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Marc Abrams

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Vegetation change is brought about by natural and anthropogenic processes, as well as an interaction of the two. Natural processes that impact vegetation include climate change, ecological disturbances (lightning fire), insect and disease outbreaks, extreme weather events, geologic phenomenon, and plant succession. Anthropogenic impacts include land-use history (e.g., fire, land clearing), and human-induced climate change. Climate change during the Holocene epoch has been attributed to natural variation as well as anthropogenic causes (e.g., fire, agriculture and greenhouse gases).[1] Studies of long-term forest dynamics have shown that oak (*Quercus* spp.) and pine (*Pinus* spp.) dominated much of the eastern United States forest biome during the Holocene epoch.[2] Their increased importance was associated with a warmer and drier climate and elevated fire frequency after glacial

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* Dr. Marc Abrams is professor of forest ecology and physiology and Endowed Steimer Professor of Agricultural Sciences at Penn State. He received his B.S. from S.U.N.Y. Binghamton and his M.S. and Ph.D. from Michigan State University. Professor Abrams's research interests include disturbance ecology, old-growth forests, tree physiology, and vegetation classification. He has an extensive publishing history and has received numerous research grants from sources including the Nature Conservancy, the National Park Service, and the National Institute for Climate Change Research. These grants support his research on topics ranging from forest composition and structure, fire history and soils analysis, to the impacts of soil warming on ecosystem and physiological responses in contrasting tree species. The author would like to thank graduate student Ben Sands for his assistance with reviewing, editing, and formatting this article.

1. *See* William Ruddiman, *How Did Humans First Alter Global Climate?*, 292 SCI. AM. 46, 46-53 (2005). *See generally* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007—THE PHYSICAL SCIENCE BASIS: WORKING GROUP I CONTRIBUTION TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (Cambridge University Press 2007).

2. Marc D. Abrams, *The Postglacial History of Oak Forests in Eastern North America*, *in* OAK FOREST ECOSYSTEMS: ECOLOGY AND MANAGEMENT FOR WILDLIFE 34-35 (William J. McShea & William H. Healy eds., 2002) [hereinafter Abrams, *Postglacial History*]; Marc D. Abrams & Gregory J. Nowacki, *Native Americans as Active and Passive Promoters of Mast and Fruit Trees in the Eastern USA*, 18 THE HOLOCENE 1123, 1123-37 (2008).

retreat.[3] As Native American populations increased throughout eastern North America so did their use of fire, land clearing and other agricultural activities.[4] Thus, climate change, whether natural or anthropogenic, and land-use history during the Holocene resulted in a dynamic equilibrium in forest and grassland structure and composition, which differed markedly from current conditions.

The magnitude of anthropogenic disturbances in North American forests changed dramatically following European settlement. These included extensive logging and land clearing, often associated with catastrophic fire, followed by the onset of the fire control era in the early 20th century, and the introduction of exotic insects and diseases.[5] All of these have led to unprecedented and rapid changes in forest composition and structure. This is particularly true for the eastern United States, which has seen the extirpation of the once dominant American chestnut (*Castanea dentata*) from blight, loss of vast white pine (*Pinus strobus*) and pitch pine (*Pinus rigida*) forests to logging, followed by intense fires, a virtual cessation of regeneration of pyrogenic plants from fire suppression (Smokey Bear Policy), intensive deer browsing, and a rapid increase in native and exotic invasive plants.[6]

One of the most dramatic changes that occurred in forests of eastern North America during the 20th century is the increase in red maple (*Acer rubrum*).[7] Red maple has become nearly ubiquitous across sites of greatly contrasting light, moisture and nutrient availability.[8] This is in stark contrast to the rather limited distribution of red maple reported in pre-European settlement forests, where it occurred mainly in poorly drained areas (and was commonly known as swamp maple).[9] The increase in red maple is thought to be related, at least in part, to the exclusion of fire in most forests, particularly those dominated by oak and

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3. Hazel R. Celcourt & Paul A. Delcourt, *Pre-Columbian Native American Use of Fire on the Southern Appalachian Landscape*, 11 CONSERVATION BIOLOGY 1010, 1010-14 (1997).

4. *See* Gregory J. Nowacki & Marc D. Abrams, *The Demise of Fire and "Mesophication" of Forests in the Eastern United States,* 58 BIOSCIENCE, 123, 123-38 (2008). *See generally* GEORGE G. WHITNEY, FROM COASTAL WILDERNESS TO FRUITED PLAIN: A HISTORY OF ENVIRONMENTAL CHANGE IN TEMPERATE NORTH AMERICA FROM 1500 TO THE PRESENT (Cambridge University Press 1996).

