Fire and Soil Health on Rangelands

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Introduction

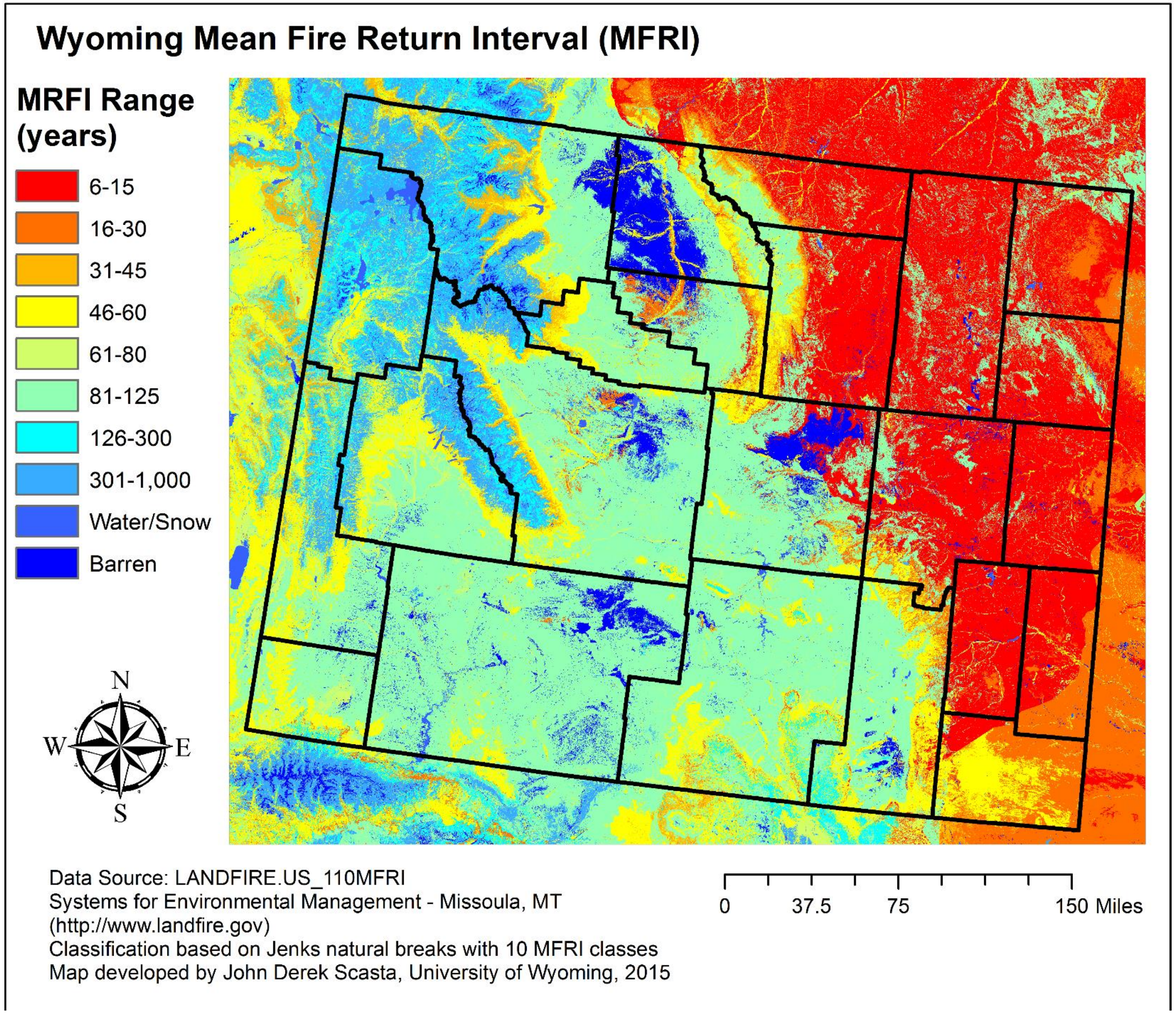
- TAMU, TTU, OSU Education
- Patch-burn grazing in mixed and tallgrass prairie
- Certified Wildland Fire Ecologist - AFE
- Certified Professional in Rangeland Management – SRM

- 38 Prescribed fires in 3 states
- Published fire-related research in the following journals: *Fire Ecology*, *International Journal of Wildland Fire*, *Rangeland Ecology and Management*, *Botanical Studies*, *EcoHealth*, *Southwestern Entomologist*, and several others

Focus

- Primarily on rangeland (non-cultivated land)
- Minor mention of forest research
- Attempt to provide broad overview
- Identify potential utility to use fire for managers

Mean Fire Return Interval (Landfire)



the average period between fires
under the presumed historical fire regime

Fire ≠ Fire

Wildfire

Unplanned

Extreme conditions (low humidity, high winds, high temp)

High intensity

Hot (> 1,000° C)

High fuel consumption

Prescribed fire

Planned

Mild conditions (moderate humidity, low winds)

Low intensity

Cool (400° to 700° C)

