Consumption**
- Burn: 3 (3)%
- Mow+burn: 0 (0)%
Drivers of Fire Behavior: it’s all about shrubs

- **Rate of Spread ($\text{m min}^{-1}$)**
  - $R^2 = 0.31$
  - $p = 0.058$

- **Shrub Cover (%)**
  - **Shrub height (cm)**
  - **Litter (Mg ha$^{-1}$)**
  - **Flame Height (m)**

- **Ave_ROS**
  - **Ave_Flame_Ht_m**

- **$R^2 = 0.80$**
  - $p = <0.001$

- **$R^2 = 0.63$**
  - $p = 0.002$

- **$R^2 = 0.00$**
  - $p = 0.991$

- **$R^2 = 0.00$**
  - $p = 0.962$

- **$R^2 = 0.63$**
  - $p = 0.002$
Palmetto recovery post burn vs. mow + burn

**Graphs:**
- **Saw Palmetto Density (individuals/ha):**
  - **Burn Only:** Red circles
  - **Control:** Green triangles
  - **Mow:** Yellow squares
  - **Mow+Burn:** Orange diamonds

- **Saw Palmetto Cover (%):**
  - **Burn Only:** Red circles
  - **Control:** Green triangles
  - **Mow:** Yellow squares
  - **Mow+Burn:** Orange diamonds

**Images:**
- **Pre-Burn:** Images of Saw Palmetto vegetation before treatment.
- **1 month Post-Burn:** Images showing Saw Palmetto post-burn recovery.
- **8 months Post-Burn:** Images illustrating long-term recovery of Saw Palmetto post treatment.
% Cover = driver of fire behavior
Overall shrub height- driver of fire behavior

- burn only
- control
- mow
- mow+burn
Percent Cover of Groundcover, Litter, and Bare Ground (shrubs <0.5m)

Control

- Shrub: 0%
- Grass: 56%
- Herb: 0%
- Litter: 2%
- Bare Ground: 42%

Burn

- Shrub: 31%
- Grass: 50%
- Herb: 14%
- Litter: 5%
- Bare Ground: 0%

Mow

- Shrub: 0%
- Grass: 50%
- Herb: 3%
- Litter: 24%
- Bare Ground: 0%

Mow+Burn

- Shrub: 49%
- Grass: 4%
- Herb: 6%
- Litter: 42%
- Bare Ground: 0%

7 months post-burn & 1 year post-mowing
Soil Nutrients (pre-burn & 1 yr post-burn)

- BD, pH, CEC
- Exchangeable K, Mg, Ca
- Base Saturation of K, Mg, Ca
- Available P
- Total C, P, N
- Organic Matter

*No Treatment Effects*
Burn only vs. mow + burn
Tree Damage

- **Burn**
- **Mow+Burn**

Histogram showing the number of trees with different crown scorch percentages and char heights at DBH.
## Summer Burns: vs winter conditions

Table 4-3 Comparison of burning conditions (weather, overstory, and fuels) between a summer and winter burn in masticated palmetto/gallberry pine flatwoods of northern Florida, USA.

<table>
<thead>
<tr>
<th></th>
<th>Burn Date</th>
<th>Temp °C</th>
<th>RH</th>
<th>Windspeed km hr⁻¹</th>
<th>Litter Moisture %</th>
<th>KBDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>28 Jul 2010</td>
<td>31-34</td>
<td>61-76</td>
<td>1.6-7.2</td>
<td>14.7 (1.1)ᵃ</td>
<td>425</td>
</tr>
<tr>
<td>Winter</td>
<td>23 Feb 2011</td>
<td>23-24</td>
<td>47-49</td>
<td>1.6-2.7</td>
<td>12.1 (0.6)ᵇᵃ</td>
<td>107</td>
</tr>
</tbody>
</table>

