

Mineralogical and micromorphological modifications in soil affected by slash pile burn.

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Abstract

Silvicultural practices, such as slash pile burning, are commonly used for fire and ecosystem management. This management technique can drastically alter chemical, physical and biological soil properties due to the high temperatures achieved during the prolonged severe burn. Little is known, however, about the impact of high-temperature slash pile burning on soil mineralogical and micromorphological properties. Soil changes were investigated in Manitou Experimental Forest in Rocky Mountains of Central Colorado to identify possible temperature-induced modifications in mineralogical and micromorphological properties that can impact thermal conductivity in soil affected by slash pile burning. Prescribed burning did not affect clay and silt fraction mineralogy. However, changes in post-burn mineralogical composition were evident in sand fractions, when compared to the pre-burn mineralogy. These differences were attributed to the formation of Mn oxide/hydroxide coatings by the process of mass transport through soil with convective air current during the fire. Resinous pine species used as fire fuel were thought to be the source of Mn input. Micromorphological analysis also confirmed the presence of Mn coatings on sand-sized grains, as well as the presence of Mn nodules and microfabric enrichment.

Keywords: slash pile burning, fire mineralogy, fire micromorphology

1. Impact of prescribed fire on soil mineralogy and micromorphology

Silvicultural practices such as slash pile burning are commonly used for fire and ecosystem management. Effect of high temperatures achieved during prolonged severe burn on chemical, physical and biological soil properties is generally well studied. Less is known, however, about the impact of high-temperature fire on soil mineralogical composition that can in turn affect soil structure and texture. Previous study by Ulery et al. (1996) found chlorite, chlorite-vermiculite, vermiculite and hydroxy-interlayered vermiculite transformed to illite as a result of slash pile burning, while kaolinite completely decomposed. Arocena and Opio (2003) also noted reduction in vermiculite in prescribed pile burning, but no kaolinite decomposition.

We investigated mineralogical and micromorphological changes in upper soil horizons after experimental slash pile burning in a managed ecosystem study. Previous studies (Massman et al., 2007) indicate that soil thermal conductivity at two slash pile burn sites was affected for years after a burn without a detectable change in soil bulk density. We hypothesized that heat-driven changes in mineralogical soil composition led to the micromorphological modifications, and, as a result, impacted thermal conductivity properties of these soils.

2. Materials and Methods

Experimental burning was conducted at the Manitou Experimental Forest (MEF) located in the Rocky Mountains of Central Colorado. Majority of soils of Manitou Experimental Forest soils are formed on biotite granite and associated igneous rocks of the Pikes Peak batholith, with few inclusions formed on red arkosic sandstone and alluvial fans. These soils have low available water holding capacity, moderately rapid permeability, and slow or medium runoff. The soil at the study site was classified as fine-loamy, mixed, frigid, Pachic Argiustolls, similar in description to PerryPark series.

Slash pile burning was carried out in November 2008. Fire was allowed to burn out naturally, and was not doused out with water. No rainfall occurred either during the burning or in the time period between the fire and sample collection. Composite soil samples were collected from the depths of 0-5 and 5-10 cm prior to the burning and four days after the burning was completed. Soil temperature before, during and after the burn was continuously measured at 0, 2, 5 and 10 cm depths (Fig. 1).

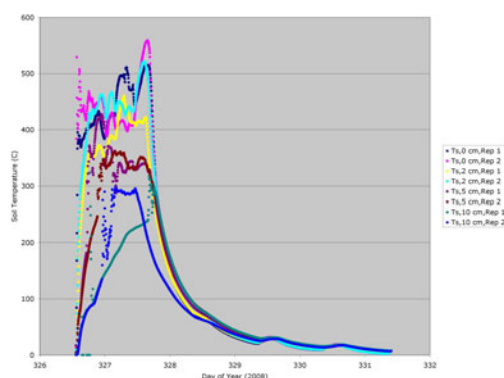


Figure 1. Soil temperature beneath the center of slash pile before, during and after prescribed burning.

