Drainage and agriculture impacts on fire frequency in a southern Illinois forested bottomland

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Abstract: Postsettlement (1909–2003) fire history of a forested bottomland in the Mississippi Embayment of southern Illinois, USA, was determined using fire-scar analysis. The study area is a forested bottomland hardwood site, with remnant pockets of the dominant presettlement bald cypress – tupelo (*Taxodium–Nyssa*) vegetation. Ditch drainage was installed in 1919, with agricultural clearing and abandonment varying throughout the early and mid-twentieth century. Commercial agricultural activities ceased after the site became part of a conservation area ca. 1950. The hydrology of the site was further modified in 1957 when it was inundated for waterfowl management. Both drainage and land clearing for agriculture were associated with increased fire frequency. Although drainage was a necessary precursor to agriculture across much of this landscape, land improvement played the stronger role in determining fire frequency. The mean fire interval for the study period (1895–1965) was 1.73 years, with a minimum of 1 year and a maximum of 15 years. This frequency contrasts with the complete fire exclusion that has prevailed in the area since 1965. These results have important implications for the maintenance and restoration of forested wetland ecosystems where the present fire regime differs dramatically from that under which the now-dominant forest vegetation developed.

Résumé : L'historique des incendies survenus depuis la colonisation (1909–2003) d'une plaine alluviale boisée dans la Baie Mississippi du sud de l'Illinois, aux États-Unis d'Amérique, a été reconstitué en utilisant l'analyse des cicatrices de feu. La zone d'étude est une station occupée par la forêt feuillue dans la plaine alluviale avec des îlots résiduels de la végétation présente avant la colonisation, dominée par le taxode (*Taxodium*) et le nyssa (*Nyssa*). Des fossés de drainage ont été creusés en 1919 mais le défrichement à des fins agricoles et l'abandon des terres ont varié tout au long du début et du milieu du 20[e] siècle. L'agriculture commerciale a cessé après l'inclusion de la zone d'étude dans le domaine public en tant qu'aire de conservation vers 1950. L'hydrologie a de nouveau été modifiée en 1957 après l'inondation de l'aire de conservation pour l'aménagement des oiseaux aquatiques. Le drainage et le défrichement à des fins agricoles ont été associés à une augmentation de la fréquence des incendies. Bien que le drainage fut un préalable nécessaire à l'agriculture presque partout dans ce paysage, l'amélioration des terres a joué un rôle plus déterminant dans la fréquence des incendies. L'intervalle moyen entre les incendies pendant la période d'étude (1895–1965) a été de 1,73 ans avec un minimum d'un an et un maximum de 15 ans. Cela contraste avec l'exclusion complète du feu depuis 1965. Ces résultats ont d'importantes répercussions pour le maintien et la restauration des écosystèmes forestiers des milieux humides où le régime des feux actuel diffère de façon draconienne de celui qui existait lorsque la végétation forestière dominante actuelle s'est développée.

[Traduit par la Rédaction]

Introduction

The consideration of past disturbance regimes is increasingly recognized as a necessary precursor to the formulation of sound forest restoration and management strategies. In particular, changes in land use, hydrologic regime, and fire frequency can alter site conditions, resulting in vast differences between current and historic vegetation composition and structure (Whitney 1994; Fredrickson 2005; Casey and Ewel 2006).

The importance of fire in influencing the development of many upland oak forests within the eastern deciduous forest region of North America has gained wide acceptance (Lorimer 1985; Abrams 1992). Studies for this region suggest a fire history consisting of frequent low-intensity fires, with fire-free intervals ranging between 2 and 24 years, followed by more frequent fires during Euro-American settlement and agricultural expansion of the eighteenth and nineteenth centuries (see summary in Whitney 1994; Batek et al. 1999). For instance, in the Missouri Ozarks, fire re-

Received 19 October 2007. Accepted 8 August 2008. Published on the NRC Research Press Web site at cjfr.nrc.ca on 1 November 2008.

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 doi:10.1139/X08-129

turn intervals during periods of native settlement were longer (11.96 ± 2.4 years, mean ± SE) than those during European settlement (3.64 ± 0.35 years) (adapted from Guyette and Cutter 1991; Batek et al. 1999). Thus, the broad diversity of regional vegetation patterns that intermix prairie, savanna, woodland, and forest can be highly dependent on the long-term relationships among topography, fuel complexes, and human settlement and land-uses, as evident from these and many other fire history studies (Patterson and Sassaman 1988; Batek et al. 1999). Generally, a common pattern emerges in which increases in human populations are accompanied by increases in fire frequencies until fires are limited by fuel availability following extensive settlement and fragmentation (Guyette et al. 2002).

In southern Illinois, recent studies have provided evidence for the widespread influence of fire in the development of prevalent second- and third-growth upland forests (Ruffner and Groninger 2006). Landscape-level fire exclusion of the late twentieth century has been implicated in broad changes in species composition and structure of these successional forests (Hutchinson et al. 2005; Ozier et al. 2006). Bottomland hardwood forests in this region are characteristically early successional, occupying recently abandoned farmlands on alluvial deposits. Early and extensive agricultural clearing, heterogeneity of forest resources, and, more recently, protection of old stands have complicated efforts to understand fire occurrence and its potential role in the development of bottomland forests.

Opinions differ regarding fire frequency in North American bottomland forests. Some researchers suggest that fire has been rare and restricted to periods of drought, when it would spread into bottomlands from adjacent upland sites (Brinson and Rheinhardt 1998; Light et al. 2002), whereas others conclude that in the prairie region fire was more common, as prairie fires would frequently burn into the adjacent bottomlands (Nelson and Sparks 1998; Dey 2002). In Arkansas, General Land Office surveyors noted burned-over areas in floodplain forests (Bragg 2003), and Orwig and Abrams (1999) found evidence of fire occurrence in a Pennsylvania bottomland forest on the Allegheny Plateau. The fires that followed European settlement are believed to have had an important influence on species composition across bottomland forests (Aust et al. 1985).

