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Soil carbon and nitrogen in a Great Basin pinyon–juniper woodland: Influence of vegetation, burning, and time

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ABSTRACT

Much of the Great Basin, U.S. is currently dominated by sagebrush (*Artemisia tridentate ssp.* (Rydb.) Boivin) ecosystems. At intermediate elevations, sagebrush ecosystems are increasingly influenced by pinyon (*Pinus monophylla* Torr. & Frém.) and juniper (*Juniperus osteosperma* Torr.) expansion. Some scientists and policy makers believe that increasing woodland cover in the intermountain western US will create new carbon storage on the landscape; however, little is currently known about the distribution of carbon on these landscapes. This is especially true of below ground pools. Our objectives were to quantify the spatial distribution of soil carbon in expansion woodlands, and to determine prescribed fire's effect on soil C and N. We looked at two treatments (control and burn), three microsites (undertree, undershrub, and interspace), and four soil depths (0–8, 8–23, 23–38, and 38–52 cm). The study was conducted over a six year period with one year pre-fire and five years post-fire data. Results for both carbon and nitrogen were similar, indicating the close relationship between the two elements in this ecosystem. Undershrub microsites had higher soil C and N concentrations than interspace and undertree microsites; however, under tree microsites had higher C:N ratio than interspace and undershrub microsites. Carbon and nitrogen concentration tended to decrease with increasing depth at both control and burn sites. Prescribed burning caused immediate increases in surface soil C and N concentration, but over intermediate to longer periods of time no statistically detectable change in soil C or N content occurred from burning.

1. Introduction

Vegetation changes associated with climate shifts and anthropogenic disturbance are thought to have major impacts on biogeochemical cycling and soils (Schimel et al., 1991, 1994). Much of the Great Basin is currently dominated by sagebrush (*Artemisia tridentate ssp.* (Rydb.) Boivin) ecosystems. At intermediate elevations, sagebrush ecosystems are increasingly influenced by pinyon (*Pinus monophylla* Torr. & Frém.) and juniper (*Juniperus osteosperma* Torr.) expansion. Pinyon and juniper woodlands have expanded their pre-European settlement range in the Great Basin by more than 60% since 1860 due to a combination of climate change, fire suppression, and overgrazing by livestock (Miller and Wigand, 1994; Gruell, 1999; Miller and Rose, 1999).

Although pinyon–juniper woodlands have expanded and receded several times over the last 5000 years, the current rate of expansion is unprecedented. Less than 10% of current woodlands are of age classes exceeding 140 years (Miller and Tausch, 2001). Pinyon and juniper expansion has resulted in increased crown fuel continuity across the landscape (Tausch, 1999a,b). Crown cover exceeding 50% is sufficient to carry high intensity fire during dry or windy periods. Woodlands with this coverage now occupy 25% of the current range, and the area is expected to double over the next 50 years (Miller and Tausch, 2001).

A growing concern in forest and rangeland ecosystems are the effects of altered vegetation composition and fire regimes on both carbon and nitrogen balances. Recent data from semi-arid forests and woodlands indicate that changes in stand densities and especially fire regimes have significant and often immediate effects on carbon and nitrogen balances (Johnson et al., 1998; Norris et al., 2001). Catastrophic wildfire can cause changes in ecosystem C budgets in a single day that overwhelm and supersede many decades of photosynthesis, respiration, and

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decomposition, setting the ecosystem on a new vector that is very different from the one it was on before the fire (Johnson et al., 1998).

The role of fire in ecosystem C changes is complex. Nitrogen is the growth-limiting nutrient in nearly all western ecosystems, and thus has a major effect on the long-term C budgets of these systems. The effects of fire and post-fire vegetation especially N-fixers can have profound, long-term effects on ecosystem C sequestration (Jonson and Curtis, 2001).

As pinyon–juniper woodlands increasingly dominate sagebrush ecosystems, they compete for available resources and often eliminate most understory vegetation (Reiner, 2004). High intensity wildfires combined with reduced understory vegetation may leave a burned area susceptible to exotic invasive species such as cheatgrass (*Bromus tectorum* L.). Invasion by cheatgrass has been documented to increase fire frequency on the landscape, and may shift community composition almost to monocultures (Young and Evans, 1973). The new annual grasslands store considerably less carbon than sagebrush steppe or woodland ecosystems (Bradley et al., 2006)

Prescribed fire has been suggested as a management tool to decrease the rate of pinyon–juniper expansion and reduce the risk of high severity wildfire. Effective use of prescribed fire requires increasing our understanding of the extended effects that prescribed fire has on nutrient cycling in pinyon–juniper woodlands and their associated sagebrush ecosystems in the Great Basin.

We have collected data one year before and several years following a spring prescribed burn in a pinyon woodland. This type of data will give insight to management effects on soil C and N over short to intermediate time periods. Our aims were to determine: 1) how soil C and N varies spatially between microsites and with soil depth a pinyon woodland; 2) the immediate effects of burning on soil C and N; and 3) changes in soil C and N pools over time since burning.

