Overstory, Fuel Loading, and Soil Nitrogen Changes Following Mechanical Mastication or Thinning Pinyon-Juniper Stands in Southwestern Colorado

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ABSTRACT

The potential for large wildfires in southwestern pinyon-juniper woodlands has increased due to extended drought and infestation of pinyon ips (*Ips confusus*), which has killed millions of trees over large areas. Woodlands surround many rural and exurban housing developments and towns complicating fuels management and fire suppression. The U.S. Forest Service and USDI Bureau of Land Management at the Dolores Service Center of the San Juan National Forest in southwestern Colorado are currently using mechanical mastication or thinning-piling-burning treatments to alter fuels and the risk of fire within the wildland-urban-interface (WUI) and to restore more natural stand densities in remote areas.

A study supported by the Joint Fire Science Program compared the effects of mastication, thinning-piling-burning, and no treatment on the overstory, understory (including invasive species), fuel loading, and soil resources of three representative pinyon-juniper stands in southwestern Colorado. Total dead and down fuel loading ranged from 5.86 to 14.60 tons/acre among sites after mastication and from 2.12 to 6.80 tons/acre after thinning-piling-burning.

Mastication of woody material has raised concerns that a shift in the carbon:nitrogen (C:N) ratio of the surface organic horizon could affect long-term site productivity by slowing decomposition and mineralization rates limiting plant available nitrogen (N). Available N mineralized in the upper 5 cm of soil from all plots was continuously measured over three years following treatments. Only the mastication treatment showed a difference over time in C:N ratio, yet no differences were found with respect to available N mineralized in the upper mineral soil. Phospholipid fatty acids (PLFA) were measured to determine microbial groups (fungi, actinobacter, gram-negative and gram-positive bacteria) with emphasis on changes in the ratio of fungi to bacteria (F:B) s in the surface mineral soil horizon (0-5 cm). Using twenty PLFA biomarkers as fingerprint of the microbial community structure in a multivariate model can also be used to determine if overall community changes have occurred. Mastication significantly lowered the F:B ratio compared to the controls, while the community structure was different among all treatments for each of the three post-treatment years.

INTRODUCTION

Pinyon-juniper woodlands are a dominant vegetation type on public lands throughout the Interior West. In this decade, the ecology and fire risk in pinyon-juniper woodlands has dramatically changed due to increased stand densities, drought, and region-wide bark beetle infestation (*Ips confusus*) resulting in high pinyon mortality (40-80%), increased fuel loadings, and risk of severe wildfires.

Managers wish to reduce fire hazards and create defensible spaces in the wildland-urban-interface (W.U.I.). Hand thinning-piling-burning prescriptions have commonly been used in the W.U.I., but mechanical mastication is another alternative where slope and soil surface conditions permit. The goal is to create a mosaic of open and wooded conditions, however little is known of the consequences of mastication on soil nutrient cycling, microbiological populations, overstory and understory vegetation, invasion of non-native species such as cheatgrass (*Anisanthia tectorum*) and musk thistle (*Carduus nutans),* and amount of dead and down woody material created.

The Forest Service and Bureau of Land Management in southwest Colorado are using hydro-mow equipment (Figure 1.) to masticate small diameter (live and dead) standing pinyon and juniper and downed woody fuels in the W.U.I., targeting 2,000 to 3,000 acres annually. Thinning-piling-burn prescriptions around sensitive areas such as archeological sites, oil and gas developments, and recreational and administrative areas are also used.

Figure 1.—Hydro-mow equipment masticating a pinyon-juniper woodland site near Egnar, Colorado.

RESEARCH LAYOUT

Three sites were selected for the study (Figure 2.).

- School (BLM; NE of Egnar, Colorado; 7,720 ± 43 ft; Sandstone Parent Material).
- Summit (BLM; N of Mesa Verde National Park, Colorado; 7,042 ± 84 ft, Mancos Shale, Sandstone Parent Materials).
- May Canyon (FS; N of Dolores, Colorado; 7,355 ± 46 ft; Sandstone, Shale Parent Materials).

