



# A Critical Examination of Timing of Burning in the Kansas Flint Hills

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## ABSTRACT

Frequent burning is a crucial ecological and economic component of the Kansas Flint Hills. Although burning is important for the preservation of tallgrass prairie and improving livestock production, it has become a controversial societal issue because of its potential impact on air quality standards. Over the past 80 years, recommendations on burning in Kansas have ranged from total fire exclusion to burning only in late April; and for the past 40 years, the concept that burning should only occur in late spring has become ingrained in the cultural practices of rangeland management. Yet the scientific basis for these recommendations has received little rigorous scrutiny. Herein, we critically review the research on dormant-season burning in the Flint Hills that formed the foundation for modern burn practices in Kansas. Close examination of the historical data does not support the tenet that burning must be limited to a narrow window in late spring. Many conclusions of the research that led to recommending burning only in late spring were ambiguous, not subjected to statistical analysis, or were influenced by an antiburn bias. Current research suggests that timing of a burn is not as critical as ranchers have been led to believe and burning does not have to be restricted to a narrow window in late April. There is an absence of scientific evidence that burning earlier in the spring adversely affects forage production, plant species composition, soil moisture, or cattle weight gain. Although there is a need for research on the consequences of burning grazed pastures at different times of the year, expanding the window for burning earlier in the dormant season should help alleviate air quality issues downwind of the burned areas and potentially be beneficial to ranchers.

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## Introduction

The Flint Hills are the largest remnant of tallgrass prairie in North America, extending from northeast Kansas southward into Oklahoma and encompassing approximately 25 000 km<sup>2</sup>. The area has remained virtually intact as native prairie since settlement because the limestone and flint outcroppings that characterize the landscape make much of the land ill-suited for cultivation. Topographically, the upland soils are relative rocky, shallow, and overlay clay strata, whereas the lowland soils are deep and arable. In most years the native prairie grasses are highly productive and forage quality is relatively high in the early growing season. For more than 100 years, the Flint Hills have been predominantly utilized for seasonal grazing by cattle (Malin, 1942). More than one million stocker cattle annually graze in the Flint Hills, either season long or only in the first half of the growing season (Duesterhaus et al., 2008). Pasture burning is an important management practice to increase livestock production (Bernardo et al., 1988), although the amount of grassland burned varies widely among years throughout the region (Mohler and Goodin, 2012).

Fire, drought, and herbivory were all crucial factors in the development of tallgrass prairie (Axelrod, 1985; Anderson, 2006). Over the past 40 years, most research on Flint Hills burning has focused on the ecological effects of fire frequency, with experimental burns ranging from annual to 20-year intervals (Gibson, 1988; Collins, 1992; Collins, 2000; Briggs et al., 2002; Heisler et al., 2003; Spasojevic et al., 2010; Collins and Calabrese, 2012). Those studies demonstrated that the warm-season grasses, which are the cornerstone of tallgrass prairie vegetation, are favored by frequent burning. Increased dominance of warm-season grasses in prairie that is annually burned in late spring, however, lowers species richness compared with infrequently burned prairie (Collins, 1992; Briggs et al., 2005; Limb et al., 2010; Spasojevic et al., 2010; Collins and Calabrese, 2012; Bowles and Jones, 2013). In prairie that has not been burned for many years, grass litter accumulates, soil resources increase, warm-season grasses and other herbaceous species decline, and woody species progressively expand (Engle and Kulbeth, 1992; Hoch et al., 2002; Briggs et al., 2005; Ratajczak et al., 2012; Craine and Nippert, 2014).

Most of the initial research on burning in Kansas was conducted on ungrazed sites, and some of the observed responses may not be commensurate with grazed areas. Fire and grazing are not independent drivers of vegetational change, and an interaction between the two can affect plant and animal responses through both positive and

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negative feedbacks (Coppedge et al., 1998; Johnson and Matchett, 2001; Briggs et al., 2002; Fuhlendorf and Engle, 2004; Fuhlendorf et al., 2009; Augustine et al., 2010). Although species richness is reduced with annual burning, prairie that is burned and moderately grazed has higher species richness than prairie that is burned and not grazed (Collins, 1992; Towne et al., 2005; Collins and Calabrese, 2012). In addition, fire intensity is lower in grazed pastures than in ungrazed prairie because herbivory reduces the fuel load and produces a mosaic landscape where some species are protected from fire. The lower fire intensity has been implicated as a potential reason why fire is sometimes ineffective in eliminating woody species from grazed pastures (Hoch et al., 2002; Veach et al., 2014). Notwithstanding potential shortcomings in extrapolating research from ungrazed sites to grazed sites, research in ungrazed prairie has been the historical foundation for recommendations on when the Kansas Flint Hills should be burned.