Low fuel consumption

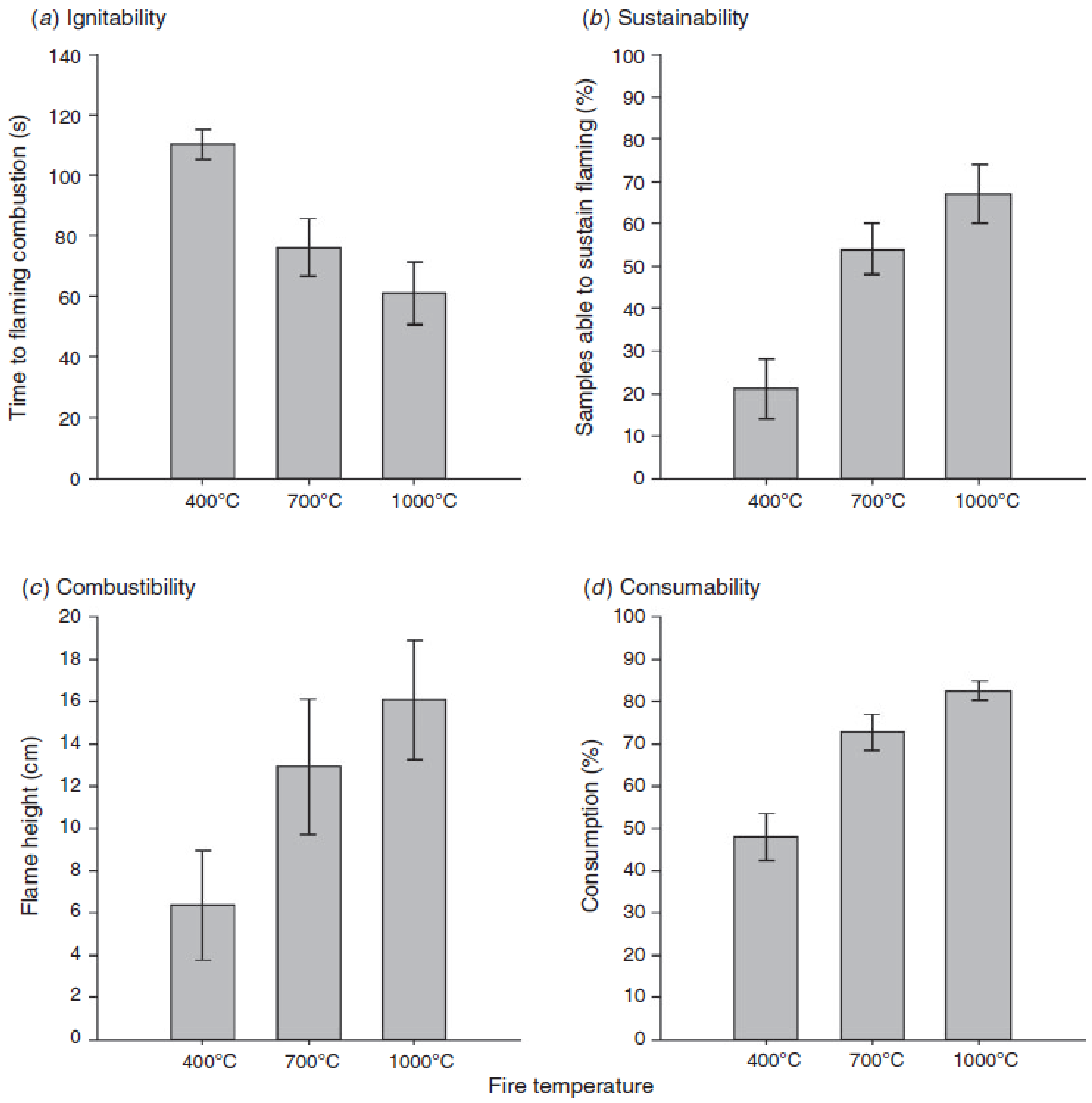
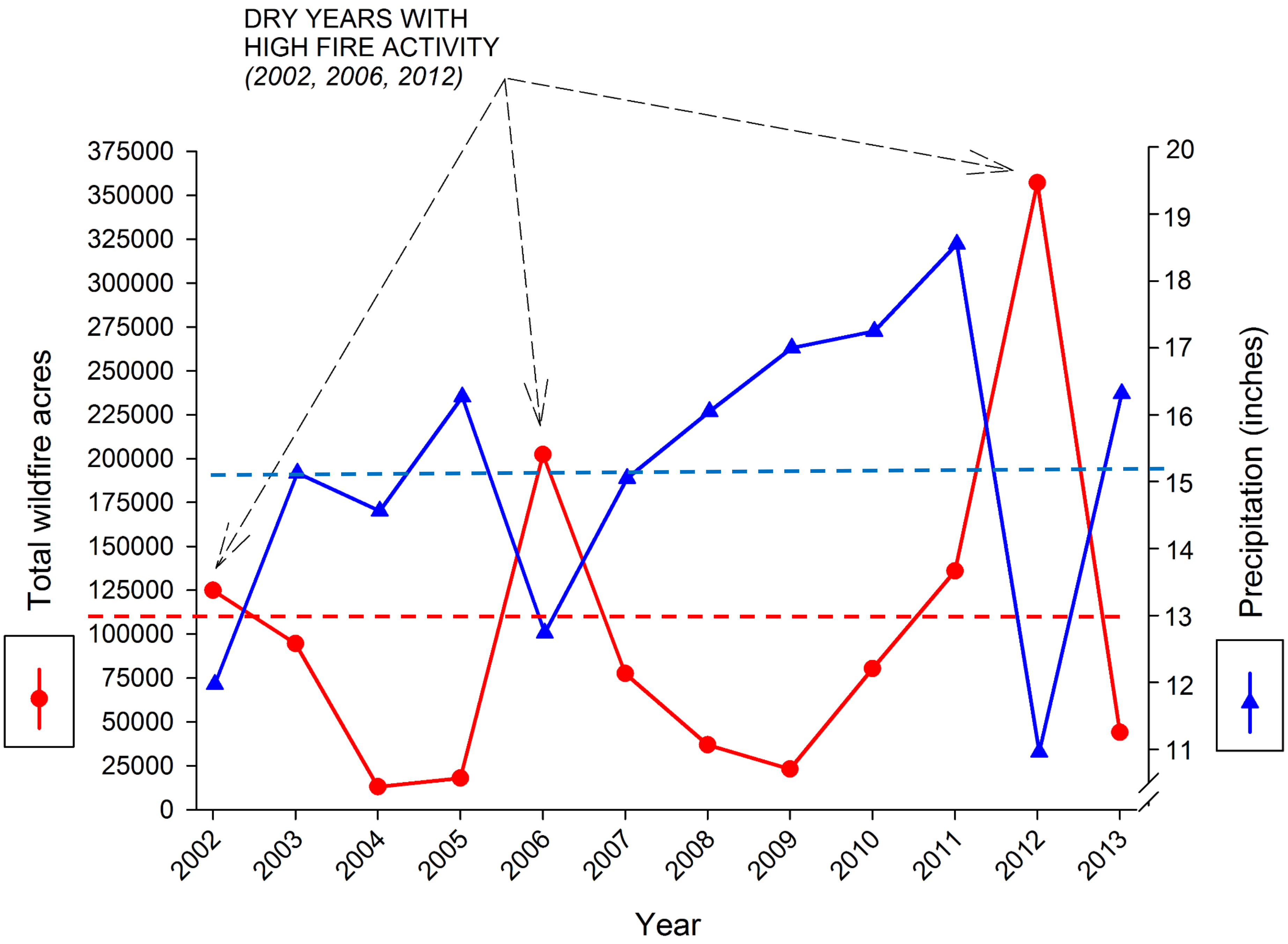


Fig. 1. Comparison of mean (±s.e.) (*a*) ignitability (time to flaming combustion), (*b*) sustainability (percentage of samples able to sustain flames >10 s), (*c*) combustibility (flame height) and (*d*) consumability (percentage of fuel consumed as the relative fuel sample weight change before and after exposure to fire), for three fire temperatures regardless of *J. virginiana* live fuel moisture (LFM). Each bar represents 24 laboratory ignition tests of 10-g subsamples across the full gradient of LFMs.

Wyoming Wildfire Trends (NIFC)



What is soil health?

- “Soil health, also referred to as soil quality, is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.” ~ NRCS 2015
- Soil organic matter
- Physical
- Chemical
- Biological