### Overstory

<table>
<thead>
<tr>
<th></th>
<th>Tree Density tph</th>
<th>Basal Area m²</th>
<th>QMD cm</th>
<th>Height m</th>
<th>CBH m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>290 (27)ᵃ</td>
<td>23.1 (3.0)ᵃ</td>
<td>32.0 (2.6)ᵃ</td>
<td>23.3 (0.9)ᵃ</td>
<td>15.8 (0.8)ᵃ</td>
</tr>
<tr>
<td>Winter</td>
<td>307 (64)ᵃ</td>
<td>18.9 (4.4)ᵃ</td>
<td>27.8 (1.6)ᵃ</td>
<td>21.0 (0.7)ᵇᵃ</td>
<td>14.7 (0.9)ᵃ</td>
</tr>
</tbody>
</table>

### Understory Fuels

<table>
<thead>
<tr>
<th></th>
<th>Shrub Height cm</th>
<th>Shrubs Mg ha⁻¹</th>
<th>Shrub Foliage Mg ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>69 (7)ᵃ</td>
<td>0.9 (0.5)ᵃ</td>
<td>0.5 (0.2)ᵃ</td>
</tr>
<tr>
<td>Winter</td>
<td>58 (13)ᵃ</td>
<td>0.6 (0.3)ᵃ</td>
<td>0.4 (0.2)ᵃ</td>
</tr>
</tbody>
</table>

### Surface Fuels

<table>
<thead>
<tr>
<th></th>
<th>Litter Depth cm</th>
<th>Duff Depth cm</th>
<th>Litter 1 h Mg ha⁻¹</th>
<th>Duff 10 h Mg ha⁻¹</th>
<th>Duff 100 h Mg ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>4.9 (0.7)ᵃ</td>
<td>5.3 (0.8)ᵃ</td>
<td>10.9 (1.6)ᵃ</td>
<td>58.8 (9.4)ᵃ</td>
<td>4.1 (1.0)ᵃ</td>
</tr>
<tr>
<td>Winter</td>
<td>6.0 (0.4)ᵃ</td>
<td>3.5 (0.6)ᵃ</td>
<td>13.4 (0.9)ᵃ</td>
<td>38.8 (6.5)ᵃ</td>
<td>1.1 (0.2)ᵇ</td>
</tr>
</tbody>
</table>

*Note: Values sharing letters within columns are not statistically different (Tukey-Kramer Test, α=0.05), ᵇ indicates marginal differences (p<0.10)
Table 4-4  Fire behavior and effects between summer (July) and winter (Feb) burning of masticated palmetto/gallberry pine flatwoods.

<table>
<thead>
<tr>
<th>Fire Behavior</th>
<th>Consumption</th>
<th>Overstory Fire Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flame Ht</td>
<td>ROS</td>
</tr>
<tr>
<td></td>
<td>m</td>
<td>m min⁻¹</td>
</tr>
<tr>
<td>Summer</td>
<td>1.5 (0.1)ᵃ</td>
<td>5.9 (1.8)ᵃ</td>
</tr>
<tr>
<td>Winter</td>
<td>1.1 (0.3)ᵃ</td>
<td>3.4 (1.0)ᵃ</td>
</tr>
</tbody>
</table>

*Note:* Values sharing letters within columns are not statistically different (Tukey-Kramer Test, α=0.05), ˢ indicates marginal differences (p<0.10)
Summer (July 2010) vs. winter (Feb. 2011) Burns

- **Burn (winter)**
- **Mow+Burn (winter)**
- **Mow+Burn (summer)**

**Graphs:**
- **Crown Scorch (%)**
- **Char at DBH (%)**
- **Char Height (m)**

**Bar Charts:**
- # of Trees on the y-axis
- Crown Scorch (%) on the x-axis for each category
- Char Height (m) and Char at DBH (%) also shown for each category.
Resulting Tree Mortality

- **Mow+Burn**
- **Burn Only**
- **Mow+Burn (summer)**

- **Mow+Burn**
- **Burn Only**
- **Mow+Burn (summer)**

- **Crown Scorch (%)** vs **DBH (cm)**
- **# of Trees** vs **DBH (cm)**

- Graphs showing the distribution of crown scorch and number of trees by diameter at breast height (DBH) for different treatments.
Duff Consumption

