Oak, Fire, and Climate Change:
The Profound Effect of Changing Conditions on the Oak Resource

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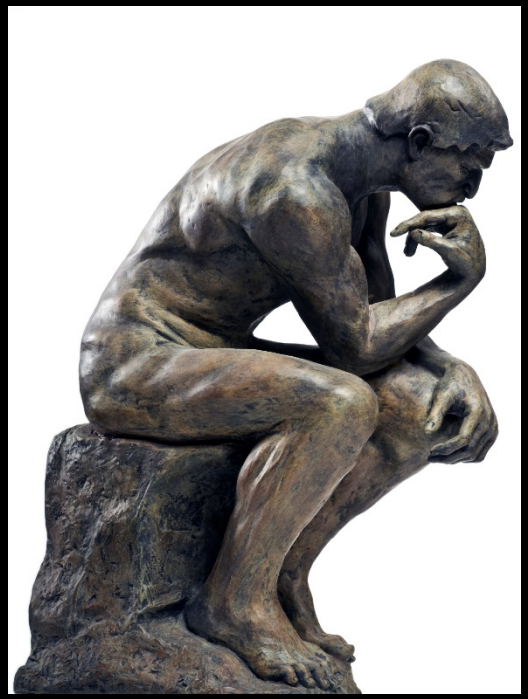
Regional Ecologist
USFS Eastern Region

Main objectives:

- Establish historic oak-fire relations
- Document the profound effect of land-use change and fire suppression policies
- Project possible effects of future climate change on the oak resource

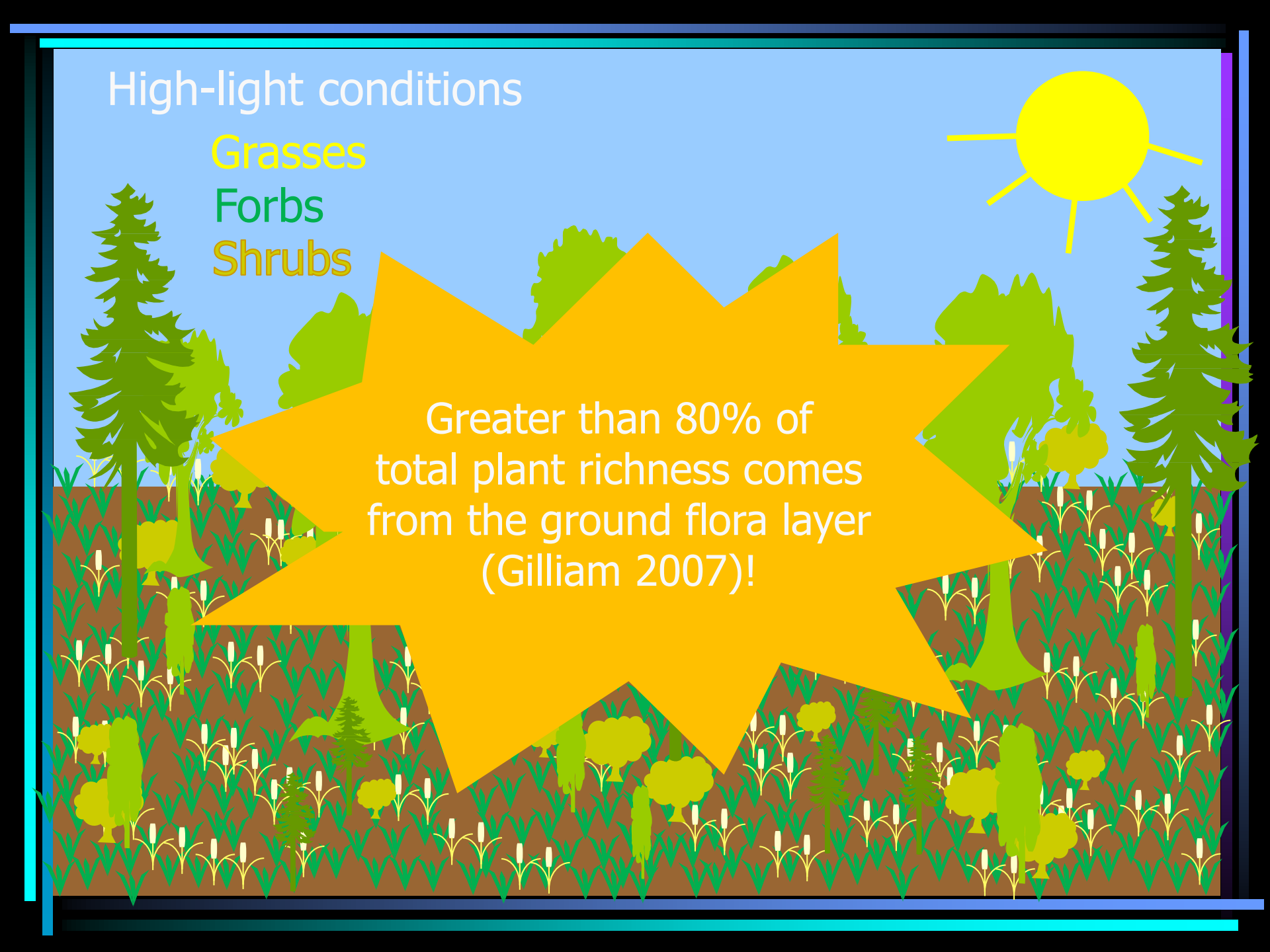
So, exactly what is the problem?



The lack of oak regeneration and the overall demise of oak ecosystems.

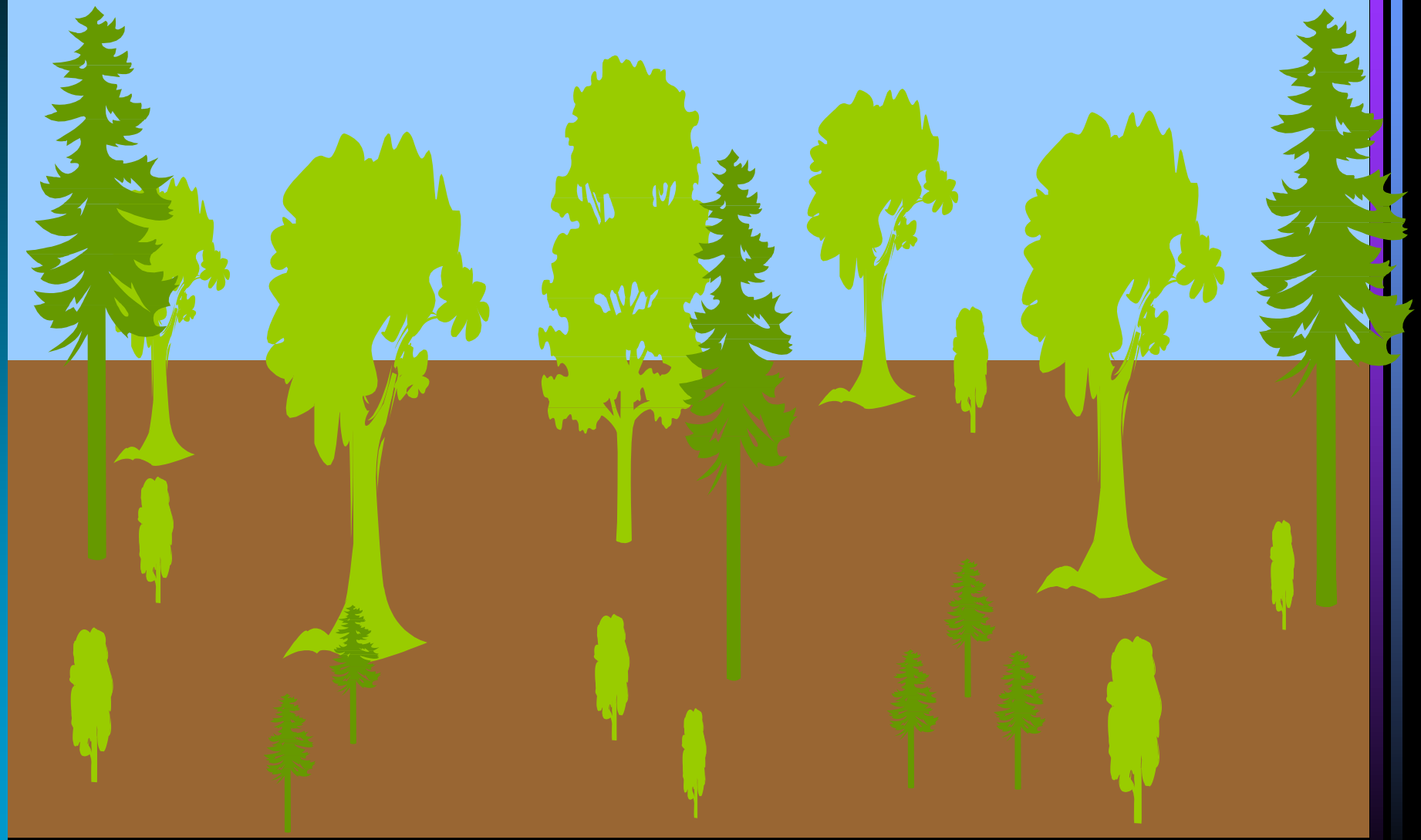
Presettlement: Oak-Pine Woodlands

Location	Density (trees/ha)	Diameter (cm)	Basal Area (m^2/ha)	Diameter Distribution
So. Illinois (Fralish et al. 1991)	125-155	30-42	9-22	x
Indiana (Cole and Taylor 1995)	68	x	x	x
Wisconsin (Cottam 1949)	35	x	3	x
Wisconsin (Dorney & Dorney 1989)	33	x	x	x
Tennessee (DeSelm 1994)	x	30	x	quasi-even
Ohio (Dyer 2001)	x	x	x	quasi-even


High-light conditions
Grasses
Forbs
Shrubs
Greater than 80% of total plant richness comes from the ground flora layer (Gilliam 2007)!

