Oak, Fire & Mesophication

Past, current and future trends of oak in the eastern United States

Gregory Nowacki
Regional Ecologist
USFS Eastern Region

"I have spent about half of my life influenced, taught, and educated against fire in nature,

…and then I have spent the other half of it using fire and trying to understand it."

E.V. Komarek, Keynote Address, First Tall Timbers Fire Ecology Conference, 1962.

Reference: S. Pyne. 2015. Between Two Fires. U of AZ Press, Tucson.

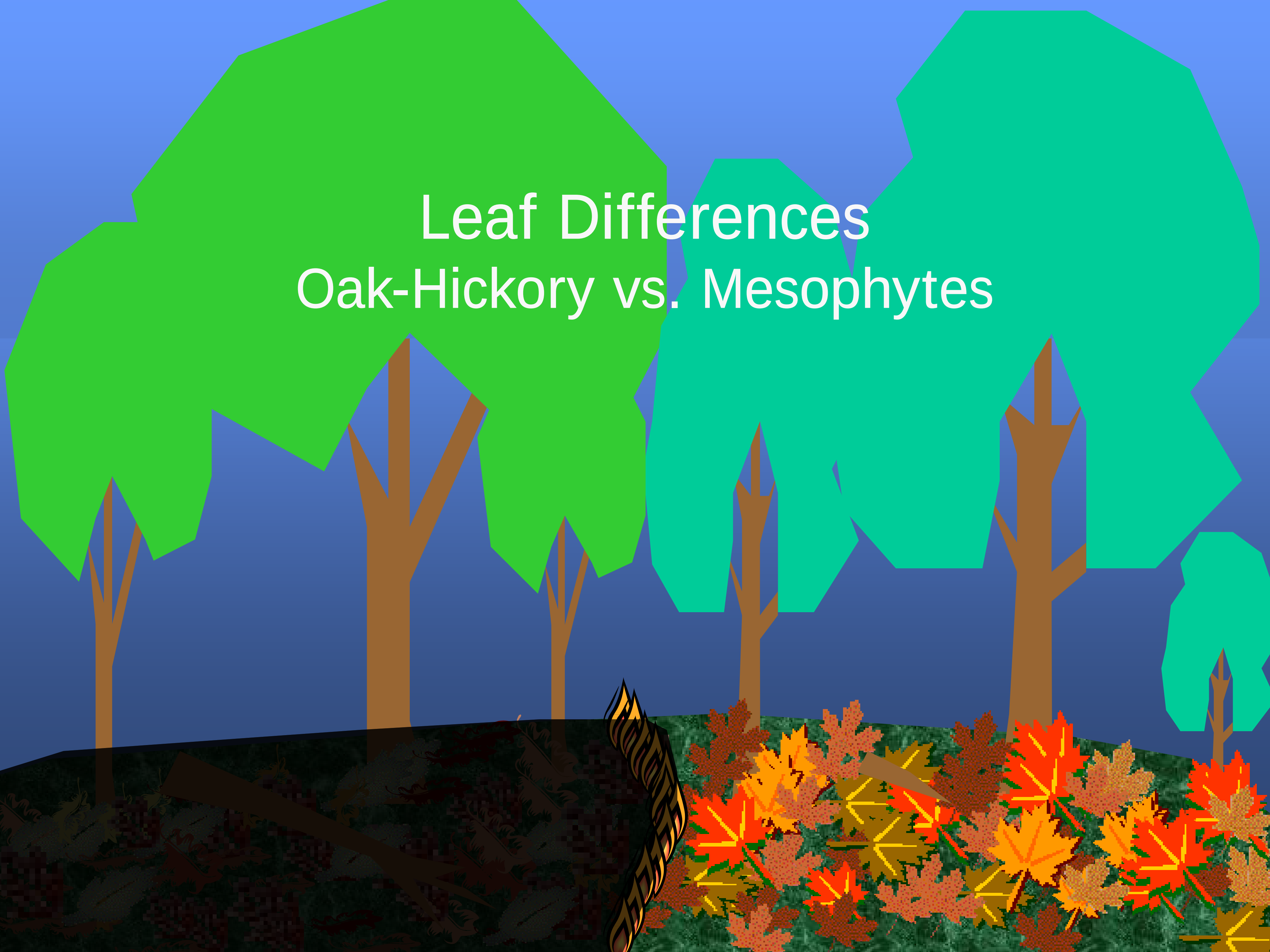
Oak is a fire- and drought-tolerant genus that possesses various adaptations...

- Thick bark (fire protection)
- Able compartmentalizer; rot resistant (fire injury)
- Aggressive sprouter (fire-based reproductive strategy)
- Opportunistic: responds favorably to disturbance
- Fuel characteristics (fire promotion)

Coarse Woody Debris Decay Rates

Oak = Hickory < Beech < Maple

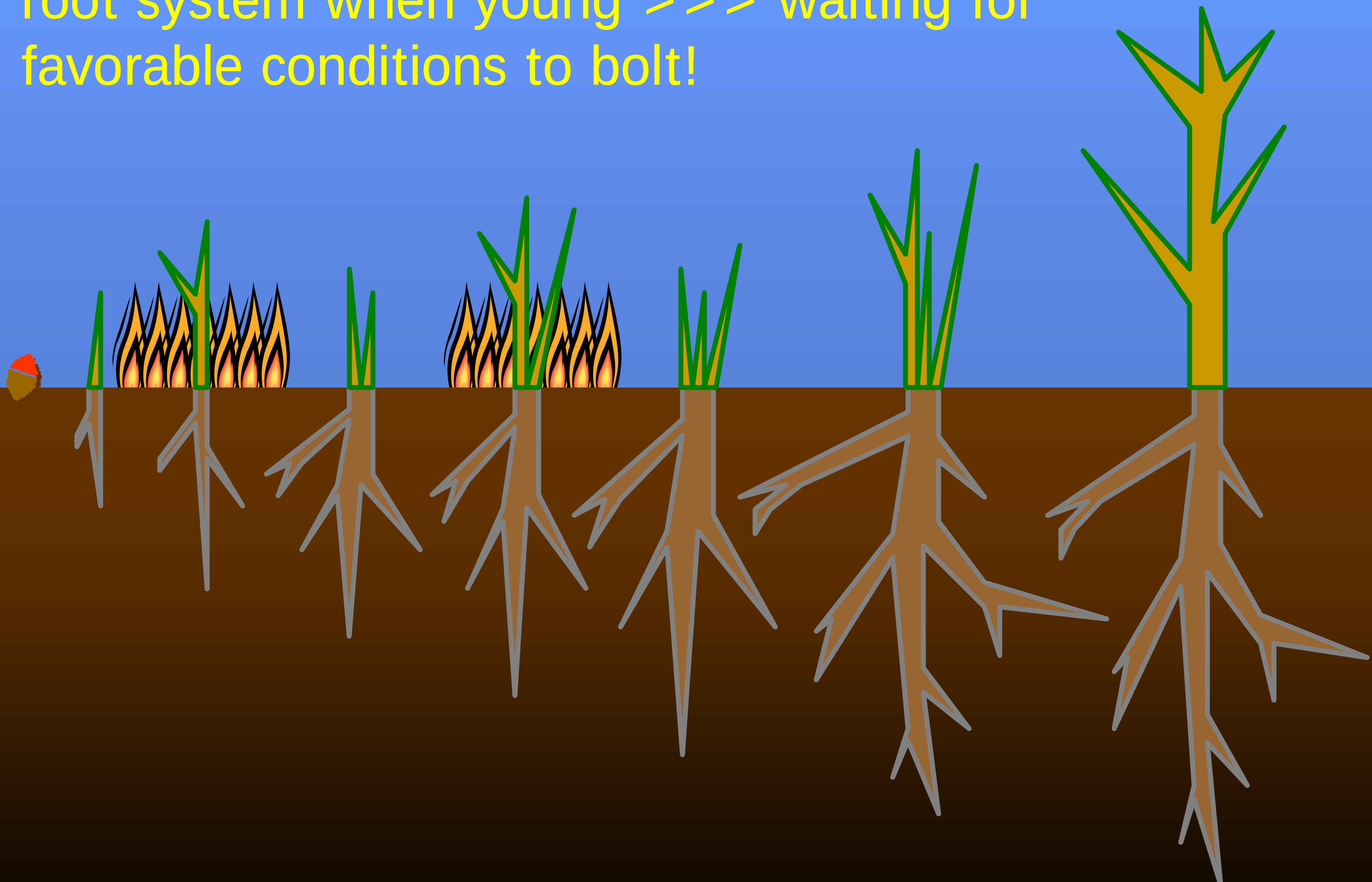
Slow Fast


Leaf Differences
Oak-Hickory vs. Mesophytes

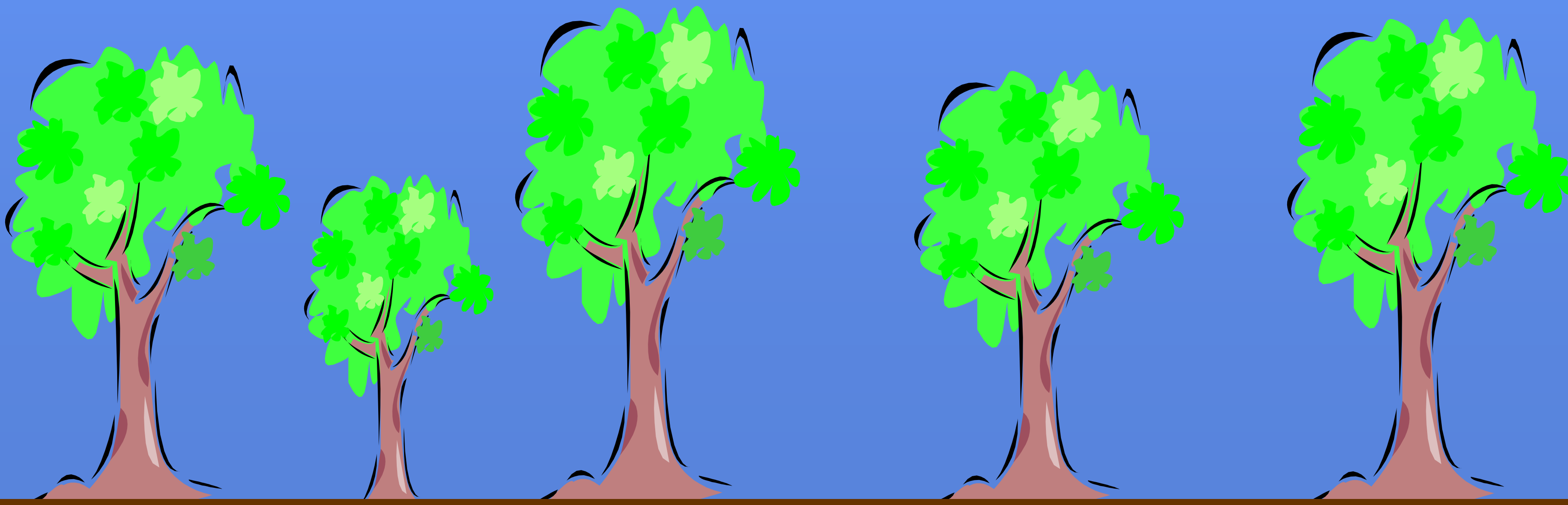
Oak is a fire- and drought-tolerant genus that possesses various adaptations ...

