SHORT-TERM CHANGES IN SOIL PROPERTIES FOLLOWING SIMULATED WILDFIRE AFTER WINTER WHEAT HARVEST

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ABSTRACT

Wildfire risk is increasing across croplands in the semi-arid Great Plains where residue accumulation and drought conditions make production systems highly vulnerable to fire. Wildfires can rapidly remove residue cover, reduce soil organic carbon (SOC), and soil water content, impacting crop productivity. However, little is known about how cropland soils respond immediately after burning when post-fire management decisions must be made. This study evaluated short-term changes in soil properties following a simulated wildfire in a winter wheat-based cropping system in western Kansas. A control burn was conducted in 2025 to simulate wildfire conditions in a 16-acre field of winter wheat stubble at the Kansas State University Agricultural Research Center near Hays, KS. One week after burning, each block was divided into ten plots and assigned soil recovery treatments in a randomized complete block design. Soil samples were collected before and two weeks after burning to quantify immediate postfire baseline conditions prior to recovery treatments implementation. Cover crops were planted in September, and manure and other soil amendments were applied in October.

Preliminary results showed significant declines in SOC at both sampling depths (0-2 and 2-6 in), with the greatest losses near the surface soil. Soil penetration resistance increased at both depths, and bulk density increased at the 2-6 in depth, indicating subsurface compaction. Infiltration decreased by 62% (6.44 to 2.44 in hr^{-1}), and residue cover dropped from 90% in the unburned control to 45% in the burned field. These results demonstrate that burning rapidly degrades SOC and soil physical properties, reducing water infiltration and increasing compaction risk in semi-arid winter wheat-based systems. These findings highlight the vulnerability of cropland soils to wildfire and the need for post-fire management strategies, such as cover crops and organic soil amendments to restore soil function and resilience. Ongoing work will assess soil recovery one year after treatment implementation.

INTRODUCTION

Wildfires are becoming an increasingly important disturbance in semi-arid cropping systems, where drought, high temperatures, and the accumulation of post-harvest residues increase the risk of fire (Vermeire et al., 2005). In winter wheat-based cropping systems of the central Great Plains, surface residues play a critical role in moderating soil temperature, conserving moisture, and protecting soil structure under water-limited conditions (Rasmussen et al., 1986; Dao, 1993). When crop stubble burns, this protective cover is rapidly removed, leaving the soil surface exposed and more susceptible to surface sealing and compaction, which can restrict water infiltration and root growth (Valzano et al., 1997).

Burning crop residue on the soil surface also alters soil carbon and nitrogen pools by eliminating organic inputs and reducing the incorporation of residue-derived carbon into the topsoil (Blanco-Canqui & Lal, 2009). As a result, declines in particulate organic matter and other labile carbon fractions have been widely reported, which are closely linked to aggregate stability and nutrient cycling (Six et al., 1999; Culman et al., 2012). These losses can trigger short-term changes in microbial activity and soil biochemical processes, particularly near the soil surface where heat exposure is greatest (Dormaar & Carefoot, 1996).

Soil biological indicators respond rapidly to disturbances that modify carbon availability and microhabitat conditions. In Great Plains cropping systems, enzyme activity and microbial community structure are strongly influenced by residue management and organic matter dynamics (Bandick & Dick, 1999; Acosta-Martínez et al., 2007). Following burning, shifts in microbial activity often occur in near-surface soils where both carbon loss and thermal stress are most severe (Dormaar & Carefoot, 1996).

Despite extensive research on residue management and soil health, relatively few studies have examined the immediate physical, chemical, and biological responses of cropland soils to wildfire (Valzano et al., 1997; Blanco-Canqui & Lal, 2009). Most of the research on wildfires have been conducted on rangelands or forest ecosystems with little work done on croplands. Agricultural soils differ from rangeland or forest ecosystems due to regular management, nutrient inputs, and crop residue management practices, all of which influence fire behavior and post-burn soil responses (Certini, 2005; Santín & Doerr,2016). With increasing wildfire frequency in semi-arid cropping systems, there is a critical need to quantify immediate post-fire changes in soil properties to inform early management decisions.