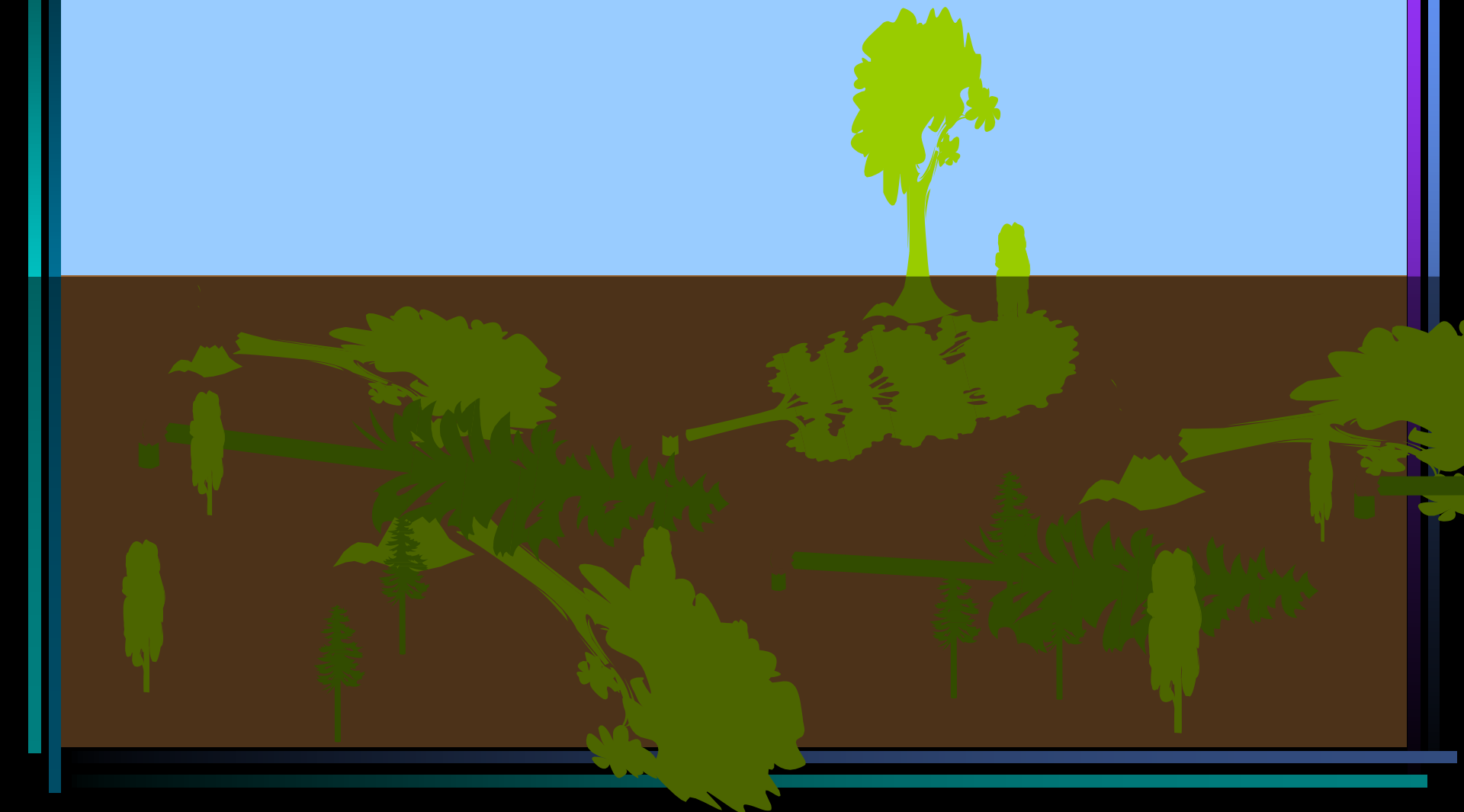
European Settlement

- The Great Cutover



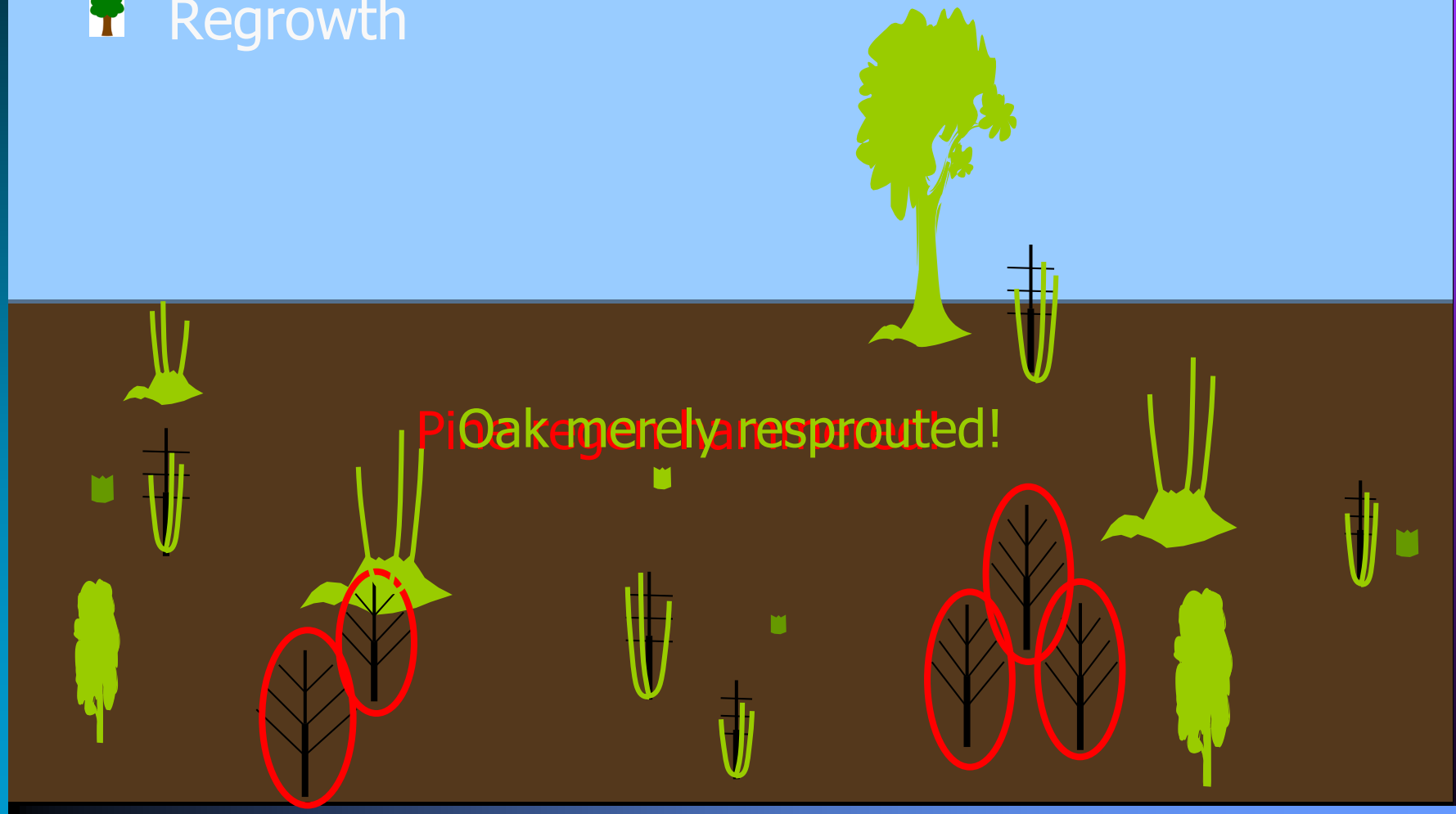
European Settlement

- The Great Cutover
- Burnovers



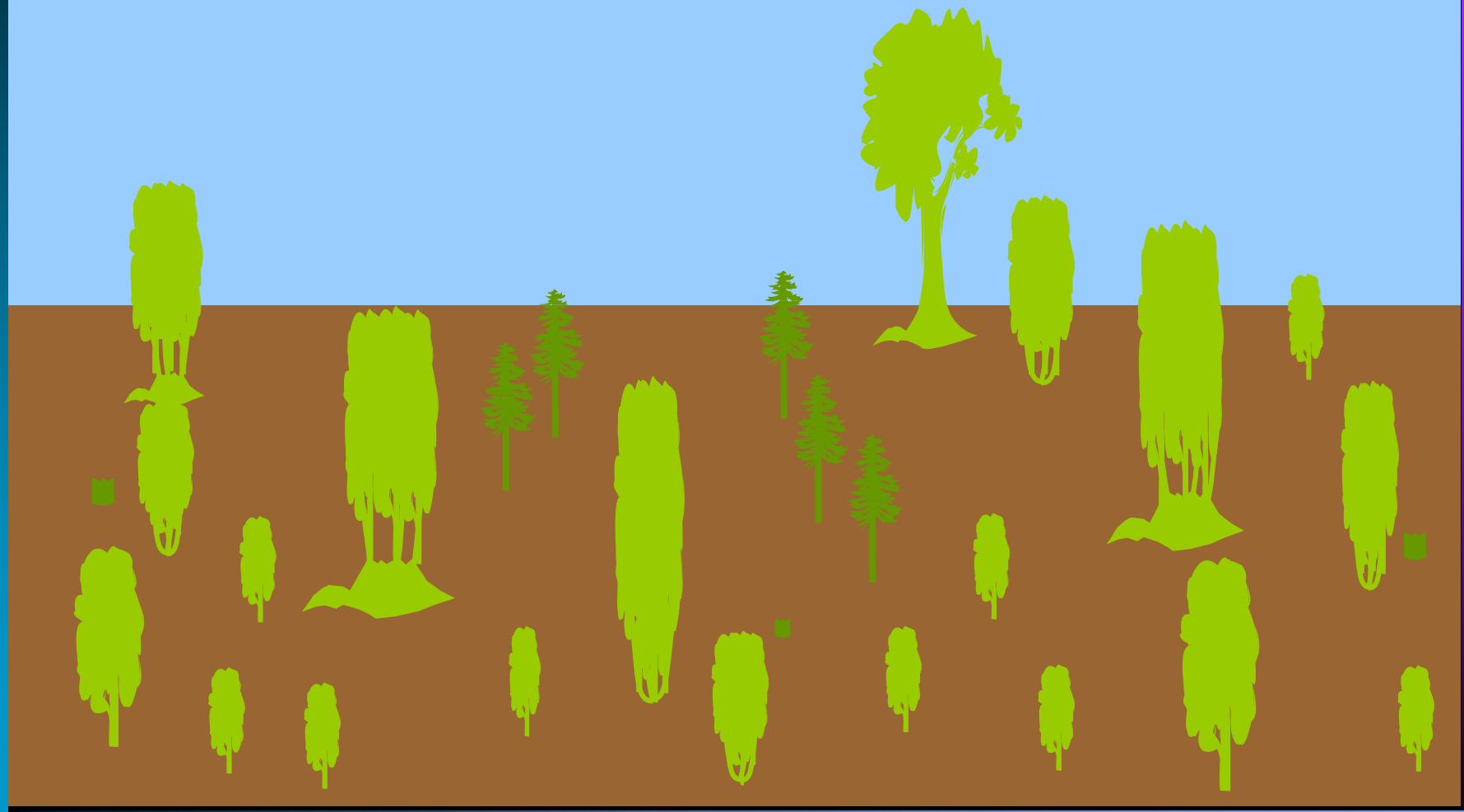
European Settlement

- The Great Cutover
- Burnovers
- Regrowth

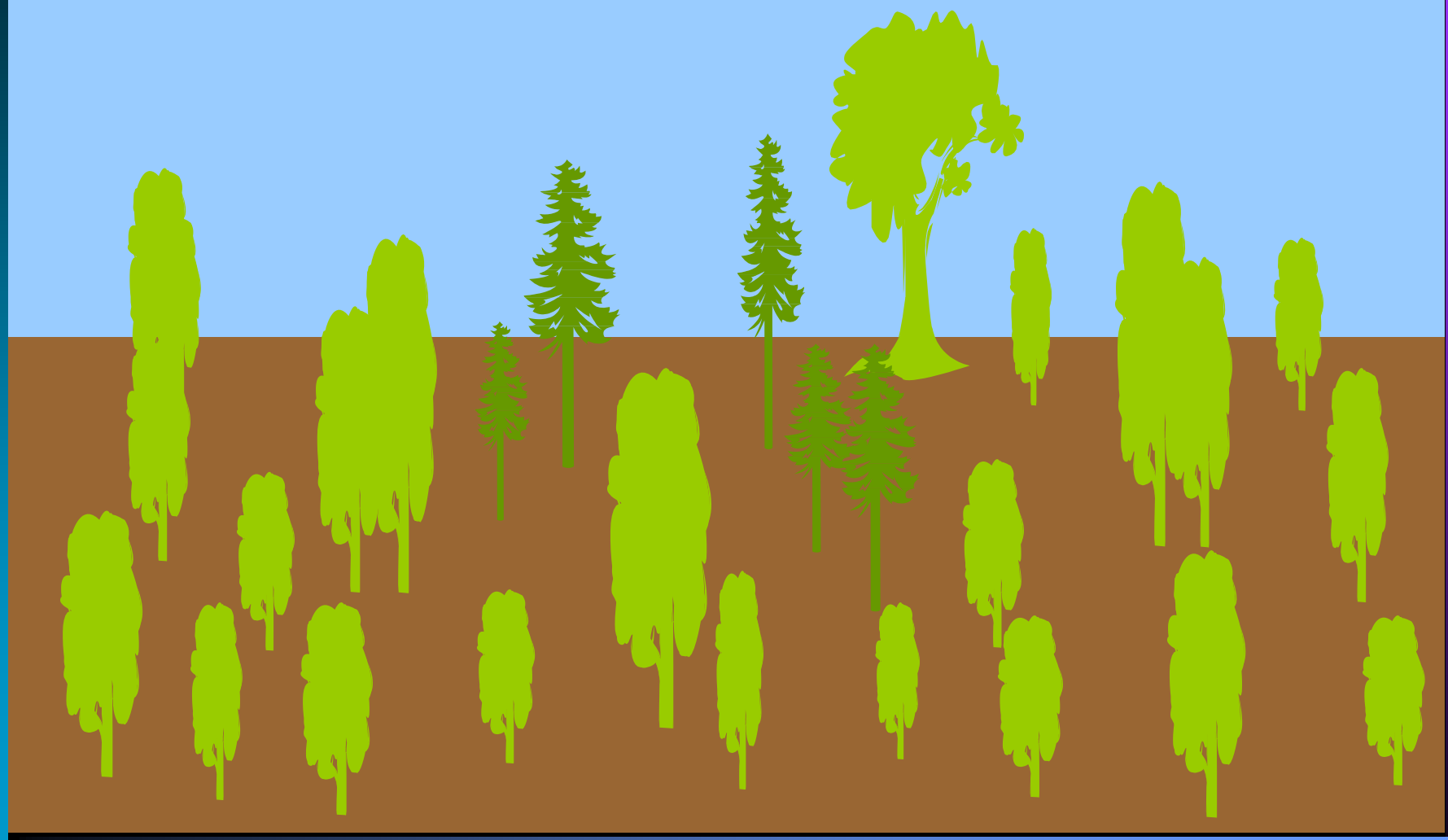


Forest Recovery

- Sprouting