5. *See generally* Marc D. Abrams, *The Red Maple Paradox: What explains the widespread expansion of red maple in eastern forests?*, 48 BIOSCIENCE 355 (1998) [hereinafter Abrams, *The Red Maple Paradox*].

6. *See id.*; WHITNEY *supra* note 4; *see also* Marc D. Abrams, *Fire and the Development of Oak Forests*, 42 BIOSCIENCE, 1992, 346-353 [hereinafter Abrams, *Fire and Development*].

7. *See* Abrams, *The Red Maple Paradox*, *supra* note 5.

8. *See id.*

9. *See id.*

pine, and its avoidance by loggers during the major clear-cut era from 1870-1920.[10] In addition, differential deer browsing on oak (favored by deer) versus red maple (avoided by deer) has also acted to promote red maple.[11] Presently, red maple dominates the understory and mid-canopy of many oak, pine, and northern hardwood forests, and it appears that it will increase in the overstory during the next century, causing widespread replacement of the historically dominant trees in the eastern United States.[12] The increase in red maple and other shade tolerant, non-pyrogenic species has contributed to the "mesophication" process (a cooling, dampening and reduced flammability of the ground layer) in many eastern oak forests, reducing the likelihood of restoring the natural fire cycle in these forests.[13] It is thought that low-to-moderate understory fire is needed for the long-term sustainability of most eastern oak forests.[14] This type of fire was highly effective in eliminating fire sensitive, shade tolerant, oak replacement trees species, while creating the proper light and forest floor conditions for oak seedlings to regenerate.[15]

Given current conditions of the ecology and management of eastern forests, the loss of oak and pine domination in eastern U.S. forests will be one of the primary consequences of the continued expansion of later successional tree species. Periodic burning of oak, hickory (*Carya* spp.) and pine types prior to European settlement was arguably a key factor limiting red maple domination in the original forests.[16] In contrast, fire suppression policy during the Smokey Bear era appears to be leading to the demise of many historically dominant trees in the eastern United States. Suppressing fire in most oak forests allows later successional, oak replacement species (e.g., red maple) to flourish, while reducing the ability of oak to regenerate and/or recruit into the forest canopy.[17]

HUMAN IMPACTS ON VEGETATION PRIOR TO THE INDUSTRIAL REVOLUTION

The long-term stability of oak existed during the last 7000-9000 years in the eastern United States.[18] This period included major climatic

10. *See generally* Abrams, *Fire and Development*, *supra* note 6; Craig G. Lorimer, *Historical and Ecological Roles of Disturbance in Eastern North American Forests: 9,000 Years of Change*, 29 WILDLIFE SOC'Y BULLETIN 425 (2001).
11. *See* Abrams, *The Red Maple Paradox*, *supra* note 5.
12. *Id.*
13. *See* Nowacki & Abrams, *supra* note 4.
14. *See* Abrams, *The Red Maple Paradox*, *supra* note 5.
15. *See id.*
16. *See id*; Abrams & Nowacki, *supra* note 2, at 1124.
17. *Id.*
18. *See* Abrams, *Postglacial History*, *supra* note 2; *see also* Lorimer, *supra* note 10.

shifts such as the Holocene Optimum centered around 3000 years ago, the Medieval Warm period around 1000 years ago and the Little Ice Age 150-500 years ago.[19] The rise in oak populations prior to the Holocene Optimum, its relative stability in the intervening cooling period (up until the Medieval Warming) and through the Little Ice Age, suggests that oaks were promoted by Native American activity.[20] For example, on the eastern Highland Rim and adjacent Cumberland Plateau of Tennessee, Delcourt reported that mixed mesophytic forest taxa (e.g., oak, ash (*Fraxinus* spp.), ironwood (*Ostrya virginiana*), hickory, birch (*Betula* spp.), walnut (*Juglans nigra*), elm (*Ulmus* spp.), beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), basswood (*Tilia americana*), and hemlock (*Tsuga canadensis*) were most abundant during the early Holocene.[21] A warming trend in the region from 8000-5000 years BP was reflected in higher pollen influx values for oak, ash, and hickory, and lower pollen influx for the mixed-mesophytic species.[22] Domination by oak continued for the remainder of the Holocene.[23]

Another important indication of humans' role in the ecology of eastern North America is the long-term persistence of disturbance-dependent vegetation types where natural disturbances are not particularly inherent to the system. In my opinion, the vast expanses of tallgrass prairie, oak savannas, oak-hickory-chestnut forests, and southern and northern pine that cover much of the eastern United States fall into this category. Tallgrass prairie once covered approximately 240 million acres in the central United States.[24] An additional 30 million acres of oak savanna covered portions of Minnesota, Iowa, Missouri, Illinois, Wisconsin, Michigan, Native Americana and Ohio.[25] Tallgrass prairie and oak savannas have persisted for most of the Holocene epoch in regions that receive 30-36 inches of rain per year, more than enough to support most central hardwood species.[26] Ironically, occurrence of

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19. *See generally* Dee C. Pederson et al., *Medieval Warming, Little Ice Age, and European Impact on the Environment During the Last Millennium in the Lower Hudson Valley, New York, USA*, 63 QUATERNARY RES. 238(2005).

