ALTERED DISTURBANCE REGIMES:
THE DEMISE OF FIRE IN THE EASTERN UNITED STATES

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1. INTRODUCTION. Most ecosystems of the eastern United States developed under the influence of fire (Pyne 1982; Wright and Bailey 1982). As such, many eastern species are adapted to and dependent on fire, either directly (jack pine) or indirectly (Kirtland's warbler). Native Americans were the principal ignition source with over 70 documented uses of fire (Lewis 1993); far exceeding natural causes (e.g., lightning). In this respect, Native Americans were a "keystone species," actively managing the environment with fire over millennia (Sauer 1975, Cronon 1983). Due to the prevalence of fire, early European explorers and settlers encountered vast landscapes of fire-adapted (pyrogenic) vegetation, spanning from northern systems of spruce-fir, aspen-birch, and pine to oak, oak-pine, and southern "pineries" (Wright and Bailey 1982). Tallgrass prairies scattered throughout owed their existence to Native Americans who, through annual/biennial burning, maintained them for big game forage and hunting (grass → game → meat → happy and flourishing families!).

European settlement and land use fundamentally changed the disturbance regime of the East. With westward expansion, forestlands were universally cut (aka, the "Great Cutover"), often subsequently burned, and many converted to agriculture. Forests that managed to regenerate responded differently based on their ecological characteristics. Where European activities mimicked the historical disturbance regime, disturbance-dependent communities such as oak-hickory were successfully maintained. In contrast, where European activities deviated largely from the historic disturbance regime, wholesale changes to forested conditions occurred. For instance, a sizeable proportion of northern hardwoods (rich, moist forests that historically rarely burned) converted to aspen-birch through repeated cutting and burning.

Social philosophies towards fire changed in the early 1900's when outbreaks of destructive wildfires led to aggressive suppression efforts (Pyne 1982). Unforeseen ecological consequences resulted across America. Open land systems (grasslands, savannas, and woodlands) succeeded to closed-canopied forests over time, followed by the eventual replacement of fire-dependent plants by shade-tolerant, fire-sensitive vegetation. This is a trend that continues largely unabated today through uninterrupted fire suppression.

2. OBJECTIVES. The fire dependency of many native plant communities necessitates that certain landscapes are managed with fire. This is an evolutionary-based principal that can not be ignored. Indeed, without fire, the ecological integrity of pyrogenic ecosystems is compromised with accumulating species loss and biodiversity reduction. By comparing past and current fire regimes, the authors attempt to document the magnitude and pervasiveness of fire regime change and discuss the ecological effects of such change in the eastern United States.

3. METHODS. Geographic Information Systems (GIS) and available vegetation data layers were used to map past and current fire regimes and temporal changes. For consistency, only data layers spanning the entire eastern United States were considered. Vegetation classes were assigned fire regime groups according to National Fire Regime Condition Class (FRCC) protocols (Figure 1). All maps were uniformly rasterized at 1-kilometer pixels for analytical purposes.

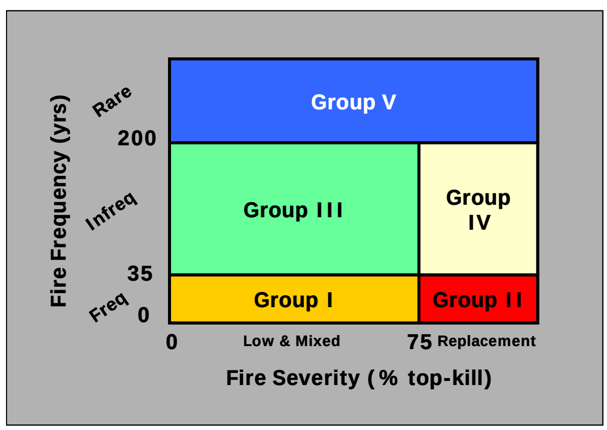

Figure 1. Five fire regime groups depicted in two-dimensional space of fire severity and frequency. Criteria breakpoints are 75% top-kill for fire severity (low & mixed vs. replacement) and 35 and 200 yrs for fire frequency (frequent, infrequent, and rare). Fire regime groups have been colored to reflect a fire gradient from extreme (red; Group II) to rare (blue; Group V).

Potential natural vegetation (version 2000; obtained through J. Menakis) was used as the basis to reconstruct past fire regimes. Fire regime groups were assigned to PNV classes as defined in Table 1.

Table 1. Potential natural vegetation codes, titles, and assigned fire regime group.