In the southeastern United States there is an extensive record of fire occurrence in cypress-dominated wetlands. In these systems, alterations in hydrology and fire frequency and seasonality drive changes in vegetative composition and succession (Marois and Ewel 1983; Casey and Ewel 2006). Previous studies have reported that natural fire tends to occur in the late spring and early summer, when lighting is frequent and fuel conditions are driest, while prescribed burns are generally conducted in late winter and early spring, when conditions are wetter (Marois and Ewel 1983; Casey and Ewel 2006). Thus, suppression of wildfires and timing of prescribed burns have led to a decrease in fire frequency and intensity in many of these sites (Kirkman et al. 2000; Duever 2005). While these relationships have been elucidated in cypress systems of the southeast, we are aware of no other attempts to document the fire dynamics of a settled forested bottomland or wetland system across the midwest region.

A salvage logging operation and vegetation recovery project conducted in response to stand devastation caused by an F4 tornado on 6 May 2003 provided a rare opportunity to establish a postsettlement fire chronology for a bottomland forest in the Mermet Lake State Conservation Area. Initial dating indicated that all available samples were of post-Euro-American settlement origin, thus limiting the temporal scope of the study, but allowing changes in fire frequency to be associated with changing land-use patterns. Thus, the objectives of this study were (1) to reconstruct the post-settlement fire history of a forested bottomland in the Coastal Plain of southern Illinois, and (2) to determine how alteration of hydrologic regime and land use influenced fire frequency.

Study site

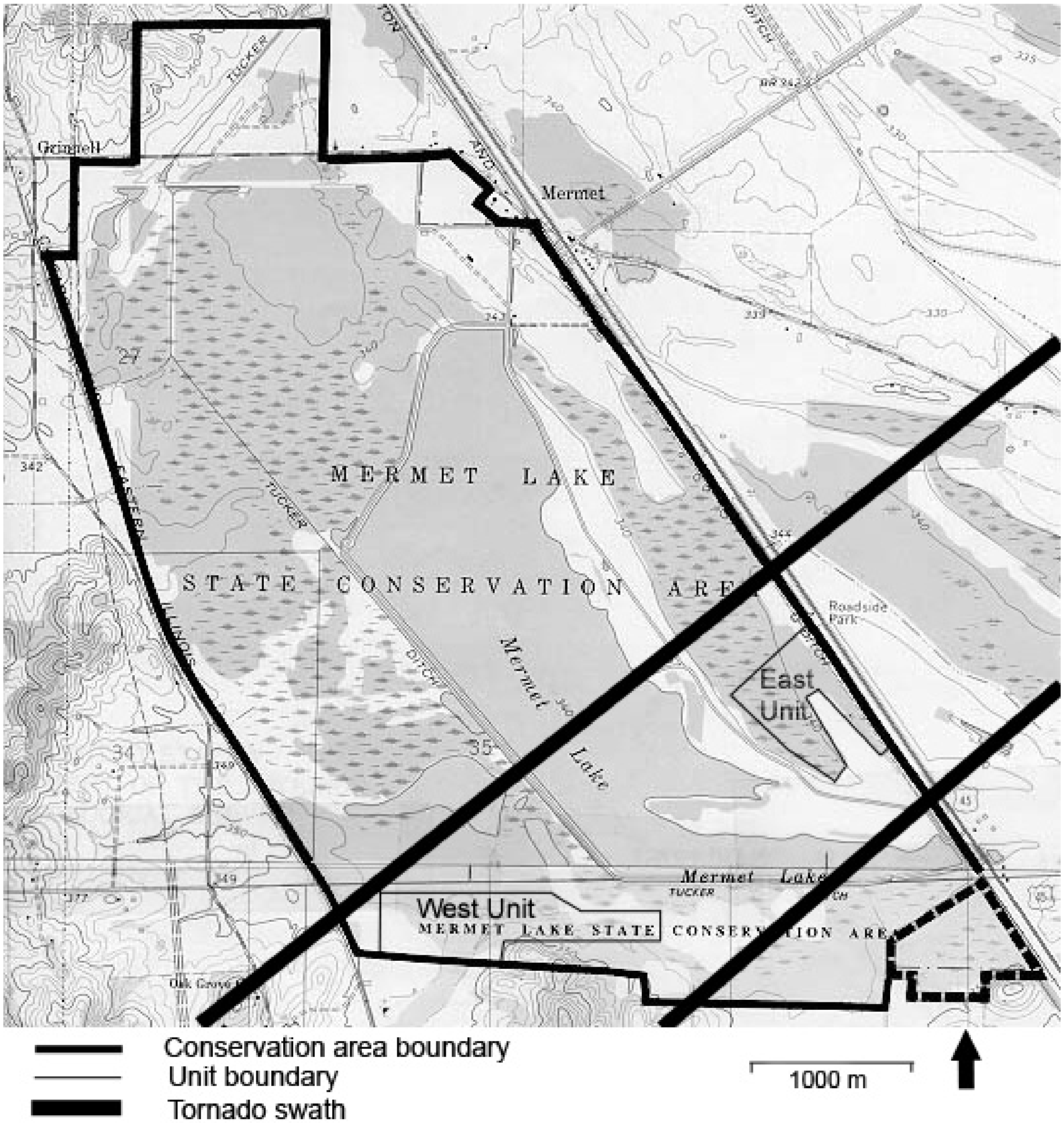
The study area is located within the Mermet Lake State Conservation Area (SCA) in Massac County, Illinois, 1 km southwest of Mermet (37°15′25″N, 88°50′30″W), and near the northern limit of the Mississippi Embayment. The site is on the historic floodplain of the Ohio River. Topography of the site is limited, with 99% of the site having a slope less than 2°. The management objectives of the conservation area focus on wildlife management and recreational use.