2. Materials and methods

2.1. Experimental area

The study is a Joint Fire Sciences Program demonstration area in the Shoshone Mountain Range on the Humboldt-Toiyabe National Forest (Austin Ranger District) in Nye and Lander Counties, Nevada. Underdown Canyon (39°15′11″ N, 117°35′83″ W) is oriented east to west and contains infrequent springs and an intermittent stream near the top of the drainage. Average annual precipitation ranges from 23 cm at the bottom to 50 cm at the top of the drainage and arrives mostly as winter snow and spring rains. Average annual temperature recorded in Austin, NV ranges from −7.2 °C in January to 29.4 °C in July. Lithology of the Shoshone range consists of welded and non-welded silica ash flow tuff. Soils developed on alluvial fans in this study are classified as loamy skeletal mixed frigid Typic Haploxerolls. The vegetation is characterized by sagebrush (*Artemisia tridentata vaseyana*) and single leaf pinyon (*Pinus monophylla*) with lesser cover of Utah juniper (*Juniperus osteosperma*). Herbaceous species include the grasses, *Poa secunda secunda* J. Presl, *Elymus elymoides* Swezey, *Stipa comata* Trin. & Rupr., *Festuca idahoensis* Elmer, and *Pseudoroegneria spicata* (Pursh) A. Löve, and the forbs, *Eriogonum umbellatum* Torr., *Eriogonum ovalifolium* Nutt., *Eriogonum elatum* Dougl. ex Benth., *Eriogonum heracleoides* Nutt., *Crepis acuminata* Nutt., *Phlox longifolia* Nutt., *Agoseris glauca* (Pursh) Raf., *Lupinus argenteus* Pursh, and *Penstemon* species. *Bromus tectorum*, an invasive annual grass, is not a large component of the study area.

The vegetation occurs in patches of variable tree dominance typical of intermediate age class woodlands in the central Great Basin and ranges from low (5% cover, 5,630 kg/ha) to high tree dominance (86% cover, 115,000 kg/ha) (Reiner, 2004).

2.2. Study design and data collection

The study was a split plot design with repeated measures. The study plots were located on northeast facing alluvial fans at elevations of 2195 m and 2225 m. Each alluvial fan in the study was approximately 2 ha. The plots at elevation 2195 m were a control, and the plots at 2225 m received a spring burn treatment. Four sub-plots were sampled on both the control and the burn treatment. Plots were characterized by intermediate tree cover (38% cover, 6722 kg/ha) at both elevations and contained a mix of trees, shrubs, and interspaces. To characterize the 2195 m control and 2225 m burn treatment plots, soil pits were dug to a depth of 100 cm, and the soil horizons were identified. Depth increments for sampling were assigned to the approximate center of the soil A_1 horizon and subsequent 15 cm increments (0–8, 8–23, 23–38, and 38–52 cm). Soil samples were taken from each of three microsites (under tree, under shrub, interspace) for each depth using a 10 cm diameter bucket auger. Sampling was conducted in November 2001 through 2004 and again in 2006 to determine temporal, spatial, and treatment differences in soil carbon and nitrogen. A second set of soil samples also were collected at soil depths 0–3 and 3–8 cm using a hand trowel to determine the immediate effects of burning and the spatial variability of soil carbon and nitrogen. These samples were collected on the burn treatment plots from each microsite on May 11, 2002 immediately before the burn. Collection locations were marked with a metal stake so that they could be located and sampled after the prescribed burn. Samples were again collected on May 15, 2002 after the prescribed fire. USDA Forest Service fire personnel burned the study plots on May 11–14, 2002 under favorable weather conditions (Air temp < 32 °C, RH $> 15\%$, wind speed < 9 m s^{-1}, and gravimetric fuel moisture $\approx 40\%$). Because soil and fuel moisture were relatively high during the time of burning, the vegetation and duff were consumed in patches creating a landscape of burned and unburned islands. Fire behavior during the prescribed burn was characterized by creeping ground fire with individual and group tree torching. Some short crown runs were also observed. Sustained crown runs were not frequent due to low wind speeds and discontinuous fuels. Soil temperatures were recorded during the fire using heat sensitive paints on metal strips (Korfmacher et al., 2002). Strips were placed at 0, 2, and 5 cm soil depths at all microsites.

All soil was brought back to the lab, dried, and sieved to 2 mm. Soils were then ground in a Wiley® mill and analyzed for total carbon and nitrogen concentration using a LECO Truspec® CN determinator. In order to look at landscape scale changes in C and N content, data was transformed into kg ha^{-1} by using the formula

$$\text{kg ha}^{-1} = (d)(\text{Db})[1-(>2\ \text{mm}\%)](\text{Conc})(F)$$

where d = depth (cm) of the soil horizon, Db = bulk density (g cm^{-3}) of that horizon, >2 mm% is the volume percentage coarse fragment of that horizon, Conc = nutrient concentration (ug g^{-1}), and F = conversion factor (0.1 cm^2 ug^{-1}).