- Thick bark (fire protection)
- Able compartmentalizer (fire injury)
- Aggressive sprouter (fire-based reproductive strategy)
- Opportunistic: responds favorably to disturbance
- Fuel characteristics (fire promotion)
- Water efficient (drought resistance)
  - tap roots exploit deep H_2O sources
  - osmotic adjustment: extract H_2O from dry soils
  - xeromorphic leaves minimizes H_2O loss

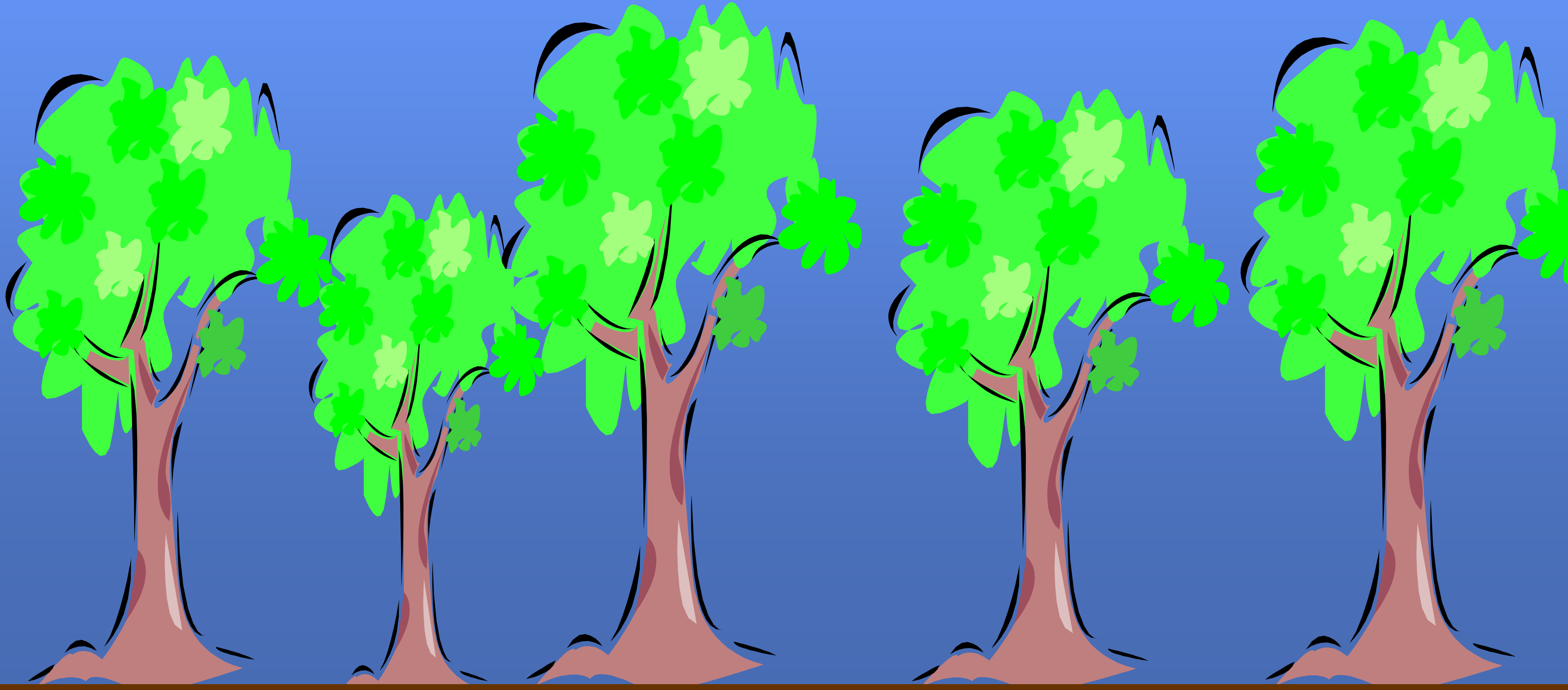
Oak Survival Strategy: heavy investment in root system when young >>> waiting for favorable conditions to bolt!