Oriented clay samples were prepared for both pre and post-burn soils. Samples were analyzed with X-ray diffraction (XRD) using Panalytical X'Pert Pro MPD diffraction system. Sand and silt fractions of pre and post-burn soil samples were also separated and analyzed with XRD as powder samples. Undisturbed pre and post-burn soil samples were air-dried and vacuum-impregnated with clear epoxy resin. Polished blocks were mounted on small (27x46 mm) glass slides and cut into thin sections. Thin sections were examined with a petrographic microscope, described and photographed. Samples were digested with HNO_3 , and extracts were analyzed with Perkin Elmer Optima 2100 DV ICP Spectrophotometer to determine total Mn concentrations in pre and post-burn samples (Fig. 2).

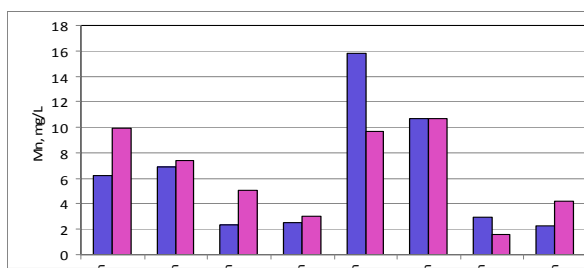


Figure 2. Total Mn concentrations in bulk soil samples and sand, silt and clay fractions in pre and post-burn samples.

3. Mineralogical changes

Kaolinite, vermiculite, mica, and interstratified illite-vermiculite were identified in clay fractions. No post-burn changes were detected in mineralogical composition of clay fraction of soil samples from either 0-5 or 5-10 cm depths (Fig. 3A, data shown for 0-5 cm sample). Mica, kaolinite, quartz, feldspars and dolomite were present in silt fraction of pre-burn soil, which remained unchanged for post-burn samples (Fig. 3B). Changes in diffraction patterns for both 0-5 and 5-10 cm depths were detected in sand fractions of post-burn soil (Fig. 3C). Differences in diffraction patterns were possibly due to the presence of pyrolusite (MnO_2), birnessite $((\text{Na}_{0.3}\text{Ca}_{0.1}\text{K}_{0.1})(\text{Mn}^{4+}, \text{Mn}^{3+})_2\text{O}_4 \times 1.5 \text{ H}_2\text{O})$, jacobsonite (MnFe_2O_4), ramsdellite (MnO_2), bixbyite $((\text{Mn}, \text{Fe})_2\text{O}_3)$, and other Mn-containing minerals.

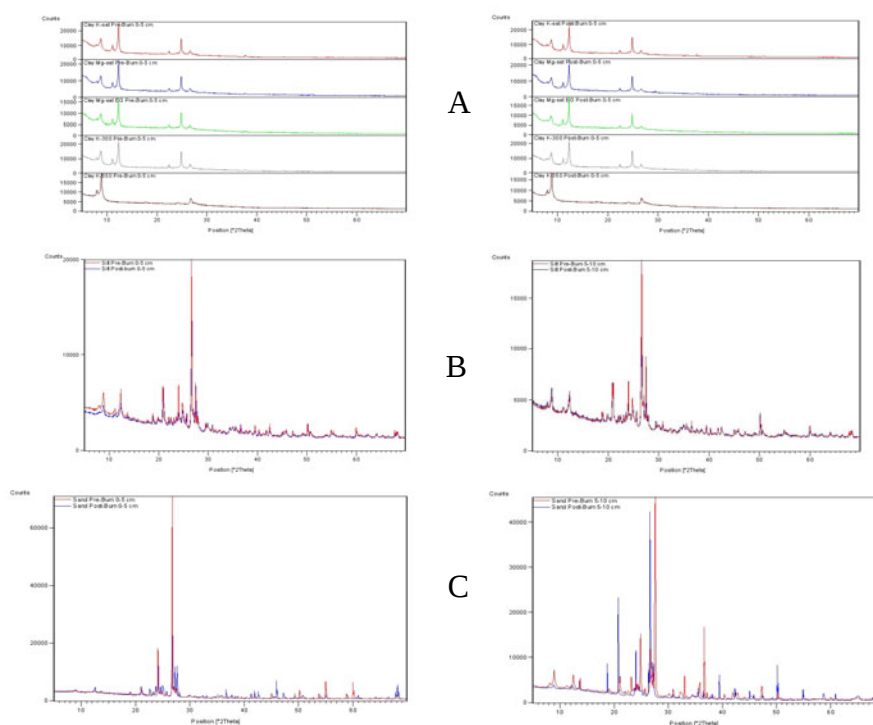


Figure 3. X-ray diffraction patterns of clay (A), silt (B) and sand (C) fractions in pre-burn (left column) and post-burn (right column) soil samples

