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CHANGES IN CARBON POOLS INFLUENCED BY CHANGES IN SOIL TEXTURE, SLOPE, AND ASPECT A DECADE FOLLOWING WILDFIRE IN BLACK SPRUCE FORESTS OF INTERIOR ALASKA

Gregory Houle
Michigan Technological University, gphoule@mtu.edu

CHANGES IN CARBON POOLS INFLUENCED BY CHANGES IN SOIL TEXTURE, SLOPE, AND ASPECT A DECADE FOLLOWING WILDFIRE IN BLACK SPRUCE FORESTS OF INTERIOR ALASKA

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Gregory P. Houle

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Thesis Advisor:	*Dr. Evan S. Kane*
Committee Member:	*Dr. Paul V. Doskey*
Committee Member:	*Dr. Chad D. Deering*
School Dean:	*Dr. Terry Sharik*

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Preface

The main body of this thesis is expected to be submitted to a peer-reviewed journal for publication. All work and analysis was conducted by Greg Houle who will serve as primary author. Dr. Evan S. Kane, Merrit R. Turetsky, and Eric S. Kasischke contributed to experimental design as well as revisions and suggestions on the final manuscript.

Abstract

Topography and parent material (PM) texture control site drainage owing to changes in water holding capacity, infiltration, and insolation. In turn, these factors also affect fire regime. However, the interactive effects of site physiography, edaphic controls, and wildfire severity on ecosystem carbon accrual after wildfire are poorly understood. Throughout the summer of 2004 an area the size of Massachusetts burned in interior Alaska, and several studies were initiated to investigate the controls on organic layer consumption. In this study we re-sampled organic layer depths, below ground carbon stocks, and site revegetation from 38 burned black spruce sites from the 2004 wildfires. We collected ten year post-fire measurements of soil and woody-debris pools with the goal of understanding effects of landscape position, site physiography (topography/aspect and parent material soil texture), and fire severity (burn depth) on changes in carbon accumulation following wildfire. We also measured seedling recruitment to ascertain changes in post-fire succession and how this might affect trajectories of ecosystem carbon storage in the future.

Chapter 1: Changes in Carbon Pools Influenced by Changes in Soil Texture, Slope, and Aspect a Decade Following Wildfire in Black Spruce Forests of Interior Alaska[1]

1.1 Introduction

Boreal forests represent one of the earth's largest biomes, encompassing an area of 14.3 million km^2. It is estimated that 714 Pg (1 Pg=10^{15} g) of carbon are stored within the boreal forest region (Apps et al. 1993). This represents more than 37% of the total amount of carbon stored in the terrestrial biosphere. The majority of this carbon is stored in peatland soils within the boreal forest which is estimated to contain 419 Pg (Kasischke et al. 1995). Boreal forest soils and peatlands are currently a net carbon sink of 0.70 Gt C yr-1 (Kasischke, 1993). Within mature black spruce, *Picea mariana,* stands in the northwestern part of North America the amount of below ground carbon stored is three to four times that of the aboveground living biomass (Bonan & Van Cleve, 1993). On average 19.5 kg/m^2 of carbon is stored in the non-living organic matter found in standing dead vegetation and the ground layer which includes litter, humus, peat, and mineral soil (Apps et al. 1993). This large amount of carbon stored in belowground pools raises question in the understanding of the stability of boreal soil carbon stocks in the face of changing fire regimes and its significance in understanding carbon storage within these systems.

Over the past three decades the frequency and severity of region-wide wildfire seasons across the interior of Alaska have increased (Kasischke et al. 2002, Kasischke and Turetsky 2006). This frequency and extent of wildfires in interior Alaska is projected to increase under a warming climate (Kasischke and Turetsky, 2006, Kasischke et al. 2010, and Flannigan et al 2005). While there is much research focused on the understanding of fire severity, postfire seedling recruitment, fire return interval, and organic layer consumption (Johnstone et al. 2010; Charron and Greene, 2002; Johnstone and Chapin, 2006; Shenoy et al, 2010; Kasischke et al. 2005), there is much uncertainty as to exactly how fire severity, topographic influence, and site drainage interact to affect post-fire surface organic characteristics and stand revegetation.

Pre-fire communities and geomorphological characteristics such as topography and parent material texture influence fire severity through effects on site moisture, organic layer depth, and vegetation structure (Kasischke and Johnstone, 2005; Kane et al. 2007; Johnson, 1992; Harden et al. 2006; Ryan 2002). Site drainage and topography influence moisture content of surface fuels (Dyrness and Norum 1983; Ryan 2002;

[1] This research will be submitted to a peer-reviewed journal for publication.

Kasischke and Johnstone, 2005; Kane et al., 2007). North facing and flat lowlands forest are cooler, wetter, have thinker organic layers, and are likely to have an under lying layer of permafrost (Rieger, 1983; Hinzman et al., 2006). This permafrost layer impedes soil drainage and therefore dictated water table height and soil moisture and therefore regulate the amount of dry fuels available for combustion. These physiographic variations interact with seasonal weather variations to influence the severity of fire and organic layer consumption during a fire event (Kasischke et al., 2000; Kasischke and Johnstone, 2005).

Following wildfire, boreal forest soils remain a net carbon source for 7-15 years due to enhanced rates of decomposition from elevated levels of soil temperature and release between 1.8 to 11 Mg C ha (O'Niell et al., 2003). When soil temperatures begin to decline as plant canopy and moss cover become reestablished. Carbon begins to accumulate within the belowground pool at a rate of 0.28-0.54 Mg C ha per year (O'Niell et al., 2003). However, the understanding of the soil C storage potential is unclear because soil C balance is determined by rates of input from NPP and out puts from continuing decomposition (Van Cleve et al. 1981).

Here, we report on the physiographic effects that regulate the depth of burning, vegetative regeneration, as well as SOC and BC accumulation, in the soils of black spruce forests of interior Alaska. In this study we quantified the post-fire organic layer and SOC recovery from the extensive wildfires that occurred in Alaska during the summer of 2004, which burned a record 2.7 x 10^6 ha. Sites included opposed north- and south-facing toposequences and adjacent foot- and toe-slopes in forests affected by these recent fire events. While the topographic orientation has been shown to exert considerable control over fire severity through changes in surface fuel moisture, effects of mineral soil texture on antecedent moisture condition and organic layer development following wildfires remain largely unexplored.

