Ecological Impacts of Anthropogenic Fire in Southwestern Ohio, USA, Documented from Public Land Survey Records from 1802 and 1803

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ABSTRACT. Public Land Survey System (PLSS) data collected in 1802 and 1803 were analyzed to evaluate the impacts of anthropogenic fire on pre-Euro-American settlement plant communities within a 50,193 ha (194-square-mile) study area east of what is now Dayton, Ohio. Surveyor data were converted to digital point, line, and polygon files using ArcMap software and mapped with some interpolation based on contemporary GIS data layers including topography, soil moisture, soil type, and Quaternary geology. Sixty-one percent of the study area was covered with woody and non-woody plant communities that are known to be shaped and/or maintained by long-term exposure to surface fires of varying intensities and frequencies: oak-hickory forest, oak woodland, oak savanna, oak barrens, and mesic prairie. Prairies and barrens were concentrated adjacent to the corridors of the Mad River and the Little Miami River and their major tributaries, while oak woodlands were concentrated in adjacent uplands. Oak-sugar maple forest covered an additional 29% of the study area, a community that was interpreted to be pyrophilic oak forest transitioning to mesophytic/pyrophobic forest in the long-term absence of fire.

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INTRODUCTION

The Records of the Public Land Survey System (PLSS) have long been an important tool in determining the plant communities that covered the midwestern landscape just before Euro-American settlement and the subsequent conversion of wilderness to farmland (Lindsey et al. 1965; Gordon 1969). In Ohio, the analysis of PLSS records to determine pre-Euro-American settlement plant communities goes back as far as 1919 and the pioneering work of Paul B. Sears (Stuckey 2010). For much of the time since this early work, fire was not considered to be a major variable determining plant communities in Ohio and the Midwest (Transeau 1935; Whitney 1982). More recently, the significance of anthropogenic fire—surface fires set intentionally by American Indians—has become accepted as a primary variable that influenced plant communities in the Midwest (and elsewhere in North America) for thousands of years prior to the displacement of the indigenous population by people of European descent (Brown 2000; Anderson 2006; Abrams et al. 2021). These ignitions, strategically applied at optimum times and locations to clear forest understories and prairies of woody growth, had profound impacts on plant communities and wildlife. The fires had the effect of creating or maintaining the woodlands, savannas, prairies, and barrens observed by the early European explorers and settlers. This diversity of plant communities and ecotones provided American Indian populations with multiple benefits (Brown 2000; Stewart 2002), including: (1) the maintenance and expansion of prairie grasslands that attracted bison (*Bison bison*) and elk (*Cervus canadensis*), large grazing herbivores that provided abundant dietary protein; (2) the destruction of forest understory that made travel easier, and hunting both quieter and more successful; (3) allowing "ring hunts" that used fire to herd game to specific points for ambush (Smith and Darlington 1907); and (4) the increased production of, and access to, edible fruits and nuts (Abrams and Nowacki 2008).

The current study uses geographical information system (GIS) mapping software to analyze PLSS data from an area east of Dayton, Ohio. This allowed the identification and mapping of major pre-Euro-American settlement plant communities, and the evaluation of the role of anthropogenic fire in the creation and maintenance of these communities.

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METHODS AND MATERIALS

Study Area

The study area was comprised of 7 PLSS townships spanning portions of Montgomery, Greene, and Clark Counties in Ohio, containing 50,193 ha (194 square miles) (Fig. 1). The entire study area was covered by Wisconsinan glaciation, which left a generally flat to slightly rolling landscape with glacial deposits and valleys providing some additional relief. The valleys of the Great Miami River, Little Miami River, and Mad River were carved by preglacial streams or glacial meltwaters, and subsequently filled with glacial sand, gravel, and clay (Norris et al. 1956).

Data Collection and Analysis

Bound books of PLSS records were examined at the Ohio History Center Archives & Library in Columbus, Ohio (Ohio Auditor of State 1797-1845), and relevant pages were photographed and used as the basis of this analysis. These data contain 2 sets of information: quantitative witness-tree records and qualitative section-line descriptions.