Pre-Burn Duff (Mg·ha⁻¹)

- Burn Only: 53.3 (9.5)
- Mow+Burn: 38.8 (6.5)
- Mow+Burn (S): 58.8 (9.4)

KBDI

- Winter: 107
- Summer: 425

(index range: 0-800)
Surface and Soil Heating

- **Surface Temperature (°C)**
  - Fuel Loading (Mg/ha): 10, 20, 30
  - Comparison: a > b > c

- **Duration of Lethal Heating (min)**
  - Fuel Loading (Mg/ha): 10, 20, 30
  - Comparison: a > b > c

- **Soil Temperature (°C)**
  - Soil Depth (cm): 2, 5, 8
  - Fuel Load (Mg/ha): 10, 20, 30
  - FMC: low (●), moderate (●)

Graphs illustrate the impact of fuel loading on surface temperature and duration of lethal heating, as well as soil temperature at different depths and fuel loads.
Longevity of treatments
Mowed plus burned sites recover more slowly than burn only sites.

Mowing prior to burning reduces fire behavior (flame length, rate of spread), but shrub recovery is nearly 100% within 2 years.

Summer burns following mowing may cause more overstory mortality likely due to fine root or basal cambium damage if burns are conducted during drier conditions.

Soil heating is unlikely to reach biological mortality thresholds, even under heavy fuel loads.

- Soil nutrients, C, CEC are not significantly impacted by treatments.
- Mowing may increase proportion of herbaceous ground cover, if only temporarily.

More information is available!
Fuel Treatments in Pine Flatwoods: 
A Photo Series Guide
For Estimating Vegetation and Fuel Biomass Change over Time
Following Mowing and Burning in Southern Pine Flatwoods Forests
Mow 1: High Pre-Treatment Palmetto Density

<table>
<thead>
<tr>
<th>Site Information</th>
<th>Fuel Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location: Osceola National Forest, Columbia County, Florida</td>
<td>Post Burn</td>
</tr>
<tr>
<td>Stand type: Mature pine flatwoods (slash pine and longleaf pine)</td>
<td>0.2</td>
</tr>
<tr>
<td>Stand History: More than 12 years since last burned</td>
<td>1.2</td>
</tr>
<tr>
<td>Tree density (per acre): 100.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Average height (ft): 78.2</td>
<td>1.0</td>
</tr>
<tr>
<td>1,000-hour (tons/acre)</td>
<td>0.0</td>
</tr>
<tr>
<td>1,000-hour R (tons/acre)</td>
<td>0.0</td>
</tr>
<tr>
<td>Duff (tons/acre)</td>
<td>24.7</td>
</tr>
<tr>
<td>Duff depth (in)</td>
<td>1.9</td>
</tr>
<tr>
<td>Litter (tons/acre)</td>
<td>6.2</td>
</tr>
<tr>
<td>Litter Depth (in)</td>
<td>2.4</td>
</tr>
<tr>
<td>Palmetto Cover (%)</td>
<td>25</td>
</tr>
<tr>
<td>Palmetto Height (ft)</td>
<td>2.9</td>
</tr>
<tr>
<td>Total Shrub Biomass (tons/acre)</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Mow and Burn 1: High Palmetto Density

<table>
<thead>
<tr>
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<tr>
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<tr>
<td>Stand type: Mature pine flatwoods (slash pine and longleaf pine)</td>
<td>0.3</td>
</tr>
<tr>
<td>Stand History: More than 12 years since last burned</td>
<td>1.4</td>
</tr>
<tr>
<td>Tree density (per acre): 110.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Average height (ft): 69.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Litter (tons/acre)</td>
<td>6.9</td>
</tr>
<tr>
<td>Litter Depth (in)</td>
<td>2.3</td>
</tr>
<tr>
<td>Palmetto Cover (%)</td>
<td>35</td>
</tr>
<tr>
<td>Palmetto Height (ft)</td>
<td>2.3</td>
</tr>
<tr>
<td>Total Shrub Biomass (tons/acre)</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Mechanical Treatments in Pine Flatwoods: A Temporary Rearrangement of Fuel Structure