The conservation area is 1064 ha in size, with 280 ha of permanent water. Approximately 162 ha of forested land was damaged by an F4 tornado in May of 2003. Within the damaged area, a salvage harvest was conducted on about 32 ha of forested land to restore access to hunters (Fig. 1). This area accounted for a majority of the mature forest of the conservation area. The harvested area was spatially bisected by a drainage ditch constructed in 1919, which created a physical barrier to the spread of fire across the site. In addition, the two units are nearly 1000 m apart. Thus, we considered the harvested area as two units, one approximately 15.5 ha in size (east unit) and the other 16.5 ha in size (west unit). The stands dominating both units at the time of the tornado became established following harvesting and agricultural abandonment during the early and mid twentieth century. Samples from which the fire history was constructed consisted of *Quercus* spp. (70%), *Carya* spp. (14%), *Liquidambar styraciflua* L. (10%), *Nyssa sylvatica* Marsh. (2%), *Ulmus* spp. (2%), and *Liriodendron tulipifera* L. (2%)

Site history

The General Land Office survey of 1807 indicated that the land composing the Mermet Lake SCA was a cypress pond prior to Euro-American settlement (Illinois Archives, Land Records, *Illinois survey field notes*, 1849. Located in Southern Illinois University Carbondale Morris Library (microfilm)). Construction of the railroad grade that parallels the east boundary of the conservation area began in 1905 and was completed in 1910, with the community of Mermet being established during this time. By 1909 most of the land at the site was being cleared and converted to agriculture. Efforts to drain the area commenced in 1919 with the completion of Tucker ditch. Conversion to agricultural land usage continued, and much of the remaining wooded areas were subjected to repeated partial cutting. Seasonal flooding

Fig. 1. Map of Mermet Lake State Conservation Area, Massac County, Illinois.



continued to limit agriculture in the area, resulting in abandonment of some lands. The economic troubles of the late 1920s and early 1930s resulted in renewed land clearing and conversion to agriculture throughout the 1930s. Land conversion followed by abandonment continued until 1949, when the state of Illinois began purchasing land to establish the conservation area.

Partial hydrologic restoration began with the creation of an impoundment and the plugging of Tucker ditch to inundate the land ca. 1957. Further hydrologic alteration occurred with the construction of a levee system and the creation of Mermet Lake in 1965. Since this time, the Mermet Lake SCA has been managed for wildlife, with controlled dormant-season flooding of portions of the conservation area for migrant-waterfowl habitat.

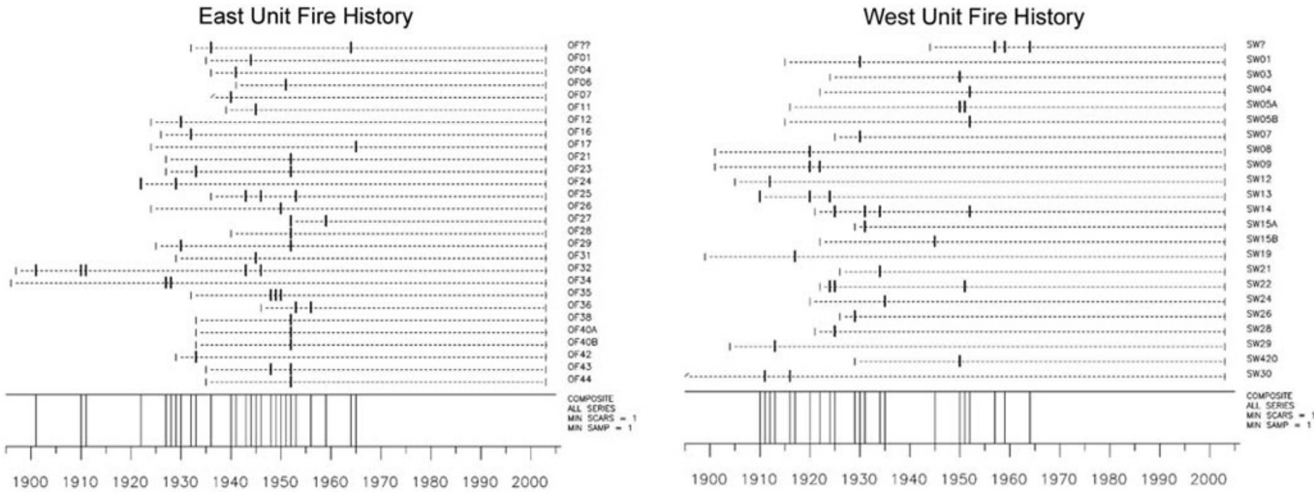
Prior to May 2003, the study area supported a closed-canopy bottomland hardwood forest dominated by *Quercus palustris* Muenchh. and *Quercus phellos* L. Other important canopy species included *Acer saccharum* Marsh., *Carya ovata* (Mill.) K. Koch, *Acer rubrum* L., *Ulmus rubra* Muhl., *Ulmus americana* L., *Ulmus alata* Michx., *Fraxinus pennsylvanica* Marsh., *Liquidambar styraciflua*, and *Nyssa aquatica* L. On 6 May 2003 this stand was nearly completely leveled by an F4 tornado. Subsequent salvage logging of all available merchantable material occurred during October–November 2003 in the west unit and January–April 2004 in the east unit.