This study evaluated short-term changes in soil properties following a simulated wildfire in a semi-arid winter wheat-sorghum-fallow system. By establishing post-burn baseline soil conditions, this work provides essential information for interpreting soil health responses and guiding post-wildfire management practices.

MATERIALS AND METHODS

This study was conducted at the Kansas State Agricultural Research Center near Hays, Kansas. The region is semi-arid, with an average annual rainfall of approximately 22.5 in and a mean annual temperature of 54.3°F (Kansas State University Mesonet, 2023).

A controlled burn of winter wheat stubble was conducted in summer 2025 to simulate wildfire conditions. Fire was ignited at a corner on the upwind side of each plot and allowed to burn as a headfire through the plot area, with a fully disked border providing a sufficient buffer for safe and continuous fire spread. One week after burning, each replicated block was divided into ten individual plots, and ten soil recovery treatments were assigned using a randomized complete block design with four replications, each containing ten plots. Individual plots served as the experimental units for all soil measurements. Soil samples were collected prior to burning and two weeks after burning from individual plots within each block before implementation of recovery treatments, and were analyzed for soil properties.

Bulk density was determined from two intact soil cores collected at two depth intervals (0-2 in and 2-6 in), dried at 105°C and expressed on a dry weight basis. Soil water infiltration was measured using an MPD automated infiltrometer (Upstream Technologies Inc., Fridley, MN, USA), and infiltration rates were recorded in inches h^{-1}. Soil penetration resistance was measured using a penetrometer (FieldScout soil compaction tester (Spectrum Technologies Inc., Aurora, IL, USA) and recorded in megapascals (MPa).

Soil recovery treatments included Pervaide and C-20 Soil Builder, which were applied to the soil using a tractor-mounted sprayer at rates of 1 gal/acre and 454 lb/acre, respectively. Cattle manure application rate was 10 tons/acre, using a manure spreader. Cover crops consisting of a mixture of triticale (× *Triticosecale;* 15 lb/acre), hairy vetch (*Vicia villosa;* 15 lb/acre), cereal rye (*Secale cereale;* 20 lb/acre), and daikon radish (*Raphanus sativus;* 1.5 lb/acre) were planted following treatment application. All soil recovery treatments were fully implemented by November 20, 2025.

The experimental treatments included: (T1) Unburned, no-till control; (T2) Burned, untreated control; (T3) Pervaide; (T4) C-20 Soil Builder; (T5) Cattle manure (10 tons/acre); (T6) Cover crop; (T7) Manure + Cover crop; (T8) Pervaide + Cover crop; (T9) C-20 Soil builder + Cover crop; (T10) Manure + Disking. All statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC).

RESULTS AND DISCUSSION

Soil Carbon

Soil Carbon declined significantly from pre-burn to post-burn at both sampling depths, with the greatest losses near the surface at the 0-2 in depth (Fig. 1). This pattern is expected in semi-arid croplands because near-surface carbon is largely derived from crop residues that are readily combusted during fire events. Since soil carbon was measured two weeks after burning, immediate losses from residue combustion and heat-driven oxidation and thermal alteration of organic matter likely exceeded any short-term carbon inputs from ash. Low biomass inputs and exposed soil surfaces in semi-arid systems further increase the vulnerability of surface carbon to oxidation and redistribution. Similar short-term soil carbon declines following burning have been reported in other semi-arid agricultural and grassland systems (Abdalla et al., 2021; Fultz et al., 2016; Novara et al., 2013).