Code	Title	Fire Regime Group
32	Plains grassland	2
33	Prairie	2
36	Wet grassland	2
38	Oak savanna (ND)	1
39	Mosaic bluestem/oak–hickory	2
40	Cross timbers	1
41	Conifer bog (MN)	4
42	Great Lakes pine forest	4
43	Spruce–fir	4
44	Maple–basswood	5
45	Oak–hickory	3
46	Elm–ash	5
47	Maple–beech–birch	5
48	Mixed mesophytic forest	3
49	Appalachian oak	3
50	Oak–northern hardwoods	3
51	Northern hardwoods	5
52	Northern hardwoods–fir	5
53	Northern hardwoods–spruce	5
54	Northeastern oak–pine	3
55	Oak–hickory–pine	3
56	Southern mixed forest	4
57	Loblolly–shortleaf pine	4
58	Blackbelt prairie	2
59	Oak–gum–cypress	3
60	Northern Floodplain	3
61	Southern Floodplain	5
62	Barren	2
63	Water	0

Advanced Very High Resolution Radiometer [AVHRR] and National Land Cover Dataset [NLCD] layers were used in tandem to map current fire regimes. The individual classification power of the two datasets was capitalized on, maximizing the number of classes to depict current vegetation (theoretically increasing accuracy). As such, AVHRR data were used to classify forestlands (by type and cover class), whereas NLCD data were applied to the remaining lands, primarily non-forested openlands. Fire regime group codes (tables 2 and 3) were applied to produce a current fire regime map.

To best depict past-to-current fire regime change the numbering system of fire regime groups was changed to better reflect a fire gradient from hottest (most frequent and severe) to coolest (less frequent and severe). Thus, the following values were used: FRG I = 2, FRG II = 1, FRG III = 4, FRG IV = 3 and FRG V = 5. A fire regime change map was then generated on a pixel-by-pixel basis using the following equation:

Fire Regime change = Current Fire Regime - Past Fire Regime

Table 2. Advanced Very High Resolution Radiometer (AVHRR) vegetation class titles and assigned fire regime group by tree cover class.

Title	0-9%	10-24%	25-59%	≥60 %
White-red-jack pine	2	1	3	4
Spruce-fir	2	1	3	4
Longleaf-slash pine	2	1	3	4
Loblolly-shortleaf	2	1	3	4
Oak-pine	2	1	3	3
Oak-hickory	2	1	3	3
Oak-gum-cypress	2	1	3	3
Elm-ash-cottonwood	2	5	5	5
Maple-beech-birch	2	5	5	5
Aspen-birch	2	1	3	3
Ponderosa pine	2	1	3	4
Lodgepole pine	2	1	4	4
Pinyon-juniper	2	1	4	4

Table 3. National Land Cover Data (NLCD) vegetation codes, titles, and assigned fire regime group.

Code	Title	FRG
11	Open water	0
12	Perennial ice/snow	0
21	Low-intensity residential	5
22	High-intensity residential	5
23	Commercial/industrial/ transport	5
31	Bare rock/sand/clay	5
32	Quarries/strip mines/gravel pits	5
33	Transitional	5
41	Deciduous forest	5
42	Evergreen forest	4
43	Mixed forest	3
51	Shrubland	1
61	Orchards/vineyards/other	5
71	Grasslands/herbaceous	2
81	Pasture/hay	4
82	Row crops	5
83	Small grains	4
84	Fallow	5
85	Urban/recreational grasses	4
91	Woody wetlands	5
92	Emergent herbaceous wetlands	4

This formula projects fire regime change over 9 classes from -4 through 0 to +4. Negative values represent trends towards more pyrogenic landscapes (higher past fire regime class ("cooler") compared to today); whereas positive values represent fire reductions (lower past fire regime class ("hotter") compared to today). The more negative or positive the values are, the more dramatic the trend.

4. RESULTS. Past and current fire regime maps are shown in Figures 2 and 3, respectively. Color palettes were specifically selected to reflect a fire regime gradient from "pyrogenic" systems carrying intense, potentially most devastating fires (FRG II; red) to "asbestos" systems that rarely burn (FRG V; blue). Note that the color spectrum (red hot to cool blue) differs somewhat from fire regime group enumeration (FRG I-V).