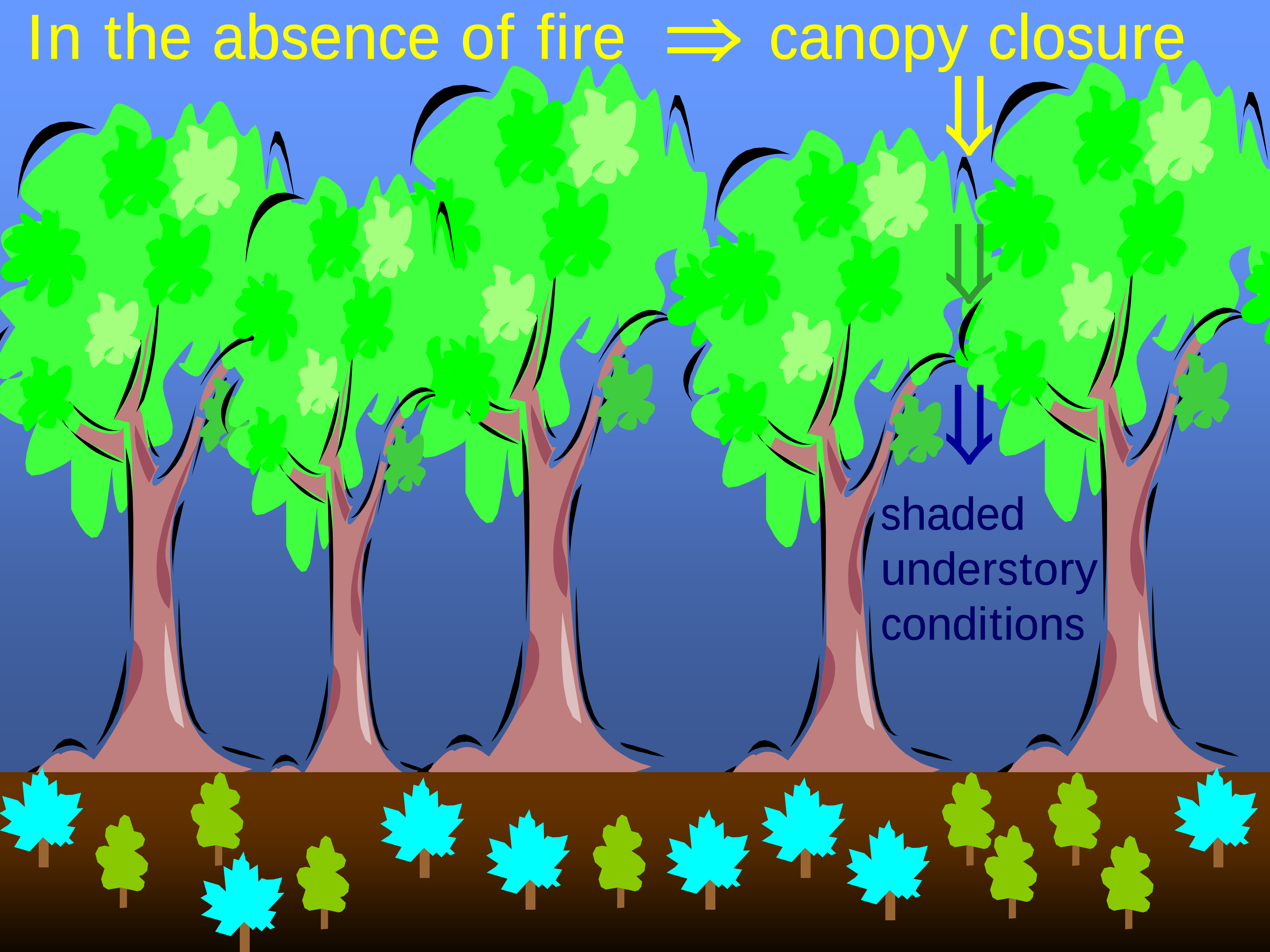


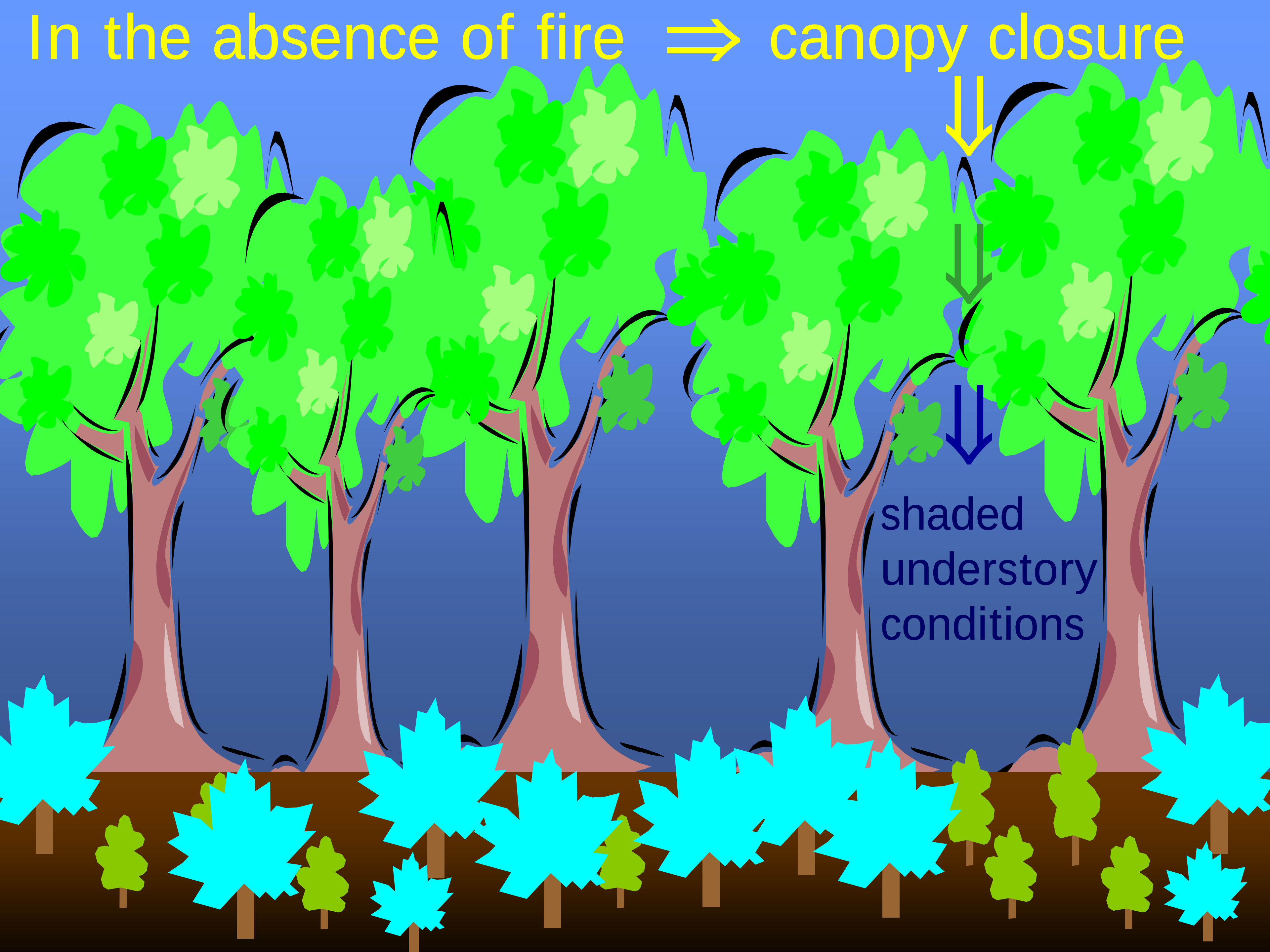
In the absence of fire



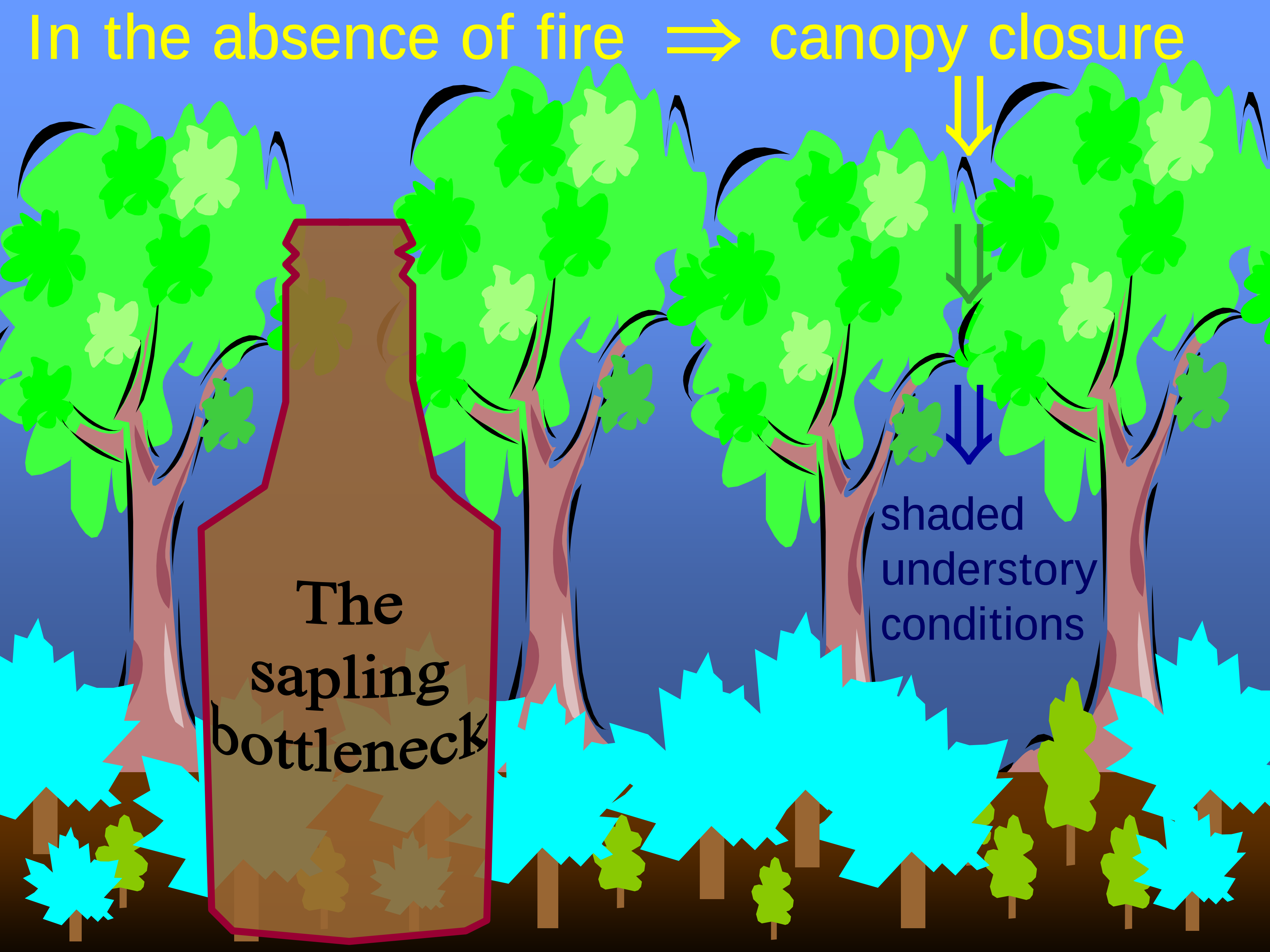
In the absence of fire ⇒




In the absence of fire ⇒ canopy closure
⇓
⇓
⇓
shaded understory conditions



In the absence of fire ⇒ canopy closure
shaded understory conditions


In the absence of fire ⇒ canopy closure
shaded understory conditions
The sapling bottleneck

So how big is this problem of altered fire regimes and "mesophication" in the eastern United States?

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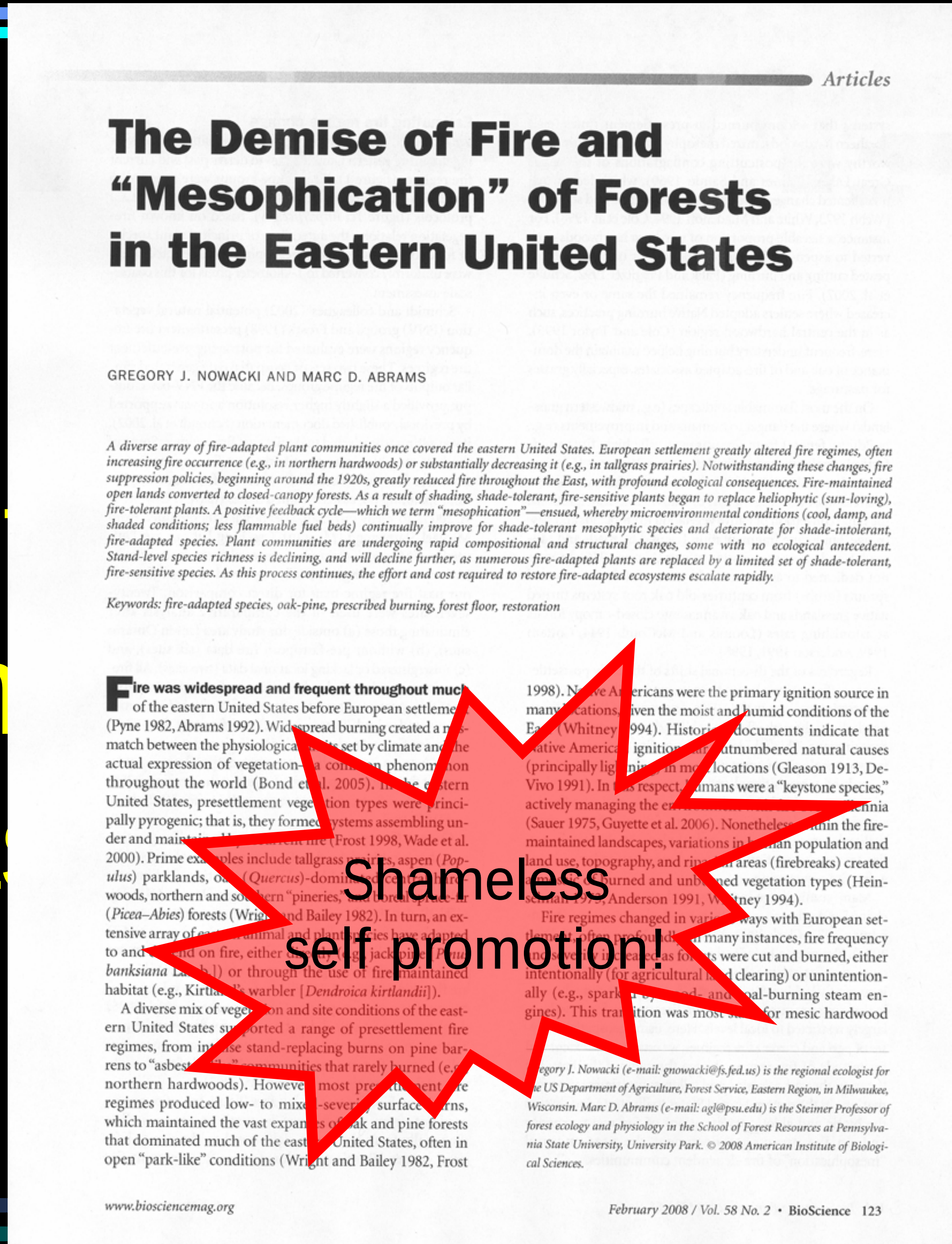

The Demise of Fire and “Mesophication” of Forests in the Eastern United States

GREGORY J. NOWACKI AND MARC D. ABRAMS

A diverse array of fire-adapted plant communities once covered the eastern United States. European settlement greatly altered fire regimes, often increasing fire occurrence (e.g., in northern hardwoods) or substantially decreasing it (e.g., in tallgrass prairies). Notwithstanding these changes, fire suppression policies, beginning around the 1920s, greatly reduced fire throughout the East, with profound ecological consequences. Fire-maintained open lands converted to closed-canopy forests. As a result of shading, shade-tolerant, fire-sensitive plants began to replace heliophytic (sun-loving), fire-tolerant plants. A positive feedback cycle—which we term “mesophication”—ensued, whereby microenvironmental conditions (cool, damp, and shaded conditions; less flammable fuel beds) continually improve for shade-tolerant mesophytic species and deteriorate for shade-intolerant, fire-adapted species. Plant communities are undergoing rapid compositional and structural changes, some with no ecological antecedent. Stand-level species richness is declining, and will decline further, as numerous fire-adapted plants are replaced by a limited set of shade-tolerant, fire-sensitive species. As this process continues, the effort and cost required to restore fire-adapted ecosystems escalate rapidly.

Keywords: fire-adapted species, oak-pine, prescribed burning, forest floor, restoration

Fire was widespread and frequent throughout much of the eastern United States before European settlement (Pyne 1982, Abrams 1992). Widespread burning created a mismatch between the physiological limits set by climate and the actual expression of vegetation—a common phenomenon throughout the world (Bond et al. 2005). In the eastern United States, presettlement vegetation types were principally pyrogenic; that is, they formed systems assembling under and maintained by recurrent fire (Frost 1998, Wade et al. 2000). Prime examples include tallgrass prairies, aspen (*Populus*) parklands, oak (*Quercus*)-dominated central hardwoods, northern and southern “pineries,” and boreal spruce-fir (*Picea–Abies*) forests (Wright and Bailey 1982). In turn, an extensive array of eastern animal and plant species have adapted to and depend on fire, either directly (e.g., jack pine [*Pinus banksiana* Lamb.]) or through the use of fire-maintained habitat (e.g., Kirtland’s warbler [*Dendroica kirtlandii*]).

A diverse mix of vegetation and site conditions of the eastern United States supported a range of presettlement fire regimes, from intense stand-replacing burns on pine barrens to “asbestos-like” communities that rarely burned (e.g., northern hardwoods). However, most presettlement fire regimes produced low- to mixed-severity surface burns, which maintained the vast expanses of oak and pine forests that dominated much of the eastern United States, often in open “park-like” conditions (Wright and Bailey 1982, Frost 1998). Native Americans were the primary ignition source in many locations, given the moist and humid conditions of the East (Whitney 1994). Historic documents indicate that Native American ignitions far outnumbered natural causes (principally lightning) in most locations (Gleason 1913, DeVivo 1991). In this respect, humans were a “keystone species,” actively managing the environment [illegible] millennia (Sauer 1975, Guyette et al. 2006). Nonetheless, within the fire-maintained landscapes, variations in human population and land use, topography, and riparian areas (firebreaks) created a mosaic of burned and unburned vegetation types (Heinselman 1973, Anderson 1991, Whitney 1994).

Fire regimes changed in various ways with European settlement, often profoundly. In many instances, fire frequency and severity increased as forests were cut and burned, either intentionally (for agricultural land clearing) or unintentionally (e.g., sparked by wood- and coal-burning steam engines). This transition was most [illegible] for mesic hardwood

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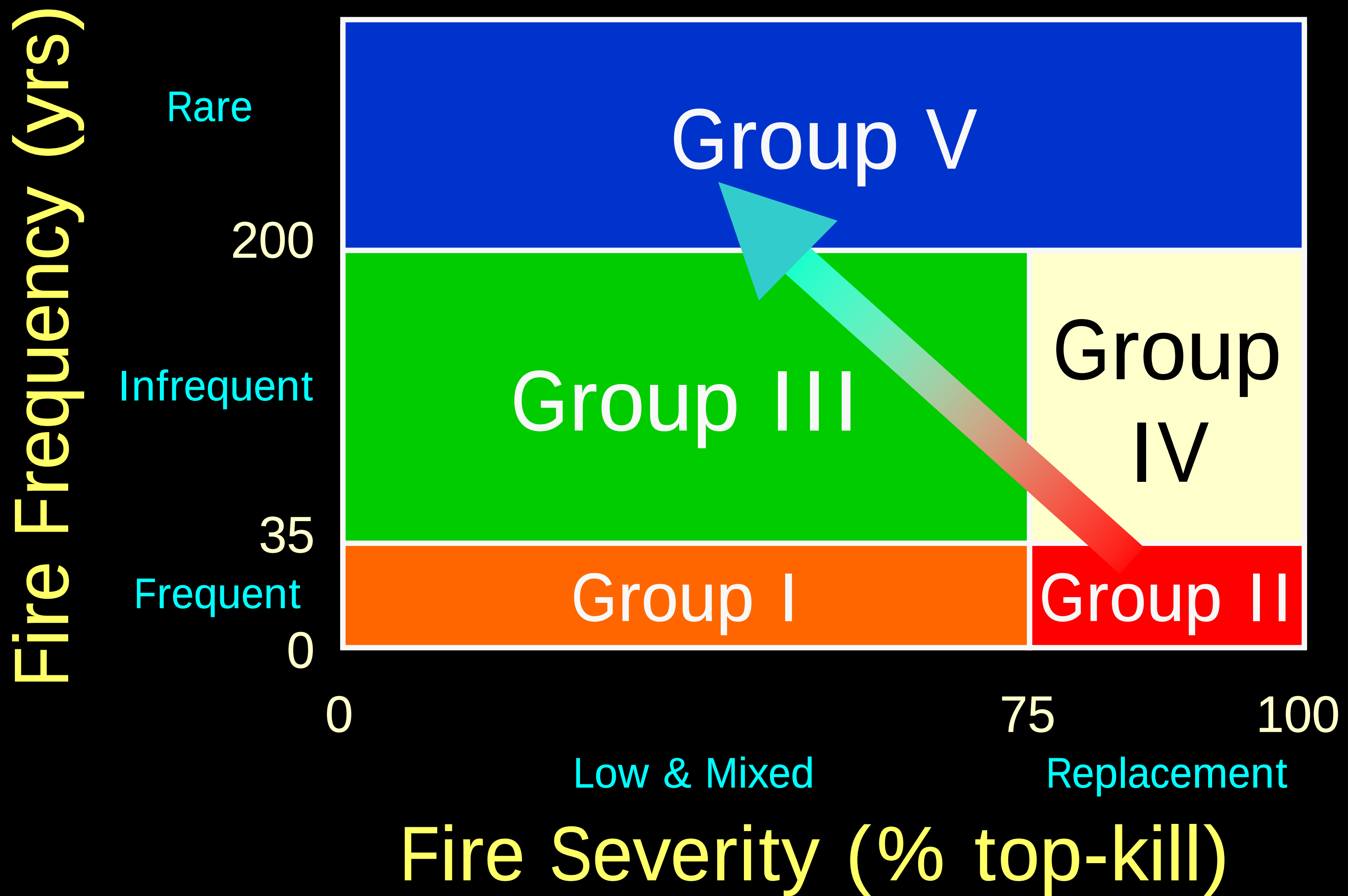
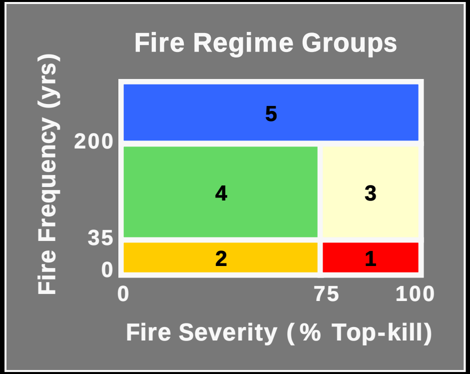
Shameless
self promotion!

