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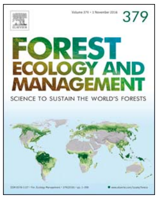

# Microbial and nitrogen pool response to fuel treatments in Pinyon-Juniper woodlands of the southwestern USA

Steven T. Overby*, Gerald J. Gottfried

*Rocky Mountain Research Station, United States Forest Service, 2500 S. Pine Knoll Dr., Flagstaff, AZ 86001, USA*

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## ABSTRACT

Wildfire mitigation in Pinyon-Juniper woodlands in the Colorado Plateau region is a management priority. Two wildfire mitigation treatments, mastication and thin-pile-burn, are often chosen based on costs and availability of equipment, yet there are ecological concerns with either treatment. Ecological outcomes from additions of low quality organic residues following mastication can potentially alter microbially mediated soil nitrogen availability, therefore we wished to evaluate the effects of the additions of low quality woody residues to the soil surface compared to thin-pile-burn treatments at three *Ips confusus* affected woodland sites in the Colorado Plateau region. Thin-pile-burn treatments consisted of thinning between 40% and 60% of the canopy cover, while mastication treatments entailed shredding dead trees and 50% of shrub canopy while retaining live pinyon trees and designated snags. Both fuels treatments achieved wildfire mitigation goals, yet twice as much basal area and three times as much volume were removed by thinning relative to mastication. Surface additions of woody residues favored bacteria, while fungal populations that typically colonize and decompose woody organic residues did not increase in the upper mineral horizon. Neither fuel treatment affected mineral soils at the plot level, but the carbon to nitrogen (C:N) ratio of the organic horizon was significantly greater with mastication compared to the control. Nitrogen availability was reduced by almost half during the non-growing season, yet fuel treatments did not significantly influence nitrogen availability compared to control. Fuel treatment as performed in our study following the large mortality event demonstrated that microbial populations and their effects on nitrogen availability are resistant to disturbances produced by wildfire mitigations treatments.

## 1. Introduction

Fuel reduction strategies aim to reduce hazardous fuel loads and provide ecosystem services. Fuel treatments such as mastication, or mechanical thinning/piling followed with a prescribed burn potentially alter soil temperatures and available soil moisture by changing stand structure (Breshears et al., 1998; Zou et al., 2008) and surface conditions (Rhoades et al., 2012). Soil moisture, temperature, and mineralogy interact with plant detrital quality and quantity to control decomposition and mineralization (Meentemeyer, 1978; Paul and Clark, 1996; Poranzinska et al., 2003; Bardgett, 2005). Drought induced stress followed by pinyon bark beetle infestation (*Ips confuses* Leconte) culminated in over 1 million ha of pinyon (*Pinus edulis* Engelm.) mortality during the 2000–2004 period on the Colorado Plateau and southwest United States (Clifford et al., 2008; Allen et al., 2010). The extended drought and infestation by pinyon bark beetle prompted fuel treatments to limit the potential size and severity of wildfires (Battaglia et al., 2010; Hicke et al., 2012). These treatments also alter inputs to decomposition and N mineralization (Attiwill and Adams, 1993; Rhoades et al., 2012; Talbot and Treseder, 2012). In spite of frequent use, there are concerns about the effects of fuel treatments on the N dynamics, microbial populations, and potential for invasion of non-native species (Brockway et al., 2002; Owen et al., 2009).

Fuel treatments in pinyon-juniper woodlands are typically accomplished by hand-thinning, piling or broadcasting the slash, followed by burning to reduce fuel loads. This technique is labor intensive and can be relatively expensive. Prescribed burning of slash and surface litter in the piled areas decreases soil organic matter leaving a residue of ash or exposed bare mineral soil (DeBano et al., 1998). An alternative is to mechanically masticate or shred small standing live and dead trees and shrubs. Mastication modifies fire behavior by restructuring fuel profiles from ladder and crown fuels to surface fuels (Agee and Skinner, 2005; Battaglia et al., 2010; Kreye et al., 2014) and is economically less costly than thinning, piling, and burning. The deposition of high lignin content material, up to 45% for pinyon (Murphy et al., 1998), on the soil surface potentially increases N immobilization (Aber and Melillo, 1982;

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* Corresponding author.
*E-mail address:* soverby@fs.fed (S.T. Overby).