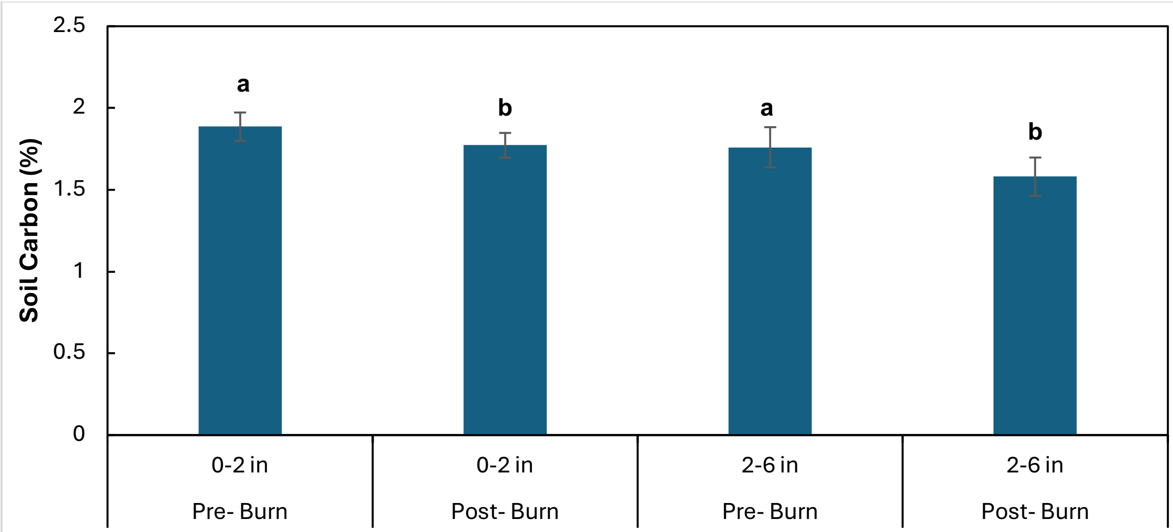

Fig.1. Short-term response of soil organic carbon to simulated wildfire in a semi-arid winter wheat-sorghum-fallow system in Hays, KS. Means with the same letter are not significantly different (*P* < 0.10).

Bulk Density

Bulk density did not differ between pre-burn and post-burn conditions at the 0–2 in depth (1.28 g cm^{-3}; Fig. 2). However, bulk density increased significantly at the 2–6 in depth from 1.37 to 1.43 g cm^{-3} following burning. This subsurface increase indicates greater soil compaction after burning, likely resulting from residue loss and post-burn surface exposure, which increase susceptibility to compaction. These changes can restrict root growth and limit water movement through the soil.

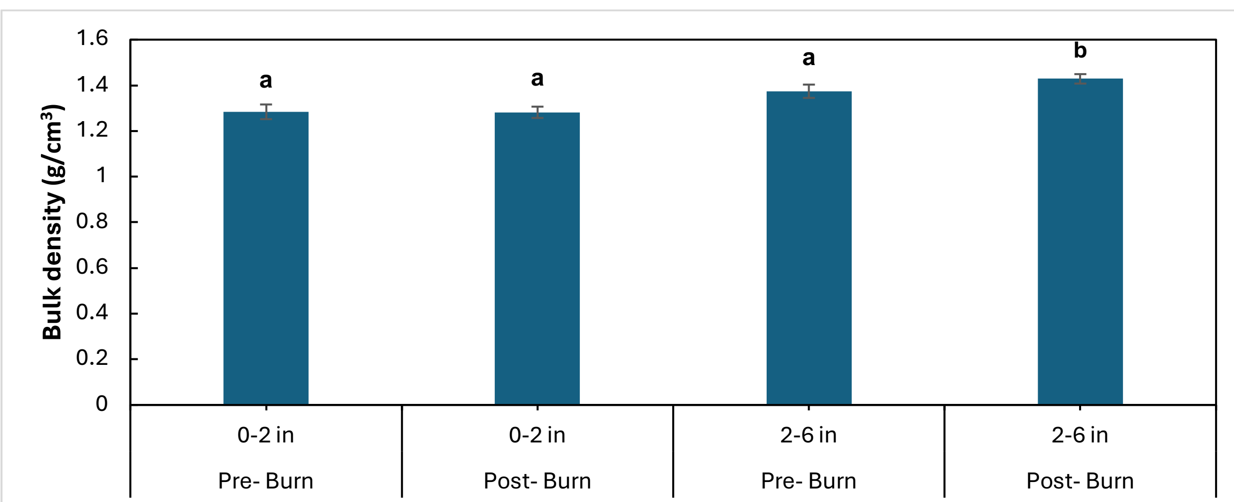

Fig. 2. Short-term response of soil bulk density to simulated wildfire in a semi-arid winter wheat-sorghum-fallow system in Hays, KS. Means with the same letter are not significantly different (*P* < 0.10).