We hypothesized that parent material soils with coarse textures would have slower rates of organic layer accrual and greater subsidence in the decade following wildfire. We also hypothesized that these changes to the organic layer would affect the distribution of fire killed trees, with relatively less standing dead biomass carbon remaining where coarse textured mineral soils and greater organic layer depth consumption occur. Specifically, we expected that as OL decrease from fire consumption the down dead debris pool would increase. Additionally we expected an interaction between our first and second hypotheses that as the amount of fine textured material decreased with the PM the amount of OL would decease and thus add to the down dead debris pool.

1.2 Methods

1.2.1 Study Site

This study took place in 38 ten-year, post-fire, sites within interior Alaska. Located in a region characterized by discontinuous permafrost, a continental climate, and temperature extremes ranging from -70C to +35C (Hinzman et al. 2006). The sites were all located in the Interior Highlands Ecoregion (http://www.epa.gov/wed/pages/ecoregions.htm) (Figure 1). All study sites were dominated by black spruce pre-fire, and ranged in density from 800 – 13 455 trees per hectare (Kasischke et al. 2008) and included north-facing slopes, south-facing slopes, dry ridge tops, and poorly drained lowlands.

During the summer of 2004, interior Alaska experienced the hottest and driest weather since 1940 (Alaska Climate Research Centre 2009). These conditions resulted in widespread fires consuming 2.7 x 10^6 ha of forests, representing the largest annual burned area in Alaska's 58-year fire record (Todd & Jewkes 2006). Study sites were established the following spring (May, 2005) in areas that were accessible from the Taylor, Steese, and Dalton Highways. Sites encompassed a range of fire severities (stand mortality and organic layer consumption), site moisture levels, topographic positions, parent material texture, and geographic dispersion across the landscape. Sites were located within a 15 minutes (~600m) walk of the road. For this study, these study sites were revisited for sampling ten years post fire using GPS coordinates taken in 2005 and a hand held GPS unit

1.2.2 Field Sampling

1.2.2.1 Soil Sampling

Once the site markers were located a random bearing was establish for a 50m baseline transect. Three 30m transects were then established, one at the center of the baseline and two randomly, interacting the baseline transect perpendicularly. Mineral soil parent material texture was sampled by digging a randomly placed soil pit within the establish site transects. 200g of texture samples were taken from 50cm down into the mineral horizon to collect site parent material. Organic layer depths were measured every five meters of the three 30m transects to determine the average OL depth for each site. Observations for OL depth were made by digging a soil pit ever five meters and measuring down from the top of the organic soil horizon down to the top of the first mineral horizon. Nine organic layer soil cores were sampled from each site from within the nine biomass plots. Biomass plots were established at the 0m, 15m, and 30m marks on the intersecting transects. Cores were sampled after biomass collection and were sampled by a 5cm diameter coil corer attached to a power drill. Cores were sampled in 20cm increments of the top OL. If bio char was prevalent in the sample the length of char was noted and then separated from the core and placed in a separate

sample bag. Core samples were noted and bag in 20cm increments and then stored in a refrigerator until lab analysis.

1.2.2.2 Dead Woody Debris
Down dead woody debris was sampled using the brown method (Brown, 1974). Diameter of down dead black spruce were recorded at the intersection of the three 30m transects and were measured using a hand caliper and classified by 5 different size classes; class I 0-0.5cm, class II 0.5-1cm, class III 1-3cm, Class IV 3-5cm, and Class V 5+cm (Nalder 1999). Decay class was also assigned with diameter measurements. Decay class categories were (1) bark and wood intact, knife unable to penetrate samples; (2) wood beginning to get mealy, still hard for knife to penetrate sample; (3) wood mealy throughout, knife can penetrate sample somewhat; (4) wood can be broken into pieces, knife easily penetrates sample; and (5) sample no longer holds shape and splits into small pieces (Manies and Harden, 2005). Standing dead black spruce were collected by measuring all standing dead black spruce that were within one meter of either side of the 30m transects. Samples were measured for basal diameter and were all assign a decay class of one.

1.2.2.3 Vegetation Characterization
Tree and tall shrub species (*Populus tremuloides*, *Alnus rubra*, *Betula neoalaskana, Picea mariana, Larix laricina, Betula* spp*., Salix* spp.) abundance was measured as stems per meter squared. It is recognized that 50 years post fire these may not all be considered canopy species but, at ten years post fire all stems greater than 75cm were counted as they are likely to shade out and influence understory species composition. Analysis involving deciduous species used only *Populus tremuloides*, *Alnus rubra, Betula neoalaskana, Betula glandulosa* as they are the dominant species in mature deciduous forests (Johnstone et al. 2010). Along each 30m transect the species and accompanying basal diameter was recorded for all individuals within 1 meter on either side of the transect giving a total sampling area of $60m^2$ per transect. Counting all species and dividing it by the total sampling area of $180m^2$ determined total stem density per site.

1.2.2.4 Fire Severity
Fire severity was represented in three ways: the depth of organic soil consumed during the burn, the post-fire organic soil layer depth and the fraction of organic soil consumed during the burn. Depth of burn and post-fire organic soil layer depth was quantified in summers of 2005 and 2006 (Kasischke et al. 2008). Depth of burn was quantified by measuring the distance from the upper most adventitious root down to the top of the organic soil layer, with the upper most adventitious root being a marker of pre-fire organic soil depth. Post-fire organic layer depth was determined by digging a soil pit and measuring the distance from the top of the organic soil down to the mineral layer. Fraction of organic soil consumed during the fire is the ratio of depth of burn to pre fire organic layer depth (the sum of depth of burn and post-fire organic layer depth).

1.2.2.5 Biomass Accumulation

A wooden frame measuring 0.5m x 0.5m was laid down at the end of each 30m transect for a total of 6 plots per site. All plants species inside the frame were destructively harvested. Vegetation was sorted, air dried and packed in paper bags by functional types (deciduous shrub, evergreen shrub, graminoids, forb, moss, and lichen). In the laboratory samples were placed in a drying oven in the laboratory at 60°C for a minimum of 12 hours. Samples were assumed to be 50% carbon by dry biomass (Schlesinger & Bernhardt 2013).