Pinyon (*Pinus edulis)* and *Utah juniper (Juniperus osteosperma*) are the most common species, although a small component of Rocky Mountain junipers (*J. scopulorum*) was also measured. Gambel oak (*Quercus gambelii)* was the most common shrub. The regional long-term mean annual precipitation is 18.4 inches.

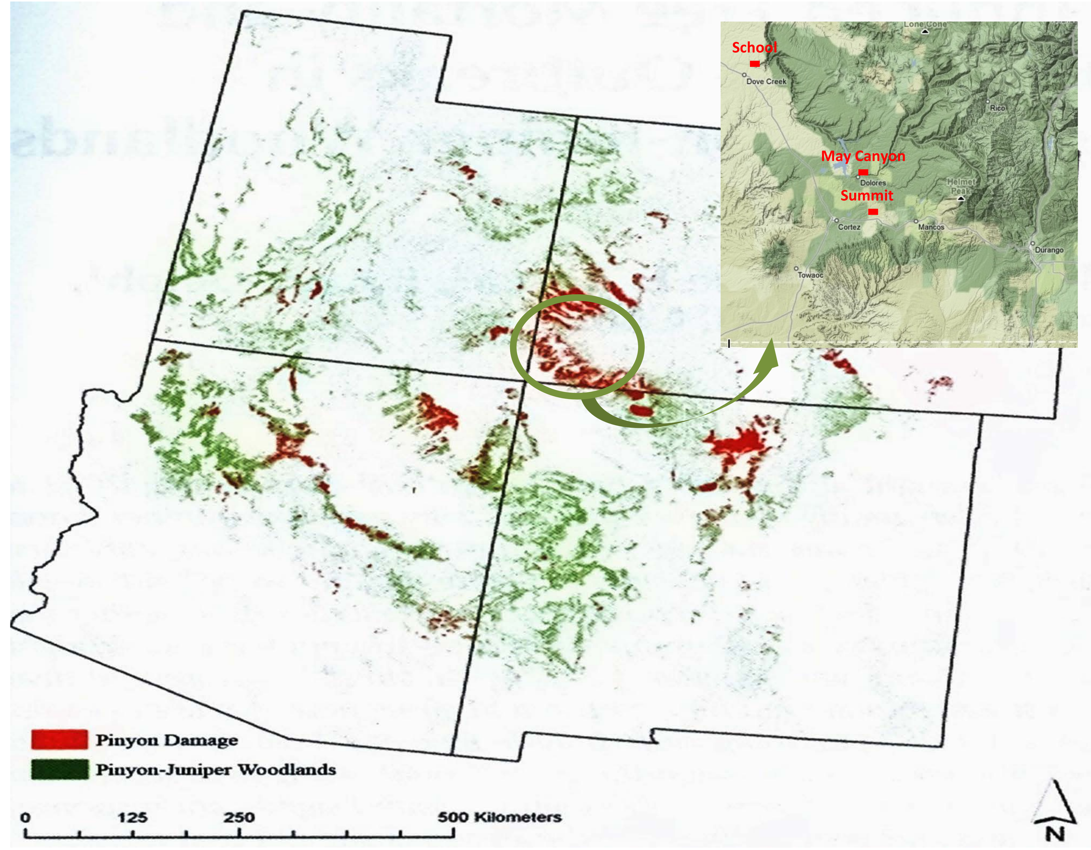

Figure 2. Pinyon mortality (2000-2005; Forest Health Protection, USFS) in the region was 40-80%. Inset shows the location of the three study sites in southwest Colorado.

Mastication, thinning-piling-burning, or control treatments were randomly assigned to three 35-acre plots with 36 randomly located sampling points per plot. Pre-treatment sampling was conducted in the fall of 2005.