- Seed-based regen



Forest Recovery



State – site, ref	Density trees/ha	Diameter cm	Basal Area m^2/ha	Diameter Distribution
IL – (Fral				
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IL – (Fral				
IN (199				
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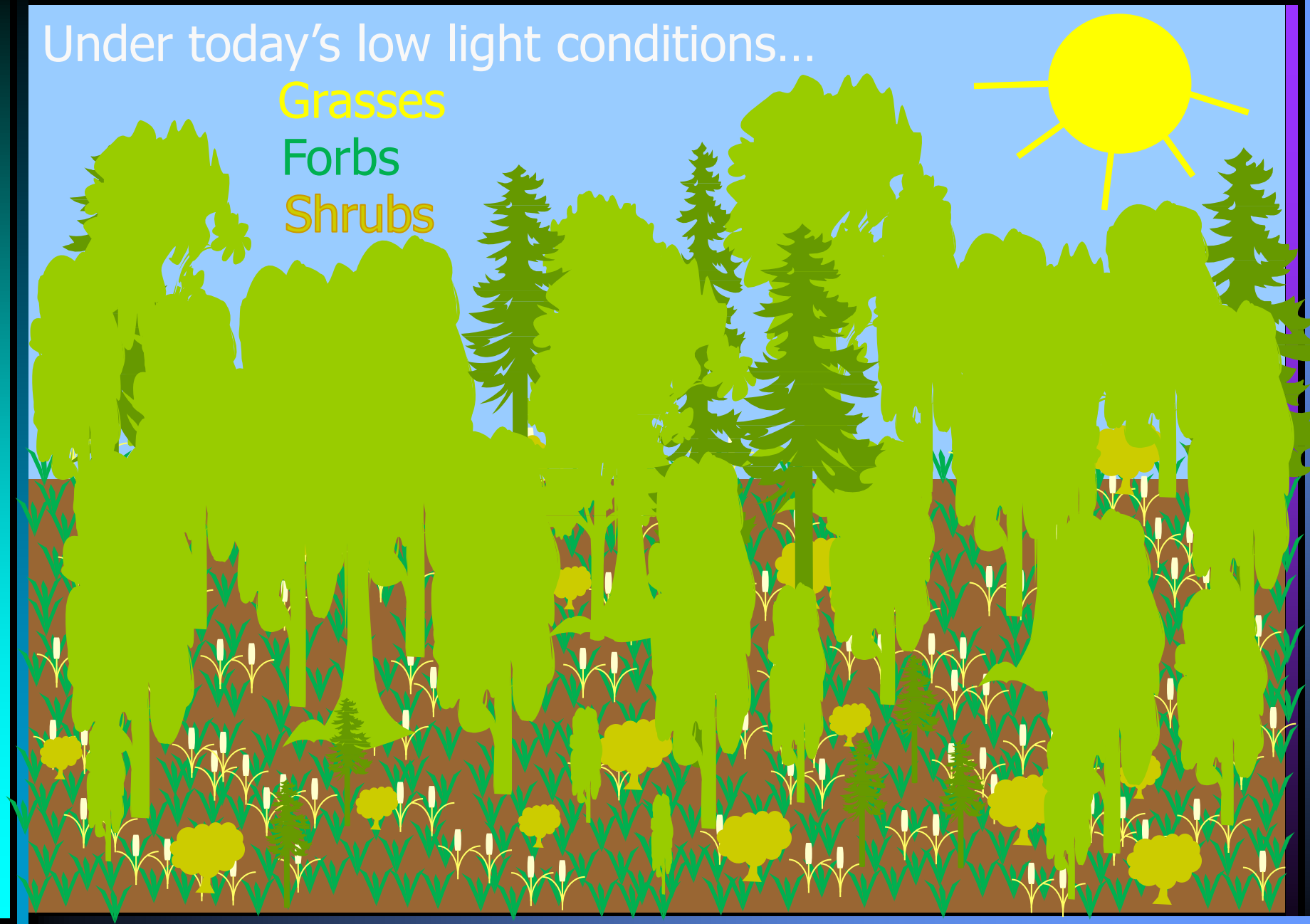
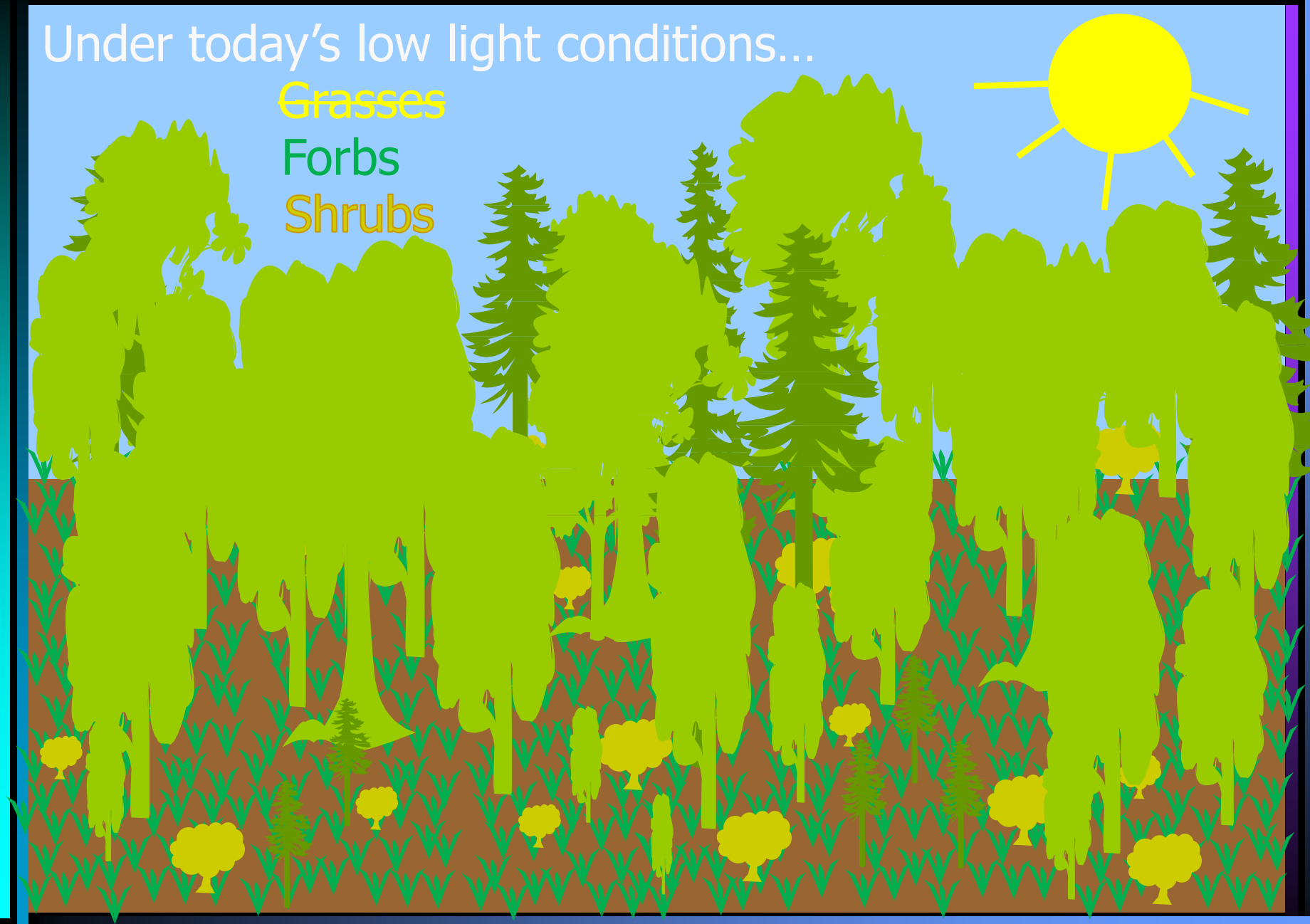
WI (				