Fire Regime Group

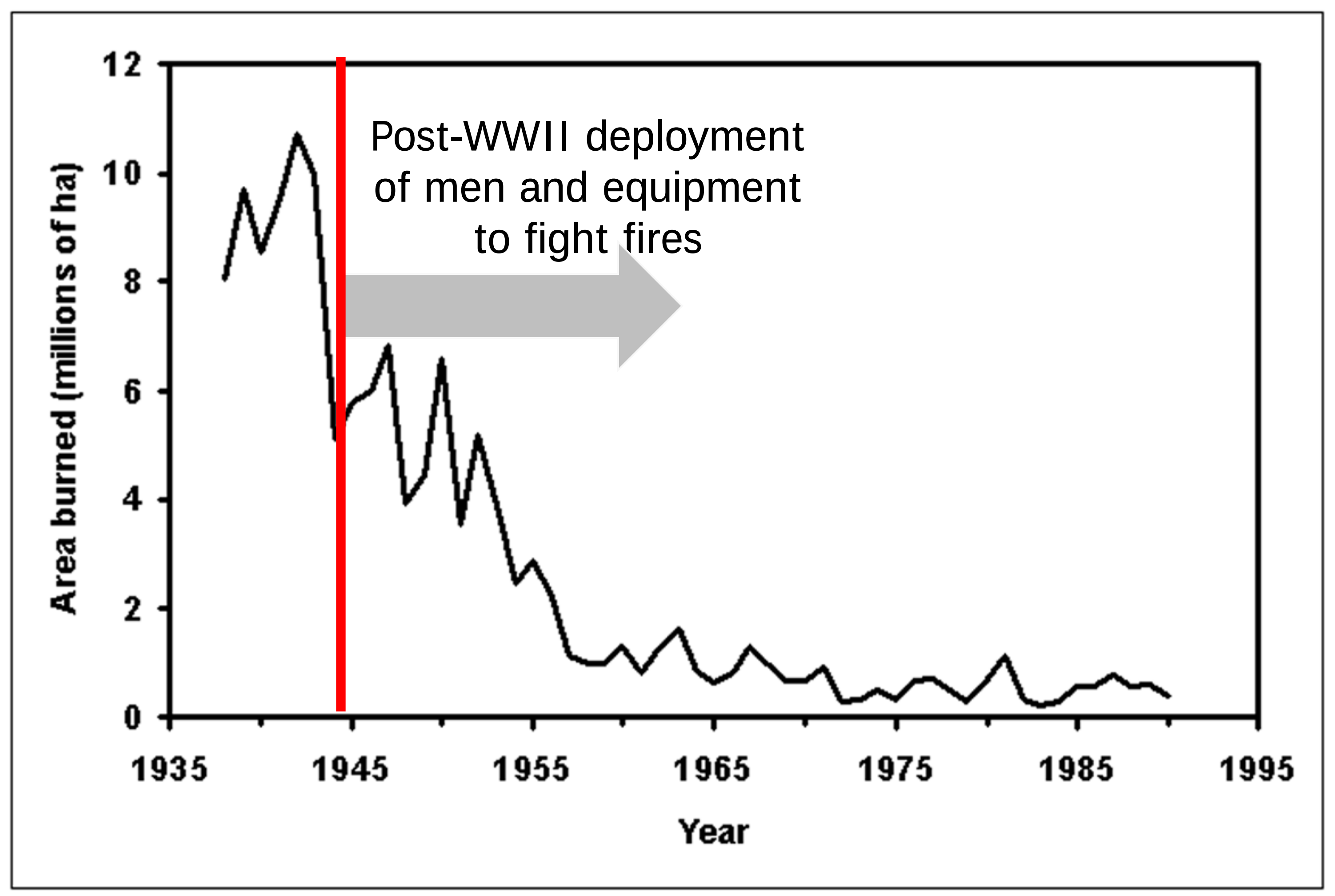


Potential Natural Vegetation map
(1 km^2 pixels)