To evaluate year by treatment differences at the landscape scale percent cover for each of the three microsites was measured using three 30 m line-intercept transects on each replicate plot (Elzinga et al., 1998). The mass of Carbon and Nitrogen calculated at each microsite was then weighted by the microsites' cover percentage on intermediate tree dominance plots. For the surface 8 cm C and N kg ha^{-1} was summed across the three microsites. For the soil profile C and N kg ha^{-1} was summed across the three microsites and four depths to 52 cm.

2.3. Statistical analyses

The Kolmogorov–Smirnov test was used to test for data normality. All data was natural log transformed to meet the assumption that the data was normally distributed. All comparisons were evaluated using SAS™ mixed effects models. Overall differences in C and N concentration between control and burn treatment plots, microsites, depths, and years were determined by evaluating treatment as a main effect, microsite as a split-plot within treatment, depth was a split-split-plot within treatment and microsite, and year was a split-split-split plot within treatment, microsite, and depth (Appendix A.1). Immediate prescribed burn effects on soil C and N concentration within the treatment plots were evaluated with treatment as a main effect, microsite as a split-plot within treatment, and depth as a split-split-plot within microsite (Appendix A.2). The overall analysis was not ideal for measuring burn effects across the landscape because mean values for microsite and depth do not necessarily reflect the sum or distribution of these sample locations on the landscape. Therefore, year by site interactions for soil C and N content were assessed at the two depth integrals described in the methods above (0–8 and 0–52 cm) by treating year and treatment as main effects (Appendix A.3). Means comparisons were made with Duncan's test ($P < 0.05$) after confirming significant main effects and interactions with the Mixed models ($P < 0.05$).

3. Results

3.1. Distribution of carbon and nitrogen

Over the 6 year study period, almost all of the terms in the overall mixed model for carbon were significant at the $P < 0.05$ level (Appendix A.1). Means comparisons revealed that mean soil carbon concentration to a depth of 52 cm was higher on the control plots than in burn plots (Fig. 1). Carbon concentrations under shrubs were typically higher than at undertree and interspace microsites on both control and burn plots (Fig. 1). Carbon was the highest near the soil surface and decreased with depth across all measurements (Fig. 1). Along temporal scales carbon was higher in 2002 and 2004 than in 2001 and 2006 (Fig. 1). The higher level interaction terms indicate that most of the spatial and temporal variation within the system occurred near the soil surface (Fig. 1).

Most terms in the mixed model for nitrogen concentrations were also significant at the $P < 0.05$ level (Appendix A.1). Mean nitrogen concentrations over the six year study period were slightly higher on the control plots than on burn plots (Fig. 2). Nitrogen concentrations were higher under shrubs than at interspace and undertree microsites, and N concentrations decreased with increasing depth (Fig. 2). Along temporal scales N was slightly higher in 2004 than in 2001 and 2006 (Fig. 2). As with carbon the higher interaction terms with nitrogen indicate that most temporal and spatial variation occurs near the soil surface (Fig. 2).

The mean ratio of C and N concentration across all samples was higher on the control than burn plots ($P < 0.05$) (Fig. 3). Carbon nitrogen ratios were highest under tree microsites, lower under