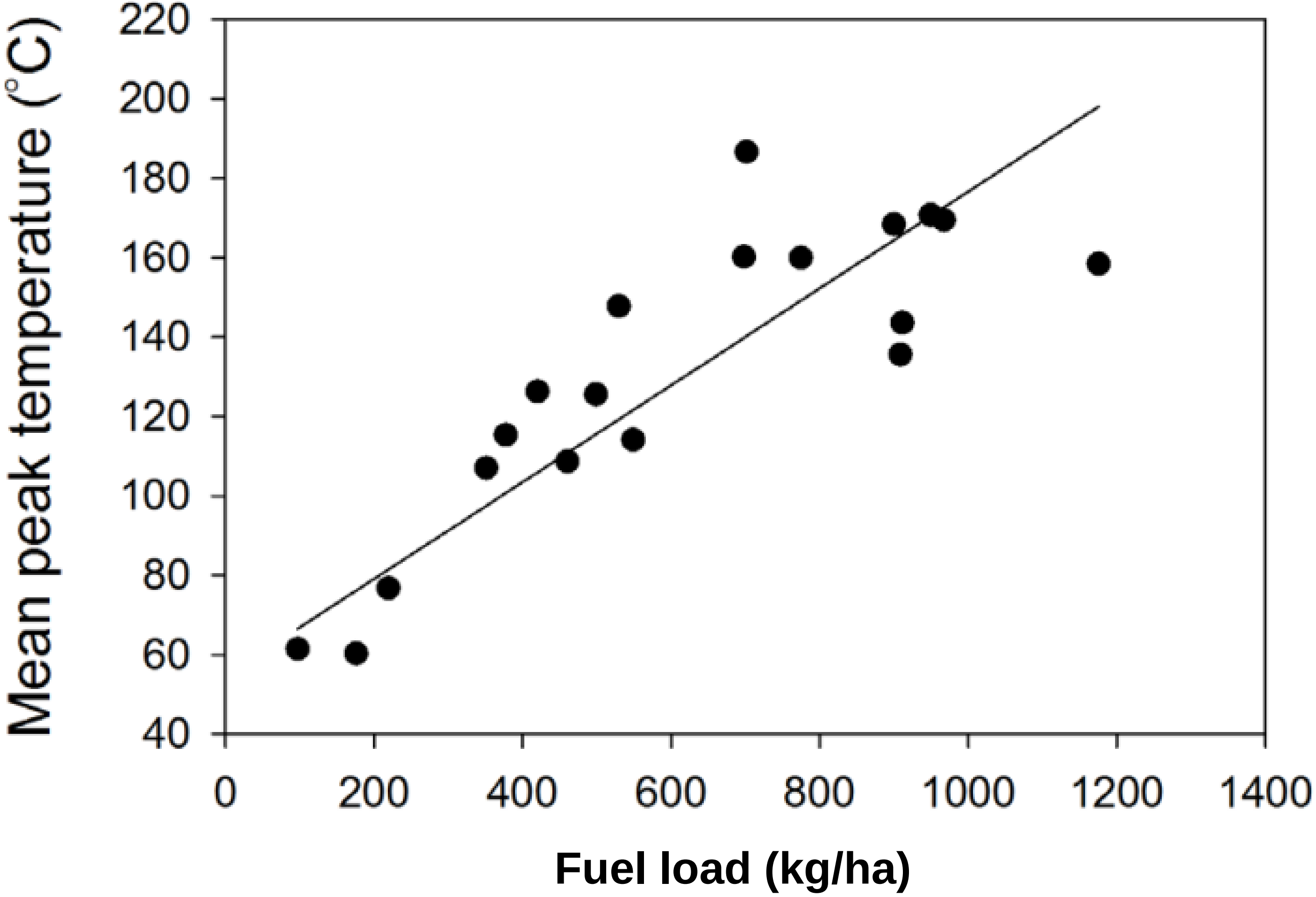
If you don’t remember anything else…

- Only a small proportion of fire generated heat (5%) is radiated to the soil
- 2nd law of thermodynamics
- Dry soil is a good insulator (DeBano et al. 1979)
- Below 2.5 cm depth, temperature rise was negligible (Giovannine and Lucchesi 1997)

Chaparral brush study (Countryman 1964; DeBano 2000)

Zone	Temperature
Canopy	1,100° C
Soil-litter interface	850° C
Mineral soil @ 5 cm	150° C

Mean Peak Fire Temperatures (Augustine et al. 2014) shortgrass steppe of CO

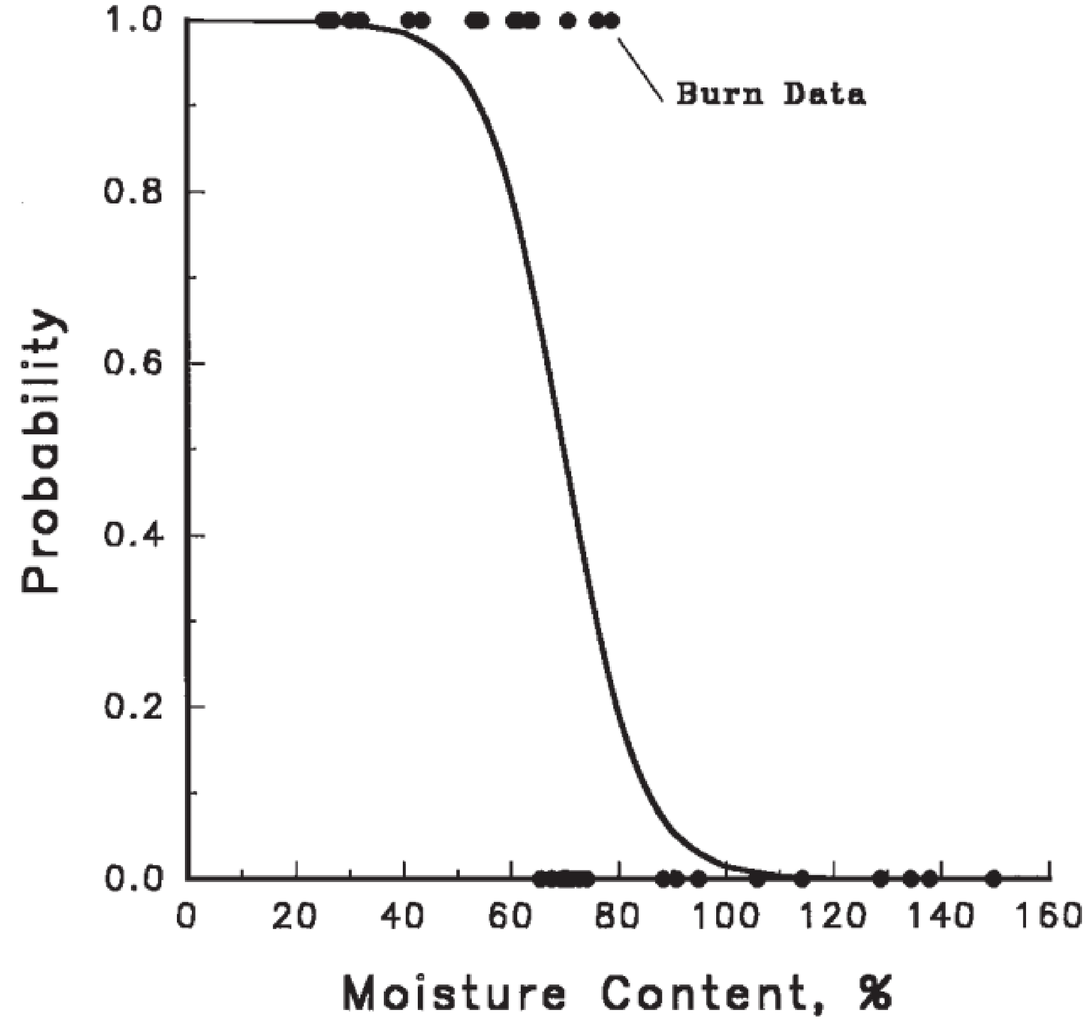


Ignition probability of organic soils

- Frandsen et al. 1997

- Prescriptions can be tailored
- Wildfire conditions cannot

Fig. 5. Example probability distribution of ignition versus moisture content (sedge meadow (upper)) from logistic regression analysis of burn/no burn data. Individual burn success data are plotted for comparison. Successes are plotted at a probability of 1 against the moisture content of the sample point, and failures are plotted at a probability of 0. Circles identify both successes and failures. Data are from the sedge meadow (Seney) sample group.