1.2.3 Laboratory Methods

1.2.3.1 Soil Core Processing

Soil cores were weighed wet and then cut in half vertically by 20cm sections. One half was designated for root processing and the other for soil bulk density. For bulk density, the wet half was weighed and then placed in a drying oven at 65^{O} C for 48 hours then dry mass was recorded. Half of the core volume was then used to calculate bulk density for each sample. Root half place in a #10 soil sieve with #270 sieve placed underneath it. This half was then picked and sorted by root class; live roots, dead roots, and forb roots. Remaining core was then placed in a tub of DI water and floated to separate remaining roots within the core. Roots were then weighed wet by root class and then dried in a drying oven at 65^{O} C for 48 hours and then were reweighed for dry weight and recorded.

1.2.3.2 Mineral Soil Texture

Parent material samples were prepared by drying in an oven at 65^{O} C for 48 hours and then were pulverized with hammer. Samples were then sieved through a #10 mesh sieve (<2mm) to remove any rocks from sample. Rock weight and percent content were then calculated from each sample. 100g of mineral soil sample was added into a 300ml beaker with 50 ml of sodium hexamedaphosphate. Beaker was then filled the rest of the way with DI water and the solution was left to soak for 20 minutes. Once soaked the solution was then blender with an electric blender for 5 minutes to suspend soil sediments. The solution was then transferred to a 1 L cylinder and was filled to the 1 L mark with DI water. A cylinder plunger was used to mix the solution and the time was noted after mix. A hydrometer was then added to the soil suspension. Hydrometer and solution temperature were recorded at 40 seconds, 2 hours, 8 hours mark from time of solution mixing. I blank solution was made and measured at the same times as the parent material solutions. Samples were then calculated for percent sand, silt, and clay using the following formulas:

% Sand = 100 – ((R1ST – RC1) / sample weight × 100)

% Silt = (R2ND – RC2) / sample weight × 100

% Clay = 100 – % Sand – % Clay

1.2.3.3 Percent Carbon

Dried bulk density sample were grinded to <2mm with a willymill and placed in labeled container. Once ground, 16 sites were selected by texture class and topographic class to be analyzed for present carbon and nitrogen using an elemental analyzer. Samples were then weighed using a micro balance, 10mg for organic 15mg for mineral, and packaged into metal tins for elemental analysis. The remaining 22 sites were then weighed into crucibles to be heated to 500^{O} C for 12 hours in a muffle furnace for LOI (loss on ignition). Samples were then re weighted to calculate percent organic matter. Percent organic matter from elemental analysis and LOI were then plotted and regressed to predict percent C for samples that were not analyzed by elemental analysis.

1.2.3.4 Char Processing

Char samples that were separated during core sampling and were recorded for wet weight and then dried in an oven at 65^{O} C for 48 hours and were then weighed for dry weight to calculate char bulk density. Samples were then ground to <2mm particle size and the same 16 sites selected for EA core percent carbon and nitrogen were used for char elemental analysis of percent carbon, hydrogen, oxygen, nitrogen, and sulfur. Char samples were measured to 8mg for C, H and N analyses and 6mg for O and S analyses. Remaining 22 sites were weighed into crucibles and heated to 500^{O} C for 12 hours in a muffle furnace and then reweighed for LOI. A similar regression for the core samples was then applied to the char samples.

1.2.3.5 Standing and Down Dead Woody Debris Pool

Standing dead black spruce trees were quantified for above ground biomass (grams/tree) using the algorithmic equation for black spruce total above ground biomass (Yarie, et al. 2007). Basal diameter was applied for each measured standing dead black spruce and calculated for biomass. Biomass was then covered to Kg carbon by applying decay class one carbon value of 46% (Manies and Harden 2005). The carbon value was then converted to Kg C per hectare using the area of the three 30m transects. Down dead black spruce were quantified using the fuel load estimate equation to estimate Kg biomass by sample size class 1-5 (Nalder et al. 1997). Present carbon was then applied to each measurement by designated decay class 1-5 (Manies and Harden 2005). Carbon value was then converted to Kg C per hectare by applying the sample area to carbon values.

1.2.3.6 Statistical Analysis

All statistical analysis was performed in SAS 9.4. Analysis of variance (ANOVA) was used to determine if landscape position (north facing slope, south facing slope, flat upland or lowland), and texture by category (rock, loam, sandy loam, or silt loam) were significantly different by use of a least significant difference (LSD) test. Linear models were processed in SAS using a Proc Reg to achieve R^2 values for predicted models. Regressions were applied to changes in OL, bulk density, and Kg C/m^2 10

years post-fire by percent sand, silt, clay, and rock content of the parent material soil and elevation. Similar regression were also applied to the number of standing dead and down dead black spruce within the study area. Data for the ratio of 10 year to pre-fire black spruce were transformed using the Arcsine transformation to reduce the variance of the percentage. All data was examined for variance using the Bartlett's test of variance.

1.3 Results

1.3.1 Organic Layer

Mean organic layer depth varied by a factor of site aspect across the landscape classes evaluated (Figure 2). Organic layer depths did not differed by aspect position prior to burning (P<.03). However, lowland (9.49cm and 10.42cm) and north facing (5.55 cm) sites differed from upland and south facing aspects 1 year following fire (P<.01) where lowland and north slopes have significantly deeper organic layers. Ten years post-fire, only lowlands (7.72, 8.71, and 12.89 cm) have significantly different mean OL depths from all other aspect positions (P<.05). Organic layer thickness 10 years after burning also varied with mineral soil texture. As percentages of fine textured material increase within the soil parent material organic layer depths increase 10 years post-fire with increasing clay particles (P<.03). Additionally, change between 1 year and 10 year post-fire OL (P<.001) also increase with increased fines within the PM (Figure 3). However, as elevation increases both pre-fire and 10 year OL depth decrease with elevation rise (P<.001). Percent OL consumption 1 year and 10 years following fire are significantly different by aspect (P<.05) where lowlands have the least amount of OL loss due to fire. In terms of OL recovery between 1 year and 10 year OL measurements lowlands also have the best rates of OM accumulation than all other aspects (P<.03) following wildfire. For PM texture clay was found to be moderately significant (P=.07) as the percentages of fines increased within the PM 10 year OL measurement are found to be more relative to pre-fire OL depths.