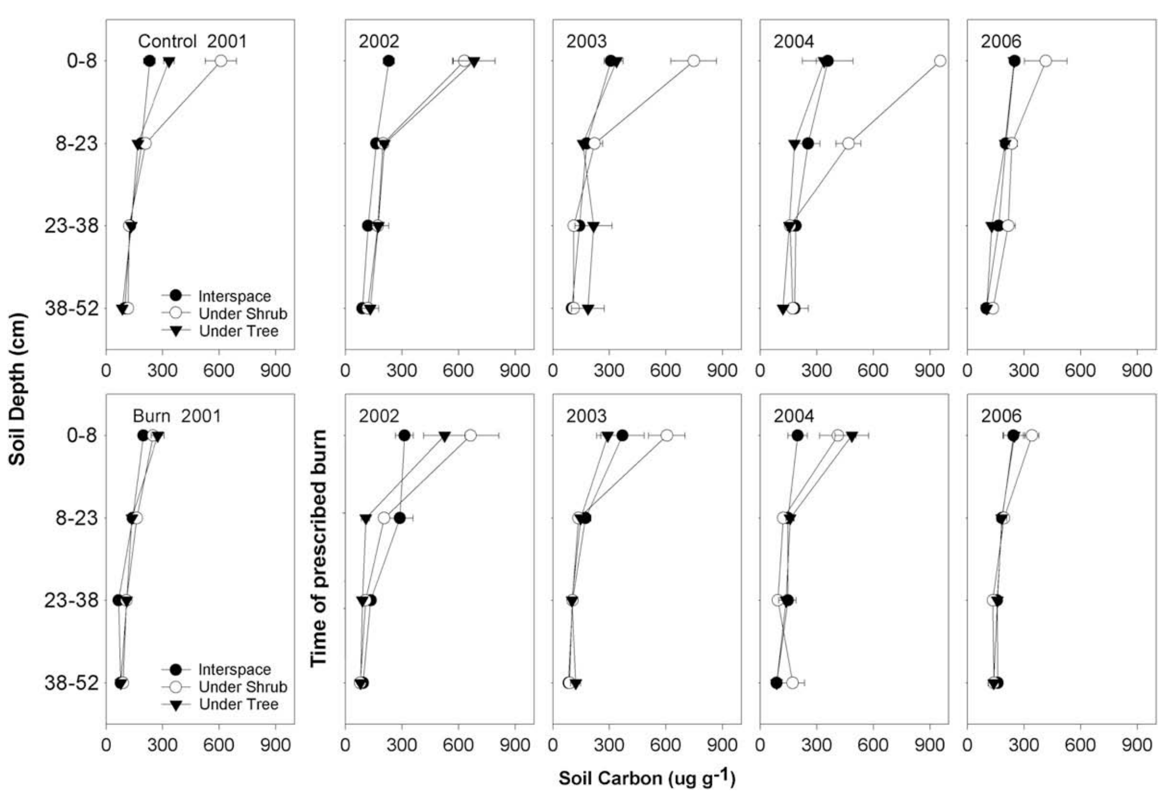

Fig. 1. Means and standard errors for the concentration of soil carbon at three microsites (interspace, undeshrub, and undertree), four depths (0–8, 8–23, 23–38, 38–52), and five years.

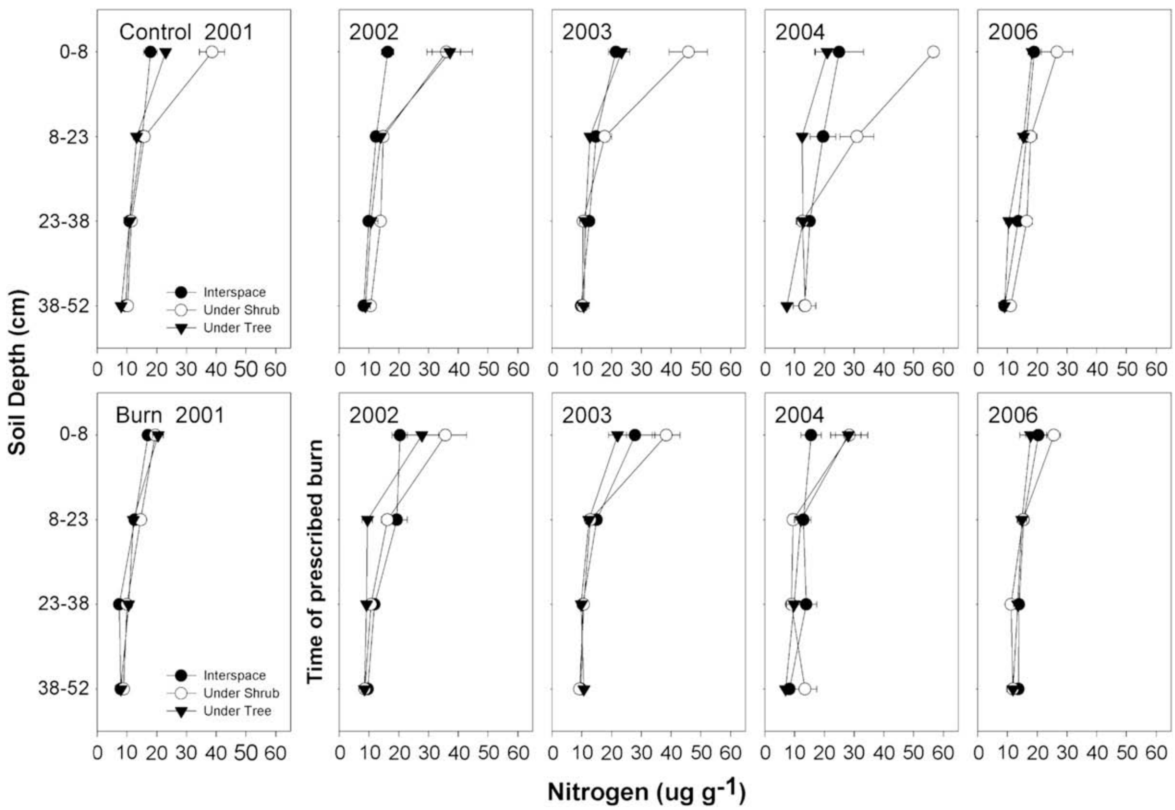

Fig. 2. Means and standard errors for the concentration of soil nitrogen at three microsites (interspace, undeshrub, and undertree), four depths (0–8, 8–23, 23–38, 38–52), and five years.

