Examining the legacy of severe fire on soil carbon cycling in montane landscapes in and around the Hayman burn, Colorado

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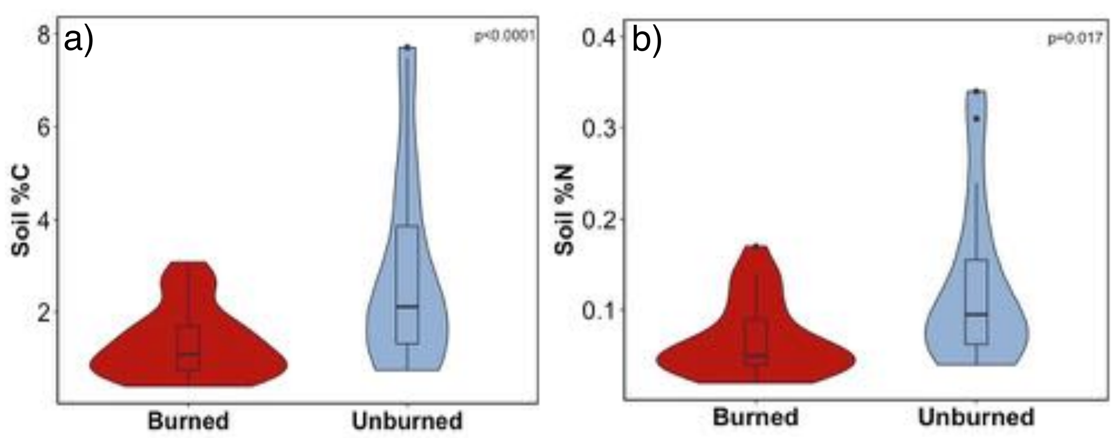
Research Question

How does soil carbon cycling differ between burned and unburned landscapes? Are the differences due to organic matter quality or soil microbes?

Increased Bioavailability in Burned Soils



Fire **significantly reduces soil organic matter**, reducing %C by 54% & %N by 64% (Fig. 2a,b). Post-fire nutrient losses attributed to soil leaching, erosion, less vegetation,[2,3,4,5] and microbes.[6]

Fig. 1: a) Amount of soil carbon (%)(p<0.0001). **b)** Amount of soil nitrogen (%) (p=0.017). Burned watersheds shown in red, unburned watersheds shown in blue.

Unburned soils respired 14% more C (mg C-CO_2 day^{-1}) (Fig. 2a) and >80 % of CO_2 respiration measured in lab is likely microbial.[4] **Burned soils are 47% more bioavailable** than unburned soils (Fig. 2b).