Jesse Kreye, David Godwin, and Leda Kobziar

MECHANICAL FUEL TREATMENTS

Prescribed burning is a dominant forest management tool used across the Southeastern U.S., yet burning is often limited due to various social, ecological, or economic factors. The use of mechanical methods as a fire surrogate or as a means to treat overgrown fuels prior to reintroducing fire has become increasingly used in the region, especially in the wildland-urban-interface (WUI) and other areas with significant smoke concerns. Mechanical treatments can include thinning of the overstory, treating understory shrubs and small trees, or a combination of both. Understory treatments commonly used in the South include “mowing”, “mulching”, “masticating” or “chipping” (depending on the equipment used) of shrubs and small trees. While different terms are used, each treatment is aimed at transforming aerial fuels to surface fuels to reduce fire behavior. Treatments are often employed as a stand-alone option in the WUI, or are followed-up with prescribed burning where possible. While specific treatment objectives may vary, reduction of potential fire behavior attributes including flame lengths, rate of spread, and crown fire potential, are emphasized. Reducing these fire behavior factors is important to both follow-up prescribed burning and potential wildfire.

TREATMENT OF FUELS IN PINE FLATWOODS

Mowing is a common mechanical fuels treatment method especially in long-unburned pine flatwoods (ca. >10 yr. old rough) of the Southeastern Coastal Plain, where understories are dominated by saw palmetto (*Serenoa repens*) and gallberry (*Ilex glabra*) shrubs. Although understory shrubs in these stands can be very dense, mature longleaf pine (*Pinus palustris*) and slash pine (*P. elliottii*) in the overstory are often sufficiently large to facilitate treatment. Treatment objectives include both reduction in fuel load and lower strata density. Following treatment, fuel bed height is greatly reduced while fuel bed bulk density is substantially increased, both of which can influence fire behavior. Fuel beds created from mowing are mixtures of small-diameter woody fuels composed of broken sticks from shrub stems, or fractured (shredded) woody debris from larger shrub or tree stems. In pine flatwoods, the bulk of the post-mowing forest floor material is often composed of shredded saw palmetto foliar material. These pine flatwoods post-treatment fuel beds can be somewhat “fluffy” or aerated compared to mowed debris generated in forests where woody shrubs or trees dominate the understory. Although the surface of such fuel beds may initially appear “fluffy,” the lower strata of mowed fuels remain relatively dense and may become more compact over time.

SUMMARY

Mechanical "mowing" treatments can alter the structure and arrangement of understory and midstory fuels in pine flatwoods thereby reducing post-treatment flame lengths and rates of fire spread. Shrubs, however, can quickly recover following treatment and reduce the longevity of this effectiveness. Surface fuels resulting from the mowing of small trees and shrubs may present challenges given that long-duration combustion can occur in these compact fuels. The timing of subsequent mechanical or prescribed fire treatments may be very important for achieving management objectives.
Thank you- questions?
Longevity of mowing effects: Shrubs and Surface Fuels

(a) Shrubs (Mg/ha) vs Time Since Treatment (months)

(b) Surface Fuel (Mg/ha) vs Time Since Treatment (months)

- ○ mature/burned
- ▲ mature
- □ plantation
Small-Scale Fire Behavior Experiment

May 2010
Temp:  28-34˚C
RH:  46-63%
Wind:  0.3-1.8 m·s⁻¹

- Flame Length
- Rate of Spread
- Fuel consumption (%)
- Heating
  - Surface temperatures
  - soil temperatures
- Fireline Intensity (kJ·m⁻¹·s⁻¹)

I = h · w · r
I  Fireline Intensity
h  heat content (kJ·kg⁻¹)
w  mass of fuel consumed (kg·m⁻²)
r  rate of spread (m·s⁻¹)

Kreye et al. 2011. *International Journal of Wildland Fire*
### Winter and Summer Burn Conditions

Table 4.3: Comparison of burning conditions (weather, overstory, and fuels) between a summer and winter burn in masticated palmetto/gallberry pine flatwoods of northern Florida, USA.