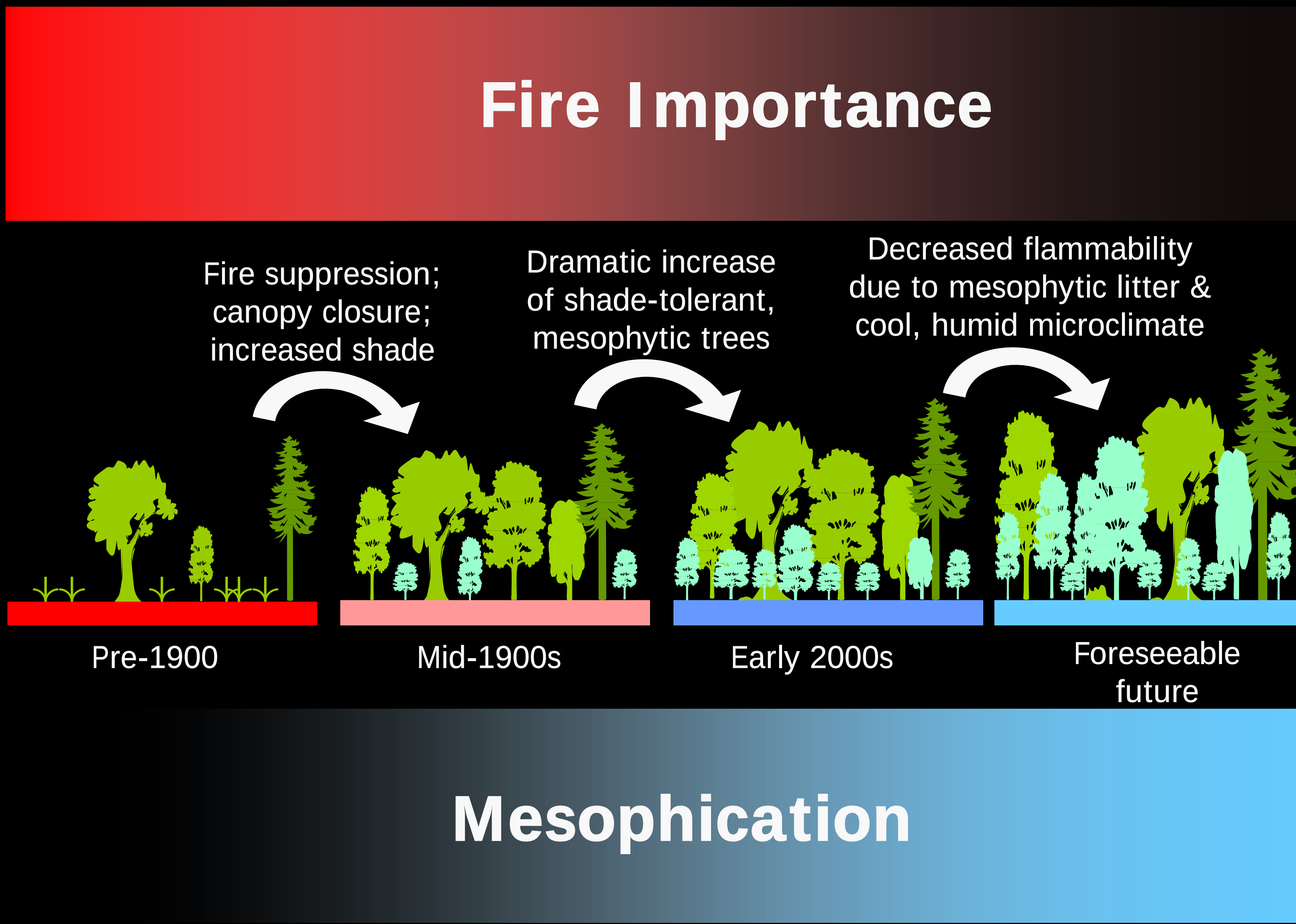


Fire Regime Change = Past FR – Current FR

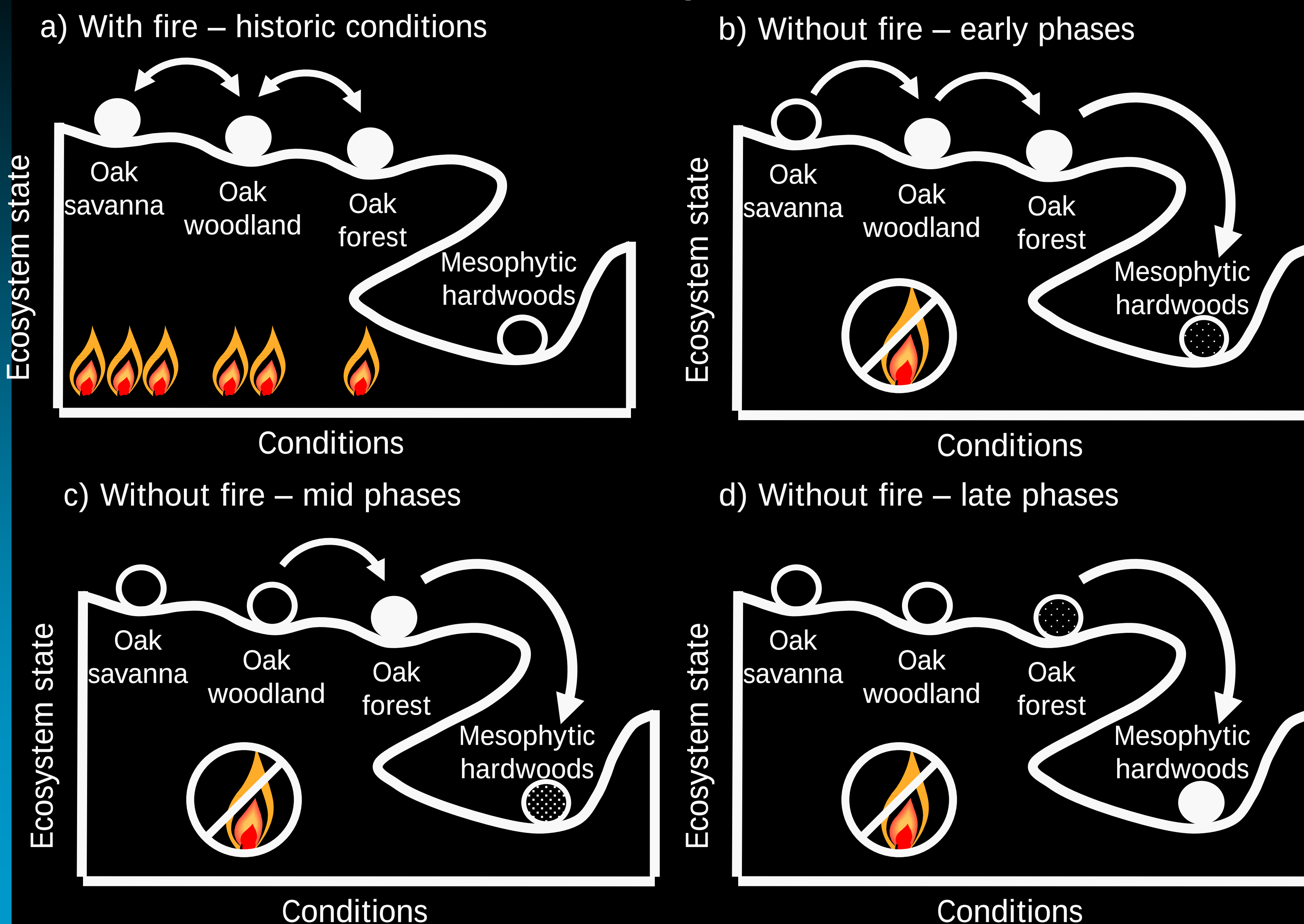
Area burned in the eastern U.S.*



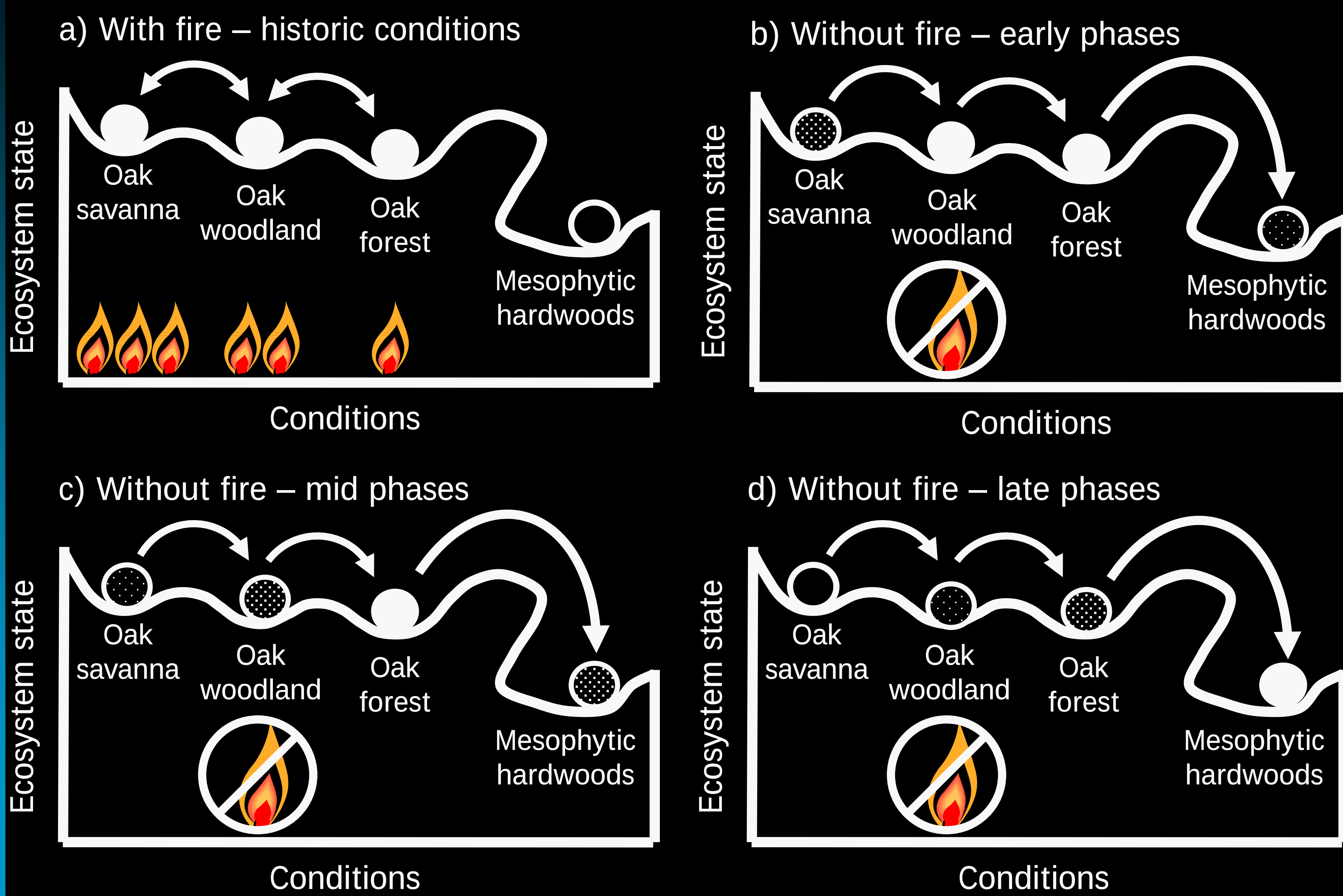
* States from Minnesota to Louisiana eastward.

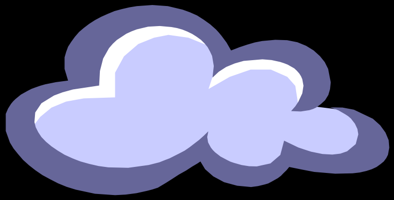

Fire Importance
Fire suppression; canopy closure; increased shade
Dramatic increase of shade-tolerant, mesophytic trees
Decreased flammability due to mesophytic litter & cool, humid microclimate
Pre-1900
Mid-1900s
Early 2000s
Foreseeable future
Mesophication

Mesic uplands

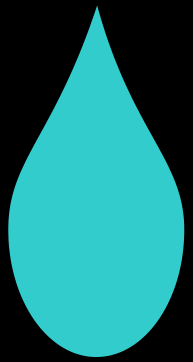


Xeric uplands





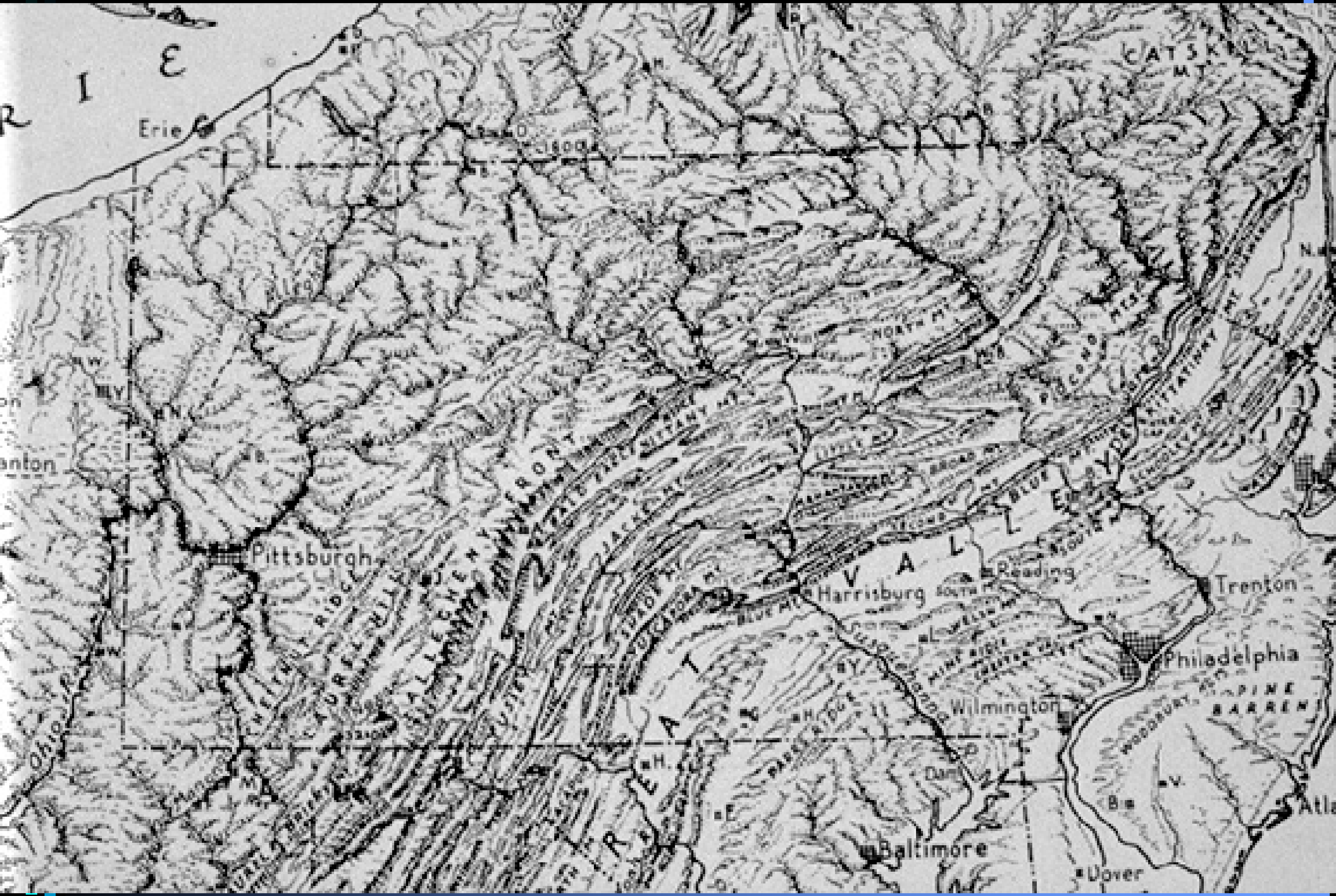
The demise of fire has been ubiquitous over the eastern U.S. leading to dire ecological problems in most locations.