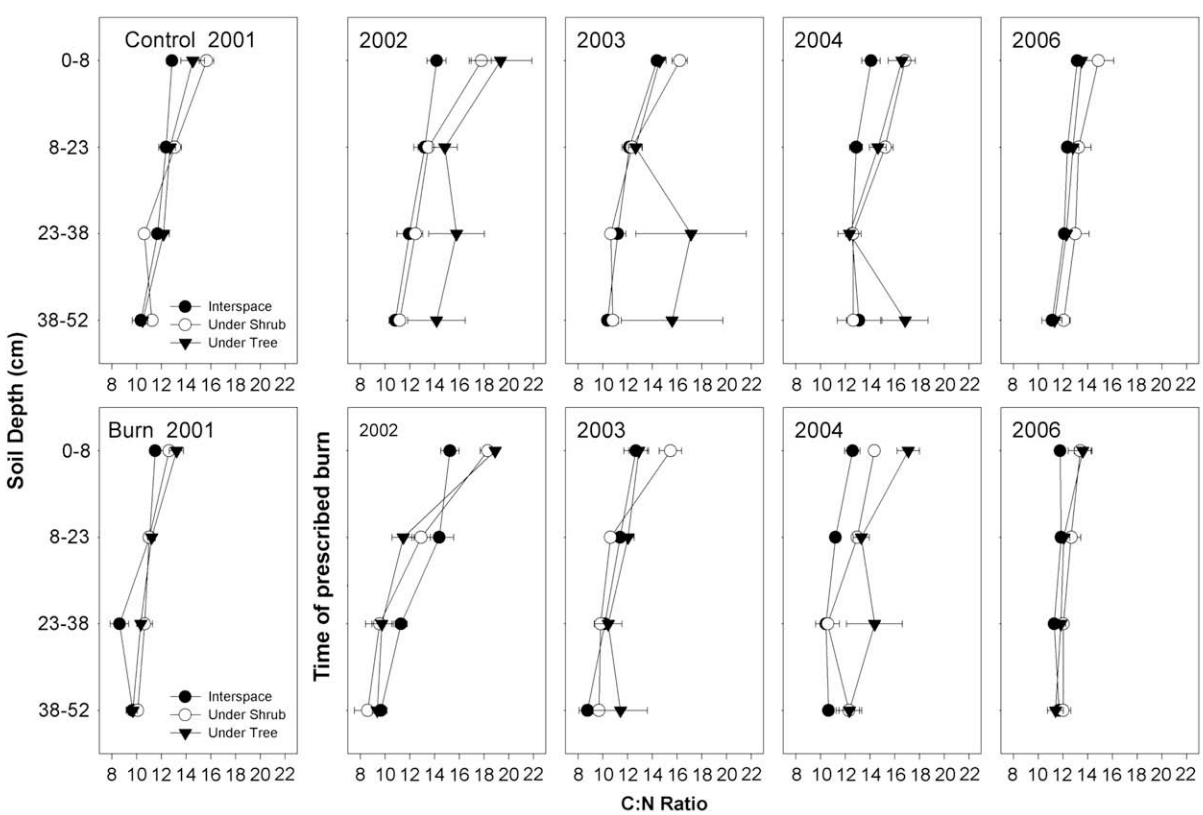

Fig. 3. Means and standard errors for the soil C:N ratio at three microsites (interspace, undeshrub, and undertree), four depths (0–8, 8–23, 23–38, 38–52), and five years.

