Comparative Analysis of Soil Properties and Carbon Stocks in Fire- and Permafrost-Affected Soils Under Black Spruce (Copper River Basin, AK)

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Background and Objective:

Soils under black spruce (*P. mariana*) -dominated forest communities cover ~29% of the land area of Alaska and vary widely in their physical, chemical, and biological properties (Ping et al., 2010). Fire is a critical component of boreal black spruce ecosystems, and studies in the Alaskan Interior on loess parent materials have shown that changes in soil properties under black spruce are particularly sensitive to fire histories and environmental change (O'Donnell et al., 2011a, 2011b). The Copper River basin is one of the southernmost locations of discontinuous permafrost in Alaska, and is underlain by extensive glaciolacustrine deposits characterized by restricted drainage, shallow permafrost, and dominated by black spruce forest communities. The objective of this collaborative study was to conduct a comparative analysis of soil properties and soil carbon stocks between late-successional and post-fire (~80 yr) sites in the Copper River basin.

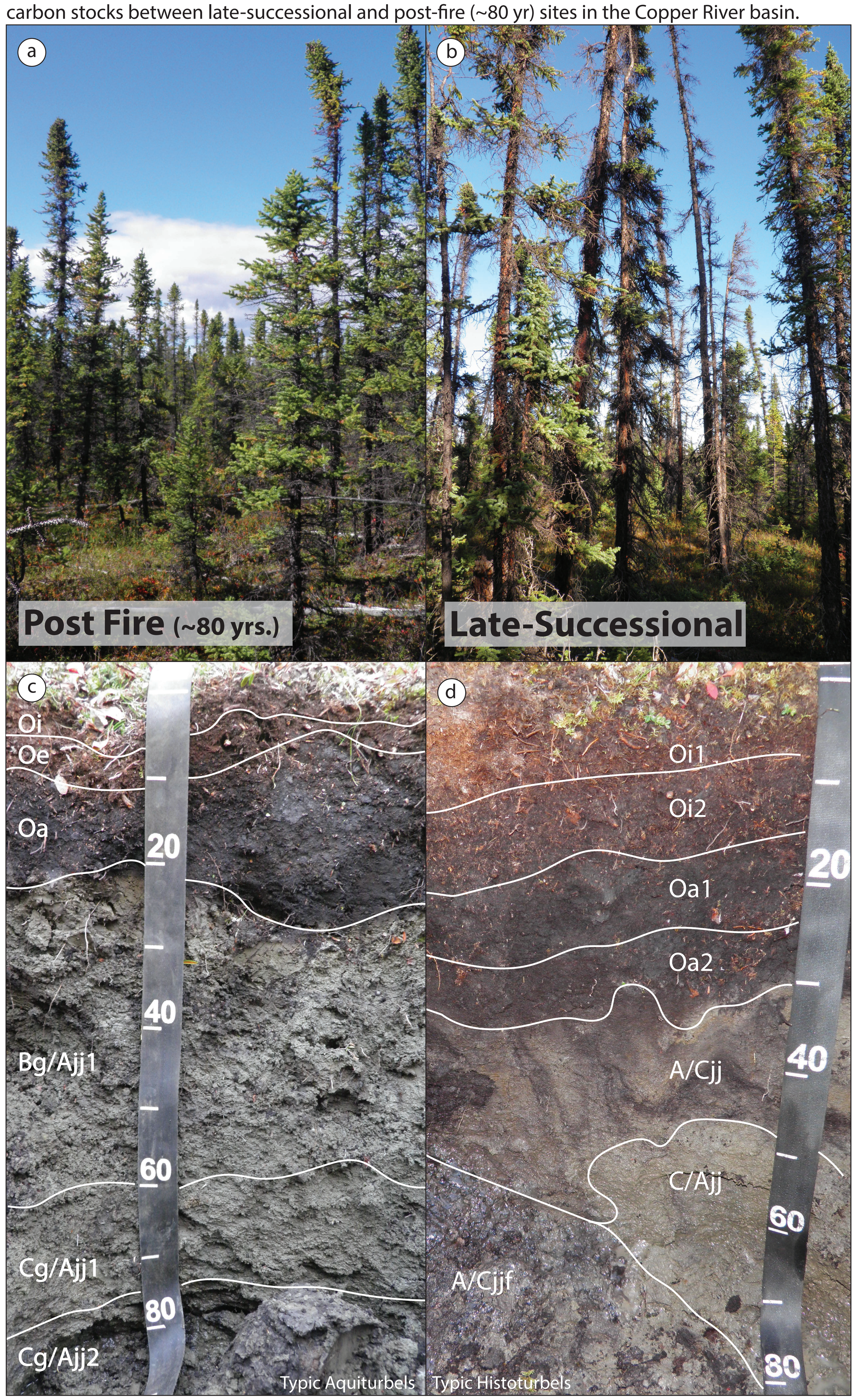

Figure 1. Tree stand and soil comparison for representative black spruce (*P. mariana*) sites in the Copper River basin. **(a)** Post-Fire (~80 yrs) black spruce site and **(b)** soil (image and annotation - N.A. Jelinski) , **(c)** Late successional black spruce site and **(d)** soil (image and annotation - N.A. Jelinski).

Results and Discussion:

Our comparative study revealed that the depth to frozen materials and permafrost was significantly deeper in 80 year post-fire sites than late-successional sites (***Table 1, Figure 2***), despite the fact that the depth of surficial organic materials was not statistically different (Table 1). Total carbon stocks to 1m depth were significantly higher in late-successional sites by an average of 17 kg m^{-2} (***Table 1***). Late successional sites exhibited water content increases in the ice-rich upper permafrost while water content in the upper permafrost in the post-fire sites did not appear to significantly increase from the loweractive layer (***Figures 2a and 2b***). While bulk density decreased in the upper permafrost of the late-successional sites, bulk density increased in the upper permafrost of the post-fire sites, potentially indicating post-fire thaw and collapse of the mineral soil with no subsequent aggradation of the permafrost table and segregation ice formation (***Figure 2c***). Interestingly, while a statistically significant linear relationship existed between thickness of the organic layer and both depth to frozen and total 1m SOC stocks for the late-successional sites, no significant relationships existed for the 80 year post-fire sites (***Figure 3a and 3b***).

These results imply that although the thickness of the organic layer may recover within 80 years post-fire, permafrost depth and total SOC stocks may still differ significantly from late-successional sites. Interactions between hydrology, stand dynamics, and climate variability may be responsible for these observations.