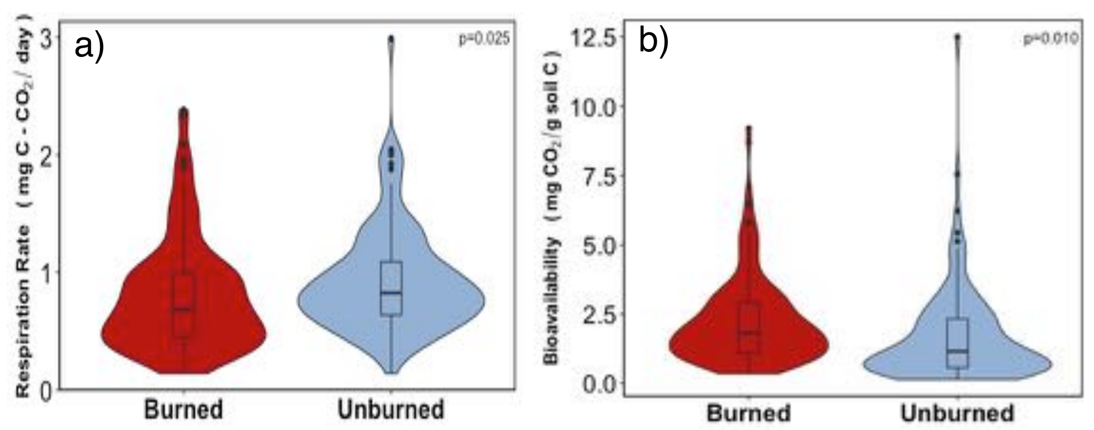
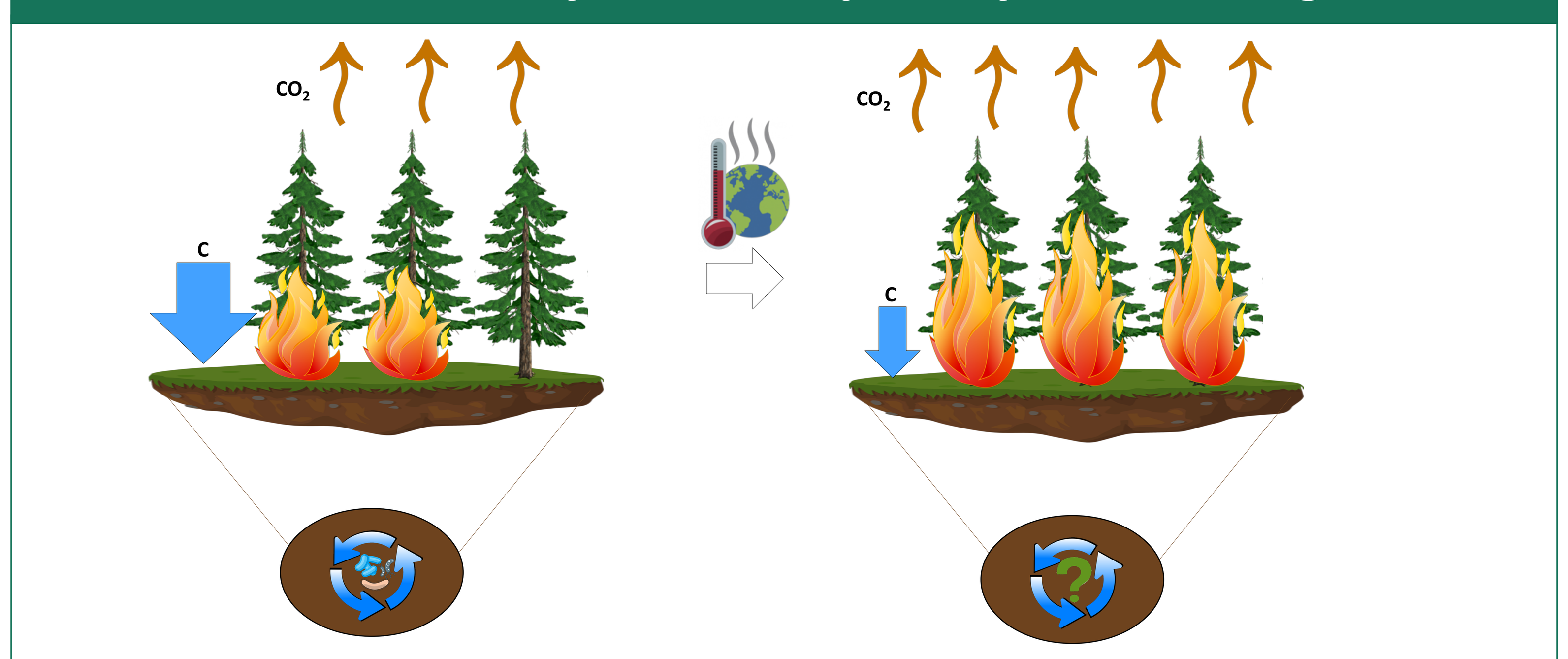


Fig. 2: a) Soil respiration rate (mg C-CO_2 day^{-1})(p= 0.025). **b)** Soil bioavailability (mg C-CO_2 g^{-1} soil C) (p= 0.010). Burned watersheds shown in red, unburned watersheds shown in blue.