1.3.2 Bulk Density

Site bulk density means for 1 year (P<.01) and 10 years (P<.01) post-fire differ by aspect positons (Figure 4). Lowlands and north facing slopes have significantly smaller bulk densities than south facing aspects 1 year following burning. However, 10 year post-fire south facing slopes are only significantly different from lowlands where south slopes have the largest mean bulk density values and lowlands have the lowest. Mean bulk density also varied with PM texture for 10 year post-fire BD and change between 1 year and 10 year BD (Figure 3). As the amount of fine textured material increases within the PM 10 year BD (P<.001) and change between 1 and 10 BD decrease (P<.01). Ten year mean bulk densities were also found to be affected by the amount of OL consumption from burning. As the percentage of 10 year OL consumption increases, 10 year bulk densities increase (P<.01).

1.3.3 Belowground Carbon

Carbon pools were not observed to vary by landscape position for 1 year, 10 year, and difference between both 1 and 10 year post-fire measurements (Figure 5). However, It was observed that as elevation increases within the landscape 10 year belowground carbon pools decrease ($P<.01$). Organic layer consumption from fire is the most significant predictor for post-fire carbon pools where increase of OL consumption decreases both 10 year carbon stocks ($P<.001$) and change between 1 and 10 year post-fire carbon stocks ($P<.03$). Parent material texture is also a factor driving belowground carbon stocks following fire (Figure 6). It is observed that as the percentage of rock increases within the PM change between 1 and 10 year carbon decreases with increasing coarse textured material ($P<.05$).

1.3.4 Standing Dead and Down Dead Carbon Pools

Down dead and standing dead black spruce do not differ across the varying topographic positons but PM texture, organic layer depth, and OL consumption do influence whether post-fire black spruce are left standing or become part of the down woody debris pool. Increases in coarse textured material to PM decrease the amount of standing dead black spruce within sites ($P<.01$). additionally OL depth and OL consumption from fire increase the number of standing dead black spruce with increasing OL depth and decreasing of OL consumption ($P<.01$). Standing and down black spruce carbon vary across the evaluated landscape positions. Lowland and north facing slopes have less down dead carbon than upland (1096.6 and 864.8 kg C/ha) aspects ($P<.03$). Pre-fire OL depths increase the amount of standing black spruce carbon with increasing OL depths ($P<.001$). Increase of OL consumption increases the down woody carbon pool (Figure 7) ($P<.01$).

1.3.5 Organic Layer Char

Charcoal layers found at the surface of the organic soil horizon have an atomic O:C ratio that is lower in sites with south and upland topographic positons than north and lowland positions (Figure 8). However, the H:C ratio of the char layer increases in sites that have north and lowland aspects compared to south and upland.

1.4 Discussion

Turetsky et al. (2011) reports on a series of Alaskan black spruce stands that burned during a severe fire year (2004). By sampling across a range of landscape conditions as well as early versus late season fire activity, they documented a range of depth of burn and resulting ecosystem carbon losses. In this study, our objective was to determine relationships between the amount of organic soil consumed during the 2004 fires and the responses 10 years post-fire, to determine whether there are relationships consistent across a range of landscape physiography by aspect and parent material texture.

Recent literature has suggested that boreal forests could be less resilient with warming due to increases in fire frequency (Kasischke & Turetsky, 2006) and burn

severity (Johnstone et al. 2006; Turetsky et al. 2011). Following severe fires that remove a large portion of the organic soil layer, a coniferous stand may move from a domain of self-replacement to a new successional trajectory of increasing dominance by deciduous species. This state change occurs because deciduous species have the competitive advantage in colonizing very shallow organic soil layers or mineral soils exposed by combustion (Johnstone et al. 2010).

Aspect does vary for OL depth 1 year and 10 years post-fire across the landscape positions (Figure 2). Where lowlands, as expected, were found to have deeper organic layer depths than all other aspects for both 1 year and 10 years after burning. This was most likely due to the fact that these lowland systems exhibit higher water table and thus higher moisture content then the other landscape positions. This increase in ground moisture effects severity of OL burning during a fire event and therefore reduces the amount of OL consumption (Turetsky er al. 2011; Kane, 2007).

As hypothesized, parent material texture influenced organic layer depths 1 year and 10 years after burning. We found that as the percentage of fine textured material increases within the parent material OL depth both 1 year post-fire, 10 years post-fire, and change between 1 and 10 year OL increase. Previous field-based studies on reduction of OL depth from burning have focused on the regulation of soil moisture content during fire (Dyrness and Norum, 1983; Kasischke and Johnstone, 2005). Factors controlling soil moisture include seasonal weather variation and time of seasonal burn (Turetsky et al. 2011; Kane et al. 2007), topography and slope (Miyanishi and Johnson 2002; Kane et al. 2007; Turetsky et al. 2011), and soil drainage influenced by parent material soil (Swanson, 1996; Harden et al. 2000). However the scope of these previous studies have been limited by not examining the interactions landscape position and parent material texture on soil organic matter consumption and distribution of standing and down dead black spruce carbon (Turetsky et al. 2011; kasischke and Johnstone, 2005; Kane et al. 2007, Harden et al. 2000; Swanson et al. 1996; Manies et al. 2005).

Our results show that depth of burn explains a significant amount of variation in below and aboveground carbon distributions ten years post-fire (figure 7). Most importantly the data suggests that increases in depth of burn influences aboveground and belowground carbon trajectories. For example, we found that as depth of burn increased, percent OL consumption, the amount of standing post-fire black spruce decrease while the amount of down dead black spruce increase. Thus decreasing the amount of aboveground carbon and contributing to the belowground carbon pool.