20. *See* Abrams & Nowacki, *supra* note 2 at 1133.

21. *See* Hazel R. Delcourt, *Late Quaternary Vegetation History of the Eastern Highland Rim and Adjacent Cumberland Plateau of Tennessee,* 49 ECOLOGICAL MONOGRAPHS 255, 270 (1979).

22. *See id.* at 267.

23. *See id.* at 277.

24. *See* Daryl D. Smith, *Tallgrass Prairie Settlement: Prelude to Demise of the Tallgrass Ecosystem, in* PROCEEDINGS OF THE TWELFTH NORTH AMERICAN PRAIRIE CONFERENCE 195 (Daryl D. Smith & Carol A. Jacobs eds., 1992).

25. *See* Victoria A. Nuzzo, *Extent and Status of Midwest Oak Savanna: Presettlement and 1985*, 6 NATURAL AREAS J. 6 (1985), *available at* http://www.epa.gov/ecopage/upland/oak/oak94/Proceedings/Nuzzo.html#1.

26. *See id.*

lightning is relatively low in the central, Lake State, and Midwest regions of the United States, as is their importance as an ignition source for large-scale fire.[27] This has led most researchers to conclude that grasslands and oak savannas were maintained by human-caused fire rather than climate.[28] Native Americans of the Central Plains used fire management to promote prairie as a grazing habitat for large herbivores, such as bison, as well as a dietary resource for themselves.[29] Kay concluded that Aboriginal burning in the United States was the dominant ecological force and that lightning-caused fires were largely irrelevant;[30] this is particularly true for most of the eastern United States.[31] The wide-spread conversion to shrubs and trees following European fire suppression is highly convincing evidence of the fire dependency of tallgrass prairies and oak savannas.[32] Very early on, Gleason recognized that the suppression of Native American fires led to the conversion of tallgrass prairie to oak forests in the Midwest.[33]

The stability of oak in the eastern forests over most of the Holocene is intriguing based on the fact that most sub-xeric oak forests are successional to more shade tolerant trees in the absence of burning.[34] Most authors report that recurring surface fire was integral to the historical development and long-term persistence of oak forests.[35] In New England, for example, paleocharcoal levels dating to 2500 years ago were lowest in northern hardwood forests, intermediate in oak and pine forests, and highest in pitch pine and oak forests.[36] In the Hudson Highlands of southeastern New York, oak forests were maintained throughout most of the Holocene epoch as a result of Native American

27. Charles E. Kay, Are Lightning Fires Unnatural? A Comparison of Aboriginal and Lightning Ignition Rate in the United States 16-28 *in*, PROCEEDINGS OF THE 23RD TALL TIMBERS FIRE ECOLOGY CONFERENCE: FIRE IN GRASSLAND AND SHRUBLAND ECOSYSTEMS, TALL TIMBERS RESEARCH STATION (Ronald E. Masters and Krista E.M. Gallery eds., 2007).

28. *See* Henry Allen Gleason, *The Relation of Forest Distribution and Prairie Fires in the Middle West*, 13 TORREYA 173, 173-181 (1913); Nuzzo, *supra* note 25.

29. *See* Abrams & Nowacki, *supra* note 2.

30. *See* Kay, *supra* note 27.

31. *Id.*

32. *See* Grant Cottam, *The Phytosociology of an Oak Woods in Southwestern Wisconsin*, 30 ECOLOGY 271, 272 (1949); Marc D. Abrams, *Historical Development of Gallery Forests in Northeast Kansas*, 65 VEGETATIO 29, 29-30 (1986); Nuzzo, *supra* note 25, at 8.

33. *See* GLEASON, *supra* note 28, at 176.

34. *See* Abrams, *Fire and Development*, *supra* note 6, at 346.

35. *See* JOHN T. CURTIS, THE VEGETATION OF WISCONSIN: AN ORDINANCE OF PLANT COMMUNITIES 334 (University of Wisconsin Press) (1959); Abrams, *Fire and Development*, *supra* note 6, at 346.