Treatments were conducted in the fall and winter of 2005-2006. Guidelines were: create a random mosaic of openings and strips 0.5-3.0 acres in size; reduce density of trees 1-10 inch d.b.h.; 80% of the woody material reduced to <1" in dia. and 6" long; reduce shrub cover by 50%, and protect live pinyon trees and designated snags. Thinning guidelines were: reduce canopy cover 40 to 60%; target dead pinyon and dense pockets of live trees; leave trees > 8 inches d.b.h. and good saplings; leave tree clumps of 0.25 to 2 acres in size; reduce shrub canopy by 50%. Post- treatment measurements were made in 2006 and 2007, with additional understory and soil sampling in 2008. Estimated thinning treatments would cost $750 per acre relative to $200 per acre for mastication.

METHODS

The overstory was measured (0.05 acre fixed circular plots) for species, diameter at root collar, insect or disease conditions, plant condition, and height and crown diameter. Dead and down material was measured using a modified Brown Technique (Brown 1974). Surface litter was sampled at randomly located points within 1 m of the point centers using 0.01 m^2 frame. Soils were sampled within the frame using a 5 x 15 cm corer attached to a slide hammer segemented into 0-5 and 5-15 cm. Subsamples from these core were analyzed for pH, soil moisture, total carbon (C) and nitrogen (N), and phospholipid fatty acids (0-5 cm only). Phospholipid fatty acids (16 PLFA) are used in determination of microbial community. Available N mineralized was collected continuously using plant root simulators (PRS) probes (WesternAg, Inc.) contained within 10 cm (w) x 15 cm (h) PVC cores.

RESULTS

__Overstory__

Table 1.—Stand conditions (trees per acre) in 2005 before treatments. Only 41 percent of the pinyon trees at Summit were alive compared to 90 percent at School.

	Pinyon-Live	Pinyon-Dead	Juniper-Live/Dead	Total
School				
Control	99	5	37	141
Mastication	111	25	22	158
Thinning	112	8	17	137
Summit				
Control	113	157	108	378
Mastication	127	153	111	391
Thinning	83	153	156	392
May Canyon				
Control	69	51	72	192
Mastication	139	53	15	207
Thinning	85	42	27	154

Changes in May Canyon between 2005 and 2007 (Table 2) showed an increase in trees per acre in the control primarily from ingrowth. There was a 24% reduction with mastication, while thinning decreased 40%. Almost twice as much basal area and three times as much volume were removed by thinning relative to mastication.

Table 2.—Stand conditions at May Canyon in 2005 and 2007. Tree volumes are based on the equations developed by Chojnacky (1985).

	2005			2007			
	Pinyon-Live	Pinyon-Dead	Juniper	Pinyon-Live	Pinyon-Dead	Juniper	Removed
Control							
Trees/ac	69	51	72	92	55	81	---------
BA/ac	12	17	38	14	18	42	---------
ft³/ac	97	156	303	123	149	327	---------
Mastication							
Trees/ac	139	53	15	127	18	12	46
BA/ac	23	13	4	22	6	4	7
ft³/ac	156	119	42	361	93	36	40
Thinning							
Trees/ac	85	42	27	61	14	17	73
BA/ac	11	12	10	7	3	7	15
ft³/ac	64	92	64	39	18	49	111

__Regeneration:__

Trees less than 4.5 ft in height were considered regeneration. Adequate regeneration is 200 trees per acre, with all nine site-treatment combinations containing satisfactory regeneration. Most of the trees were between 3.1 and 12.0 inches in height and were established prior to treatment. The distribution of trees is often more important than the number of trees. If we assume that a plot with less than 10 trees (200 trees per acre) is understocked, 61% of the mastication plots and 50% of the thinning plots were understocked at School. The corresponding numbers were 31% and 36% at Summit and 36% and 28% at May Canyon.

__Dead and Down Material:__

Woody fuel (tons/acre) fluctuated throughout the three years (Table 3). Initial values were very large at Summit due to high *Ips* mortality. Increases in 2007 are toppled dead pinyon trees.

Table 3.—Total fuel loading by plot in tons per acre based on Brown (1974).