As predicted, trends between parent material texture, organic layer accrual, and changes to soil bulk density following fire are significant (Figure 3 and Figure 4). We observed that as the percentage of fine textured material (percent clay) increase within the PM influences the depth of burn, OL accrual following burn, and post-fire bulk density. As percent clay increases depth of burn decreases and changes in bulk density and change between 1 and 10 year post-fire OL depths increase.

Our data, in combination with other published studies on post-fire belowground carbon stocks, suggests that it would take approximately 50 years to re-accumulate the carbon lost during organic layer combustion in comparison to current fire return intervals in this region of between 80 – 120 years (Hart and Chen 2006; O'Niell et al. 2003). Increasing fire frequency, severity or late season burning could cause ecosystems to be a net source of carbon to the atmosphere across multiple fire cycles. However, this will only occur if there is sufficient organic soil to burn. On the other hand, Alexander et al. (2015) found that shifts from black spruce stands to greater deciduous cover lead to a substantial increase in aboveground carbon accumulation in intermediated age stands. Despite these rapid rates of biomass accumulation, it is unclear how long this carbon could be preserved in this ecosystem state with fast turnover rates (relative to the conifer domain) and whether ultimately this carbon will be transferred to soil layers. Thus, while it is clear that both carbon losses associated with combustion as well as carbon gains via plant regrowth and OL accrual will be altered in a warming world, the balance between these processes will depend on a variety of factors such as fire behavior but also plant trails and post-fire nutrient cycling.

1.5 Conclusion

Soil organic layer consumption from fire and OM accrual following fire is a complex process dependent on a number of landscape characteristics and climate factors including topographic sequence, mineral soil texture, vegetation characteristics, presence of permafrost, time of burning event, and seasonal variations of climate. Late season fires have the potential for deeper burning than early season fires (Turetsky et al. 2011). Soil moisture and permafrost depth is also very important in regulating OL consumption from wildfires (Kasischke and Johnstone, 2005).

Together, field measurements, laboratory experiments, and models provide strong evidence that interactions between landscape position, soil parent material texture, and seasonal burning regulate C source-sink dynamics within black spruce systems following wildfire disturbance. Our data suggest that higher C emissions are likely to occur from wildfires occurring in sites with deeper organic layer if conditions in boreal forests become drier. Fire activity and frequency has been increasing in Alaska over the past four decades with this past decade experiencing the largest amount of landscape burned within interior Alaska since recorded history (Kasischke et al. 2005). Changes to climate warming are likely to owe to increases in the amount of late-season burning and reduction of soil moisture. Thus, increasing the potential for deeper burning of soil organic layer.

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1.7 Tables

Table 1.1 Description of site physiography with percent sand silt clay, and rock and OL depths of sites sampled during the summer 2014 field season.

Site	Texture	Aspect	% Sand	% Silt	% Clay	% Rock	Pre-fire		1 YR Post-fire		10 YR Post-fire	
							Mean OL	SE	Mean OL	SE	Mean OL	SE
BYM01	Rock	Flat Upland	0	0	0	100.00	28.9	1.75	9.1	1.22	8.76	.60
BYM02	Rock	Flat Upland	0	0	0	100.00	28.9	1.27	4.6	0.84	8.60	0.76
BYM03	Loam	Flat Upland	38	47	15	22.61	29	1.72	7.5	0.88	9.24	0.92
BYM04	Rock	North Slope	0	0	0	100.00	41.2	1.97	12.9	2.09	18.20	1.78
BYM05	Rock	North Slope	0	0	0	100.00	36.4	1.57	21.4	1.82	19.28	1.67
BYM12	Silt Loam	North Slope	36.6	57.4	12	0.24	34.4	1.72	20.9	1.5	11.54	1.29
BYM13	Sandy Loam	North Slope	55	40	5	54.79	31.2	2.02	18	1.97	17.72	2.26
BY-14	Rock	North Slope	0	0	0	100.00	25.1	1.18	12.5	1.52	9.56	1.31
BYM15	Rock	North Slope	0	0	0	100.00	24.5	1.24	8.4	0.71	6.52	0.86
BYM25	Silt Loam	Flat Lowland	37.4	10	52.6	0	27.6	1.57	19.7	2.23	32.36	1.56
BYM28	Silt Loam	Flat Lowland	43	51	6	4.64	27.1	1.43	14.5	1.7	16.60	1.79
BYM29/30	Rock	South Slope	0	0	0	100.00	1.25	1.25	6	0.68	7.24	0.66
BYM32	Silt Loam	South Slope	45	46	9	42.90	22.7	0.88	11.3	1.34	13.54	1.37
BYM38	Rock	Flat Lowland	0	0	0	100.00	33.2	1.78	18.7	2.91	18.68	1.35
BYM9/10	Sandy Loam	South Slope	53	41	6	39.29	38.7	3.45	13	1.05	10.00	1.22
EC03B50	Silt Loam	Flat Upland	27.5	20	52.2	61.10	18.4	1.04	9.8	0.9	15.60	1.72
EC03B59	Silt Loam	South Slope	32	54	14	63.83	28	1.61	12.1	1.5	8.72	0.86
EC03BG1	Silt Loam	South Slope	35	50	15	2.41	25.7	1.19	8.9	0.73	10.16	0.82

