FIRE EFFECTS ON SOILS

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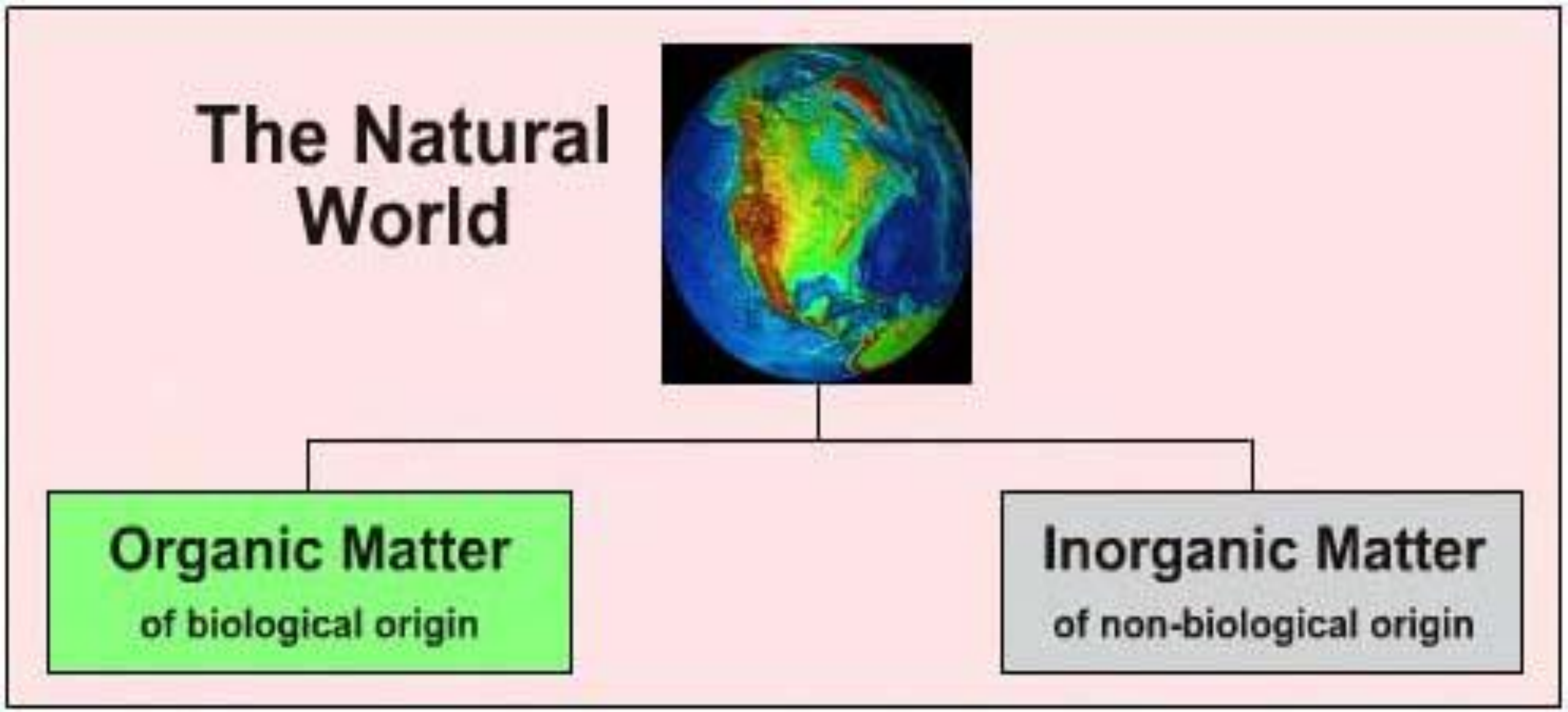
Soil, Water, and Environmental Sciences

SOILS CONTAIN BOTH ORGANIC AND INORGANIC MATTER COMPONENTS



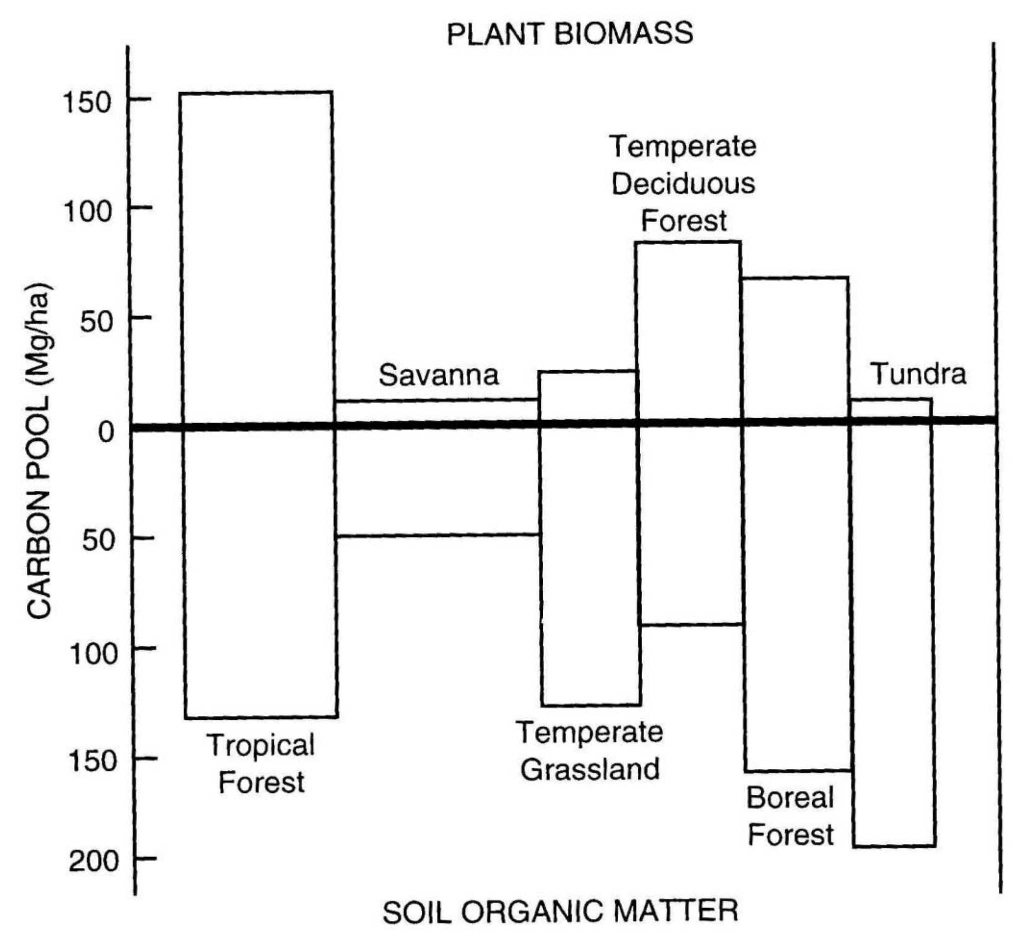
WHAT IS ORGANIC MATTER?

- Substances whose molecules contain one or more (often many more) carbon atoms (excluding carbonates, cyanides, carbides, and a few others; see inorganic compound).
- The modern chemical classification system says that to be "organic" a substance must possess carbon hydrogen (C-H) chemical bonds, and that "inorganic" substances do not possess C-H bonds. Under this system, oxygen is inorganic. And, ironically, so is urea, H2NCONH2.

LOCATION OF ECOSYSTEM CARBON

- Living biomass in green plants (mostly woody plants)
- Heterotrophs (animal and plant)
- Dead biomass in dead wood
- The forest floor (litter-duff)
- Mineral soil

ECOSYTEM ORGANIC MATTER DISTRIBUTON

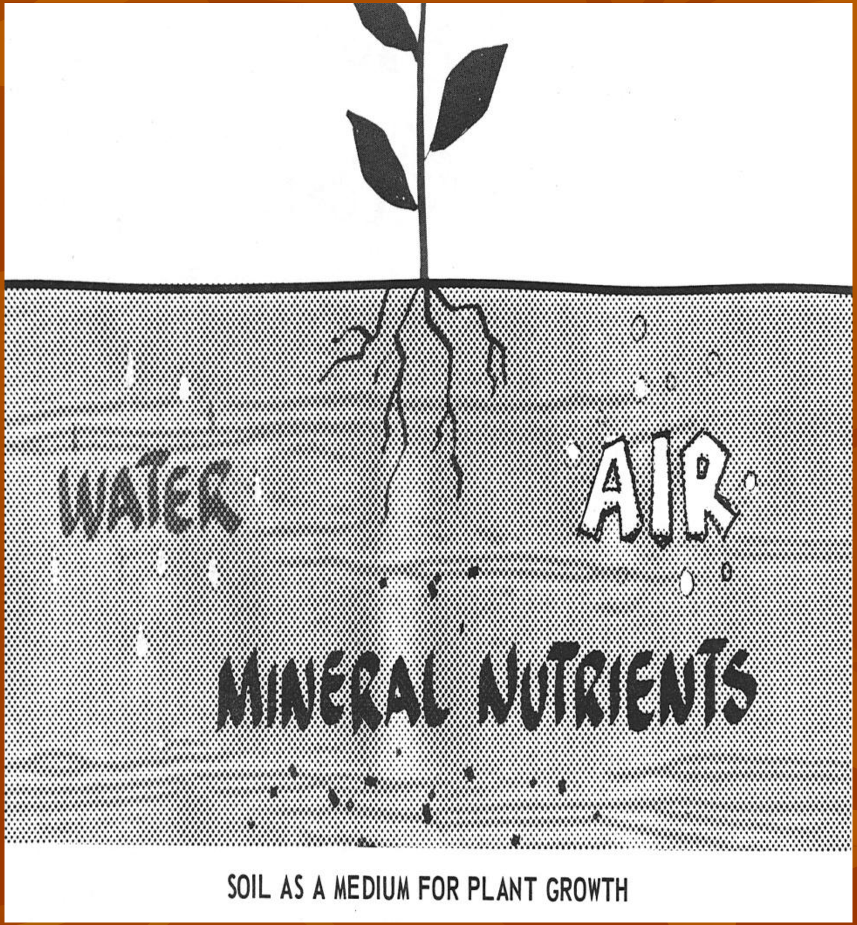


IMPORTANCE OF SOIL ORGANIC MATTER

- Affects soil physical, chemical, and biological properties.
- Component of soil structure.
- Provides an energy source for microorganisms
- Storehouse for plant nutrients.
- Acts as a chelating agent for plant nutrients.
- Is easily volatilized by soil heating during fires.