Methods

Data collection

In March 2005 a census of the salvaged area was conducted, and all stumps resulting from the salvage harvest with possible fire scars were located and flagged. Cross sections of all flagged stumps were taken in April–May 2005. All samples were taken within 30 cm of the ground line,

Fig. 2. Fire history by research unit at Mermet Lake Conservation Area. Horizontal lines are individual samples, and bold vertical ticks indicate fire scars. The vertical lines in composite summary at bottom of graph indicate fire occurrence.



and scars were determined to be of fire origin by the presence of charcoal and (or) an incomplete annual ring revealing the presence of cambial growth containing callus tissue (Guyette and Cutter 1991; Guyette et al. 2003). All samples with scars of indeterminable origin were excluded from further consideration. This produced 28 samples from the east unit, providing a record from 1896 to 2003, and 23 samples from the west unit, providing a record from 1895 to 2003. The areas from which samples were taken made up 20 ha (11 ha in the east unit and 9 ha in the west unit). No samples were taken from old snags or downed logs, and all indications, such as twisted and uprooted boles and suitability for commercial salvage harvest, suggest that sampled individuals were alive at the time of the tornado.

Skeleton plots were used to determine signature years for cross-dating purposes (Phipps 1985). Data collected for each sample included date of pith, year of fire scars, season of scarring, and year of death (Fig. 2). Season of scarring was documented as dormant season, early growing season, or mid growing season. Damage to earlywood indicated an early growing season fire, whereas damage to latewood indicated a mid growing season fire. Problems of cross dating were minimal, as the incidence of false rings is rare in the fast-growing species that compose the majority of samples. This is especially true for rich alluvial bottomland sites where annual ring widths of 1/4 inch or greater are typical.

Historic drainage status was determined through integration of Massac County tax assessment records, data provided by Illinois Department of Natural Resources (IDNR), aerial photographs, and personal communications with landowners. From these data, three drainage periods were established: predrainage (≤1919), the period before construction of the drainage ditch; drainage (1920–1957), the period during which the site was actively drained; and inundation (1958–1965), the period beginning with the plugging of the drainage ditch and ending with the completion of the current hydrologic control system. Since 1965 fire has been excluded as a result of increased site moisture, significant reduction of ignition sources, and active fire suppression until the conclusion of the study in 2003. The percentage of improved land was determined from the first available tax assessment records for the period 1909 to the final assessment in 1945 and from IDNR records for 1949 to 1957. Values derived from tax assessments and IDNR records were cross-referenced with aerial photographs from 1938, 1946, 1949, and 1957 to insure accuracy. Improved land status included land where the forest was cleared and converted to other usage, i.e., agriculture fields, pastures, and construction of structures. Two periods of land improvement were established for both units from these data, even though land improvement differed on the two units: 1909–1930 (high improvement in the west unit and low improvement in the east unit) and 1931–1957 (low improvement in the west unit and high improvement in the east unit).

Table 1. Percentage of improved land by research unit at Mermet Lake Conservation Area.

	Percentage of improved land†	
Year*	East unit	West unit
1909	13	22
1915	13	45
1920	13	47
1925	14	38
1930	14	20
1935	37	20
1940	37	20
1945	37	20
1949	37	20
1957	37	20

*All values are based on county tax assessment records for 1909–1945; IDNR records for 1949; and aerial photographs from 1938, 1946, 1949, and 1957.

†Percentage of improved land within sections 35 and 36 T14S R3E (east) and section 2 T15S R3E (west). Each section encompasses approximately 259 ha.

Data analysis

Analysis of the entire site was conducted for the entire study period and drainage periods, while the two research

Table 2. Fire-interval analysis for Mermet Lake Conservation Area.

Unit, modification, and time period*	Samples (n)†	No. of scarred samples	Fire intervals (n)	Mean fire interval (years)	Min. fire interval (years)	Max. fire interval (years)	Weibull Median (LEI–UEI)‡
Total study period							
Combined 1895–1965	51	51	37	1.73	1	9	1.56 (0.23–4.60)
Drainage by study period							
Combined predrainage 1895–1919	12	6	8	3.00	1	9	2.76 (0.25–10.60)
Combined drainage 1919–1957	51	46	28	1.36	1	4	1.31 (0.37–2.69)
Combined inundation 1958–1965	51	4	3	2.67	1	5	2.41 (0.50–5.81)
East predrainage 1896–1919	2	1	4	5.75	1	9	7.84 (0.82–27.80)
East drainage 1920–1957	28	27	22	1.73	1	5	1.66 (0.35–3.99)
East inundation 1958–1965	28	3	3	2.67	1	5	3.11 (0.69–7.24)
West predrainage 1895–1919	10	5	7	3.43	1	15	2.79 (0.09–19.74)
West drainage 1920–1957	23	19	14	2.71	1	10	2.37 (0.31–7.44)
West inundation 1958–1965	23	1	3	2.67	1	5	3.50 (1.34–6.01)
Land improvement by study period							
East 1909–1930 (low improvement)	10	5	7	3.00	1	11	2.02 (0.14–9.17)
East 1931–1957 (high improvement)	28	24	17	1.59	1	4	1.55 (0.41–3.30)
West 1909–1930 (high improvement)	20	13	12	1.75	1	4	1.64 (0.41–3.56)
West 1931–1957 (low improvement)	23	12	8	3.38	1	10	2.64 (0.29–9.08)

*Time periods exclude the 38 year period of fire exclusion from 1965 to 2003.
†The number of individual trees that were present during a time period and (or) in a unit and used for analysis.
‡LEI is the estimated Weibull lower 95% exceedance value, and UEI is the estimated upper 5% exceedance value.

units were separated for the drainage and land-improvement analysis because of their spatial separation, impediment of fire spread by the drainage ditch, and differing land-use histories (Table 1).

