Soil nitrogen availability in Colorado conifer forests after fuel reduction mulching treatments

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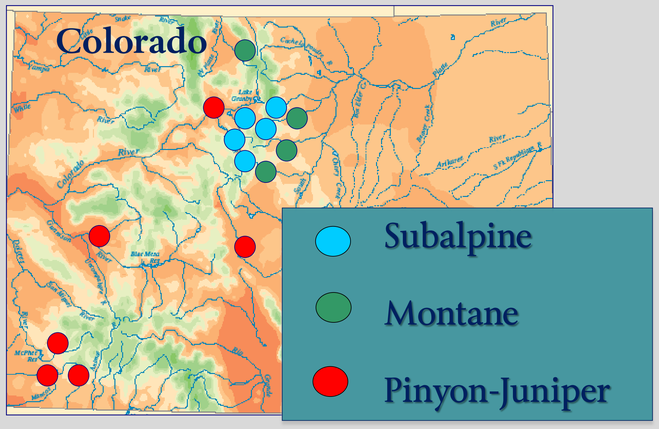
Background & Objectives

Mechanical methods for reducing woody fuel loads are being implemented on millions of acres throughout western North America. Redistribution of standing forest biomass to the soil surface by these treatments has no ecological analogue and may have important implications for long-term forest productivity.

Our primary objective was to identify if the effects of forest mulching on soil nitrogen cycling can be generalized across conifer ecosystems. We also compared how mulching effects varied with the depth of applied mulch.

Mulched lodgepole forest near Fraser, Colorado.



Study Areas

We evaluated mulch effects at 15 sites distributed across the southern Rocky Mountains & Colorado Plateau regions.

Forest Type	Elevation (m)	Precipitation Annual Total (cm)	Temperature Min (°C)	Temperature Max (°C)	Overstory Basal Area Untreated (m^2 ha^{-1})	Overstory Basal Area Mulched (m^2 ha^{-1})	Overstory Basal Area Reduction (%)
Subalpine / Mixed Conifer							
Pinus flexilis (44%), *Pinus ponderosa* (38%)	2900	9.3	-5.0	10.6	32.6	8.9	73
P. contorta (98%)	2818	10.3	-1.8	10.9	32.7	13.8	58
P. contorta (100%)	2800	10.3	-1.8	10.9	31.3	15.7	50
P. contorta (58%), *P. ponderosa* (30%), *Pseudotsuga menziesii (12%)*	2760	10.3	-1.8	10.9	34.8	3.4	90
P. contorta (100%)	2657	7.7	-8.1	11.3	38.3	12.4	68
Montane							
P. ponderosa (94%), *Pseudotsuga menziesii* (6%)	2360	6.3	-1.9	17.1	16.7	7.4	56
P. ponderosa (58%), *Pseudotsuga menziesii* (42%)	2300	6.3	-1.9	17.1	28.6	13.7	52
P. ponderosa (68%), *Pseudotsuga menziesii* (32%)	2130	6.3	-1.9	17.1	26.2	6.7	74
P. ponderosa (50%), *Pseudotsuga menziesii* (50%)	2100	8.6	1.4	14.2	36.0	17.2	52
Pinyon-Juniper							
P. edulis (89%), *Juniperus* sp. (10%)	2400	4.3	-1.7	17.2	30.2	5.5	82
P. edulis (39%), *Juniperus* sp. (61%)	2250	7.3	-0.6	16.5	12.7	4.9	61
P. edulis (65%), *Juniperus* sp. (35%)	2200	3.8	1.4	17.4	17.2	6.4	63
P. edulis (12%), *Juniperus* sp. (88%)	2200	4.7	-5.6	12.8	37.6	22.6	40
P. edulis (22%), *Juniperus* sp. (78%)	2170	7.1	2.6	16.9	23.2	15.1	65
P. edulis (16%), *Juniperus* sp. (84%)	1915	5.1	0.5	18.1	11.5	2.5	78

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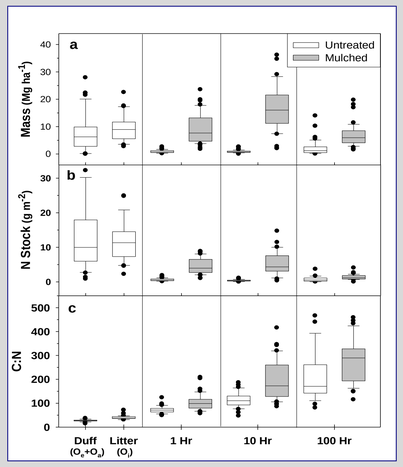
Mulch Additions



Mulching added 29 Mg ha^{-1} of 1, 10 & 100 hour size residue on average. This is equivalent to 1.6-times the mass and twice depth of the forest floor in untreated forests.