Despite recent advances in our understanding of fire in the region, the one constant for almost all research on Flint Hills burning has been that the fires have occurred in late spring. Research on the timing of burns has been a subordinate issue compared with research on the consequences of fire frequency. In other grassland regions, strategic prescribed fire at different times in the dormant season has been utilized as a management tool to selectively depress or enhance plant species (Ruckman et al., 2012; Luna et al., 2014), manipulate the balance of C<sub>3</sub> and C<sub>4</sub> species (Steuter, 1987), control woody species (Owens et al., 2002; Ansley et al., 2015), stimulate flowering (Platt et al., 1988; Pavlovic et al., 2011), or alter the proportion of plant functional groups (Coppedge et al., 1998). Although time of burning can affect various aspects of the plant community, late spring has become accepted as the default time for almost all fire research in the Kansas Flint Hills.

The general acceptance that late spring is the best time to burn the prairie originates from a small set of studies conducted more than 40 years ago. In the subsequent decades, ranchers have not been exposed to any alternative options on time of burning. The recommendations to burn in late spring were predicated on the belief that burning at that time would minimize reductions in biomass production, reduce soil moisture loss, increase production of warm-season grasses, eliminate woody species and undesirable forbs, and increase cattle weight gain (Anderson, 1964; Anderson, 1965; McMurphy and Anderson, 1965; Anderson et al., 1970). The ecological and economic reasons promoted in these recommendations were influential incentives for ranchers to only burn in late spring.

There is little dispute that frequent burning in late spring has maintained Flint Hills grasslands. Widespread synchronized pasture burning in late spring, however, has become a societal issue that affects numerous people because air quality thresholds are often exceeded. The production of large amounts of smoke from en masse late-spring burning facilitates the formation of ground-level ozone in concentrations that often exceed US Environmental Protection Agency (EPA) standards (Liu, 2014; Kansas Flint Hills Smoke Management, 2015). Airborne chemical and particulate pollutants created from burning can increase the incidence of asthma, cardiovascular problems, lung cancer, and acute bronchitis (Pope et al., 2002). Exceeding federal air quality standards can trigger regulatory costs for municipalities and instigate potential interstate lawsuits when smoke is transported across state borders (Kansas Department of Health and Environment, 2010). Recent proposals by the EPA to lower the allowable ozone threshold will only increase the importance of sound recommendations on the timing of burning in the Flint Hills.

Potential mechanisms to reduce downwind smoke pollution include policies that regulate the amount of burning on a particular day, burning less frequently, or burning earlier in the spring to distribute smoke production over a longer time period when ozone is less likely to be formed. However, bureaucratic intervention on regulating individual burns or burning less frequently would be unpopular and may not be feasible options for regional grassland stewardship. If burning earlier in the spring is to be considered as a reasonable solution to reduce smoke pollution,

then an in-depth reevaluation of the research that led to the current recommendations of late-spring burning is necessary.

Engle and Bidwell (2001) previously reviewed the response of North American prairies to seasonal fire and concluded that prairie vegetation is more resilient to burning at different times in the year than what is commonly believed. However, they also postulated that “Conventional wisdom in the region holds that burning in the dormant season other than in the late dormant season (late spring) always reduces herbage production and increases weedy forbs relative to desirable forage grasses” (p. 3). Subsequent to that review, there has been extensive research on the response of tallgrass prairie to time of burning, which calls into question many generalities that are accepted as conventional wisdom.

Our objective here is to critically review the research that established the foundation for the long-standing recommendation that grasslands in Kansas should only be burned in the late spring. To accomplish this, we focus on the initial studies from burning on different dates that were conducted at Kansas State University from 1930–1970. Although fire research over the past 30 years throughout the region (primarily at Konza Prairie and Oklahoma State University) has contributed immensely to understanding various aspects of grassland burning, there is a paucity of information on timing of burns. Therefore the intent of this review is to examine the limitations and any potentially misleading conclusions drawn from the studies that were responsible for forming the recommendations that Flint Hills prairie should only be burned in late spring. Because most pasture burning in the Flint Hills traditionally occurs annually during the dormant season, fire in the growing season (i.e., summer burning) is not covered here.