Analyses were conducted using FHX2 software (Grissino-Mayer 2001), which included summarizing the individual fire scars to produce a composite distribution of fire return intervals. In addition to these complete fire-to-fire return intervals, censored intervals were also incorporated (Finney 1995; Polakow and Dunne 1999; Niklasson and Granstrom 2000; Polakow and Dunne 2001; Le Goff et al. 2007). Polakow and Dunne (1999) state that censored observations provide useful information that should not be excluded and describe the types of censoring that can be performed. In particular, they identify the interval from the beginning of a study to the first fire and the interval from the last fire to the end of the study as two possibilities of incomplete, or censored, intervals. The study endpoints are defined by treatment changes in historical time (Polakow and Dunne 2001), and here are determined by drainage and land-use histories. Fire frequency was analyzed using the distribution of fire-interval data. Measures of the distribution included mean fire interval (MFI) and observed minimum and maximum fire intervals. For each time period the distribution of fire intervals was summarized using the two-parameter Weibull distribution. The LIFEREG procedure of the SAS statistical analysis software (SAS Institute Inc. 2004) was used for maximum likelihood estimation that incorporates censored data (Le Goff et al. 2007). The Weibull median fire interval (equivalent to a 50% exceedance value) and the lower 95% and upper 5% exceedance values were calculated for each time period. An exceedance value is the converse of the usual percentile of a distribution.

Exploratory analyses of variance were performed with the GLM procedure of the SAS software (SAS Institute Inc. 2004) to examine support for the effects of drainage and land improvement on MFI. Though treatments were not imposed in an experimental design framework, this exploration is useful for hypothesis development, but is not confirmatory (Hoaglin et al. 1991).

Logistic regression was conducted to determine whether fire occurrence was related to incidence of drought using the mean Palmer Drought Severity Index (PDSI) for the period 1900 to 1965 (National Oceanic and Atmospheric Administration 2005). The mean PDSI was calculated using the PDSI for the 3 months preceding a fire season. January to March was used for early growing season fires, April to June for mid to late growing season fires, and July to September for dormant season fires.

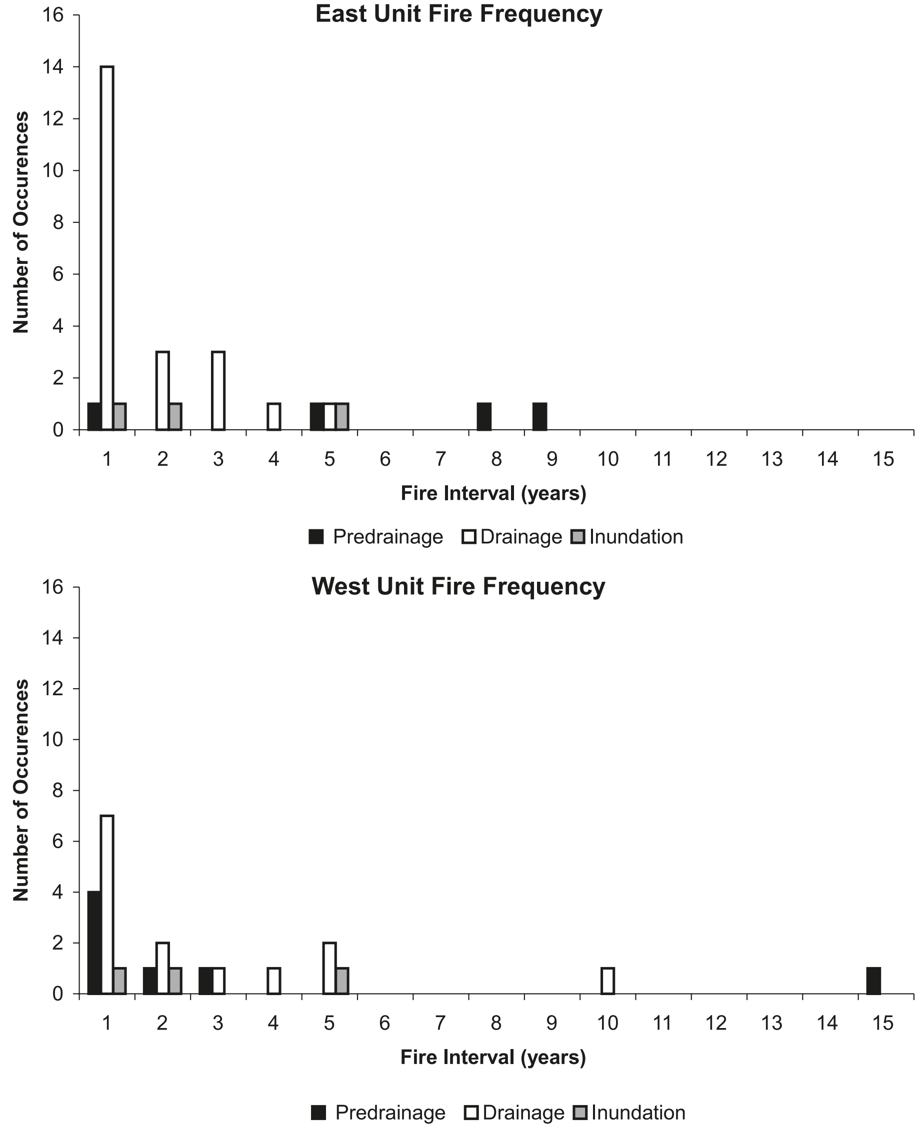
Results

The fire-scar record included 37 fire intervals from 1895 to 1965 for the entire study area, followed by a 38 year fire-free period from 1965 to 2003, during which fire was actively suppressed (Table 2). The MFI for the entire study period was 1.73 years, with a minimum fire interval of 1 year and a maximum fire interval of 9 years. Estimated Weibull distributions are summarized in Table 2, including the Weibull median and the lower 95% (LEI) and upper 5% (UEI) exceedance values.