Fire Severity and Frequency Increasing



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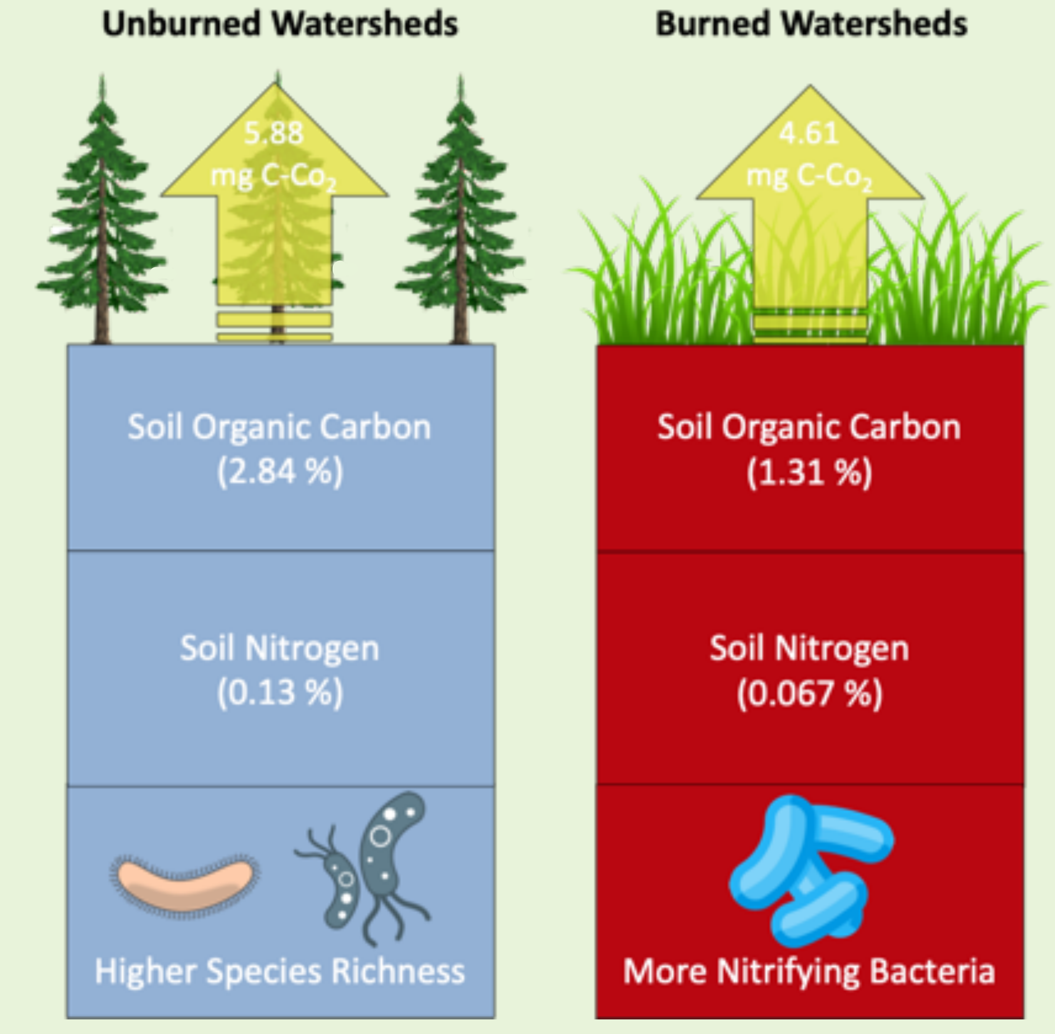
Main Conclusion

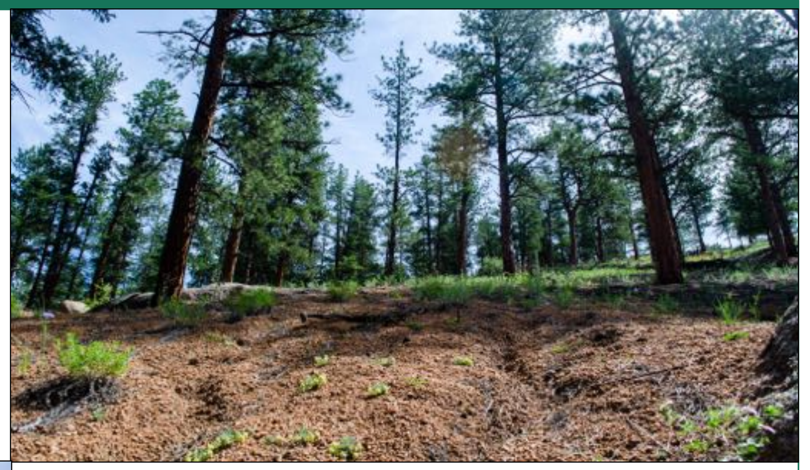
Increased soil carbon bioavailability within burned landscapes decreases total soil carbon storage.