	2005	2007
School		
Control	2.19	2.44
Mastication	1.03	5.86
Thinning	2.50	2.41
Summit		
Control	17.83	12.67
Mastication	17.50	14.60
Thinning	9.68	6.80
May Canyon		
Control	5.18	9.20
Mastication	3.55	5.97
Thinning	2.68	2.12

Understory

Preliminary results showed significant differences in understory species assemblages for both mastication and thinning piling-burning treatments using multi-response permutation procedures (MRPP). Cheatgrass and musk thistle increased in frequency in the thinning-piling-burning, while Canadian thistle increased in the mastication plots. The higher the frequency in the pre-treatment plots of these species, the greater the post-treatment increase. Gambel oak had recovered to near pre-treatment cover by the third year post-treatment.

Soils

Treatments did not significantly alter pH, available N mineralized (0-5 cm mineral soil), or total C and N in the mineral soil, but the C:N ratio was significantly increased (>30:1) in the surface litter horizon (Figure 2.)

Microbial populations (0-5 cm mineral soil) were significantly different post-treatment (MRPP analysis of 16 PLFA biomarkers). Fungal:bacterial biomass ratio was significantly different for pre-treatment mastication and year 3 post-treatment. This difference was due to increases in gram-negative and gram-positive bacteria (Figure 3.). These increases were due to increased moisture, and moderation of soil temperatures throughout the year under masticated surface litter.

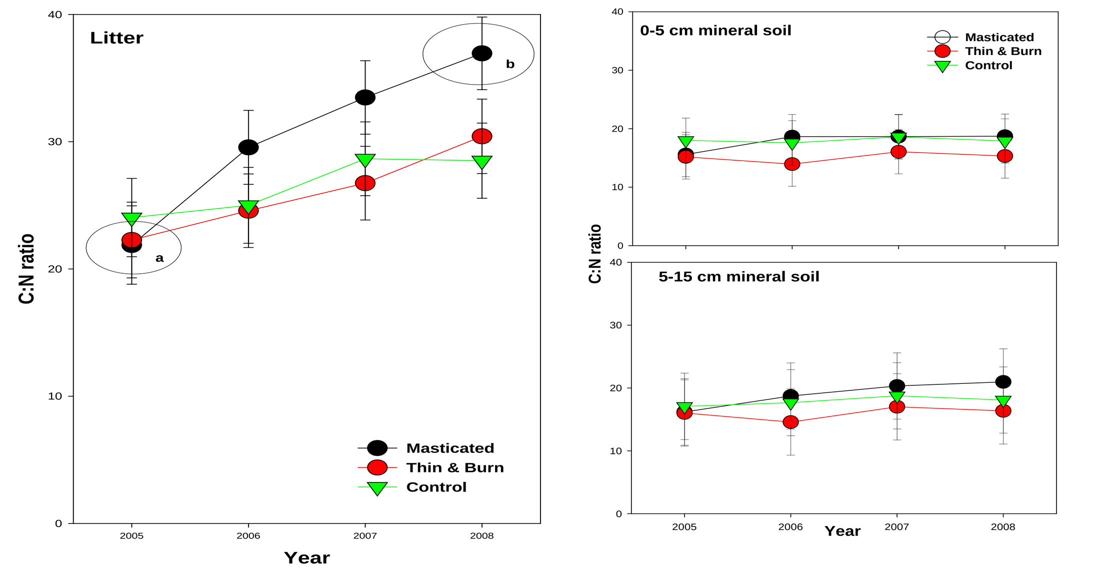

Figure 3. Total C:N ratios for surface litter and mineral soil in Pinyon-Juniper treatments site, San Juan National Forest, Colorado.