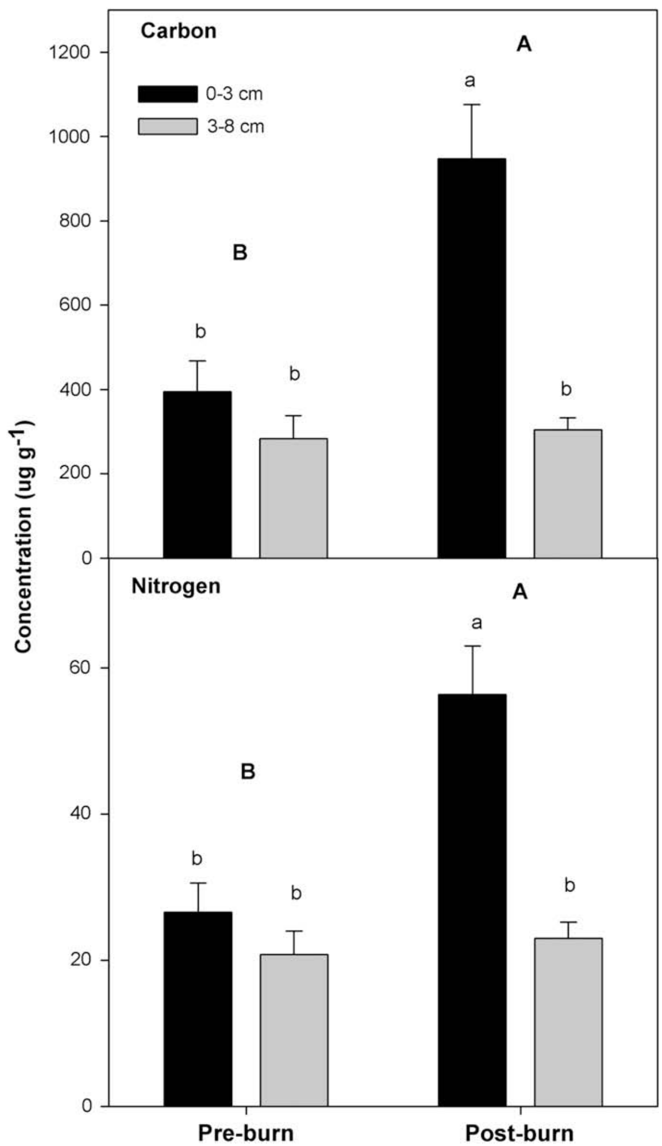

Fig. 4. Means and standard errors for pre- and post-burn soil carbon and nitrogen concentration on the treatment plots at two depths (0–3 and 0–8 cm). Means not represented by a common letter are significantly different. Capital letters indicate treatment effects. Lower case letters indicate treatment–depth interactions.

shrub microsites and lowest at interspace microsites. The C:N ratio of soil tended to decrease with depth to 38 cm (Fig. 3). Carbon to nitrogen ratio was highest in 2002 and 2004, lower in 2003 and 2006, and lowest in 2001 (Fig. 3). Higher level interactions showed that changes in C:N ratio were evident through the soil profile (Fig. 3).

3.2. Effect of burning on carbon and nitrogen

Burning had identical immediate effects on both carbon and nitrogen. Burning resulted in an immediate increase of both carbon and nitrogen concentration at the soil surface (0–3 cm) (Fig. 4). However, no change in soil just below the surface (3–8 cm) was observed (Fig. 4). Burning did not have a significant interaction with microsite for carbon or nitrogen.

Burning had no statistically significant longer term effect on total soil carbon or nitrogen content at the soil surface (0–8 cm) or to a depth of 52 cm as indicated by the year by site interaction

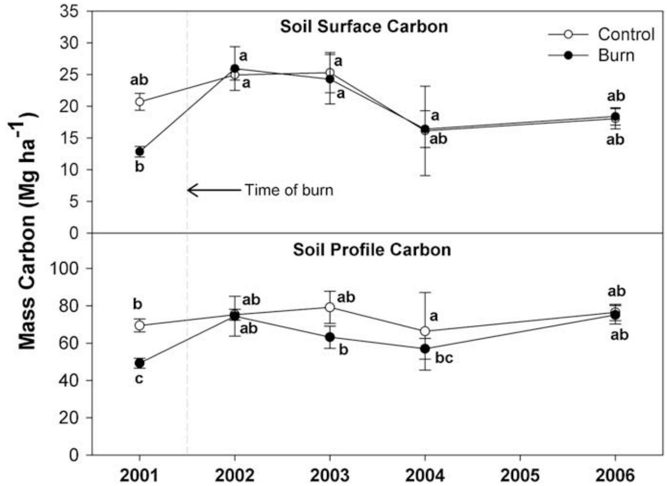

Fig. 5. Means and standard errors for five years of pre- and post-burn near surface (0–8 cm) and soil profile to 52 cm total soil carbon. Means not represented by a common letter are significantly different.

term in the mixed model (Appendix A.3) (Figs. 5 and 6). There were no significant temporal influences on surface (0–8 cm) or soil profile (0–52 cm) total C or N content during the study period.

4. Discussion

4.1. Distribution of carbon and nitrogen

Over the entire six year study period the control plots had higher carbon and nitrogen concentrations than burn plots. It is unclear exactly why C and N concentrations are different between the two sites, and it is noteworthy that the absolute value of the difference is small. Similarly when C and N contents are compared no site differences are significant (Appendix A.3). The difference in C and N concentration between the two sites appears directly related to differences observed in surface soils below shrub canopies. Most other measurements of C and N concentration are similar (Figs. 1 and 2). The observed difference could be related to

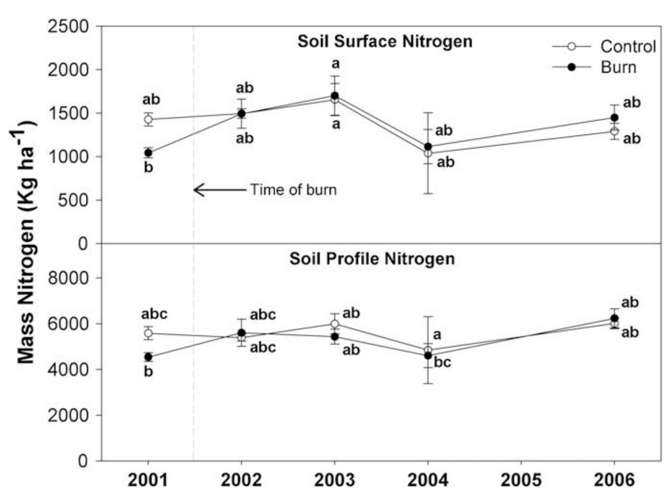

Fig. 6. Means and standard errors for five years of pre- and post-burn near surface (0–8 cm) and soil profile to 52 cm total soil nitrogen. Means not represented by a common letter are significantly different.