Study Sites

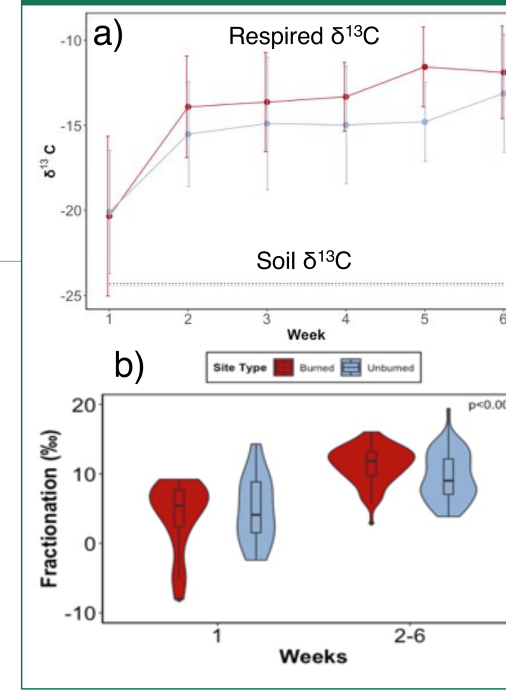
- **Hayman fire** burned 559 km² in 2002, the largest fire in recorded Colorado history.
- Severe (i.e. stand-replacing) burn.
- **17 years post-burn experiencing little recovery.**[12]

Burned site (x3) groundcover characterized by **grasses**, **forbes**, and **woody debris**



Unburned site (x2) groundcover characterized by **Ponderosa pine** with ~2-3 inches of **pine litter and duff**

Organic Matter Quality and Processing



Fire alters organic matter quality. **Burned plots have more grasses & forbes**, providing more labile OM inputs, **increasing soil respiration** likely due to increased nitrification potential.[7,8]

Burned soils tend to have higher $\delta^{13}C$ and $\delta^{15}N$, also indicative of tight C and N cycling. Burned soils also export more nitrate to streams.

Respired CO_2 from burned soils was significantly more **enriched in $\delta^{13}C$** than unburned soils (p= 0.019)(Fig. 3a,b). Fractionation differences could be due to different OM pools as well as differences in microbiomes.

Fig. 3: Fractionation between soil $\delta^{13}C$ and $\delta^{13}C$ of respired CO_2. **a)** Weekly $\delta^{13}C$ of respired CO_2 (solid lines) compared to soil $\delta^{13}C$ (dotted lines) between burned and unburned soils. **b)** Fractionation (‰) between week 1 and weeks 2-6 (p<0.0001). Burned watersheds shown in red, unburned watersheds shown in blue.

Microbial Communities

Beta-diversity is different between burned and unburned communities (Fig. 4). **Vegetative community is a long-term dominant driver** of microbial community assembly and structure.[10]

Greater species richness in unburned communities (Fig. 5b) leads to **more carbon sequestration.**[11]

Burned soils have more nitrifying bacteria. More charcoal and ammonium in burned soils maintains nitrifying microbial activity following fire,[7,8] **increasing mineralization rates.**[7,8]

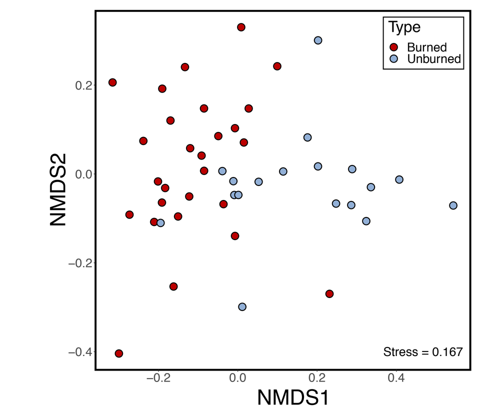


Fig. 4: NMDS of operational taxonomic unit and soil chemical properties (beta-diversity). Burned watersheds shown in red, unburned watersheds shown in blue. Burned and unburned soil microbial communities are statistically dissimilar (ANOSIM: 0.357, p< 0.001).