<table>
<thead>
<tr>
<th>Burning Conditions</th>
<th>Burn Date</th>
<th>Temp $^\circ$C</th>
<th>RH %</th>
<th>Windspeed $km\cdot hr^{-1}$</th>
<th>Litter Moisture %</th>
<th>KBDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>28 Jul 2010</td>
<td>31-34</td>
<td>61-76</td>
<td>1.6-7.2</td>
<td>14.7 (1.1)$^a$</td>
<td>425</td>
</tr>
<tr>
<td>Winter</td>
<td>23 Feb 2011</td>
<td>23-24</td>
<td>47-49</td>
<td>1.6-2.7</td>
<td>12.1 (0.6)$^{ab}$</td>
<td>107</td>
</tr>
</tbody>
</table>

### Overstory

<table>
<thead>
<tr>
<th>Tree Density $tph$</th>
<th>Basal Area $m^2$</th>
<th>QMD $cm$</th>
<th>Height $m$</th>
<th>CBH $m$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>290 (27)$^a$</td>
<td>23.1 (3.0)$^a$</td>
<td>32.0 (2.6)$^a$</td>
<td>23.3 (0.9)$^a$</td>
</tr>
<tr>
<td>Winter</td>
<td>307 (64)$^a$</td>
<td>18.9 (4.4)$^a$</td>
<td>27.8 (1.6)$^a$</td>
<td>21.0 (0.7)$^{ab}$</td>
</tr>
</tbody>
</table>

### Understory Fuels

<table>
<thead>
<tr>
<th>Shrub Height $cm$</th>
<th>Shrubs $Mg\cdot ha^{-1}$</th>
<th>Shrub Foliage $Mg\cdot ha^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>69 (7)$^a$</td>
<td>0.9 (0.5)$^a$</td>
</tr>
<tr>
<td>Winter</td>
<td>58 (13)$^a$</td>
<td>0.6 (0.3)$^a$</td>
</tr>
</tbody>
</table>

### Surface Fuels

<table>
<thead>
<tr>
<th>Litter Depth $cm$</th>
<th>Duff Depth $cm$</th>
<th>Litter $Mg\cdot ha^{-1}$</th>
<th>Duff $Mg\cdot ha^{-1}$</th>
<th>1 h</th>
<th>10 h</th>
<th>100 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>4.9 (0.7)$^a$</td>
<td>5.3 (0.8)$^a$</td>
<td>10.9 (1.6)$^a$</td>
<td>4.1 (1.0)$^a$</td>
<td>6.6 (0.6)$^a$</td>
<td>2.5 (1.1)$^a$</td>
</tr>
<tr>
<td>Winter</td>
<td>6.0 (0.4)$^a$</td>
<td>3.5 (0.6)$^a$</td>
<td>13.4 (0.9)$^a$</td>
<td>1.1 (0.2)$^b$</td>
<td>2.1 (0.3)$^b$</td>
<td>1.1 (0.6)$^a$</td>
</tr>
</tbody>
</table>

*Note: Values sharing letters within columns are not statistically different (Tukey-Kramer Test, α=0.05), $^a$ indicates marginal differences (p<0.10)*
Post treatment Litter Moisture Content

Live (shrubs) Moisture Content
Mowing → Shrubs/Small Trees

- **Saw Palmetto**
  - Density (individuals/ha)
  - TST (months)
  - Graph showing changes over time with different markers for mature/burned, mature, and young Saw Palmetto.

- **Shrubs**
  - Density (individuals/ha)
  - TST (months)
  - Graph showing changes over time with different markers for mature/burned and mature shrubs.

- **Small Trees (Understory)**
  - Density (individuals/ha)
  - TST (months)
  - Graph showing changes over time with different markers for mature/burned and mature small trees.

- **Shrubs and Small Trees (Understory)**
  - Species Richness
  - TST (months)
  - Graph showing changes over time with different markers for mature/burned and mature shrubs and small trees.