EC03BG2	Silt Loam	North Slope	27.5	22.5	50	0	18.7	0.75	3.9	0.3	8.44	0.79
GTM04	Rock	North Slope	0	0	0	100.00	39.4	1.48	15.7	1.67	11.60	2.11
GTM05	Silt Loam	Flat Lowland	32	7	61	0	43.8	2.87	30.6	2.73	41.04	2.64
GTM21	Rock	Flat Upland	0	0	0	100.00	39.9	2.48	17.6	2.46	36.56	1.80
GTM32	Rock	Flat Upland	0	0	0	100.00	33.9	2.16	1.7	0.64	5.18	0.60
PEM01	Loam	South Slope	50	15	35	56.01	21.6	0.9	3.3	0.61	7.12	0.70
PEM02	Loam	Flat Lowland	51	9	40	55.98	27.5	1.51	9.4	0.81	5.88	0.48
PEM03	Loam	Flat Upland	52.5	35	12.5	82.03	19.7	0.84	8.2	0.53	8.08	0.57
PEM04	Sandy Loam	North Slope	54	36	10	72.67	26.4	1.39	9.2	2.19	9.48	0.65
PEM07	Sandy Loam	South Slope	57.3	16.7	26	65.93	17.5	1.34	6.6	1.22	10.32	0.94
PEM14/19	Sandy Loam	Flat Lowland	71	20	9	49.54	30.8	1.36	19	1.09	5.32	0.39
PEM17/18	Loam	South Slope	49	39	12	60.60	16.6	0.55	2.8	0.47	15.28	0.88
PEM21	Sandy Loam	Flat Lowland	70	26	4	29.34	24.1	1.38	11.7	0.97	7.20	0.56
PEM22	Loam	Flat Upland	49.8	40.2	10	6.02	26.9	1.5	12.8	1.02	15.44	1.29
PEM25	Loam	North Slope	47	38	15	61.28	30.2	1.36	11.3	1.01	21.24	1.46
PEM30	Loam	North Slope	40	42	18	57.40	27.6	0.92	9.3	0.9	10.80	0.87
PEM61	Silt Loam	Flat Upland	40	50	10	47.97	20.2	0.56	5.8	0.44	10.62	1.17
Porc5aB	Loam	Flat Upland	42	16	42	45.68	23.1	0.54	6.5	0.42	9.88	0.83

1.8 Figures

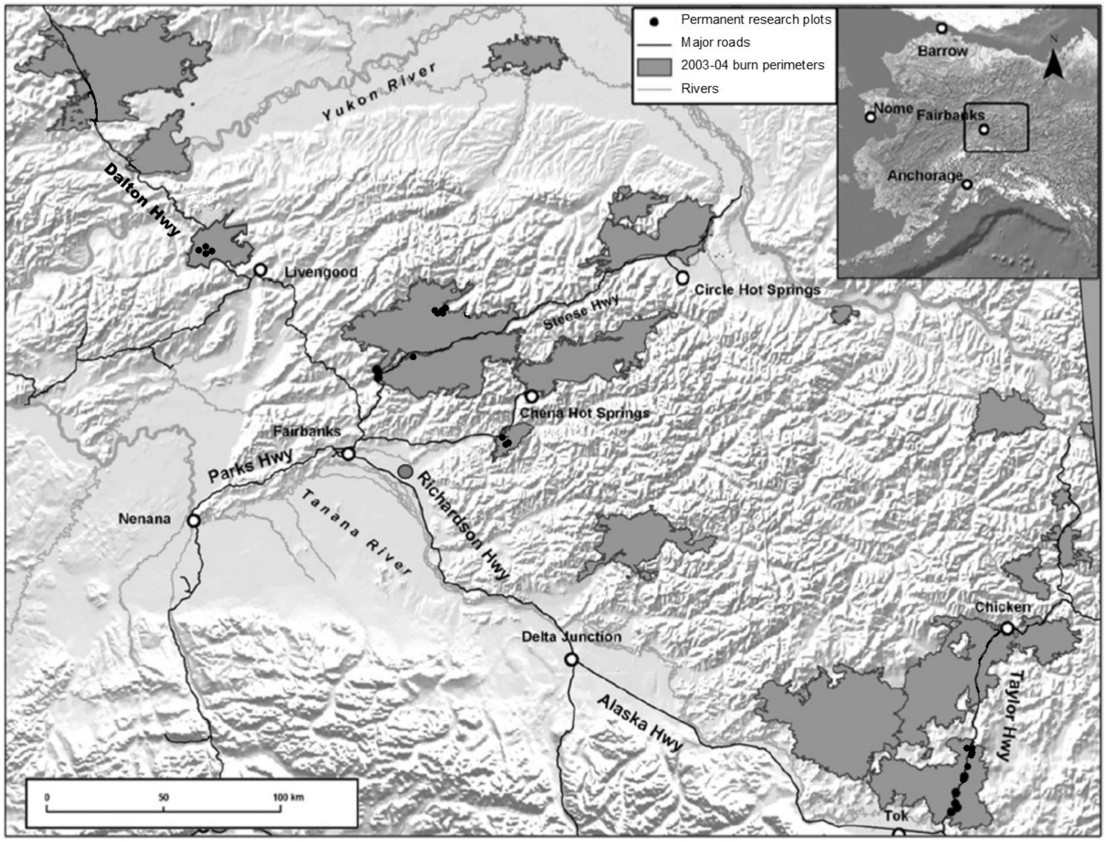

Figure 1. Map of study sites in interior Alaska. Sites are depicted as black circles within the larger fire events shown as grey filled polygons.

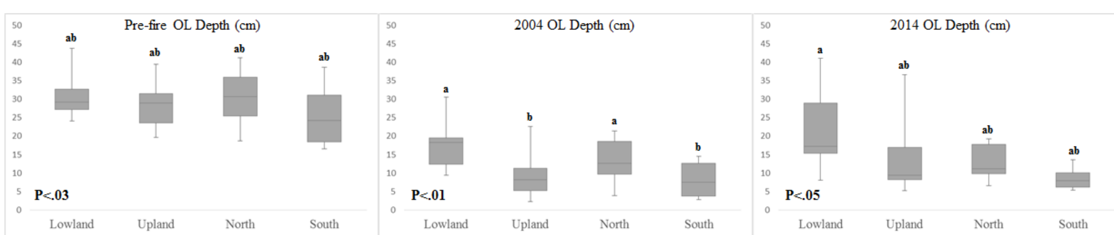

Figure 2. Distribution of pre-fire, 1 year, and 10 year OL means by aspect.