Witness trees were individual trees that the surveyor selected and blazed along section lines and at section, quarter-section, and lot corners, recording species and diameter. Corners were marked with 2 trees, for which surveyors noted the bearing and distance of each tree from the corner. Witness tree species, diameter, line distance, and bearing distance were plotted as a geodatabase point file in a geodatabase in ArcMap 10.2.3. Each tree species was designated as fire tolerant (pyrophilic) or fire sensitive (pyrophobic) (Table 1) per Thomas-Van Gundy and Nowacki (2016).

Surveyors made comments in their field notes for each 1.6 km (1.0-mile) section line they traversed, briefly describing the vegetation cover, understory thickness, stream crossings, and any other features deemed notable. Sections that were subdivided into quarter-sections or lots provided additional line data. Each section line and its corresponding field note entries were incorporated into a line file in the geodatabase.

A third set of PLSS information obtained were the images of the original plat maps for the PLSS townships within the study area. Plat maps outlined the borders of prairies and the courses of streams that the surveyors encountered. These were downloaded from the U.S. Bureau of Land Management (General Land Office Records 1787-) and georeferenced to overlay with the other layers in ArcMap. A list of major cover types—described by the surveyors—was compiled and each assigned to a community type described from the study area by Gordon and Flint (1966), or a modern community description published by the Michigan Natural Features Inventory (MNFI) or the Wisconsin Natural Heritage Inventory (WNHI) (Epstein 2017; Cohen et al. 2020). A map of the pre-Euro-American settlement plant communities within the study area was then created in ArcMap based on PLSS data, with some interpolation based on other digital layers including soil types, topography, soil moisture, streams, Quaternary geology, and aerial photography (orthophotos). Locations of historic "Indian Towns, Villages, Camps and Trails" were also plotted in GIS from a map by Lewis and Dawley (1902).

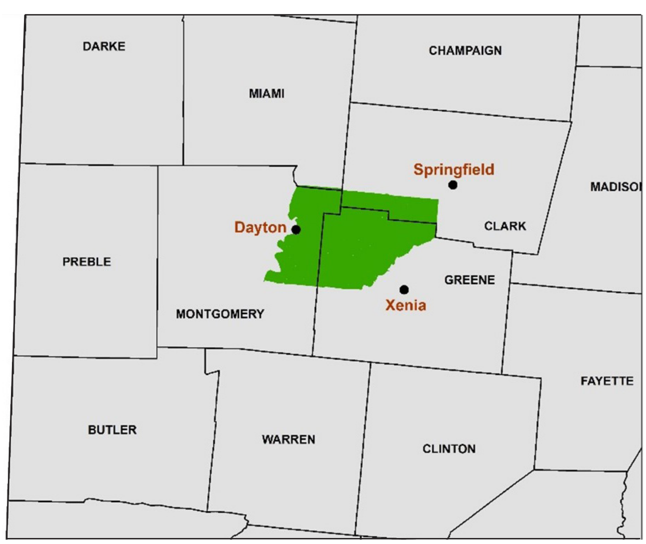

FIGURE 1. Study area in southwestern Ohio

Table 1
Number of witness trees documented and plotted in the study area by species and community type