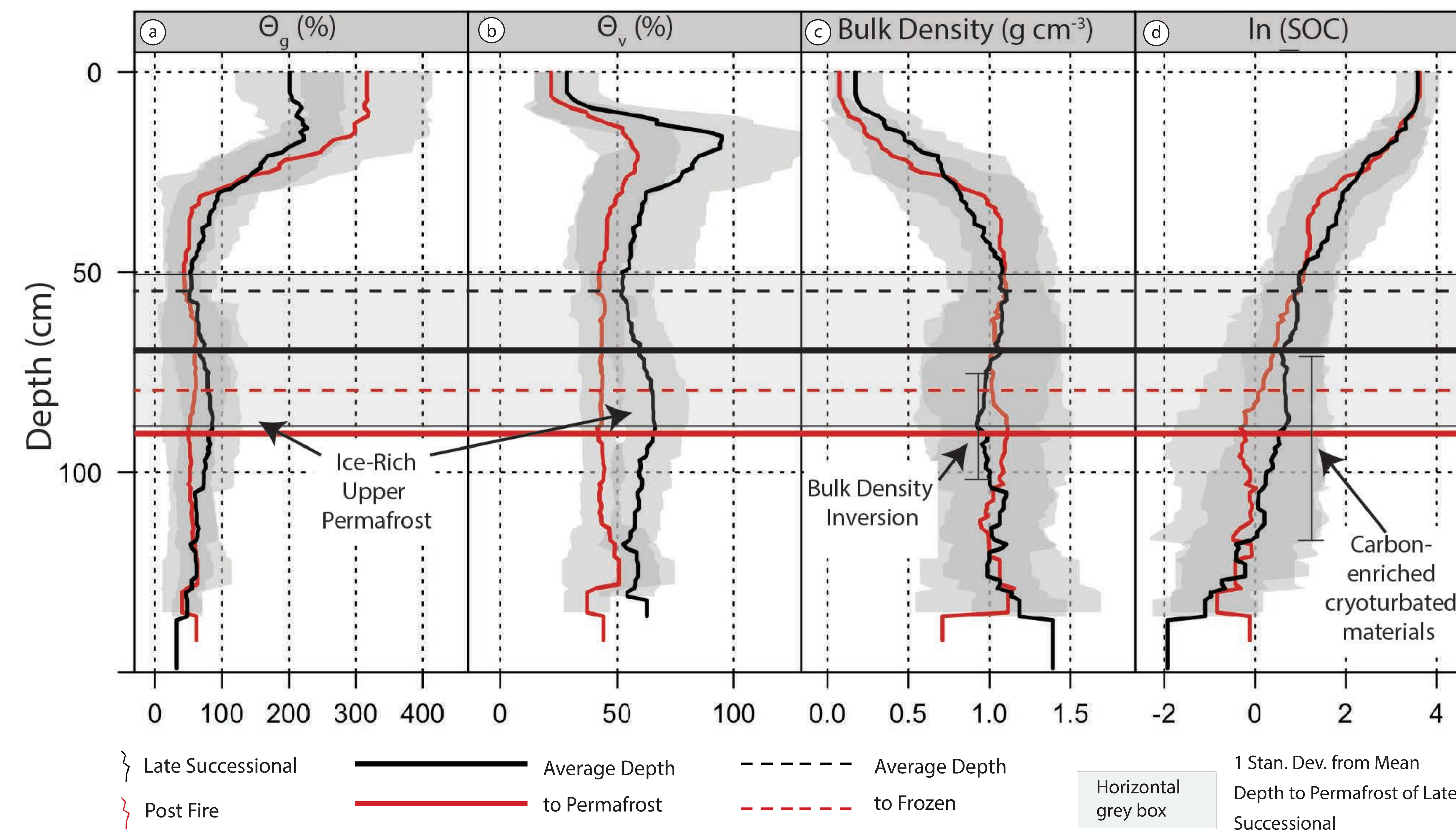

Figure 6. Plots of slabbed depth profiles (using the AQP package in R (Beaudette et al., 2013)) of **(a)** Gravimetric Water Content , **(b)** Volumetric Water Content, and **(c)** bulk density, and **(d)** the natural logarithm of SOC concentration (%). The vertically oriented black and red lines on each panel represent the group average of each 1-cm slab (for late-successional (black), n = 22; and 80 yr post-fire (red), n = 22), plotted with depth in the profile, while the shaded grey region represents +/- one standard deviation from the mean, calculated for each individual depth increment.

Average:	Late Successional	Post Fire
Total Carbon Stock to 1 Meter (kg*m^{-2})	50 ± 12	27 ± 10
Depth of Organics (cm)	31 ± 10	28 ± 7
Percent of 1 Meter C. Stock in Organic Material	56 ± 14	39 ± 15
Depth to Frozen (cm)	56 ± 12	79 ± 27
Percent of 1 Meter C. Stock in Cryoturbated Materials	43 ± 14	54 ± 55

Table 1. Summary of 1m SOC stocks, depth of surficial organic layer, proportion of 1m SOC stock in organic materials, depth to frozen materials, proportion of 1m SOC stock in cryoturbated mineral materials for late-successional (n=22) and ~80 yr post-fire (n=22) sites on lacustrine soils in the Copper River basin. The percent of 1m SOC stocks in organic and cryoturbated materials was calculated for individual sites prior to averaging.

Methods:

In late August of 2017 and 2018, a total of 44 sampling sites (22 late-successional and 22 ~80-year post-fire) were chosen within the Glacial Lake Ahtna lacustrine plain of the Copper River basin using satellite imagery and observations of tree stand density and growth habit. Preliminary work in 2016 indicated that the post-fire sites likely experienced a stand-replacing fire ~80 years prior to sampling, while late-successional sites had not experienced fire in at least the previous 150-180 years. At each site, soil morphology was characterized by hand digging a soil pit in the active layer, followed by permafrost sampling using a SIPRE (Snow, Ice, and Permafrost Research Establishment) corer to depths of 1-2m. Cross-sectional tree samples were also taken from each plot to aid in the determination of fire histories. Samples of known volumes were taken from organic materials using the standardized USDA-NRCS RApid Carbon Assessment (RACA) box, samples of unfrozen mineral materials in the active layer were taken using a ring of known volume, and frozen materials were sampled using the SIPRE auger. Soil organic carbon (SOC) was determined by dry combustion and loss on ignition.

Figure 5. E. GreyBear and K. Finnesand operating SIPRE corer to extract permafrost core samples.