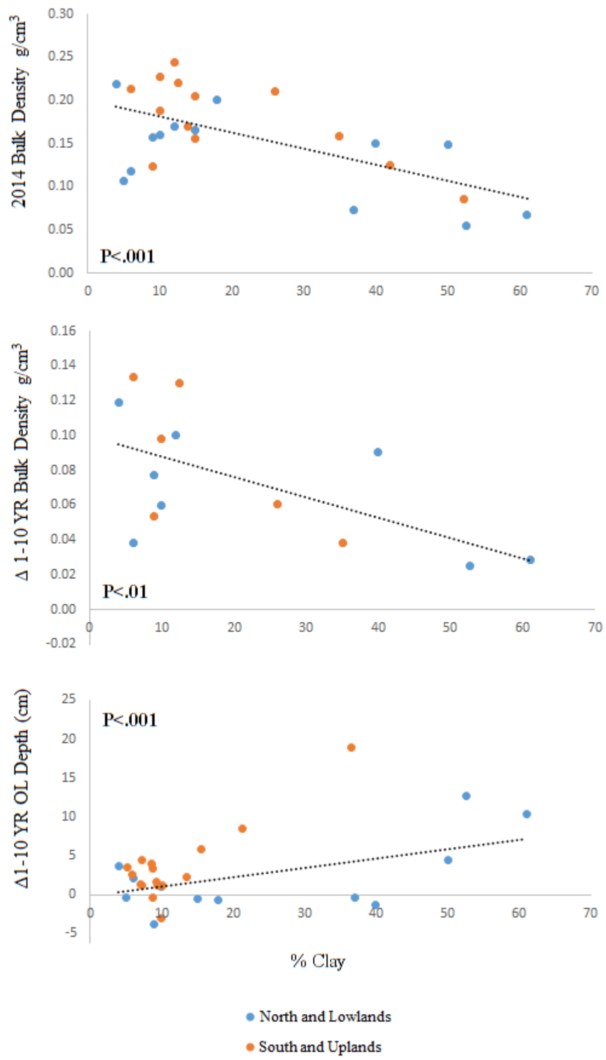

Figure 3. 10 year bulk density, change between 1 and 10 year bulk density, and change in 1 and 10 year OL depth regressed by percent clay and separated by landscape position.

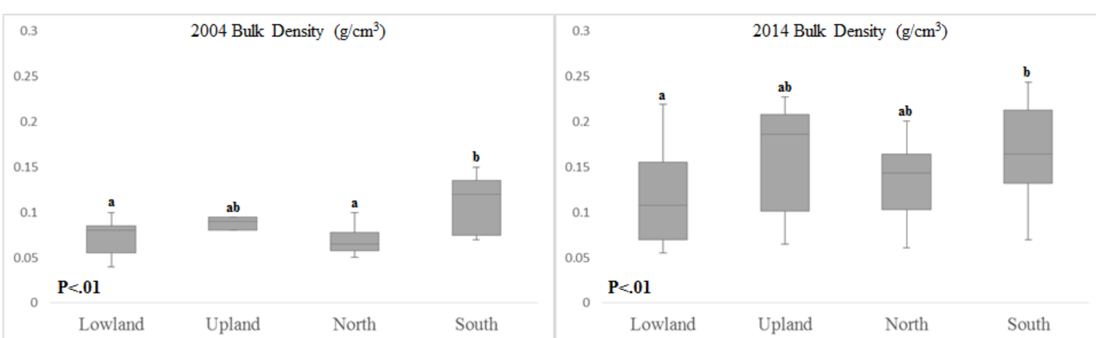

Figure 4. 1 year and 10 year bulk densities by aspect.

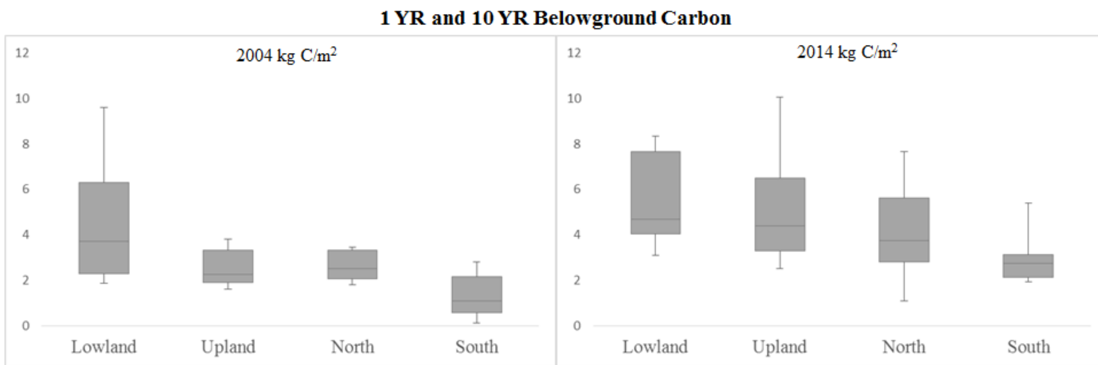

Figure 5. 1 year and 10 year belowground carbon pool by aspect.

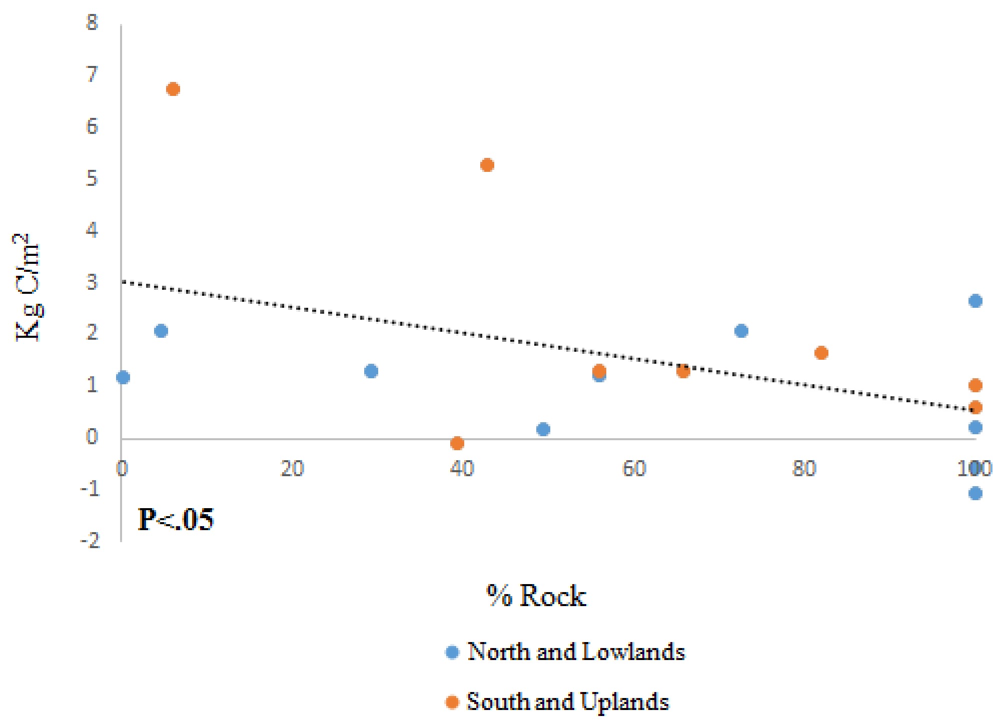

Figure 6. 10 year belowground carbon by percent rock separated by landscape position.