Soil Penetration Resistance

Soil penetration resistance increased significantly after burning at both sampling depths (Fig. 3). Resistance increased from 0.90 to 1.22 MPa at the 0–2 in depth and from 1.18 to 1.74 MPa at 2-6 in depth, indicating greater soil strength and compaction following the burn. These increases are consistent with residue loss and post-burn structural changes that increase the susceptibility of semi-arid soils to compaction.

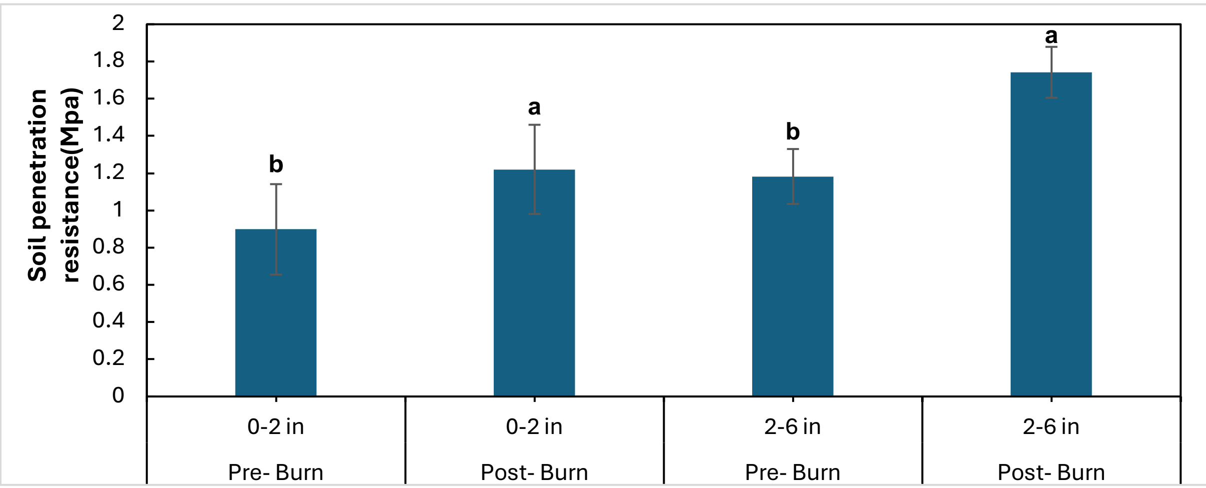

Fig. 3. Short-term response of soil penetration resistance to simulated wildfire in a semi-arid winter wheat-sorghum-fallow system in Hays, KS. Means with the same letter are not significantly different (*P* < 0.10).

Infiltration

Soil water infiltration declined significantly following burning (Fig. 4). Mean infiltration rate decreased from 6.44 in hr^{-1} under pre-burn conditions to 2.44 in hr^{-1} under post-burn conditions, representing a 62% reduction. This decline corresponds with observed increases in soil penetration resistance and bulk density, indicating reduced pore continuity and limited water movement through the soil profile following burning.