1. Soil organic matter

Soil organic matter

- Quantity and quality changes
- Content can increase or decrease based on fire intensity and type
- SOM content changes may range from its almost total destruction to increases in the surface layers as a consequence of external inputs, mainly from dry leaves and partially burnt plant materials in fires affecting the tree canopy (Chandler et al., 1983) and incorporation of necromass

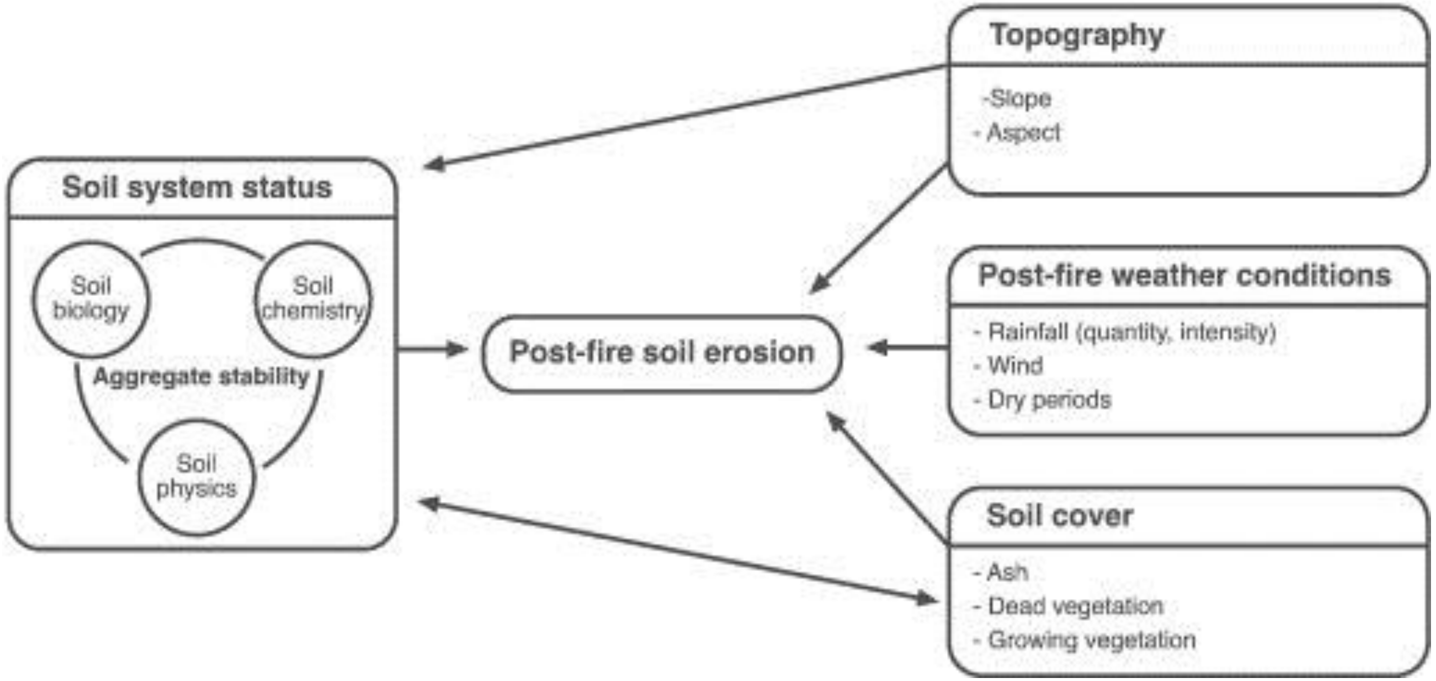
Soil organic matter (Rice and Owensby)

- In fire-prone rangelands
- Mechanisms to prevent catastrophic changes to soil physical and chemical properties
- Grass root systems prevent significant erosion

2. Physical

Erosion

- Variable
- Water repellency can reduce erosion
- Aggregate stability can alter infiltration
- More research is needed



Patch-burn grazing and erosion

- OK (Vermeire et al. 2005 – J Env Qual) Coarse textured sandy soils found an increased rate of erosion on burned patches but no drifting or blowouts were observed
- When spring weather promoted early plant growth, erosion was similar between burned and unburned patches100.
- Soil water content and plant productivity were unaffected by PBG but soils in burned patches were 1° to 3° C warmer than unburned plots.
- NE (Ozaslan et al. 2015 – J Env Qual) Silty clay loam soils also resulted in warmer soil surface, higher bare ground, lower litter, greater runoff depth, and greater sediment loss in recently burned patches but no difference in soil compaction, soil C, or total N

Water repellency (Review by DeBano 2000)

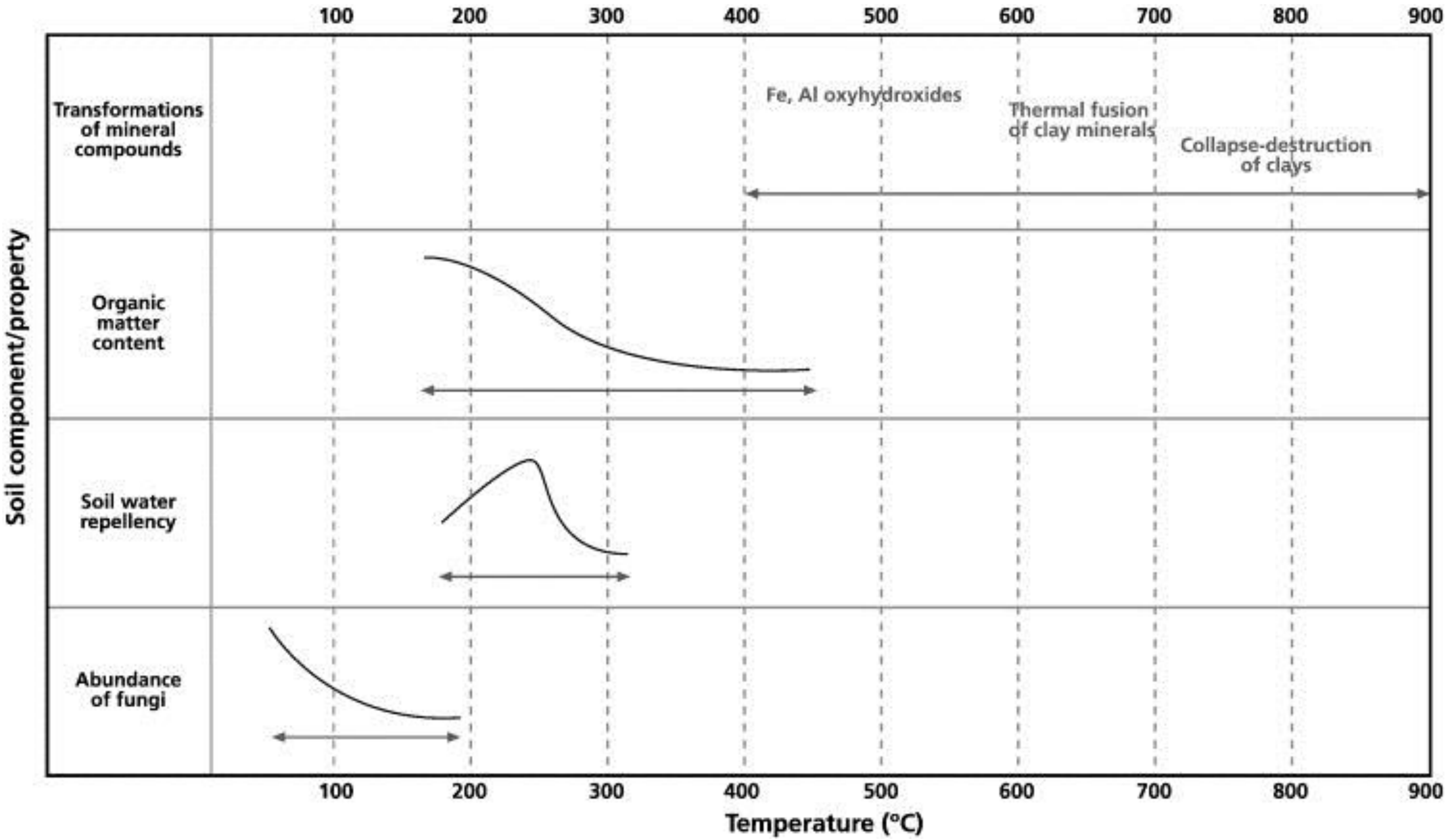
- Little change at soil temps < 175° C
- Intense repellency formation between 175° to 200° C
- Water repellency destroyed between 280° to 400° C
- Highly dependent on:
  - Amount and type of organic matter
  - Soil texture
  - Soil water content
  - General soil-plant environment