SOIL AS A MEDIUM FOR PLANT GROWTH

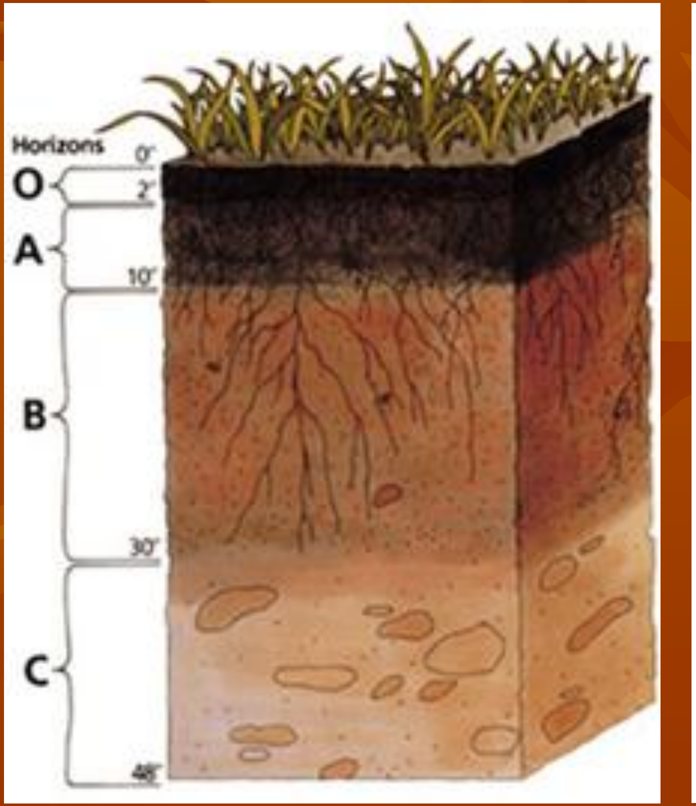
- Contains pore space among mineral particles.
- Pore space contains water, air, and plant nutrients.
- Pore space can vary widely among different soils.

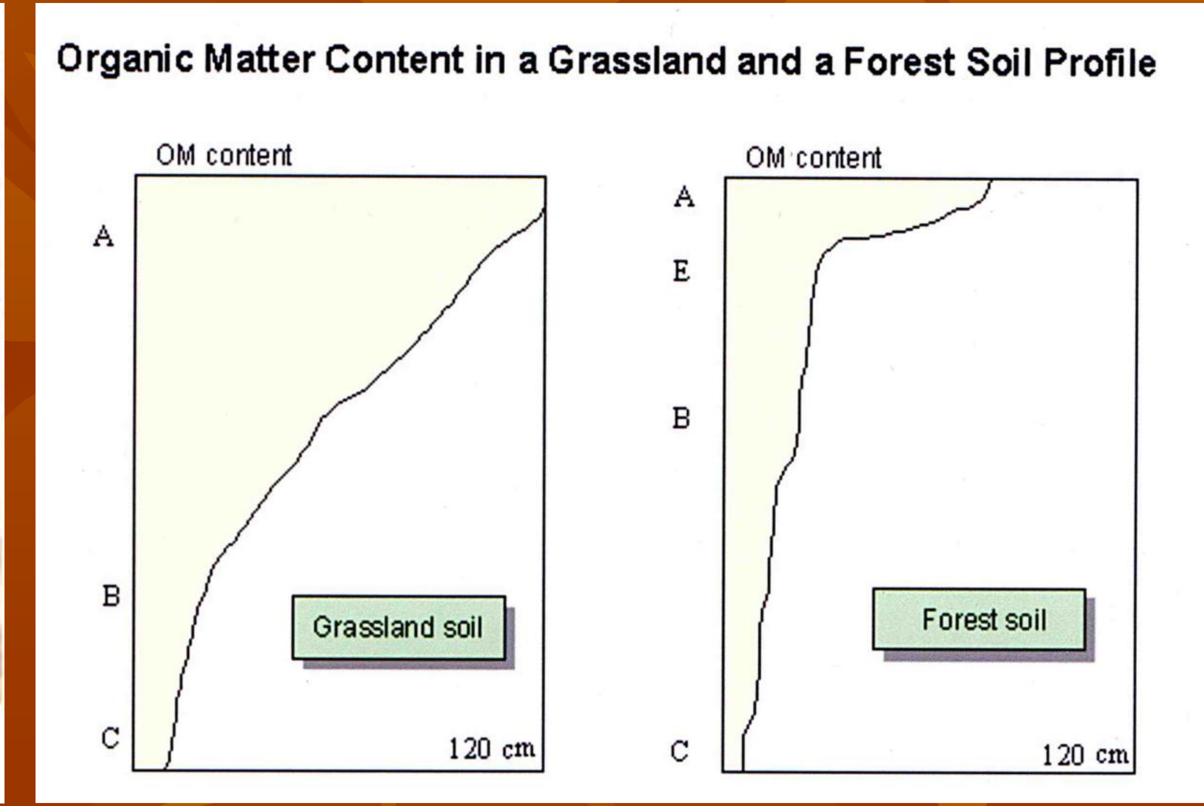


FACTORS AFFECTING SOIL PROPERTIES DURING A FIRE

- Location of the soil property
- Temperature thresholds of soil properties
- Fire severities and soil heating

SOIL PROFILE – Organic Matter Distribution

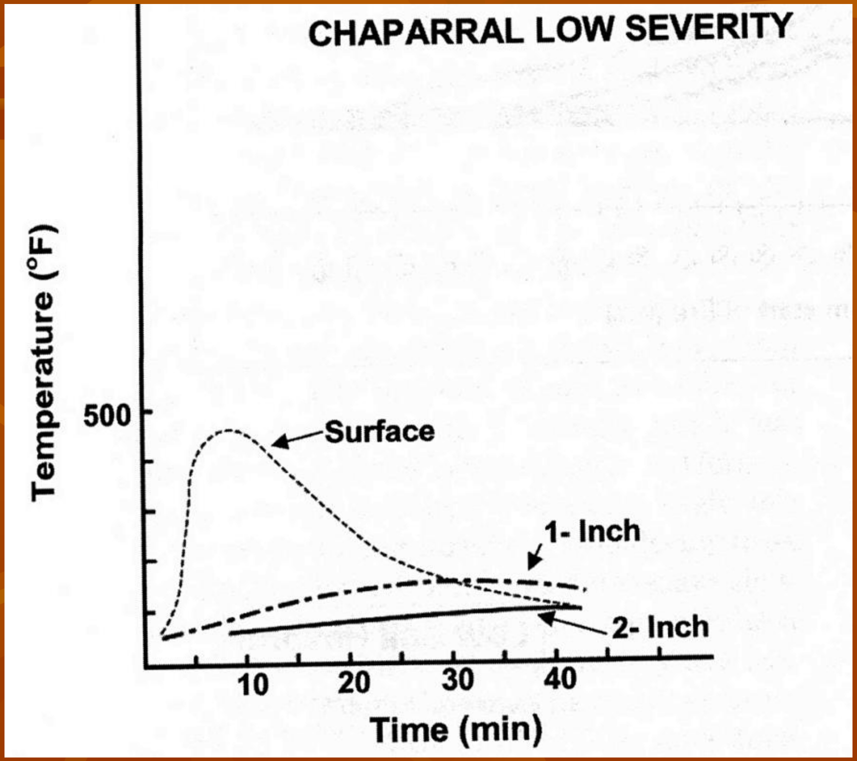


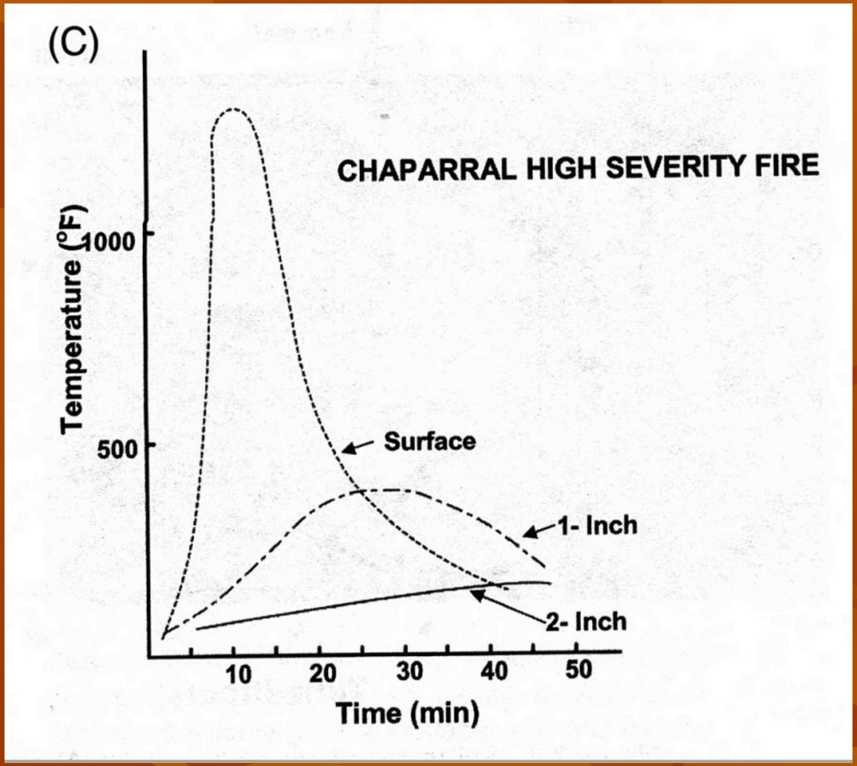

Organic Matter Content in a Grassland and a Forest Soil Profile

FIRE SEVERITY & INTENSITY

- *Fire Severity* – a term used to described ecosystem responses to fire (i.e., effect of fire on soils, water, fauna, flora, and atmosphere).
- *Fire Intensity* – a term reflecting the amount and rate of surface fuel consumption.