Effects of drainage

Prior to drainage, the MFI was 3.00 years for the 24 years of data, with minimum and maximum fire intervals of 1 and 9 years, respectively. During the ensuing 37 years, when the site was actively drained, the MFI decreased to 1.36 years, with a minimum interval of 1 year and maximum of 5 years.

Fig. 3. Fire-interval distribution by drainage period for east and west units.



During the 7 year period when the site was inundated — following the plugging of the drainage ditch in 1957 until 1965 — the MFI increased to 2.67 years, with minimum and maximum intervals of 1 and 5 years, respectively. This period was followed by 38 years of fire exclusion due to increased moisture and fire suppression.

In the east unit, during the predrainage period, the MFI was 5.75 years, with four fire intervals ranging from 1 to 9 years. Following drainage, the MFI decreased to 1.73 years with minimum and maximum intervals of 1 and 5 years, respectively. During the ensuing 7 year period of inundation, the MFI was 2.67, with a fire-interval range of 1 to 5 years.

In the west unit, the predrainage period produced an MFI of 3.43 years, with minimum and maximum intervals of 1 and 15 years, respectively. Under the influence of drainage, the MFI was 2.71, with minimum and maximum intervals of 1 and 10 years, respectively. Following inundation the MFI was 2.67, with an interval range of 1 to 5 years.

Figure 3 illustrates the fire-interval distribution for each unit and drainage period. A simple analysis of variance of the MFI, using units as replication, and the three drainage periods as treatments indicated nonsignificant treatment effects ($p = 0.1933$). This does not provide support for the hypothesis suggesting that drainage has an effect on fire interval.

Effects of land improvement

In the east unit for the period 1909 to 1930, land improvement was low (Table 1), and the MFI for the unit was 3.00 years, with a fire-interval range of 1 to 11 years. For the period 1931 to 1957 when land improvement was high, the MFI was 1.59 years, with an interval range of 1 to 4 years.

In the west unit during the early period (1909 to 1930), land improvement was high (Table 1), and the MFI was 1.75 years, with a minimum interval of 1 year and maximum interval of 4 years. In the later period (1931 to 1957), the percentage of improved land decreased, and the MFI was 3.32, with minimum and maximum fire intervals of 1 and 10 years, respectively.

Fig. 4. Fire-interval distribution by land-improvement period for east and west units.

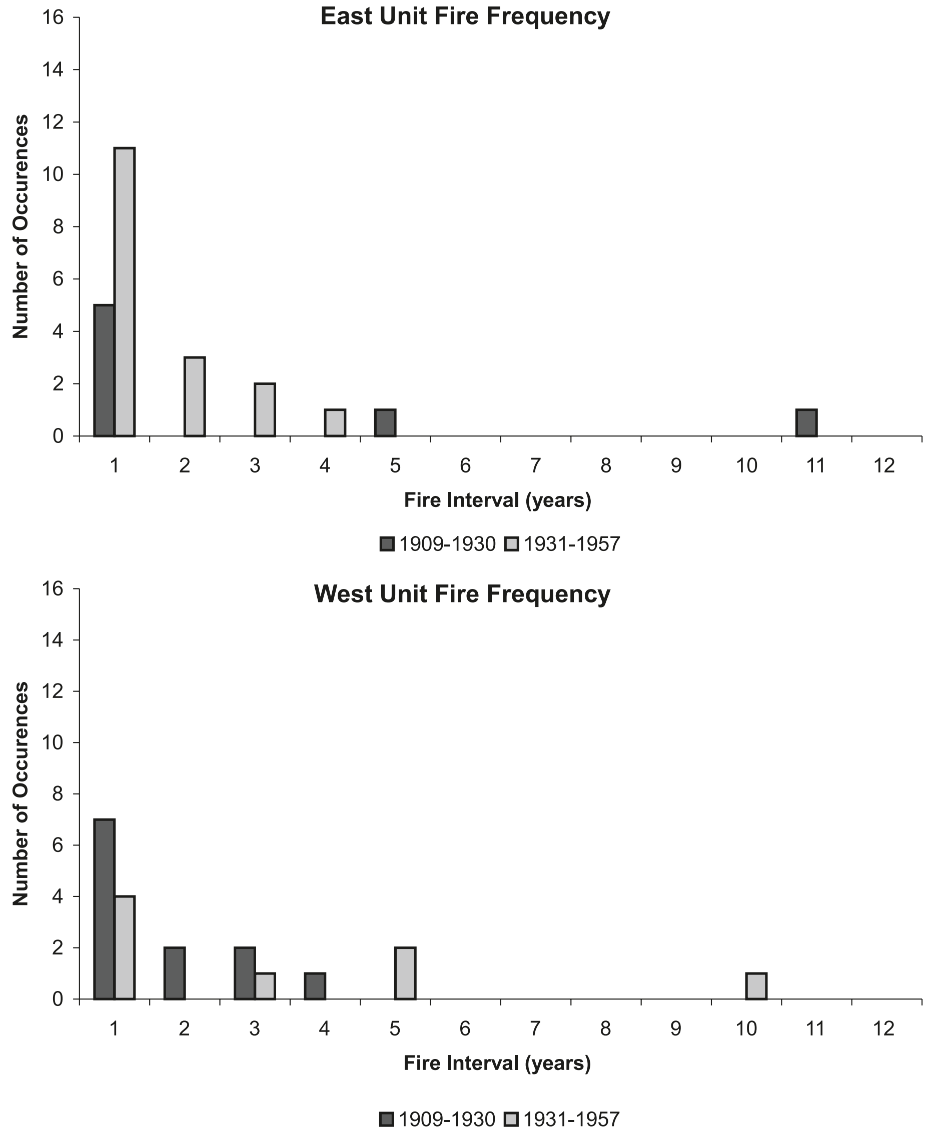


Figure 4 illustrates the fire-interval distribution for each unit and land-improvement period. A simple analysis of variance of the MFI, using units as replications and the two land-improvement classes as treatments indicated a significant treatment effect (p = 0.0176). This does provide support for the hypothesis suggesting that land improvement has an effect on fire interval.