Genus/ species	Common name	Surveyor name	Fire tolerance	Number of wittiness trees	Average DBH (cm)	Oak woodland	Oak savanna	Oak barrens	Oak-hickory forest	Wet prairie and fen	Mesic prairie	Oak-sugar maple forest	Oak-sugar maple woodland	Bottomland forrest
Acer negundo	Boxelder	Boxelder	Pyrophobic	1	30									1
Acer rubrum or *Acer saccharinum*	Red maple or silver maple	Maple	Pyrophobic	21	36				1		1	12		7
Acer saccharum	Sugar maple	Sugar, sugartree	Pyrophobic	40	34				3			34	1	2
Aesculus glabra	Ohio buckeye	Buckeye	Pyrophobic	20	29				2			4		14
Carpinus americanus or *Ostrya virginiana*	American hophorn-beam, ironwood	Ironwood	Pyrophobic	11	19				1			8		2
Carya spp.	Hickory	Hickory*	Pyrophilic	228	33	16	7	22	89		13	77		4
Celtis occidentalis	Common hackberry	Hackberry	Pyrophobic	23	45			2				3	1	17
Cercis canadensis	Eastern redbud	Redbud	Pyrophobic	1	10									1
Cornus florida	Flowering dogwood	Dogwood	Pyrophilic	27	17			1	10			15	1	
Fraxinus americana or *F. pennsylvanica*	White ash or green ash	White ash, w. ash	Pyrophobic	31	38				10			11		10
Fraxinus nigra	Black ash	Hoop ash, black ash	Pyrophobic	8	30				3			5		
Fraxinus quadrangulata	Blue ash	Blue ash, bl. ash	Pyrophobic	27	49	1			1			16		9
Fraxinus sp.	Ash	Ash	Pyrophobic	1	25							1		
Gleditsia triacanthos	Honey locust	Honey locust	Pyrophobic	26	41				3	2	8	11		2
Juglans cinerea	Butternut	White walnut, butternut	Pyrophobic	2	36							2		
Juglans nigra	Black walnut	Black walnut	Pyrophobic	39	43	2	1	1	10		3	13		9
Liriodendron tulipifera	Yellow poplar	Poplar	Pyrophobic	7	59							7		
Morus rubra	Red mulberry	Mulberry	Pyrophobic	10	32		1				1	8		
Platanus occidentalis	American sycamore	Sycamore	Pyrophobic	16	52						2			14
Populus deltoides	Eastern cottonwood	Water poplar	Pyrophobic	1	61						1			
Populus grandidentata	Bigtooth aspen	Aspen	Pyrophobic	3	49	1			1			1		
Prunus serotina	Black cherry	Cherry	Pyrophobic	33	41		1	3	8		4	13		4
Quercus alba, some *Q. muhlenbergii*	White oak, some chinquapin oak	White oak	Pyrophilic	418	46	57	6	19	175	5	19	124	4	9

* Includes shagbark (*Carya ovata*), mockernut (*C. tomentosa*), shellbark (*C. laciniosa*), bitternut (*C. cordiformis*) and pignut (*C. glabra*).

(Continued)

Table 1 (continued)
Number of witness trees documented and plotted in the study area by species and community type

Genus/ species	Common name	Surveyor name	Fire tolerance	Number of wittiness trees	Average DBH (cm)	Oak woodland	Oak savanna	Oak barrens	Oak-hickory forest	Wet prairie and fen	Mesic prairie	Oak-sugar maple forest	Oak-sugar maple woodland	Bottomland forrest
Quercus marcrocarpa or *Q. bicolor*	Bur/swamp white oak	Bottom oak	Pyrophilic	19	44	1		1	2	4	4	3		4
Quercus marilandica	Blackjack oak	Blackjack oak, black jack	Pyrophilic	7	33			1	2		1	3		
Quercus palustris	Pin oak	Pin oak	Pyrophilic	6	42				3		1	1		1
Quercus rubra	Red oak	Red oak, r oak	Pyrophilic	40	56	1			12			23	2	2
Quercus sp.	Oak	Oak	Pyrophilic	2	46				1				1	
Quercus velutina	Black oak	Black oak, b oak, blk oak	Pyrophilic	185	49	34	5	9	86	4	9	32	2	4
Sassafras albidum	Sassafras	Sassafras	Pyrophilic	1	51							1		
Thuja occidentalis	White cedar	White cedar	Pyrophobic	4	18							2		2
Tilia americana	American basswood	Lynn	Pyrophobic	8	39	1			1			4		2
Ulmus americana	American elm	Elm	Pyrophobic	103	39	2		3	20	2	6	48	3	19
Ulmus rubra	Slippery elm	Red elm	Pyrophobic	13	31				3			8	1	1
			Totals (full table)	1,382		116	21	62	447	17	73	490	16	140

RESULTS

Nine major plant communities from the study area were identified (Table 2) and mapped (Fig. 2).

Oak Woodland

Oak woodlands were designated as such if surveyors noted open conditions under a canopy of pyrophilic trees, but made no mention of pyrophobic canopy trees in line descriptions. Ninety-four percent of witness trees in oak woodlands were pyrophilic, and were dominated by white oak (*Quercus alba*) (49%), black oak (*Quercus velutina*) (29%) and hickory (*Carya* spp.) (14%). These characteristics are consistent with the oak woodland community type in Wisconsin—which had a canopy cover >50% to approaching 100%—with frequent fires of low-intensity maintaining the understory in an open condition, free of dense growths of shrubs and saplings (Epstein 2017). Hanberry et al. (2020) considered oak woodlands to be a type of open forest, which spanned the spectrum between grasslands and closed canopy forests. An open forest (per Hanberry et al.) was defined as a fire-dependent bilayer ecosystem consisting of a single overstory dominated by fire-tolerant tree species, an herbaceous ground layer, and with limited midstory shrub and tree cover. Most oak woodlands in the study area were in uplands in the east-central section.