### Early research on time of burning in the flint hills

Intentional burning by Native Americans occurred at different times of the year, and historical records of early pioneers are replete with observations of autumn and early spring fires. Once European immigrants settled in the area, however, any grassland burning was considered dangerous and undesirable. By the 1880s, the influx of transient cattle from Texas for summer grazing was an impetus for ranchers to revive intentional burning because animal performance was better if the old grass cover was removed (Kollmorgen and Simonett, 1965; Isern, 1985). At that time there was widespread opposition to pasture burning, and most nonranchers considered prairie fires destructive and unnecessary (Hoy, 1989; Hoy and Isern, 1995). In a preliminary examination on burning, Hensel (1923a) observed that “Opinion among stockmen on the burning question is divided. Some favor it strongly, while others are decidedly opposed to it. Among scientific men, the belief has always been held that it is injurious” (p. 184).

To address the impact of pasture burning, Kansas Agricultural Experiment Station initiated a study in 1918 to compare vegetation between a burned plot and an unburned plot in an ungrazed area. After 4 years of annual burning in late March to early April, Hensel (1923b) concluded that the study “failed to show that burning is injurious” (p. 642). In a subsequent experiment, Aldous (1934) established a series of 10 × 20 m plots on an ungrazed upland prairie to study the effects of burning either annually or biennially at four different times in the dormant season. Treatments were winter burn (1 December), early-spring burn (20 March), mid-spring burn (10 April), late-spring burn (5 May), and an unburned control. After 6 years, Aldous concluded that although annual burning increased the number of plant stems, it was not a beneficial practice because it lowered soil moisture levels in some years and reduced average biomass production by 33–47% compared with the unburned plot. The largest reductions in biomass occurred the earlier the plot was burned.

In both of these initial burn studies, the treatments were not replicated in space and the unburned plot was annually mowed and raked in late April because litter accumulations “attracted rodents and tended to cause abnormal fungus growth” (Aldous, 1934, p. 13). Treating the

unburned comparison in this fashion was considered acceptable to evaluate changes in biomass production from burning since the highest yields occurred in plots that were not burned. However, preventing mulch accumulations by annually mowing the plot and removing the vegetation is not an analogous comparison to unburned prairie and obscures the long-term impact of not burning. Even though these studies never had a true unburned comparison plot, the putative reduced biomass production from burning served as the foundation for subsequent fire suppression dogma, and for the next 30 years most academicians recommended that fire not be a part of normal range management practices (Hanks and Anderson, 1957).

The condemnation of burning Flint Hills prairie continued until the mid-1960s. Following decades without burning, eastern redcedar (*Juniperus virginiana* L.) progressively invaded many pastures in the region and the importance of periodic fire to prevent establishment of woody species and maintain the integrity of tallgrass prairie was eventually acknowledged (Owensby et al., 1973; Bragg and Hulbert, 1976). Once frequent fire was sanctioned as a necessary component of grassland management, the remaining issue dealt with timing of the burn and how it affected various ecological factors.

#### Biomass Production

Burning in late spring was endorsed as the most acceptable time to conduct a fire after a 26-year follow-up study on the Aldous plots concluded that average biomass production was 13% higher in the late-spring burned plot than in the early-spring burned plot (McMurphy and Anderson, 1963). But because the treatment design was repeated only in time, not space, there was no measure of variability for a given treatment nor was there any assessment of potential treatment-confounded site effects. Consequently, even though the data were analyzed using years as a replicate, there was little statistical basis for extending the results beyond the focal 200 m<sup>2</sup> plot, no less to the entire Flint Hills. In that study, the highest biomass yields occurred on the unburned plot, but to appease those ranchers who defiantly planned to burn, the prevailing antiburn recommendations were equivocated to suggest that if burning was deemed necessary, then burning in late April would reduce biomass production the least and be less “harmful” than burning at other times (McMurphy and Anderson, 1963).

A subsequent 8-year study in grazed pastures that also did not have replicated treatments (Owensby and Anderson, 1967) made the same conclusion after finding that forage production was similar between an unburned pasture and a pasture burned annually in late spring (~1 May) but was lowest in a pasture burned annually in early spring (~20 March). However, because the data were analyzed using years as replicates, any purported significant differences among treatments are inconclusive. That same biomass data were subsequently republished in an ensuing publication (Anderson et al., 1970), which further reinforced the belief that if a pasture is to be burned, the burn should occur in late spring. Although the studies suggested that total biomass production was reduced from burning early in the spring, the evidence is not convincing.

#### Soil Moisture

One of the primary reasons for initially recommending that tallgrass prairie not be burned was based on concern that the denuded soil would increase runoff, reduce water infiltration, and increase evaporation, which would subsequently reduce biomass production (Aldous, 1934; Hanks and Anderson, 1957; Anderson, 1961; Bieber and Anderson, 1961; McMurphy and Anderson, 1963; Anderson, 1965; McMurphy and Anderson, 1965; Anderson et al., 1970). In those experiments, plots burned in early spring putatively had lower soil moisture levels compared with unburned plots or plots burned in late spring.