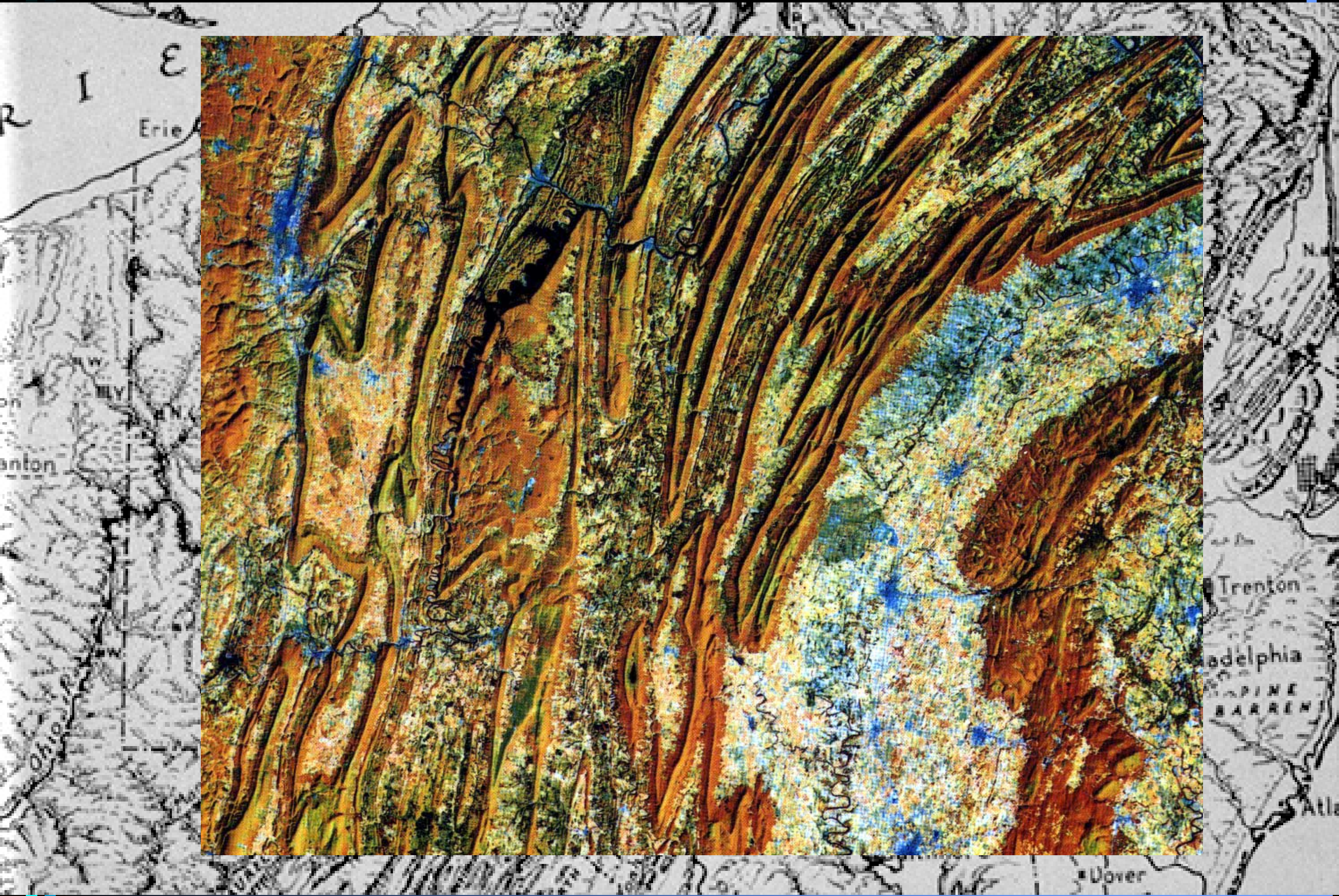
Examples

The Central Pennsylvania Oak Story

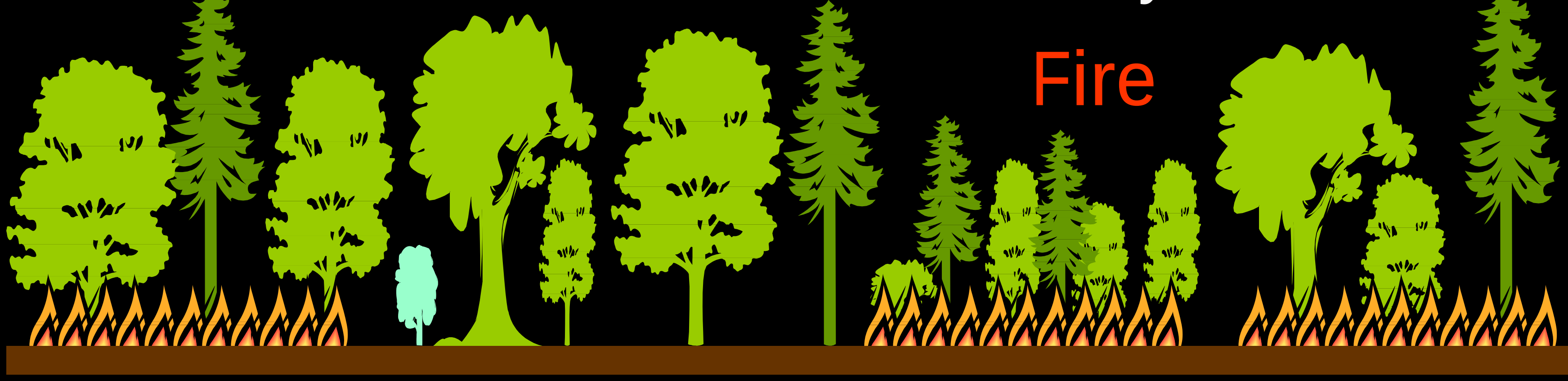
Nowacki, G.J. and M.D. Abrams. 1992. Community, edaphic and historical analysis of mixed oak forests of the Ridge and Valley Province in central Pennsylvania. Canadian Journal of Forest Research 22:790-800.



Erie
Pittsburgh
Harrisburg
Reading
Trenton
Philadelphia
Wilmington
Baltimore
Dover
CATSKILL MT.
PINE BARRENS


Erie
Trenton
Dover

Presettlement: Oak-Pine-Chestnut-Hickory



Exploitation: 1775-1900

Pines selectively removed

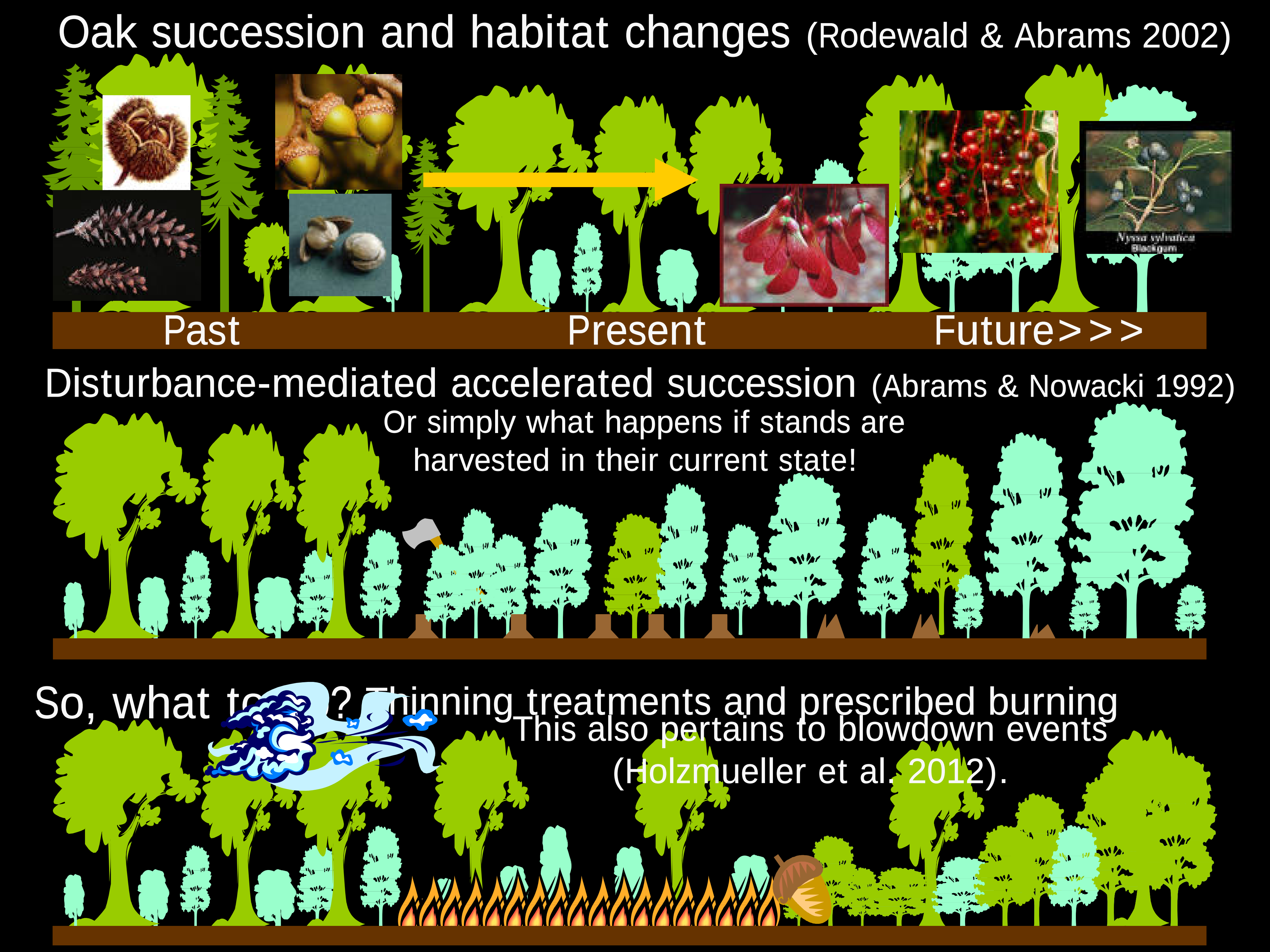
Hardwoods coppicing

Pennsylvania Fires

Year	Hectares
1908	407,700
1913-19	108,155
1920-29	72,378
1930-39	42,049
1940-49	21,158
1950-59	12,784
1960-69	8,634
1970-79	3,240
1980-89	3,388

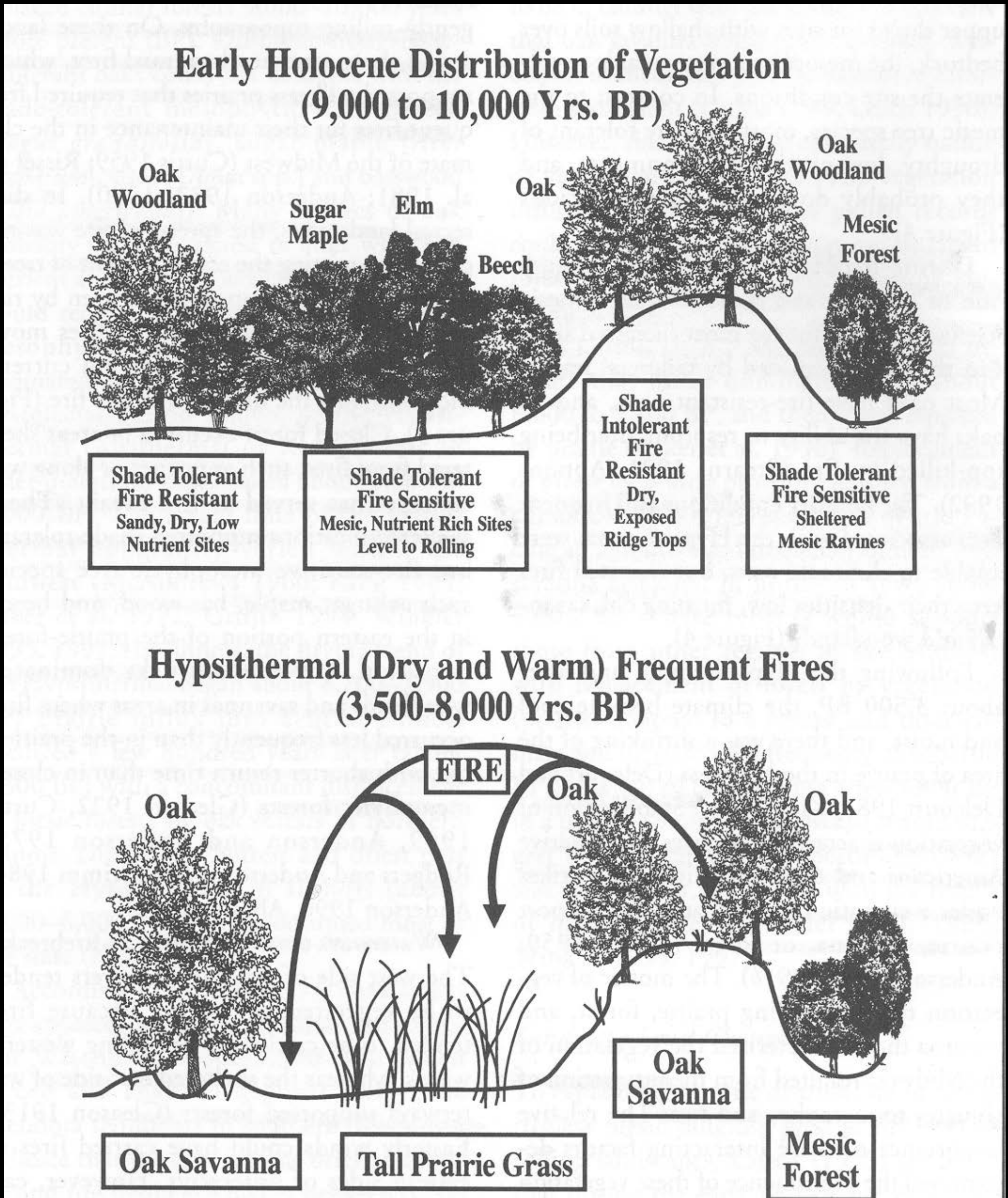
Modern: 1900-today

Chestnut blight


Oak succession and habitat changes (Rodewald & Abrams 2002)
Nyssa sylvatica
Blackgum
Past
Present
Future>>>
Disturbance-mediated accelerated succession (Abrams & Nowacki 1992)
Or simply what happens if stands are harvested in their current state!
So, what t
? Thinning treatments and prescribed burning
This also pertains to blowdown events (Holzmueller et al. 2012).

Development of Oak savannas, Woodlands, and Forests in Illinois.

Based on the research of:
Roger Anderson,
Illinois State Univ.,
Normal, IL.