36. *See* T. Parshall & D.R. Foster, *Fire and the New England Landscape: Regional and Temporal Variation, Cultural and Environmental Controls*, 29 J. BIOGEOGRAPHY 1305, 1308-09 (2002).

fires.[37] A dramatic increase of oak, hickory, chestnut and pine in eastern Kentucky after 3000 yrs BP corresponded to increased fire and anthropogenic activity.[38] Hickory, oak and walnut were the most frequent native mast tree nutshell remains, indicating that these species were an important food source of the Native Americans during the Holocene.[39] In the southern Blue Ridge Mountains of North Carolina, oak, chestnut, pine and birch were the dominant tree taxa during the last 4000 years.[40] There was a constant influx of charcoal during that period, including charcoal produced from regional, watershed, and local fires, as well as small, medium and large charcoal particles, respectively.[41]

The long-term domination of pine along the northern and southern tiers of the eastern United States suggests recurring disturbance in much of the same way as in oak forests. Pines are light-demanding, early successional and fire adapted.[42] In the absence of fire they will be replaced by more shade tolerant hardwoods in one generation.[43] In the northern hardwood-conifer forest at Mirror Lake, New Hampshire, peak domination of white pine and oak occurred in the early Holocene epoch (9000-7000 yr BP) when the climate was warmer and drier than at present; charcoal was most abundant 8000-7000 years BP.[44] Between 10,000 to 6,000 years BP, an expansion of pine and increase in paleocharcoal occurred in central Appalachia and the New Jersey Coastal Plain.[45] In eastern Kentucky, where lightning-caused fires are rare, a large increase of pine, oak, hickory and chestnut after 3000 yrs BP was associated with frequent fire attributed to anthropogenic activity.[46] In southern New York, the Medieval Warm Period was characterized by a large increase in charcoal and oak and pine dominance from ~800-1300 A.D.[47] The region experienced an increase in spruce (*Picea* spp.) and hemlock during the Little Ice Age between 1500 and 1850.[48] At

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37. *See* Terryanne.E. Maenza-Gmelch, *Holocene Vegetation, Climate, and Fire History of the Hudson Highlands, Southeastern New York, USA*, 7 THE HOLOCENE 25, 35 (1997).

38. *See* Paul A. Delcourt et al., *Prehistoric Human Use of Fire, the Eastern Agricultural Complex, and Appalachian Oak-Chestnut Forests: Paleoecology of Cliff Palace Pond, Kentucky*, 63 AM. ANTIQUITY 263, 273, 275-276 (1998).

39. *See id.* at 263, 266.

40. *See* Delcourt & Delcourt, *supra* note 3, at 1010, 1012.

41. *See id.* at 1012-1013.

42. *See id.* at 1010-1013.

43. *See id* at 1010-1014.

44. *See* AN ECOSYSTEM APPROACH TO AQUATIC ECOLOGY: MIRROR LAKE AND ITS ENVIRONMENT (Gene E. Likens ed., Springer-Verlag 1985).

45. *See generally* William A. Watts, *Late Quaternary Vegetation of Central Appalachia and the New Jersey Coastal Plain*, 49 ECOLOGICAL MONOGRAPHS 427(1979).

46. *See* Delcourt et al., *supra* note 38, at 263-78.

47. *See* Pederson et al., *supra* note 19, at 238-49.

48. *Id.*

Crawford Lake in southern Ontario, Canada, Clark and Royall reported on the transformation of northern hardwood (beech-maple) forests to white pine-oak forests in response to Iroquois cultivation and burning during the 1400s.[49] Northern hardwood-conifer forests across a longitudinal gradient in the northeast and north-central United States and southern Ontario reveal patterns of pine and oak abundance, and fire frequency over the last 200 years.[50] The most western forests in Minnesota and Wisconsin were dominated by pine, oak, and birch and contained the most evidence of past fires relative to forests further east.[51]

Oak, pine, and chestnut dominated forests in northwest Florida have dated as far back as 40,000 years, with oak dominating after 12000 year BP.[52] During the early Holocene epoch in southern Alabama, sandy upland forests were first dominated by oak and hickory, followed by southern pines after 5000 years BP.[53] In a review of fire history in the south, Fowler and Konopik concluded that anthropogenic fires were the key form of disturbance in southern ecosystems for more than 10000 years.[54] Quarterman and Keever concluded that forest fires were set by Native Americans, European settlers, and lightning between 1600 and 1800 on the southern Coastal Plain.[55] Native Americans cleared land for agriculture by girdling and burning trees.[56] Longleaf pine (*Pinus palustris*) was maintained by periodic fire at a 2-3 year interval and without fire southern pine forests convert to more shade tolerant hardwoods.[57] While lightning strikes and lightning-caused fires are higher in the south than any other parts of the country,[58] there is little doubt that the multi-millennia domination of pine on the southern

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49. *See generally* James S. Clark & P. Daniel Royall, *Transformation of a Northern Hardwood Forest by Aboriginal (Iroquois) Fire: Charcoal Evidence from Crawford Lake, Ontario, Canada*, 5 HOLOCENE 1(1995).