4. Micromorphological changes

Examination of thin sections of post-burn soil samples showed increased presence (as compared to pre-burn samples) of dark-colored Mn/Fe nodules, coatings (mangans and ferri-mangans) on surfaces of sand-sized grains, increased microfabric enrichment with Mn-containing materials, and alteration of soil microstructure through pore infilling (Fig. 4).

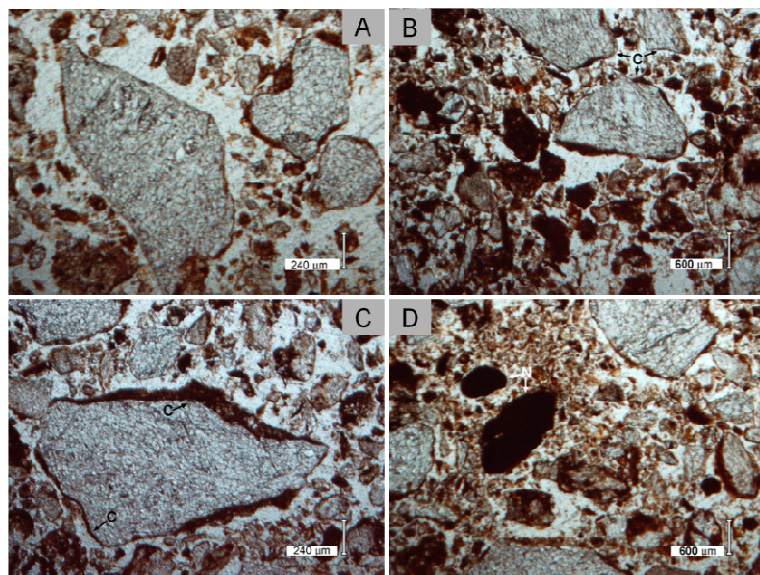


Figure 4. Microphotograph from thin sections of A: pre-burn soil sample, 0-5 cm depth; B: post-burn soil sample, 0-5 cm depth; C: post-burn soil sample, 0-5 cm depth; D: post-burn soil sample, 5-10 cm depth, showing Mn-enriched nodules (N) and coatings on surfaces of sand-size grains (C).

Past studies (Gonzalez Parra et al., 1996) showed significant increase of total Mn concentrations in easily reducible oxide forms in surface horizons of soils affected by wildfire. Several vegetation species, especially resinous coniferous types, may accumulate Mn in their leaves and needles, reaching amounts of $>1000 \mu\text{g/g}$, which is later transferred into soil as a result of ash deposition. Results of chemical analysis showed Mn enrichment of post-burn soil material, and sand fraction in particular, at both 0-5 and 5-10 cm depths (Fig. 2). This increase in Mn compounds in surface horizons was attributed to the element's deposition with slash pile ash. Mass transport of these compounds through surface soil horizons is thought to be due to fire-induced air circulation within the soil during prolonged high-temperature burns (Massman et al., 2009).

5. Conclusions

Slash pile burning did not affect clay and silt fraction mineralogy for both 0-5 and 5-10 cm post-burn samples. However, changes in post-burn mineralogical composition were evident in sand fractions. These differences were attributed to the formation of Mn oxide/hydroxide coatings by the process of mass transport through soil with convective air current during the fire. Resinous pine species used as fire fuel were thought to be the source of Mn input. Micromorphological analysis showed presence of Mn/Fe coatings on sand-sized grains, as well as the presence of Mn nodules and microfabric enrichment, confirmed

by increased total Mn concentration in post-burn samples. Some degree of microstructure alteration due to the mass transport of Mn compounds during fire was detected throughout post-burn samples, which can feasibly lead to the changes in thermal conductivity and other physical properties of these soils.

6. References

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