Oak Savanna

Cohen et al. (2020) referred to this open forest community as oak openings: a fire-dependent savanna dominated by oaks, with or without a shrub layer, and a predominantly graminoid ground layer composed of species associated with both prairie and forest communities. Epstein (2017) also referred to this community as oak openings, with a canopy closure >0% to approaching 50%. Surveyors did not use the term savanna or oak opening in line descriptions from the study area, but did describe vegetation observed along several section lines as being a mix of prairie and timbered land. These were designated as oak savanna in this study, which included <1% of the study area. Cohen et al. (2021) proposed a required fire frequency range of 1 to 10 years to maintain this diverse community type.

Oak Barrens

Surveyors used the term "barrens" in line descriptions in the study area where they deemed the land as not being suitable for productive agriculture, due to a perception of soil infertility or dryness. Oak barrens were thinly stocked savannas that were usually located adjacent to mesic prairies on gravelly glacial deposits including outwash, alluvium, alluvial terraces, kames, and kame terraces. Eighty percent of oak barrens in the study area were covered in low thickets of shrubs and small trees, particularly American hazelnut (*Corylus americana*), American plum (*Prunus americana*), and young oaks (*Quercus* spp.). The general character of the vegetation, its landscape context, and the dominance of white oak, hickory, and black oak as woody components is consistent with MNFI's oak barrens natural community type—which had an estimated fire frequency range of 5 to 20 years (Cohen et al. 2021).

Oak-hickory Forest

Forests with canopies dominated by pyrophilic species, primarily oaks and hickories, (and with no mention of pyrophobic species in the line descriptions nor mention of an open understory) were categorized as oak-hickory forest. Dominant witness trees were white oak (39%), hickories (20%), and black oak (19%). Gordon and Flint (1966) mapped this community as the mixed oak forest community in the study area. Cohen et al. (2020) referred to this community as dry-mesic southern forest, which Cohen et al. (2021) classified as fire dependent with a fire frequency of 10 to 20 years being necessary to maintain it. Fifty percent of oak-hickory forests in the study area contained a thick understory of shrubs, particularly American hazelnut, flowering dogwood (*Cornus florida*), "briars", "grapevines", and "brush." These sections are proposed to be oak-hickory forests or oak woodlands that had been excluded from fire long enough to allow this understory to develop.

Wet Prairie and Fen

These were wet herbaceous-dominated plant communities described specifically as wet prairie or boggy prairie by surveyors. Significant remnants of pre-Euro-American settlement wetland communities are still present in the study area, particularly in the Beaver Creek Wetlands along Beaver Creek (Nolin and Runkle 1985; Schmalhofer et al. 1992). These remnants contain communities that are consistent with MNFI's emergent marsh, wet prairie, southern wet meadow, and prairie fen communities (Cohen et al. 2020). Wet prairies and fens were found in a similar landscape context as mesic prairies, but the wet prairies and fens had poor drainage and/or groundwater upwellings that provided near-constant moisture. Cohen et al. (2021) considered fire frequency as variable, between 5 and >100 years.

Mesic Prairie

The mesic prairies were warm-season grasslands, described as prairie, where the surveyor did not encounter wet or saturated soils. Larger units were concentrated on alluvium and outwash along the corridors of the Mad River (and its tributary Mud Run) and the Little Miami River (and its tributaries Beaver Creek and Ludlow Creek). A 114-acre remnant of this community in the study area has been an active restoration project since 1986: the Huffman Prairie State Natural Landmark on Wright-Patterson Air Force Base (Nolin 2018). The site is dominated by the grasses big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and Indiangrass (*Sorghastrum nutans*), and a variety of prairie forbs that grow from loamy soil over glacial outwash deposits. This community and landscape context is consistent with MNFI's mesic prairie community, with a proposed fire frequency range of 1 to 2 years (Cohen et al. 2021). Twenty-one percent of mesic prairies were overgrown with brush and small trees, and had evidently been free of fire long enough to allow invasion by woody species.