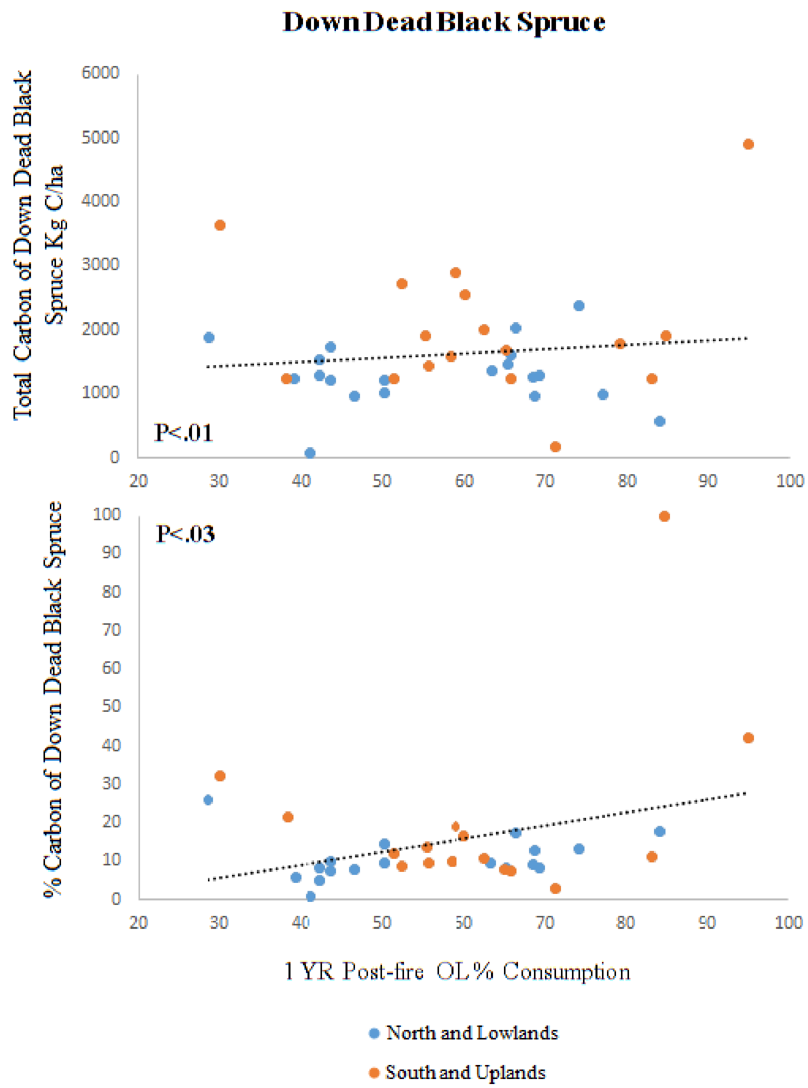

Figure 7. Down dead black spruce total carbon and percent distribution of carbon by 1 year OL consumption separated by landscape position.

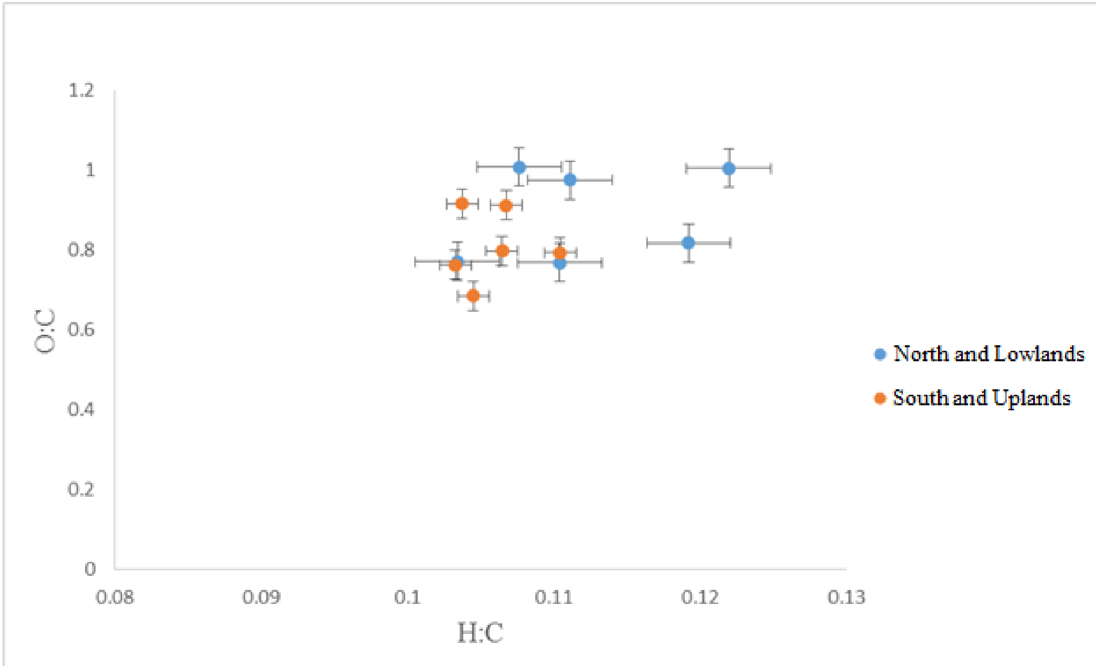

Figure 8. Char layer O:C to H:C ratio by landscape position.