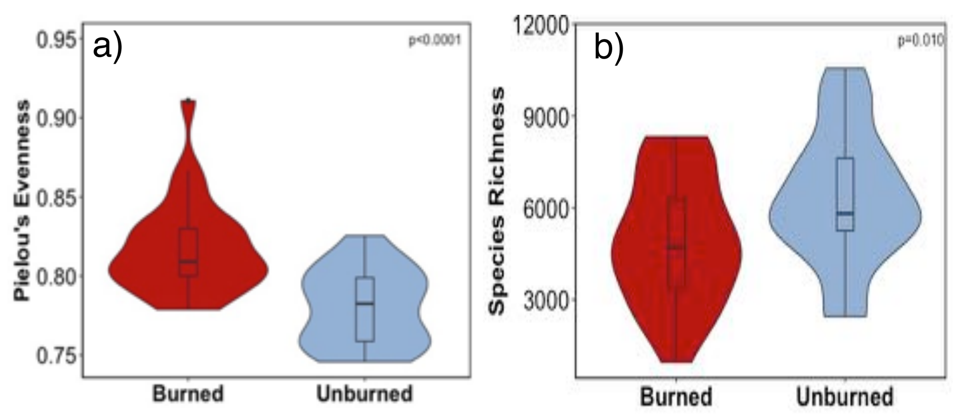
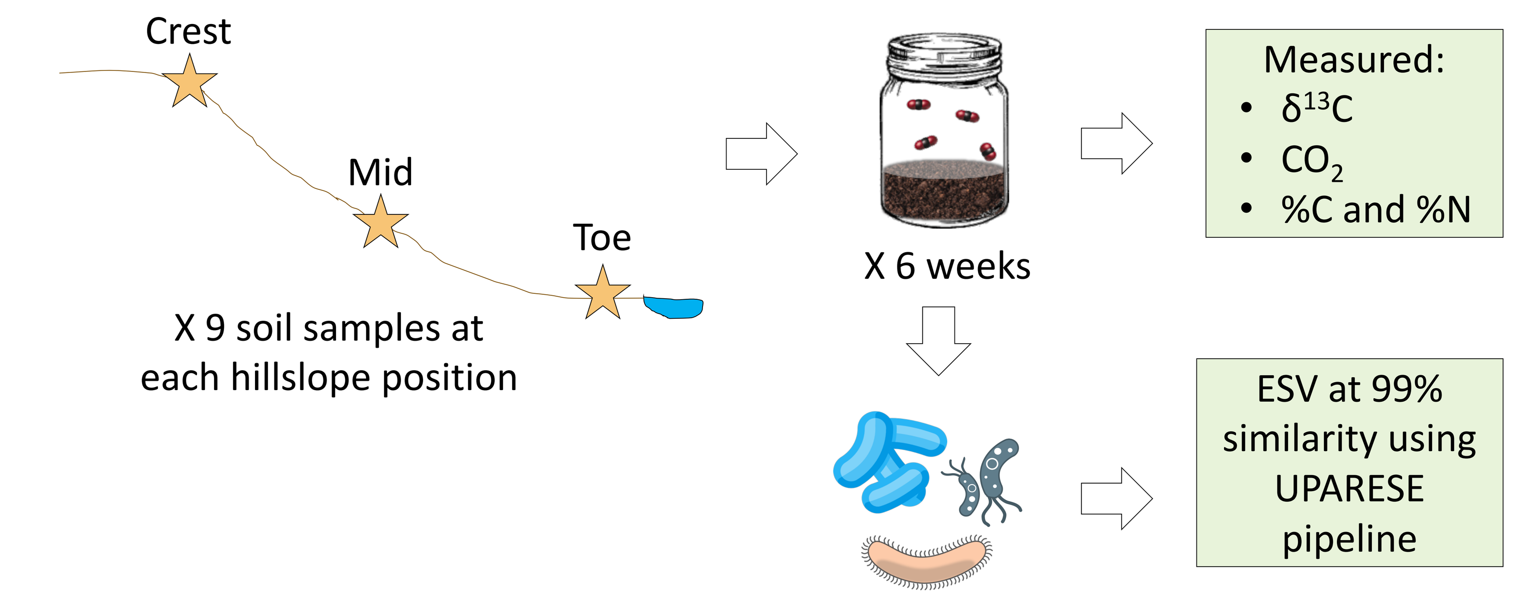


Fig. 5: Alpha diversity metrics of microbial communities. Burned watersheds shown in red, unburned watersheds shown in blue. **a)** Pielou's Evenness (between 0 and 1) (p<0.0001). **b)** Species Richness (p= 0.01).

Methods



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