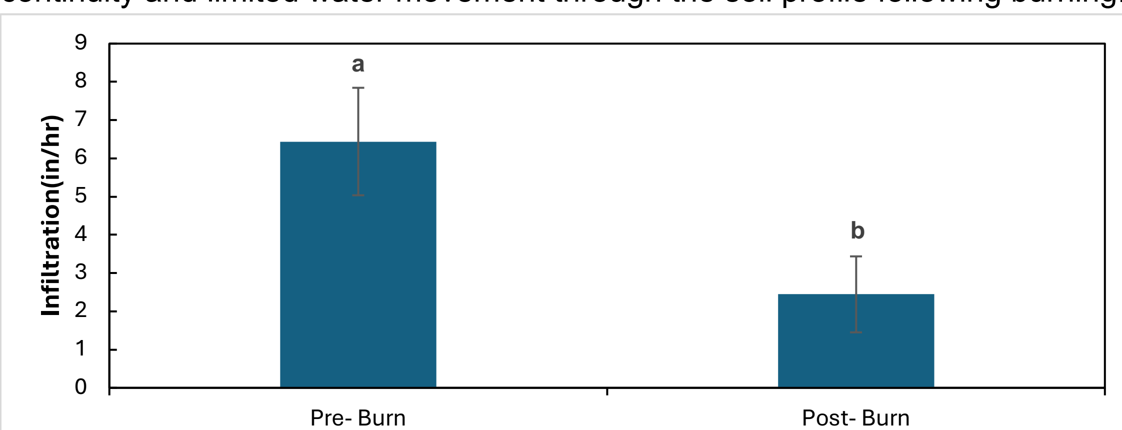

Fig. 4. Short-term response of infiltration rate to simulated wildfire in a semi-arid winter wheat-sorghum-fallow system in Hays, KS. Means with the same letter are not significantly different (*P* < 0.10).

REFERENCES

Abdalla, K., Chivenge, P., Ciais, P., & Chaplot, V. (2021). Long-term (64 years) annual burning lessened soil organic carbon and nitrogen content in a humid subtropical grassland. *Global Change Biology*, *27*(24), 6436–6453. https://doi.org/10.1111/gcb.15918

Acosta-Martínez, V., Mikha, M. M., & Vigil, M. F. (2007). Microbial communities and enzyme activities in soils under alternative crop rotations compared to wheat–fallow for the Central Great Plains. *Applied Soil Ecology*, *37*(1-2), 41-52.

Bandick, A. K., & Dick, R. P. (1999). Field management effects on soil enzyme activities. *Soil biology and biochemistry*, *31*(11), 1471-1479.

Blanco-Canqui, H., & Lal, R. (2009). Crop residue removal impacts on soil productivity and environmental quality. *Critical reviews in plant science*, *28*(3), 139-163.

Culman, S. W., Snapp, S. S., Freeman, M. A., Schipanski, M. E., Beniston, J., Lal, R., ... & Wander, M. M. (2012). Permanganate oxidizable carbon reflects a processed soil fraction that is sensitive to management. *Soil Science Society of America Journal*, *76*(2), 494-504.

Dao, T. H. (1993). Tillage and winter wheat residue management effects on water infiltration and storage. *Soil Science Society of America Journal*, *57*(6), 1586-1595.

Dormaar, J. F., & Carefoot, J. M. (1996). Implications of crop residue management and conservation tillage on soil organic matter. *Canadian Journal of Plant Science*, *76*(4), 627-634.

Fultz, L. M., Moore-Kucera, J., Dathe, J., Davinic, M., Perry, G., Wester, D., ... & Rideout-Hanzak, S. (2016). Forest wildfire and grassland prescribed fire effects on soil biogeochemical processes and microbial communities: Two case studies in the semi-arid Southwest. *Applied Soil Ecology*, *99*, 118-128.

Kansas Mesonet. (2023). *Station metadata and climate normals (1991–2020): Hays (WKREC)*. Kansas State University Weather Data Library. Accessed January 5, 2026, from https://mesonet.k-state.edu/

Novara, A., Gristina, L., Rühl, J., Pasta, S., D'Angelo, G., La Mantia, T., & Pereira, P. (2013). Grassland fire effect on soil organic carbon reservoirs in a semiarid environment. *Solid Earth*, *4*(2), 381–385. https://doi.org/10.5194/se-4-381-2013

Rasmussen, P. E., Rickman, R. W., & Douglas Jr, C. L. (1986). Air and Soil Temperatures during Spring Burning of Standing Wheat Stubble 1. *Agronomy Journal*, *78*(2), 261-263.

Santín, C., & Doerr, S. H. (2016). Fire effects on soils: the human dimension. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *371*(1696), 20150171.

Six, J., Elliott, E. T., & Paustian, K. (1999). Aggregate and soil organic matter dynamics under conventional and no-tillage systems. *Soil Science Society of America Journal*, *63*(5), 1350-1358.

Valzano, F. P., Greene, R. S. B., & Murphy, B. W. (1997). Direct effects of stubble burning on soil hydraulic and physical properties in a direct drill tillage system. *Soil and Tillage Research*, *42*(3), 209-219.

Vermeire, L. T., Wester, D. B., Mitchell, R. B., & Fuhlendorf, S. D. (2005). Fire and grazing effects on wind erosion, soil water content, and soil temperature. Journal of environmental quality, 34(5), 1559-1565.