FIRE SEVERITY AND SOIL HEATING

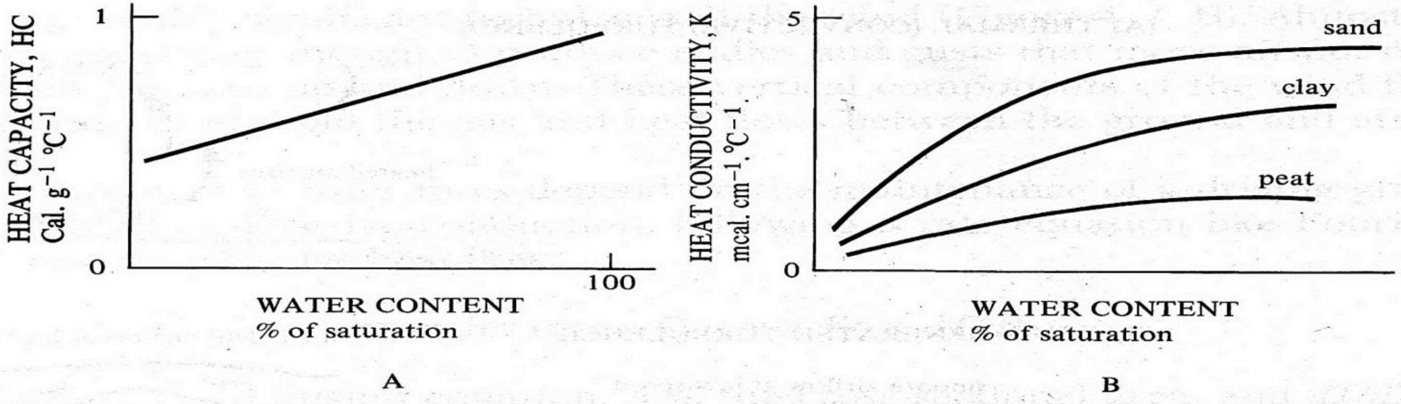




HEAT TRANSFER IN SOILS

- Important transfer processes are conduction, vaporization, and condensation.
- Soil water has an important role in heat transfer below the boiling point of water 100 °C (212 °F) .

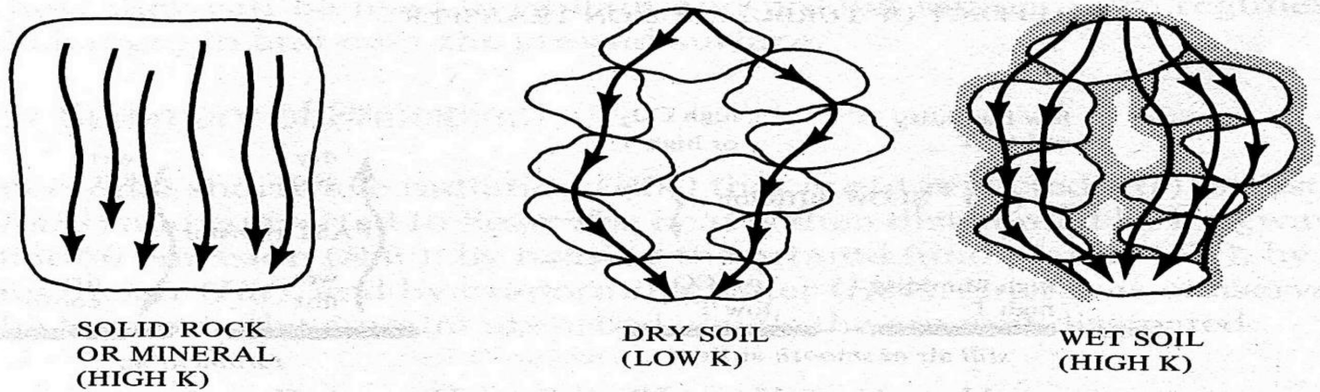
HEAT TRANSFER IN DRY AND WET SOILS



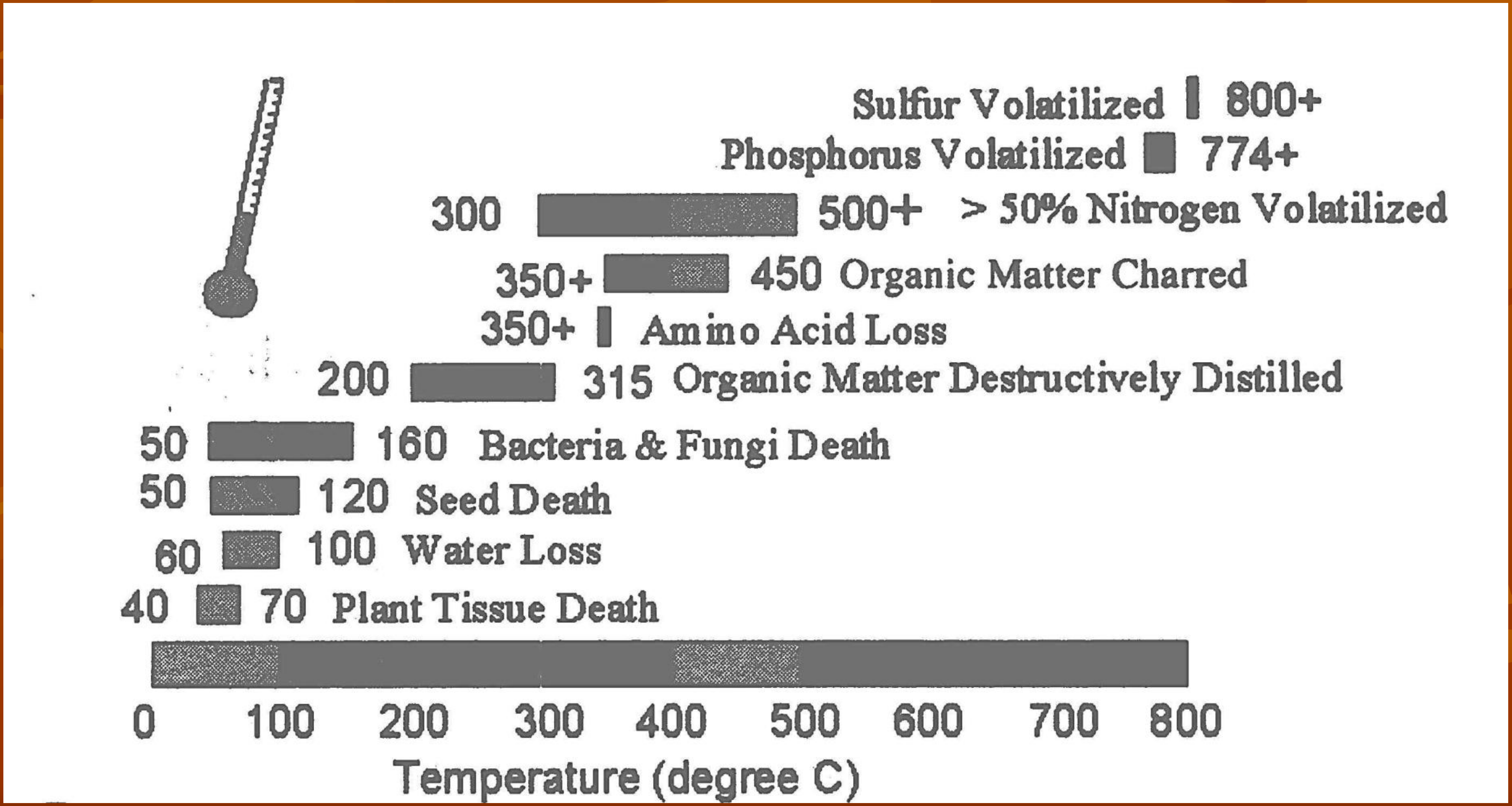
HC = quantity of heat required to change temperature by 1 °C

K = quantity of heat (cal) transmitted per second through a layer 1 cm thick across an area 1 cm^2 when the temperature difference is 1 °C (i.e., temperature gradient = 1 °C/cm)

HEAT FLOW PATHS



TEMPERATURE THRESHOLDS *of select soil properties*



EFFECT OF FIRE SEVERITY

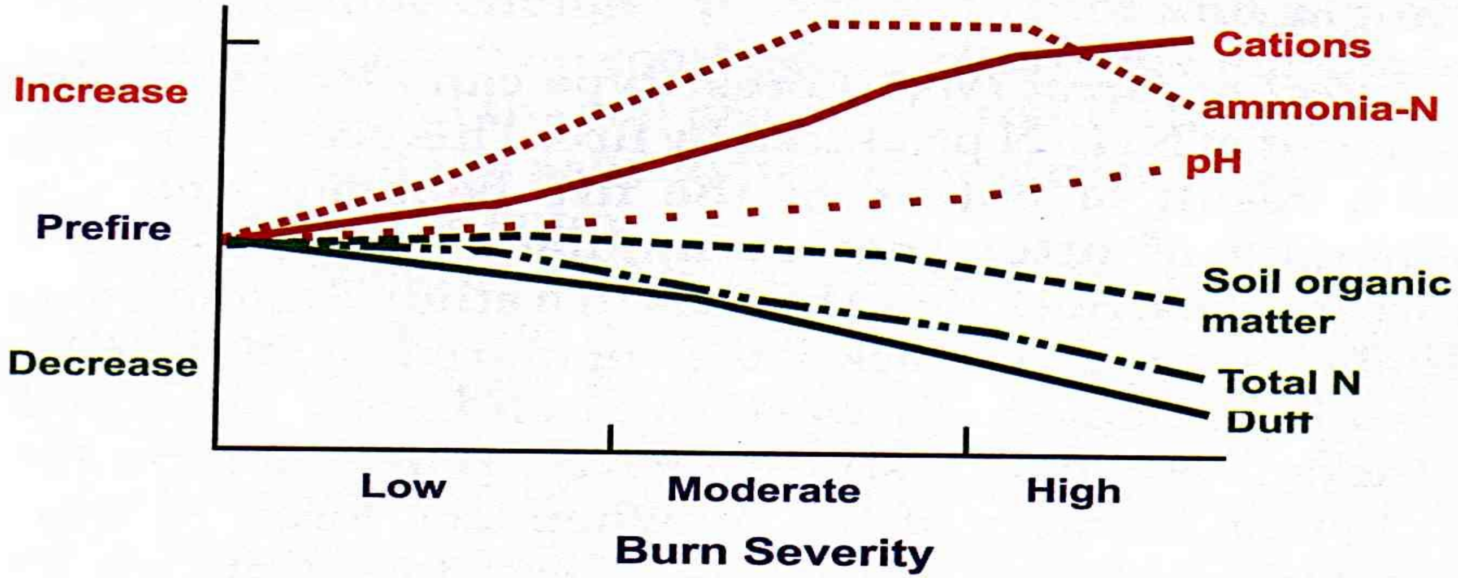
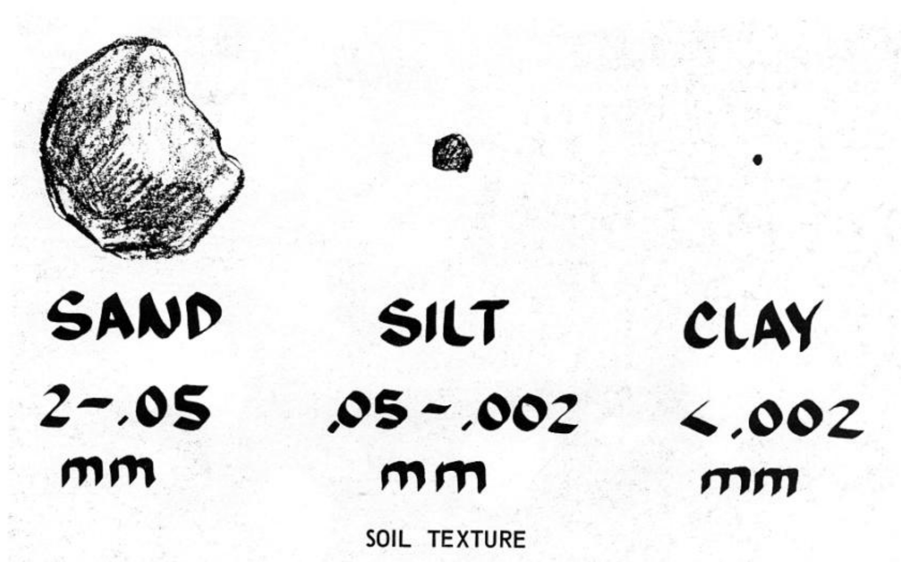