Oak-sugar Maple Forest

Forests that were described in section line comments as a mixture of pyrophilic oaks and hickories—as well as pyrophobic species such as sugar maple (*Acer saccharum*), black cherry (*Prunus serotina*), white ash (*Fraxinus americana*), and American elm (*Ulmus americana*)—forming the overstory canopy are designated as oak-sugar maple forests. Gordon (1969) described this community and mapped it in the study area (Gordon and Flint 1966), noting that it was not only characterized by the absence or scarcity of American beech (*Fagus grandifolia*) but also by the presence of soils derived from rocks and gravels that contain a high percentage of calcium carbonate. In the current study these forests are proposed to be transitional, where pyrophobic species were in the midst of replacing pyrophilic species (in the long-term absence of fire). This process of "mesophication" has continued and expanded throughout the Midwest and in the study area since the early land surveys (Runkle et al. 2005; Nowacki and Abrams 2008). Eighteen percent of oak-sugar maple stands had thick understories of hazel, "briars," and grape vines. In one section line description the surveyor noted "timber killed by fire," indicating that this community was at least occasionally impacted by fire.

Oak-sugar Maple Woodland

Oak-sugar maple woodlands were modified oak-sugar maple forests where surveyors noted an open understory/midstory, consistent with a recent occurrence of one or more surface fires.

Bottomland Forest

Bottomland forests were closed-canopy forests of floodplains and poorly drained areas. Common species included American elm, ash (*Fraxinus* spp.), common hackberry (*Celtis occidentalis*), American sycamore (*Platanus occidentalis*), black walnut (*Juglans nigra*), and Ohio buckeye (*Aesculus glabra*). Two-thirds of these areas were brushy, particularly with common pricklyash (*Zanthoxylum americanum*). Gordon and Flint (1966) mapped these communities in the study area as elm-ash swamp forest. MNFI communities that are consistent in species composition and landscape context to those in the study area include southern hardwood swamp for forested wetlands in flat, poorly drained, areas and floodplain forest for forests of riparian floodplains. Cohen et al. (2021) considered fire frequency of both of these communities as very infrequent, >500 years.

Table 2
Major plant communities documented by surveyors in the study area

Community	Area (ha)	Area (acres)	Percent of area	Percent brushy	No. witness trees	No. bearing trees	Percent pyrophilic	Mean DBH (cm)	Avg. bearing Distance (m)
Oak woodland	4,236.61	10,468.66	8.44	0.00	116	62	94	42	10.44
Oak savanna	359.27	887.76	0.72	0.00	21	8	86	40	19.40
Oak barrens	3,162.95	7,815.65	6.30	79.73	62	30	86	36	9.40*
Oak-hickory forest	19,151.05	47,322.24	38.15	51.38	448	278	85	43	7.80
Wet prairie and fen	1,741.63	4,303.57	3.47	5.13	17	14	76	40	13.49*
Mesic prairie	3,684.54	9,104.50	7.34	11.23	73	46	64	39	10.61*
Oak-sugar maple woodland	372.57	920.62	0.74	0.00	16	12	63	45	7.83
Oak-sugar maple forest	14,185.03	35,051.21	28.26	26.20	489	290	57	41	7.47
Bottomland forest	2,570.90	6,352.69	5.12	68.22	140	87	17	43	9.68
Stream/river/pond	728.83	1,800.94	1.45	N/A	N/A	N/A	N/A	N/A	N/A
Total	**50,193.38**	**124,027.84**	**100.00**	—	**1,382**	**827**	—	—	—

* Does not include points where there were no bearing trees.