50. *See* James S. Clark & P. Daniel Royall, *Local and Regional Sediment Charcoal Evidence for Fire Regimes in Presettlement North-eastern North America*, 84 ECOLOGY 365, 378 (1996).

51. *Id.*

52. William A. Watts et al., *Camel Lake: a 40,000-yr Record of Vegetational and Forest History from Northwest Florida*, 73 ECOLOGY 1056, 1063 (1992).

53. Paul Delcourt, *Goshen Springs: Late Quaternary Vegetation Record for Southern Alabama*, 61 ECOLOGY 371, 384-85 (1980).

54. Cynthia Fowler & Evelyn Konopik, *The History of Fire in the Southern United States*, 14 HUM. ECOLOGY REV. 165, 165 (2007).

55. Elsie Quarterman & Catherine Keever, *Southern Mixed Hardwood Forest: Climax in the Southeastern Coastal Plain, U.S.A*, 32 ECOLOGICAL MONOGRAPHS 167, 169 (1962).

56. *Id.*

57. *See id.*

58. *See* Kay, *supra* note 27.

Coastal Plain was a result of frequent burning from Native American land-use practices.[59]

For much of the Holocene epoch, climate has been cyclic.[60] During cooler periods (e.g., the Little Ice Age), oak, pine and prairie persisted albeit at somewhat lower levels than the intervening warm periods (e.g., Holocene Optimum and Medieval Warm periods),[61] presumably due to a decline in the number, extent and intensity of Native American fires. Their dominance rose in warmer periods when the influence of fire was that much greater. Species' abundances waxed and waned in relation to climate change, as reported in many palynological studies.[62] When European settlers first arrived to the American continent, they described it as a great wilderness.[63] That, however, is not my interpretation. I view the pre-Columbian eastern United States as a network of actively and passively managed forest and prairie used by Native Americans to promote mast, other edible plants, and grazing areas for the wildlife they hunted.[64] The vast majority of the eastern United States was *not* a climax forest dominated by late successional sugar maple, beech basswood or hemlock.[65] Nor was it an edaphic climax of mostly xeric and nutrient poor sites unsuitable for climax tree species.[66] The majority of the eastern United States at the time of European settlement was mixed-oak, hickory and chestnut forest, northern and southern pines, and tallgrass prairie maintained as such by Native American management to meet their dietary needs.[67] In the absence of such management, these vegetation types do not persist.[68] I have argued that the impact of Native American land-use practices in the eastern forest and tallgrass prairie were ubiquitous, not merely localized.[69]

HUMAN IMPACTS ON VEGETATION FOLLOWING THE INDUSTRIAL REVOLUTION

Over many millenia, oak and pine forests and tallgrass prairie vegetation persisted through changes in climax and low-to-moderate

59. *See* Quarterman & Keever, *supra* note 55.
60. *See* Timothy J. Osborn and Keith R. Briffa, *The Spatial Extent of 20th Century Warmth in the Context of the Last 1200 Years*, 311 SCI. 841, 841-844 (2006).
61. *See* Abrams and Nowacki, *supra* note 2.
62. *See id.*
63. *See id.* at 1127.
64. *See id.* at 1123-37.
65. *See id.* at 1129-32.
66. *See* Abrams and Nowacki, *supra* note 2.
67. *See id.* at 1129-33.
68. *See id.* at 1133.
69. *See id.* at 1133-34.

intensity human impacts (e.g., periodic surface fire).[70] However, this dynamic went into disequilibrium following the Industrial Revolution starting around 1800 (Fig.1). The first major land-use event that followed European settlement was land-clearing and the cutting of the forests for building material and firewood.[71] As momentum increased with a rising population and the demand for wood by the charcoal iron industry, this escalated into the "Great Cutover" during the 19th century.[72] The forests were used for industrialization, agriculture, and the basis of material progress.[73] Although iron furnaces in the United States date back to the early 1700s, their peak activity was in the middle 19th century.[74] By 1856, there were 560 iron producing furnaces and 78% used wood charcoal (as opposed to coal).[75] Each furnace required the wood from approximately 150 acres of forest per year over a 50 year period. Areas near furnaces were often cut at a 25-30 year cycle, creating coppice (sprout) forests.[76] Other industrial uses of wood included railroads, mines (props), ship building, and manufacturing, although the largest consumption remained for domestic uses.[77] Most of New England, New York, the eastern seaboard, and the Ohio Valley were already logged at least once by the mid-nineteenth century.[78] Approximately 99% of the original forest was gone by 1920.[79]