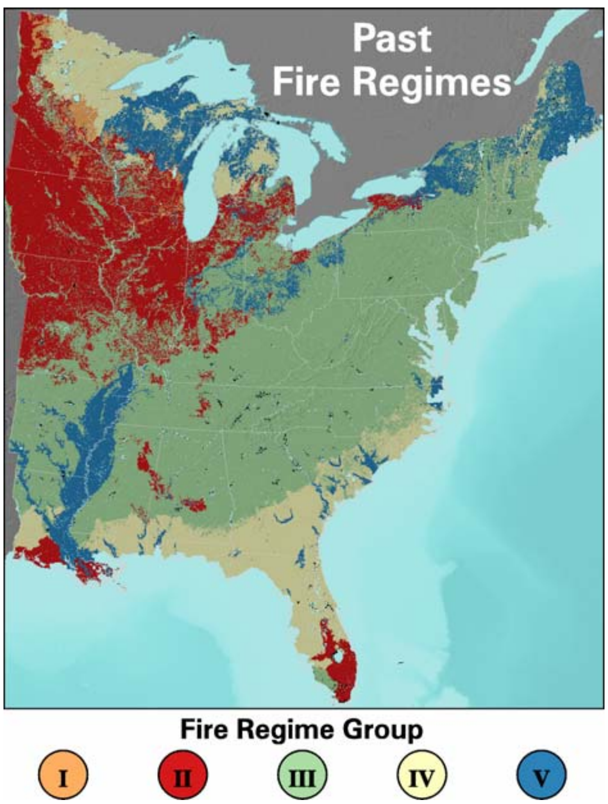

Figure 2. Past (presettlement) fire regimes by group based on potential natural vegetation (2000). Fire regime group assignments of vegetation types are listed in Table 1.

The degree of change between past and current fire regimes, as captured by Figure 4, varied across the East. The largest reductions of fire (depicted in blue) were centered in the Midwest. Substantial reductions of fire (represented by greens) also occurred in northern Minnesota, along a southeast-northwest trending span from central Indiana to Massachusetts, and on the Coastal Plain from southern Louisiana to North Carolina. Increases in fire were less pronounced and occurred in four sectors: northern Wisconsin and Michigan, Maine, certain areas of the Piedmont, and in portions of Arkansas and Louisiana. Areas outside the above remained largely unchanged (as depicted by yellows).

Figure 3. Current fire regimes by group based on the Advanced Very High Resolution Radiometer (AVHRR)-National Land Cover Data (NLCD) hybrid map. Fire regime group assignments of vegetation types are listed in Table 2.

5. CONCLUSIONS. There has been a general "cooling" of the eastern U.S. landscape over time. This trend is consistent with the historical record, which points towards wholesale fire reduction, both spatially and temporally, across the East (Pyne 1982). The suppression of fire was due to convergence of events, including elimination of Native burning, building of road networks (fire breaks and access), forest/prairie conversion to croplands (fuel change/reduction), and aggressive 20th century fire fighting.

Figure 4. Past-to-current fire regime change map based on spatial analysis of PNV (past) and AVHRR-NCLD (current) fire regime maps. Negative values represent shifts towards more fire, whereas positive values represent shifts to less fire. The departure from zero relates to the extent of fire regime change.

The reduction of fire was most dramatic in the Midwest where a mosaic of grasslands and open woodlands has been replaced by an agriculture-dominated landscape that rarely burns. Fire reductions extended northward into the subboreal portions of Minnesota and eastward across oak-dominated landscapes, the latter of which is well documented (Abrams 1992). Due to the lack of rejuvenating surface burns, oaks are rapidly being replaced by fire-sensitive mesophytic species (primarily maple). These mixed mesophytic species further "fire-proof" conditions by deep shading (promoting cooler and moister understory conditions) and producing fuels that are not conducive to burn (moist, rapidly decaying woody debris; dropping wet, flaccid foliage in the fall).

Exceptions of this trend do exist. Portions of the South, particularly the Piedmont, seemed to be burning at a similar or more frequent rate than historically. The maintenance of pine forests through frequent surface burning may partially explain this phenomenon. The projected increase in fire in the Upper Great Lakes states is probably an artifact of higher present-day levels of aspen-birch (fire-dependent forest type) compared to the past. The increase of fire in Maine is probably an anomaly, resulting from the generalness of PNV classes used to depict past fire regimes (northern hardwood-spruce forests; FRG V) compared to the preciseness of AVHRR-NLCD classes used to depict current fire regimes (spruce-fir; FRG IV). The coarse-scale maps generated by this analysis limit them to general application and interpretation.

6. SELECTED REFERENCES

Abrams, M., 1992: Fire and the development of oak forests. BioScience 42:346-353.

Cronon, W., 1983: Changes in the land: Indians, colonists and the ecology of New England. Hill and Wang, New York, NY.

Lewis, H.T., 1993: Patterns of Indian burning in California: Ecology and ethnohistory. P. 55-116 *in* T.C. Blackburn and K. Anderson (eds.), Before the wilderness: Environmental management by Native Californians, Ballena Press, Menlo Park, CA.

Pyne, S. J., 1982: Fire in America: A cultural history of wildland and rural fire. Princeton University Press, Princeton, NJ.

Sauer, C.O., 1975: Man's dominance by use of fire. Geoscience and Man 10:1-13.

Wright, H. A., Bailey, A. W., 1982: Fire Ecology: United States and southern Canada. John Wiley & Sons, New York, NY.

AUTHOR BIOGRAPHY

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