Figure 3.15—Generalized patterns of decreases in the forest floor (duff), total N, and organic matter, and increases in soil pH, cations, and NH_4 associated with increasing levels of fire severity. (Figure courtesy of the USDA Forest Service, National Advanced Fire and Resource Institute, Tucson, AZ).

SOIL PHYSICAL PROPERTIES

- Soil Texture

- Soil Structure



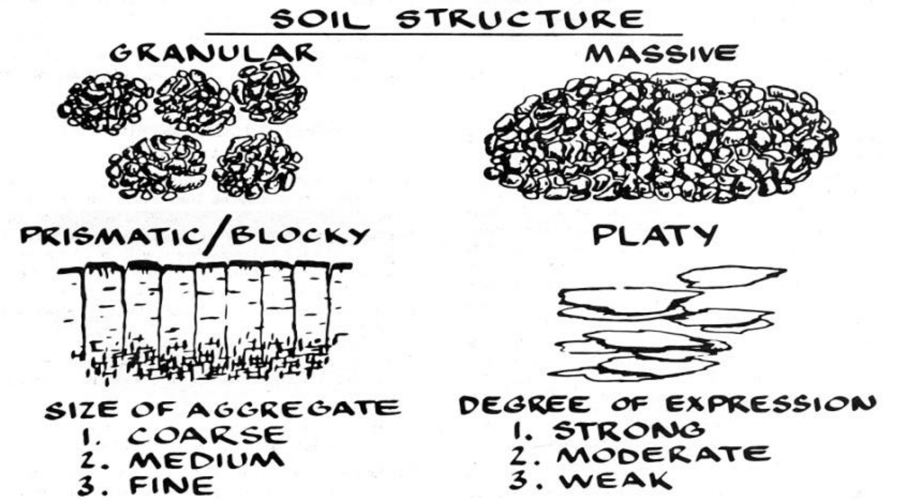
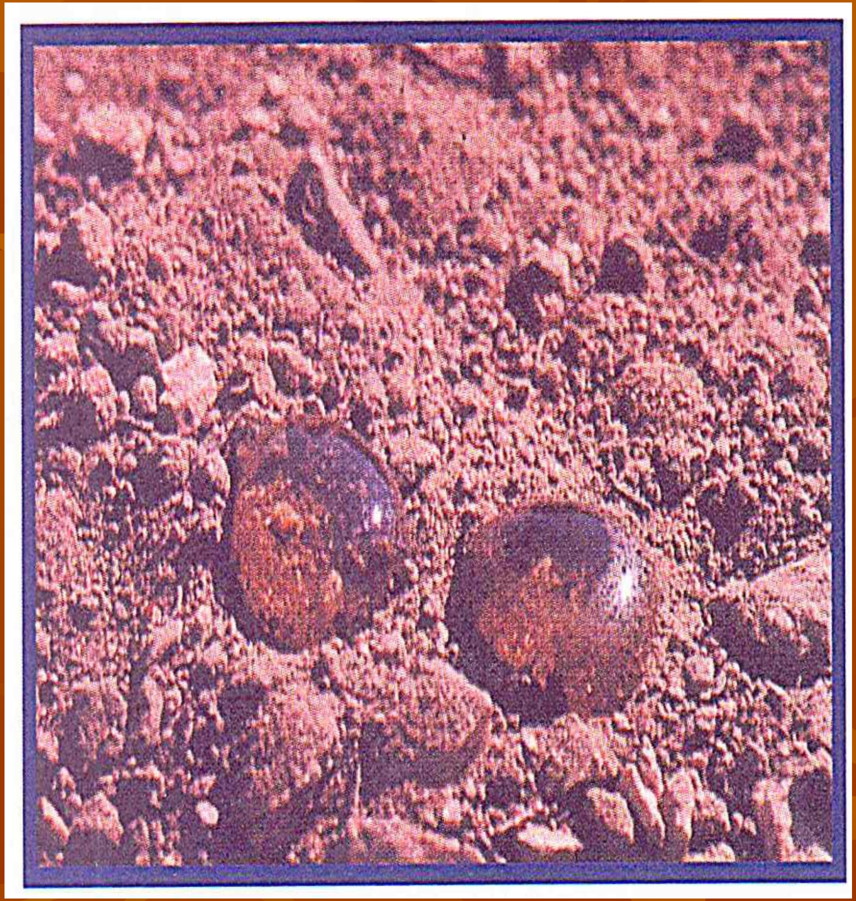


Figure 3. Examples of soil aggregates. The kind, size, and strength of aggregate found varies with the texture, composition, depth, management, and mode of formation of the soil.

SOIL WATER REPELLENCY

NATURE OF SOIL WATER REPELLENCY

- Water droplets “ball up” on the surface of a dry soil.
- Water droplets may be absorbed over time or not at all.
- Soil particles are coated with organic substances.