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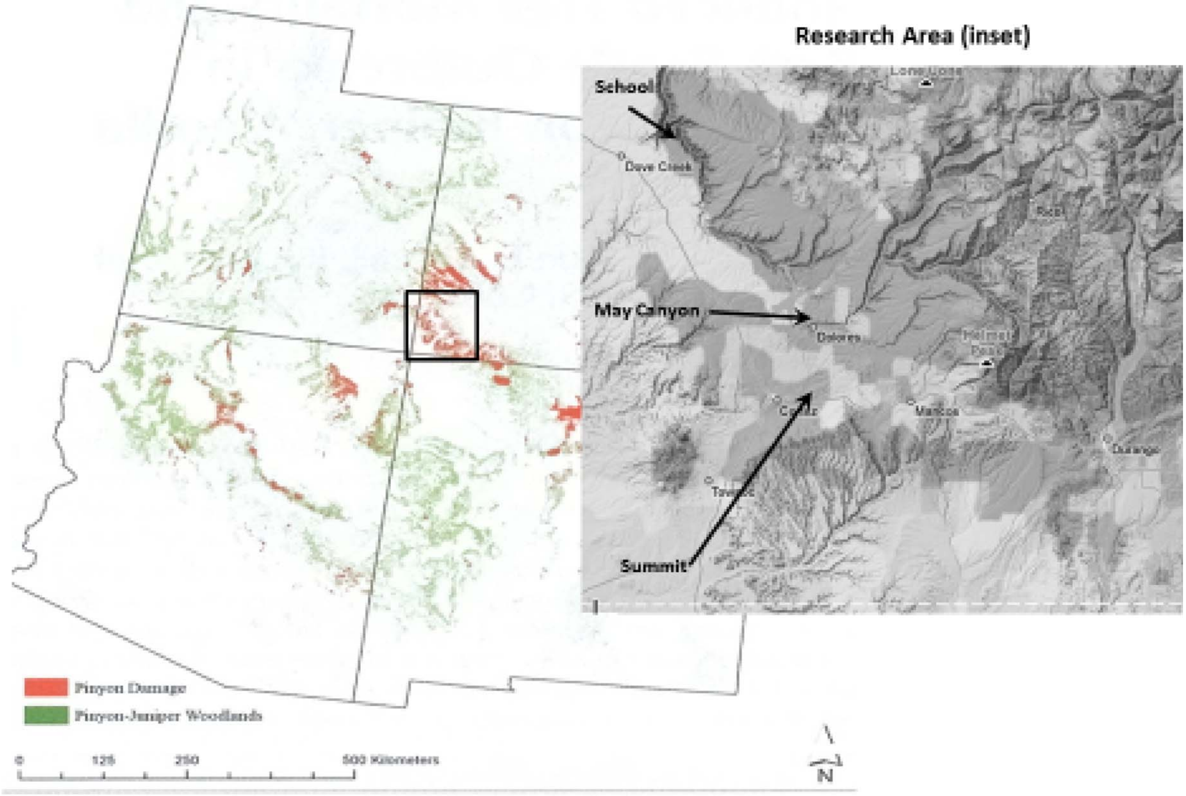

**Fig. 1.** Three fuels treatment study sites in the Colorado Plateau of southwest Colorado, USA.

Talbot and Treseder, 2012) and alters soil microbial populations (Blumenthal et al., 2003; Bardgett, 2005). Mechanical deposition of this high lignin and high C:N mass ratio organic residue on the soil surface is not comparable to any natural event (Rhoades et al., 2012).

Forest litter typically has a C:N ratio of 30:1 while pine wood has a ratio of 286:1 (Tisdale et al., 1985). Increasing C:N ratios of litter inputs should slow decomposition and turnover by microorganisms and immobilize N in the surface mineral soil (Wang and Bakken, 1997). Moisture deficits have also been shown to shift microbial communities to favor fungi (Harris, 1981) over bacteria (Nazih et al., 2001; Uhlirova et al., 2005), yet the addition of masticated woody debris increases available soil moisture and ameliorates soil temperature extremes (Brockway et al., 2002; Blumenthal et al., 2003). These abiotic changes should potentially lower fungi to bacteria (F:B) ratios, yet with the addition of woody material with a high C:N ratio, these changes favor increased F:B ratios (Bardgett et al., 1996; Myers et al., 2001; Siira-Pietikainen et al., 2001; Hogberg et al., 2007). Low quality litter with high C:N ratio and secondary compounds such as lignins and phenolics are linked with infertile soils dominated by fungi (Bardgett, 2005).

Thin-pile-burn can reduce total fuel loads, but there are ecological concerns due to the duration of heat pulse from pile burns (Owen et al., 2009). Fire can reduce detrital inputs to soil and result in the loss of decomposer microorganisms due to lethal temperatures (DeBano et al., 1998). Soil bacteria and fungi, the primary decomposers, process between 80% and 90% of all plant detritus via production of extracellular enzymes (Bardgett, 2005). Even though losses of organic matter due to combustion can be as high as 85%, increased nitrogen (N) availability (Covington and Sackett, 1992, Kaye and Hart, 1998, Hart et al., 2005), soil insolation and soil moisture (Hart et al., 2005, Simonin et al., 2007), surface soil pH (cation deposition), and the addition of charcoal (Hart et al., 2005) can enhance microbial activity (Pietikinen and Fritze, 1995; Pietikäinen et al., 2000). Yet prescribed fire can also

**Table 1**
Stand data for fuel reduction study in southwest Colorado, USA. Mastication and thin-pile-burn treatments done winter of 2005–2006. Most of the trees removed during operations were classified as “dead” during the 2007 inventory.

| | | 2005 (pre-treatment) | | | 2007 (post-treatment) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Site | Treatment | Pinyon live (trees per ha) | Pinyon dead | Juniper live | Pinyon live | Pinyon dead | Juniper live | Pinyon treated | Juniper treated |
| May Canyon | Control | 165 | 114 | 163 | 172 | 121 | 174 | 0 | 0 |
| | Mastication | 310 | 106 | 29 | 304 | 141 | 18 | 101 | 4 |
| | Thin-pile-burn | 183 | 95 | 57 | 147 | 161 | 26 | 163 | 20 |
| Summit | Control | 249 | 348 | 233 | 310 | 374 | 240 | 0 | 0 |
| | Mastication | 306 | 312 | 229 | 275 | 312 | 147 | 216 | 53 |
| | Thin-pile-burn | 183 | 339 | 321 | 178 | 383 | 141 | 339 | 128 |
| School | Control | 218 | 11 | 79 | 275 | 26 | 90 | 0 | 0 |
| | Mastication | 244 | 55 | 46 | 180 | 139 | 37 | 125 | 20 |
| | Thin-pile-burn | 246 | 20 | 37 | 139 | 174 | 31 | 156 | 11 |