Seasonal and precipitation influences

Most fires occurred during the dormant season (Table 3). Growing season fires were more frequent during the early growing season and appear to be unassociated with drainage, development, or climatic conditions. Fire occurrence was unaffected by the occurrence of drought relative to normal or high-precipitation years (p = 0.90) (Fig. 5).

Table 3. Fire seasons at Mermet Lake Conservation Area from 1895 to 1964.

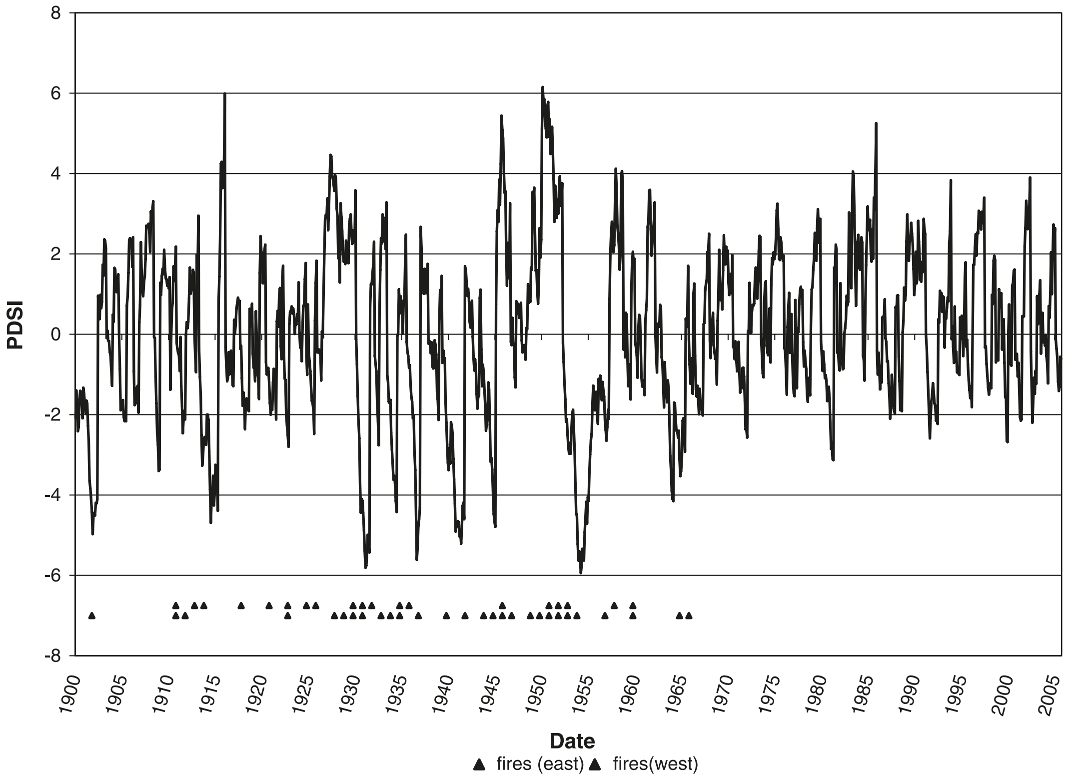
	Percentage of fire scars by season		
Unit (no. of scars)	Dormant	Early growing	Mid growing
East (44)	91	7	2
West (35)	86	11	3
Total (79)	89	9	2

Discussion

The results of this study suggest that ditch drainage and, more importantly, land improvement were associated with increased fire frequency on this bottomland site. Fire frequency for the entire study site and period was higher than the frequencies that are typically reported for oak forests in the central and eastern United States (Guyette and Cutter 1991; Shumway et al. 2001). These data indicate that this altered wetland system, where natural fire would be rare, burned more frequently than upland oak forests in this region, where fire has been shown to be an important determinant of forest composition and structure.

These findings contradict most reports from southeastern cypress wetlands, where fire suppression associated with

Fig. 5. Fires occurrence plotted against the Palmer Drought Severity Index (PDSI) for Mermet Lake Conservation Area. PDSI values of zero equal normal moisture (precipitation), negative values indicate below normal moisture, and positive values indicate high moisture.



Euro-American settlement led to a decrease in fire frequency (Duever 2005; Casey and Ewel 2006). However, altered hydrology produced dryer conditions and was associated with increased fire frequency and severity in some cypress wetlands (Duever 2005). In these systems, as in the present study, altered hydrology was associated with dryer conditions and changes in vegetative composition, regardless of whether fire frequency increased or decreased.

In light of the varying results from drained southeast cypress wetlands, the development at Mermet Lake and the concurrent national trend towards fire suppression invite the following question: what was the driving force behind increased fire frequency at this site? Across the site, fire frequency was not significantly associated with drainage. When the research units were analyzed separately, both had an increase in fire frequency following drainage, but the increase was much greater in the east unit than that in the west unit. This finding, in conjunction with the high predrainage fire frequency, suggests that drainage was not the lone factor affecting fire occurrence. Thus, another variable is needed to explain the varying fire occurrence throughout the study period.