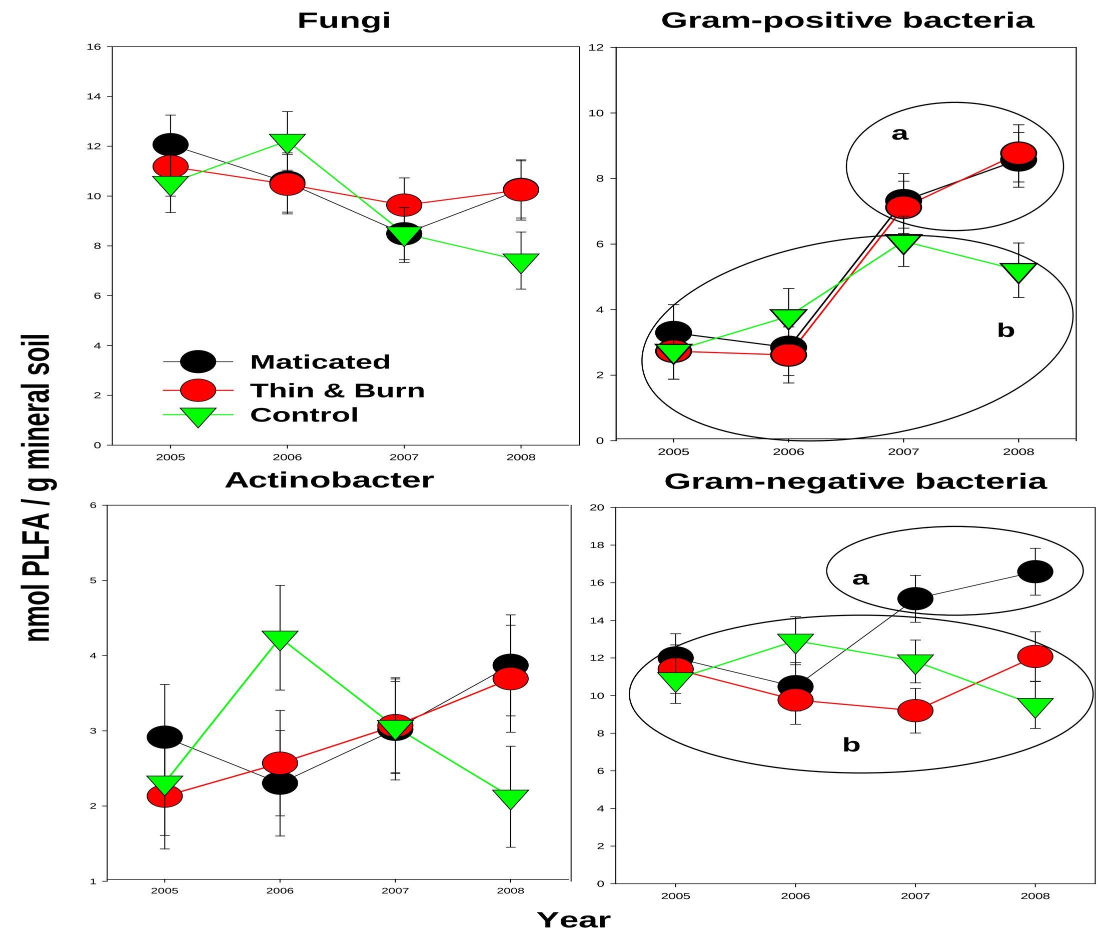

Figure 4. Pinyon-Juniper soil microbial groups (PLFA biomarkers) pre- and post-treatment, San Juan National Forest, Colorado.

CONCLUSIONS

- Mastication and thinning treatments created mosaics of vegetation and fuel conditions.
- Treatments left healthy pinyon and juniper overstory trees and regeneration to maintain sustainable stands. Gambel oak recovery is a concern for tree regeneration and survival.
- Fuel loading in residual areas was variable but will increase as *Ips*-killed trees continue to fall.
- Fuels in the thinning areas generally declined or did not change, but fuels generally increased on the mastication sites over the study period.
- Thinning-piling-burning removed more trees than mastication, but at a higher cost.
- Treatments did alter the understory community. Cheatgrass and musk thistle increased with thinning-piling-burning, while sprouters (Gambel oak) and stoloniferous (Canadian thistle) increased with mastication.
- Treatments did not affect mineral soils, but the C:N ratio of the litter layer significantly increased with mastication and fungal populations that typically decompose this material did not increase in the upper mineral soil. Concerns of long-term increases in surface fuels due to slowed decomposition and possible immobilization of soil N if C:N ratios continue to increase.

References

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