Fire ecology of prairie ecosystems

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Prairie ecosystems

- Ranged from central Canada south to Mexico, and from the Rocky Mountains east to Indiana
- Prairies once occupied 400 million ha, almost 20% of the North American continent
  - Tall grass: 99% decline from 65 million ha historically
  - Mixed grass: 76% decline from 63 million ha historically
  - Short grass: 66% decline from 18 million ha historically
- In US, 16 national grasslands and 5 national parks
- Soils are high in organic matter and very fertile
Importance

- Extensive and intensive agriculture, especially in what was the tall-grass prairie
- The “Dust Bowl” of the 1930s occurred in the mixed-grass prairie, the result of drought, over-grazing, and excessive cultivation
- The Ogallala aquifer, one of the world’s largest, provides drinking and irrigation water, is rapidly being depleted (Sierra Club 2001, http://www.sierraclub.org/ecoregions/prairie.asp)
- The largest extant tall-grass prairie remnants are in the Osage Hills of Oklahoma and the Flint Hills of Kansas
Wildlife

- Prairies are very important habitat for birds and other animals
- More than half of US waterfowl migrate through the prairie potholes region
Fire effects on wildlife

- Most animals escape the direct impacts of fire by flying or running away, or escaping into burrows in the ground, but nests and fledglings are vulnerable.
- Most fire effects on wildlife are indirect. They depend on how fire alters wildlife habitat.
Environment

- Continental climate
  - Cold, harsh winters
  - Summer thunderstorms
  - Relatively dry
  - Windy

- Episodic droughts
Three major zones

- Tall-grass prairie in the more humid east adjacent to deciduous forest
- Short-grass prairie in semi-arid West
- Mixed-grass prairie in between

Fig. 2. Extent of historical (pre-European) tall grass, mixed-grass, and short-grass prairies on the North American Great Plains.

Climate

- **East-West gradient in annual precipitation**
  - 750-1000 mm in tall-grass
  - 300-500 mm in mixed-grass prairie
  - 250 to 300 mm in short-grass prairie

- **North-South gradient in temperature**

[Map of North America showing climate zones](http://climate.konza.ksu.edu/)
Why are these grasslands not forested?

- Drought?
- Fire?
- Grazing?
- Soils?
Shifting grass-woody plant composition

- **Drought**
  - Young woody plants are drought-sensitive
  - Prolonged drought can result in shifts in species composition, invasion of exotics and degradation

- **Fire**
  - Frequent fires favor grasses over woody species
  - Fire limits the encroachment of the eastern deciduous forest into the grasslands

- **Grazing**
  - Bison and cattle prefer grass; grazing can increase shrubs and trees
  - Removes fine fuels
General fire effects in prairies

- Grasses recover post-burn more quickly than shrubs and trees
- Young and small woody plants more susceptible to fires than old, large ones
- Many shrubs resprout but can be killed if
  - Fires are too frequent
  - Vigor is low
  - Fire interacts with grazing, browsing, or insect damage
Historical role of fire in prairies

- Fire was prevalent
- Indians used fire in hunting and warfare, as well as for domestic and ceremonial purposes (Pyne 1982)
- Some feel that the effectiveness with which indigenous cultures in all grasslands used fires may have delayed development of agriculture (Pyne 1982, 1995)
Historical role of fire in prairies

- Fire history inferred from
  - Prevalence of lightning and human ignition
  - Rolling topography and continuous fuels would have allowed fires to spread widely
  - Many of the grasses and other plants are very tolerant of fire
- When fires did occur they were large
  - When a cavalry troop crossed a burned area near the Red River in North Dakota, their horses almost starved before reaching the other side
- Fire effects
  - Fire consumed and sped decomposition of dead and decaying vegetation
  - Fires recycled nutrients
  - Fires exposed soil to sun which warmed the ground in early spring
  - Altered structure and composition
Bison

- Keystone species (Knapp 1999)
- Once very abundant in the Great Plains, reduced to a few thousand, now ~150,000
- Most studies of bison-grassland ecology is from mixed- and short-grass prairies
- Most studies in tall-grass prairie ecosystems are in areas grazed by cattle or not grazed.
- Recently reintroduced to tall-grass prairie sites that are extensive enough to study interactions with fire (Knapp 1999)
Herbivory patterns

- Herbivory was often very intense but of short duration as a herd of bison or elk or grasshoppers grazed and moved on, allowing plant recovery during periods of rest.
- Most herbivory is by animals other than the large mammals: rodents, insects, and nematodes.
- Herbivory recycled biomass and redistributed nutrients.
- Sometimes favored recruitment through soil disturbance and seed dispersal.
Different herbivores select different plants