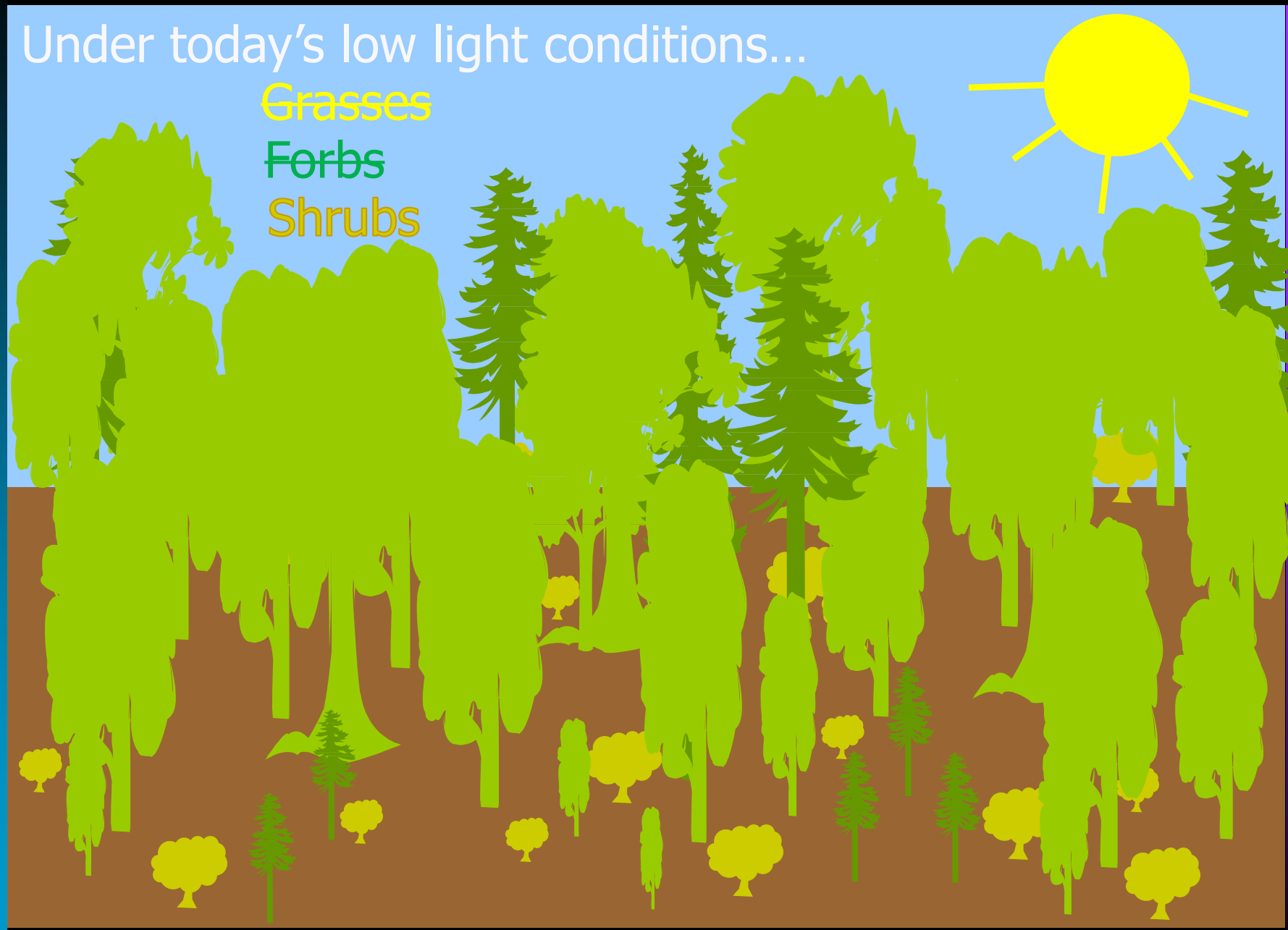
Presettlement to present-day comparison

- ▲ Increase in tree density: 2 to 10x
- ▼ Decrease in average tree diameter: -10 to -20 cm
- ▲ Increase of basal area: average 7 m^2/ha

Diameter distribution shift from a quasi-even to inverse J-shape


Under today's low light conditions…
Grasses
Forbs
Shrubs


Under today's low light conditions…
~~Grasses~~
Forbs
Shrubs


Under today's low light conditions…
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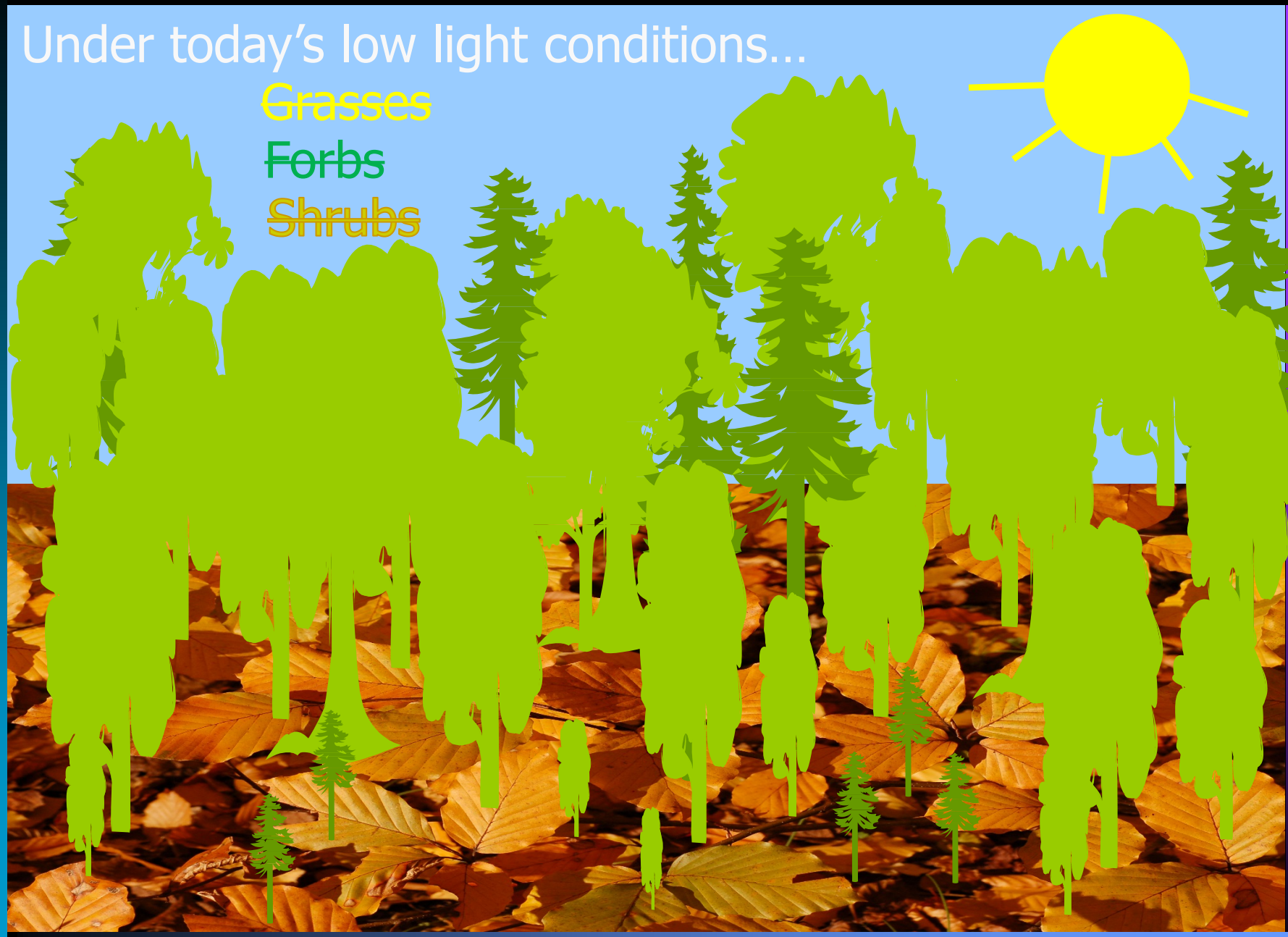
Under today's low light conditions…
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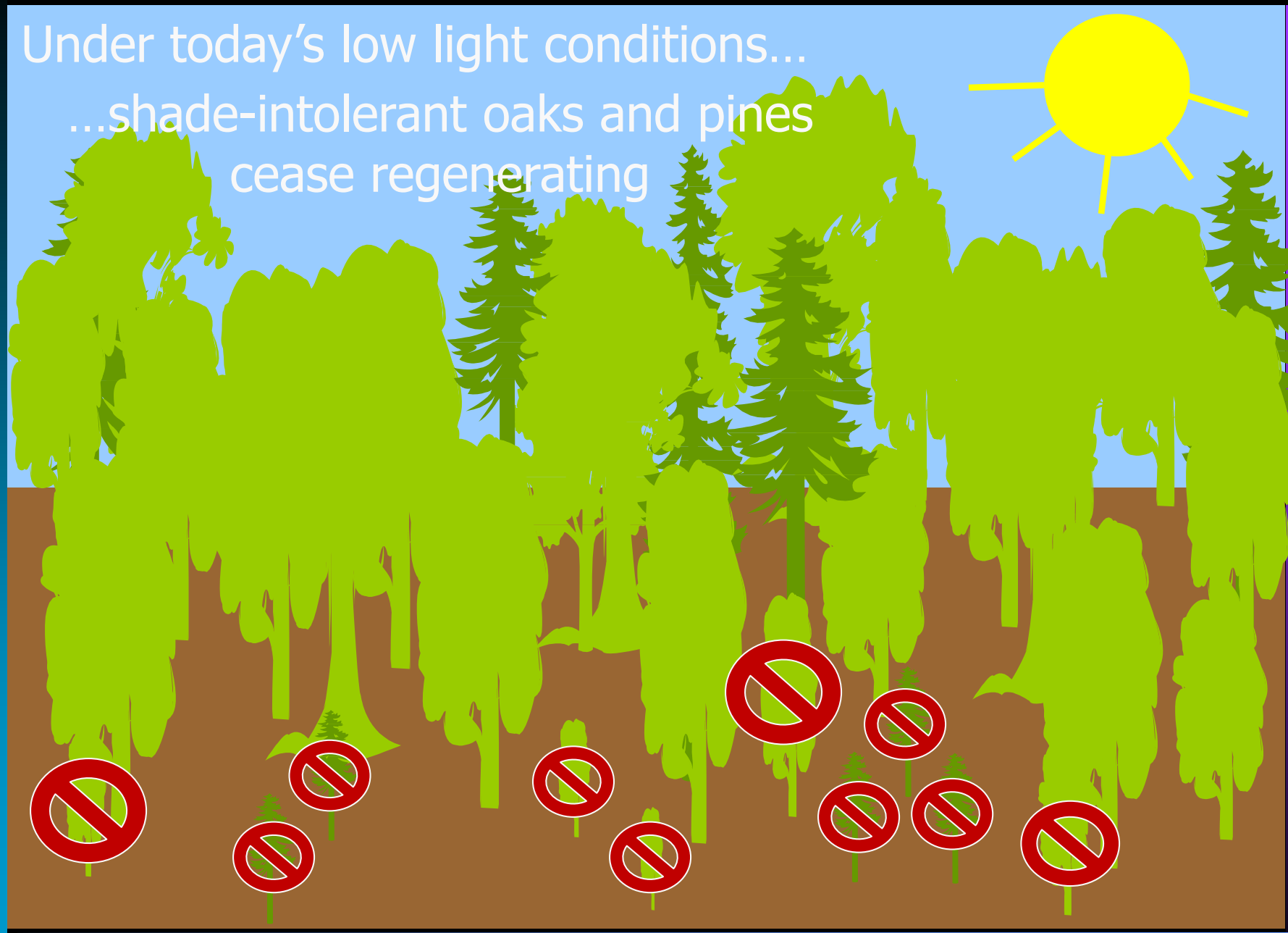
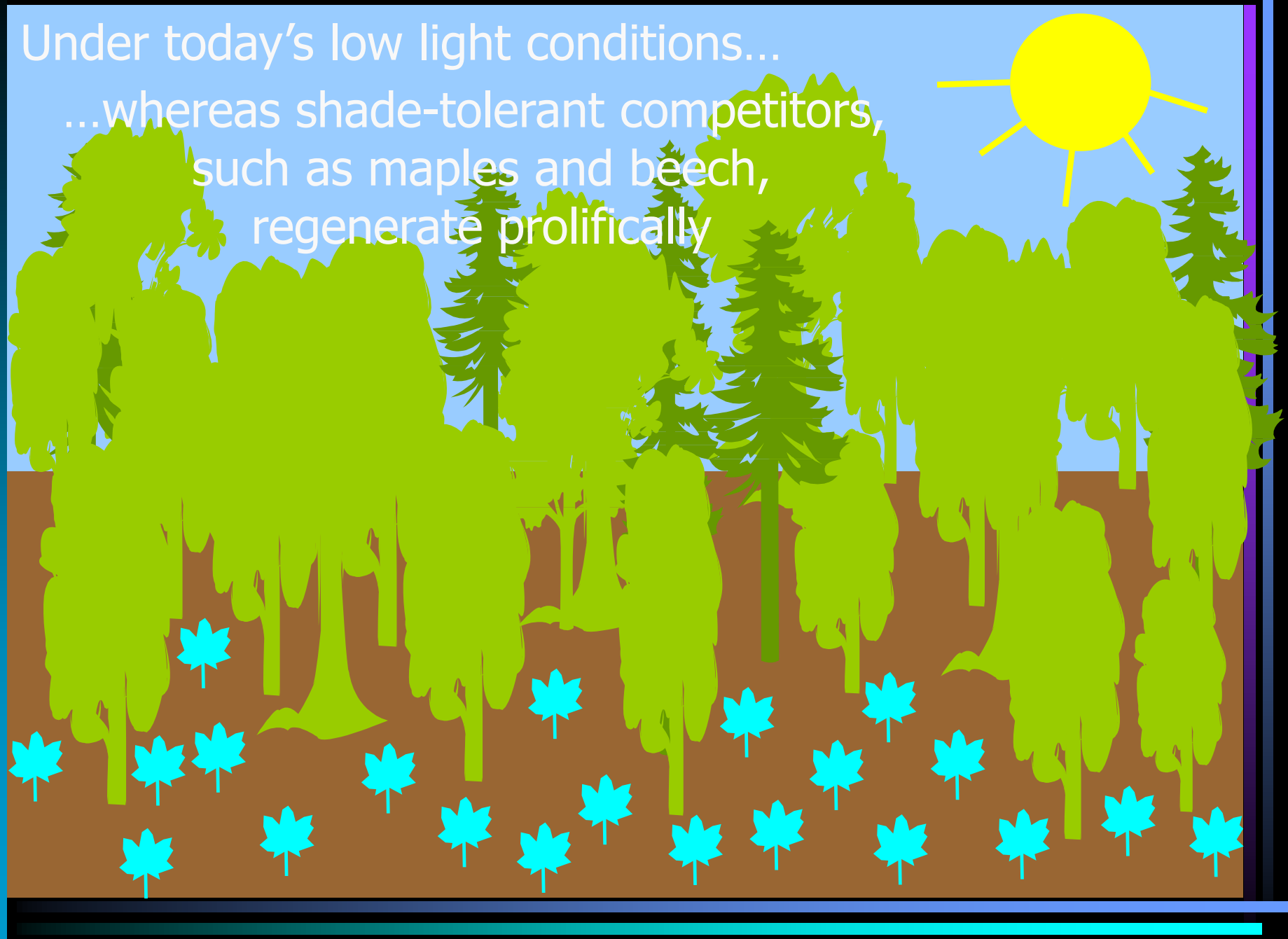