N added in mulch represents a 10-fold increase over that found in comparable material in untreated forests, but mulch substrate quality (*e.g.,* C:N ratio) is substantially lower.

The extent of exposed forest floor and rock declined and herbaceous plants cover doubled.

Forest Type		Depth Litter (cm)	Depth Duff (cm)	Cover 1&10 hr (%)	Cover 100 hr (%)	Cover 1000 hr (%)	Cover Forest Floor (%)	Cover Rock (%)	Cover Soil (%)	Cover Graminoid (%)	Cover Forb (%)	Cover Shrub (%)	Cover Tree (%)
Subalpine / Mixed Conifer	Untreated	2.1	1.3	4.6	2.2	0.9	80.5	4.9	5.2	0.6	0.4	2.3	1.5
	Mulched	4.1	0.4	37.1	8.9	1.8	44.7	2.2	3.6	1.8	1.4	1.3	0.4
Montane	Untreated	2.0	1.3	5.3	2.3	2.1	78.4	1.6	8.2	1.7	1.3	5.5	3.5
	Mulched	3.7	0.0	33.4	5.6	2.4	42.9	1.4	12.4	3.8	3.3	3.1	0.1
Pinyon-Juniper	Untreated	1.1	0.4	5.1	0.9	1.2	45.9	11.2	33.0	2.2	1.3	7.3	5.9
	Mulched	1.7	0.5	28.4	2.1	1.2	35.2	7.1	23.2	4.7	1.7	5.6	1.0
Total	Untreated	1.6	1.0	5.0	1.7	1.3	66.3	6.5	17.0	1.6	1.0	5.1	3.8
	Mulched	3.1	0.4	32.6	5.3	1.7	40.4	3.9	13.8	3.5	2.0	3.5	0.6

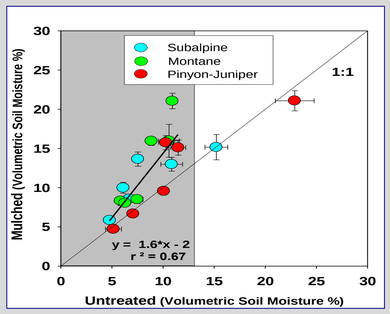
Soil Nitrogen Availability

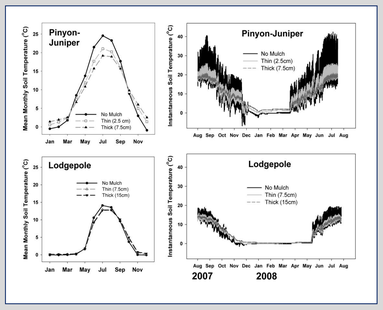
Forest Type	IER-Ammonium Untreated (mg N bag^{-1})	IER-Ammonium Mulched (mg N bag^{-1})	IER-Nitrate Untreated (mg N bag^{-1})	IER-Nitrate Mulched (mg N bag^{-1})	Total IER N Untreated (mg N bag^{-1})	Total IER N Mulched (mg N bag^{-1})	Nitrate Proportion Untreated (%)	Nitrate Proportion Mulched (%)
Subalpine / Mixed Conifer	0.20	0.28*	0.84	1.23*	1.04	1.51**	67.80	68.19
	(0.02)	(0.04)	(0.09)	(0.18)	(0.11)	(0.19)	(2.45)	(2.35)
Montane	0.21	0.29*	0.76	1.17**	0.96	1.46**	83.46	77.48
	(0.04)	(0.04)	(0.07)	(0.14)	(0.10)	(0.15)	(1.43)	(1.78)
Pinyon-Juniper	0.06	0.04	0.92	0.94	0.98	0.98	93.40	94.25
	(0.01)	(0.01)	(0.09)	(0.09)	(0.10)	(0.09)	(1.01)	(1.00)
All Types	0.16	0.20**	0.84	1.11**	1.00	1.32**	81.55	79.97
	(0.01)	(0.02)	(0.05)	(0.08)	(0.06)	(0.09)	(1.63)	(1.73)
Main Effects	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
Treatment	4.61	0.032	6.66	0.010	8.26	0.004	1.54	0.215
Forest Type	6.29	0.013	0.04	0.965	0.26	0.774	8.84	0.004
Treatment x Forest Type	3.56	0.029	1.40	0.247	2.12	0.121	2.90	0.056