- **Bison**
  - Not very selective, mostly ate grass

- **Cows**
  - Prefer grass more than forbs; both much more than shrubs

- **Antelope** select forbs, grasses and shrubs

- **Rodents and birds** prefer plants with large seeds
Combinations of factors

- In humid east, fire was very important in limiting tree encroachment
- In semi-arid west, woody plants are drought-limited
- Topography also important
  - Woody plants in draws (more water) and on rocky hillsides (less fire)
Tall grass prairie

- Once vast (68 million ha)
- Less than 5% of this area now (Samson and Knopf 1994)
- Mostly converted to agriculture and urban areas
- An endangered ecosystem (Noss 19xx)
- Most remnants are relatively small and seldom burn, but several large tracts are protected, especially in Flint Hills and in Manitoba
Sometimes call the “true prairie”

- Dominated by tall grasses, many are > 2 m
  - *Andropogon scoparium*, big bluestem
  - *Buchloe dactyloides*, buffalo grass
  - *Bouteloua curtipendula*, grama
  - *Koeleria cristata*, june grass
Historical fire frequency unknown

- Estimated historical fire frequency ranges from 3 to 5 yr
- Burning every three years works well to maintain tall grass prairie composition and structure
- Can tolerate annual burning
- Unburned prairies deteriorate
Fires in tall grass prairie

- Maintain grassland against encroaching trees
- Release nutrients from accumulated litter
  - Less nitrogen is lost when plants are dormant when burned -- plants redistribute some of the N prior to senescence
- Frequent spring burns favor warm-season over cool-season grasses

Spring burn at Konza prairie,
http://xxx
Cool and warm season grasses

- **Cool-season grasses - C$_3$ photosynthesis**
  - *Stipa, june grass, Kentucky blue grass*
  - Actively growing in cool weather of spring and fall
  - Dormant in summer
  - Increasingly important as you go north

- **Warm season grasses - C$_4$ photosynthesis**
  - *Big bluestem, switchgrass, Indian grass, little bluestem, sideoats grama, blue grama, wheat grass and buffalo grass*
  - Actively grow in the high temperatures of summer. They are dormant in the spring.
Grass response to fire

- Depends on
  - Site conditions
  - Soil moisture at time of fire and after
  - Growth form of the plant (stoloniferous plants are generally more susceptible than bunchgrass and rhizomatous plants)
  - Whether plants are “cool” or “warm season”
    - Plants are more sensitive to fire when they are actively growing
    - In the absence of fire, cool-season grasses often increase, as do non-native species
Forbs

- Forbs contribute greatly to the species richness and diversity
- They are infrequent
- Forbs are very responsive to disturbance and environmental conditions
- Fires harm forbs if they are actively growing

Picture credits: Manitoba
Trees and shrubs

- Locally abundant, especially in riparian areas, river breaks, and in rocky areas where they are more protected from fire.
- In the absence of fire, Juniperus virginiana and other trees and shrubs will advance into grasslands.

North Saskatchewan River at Batoche, Saskatchewan, 1980.
Parks Canada/Photo Services/H.08.81.04.03(03),
http://parkscanada.pch.gc.ca/aborig/aborig14_e.htm
Fire and drought interact

- When fires occur in a drought, fire effects are more pronounced.
Mixed-grass prairie

Mixed grass prairie, Theodore Roosevelt National Park, North Dakota

Mixed-grass prairie in the sandhills of Nebraska

Mixed grass prairie

- Mix of species from the tall grass and short grass prairies
- Dominated by grasses, but forbs add much species diversity
  - Biomass: roughly 80% grasses and 20% forbs
- Vegetation is well adapted to fire
- Species composition varies with moisture, topography, recent disturbance history, herbivory, presence of exotic species
Fire effects

- Relatively little is known about fire effects
- Even though much of the mixed prairie was not plowed, little of it burns
- The amount of available fuel is often limited, particularly if sites are grazed
- Plants recover from fire, but often decrease in productivity and abundance following fire
- Drought accentuates the effects of fires
Shrub and tree response to fire

- **Mesquite dominates in southern mixed prairie**
  - Trees are easily killed by fire when small (e.g. less than 1.5 yr), but very tolerant of fire when bigger (e.g. more than 3.5 yr)
  - Fire effects also depend on disturbance history, vigor, quantity of fine fuel, grass competition, and presence of insect damage (Wright and Bailey 1980)

- **Juniper has thin bark and highly flammable foliage, and is readily killed by fire**

- **Many shrubs resprout and can regain preburn abundance within 3-6 yr after fire** (Wright and Bailey 1980)
Short grass prairie

A buffalo wallow near Keota, CO.

Parks Canada/A. Cornellier/ 08.81.10.01(43)

http://parkscanada.pch.gc.ca/aborig/aborig14_e.htm
Short grass prairie

- Drier than either mixed or tall grass prairie
- Droughts are much more frequent, occurring as often as 4 out of 10 yr

Fire effects

- Fires were probably relatively infrequent
- Little of the short grass prairie was cultivated, but much was grazed
- Most plant species are harmed by fires, especially during droughts
- Most recover