Under today's low light conditions…
…shade-intolerant oaks and pines
cease regenerating


Under today's low light conditions…
…whereas shade-tolerant competitors,
such as maples and beech,
regenerate prolifically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Mesophication

So, what's driving mesophication?

Climate Change

Oak Overbrowsing

Passenger Pigeon extinction?!?

Fire Suppression

So, what's driving mesophication?

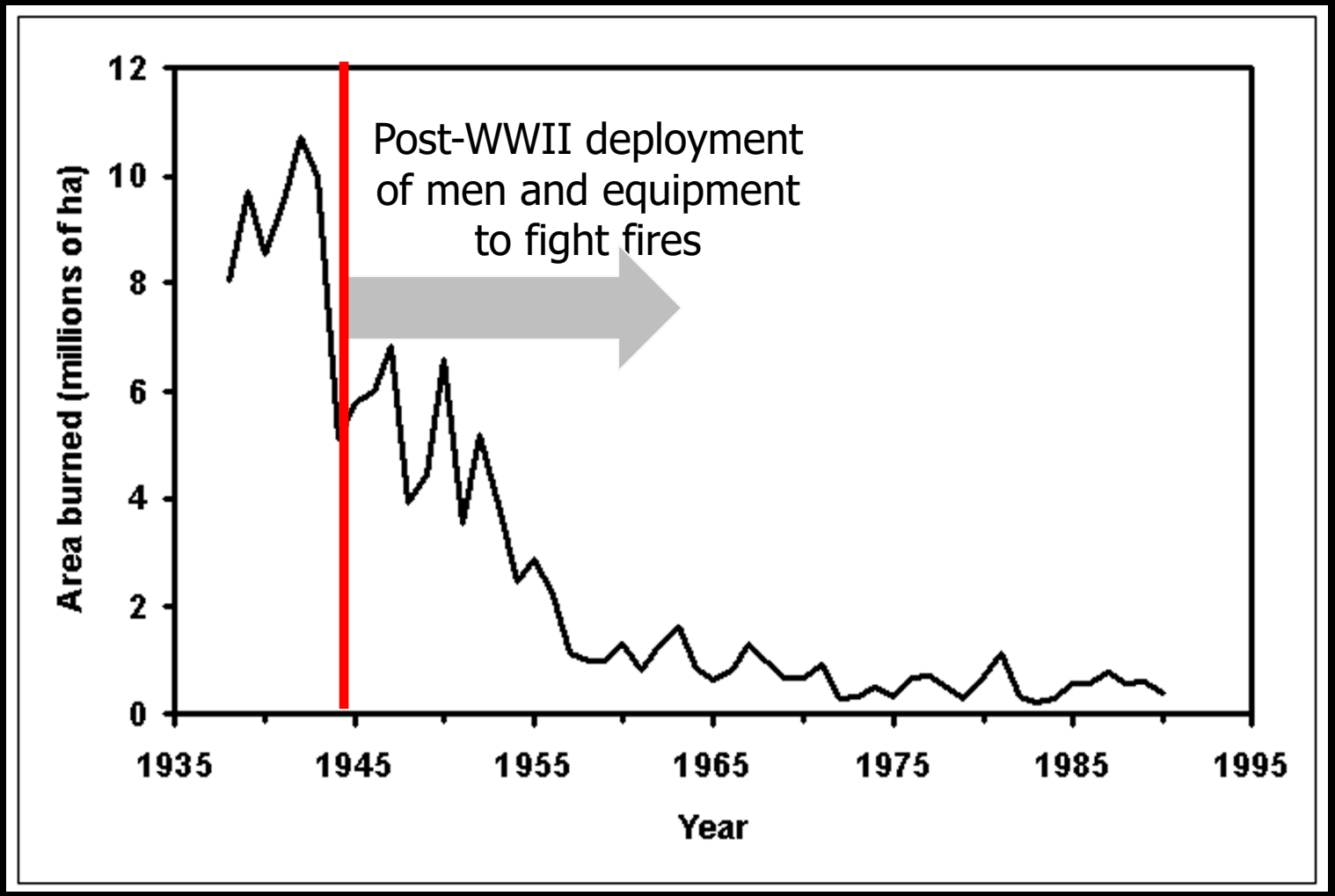
Climate Change

Oak Overbrowsing

Passenger Pigeon extinction?!?

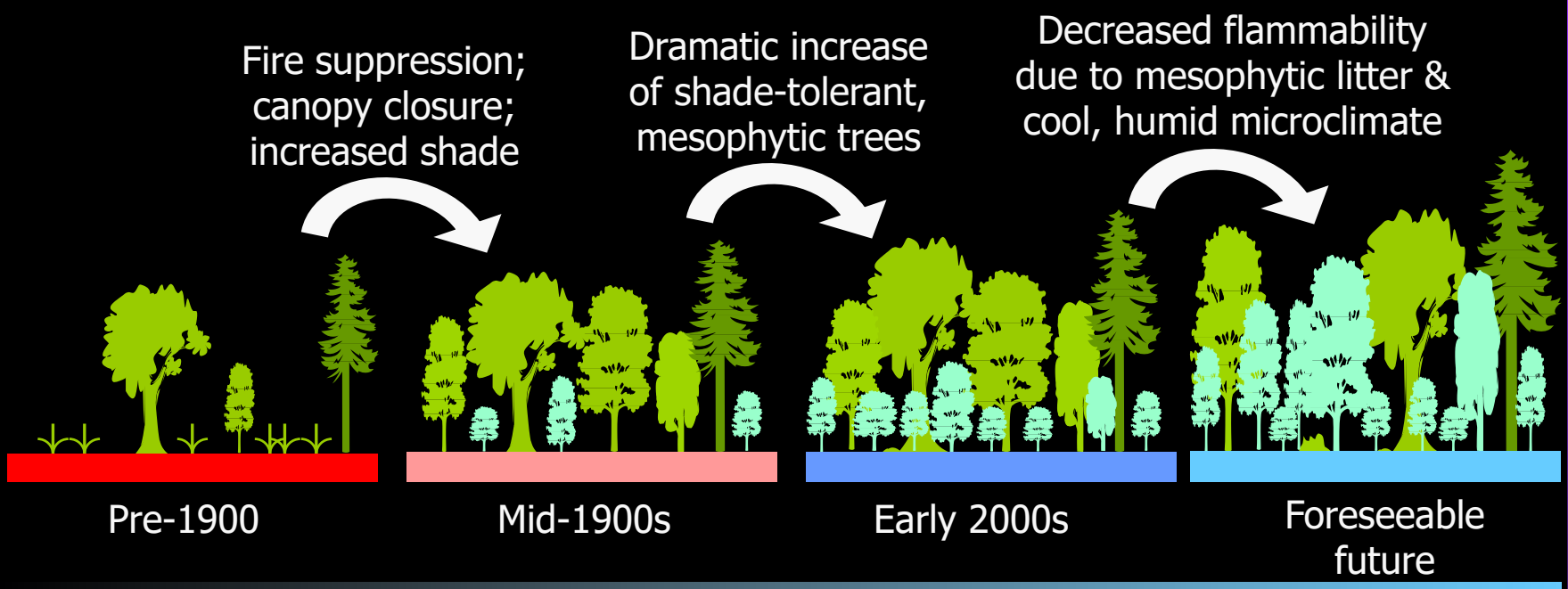
Fire Suppression

Area burned in the eastern U.S.*



* States from Minnesota to Louisiana eastward.