FIRE-INDUCED REPELLENCY

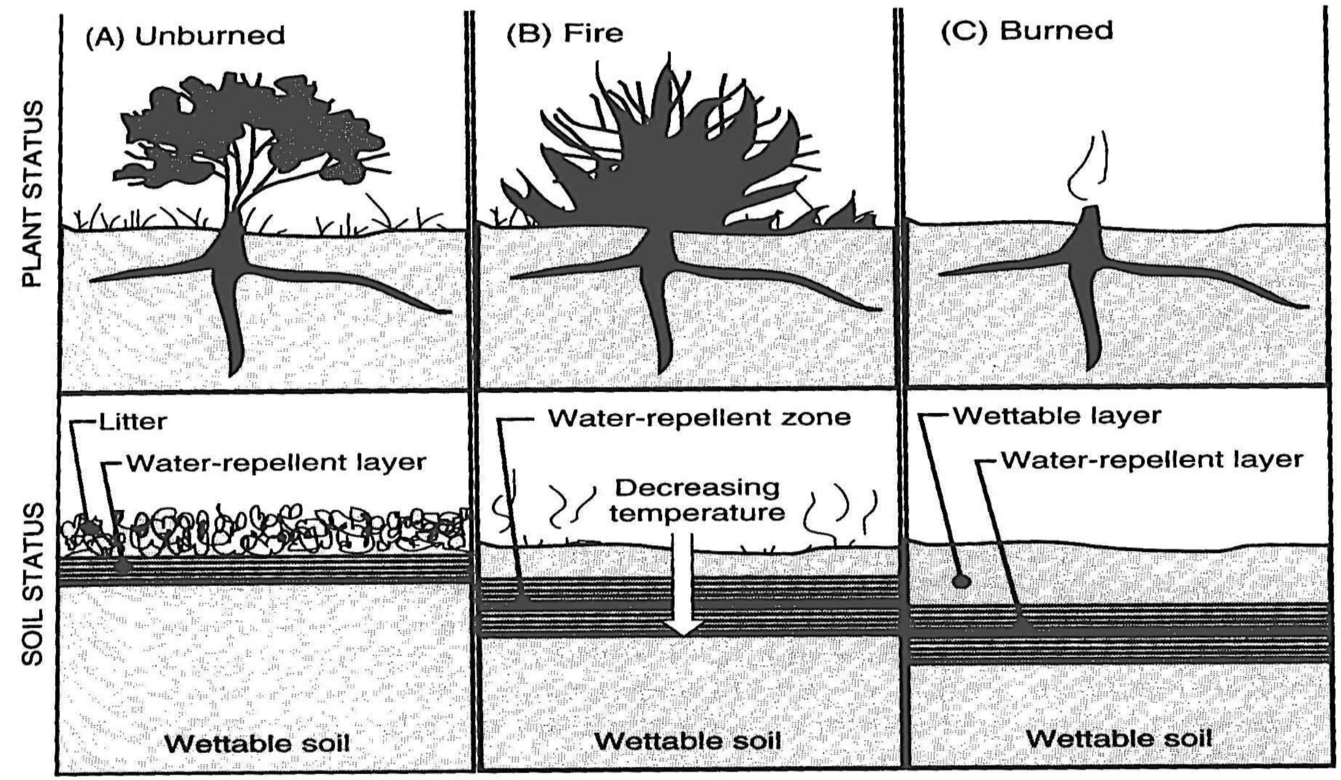
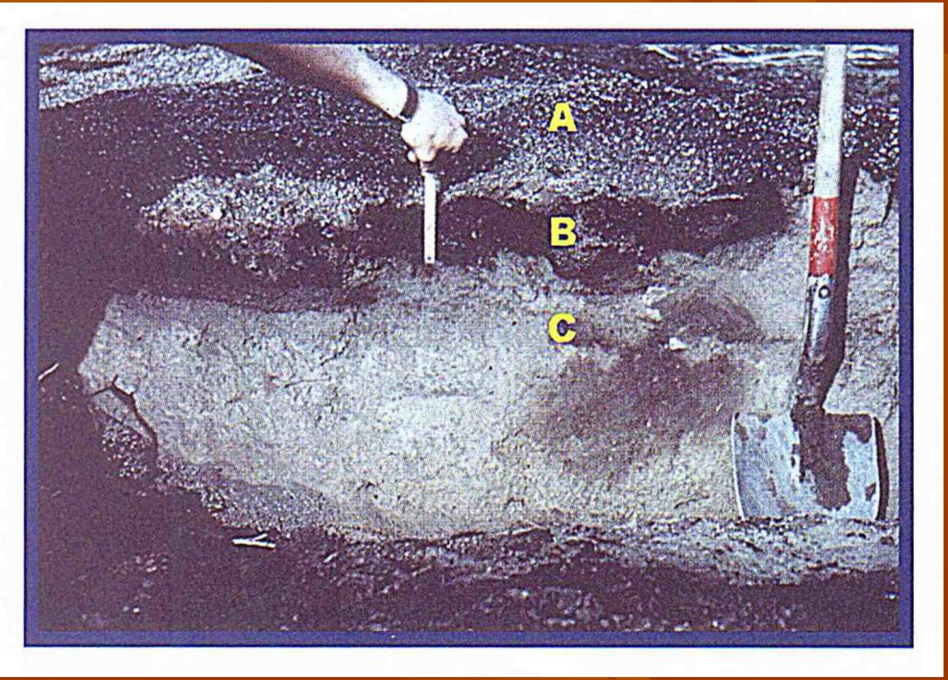
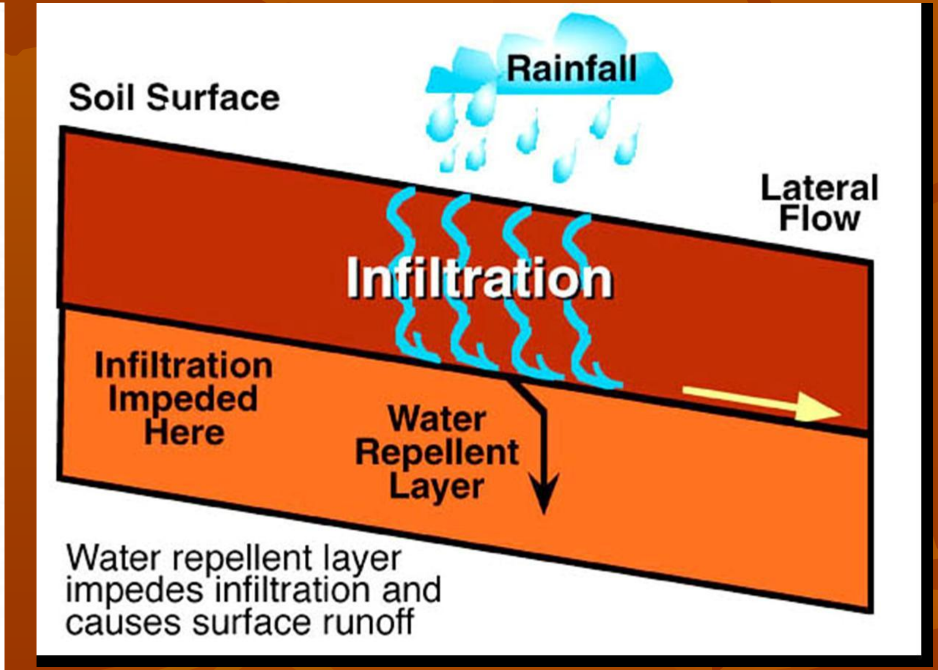


FIGURE 5.4 Soil water repellency is altered by fire. (A) Hydrophobic substances accumulate in the litter and duff layers and in the mineral soil immediately beneath them before a fire; (B) fire then burns the vegetation, litter and duff layers, causing hydrophobic substances to move downward along temperature gradients; and (C) a water-repellent layer is present below and parallel to the soil surface on the burned area. (Adapted from DeBano 1981.)

WATER REPELLENCY AND INFILTRATION





Water repellent layer impedes infiltration and causes surface runoff

SUMMARY – FIRE EFFECTS

- Soil is a complex and dynamic component of terrestrial ecosystems worldwide.
- Fire severity is an important factor affecting soil changes during fire.
- Heat transfer in soil is affected by soil moisture.
- Soil organic matter, soil nitrogen, and soil structure are important soil properties changed by fire.
- Soil biological properties are particularly affected by soil heating temperatures.

Low-intensity, fire-induced changes of soil structure and hydraulic properties in a woodland-rangeland ecosystem

Karletta Chief, M. Young, and David Shafer

Funded by:

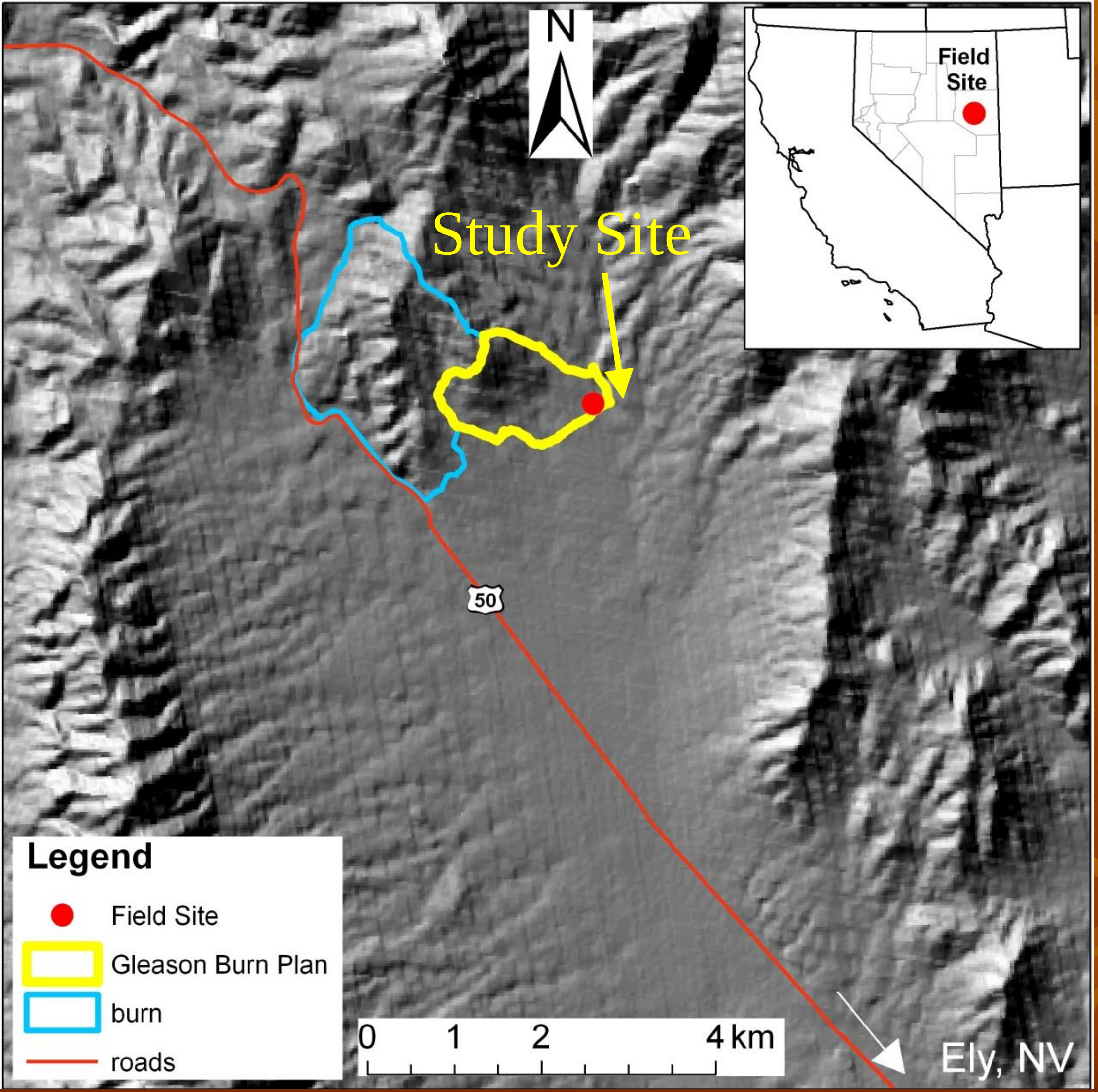
NSF

DRI
Desert Research Institute

Objectives

- Determine differences and changes in K_f , k_a, and soil physical properties at interspace and coppice microsites immediately before and after burn and following a 13 month period
- Quantify the effect of fire on soil structure and hydrophobicity and respective influence of those changes on hydraulic properties