Water repellency…

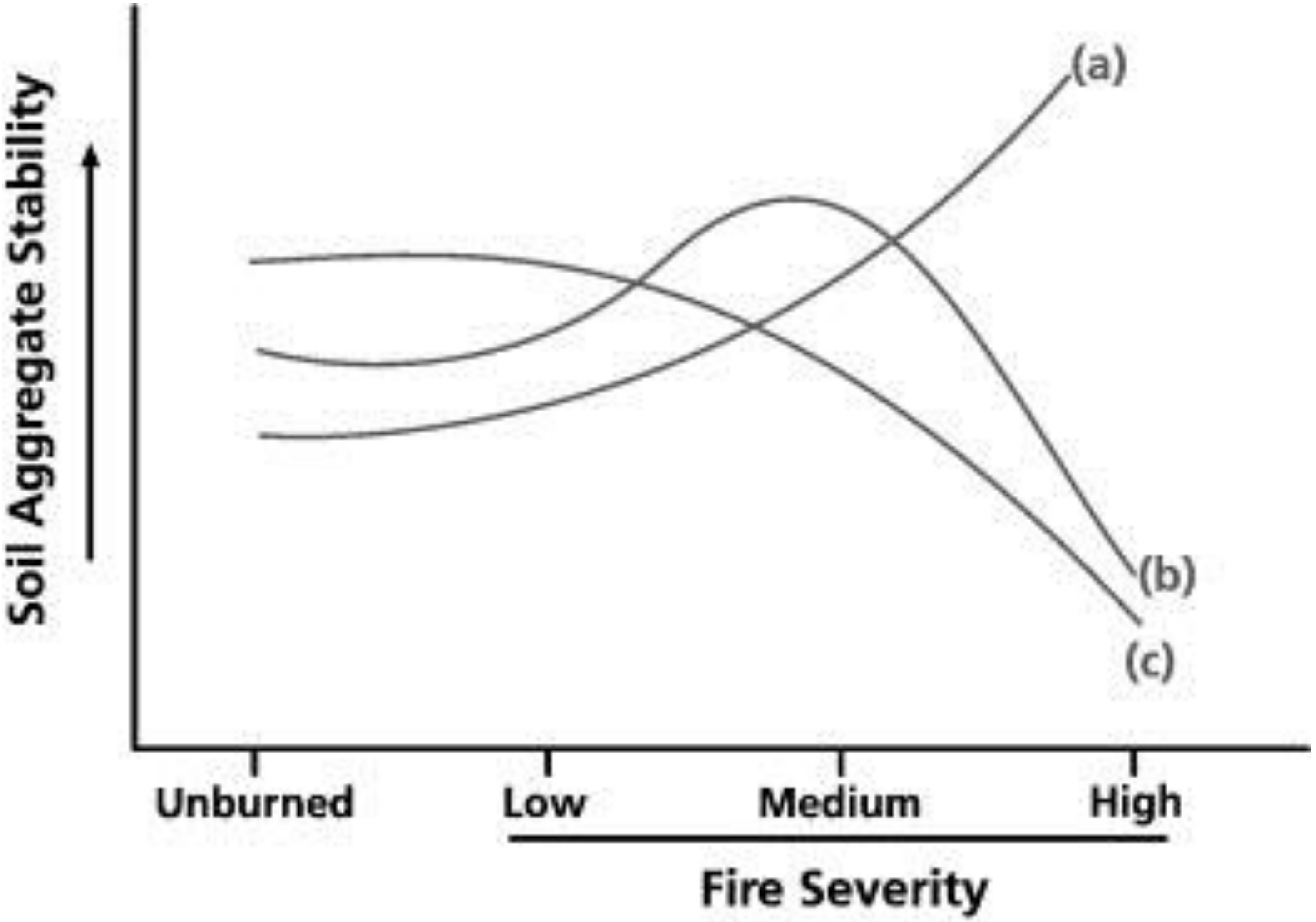
- “The only practical solution to manage fire-induced water repellency on wildland areas appears to be the regular use of prescribed fire as part of a comprehensive fuels management program.”
- Burning should be implemented on a regular basis to minimize soil heating under conditions of moderate soil moisture (Robichaud, 1996).
- Frequent burning would reduce the dead fuel loading on areas, allowing fire managers to conduct low severity prescribed burns that would produce less opportunity for creating heat-induced water repellency.
- The regular reduction of fuel loading would further reduce the risk of high severity wildfires occurring

Soil Aggregation (Review by Mataix-Solera 2011)

- Aggregate stability (AS) refers to soil structure resilience in response to external mechanical forces
- Variable reports – increases (5) or decreases(3) or no change post-fire (8)
- Low-severity fires typically do not cause AS changes
- High-severity fires can cause variable AS changes



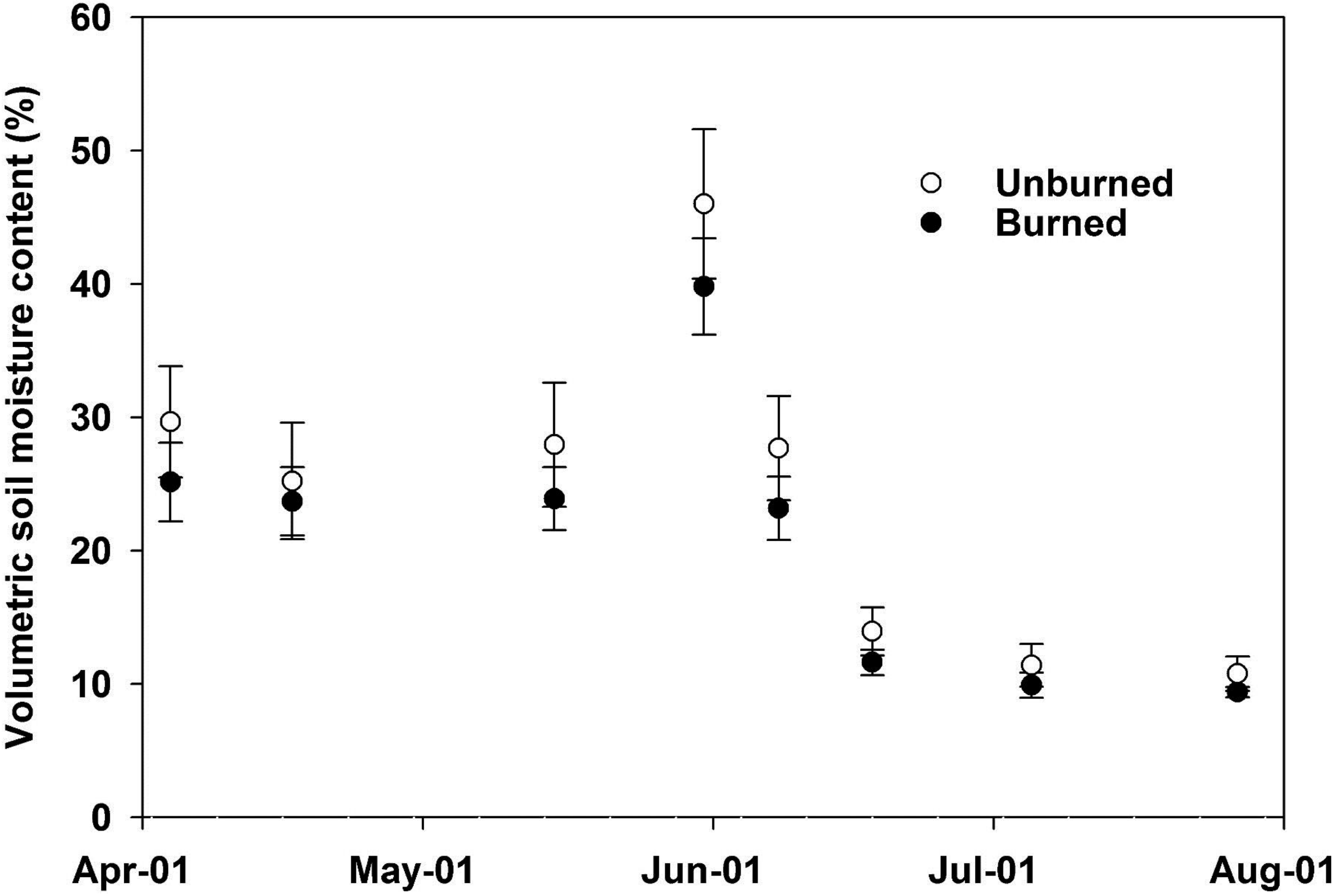
Mataix-Solera Review (2011) Fig. 3. The main soil components or properties relevant to aggregation and their changes at different temperatures. Horizontal lines indicate the approximate range of temperatures at ones which each property changes. The curves represent the magnitude and trend of the changes induced by fire at particular temperatures. These ranges can vary depending on the type of soil and also on the duration of a given temperature. Based in different studies (e.g.: DeBano et al., 1976, Giovannini et al., 1988, Soto et al., 1991, Neary et al., 1999, Ketterings et al., 2000 and Arcenegui et al., 2007).