Much of the forested area in the eastern United States was converted by land-clearing for agriculture and the expansion of towns and cities during the nation's building period. Williams estimates that 164 million acres of forest were cleared for agriculture by 1860.[80] Between 1850 and 1920 the forested area of the eastern United States declined from approximately 230 million hectares to 147 million hectares.[81] The loss of forested land to agricultural clearing ranged from 22-76% (averaging 50%) in 12 eastern states.[82] By 1920, old-growth forests totaled less than 0.5%, while the native tallgrass prairie was

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70. *See id.*
71. *See* Michael Williams, *Clearing the United States forests: pivotal years 1810–1860*, 8 J. HIST. GEOGRAPHY 12, 12-28 (1982).
72. *Id.*
73. *See id.*
74. *See id.*
75. *See id.*
76. *See* Williams, *supra* note 71.
77. *See id.*
78. William B. Greeley, *The Relation of Geography to Timber Supply*, 1 ECON. GEOGRAPHY 1, 1-11 (1925).
79. *See id.*
80. *See* Williams, *supra* note 71.
81. *See id.*
82. *See* WHITNEY, *supra* note 4.

reduced in area by 99%.[83] The second-growth forests that formed in the cut-over areas were subsequently grazed by livestock (pigs, sheep and cattle), resulting in great losses of acorns and nuts, tree seedlings, other understory plants, and soil compaction.[84] Prior to 1850, commercial forestry in the eastern United States was typically limited to small sawmills in most towns.[85] The subsequent increasing demands for timber lead to the large-scale commercialization of the forest industry by the second half of the 19th century, including steam-powered saws and railroad logging.[86] Logging escalated, leading to the height of the clearcut era from 1870-1920.[87] This "Great Cutover" logged billions of board feet of timber in the east and produced vast areas covered in "slash" (logging debris).[88] As the slash dried, huge wildfires followed, with an intensity rarely experienced in the original forest.[89]

The resilience of eastern forest to the vast clearcutting and intensive fires is a reflection of the disturbance tolerance attributes for most of its species. Indeed, the eastern forest initially came back much the same as it was before.[90] Whitney compared the composition of presettlement versus more recent (1960-1982) forests in four northeastern locations and found that most major species changed very little.[91] Exceptions to this include an increase in sugar maple and red maple in some areas, a decline in beech and hemlock, and an increase in red oak (*Quercus rubra*) and chestnut oak (*Quercus prinus*).[92] Most of these changes were less than 10%, although the beech decline was larger.[93] White pine also declined significantly, which was attributed to it being selectively logged during the early clearcut era and its inability to sprout like most hardwoods.[94] White pine increased in some areas of New England as an old-field invader in the first half of the 20th century as farms were abandoned for more productive land in the Midwest.[95] The Lake States experienced a large increase in aspen-birch as a direct result of

83. *See id.*
84. *See id.*
85. *See id.*
86. *See id.*
87. *See* WHITNEY, *supra* note 4.
88. *See id.*
89. *See generally* STEPHEN J. PYNE, FIRE IN AMERICA: A CULTURAL HISTORY OF WILDLAND AND RURAL FIRE (Princeton University Press 1982).
90. *See* WHITNEY, *supra* note 4, at 196.
91. *See id.*
92. *See id.*
93. *See id.*
94. *See* Marc D. Abrams, *Eastern White Pine Versatility in the Presettlement Forest*, 51 BIOSCIENCE 967, 967–79 (2001).
95. *See id.*

clearcutting and burning the original pine and hardwood forests.[96] Another casualty of the clearcut era was white oak (*Quercus alba*), one of the east's most dominant tree species, which declined in many eastern forests between the presettlement and present-day.[97] Northern red oak and chestnut oak increased in the wake of white oak's decline.[98]

One of the most profound impacts on the eastern forest during the early 20th century was a result of exotic diseases such as, the chestnut blight fungus (*Cryphonectria parasitica*), introduced to America in the early 1900s.[99] Chestnut was once a dominant along the Appalachian Mountains from Maine to Georgia, where it typically represented 10-20%, and as high as 50-90%, of the forest composition along with oaks and hickories.[100] As a result of the blight, nearly 100% of mature chestnut trees were extirpated, relegating the species to understory sprouts (the blight does not kill the root system).[101] As the chestnut was killed off, neighboring trees such as oak and hickory filled the chestnut gaps, thereby maintaining productive forests.[102] Red maple also started its rise in the eastern forest at this time in response to the chestnut blight and clearcut era logging.[103]