Upper Gleason Creek Watershed



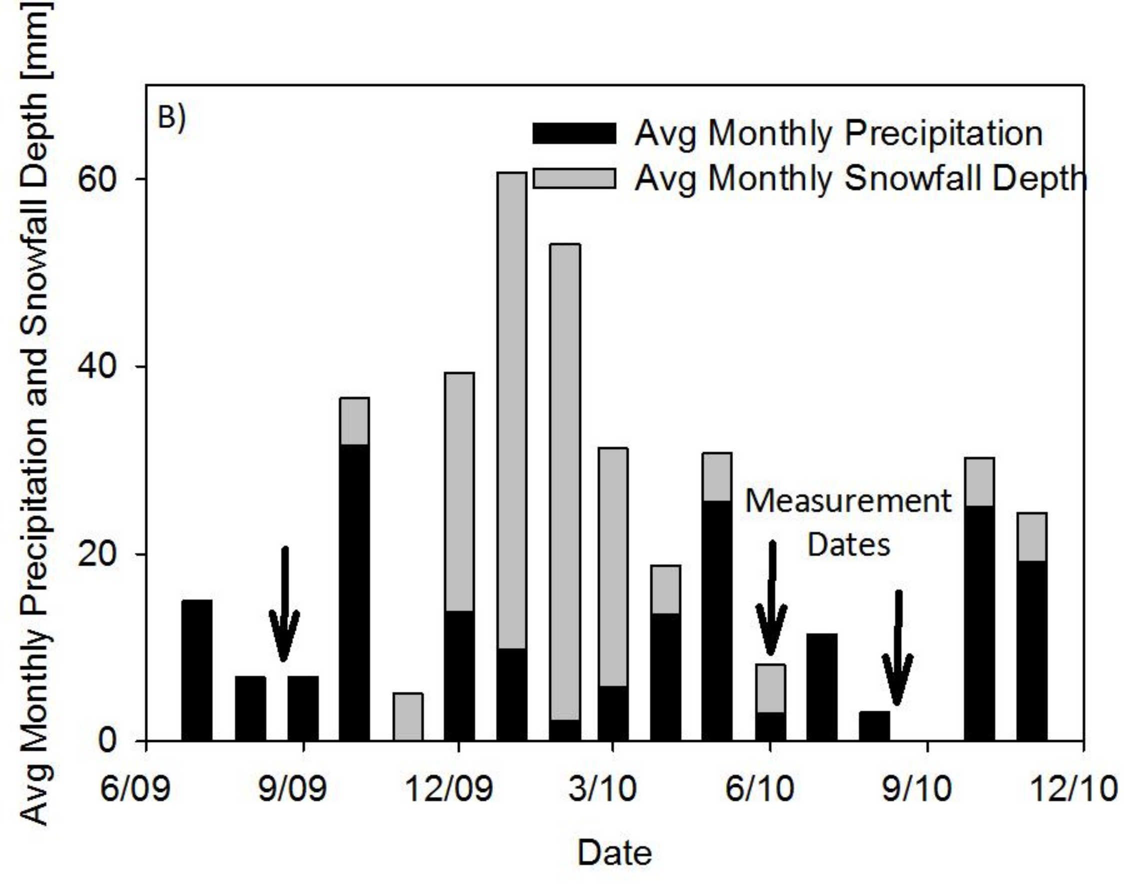
Watershed Description

- Elevation: 2183-2397 m
- Slope: 15-45%
- Location: 30 km NW of Ely, NV
- Sagebrush steppe/pinyon-juniper woodland

Prescribed Fire Goals

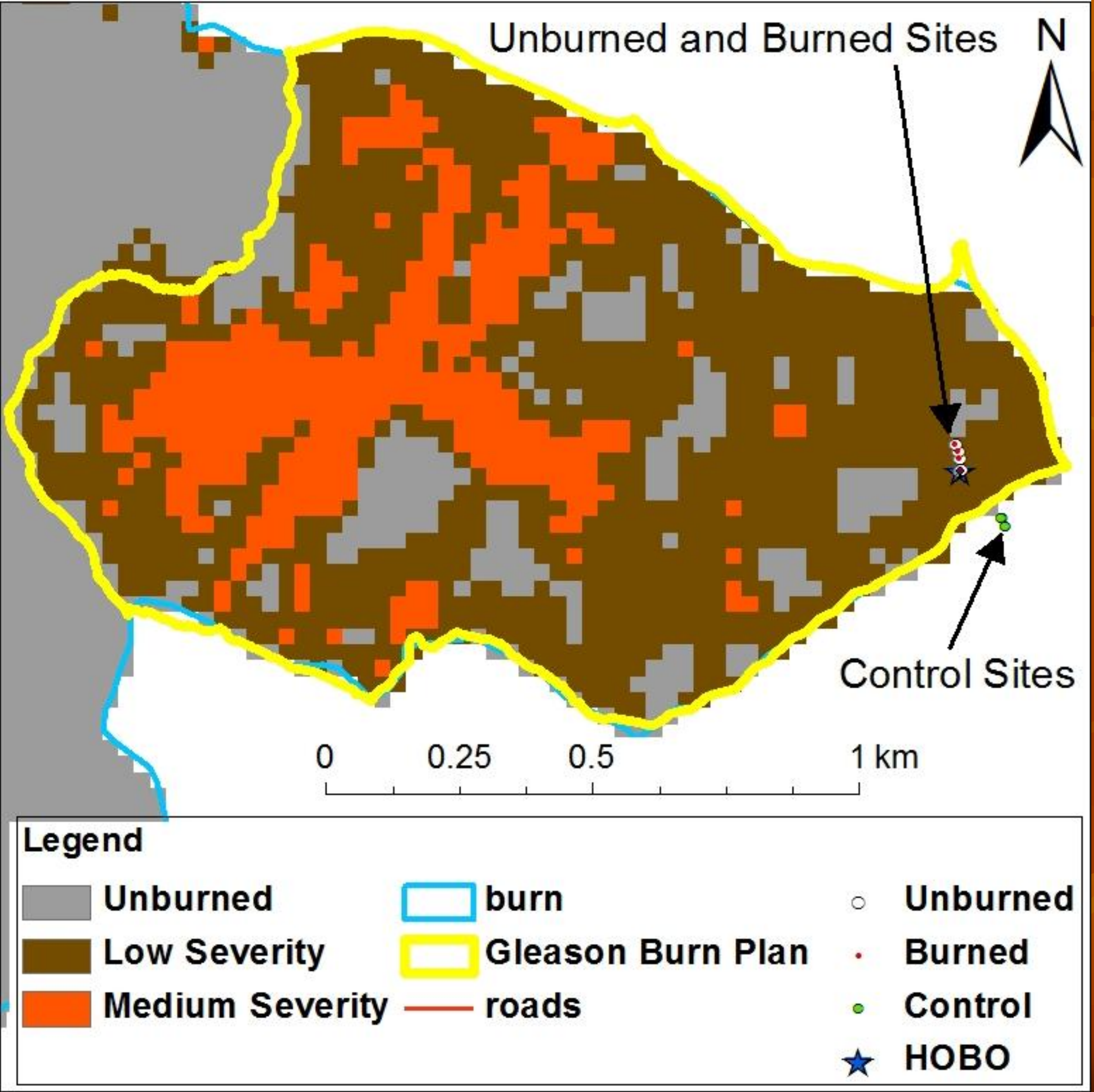
- Reduce flooding to Ely
- Restore sagebrush comm.
- Reduce erosion
- Create heterogeneous veg. from herbaceous to threshold

Precipitation



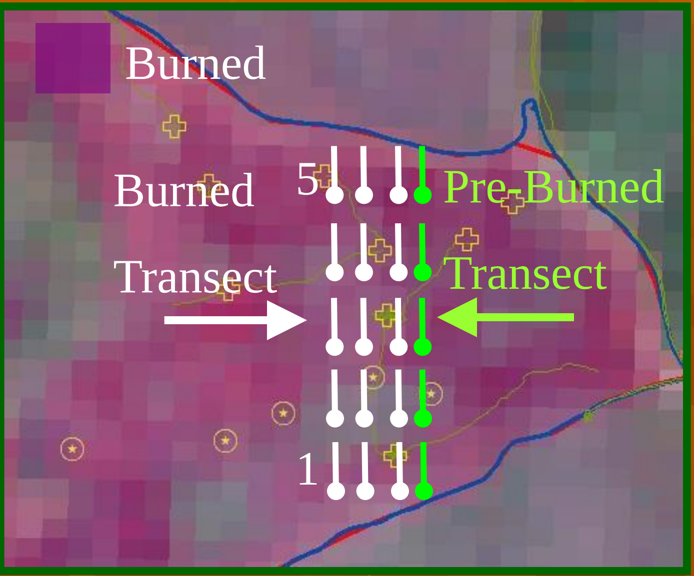
- Mainly as winter snow with spring & fall thundershowers
- Wettest months: Oct, Mar, & May (25-33 mm)
- Mean snowfall > 152 mm occurred in Dec-Mar

8/13/09 Prescribed Burn



- Max fuel load:16-44 metric tons/hectare in closed PJ at higher elevations
- Low to medium intensity burn
- 155 ha burned

Pre- and Post-Burn Measurements



Pre-Burned (8/4/09)

Per sub-transect:

- 4 coppice
- 4 interspace

Per transect:

- 5 sub-transects
- *n*=40

Post-Burn #1 (8/18/09)

Post-Burn #2 (6/7/10)

Post-Burn #3 (8/31/10)

Methods

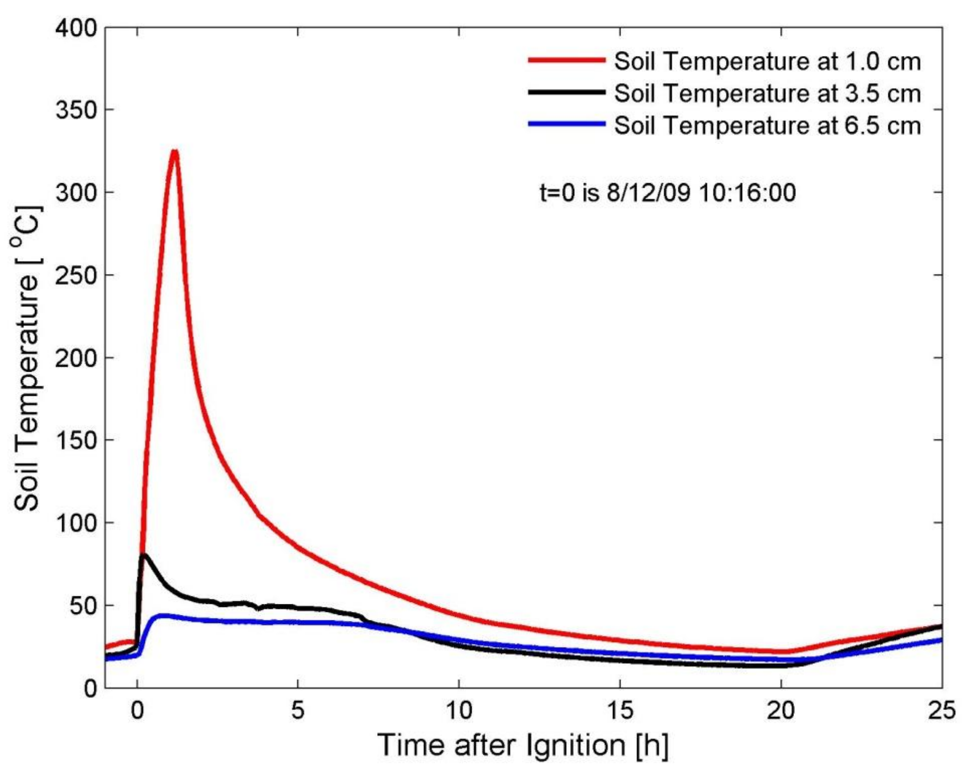
K_f (TI)

k_a (Air Permemeter)