past fire history, vegetation history, nutrient availability, or microclimatic differences which affect shrub productivity, and microbial respiration and biomass (Klopatek et al., 1991; Norris et al., 2001; Hibbard et al., 2003). We compared nutrient availability on both sites and found that the control site had lower available Ca^{2+}, K^{+}, and Na^{+} compared to the burn site, but we are unsure how this would affect total soil C or N (Rau et al., 2008). Because we have no data related to fire history or microclimate for each individual site further explanation of site differences would be speculative.

Undershrub microsites had higher C and N concentrations than undertree and interspace microsites, but only near the soil surface (Figs. 1 and 2). The tendency for highest carbon and nitrogen at undershrub microsites contrasts slightly with observations from data obtained for root biomass in this system (Rau et al., in press). It was determined that both undershrub and undertree microsites contained 25% more root biomass or approximately 960 kg ha^{-1} more C and 40 kg ha^{-1} more N than interspace microsites (Rau et al., in press). Although the root biomass accounts for only a small fraction of total C and N at each microsite (<2% C and <0.5% N) root turnover, incorporation of root exudates, and incorporation of surface litter into soil C and N are major long term factors affecting soil C and N, these results suggest an interesting dichotomy (Sturges, 1977; Jackson et al., 1996). Because this site is considered expansion woodland, and has been most recently dominated by sagebrush grassland, it is possible that the increased root mass at undertree microsites resulting from tree establishment is a recent phenomenon and the processes that result in increased carbon concentration have not had adequate time to produce measurable change in C and N. This may be supported by the C:N ratio of soil observed at the undertree microsite which was greater than undershrub and interspace. If the roots of trees have a higher C:N ratio than shrub or herbaceous roots then decomposition and incorporation of tree root carbon into soils will be delayed.

Nearly identical patterns exist for both carbon and nitrogen distribution through the soil profile to 52 cm (Figs. 1 and 2). Carbon and nitrogen concentration and C:N ratio generally decrease with depth. However, the C:N ratio below tree canopies decreases less with increasing soil depth compared to undershrub and interspace (Fig. 3). The decrease in C, N, and C:N with increasing depth in this system is probably related to litterfall, and possibly past and current rooting density (Sturges, 1977; Jackson et al., 1996). The distribution of total C and N corresponds relatively well with the distribution of root biomass below shrubs and interspaces (Rau et al., in press). However, there is a discrepency again at the undertree microsite. Root biomass under trees was typically concentrated at lower depth (23–52 cm) near the lithic contact (Rau et al., in press). More data from additional sites will be needed to further understand how tree encroachment influences soil C and N pools in arid woodlands.

4.2. Effect of burning on carbon and nitrogen

Burning resulted in an immediate increase in both carbon and nitrogen concentration at the soil surface (0–3 cm) (Fig. 4). This contrasts with some observations of both prescribed and wildland fire, but is consistent with others (Jonson and Curtis, 2001). Fire generally oxidizes organic matter on and near the soil surface driving off C and N as CO, CO_2, NO_2, N_2O, etc. (Johnson et al., 2004). Temperature data from the fire indicates that surface temperatures reached 200–300 °C; hot enough to oxidize carbon and nitrogen. However, temperatures may not be hot enough to oxidize carbon just below the soil surface (Rau et al., 2005). Temperature data and results from chemical analysis confirm that the fire was not hot enough (<80 °C) to produce significant changes in total soil carbon and nitrogen just below the soil surface (2 cm) (Rau et al., 2005). The result could have been that ash and partially combusted material from above ground biomass was deposited on the soil surface and incorporated into the soil profile. These materials could have contributed the additional C and N observed after burning.

Through the six year study period burning had no statistically detectable influence on total soil carbon or nitrogen content near the soil surface (0–8 cm) or to a depth of 52 cm as indicated by the mixed model. However, data from immediate measurements and close inspection of Figs. 4 and 5 suggests burning increased C and N content to levels similar to the control plots. Because burning only increased C and N within the first 0–3 cm of soil it is likely that this change was not statistically detectable when integrated into the 0–8 cm or 0–52 cm increments. Similarly, the processes that effect larger changes in soil profile total C and N following fire, such as N-fixation, microbial respiration, and incorporation of litter or root materials into soil, may not have had a long enough period to detectably influence landscape scale C and N pools on this site.

A related study from this site observed a large increase in legume cover following the burn, and an increase in extractable nitrogen adjacent to the legume, *Lupinus argenteus* (Goergen and Chambers, in press). We hypothesized that the large increase in legume cover following the prescribed burn would eventually lead to recovery of N lost from fire or increase N following fire (Johnson et al., 2004). At this time neither of those scenarios has proved true. However, it is possible that over longer periods we may see significant changes in surface soil 0–8 cm N (Fig. 5).