All the factors discussed above may pale in comparison with the suppression of forests fire since the 1930s, known as the Smokey Bear era. Indeed, this topic has received a huge amount of attention in the ecological literature. It is now well-recognized that periodic burning was and is an ecological requirement for the long-term perpetuation and health of tallgrass prairie and most oak, hickory, the former chestnut forests, and northern and southern pine.[104] As a result of post-1930s fire suppression, most eastern oak-hickory-pine forests and savannas and tallgrass prairie on sub-xeric sites have undergone dramatic changes in

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96. *See* Brian J. Palik & Kurt S. Pregitzer, *A Comparison of Presettlement and Present-Day Forests on Two Bigtooth Aspen-Dominated Landscapes in Northern Lower Michigan,* 127 AM. MIDLAND NATURALIST 327, 327-38 (1992); *see also* Nowacki & Abrams, *supra* note 4.

97. *See* Marc D. Abrams, *Where has all the white oak gone?* 53 BIOSCIENCE 927, 927-39 [hereinafter Abrams, *White Oak*].

98. *See id.*

99. *See* Gary M. Lovett et al., *Forest Ecosystem Responses to Exotic Pests and Pathogens in Eastern North America*, 56 BIOSCIENCE 395, 395-405 (2006).

100. *See* Abrams, *White Oak, supra* note 97, at 929.

101. *See* Catherine Keever, *Present Composition of Some Stands of the Former Oak–Chestnut Forest in the Southern Blue Ridge Mountains*, 34 ECOLOGY 44, 44–55 (1953); *see also* Charles M. Ruffner & Marc D. Abrams, *Relating Land-Use History and Climate to the Dendroecology of a 326-year Old Quercus PrinusTalus Slope Forest*, 28 CAN. J. FOREST RESEARCH 347, 347-58 (1998).

102. *See id.*

103. *See* Abrams, *The Red Maple Paradox*, *supra* note 5.

104. *See* Abrams, *Fire and Development*, *supra* note 6; *see also* Nowacki & Abrams, *supra* note 4.

composition and structure, resulting in the successional replacement by more shade tolerant species.[105] Fire suppression in tallgrass prairie and savannas leads to a rapid increase in shrubs and tree invasion moving these systems to shrublands or closed canopy forests where oaks can no longer regenerate.[106] The oak-hickory and pine forests further east, which lack shade tolerance, are also undergoing successional replacement in the absence of periodic burning, mainly by the shade tolerant red maple.[107] Other later successional or gap opportunistic species increasing in eastern oak and pine forests include sugar maple, beech, hemlock, blackgum (*Nyssa sylvatica*), white ash (*Fraxinus americana*), black birch, (*Betula lenta*) tulip poplar (*Liriodendron tulipifera*) and black cherry (*Prunus serotina*).[108] It is interesting to note that nearly all late successional trees, with the exception of blackgum, are sensitive to fire and are readily killed by repeated burning.[109] The range of beech and blackgum, like red maple, includes nearly the entire eastern forest.[110] The range of sugar maple covers the entire northern half of the eastern forests, whereas hemlock's range covers the northern states and the entire Appalachian chain.[111] The scarcity of late successional tree species in the pre-European forest (outside of the northern hardwoods) is best explained by their subjugation from periodic fire (not from climate or soils). Nowacki and Abrams further analyzed this phenomenon and reported that taxa showing the largest decrease from presettlement to present day are the fire-dependent oak, chestnut, hickory and pine.[112] Beech has also declined in many areas as a result of cutting the original forest, coupled with more recent beech bark disease (*Nectria ditissima*).[113] The increased oak in certain forests in the early 20th century appears to be temporary as they are presently being replaced

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105. *See id.*

106. *See* Cottam, *supra* note 32; Nuzzo, *supra* note 25; Abrams, *Fire and Development*, *supra* note 6.

107. *See* Abrams, *The Red Maple Paradox*, *supra* note 5.

108. *See* Abrams, *Fire and Development*, *supra* note 6; *see also* Nowacki & Abrams, *supra* note 4.

109. *See* Abrams, *Fire and Development*, *supra* note 6; *see also* Marc D. Abrams, *Tales from the Blackgum: a Consummate Subordinate Tree*, 57 BIOSCIENCE 347, 347-59 (2007).

110. *See* U.S. DEP'T. OF AGRIC., AGRICULTURAL HANDBOOK 654, SILVICS OF NORTH AMERICA, 2 HARDWOODS 325-26 (Russell M. Burns & Barbara H. Honkala, tech. eds. 1990) *available at* http://www.na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm.