Mataix-Solera Review (2011) Fig. 6. Three different patterns of aggregate stability changes in relation to fire severity: a) soil with a high clay content, calcium carbonate, Fe and Al oxides as principal cementing substances; b) soil with organic matter as the principal binding agent and originally hydrophilic or with low water repellency; and c) a sandy soil which is highly water-repellent and has organic matter as the principal binding agent.

Soil Moisture

- Shortgrass steppe
- Augustine et al. 2010

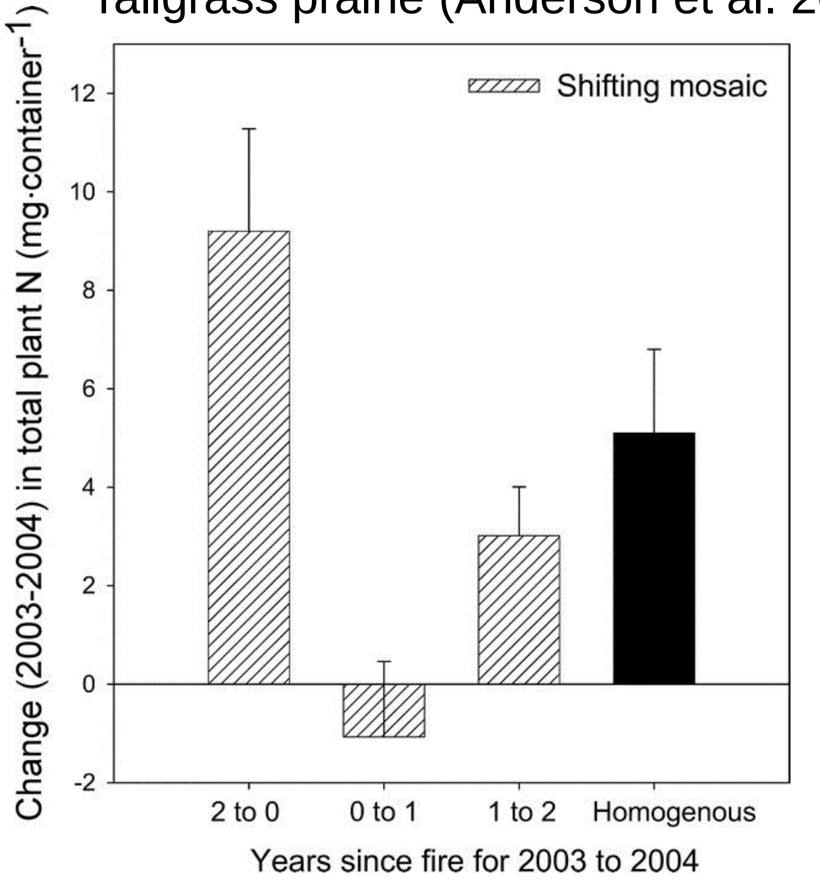


3. Chemical

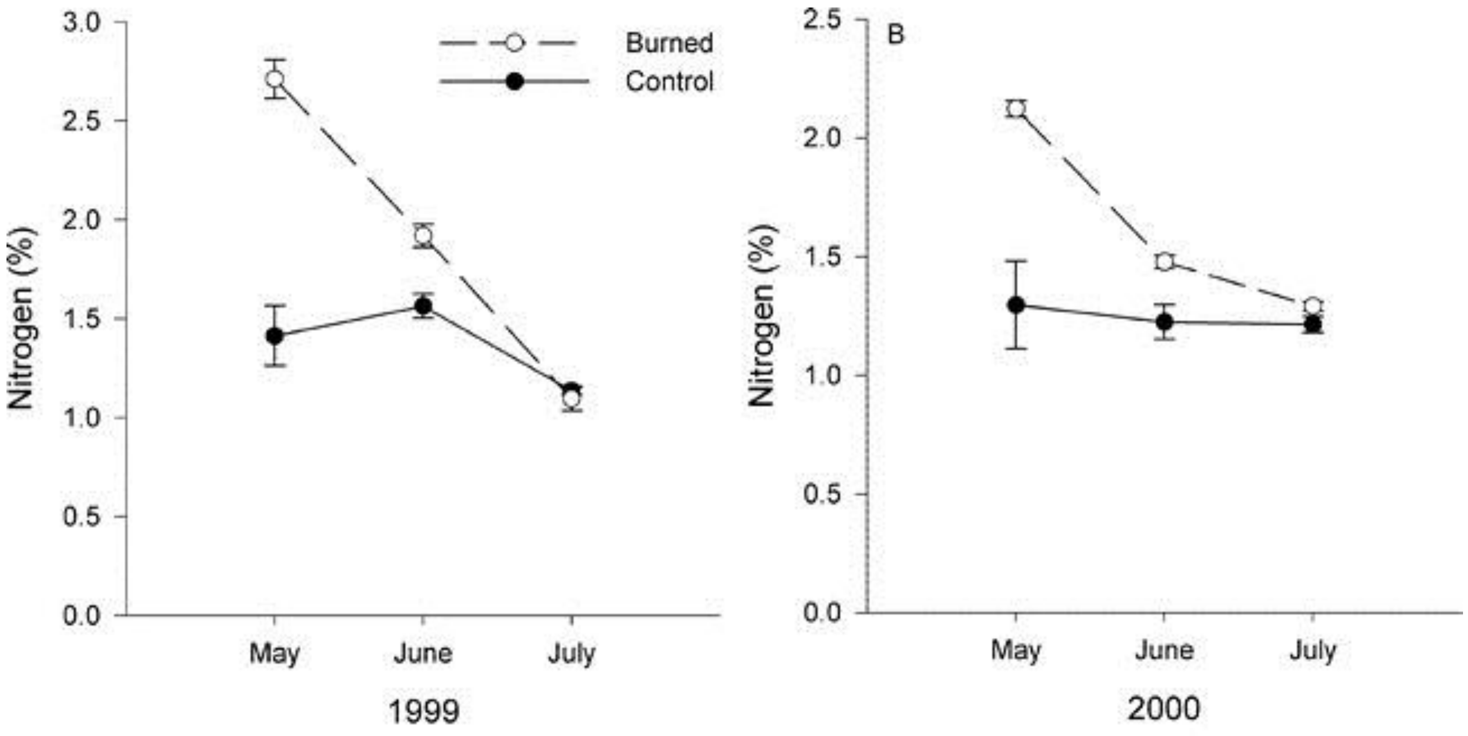
Soil nutrients and fertility

- May cause short-term short pulse of plant available N

Tallgrass prairie (Anderson et al. 2006)



Shortgrass steppe (Augustine et al. 2010)



Soil inorganic nitrogen

- In arid and semiarid ecosystems, fire can potentially affect ecosystem dynamics through changes in soil moisture, temperature, and nitrogen cycling, as well as through direct effects on plant meristem mortality
- (Augustine et al. 2014)

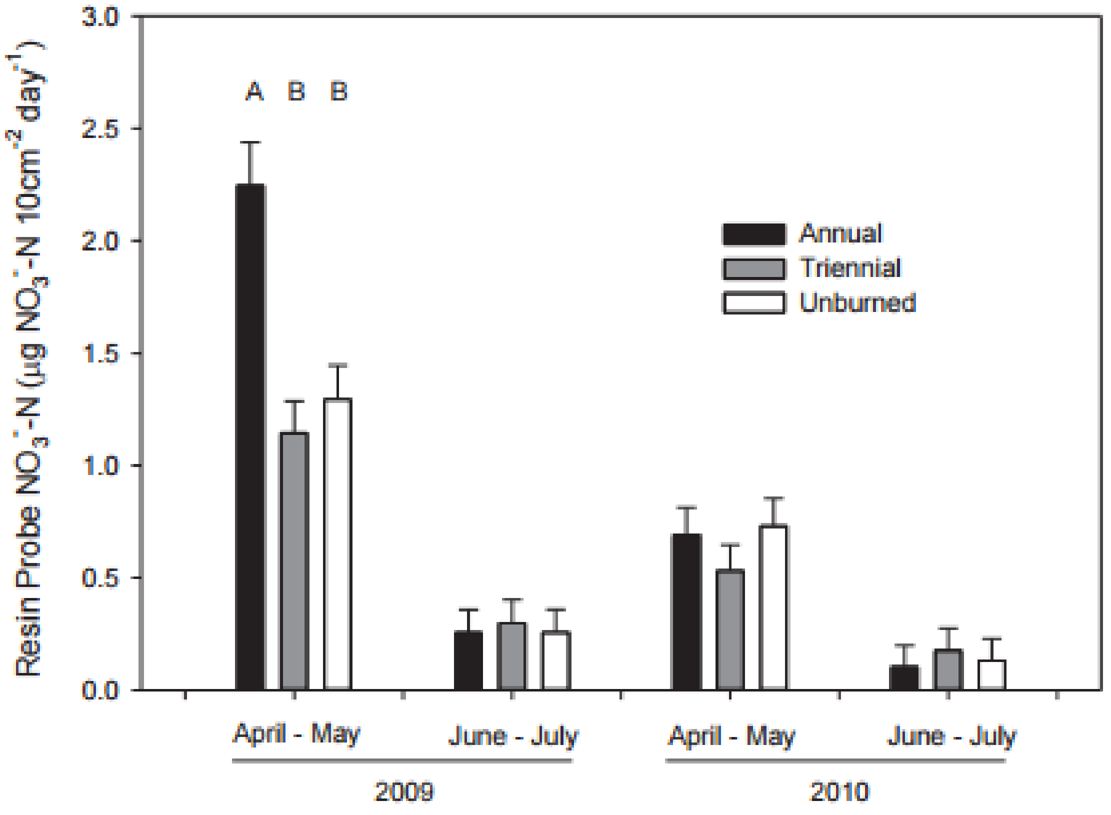


Fig. 2. Soil NO_3^-—N availability (mean + 1 SE) measured by PRS resin probes in burned and unburned shortgrass steppe at the Central Plains Experimental Range in north-eastern Colorado. See text for the number of days for probe incubations in each season and year. Bars with different letters above them are significantly different at the $P < 0.05$ level.

Plant productivity and nutrients

- 10-yr Kansas study (Abrams et al. 1986) demonstrated:
  - Greater biomass in lowland sites with fire
  - No difference in upland sites with fire
  - Removal of detritus in productive prairies may stimulate plant growth
- Johnson and Matchett (2001) in Kansas concluded:
  - Annual burning caused 25% increase in root growth vs. not burning
  - Grazing and burning combined improved root tissue quality (C:N ratio = 40) and promoted faster cycling of N