Fire Importance



Mesophication

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

- Thick bark (fire protection)
- Able compartmentalizer; rot resistant (fire injury)
- Aggressive sprouter-based reproductive strategy)
- Opportunistic: resp favo isturbance
- Fuel characteristics (fire p


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


Erie
Trenton
Dover

Presettlement: Oak-Pine-Chestnut-Hickory

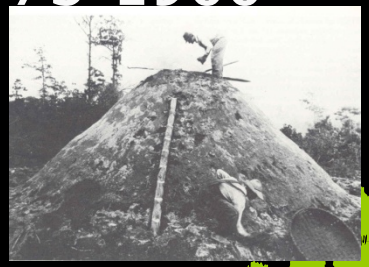
Fire

Exploitation: 1775-1900

Pines selectively removed

Hardwoods coppicing

Fire



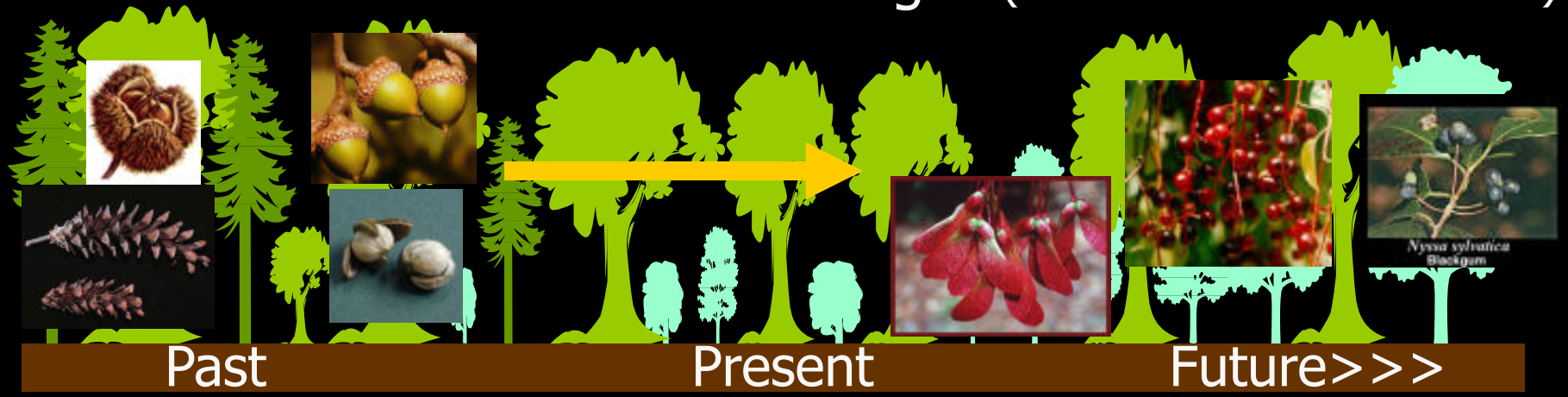
Modern: 1900-today

Chestnut blight

Pennsylvania Fires

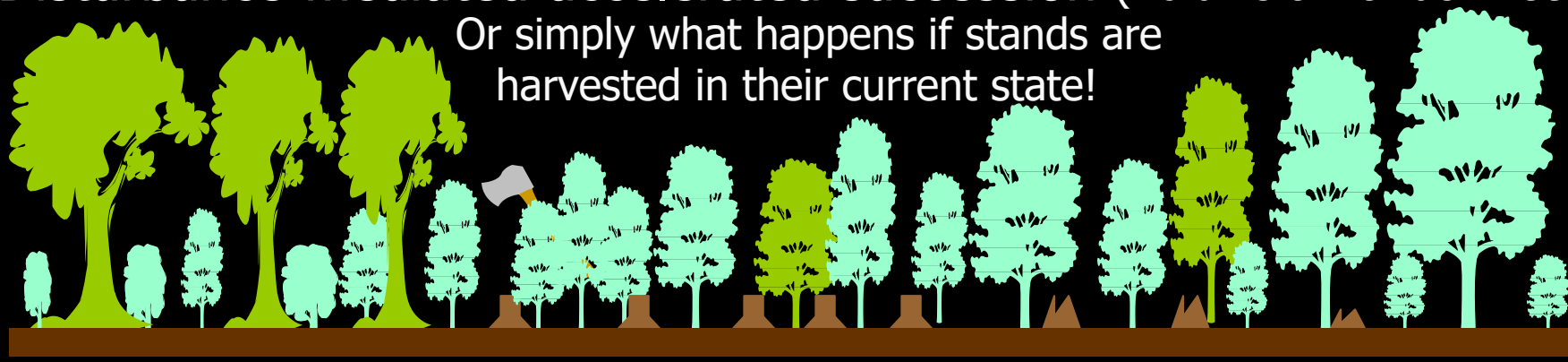
Year	Hectares
1908	407,700
1913-19	108,155
1920-29	72,378
1930-39	42,049
1940-49	21,158
1950-59	12,784
1960-69	8,634
1970-79	3,240
1980-89	3,388

Oak succession and habitat changes (Rodewald & Abrams 2002)



Disturbance-mediated accelerated succession (Abrams & Nowacki 1992)

Or simply what happens if stands are harvested in their current state!



So, what to [illegible]?

This also pertains to blowdown events (Holzmueller et al. 2012).

Prescribed burning is needed!

But is not enough for the restoration of pyrogenic ecosystems!!!

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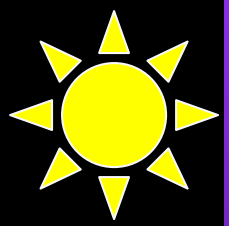
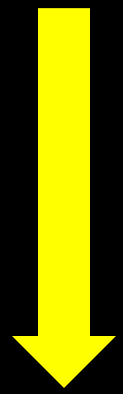
But is not enough for the restoration of pyrogenic ecosystems!!!

At The Morton Arboretum (IL), even 20+ yrs of annual prescribed burning combined with understory thinning has failed to produce conditions necessary for successful oak recruitment.

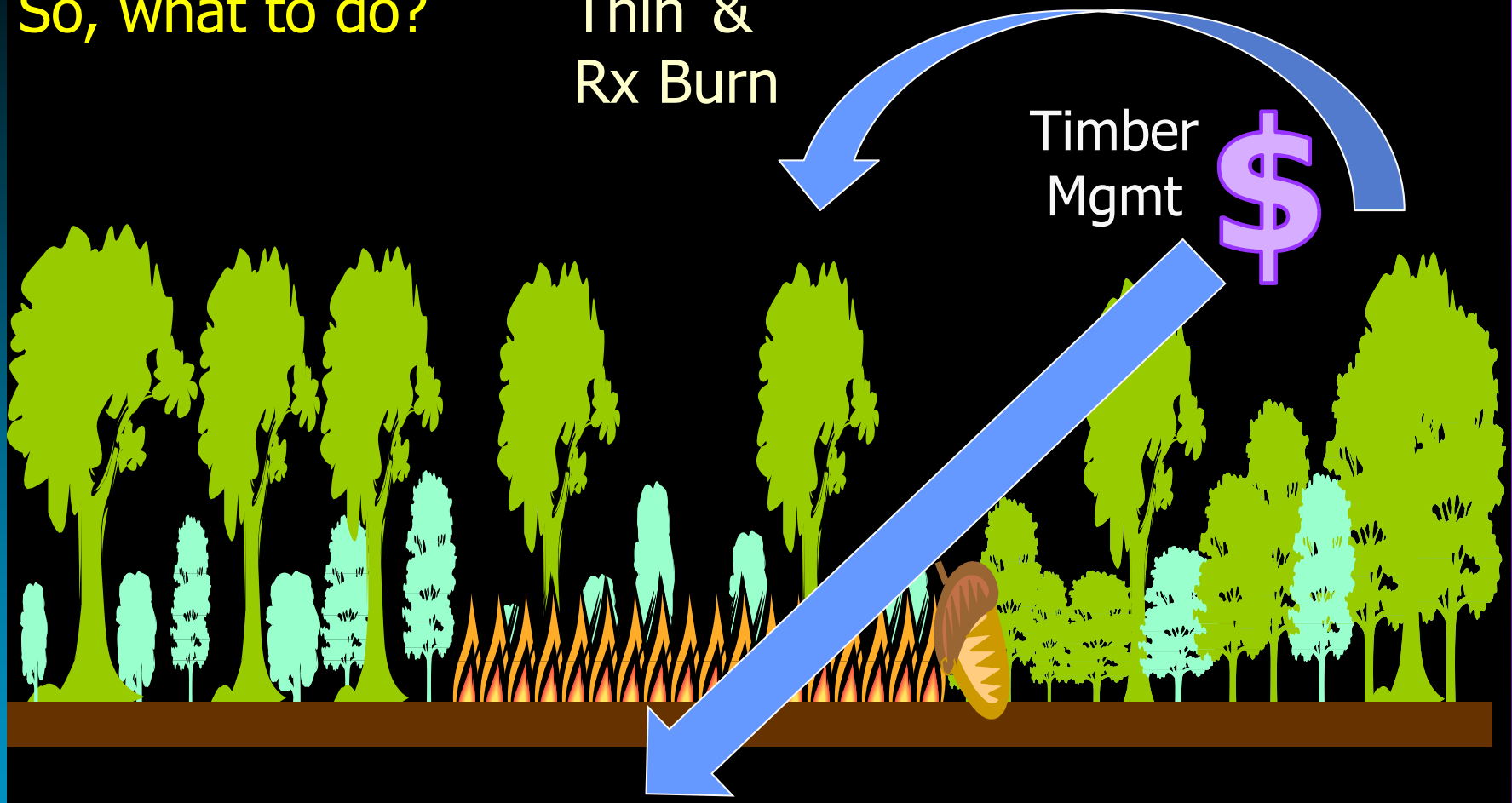




10 sites	Oak Seedlings		Oak Saplings	
	Density (#/ha)	Relative Density	Density (#/ha)	Relative Density
Average	226	1.6%	9	0.3%
Range	36-503	0.1-9.5%	0-36	0.0-4.9%

Carter et al. 2015. Assessing patterns of oak regeneration and C storage in relation to restoration-focused management, historical land use, and potential trade-offs. Forest Ecology & Management 343:53-62.

So, what to do?