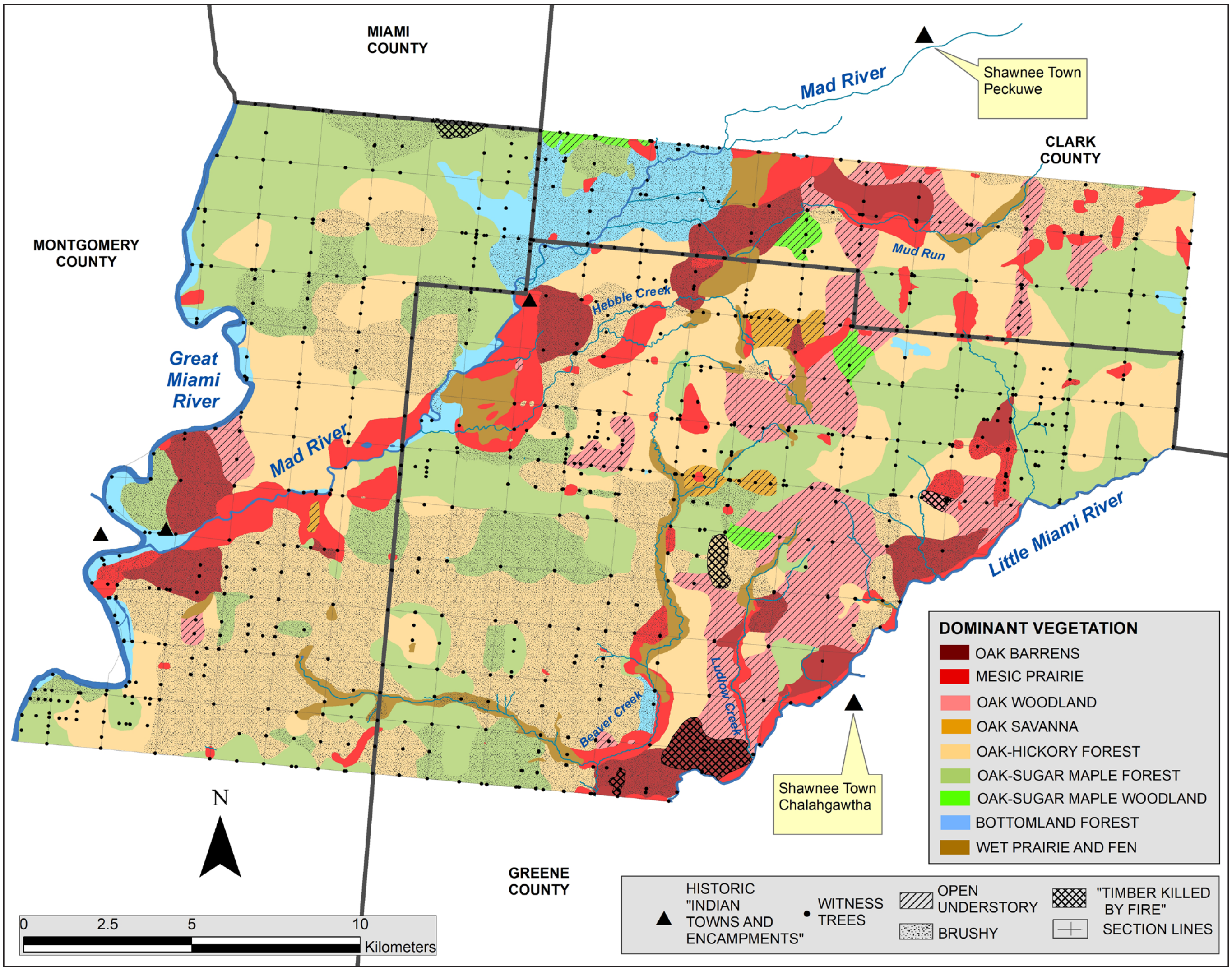

FIGURE 2. Major plant communities documented by surveyors in the study area

DISCUSSION

The dominance of fire-dependent plant communities—portions of which appear to have been in various stages of post-fire succession at the time of the public land surveys—suggests a long and complex anthropogenic fire history. Pyrophilic plant communities are similar to others in Ohio (Brewer and Vankat 2004), and other midwestern states (Epstein 2017; Cohen et al. 2020), that are linked to continuous anthropogenic fire by American Indians (Anderson 2006; Abrams et al. 2021; Cohen et al. 2021).

Anthropologists have identified 6 distinct periods of American Indian occupation in western Ohio over the last 5,000 years: Archaic, Early Woodland, Middle Woodland, Late Woodland, Late Prehistoric, and Historic (Lepper 2005). Little is known of the prehistoric peoples in the study area, or the rest of Ohio, except from analysis of artifacts they left behind. The last known pre-contact population in the vicinity of the study area was the Fort Ancient Culture within the Late Prehistoric Period. Some historians believe that the Shawnee tribe, encountered in the Historic Period, originated from the Fort Ancient Culture (Warren 2014). Starting about 1650 the resident Fort Ancient population in the Ohio Valley was reduced, and perhaps driven from the region, by the powerful Iroquois Confederation that sought to dominate the trade in beaver pelts (Lepper 2005). Native populations were also likely impacted by the arrival of smallpox and other old-world diseases (Crosby 1976).