Anderson (1998)

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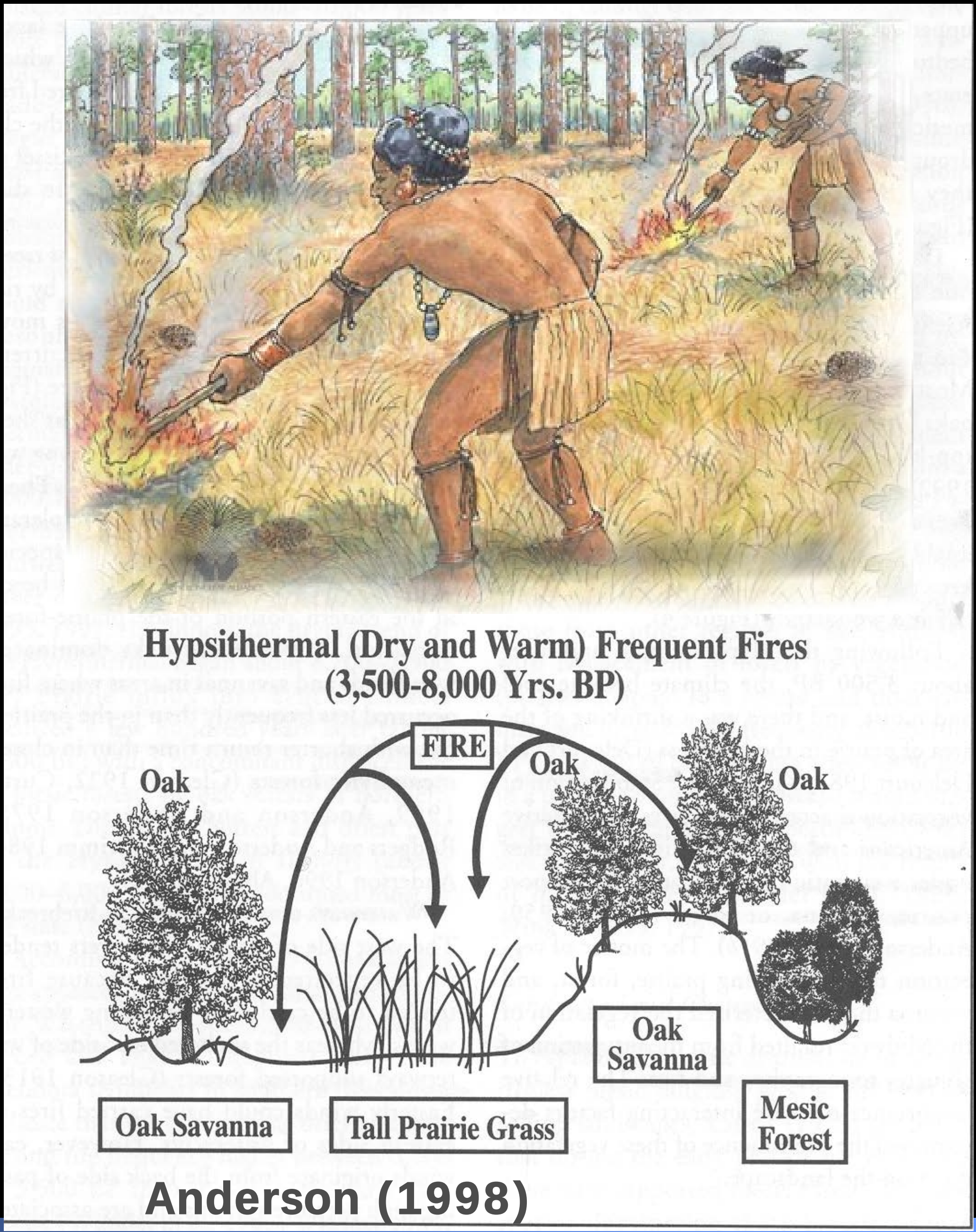

Anderson (1998)

The Holocene 18,7 (2008) pp. 1123–1137

Native Americans as active and passive promoters of mast and fruit trees in the eastern USA

Marc D. Abrams[1]* and Gregory J. Nowacki[2]

([1]School of Forest Resources, 307 Forest Resources Building, Penn State University, University Park PA 16802, USA; [2]USDA Forest Service, Eastern Regional Office, 626 E Wisconsin Avenue, Milwaukee WI 53202, USA)

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A HOLOCENE RESEARCH REVIEW

Abstract: We reviewed literature in the fields of anthropol[illegible], archaeology, ethnobotany, palynology and ecology to try to determine the impacts of Native Americ[illegible] active and passive promoters of mast (nuts and acorns) and fruit trees prior to European settlement. M[illegible] a critical resource for carbohydrates and fat calories and at least 30 tree species and genera were u[illegible] the diet of Native Americans, the most important being oak (*Quercus*), hick[illegible] *Carya*) and chestnut ([illegible]), [illegible]ch dominated much of the eastern forest, and walnut (*Juglans*) to a le[illegible]nt. Fleshy tree [illegible] were m[illegible] accessible in human-disturbed landscapes, and at least 20 fruit- and b[illegible]-pro[illegible]ing trees [illegible] commonly u[illegible]ized by Native Ameri[illegible]. They regularly used fire and tree girdling [illegible] managem[illegible] to[illegible] for a multitude [illegible] purposes, inclu[illegible] and clearing, promotion of favoured mast a[illegible] fruit trees, v[illegible]ion control and p[illegible]rage for bi[illegible]imals. This latter point also applies to the v[illegible] fire-maintained prairie region further [illegible]st. N[illegible] Ameri[illegible]s were a much more important ig[illegible]on source[illegible] lightning throughout the eastern [illegible] except fo[illegible]e extreme Southeast. First-hand accou[illegible] mention mast and fruit trees or orchards [illegible] the immedia[illegible] vicinity of Native American villages and suggest [illegible] these trees existed as a direct result of Indian manage[illegible]. We conclude that Native American land-use practices not only had a profound effect on promoting [illegible] fruit trees but also on the entire historical development of the eastern oak and pine forests, sa[illegible] and tall-grass prairies. Although significant climatic change occurred during the Holocene, inclu[illegible] the 'Mediaeval Warming [illegible] and the 'Little Ice Age', we attribute the multimillennia dominat[illegible] the eastern biome by prairie gr[illegible] and/or mast trees primarily to regula[illegible] and other forms of management by Indians to meet their gastronomic needs. Otherwise, drier prai[illegible] and open woodlands would have converted to closed-canopy forests and more mesic mast trees would have s[illegible]ceded to more shade-tolerant, fire-sensitive trees that are a significantly inferior dietary resource.

Key words: Indian diet, fire, land-use history, cultivation, oak, hick[illegible], fruit trees, Holocene.

More shameless self promotion!

Introduc[illegible]on

Vegeta[illegible] is forever dynamic because the environment in which it gr[illegible] constantly altered by changing climate, edaphic [illegible] tions, disturbance regimes [illegible] anthropogen[illegible] impacts. [illegible] vegetation is always changing, a [illegible]tral questi[illegible] in ec[illegible] 'what is natural vegetation?' (Lorim[illegible], 2001; [illegible]illiams, 20[illegible] It may be argued that the natural ve[illegible]tatio[illegible] the USA is what existed immediately prior [illegible] European settlement [illegible]fter which severe re[illegible] exploitati[illegible] produced radical changes in community [illegible]position [illegible] s[illegible]cture (Fuller *et al.*, 1998; Abrams, 2003; [illegible]ulte *et al.*, 2007[illegible] ur ability to discern or approximate the pre-[illegible]uropean settlement forest via the wide availability of witness-[illegible]ee data from public-land surveys partially explains this bias. Nevertheless, the European settlement legacy or ecological footprint in the USA is very large (Rees, 1992). In contrast, early Native Americans lacked European technology and may have had a much lighter touch on the landscape and thus a more harmonious, less intrusive relation with vegetation, leaving a smaller ecological footprint. But is this true?

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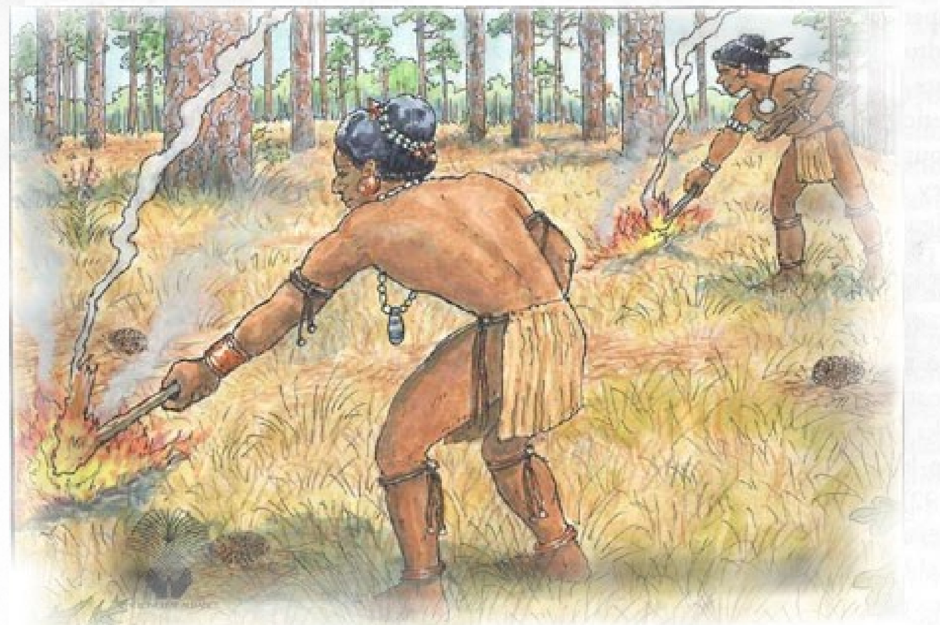
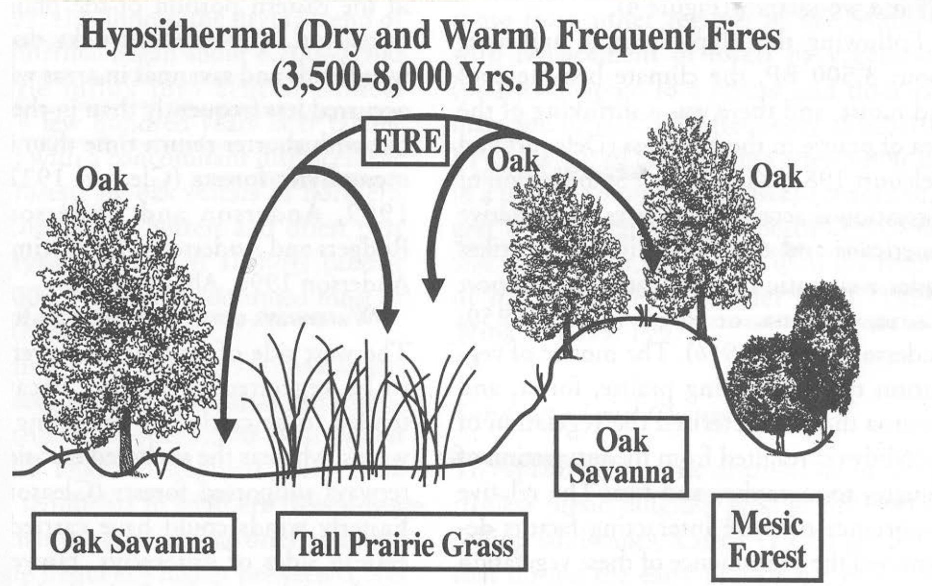
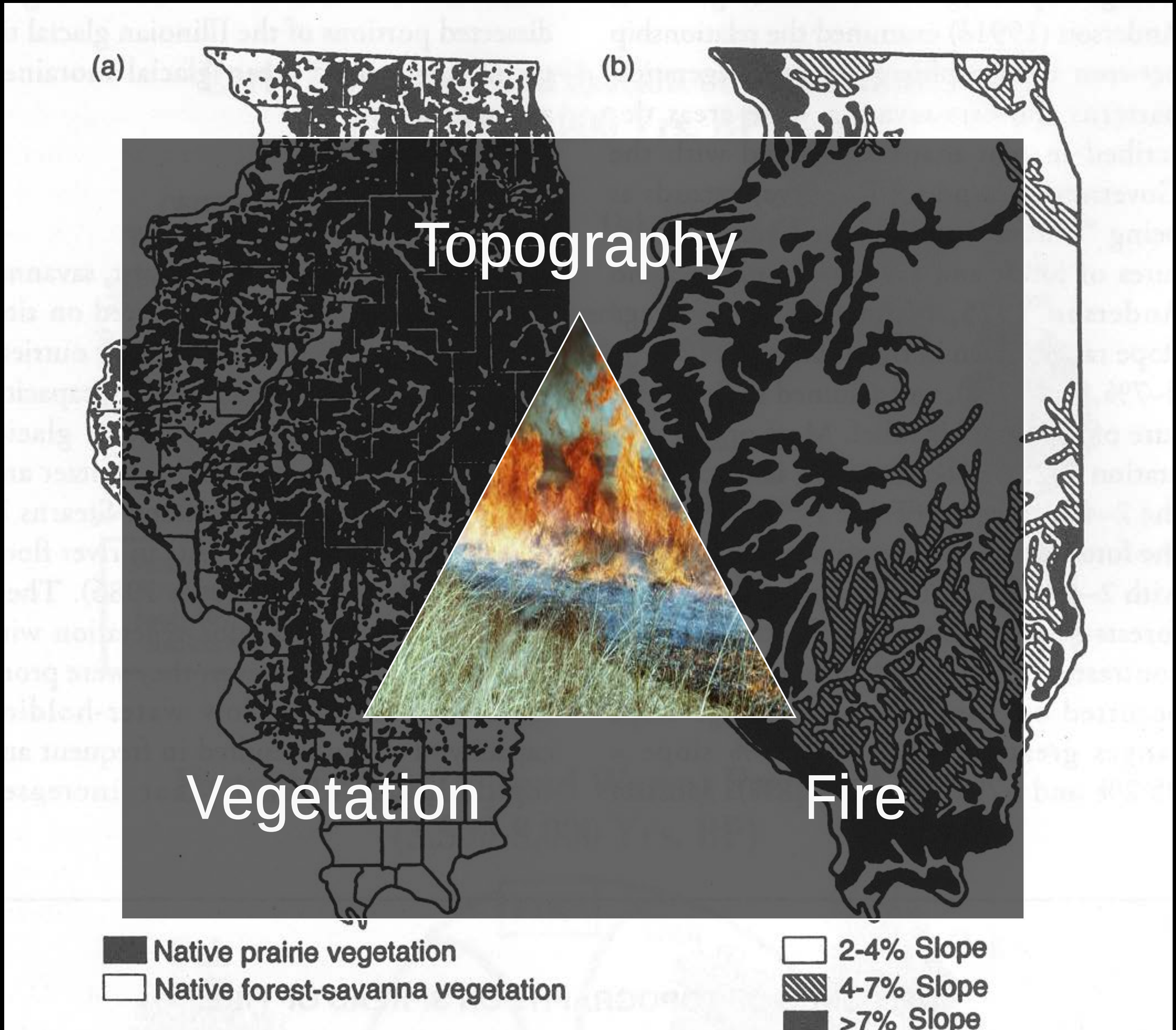