Bulk density; Soil texture

WDPT (Hydrophobicity)

Soil Temperature during Burn



- At 1 cm, Tmax=326 °C
- At 1 cm, T>Tthreshhold for 4 h
  - nutrients are volatized, complete dehydration occurs at 220 °C
  - soil props irreversibly damaged (soil structure, wettability, OM, 100, 250, 300 °C respectively)
- At 3.5 cm, Tmax=81 °C for 20 min
- At 6.5 cm, Tmax=44 °C for 40 min
- 20 hours before reaching ambient temps

Hydrophobicity Classes

Hydrophobicity Class	Descriptive label	WDPT
1	Very hydrophilic	<5 s
2	Hydrophilic	5-60 s
3	Slightly hydrophobic	60-180 s
4	Moderately hydrophobic	180-600 s
5	Strongly hydrophobic	600-3600 s
6	Very strongly hydrophobic	1-5 h
7	Extremely hydrophobic	>5 h

WDPT

- Hydrophilic for unburned soils
- At coppice, ash depth ranged from 0.5 to 6 cm (avg. 3 cm)
    - Avg WDPT indicated slight to moderate hydrophobicity. Slight hydrophobicity remained after 382 days
- At interspace, ash depth ranged from 0-0.1 cm
    - Majority of measurements very hydrophilic (WDPT <5 s) at the surface

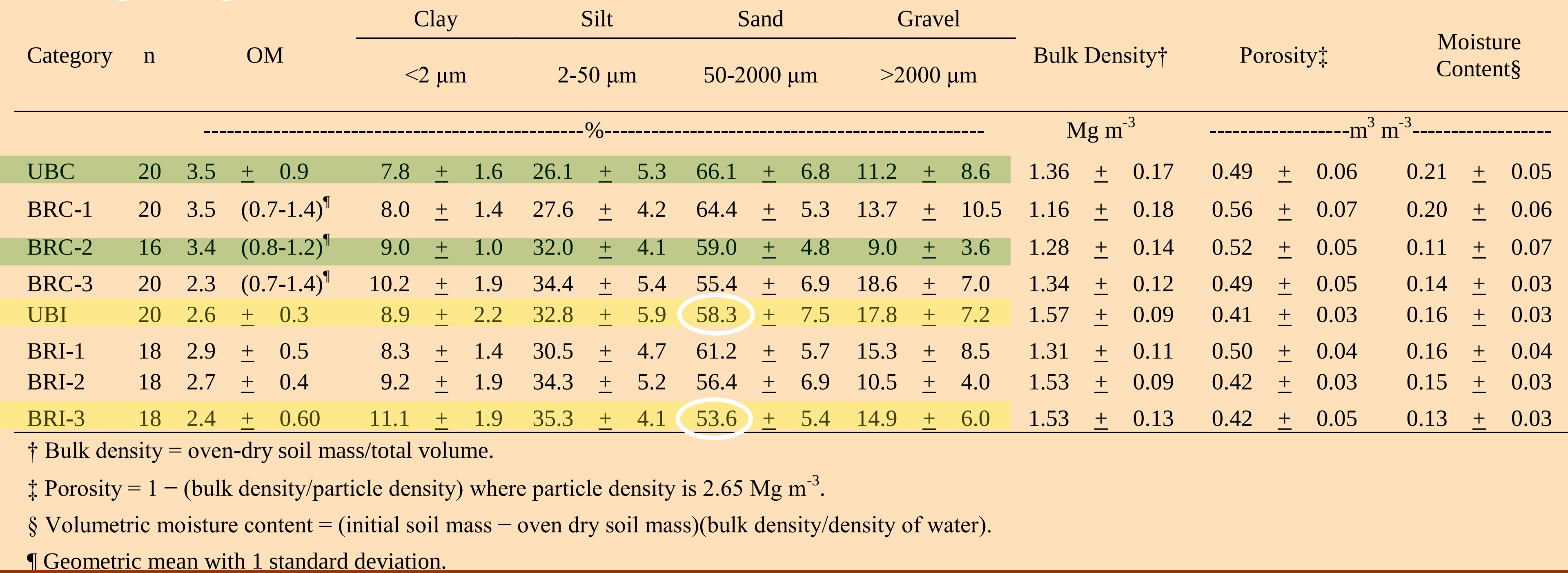
Soil PSD and Physical Props

Coppice:

- More Sand than Interspace
- No sig change in Post-fire PSD

Interspace:

- Sig dec in Sand, Inc in Silt after 299 days



Category	n	OM	Clay <2 µm	Silt 2-50 µm	Sand 50-2000 µm	Gravel >2000 µm	Bulk Density†	Porosity‡	Moisture Content§
		----------%----------					Mg m^{-3}	----------m^3 m^{-3}----------	
UBC	20	3.5 ± 0.9	7.8 ± 1.6	26.1 ± 5.3	66.1 ± 6.8	11.2 ± 8.6	1.36 ± 0.17	0.49 ± 0.06	0.21 ± 0.05
BRC-1	20	3.5 (0.7-1.4)¶	8.0 ± 1.4	27.6 ± 4.2	64.4 ± 5.3	13.7 ± 10.5	1.16 ± 0.18	0.56 ± 0.07	0.20 ± 0.06
BRC-2	16	3.4 (0.8-1.2)¶	9.0 ± 1.0	32.0 ± 4.1	59.0 ± 4.8	9.0 ± 3.6	1.28 ± 0.14	0.52 ± 0.05	0.11 ± 0.07
BRC-3	20	2.3 (0.7-1.4)¶	10.2 ± 1.9	34.4 ± 5.4	55.4 ± 6.9	18.6 ± 7.0	1.34 ± 0.12	0.49 ± 0.05	0.14 ± 0.03
UBI	20	2.6 ± 0.3	8.9 ± 2.2	32.8 ± 5.9	58.3 ± 7.5	17.8 ± 7.2	1.57 ± 0.09	0.41 ± 0.03	0.16 ± 0.03
BRI-1	18	2.9 ± 0.5	8.3 ± 1.4	30.5 ± 4.7	61.2 ± 5.7	15.3 ± 8.5	1.31 ± 0.11	0.50 ± 0.04	0.16 ± 0.04
BRI-2	18	2.7 ± 0.4	9.2 ± 1.9	34.3 ± 5.2	56.4 ± 6.9	10.5 ± 4.0	1.53 ± 0.09	0.42 ± 0.03	0.15 ± 0.03
BRI-3	18	2.4 ± 0.60	11.1 ± 1.9	35.3 ± 4.1	53.6 ± 5.4	14.9 ± 6.0	1.53 ± 0.13	0.42 ± 0.05	0.13 ± 0.03

† Bulk density = oven-dry soil mass/total volume.

‡ Porosity = 1 − (bulk density/particle density) where particle density is 2.65 Mg m^{-3}.

§ Volumetric moisture content = (initial soil mass − oven dry soil mass)(bulk density/density of water).

¶ Geometric mean with 1 standard deviation.

- Previous research shows fire causes increase in sand due to collapse & loss of clay and aggregates
- Low intensity fire, did not impact clay. Poss. that exposed non-veg’d surfaces at interspace could be more vulnerable to erosion and transport of fines by wind and large particles by water

Soil Structure

Coppice:

@5 days @299 days @383 days

- Fine/Med Mod SBK & Gran. ->Med Wk ->Ms ->Ms

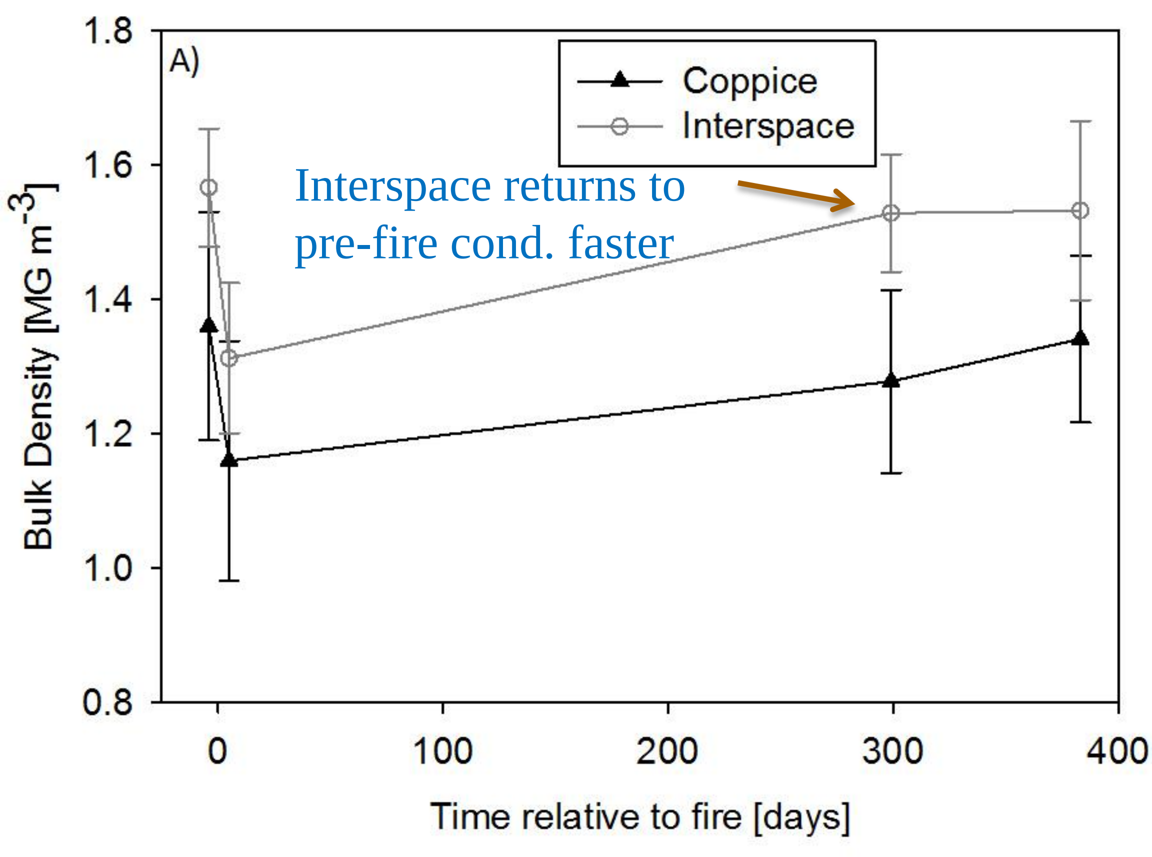


Interspace:

- Crs Mod/strong SBK -> Med/Crs Wk SBK ->Wk Med SBK ->Fine Weak SBK




Soil Properties: Bulk Density

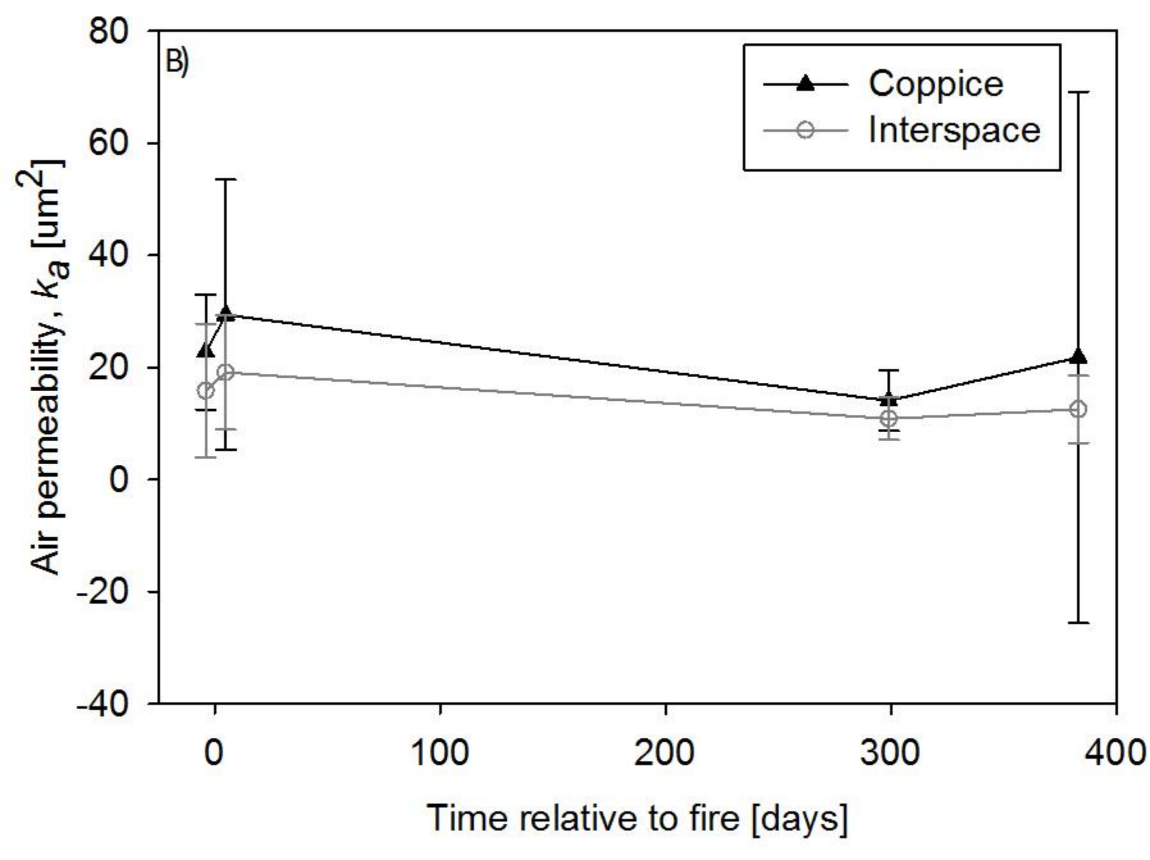


Interspace returns to pre-fire cond. faster

n=	Coppice	Interspace
unburned	20	20
Burned #1	20	18
Burned #2	18	18
Burned #3	20	18

- Interspace was higher than coppice (due to biol activity at coppice)
- After burn, decrease for interspace & coppice (16%; 15%)
- After 299 days, ρ_b increases (for interspace near initial value)
- After 383 days, no change for interspace but 5% increase for coppice

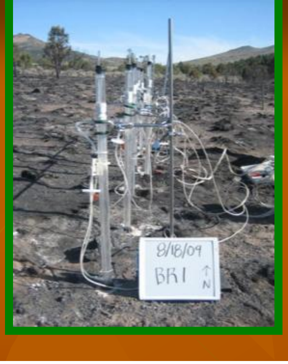
k_a



- Post-fire *ka* increased for interspace and coppice (20% and 29% resp) DUE to DIFF MECHANISMS
- @coppice: dec. in p_b, inc in macropores or pref flowpaths due to hardened peds
- @ interspace: SS deterioration, lack of veg ->breakdown of densely packed soil through vapor expansion

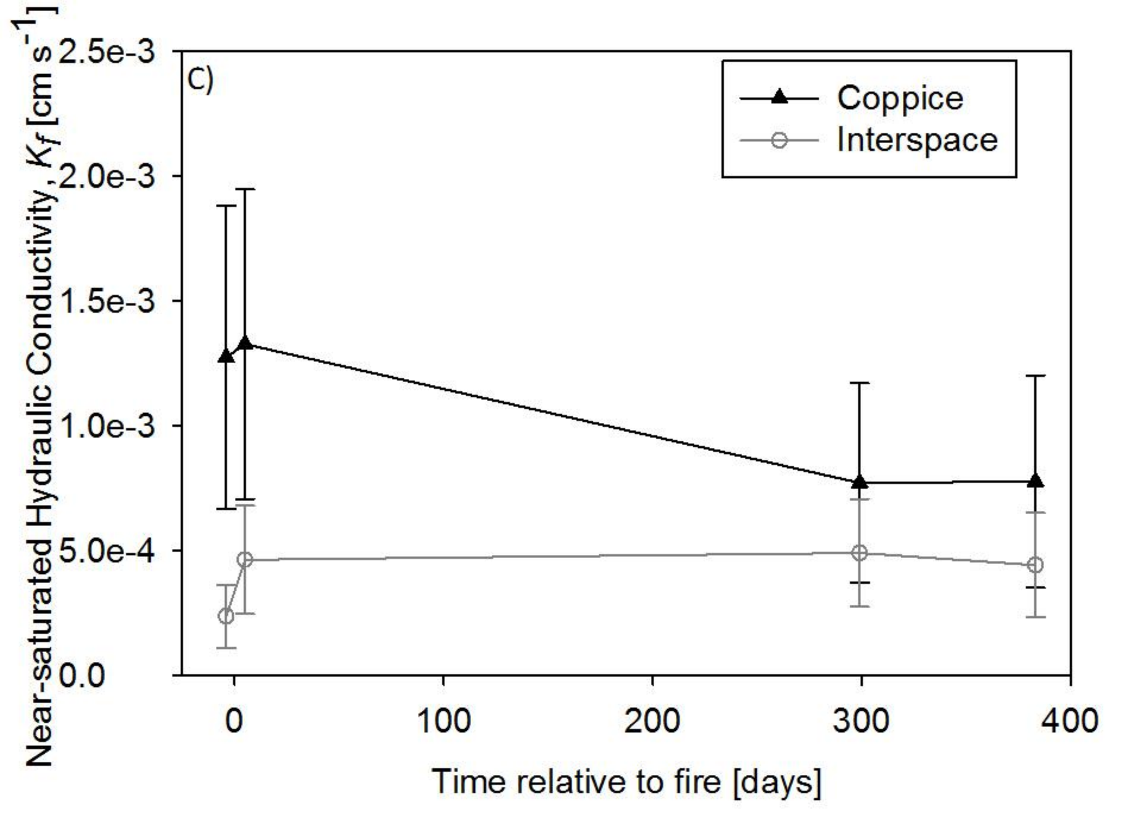
•After winter/spring-snow/rainfall season, k_a dec below pre-fire levels by 38% and 31% for coppice and interspace, resp ->attributed to collapse of soil particles due to snowpack loading

•After summer season, k_a at coppice inc ->biol activity; HOWEVER @ interspace, k_a not sig diff



K_f

- @ interspace: analogous to k_a, K_f was always lower & sig diff. than coppice
- After burn, @interspace, K_f increased by 95% and @coppice increase by 4%
- @coppice, avg K_f not sig diff. for unbuned &burned
- Although, k_a showed clear increase in pore space, the slight to moderate hydrophobicity at coppice indicates preference to type of fluid thus no sig inc in K_f



- Conversely, post-fire K_f was higher at interspace, where WDPT was lower
- K_f stabilized after winter/spring-snow/rainfall season as did ρ_b and k_a
- Summer season has less impact on coppice than interspace

Conclusion

- Most significant changes occurred immediately after the fire
- Soil physical changes at interspace could be attributed to transfer of heat and vaporized water, weakening soil structure through pore expansion
- Soil structure changes play more significant role at interspace
- At coppice, soil physical changes could be most attributed to changes due to transfer of organic matter that disaggregated soil particles and resulted in hydrophobicity
- Coppice and interspace microsites behave and recover differently before and after a fire, however, hydraulic properties are more similar 1 year after the fire
- Seasonal changes (precipitation, winter snowpack, and temperature) reversed soil property changes, where K_f, k_a, and porosity decrease, and bulk density increases.

Conclusion

- Although, fire effects may increase soil erosion immediately afterward, mechanisms leading to this result for a low-intensity fire could be attributed to soil aggregate and structure instability, rather than erosion due to lower infiltration capacity and increased runoff
- Post-fire conditions observed immediately after the fire, after a winter/spring-snow/rainfall season, and after one summer at the Upper Gleason resulted in a dynamic change to soil physical and hydraulic properties, which were attributed to expansion of soil pores, compaction, and hydrophobicity in different combinations and time periods for coppice and interspace microsites.
- Unique opportunity for a true comparison of pre- and post- fire conditions

THE END – *Thank You!!!*