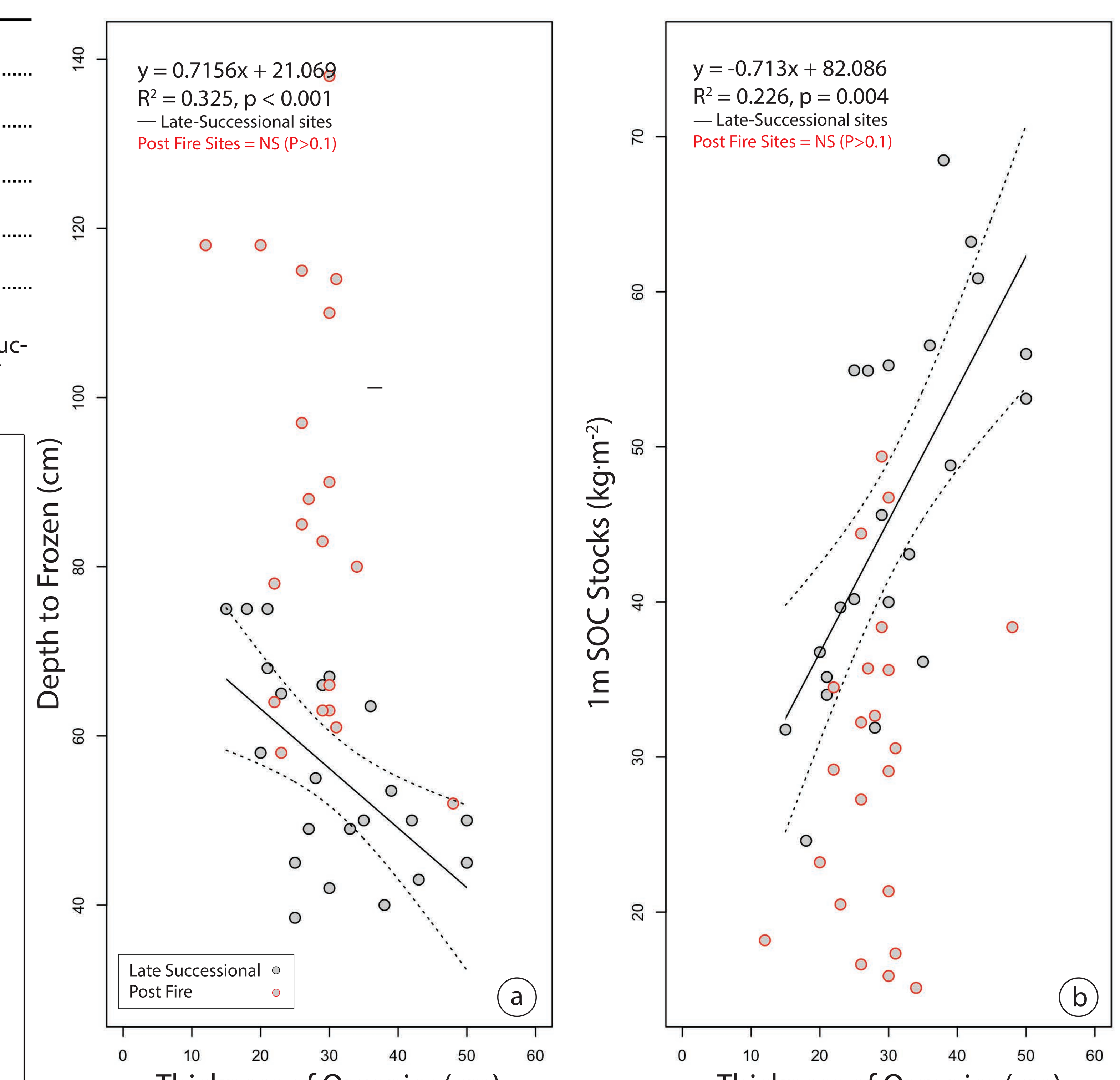

Figure 3. Scatter plots showing relationships between the thickness of surficial organic materials at each site and **(a)** depth to frozen materials and (b) 1m SOC Stocks (kg m^{-2}) for late-successional (n=22) and ~80 yr post-fire (n=22) sites. Linear relationships for post-fire sites were not significant (p > 0.1). Dotted lines represent the 95% C.I. of the slope of the regression line for late-successional sites.

References: O'Donnell et al., 2011a. Global Change Biology 17:1461-1474; O'Donnell et al., 2011b. Biogeosciences 8: 1367-1382; Ping et al., 2010 SSSAJ 74: 969-978; Beaudette et al., 2013. Computers and Geosciences 52: 258-268; R Core Team, 2016. R: A language and environment for statistical computing.

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