Anderson (1998)



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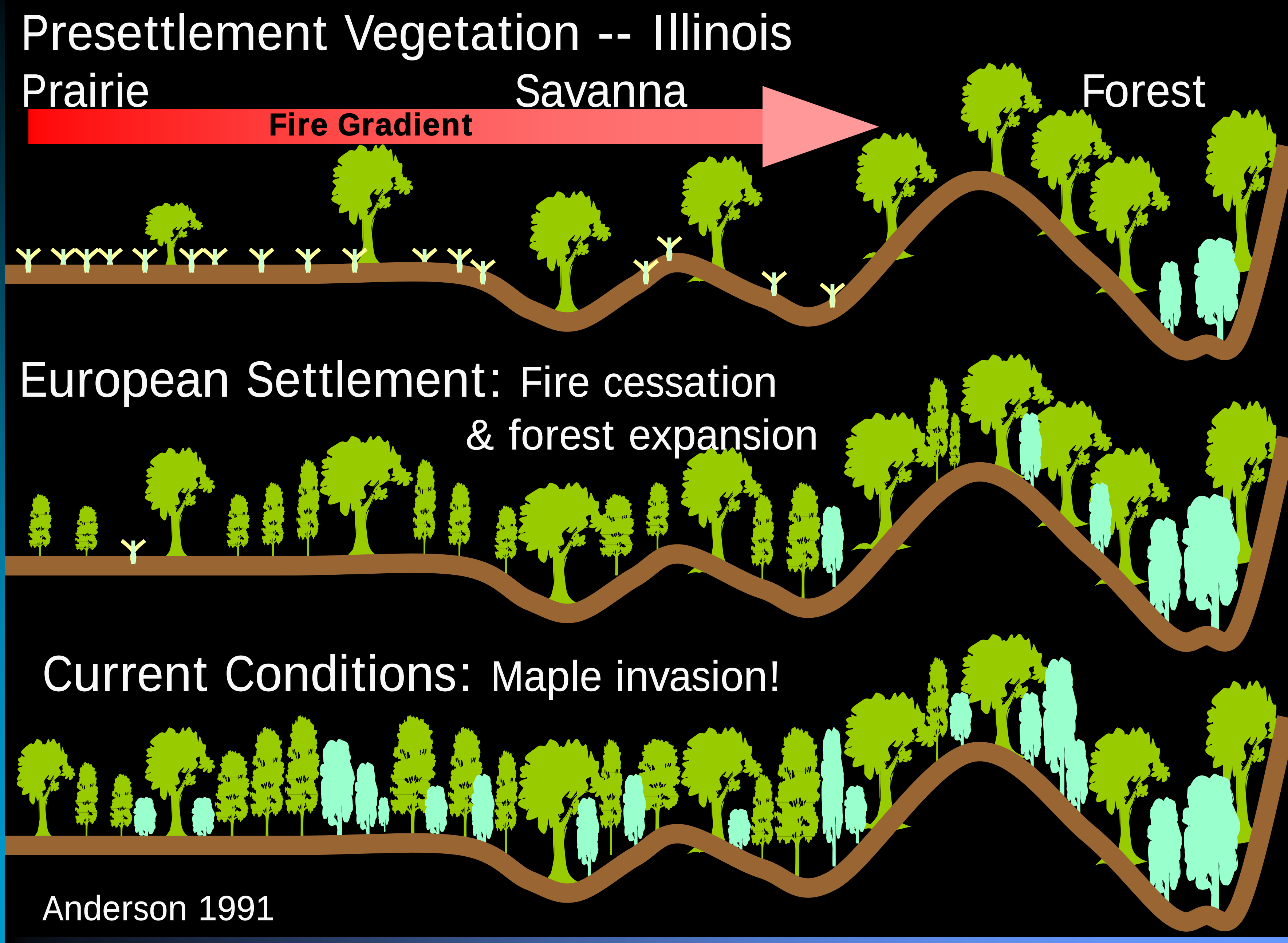
Presettlement Vegetation -- Illinois
Prairie
Savanna
Forest
Fire Gradient
European Settlement: Fire cessation
& forest expansion
Current Conditions: Maple invasion!
Anderson 1991

Structural Changes: Presettlement (1806-07) to Modern (1970s)

Fralish et al. 1991

Vegetation Type/Site	**Presettlement Structure**	**Modern Structure**
Oak-hardwoods (terrace)	Density = 155 trees/ha QMD = 42 cm BA = 22 sq m/ha	Density = 457, 311 trees/ha QMD = 23, 35 cm BA = 20, 30 sq m/ha
Oak forest (low north slope)	Density = 146 trees/ha QMD = 36 cm BA = 15 sq m/ha	Density = 438, 345 trees/ha QMD = 26, 32 cm BA = 24, 28 sq m/ha
Oak forest (high north slope)	Density = 144 trees/ha QMD = 36 cm BA = 14 sq m/ha	Density = 425, 377 trees/ha QMD = 25, 30 cm BA = 20, 26 sq m/ha
Oak forest (ridgetop)	Density = 127 trees/ha QMD = 38 cm BA = 14 sq m/ha	Density = 487, NG trees/ha QMD = 25, NG cm BA = 24, 20 sq m/ha
Oak forest (rocky south slope)	Density = 125 trees/ha QMD = 30 cm BA = 9 sq m/ha	Density = 650, 393 trees/ha QMD = 17, 22 cm BA = 15, 15 sq m/ha
Oak forest (south slope)	Density = 144 trees/ha QMD = 36 cm BA = 16 sq m/ha	Density = 506, 415 trees/ha QMD = 22, 25 cm BA = 16, 21 sq m/ha

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▲ tree density

▼ mean diameter

▲ basal area

Western Star Oak Flatwoods
Houston/Rolla RD, Mark Twain NF

Untreated

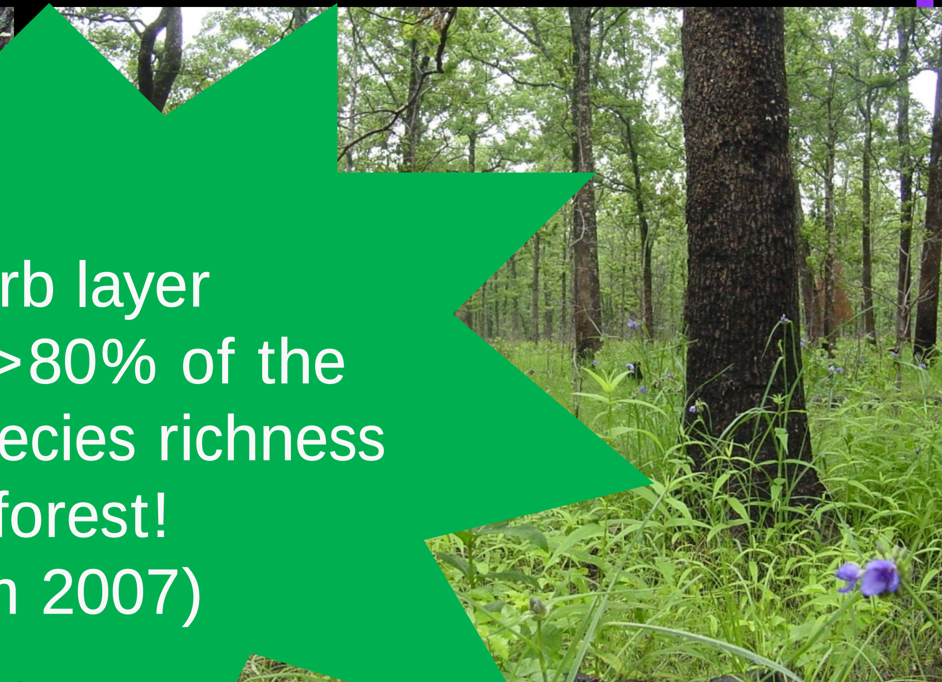
Typical present-day conditions:
- Continuous canopy; high density
- Shaded understory
- Depauperate ground flora
- Deep leaf litter

Thinned, burned

Restored (thin & 5 burns over 15 yrs):
- Open canopy; historic density
- High-light conditions
- Robust & diverse ground flora
- Negligible leaf litter

Western Star Oak Flatwoods
Houston/Rolla RD, Mark Twain NF

Untreated | Thinned, burned



The herb layer represents >80% of the total plant species richness of a forest!
(Gilliam 2007)

Typical present-day con…
- Continuous canopy; hig… density
- Shaded understory
- Depauperate ground flora
- Deep leaf litter

…red (thin & 5 burns over 15 yrs):
- …pen canopy; historic density
- High-light conditions
- Robust & diverse ground flora
- Negligible leaf litter

Conclusions

- Oak is a pyrogenic (fire-dependent) genus based on tree life histories and physiological characteristics.
- Fire formerly played a significant role throughout the East!
- Fire suppression efforts over the last century have been extremely effective — to the detriment of fire-dependent plant communities.

Conclusions

- Fire suppression has had cascading effects, changing openlands to closed forests and allowing fire-sensitive, shade-tolerant species to prosper (esp. maples) at the expense of oaks.

- Prescribed burning and thinning is needed in order to maintain oak communities (including attendant ground flora!).

- Opportunities for restoring pyrogenic ecosystems are rapidly waning...

The shared materials are not new observations, nor are the remedies rocket science.

Oak succession, primarily to maples

- Dix 1957: detected in DC forests

What's the principal problems/limitations?

- Carvell and Tryon 1961
- 1) Lack of sunlight reaching the forest floor
- 2) Lack of disturbance (thinning, grazing & burning)

What's the solution?

- Thinning and burning!

Dix, R.L. 1957. Sugar maple in forest succession at Washington, D.C. Ecology 38:663-665.

Carvell, K.L. and E.H. Tryon. 1961. The effect of environmental factors on the abundance of oak regeneration beneath mature oak stands. Forest Science 7:98-105.

Questions?

Questions?

Questions?

Questions?

Questions?

Questions?