…but for ecosystem restoration, you maintain open conditions through burning w/ periodic pauses for regen (cohorts)

Success stories do exist!
Western Star Oak Flatwoods, Mark Twain NF

Untreated

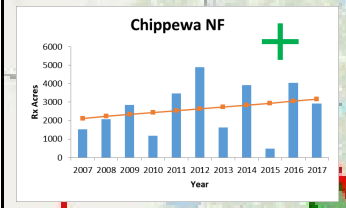
Typical present-day conditions:
- Continuous canopy; high density
- Shaded understory
- Depauperate ground flora
- Deep leaf litter

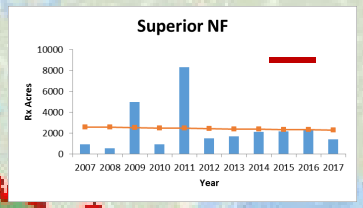
Thinned, burned

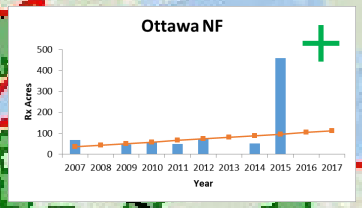
Restored (thin & 5 burns over 15 yrs):
- Open canopy; historic density
- High-light conditions
- Robust & diverse ground flora
- Negligible leaf litter

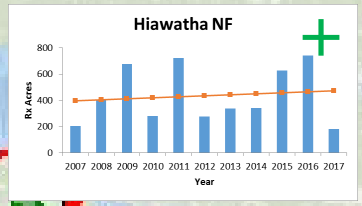
Current Trends in Prescribed Burning

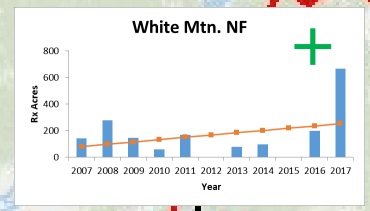
Eastern Region

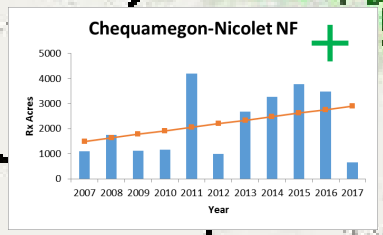


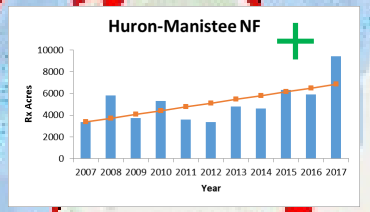


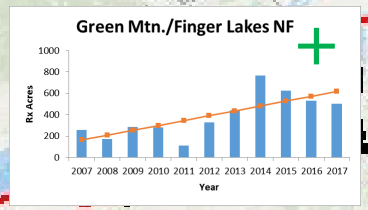


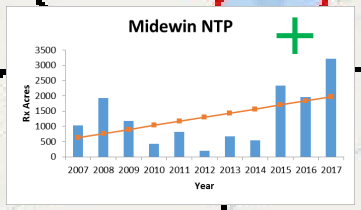


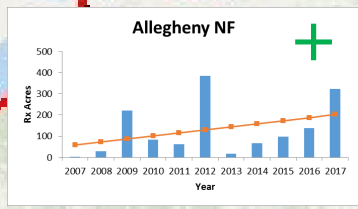


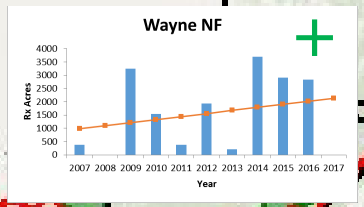


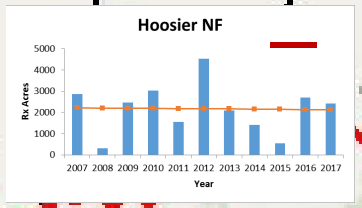


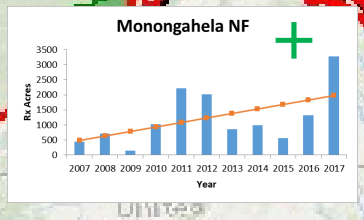


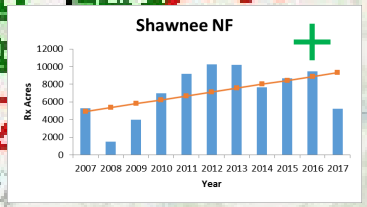






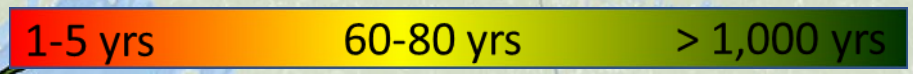






How do Current Levels of Prescribed Burning equate to Historic Fire Regimes?

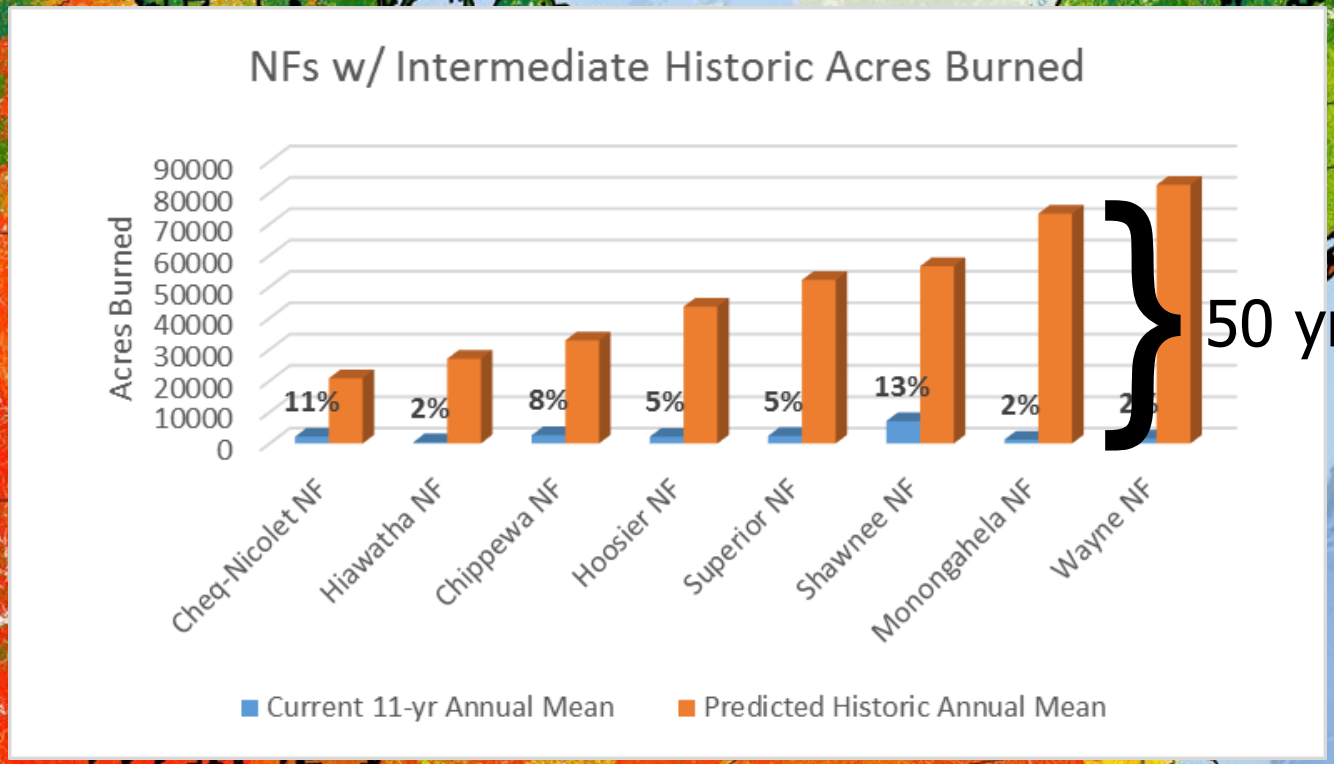
LANDFIRE'S Historic Mean Fire Return Interval



National Forest	Current 11-yr Annual Mean (Acres)	Predicted Historic Annual Mean (Acres)	Historic Rx Burned (%)
Green Mtn & Finger Lakes National Forests	391	1,095	35.7
White Mtn National Forest	168	2,212	7.6
Allegheny National Forest	130	2,515	5.2
Midewin National Tallgrass Prairie	1298	3,367	38.6
Ottawa National Forest	73	7,527	1.0
Cheq-Nicolet NF	2198	20,790	10.6
Hiawatha NF	435	27,007	1.6
Chippewa NF	2638	32,862	8.0
Hoosier NF	2167	43,654	5.0
Superior NF	2431	52,141	4.7
Shawnee NF	7119	56,538	12.6
Monongahela NF	1234	73,294	1.7
Wayne NF	1557	82,483	1.9
Huron-Manistee National Forest	5117	143,982	3.6
Mark Twain National Forest	32725	450,995	7.3
Eastern Region R09	59682	1,000,461	6.0

LANDFIRE'S Historic Mean Fire Return Interval

1-5 yrs 60-80 yrs > 1,000 yrs



Wave of fire: an anthropogenic signal in historical fire regimes across central Pennsylvania, USA

Michael C. Stambaugh,[1,†] Joseph M. Marschall,[1] Erin R. Abadir,[1] Benjamin C. Jones,[2] Patrick H. Brose,[3] Daniel C. Dey,[4] and Richard P. Guyette[1]