The pattern of land improvement differed between the two units. The west unit had greater improvement early in the study period, followed by a decline. While in the east unit, land improvement was low early in the study period and increased after land improvement was abandoned in the west unit. The incidence of fire closely followed the percentage of land improved for the two units. As land improvement increased or decreased, so did fire occurrences, a pattern that is consistent with that of upland sites and the hydrologically altered Big Cypress region of Florida (Abrams 1985; Duever 2005). Increased fire frequency related to land development is consistent with the historically prevalent practice of brush burning on bottomland sites with little concern for fire spreading into adjacent woodlands (Max Hutcheson, personal communication, 2006). This practice, combined with the high productivity and rapid vegetative recovery of this site following recent disturbances, suggests that continuous clearing of brush would have been necessary to maintain improved lands prior to the widespread use of herbicides or mechanical means for accomplishing the same objectives. Therefore, brush burning could provide a fairly continuous ignition source on this landscape.

Drainage of the site would provide more favorable conditions for land conversion to agriculture, thus providing increased ignition sources and fire occurrence. The more mesic site conditions combined with increased fire frequency would favor the less hydric, fire-tolerant oaks that dominated the site at the time of purchase by the state of Illinois. Agricultural abandonment, inclusion in a conservation area, inundation, and decline in agricultural fire on adjacent lands returned the fire frequency closer to presettlement levels. These actions also resulted in reduced ignition sources and a wetter environment, both of which would be expected to reduce fire occurrences. The most recent 38 year fire-free period has resulted in an understory of shade-tolerant species developing under the maturing oak-dominated canopy, possibly indicating another shift in forest vegetation composition following the latest tornadic disturbance.

Railroad operations have been associated with increased wildland fire occurrence, commonly serving as an ignition source in southern Illinois as recently as the 1960s (Haines et al. 1975). However, the railroad along the east boundary of the east unit, which has been in operation since 1910, appears to have had little influence on the fire regime. If railroad-ignited fires were a major component of fire history in this area, an increase in fire occurrence in the east unit would be expected to coincide with the construction of this line beginning in 1905, periods of heavy rail traffic during World Wars I and II, or with the drier conditions that accompanied historic drainage periods. However, no increase in fire occurrence was observed at any of these times. In fact, despite the heavy rail traffic, there was actually a decline in fire frequency during the war years. In the east unit, an increase in fire occurrence did not occur until the late 1920s, when land improvement was increasing. Like drainage, railroad operation may be associated with increased fire frequency to the extent that it played a central role in fostering European-American settlement in this region.

The lack of a relationship between drought and fire occurrence is consistent with other research in this region (Sutherland 1997; Guyette et al. 2003) and eliminates changes in drought conditions as an explanation for fluctuating fire occurrence. The predominance of fire during the dormant season is also consistent with research on upland sites and postsettlement cypress wetlands of the southeast. In southern Illinois, the driest periods occur during the growing season and are when natural fire is most likely to occur. The prevalence of dormant-season fires, when conditions are wetter and fire unlikely to spread, is a result of postsettlement cultural practices. This anthropogenic fire regime represents a potentially important deviation from the expected natural fire regime described above. The lack of association between fire and drought at Mermet Lake further underscores these differences.

The postsettlement fire history of this forested wetland site parallels that of upland forests of this region in that fire frequency first increased with settlement, followed by a nearly fire-free period during recent decades (Guyette et al. 2002; Ruffner and Groninger 2006). On forested uplands, agricultural land uses and accompanying fires led to drier conditions and changed forest composition, and these dynamics appear to have also occurred on this site (Nelson et al. 2008).

Conclusion

The results of this study indicate that the variation in fire frequency coincided with changes in drainage and land-improvement patterns. Drainage and agriculture are typically considered conjoined incendiary activities in settled wetland areas. However, the distinct agricultural histories of the two adjacent research units in this study suggest that this relationship may not always be so straightforward. Differences in fire history between the two units following ditch installation, as measured by the upper exceedance value, suggest that drainage in itself had a limited effect on fire occurrence. More importantly, drainage most likely produced drier conditions, at least in the east research unit, allowing for an increase in land improvement, which, in turn, increased fire occurrence. Neither climatic conditions nor the close proximity of the railroad had a detectable influence on fire occurrence.

This research has important implications for forested wetlands in landscapes with a history of drainage, agriculture, and anthropogenically increased fire. The modification of drainage systems and the agricultural abandonment at Mermet Lake to approach presettlement hydrology are consistent with wildlife and natural areas management objectives often mandated for publicly owned wetlands. Present fire suppression policies are also producing conditions thought to be nearer to historic norms than those associated with the first half of the twentieth century. However, the dominant vegetation now occupying this site established under fire and hydrologic regimes quite different from the ostensibly more natural conditions presently prevailing. This incongruity potentially produces at least three problems for managers to consider. First, the vegetation now dominating this site reflects a history of drier conditions and high fire frequency and may not be well suited for present management under wetter conditions, even though these conditions reflect more historic norms. Second, fire exclusion associated with this site since 1965 may not be consistent with presettlement conditions where fire was most likely rare, but not necessarily absent. Third, actual land-improvement status, as opposed to drainage history, needs to be considered to accurately reconstruct postsettlement fire regimes.

The forest health declines reported in managed wetlands elsewhere in this region may be at least partly attributable to radical fluctuations in hydrology and fire regimes over the past several decades. Changes in hydrology alone affect forest composition and structure and can be expected to drive a site towards dominance by less hydric species (Peterson and Pickett 1995). An associated increase in fire frequency may have compounded this effect. Maintenance of healthy forest ecosystems in wetlands with a similar history of drainage and agricultural clearing as here at Mermet Lake SCA may require the active restoration of predrainage forest types in addition to hydrologic restoration. Managers may also need to consider reintroducing fire into forested wetlands to achieve the full range of restoration and maintenance objectives.

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