p < 0.1 *p < 0.05*

Mulching had positive effects on soil nutrition on average. IER NH_4 & NO_3 were significantly higher in mulched subalpine and montane sites; mulching increased total IER-N by ~50% in these forests.

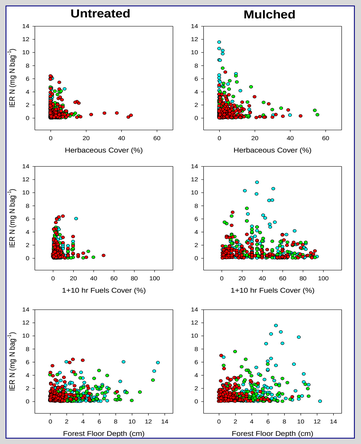
Soil Climate



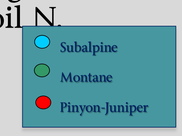


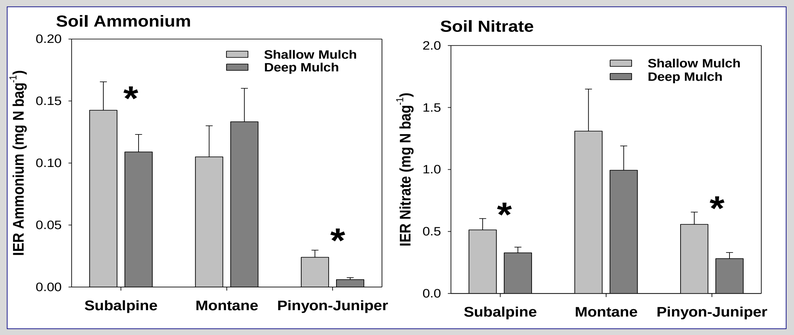
Mulching increased soil moisture and decreased soil temperature. For example, in PJ forests mean summer soil temperatures were 3.4 & 5.2 °C lower under thin and thick mulch compared to unmulched plots. In lodgepole, mulch lowered summer soil temperature by ~ 1.1 °C.

Mulch Depth Effects



Mulching increases average herb and fine fuel cover and forest floor depth as well as the variability of these factors. Mulching similarly increases concentrations and the degree of variability in soil N.





In contrast to the positive effects of mulch applied operationally, residue added in excess of 15 cm deep in experimental plots generally had the opposite effect on soil N availability. Total resin N was 20 to 50% lower in deep compared to shallow mulch beds in the 3 forest types.

		Subalpine / Mixed Conifer		Montane		Pinyon-Juniper	
Mulch N%	None	0.35	(0.01)	0.32	(0.01)	0.29	(0.01)
	Shallow	0.39	(0.01)	0.43	(0.03)	0.31	(0.02)
	Deep	0.46	(0.03)	0.48	(0.03)	0.36	(0.02)
Mulch C%	None	47.48	(0.78)	46.15	(0.86)	44.99	(0.67)
	Shallow	49.76	(0.60)	49.57	(0.89)	46.04	(0.30)
	Deep	48.69	(1.27)	49.64	(0.83)	45.93	(0.92)
Mulch C:N	None	136.50	(3.72)	143.05	(4.32)	156.31	(4.12)
	Shallow	127.04	(3.20)	120.29	(6.84)	151.79	(11.84)
	Deep	113.33	(7.33)	106.95	(6.88)	133.07	(6.81)

Mulch N concentration increased and its C:N ratio narrowed over the course of the study. Twice as much N accumulated in mulch placed in deeper beds. The increase in mulch N in subalpine and montane forests was double that pinyon-juniper forests.

Summary

Based on our findings, it seems unlikely that for the mulch depths typically generated by mechanical fuel reduction projects that mulching treatments will have negative consequences on soil N availability in most Colorado conifer forests.

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