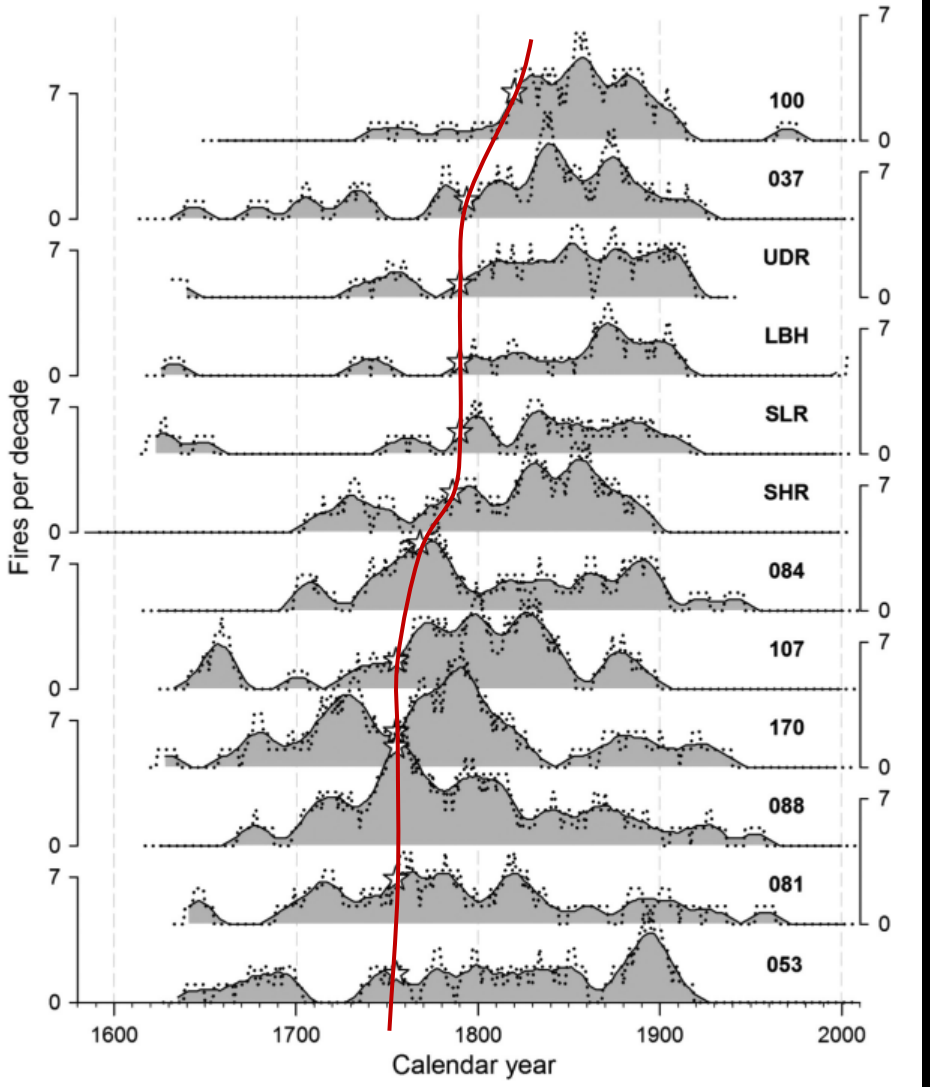
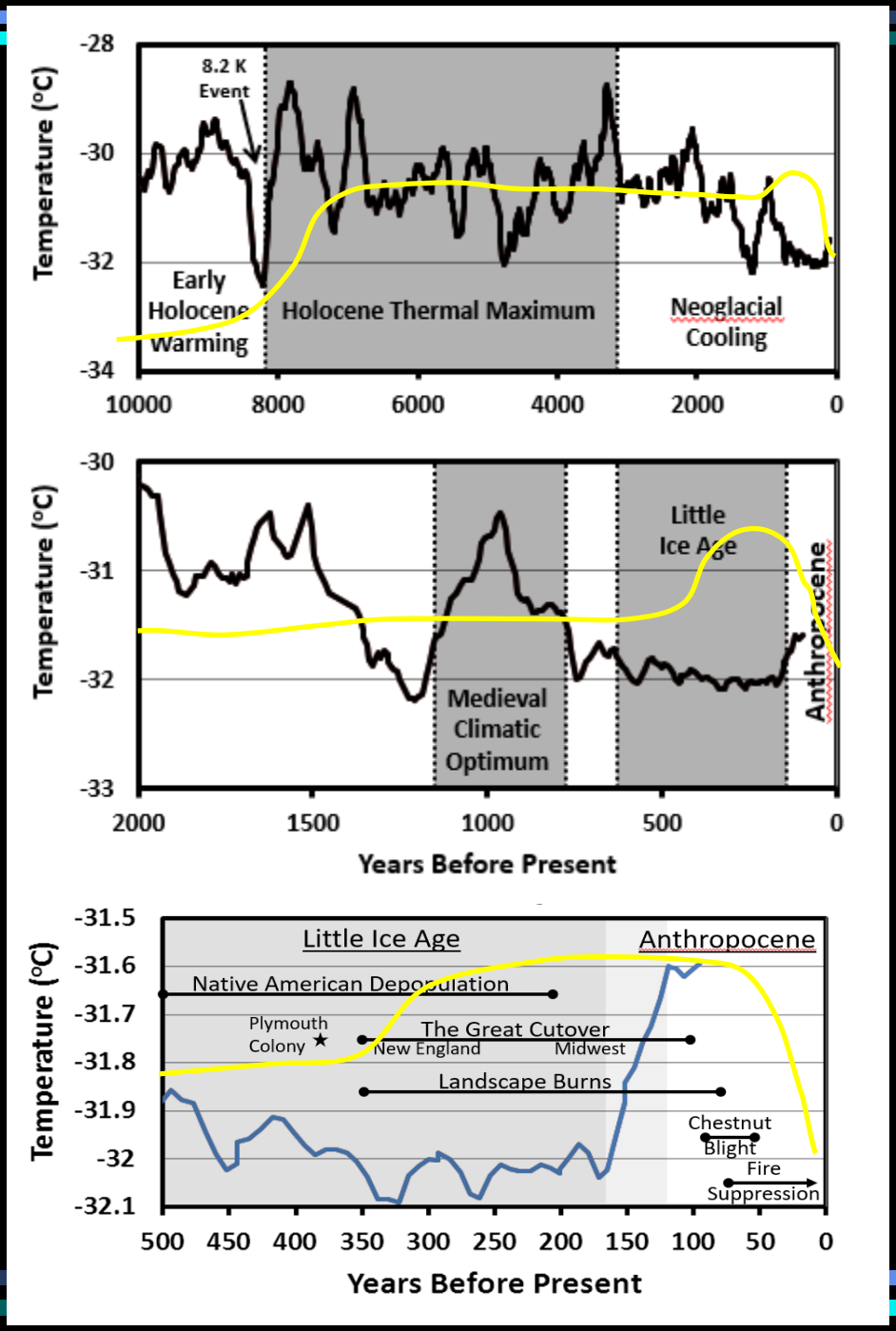


Fig. 6. Decadal-scale fire frequency across central Pennsylvania. Fires per decade (FPD, dotted line) was calculated using a moving window. The longer-term wave form (gray shaded areas) represents a 17-yr moving average of FPD. Study sites are sorted by Euro-American settlement dates and indicated by stars.

Greenland Ice Core Temperature



— Oak Importance

Landscape Ecol (2020) 35:2759–2775
https://doi.org/10.1007/s10980-020-01119-0

RESEARCH ARTICLE

The importance of land-use legacies for modeling present-day species distributions

Xin Chen · Laura Leites

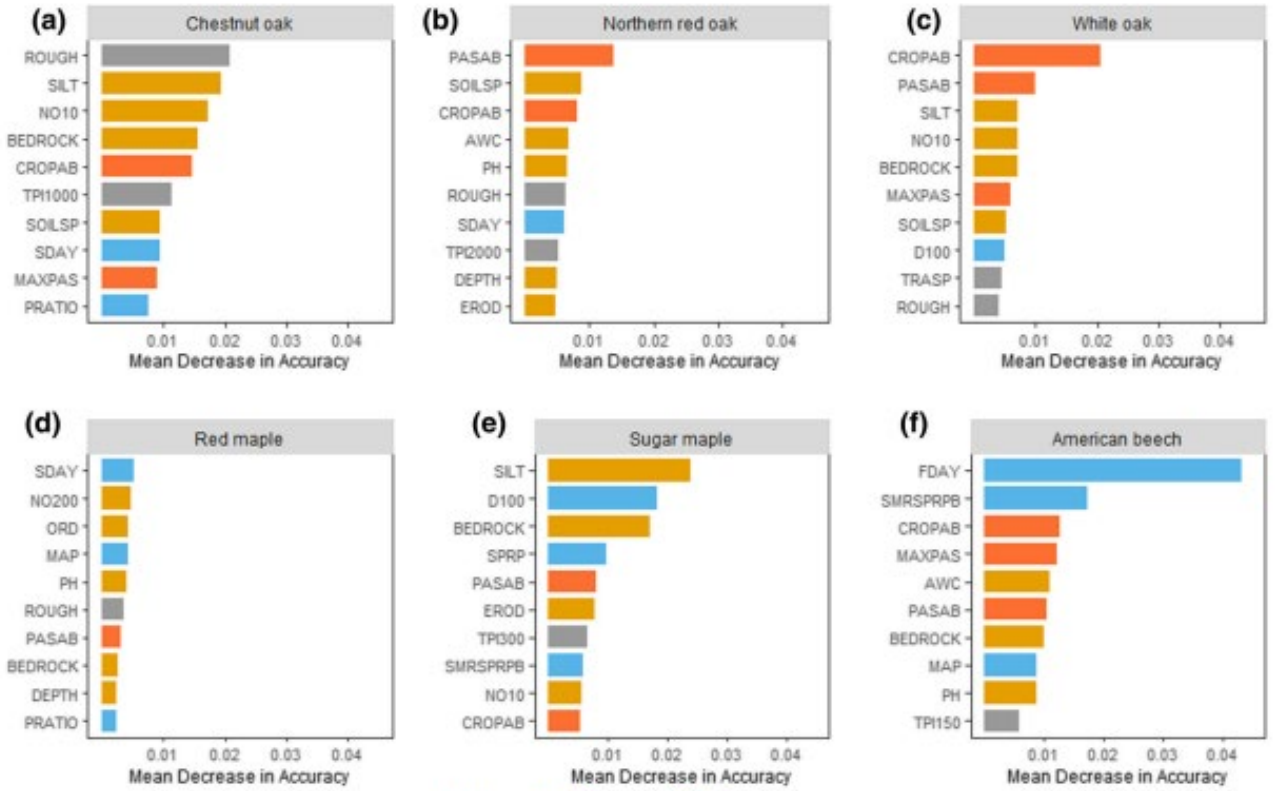


Fig. 7 Local variable importance (top 10 predictors) of SDM_{LU} derived from plots with CROPAB > 1% for each species: **a** chestnut oak **b** northern red oak. **c** white oak, **d** red maple, **e** sugar maple, and **f** American beech. Variable acronyms are described in Table 3

Predicted climate change effects on primary oaks based on USFS Tree Atlas models.

	White oak	Northern red oak	Black oak	Chestnut oak
Adaptability	High	High	Medium	High
Future suitable habitat	Small increase	Small increase	Increase	Small increase
Capability to cope	Very good	Very good	Very good	Very good
Infilling ability	Very good	NR	Very good	Excellent

Capability: An overall estimate of capability for the species to cope or persist with the changing climate within the eastern US.

Infilling: Migration model (SHIFT) that calculates the likelihood of colonization.

Climate Change Tree Atlas (Version 4) https://www.fs.fed.us/nrs/atlas/tree/

Climatic Change (2018) 146:103–116
DOI 10.1007/s10584-017-2065-2

CrossMark

Vulnerability of forests of the Midwest and Northeast United States to climate change

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Shifts in upland forest composition: Temperate broadleaf forests are common in upland areas across the region. The composition of these forests varies greatly... Fire suppression in temperate forests for nearly a century has allowed widespread expansion of mesic, shade-tolerant species (e.g., red maple, sugar maple, basswood [Tilia americana]), often to the detriment of fire-dependent species in a general mesophication of habitats (Nowacki and Abrams 2008; McEwan et al. 2011; Hanberry et al. 2012). Forest communities featuring a greater abundance of oak and southern pine species have generally been assessed as being less vulnerable to projected changes in climate (Manomet and NWF 2012; Brandt et al. 2017a). These systems are adapted to hotter, dry summers and frequent fires, which are projected to increase across much of the region. The ability of these forests to expand to new areas will likely depend on the role of fire and site-specific factors such as soil moisture and evaporative demand during summer months.

Enhanced fire risk: Wildfires are currently relatively infrequent in the region due to a combination of past management history, relatively high precipitation, and fire suppression efforts (Nowacki and Abrams 2008). However, fire has played an important role in shaping many of the region's forest communities in the past, especially oak, hickory, and oak-pine forests. By the end of the century, most models project an increase in wildfire probability (Moritz et al. 2012), with weather conditions that tend to promote large wildfires (hot, dry conditions with upper atmospheric instability) occurring more frequently (Tang et al. 2015). The increase in wildfire risk may be greatest in southern Ohio, West Virginia, and western Pennsylvania (Heilman et al. 2015). Fuel loads from pest-induced tree mortality and blowdown events could further increase fire risk, but the relationship between these factors can be complex (Handler et al. 2012).

Summary

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

- 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.

- Both prescribed burning and thinning are needed in order to maintain oak communities. Use timber mgmt receipts to generate funds needed for long-term oak ecosystem restoration.

- Oak is capable of coping with a hotter and drier future climate, however certain regeneration parameters still need to be met (fire, high light conditions, limited competition).

Questions?

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"Restoration uses the past not as a goal but as a reference point for the future. If we seek to recreate the temperate forests, tall grass savannas, or desert communities of centuries past, it is not to turn back the evolutionary clock but to set it ticking again." (Falk 1990)