Importance of Nitrogen

- NPP is N limited in most terrestrial ecosystems
- N is critical for plant growth and microbial breakdown of cellulosic material in the rumen
- Authors from three studies have stated:
  - This interaction between fire and grazing and the resulting increase in plant available nitrogen may offer a strategic management approach for sustaining livestock production; likely because nitrogen content is used to calculate crude protein, the primary measure of feed quality.
  - Furthermore, the disturbance of fire in tallgrass prairie removes litter, increasing productivity, nutrient cycling and plant available nitrogen

Carbon

- Total soil organic C result from interaction between:
  - Vegetation; Soil organisms; Climate; Parent material; Time; Disturbances
- Grazing lands contain 10-30% of worlds soil organic carbon
- Rice 2000 reported annual burning and grazing tallgrass priaire increased Soil C storage 0.22 Mg per ha per year
- Burning of biomass can produce charcoal, C form resistant to decomposition (Skjemstad et al. 1996)
- Burning can alter the density of stored C by altering woody plant density or encroachment

4. Biological

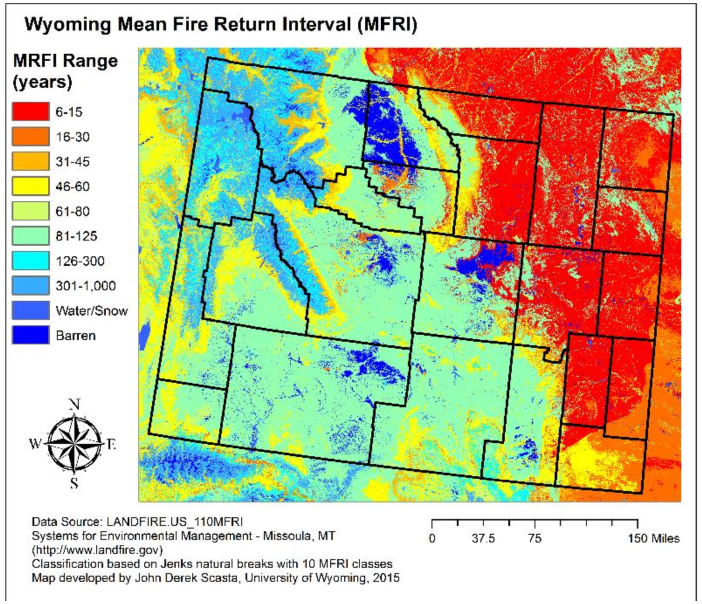
Biological

- The immediate direct effect of fire on soil microbiology is normally a reduction in the microbial biomass.
- The maximum temperatures reached in topsoil often considerably exceed those required for killing most living beings (DeBano et al., 1998).
- In extreme cases, the topsoil can undergo complete sterilization.
- Several authors have found a dramatic negative effect on microbes immediately after fire (Meiklejohn, 1955, Ahlgren and Ahlgren, 1965, Dunn et al., 1979, Theodorou and Bowen, 1982 and Deka and Mishra, 1983), and especially on fungi (Wright and Bollen, 1961, Ahlgren and Ahlgren, 1965, Widden and Parkinson, 1975 and Tiwari and Rai, 1977).
- Mataix-Solera 2011