5. Conclusions

Although this data is only applicable at this location it suggests interesting implications for carbon storage. Current paradigm suggests that as woodlands encroach into arid landscapes, carbon storage on the landscape should increase (Norris et al., 2001; Hibbard et al., 2003). This may be true for aboveground biomass, but may not be applicable for soil carbon. Data from our study on root distribution in this woodland indicates that tree roots and vertical carbon distribution are not synchronous (Rau et al., in press). It is feasible that tree encroachment in this woodland was relatively recent and uncommon for long periods prior to our study. For these reasons the soil profile C and N does not reflect current vegetation distribution.

Fire is an integral part of semi-arid sagebrush and woodland systems. Years of fire suppression in these landscapes have increased fuel loads and left ecosystems open to exotic invasions. Prescribed fire in these transition woodlands has been shown as an effective way to re-establish native herbaceous understory biomass (Dhaemers, 2006). Although prescribed fire releases carbon and nitrogen from litter and aboveground biomass, this study suggests that it may not have a large impact on soil pools, as has been found in other studies (Klopatek et al., 1991; Caldwell et al., 2003; Johnson et al., 2004).

Acknowledgments

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Appendix A.1

	Carbon			Nitrogen		CN	
	df	*F*	*P*	*F*	*P*	*F*	*P*
Treatment	1	23.54	0.0028	9.31	0.0225	47.99	0.0004
Replicate (Treatment)	6						
Microsite	2	30.34	<0.0001	38.05	<0.0001	17.06	0.0003
Microsite* Treatment	2	7.56	0.0075	10.92	0.0020	1.40	0.2846
Microsite*Replicate (Treatment) Error A	12						
Depth	3	248.41	<0.0001	252.67	<0.0001	70.54	<0.0001
Depth* Treatment	3	2.66	0.0574	3.17	0.0316	1.13	0.3450
Depth*Microsite	6	23.74	<0.0001	20.23	<0.0001	3.57	0.0047
Depth* Treatment *Microsite	6	3.30	0.0077	2.54	0.0309	1.05	0.4053
Depth*Microsite*Replicate (Treatment) Error B	54						
Year	4	9.78	<0.0001	5.01	0.0007	14.67	<0.0001
Year* Treatment	4	3.99	0.0037	5.34	0.0004	1.80	0.1288
Year*Microsite	8	1.77	0.0838	2.08	0.0382	2.18	0.0296
Year*Depth	12	4.02	0.0002	3.24	0.0015	2.40	0.0162
Year* Treatment *Microsite	8	7.32	<0.0001	4.83	<0.0001	4.89	<0.0001
Year*Microsite*Depth	24	1.29	0.2216	1.16	0.3161	1.52	0.1177
Year* Treatment *Depth	12	2.72	<0.0001	2.09	0.0026	1.25	0.2011
Year* Treatment *Microsite*Depth	24	1.63	0.0354	1.77	0.0164	0.80	0.7356
Year*Depth*Microsite*Replicate (Treatment) Error C	262						

Appendix A.2

	Carbon			Nitrogen	
	df	*F*	*P*	*F*	*P*
Concentration					
Microsite	2	1.10	0.3734	0.62	0.5571
Replicate (Microsite) Error A	9				
Depth	1	42.77	0.0001	32.97	0.0003
Depth*Microsite	2	3.27	0.0855	1.37	0.3022
Depth*Replicate (Microsite) Error B	9				
Treatment	1	10.09	0.0055	11.37	0.0037
Treatment*Depth	1	7.69	0.0130	7.27	0.0153
Treatment*Microsite	2	0.09	0.9117	0.41	0.6674
Treatment*Depth*Microsite	2	0.07	0.9371	0.22	0.8080
Treatment*Depth*Replicate (Microsite) Error C	17				
Content					
Microsite	2	0.05	0.9479	0.23	0.7956
Replicate (Microsite) Error A	9				
Treatment	1	7.99	0.0198	8.2	0.0187
Treatment*Microsite	2	0.29	0.7562	0.74	0.505
Treatment*Replicate (Microsite) Error B	9				

Appendix A.3

	Carbon			Nitrogen	
	df	*F*	*P*	*F*	*P*
Soil Surface					
Treatment	1	2.99	0.1344	0.58	0.4754
Replicate (Treatment) Error A	6				
Year	4	1.52	0.2268	1.74	0.1736
Year* Treatment	4	0.50	0.7393	0.42	0.7936
Year*Replicate (Treatment) Error B	24				
Soil Profile					
Site	1	2.99	0.1344	0.58	0.4754
Replicate (Treatment) Error A	6				
Year	4	1.52	0.2268	1.74	0.1736
Year*Site	4	0.50	0.7393	0.42	0.7936
Year*Replicate (Treatment) Error B	24				

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