111. *See* U.S. DEP'T. OF AGRIC., AGRICULTURAL HANDBOOK 654, SILVICS OF NORTH AMERICA, 1 CONIFERS 604-05 (Russell M. Burns & Barbara H. Honkala, tech. eds. 1990) *available at* http://www.na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm.

112. *See* Nowacki & Abrams, *supra* note 4, at 132.

113. *See id.*

by the non-oak tree species mentioned above and have had very little oak recruitment in the last half-century.

In conclusion, the extensive logging and land clearing, wildfires, the introduction of exotic insects, diseases and invasive plants, increasing deer browsing and the Smokey Bear era had led to unprecedented and rapid changes in forest composition and structure. The eastern United States has seen a near extirpation of the once-dominant chestnut, elm and butternut species from blight, a loss of many white pine forests, a decline in the super-abundant white oak, and a conversion of about 50% of its forests and 99% of its tallgrass prairie to agriculture. There has been a virtual cessation of oak, hickory and pine regeneration, and the rise of red maple *et al.* in the remaining forests.[114] The replacement of fire adapted trees by later successional species has resulted in a "mesophication" (cooling, dampening, and shading) of the forest understory, rendering these ecosystems less prone to prescribed or natural fire.[115] Indeed, the eastern landscape has undergone a near complete transformation over the last 350 years.[116] Anthropogenic impacts during the late 19th and 20th centuries have been continuous and significant in terms of their impacts on forests in the eastern United States (Fig. 1).[117] Unfortunately, the dynamic equilibrium that perpetuated vast upland oak and pine, savannas and tallgrass prairie during the most of the Holocene was destroyed in the few centuries following European settlement, threatening the long-term sustainability of these major vegetation types.

114. *See* Abrams, *Fire and Development*, *supra* note 6; Abrams, *The Red Maple Paradox*, *supra* note 5; WHITNEY, *supra* note 4; Nowacki & Abrams, *supra* note 4.

115. *See* Nowacki & Abrams, *supra* note 4.

116. *See* WHITNEY, *supra* note 4; D.R. Foster et al., *Land-Use History as Long-Term Broad-Scale Disturbance: Regional Forest Dynamics in Central New England*, 1 ECOSYSTEMS 96, 96-119 (1998); Abrams & Nowacki, *supra* note 2.

117. *See generally* Abrams, *Postglacial History*, *supra* note 2.

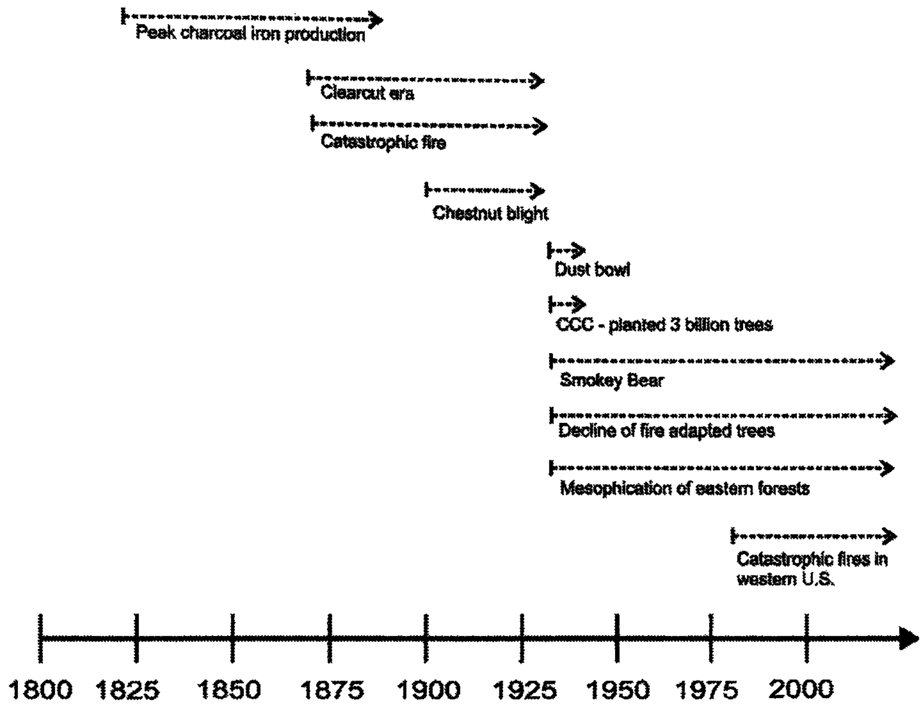

Fig. 1. Major land-use history events following European settlement in the eastern United States