Documentation of habitation in the region began again in the 1720s, with the establishment of Shawnee towns on the Ohio and Scioto Rivers (Warren 2014). The major Shawnee town of Chalahgawtha, or Old Chillicothe, was located along the Little Miami River on the eastern edge of the study area; this town had proposed establishment dates between 1758 (Galloway 1934) and 1774 (Sugden 1997). However, there is documentation that anthropogenic fire was likely used to manage established prairie grasslands along this section of the Little Miami River 52 years before the public land surveys, and likely long before that. On March 2, 1750, frontiersman Christopher Gist and his party, travelling southeast and following the established trail to Shannoah Town on the Ohio River, encamped on the Mad River. The next morning, he set off alone and made the following entry in his journal after a journey of 30 miles (Gist and Darlington 1893):

> *Sunday 3.—This Morning We parted, They for Hockhockin, and I for the Shannoah Town, and as I was quite alone and knew that the French Indians had threatened Us, and woud probably pursue or lye in Wait for Us, I left the Path, and went to the South Westward down the little Miamee River or Creek, where I had fine traveling thro rich Land and beautiful Meadows, in which I coud sometimes see forty or fifty Buffaloes feeding at Once—The little Miamee River or Creek continued to run thro the Middle of a fine Meadow, about a Mile wide very clear like an old Field, and not a Bush in it, I coud see the Buffaloes in it above two Miles off: I travelled this Day about 30 M.*

Chalahgawtha was of strategic importance in the conflict between the Shawnee and Euro-American settlers in Kentucky. The town was destroyed several times between 1779 and 1790 but rebuilt each time by the Shawnee (Galloway 1934). The town site, and all of southwestern Ohio, was subsequently ceded to the United States by the Treaty of Greenville in 1795, although some burning apparently continued up to the time of the PLSS surveys. In 1803, surveyor Israel Ludlow, while traversing an oak woodland located 6.25 km north of the town site, noted "much dead timber, fire burning the woods" in the section line description. Six other section line descriptions from the study area referred to "timber killed by fire," 5 of which were within 7 km of the site of Chalahgawtha. Oak barrens and mesic prairies also appear to be disproportionately represented near the town site, and most of the mapped oak woodlands in the study area were located on uplands to the north of the town—between Chalahgawtha and the other major Shawnee town in the region, Peckuwe, along the Mad River (Winkler 2018).

Two other historic American Indian settlements or encampments were mapped from the study area, and both were proximate to concentrations of mesic prairies, barrens, and/or oak woodlands. Lewis and Dawley (1902) mapped American Indian encampments at the mouth of the Mad River as late as 1796, and Dills (1881) mentioned a small town 14 km upstream on the Mad River that persisted until the early 1790s. The current study did not investigate whether a significant correlation existed between pyrophilic plant communities and proximity to American Indian settlement sites, but this may be worthy of further research. Tulowiecki et al. (2019) modelled and mapped oak savanna distribution and American Indian settlements ca. 1795 in western New York State, and suggested that oak savannas there were attributable to American Indian land use and dry environmental conditions. Their models of oak savanna distribution that considered proximity to American Indian settlements had higher predictive performance, and inferred those oak savannas occurred within approximately 15 km (9.3 miles) of village sites.

Conclusions

Analysis of PLSS records from the study area indicate that approximately 61% of the vegetation in the early 1800s was composed of plant communities that are known to be fire dependent. Mesic prairies and oak barrens, indicators of continuous and long-term applications of required surface fires, were concentrated near the corridors of the Mad River, the Little Miami River, Mud Run, Beaver Creek, and Ludlow Creek. Concentrations of oak woodland and oak savanna were located in uplands in the east-central section of the study area and adjacent to mesic prairies and oak barrens. Oak-sugar maple forests covered an additional 29% of the study area; this community was interpreted to be pyrophilic oak-hickory forest transitioning to mesophytic/pyrophobic forest in the long-term absence of fire.

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SUPPLEMENTAL MATERIAL

Supplemental material (a high-resolution map of Fig. 2) to accompany this report is available at: http://hdl.handle.net/1811/102583

ERRATUM

3/26/2024: Corrected missing data from Table 1 on page 88.