Bacteria

- Immediately reduced post-fire
- Increase rapidly often exceeding levels in untreated soils
- Species composition may be altered
- Ojima et al. 1994 reported short-term enhancement of microbial activity in tallgrass prairie
- Hamman et al. 2007 reported no change in soil moisture, pH or temperature from low-severity fire but high-severity increased soil moisture, temperature and decreased pH. Microbial biomass did not change regardless of fire intensity but composition was altered.

Conclusion



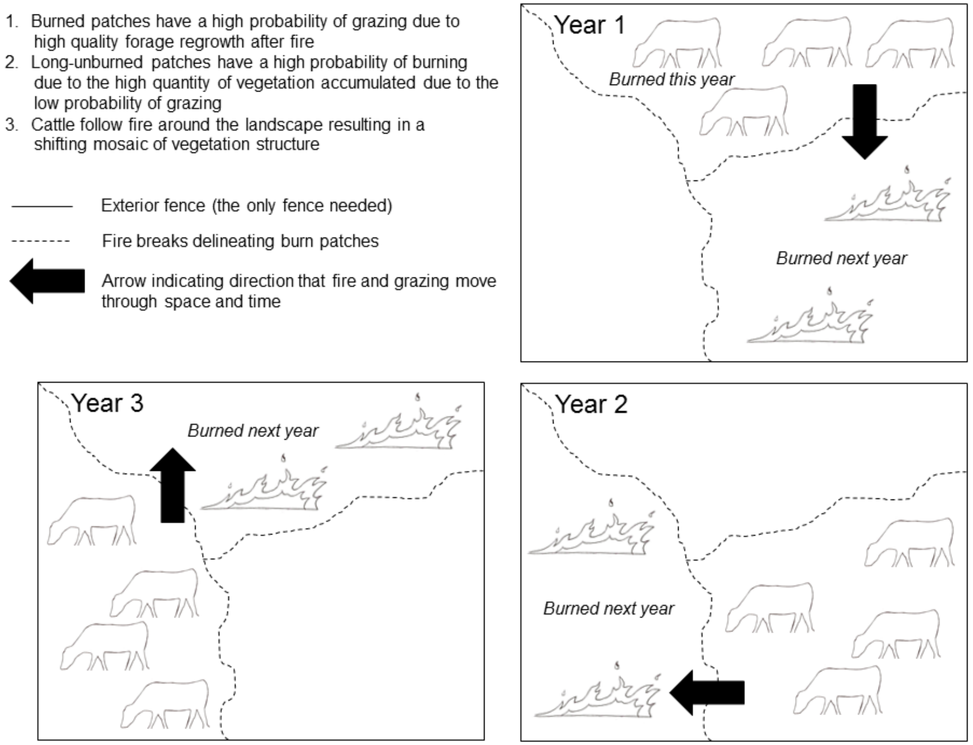
- Fire is going to occur on rangelands
- Broad-scale suppression can lead to fuel accumulation and greater wildfire intensity
- Negative effects on soils are often short-term
- Some potential positive short-term effects
- Must understand the historical fire regime to understand how to manage native rangeland ecosystems with appropriate fire frequencies and intensities

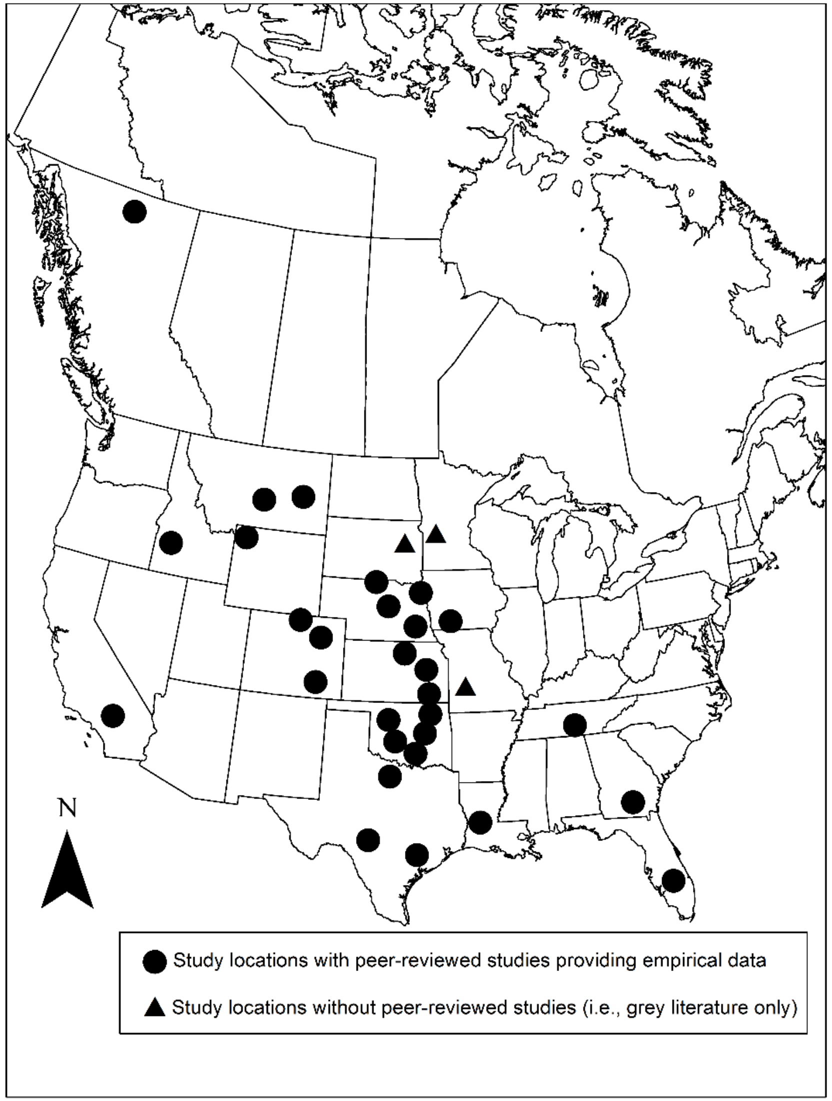

Soil health consequences without fire

- State-change to juniper woodlands can increase soil erosion (Davenport et al. 1998)
- Fire will occur when precipitation and fuel patterns dictate
- Could lead to intense wildfires and drastic state change
- Have to develop strategies to incorporate fire at appropriate spatial and temporal scales to minimize drastic events
- Maintenance of the native plant community composition and structure
- Maintaining existing soil health versus improvements?

Historically fire and grazing were interactive

- Patch-burn grazing or burning a portion of a pasture and allowing herbivores to select for the burn patch





Questions and Discussion

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