Despite these studies linking reduced soil moisture to timing of burning and concomitant low biomass production, there is a lack of

convincing evidence that burning Flint Hills prairie early in the spring has any substantial impact on soil moisture. Much of the data are equivocal, and there are a number of reasons to be skeptical of their conclusions. First, all but one of the studies occurred in the ungrazed, unreplicated Aldous plots and any purported differences in soil moisture were not subjected to statistical analyses. Consequently, site variability may be the most likely causal mechanism for differences in soil moisture among the treatments. Second, Bieber and Anderson (1961) prejudicially concluded that “early burning tends to reduce moisture content of the soil” (p. 187), but their supporting data only graphed soil moisture levels of the unburned plot compared with the plot burned on 1 May. Third, Hanks and Anderson (1957) concluded that water infiltration was reduced if biomass was removed by burning but inexplicably was not reduced in the unburned plot if top growth and mulch were removed by mowing and raking.

Lastly, in the only examination of soil moisture in grazed pastures burned at different times, Anderson et al. (1970) measured soil moisture in each of two landscape positions. Data were aggregated to the entire soil profile and averaged across 5 years, but no statistics were performed to examine if any treatment differences were significant. The authors reported that “among burned pastures, the one burned earliest has been lowest in moisture” (p. 84). Their graphs, however, indicated that there was little difference in year-long fluctuations in soil moisture among the pastures burned at different times on the claypan sites. Their data did suggest that in areas with deep soil, moisture levels were lower in the pasture burned in early spring than in the pasture burned in late spring. Yet the unburned pasture had substantially lower soil moisture levels than all other treatments despite supposedly having the least runoff and evaporation. In addition, soil moisture levels followed similar patterns of change over time in both the early-spring and late-spring burned pasture. On the basis of the absence of meaningful analyses of the data, there is a lack of convincing evidence that burning Flint Hills prairie early in the spring has any substantial impact on soil moisture.

#### Plant Composition

Vegetation in the Flint Hills is dominated by warm-season perennial grasses, and any treatment that shifts the composition to other herbaceous components was considered to be undesirable. Supportive rationale to discourage burning at any time other than late spring derived from studies that concluded burning early in the season increased the amount of weeds (i.e., herbaceous forbs) and cool-season grasses (Anderson, 1961; McMurphy and Anderson, 1965; Owensby and Anderson, 1967). But other studies have found that individual plant species differ in their response to time of burning. Some of the discrepancies may be due to differences in soil type or topographic position, grazing (or the lack thereof), and drought spells. The response of most perennial species to time of burning, however, requires long-term data because change is not abrupt but rather a gradual shift over time with repeated annual burning (Towne and Kemp, 2003; Towne and Craine, 2014).

Some changes in plant composition with burning at different times were apparent from changes in biomass of different plant functional groups, but in many cases reporting of biomass responses did little to help understand how timing of fire affected plant community composition. For example, because estimates of total biomass production in the McMurphy and Anderson (1963) study were a heterogeneous mixture of grasses, forbs, and woody plants, the impact of time of burning on individual forage components was obscured. The Owensby and Anderson (1967) study separated biomass into “forage” (defined as grasses, sedges, and perennial forbs that are grazed by livestock) and “weeds” (all other plants in the clipped sample). However, exact identity of the forbs in the forage category was ambiguous, and many of the purported plants in the weed group included nutritious species that may be browsed by livestock. A subsequent 10-year study on replicated plots



burned annually at four different times in the dormant season separated clipped biomass into grass and forb components (Towne and Owensby, 1984). In that study grass production was higher and forb production was lower in late-spring burned plots than in the other burn treatments. In contrast, more intense clipping studies in ungrazed grassland have indicated that grass production does not differ among prairie burned annually at different times in the dormant season on either upland or lowland topographic positions, but forb production is lowest in sites burned annually in late spring (Towne and Kemp, 2003; Towne and Craine, 2014). Current data suggest that at least in ungrazed prairie, burning earlier in the spring will increase the production of forbs compared with prairie burned in late spring, but grass production is similar among different burn times.

The effects of annual burning at different times on the abundance of warm-season grasses has been mixed but varied among individual species. The preponderance of research agrees that annual burning at any time in the dormant season increases the abundance of big bluestem (*Andropogon gerardii* Vitman), although the largest increases occur from midspring or late-spring burning (Aldous, 1934; McMurphy and Anderson, 1965; Anderson et al., 1970; Towne and Owensby, 1984). Indiangrass (*Sorghastrum nutans* [L.] Nash), another dominant species in tallgrass prairie, declined on upland sites with early-season burning in some studies (Aldous, 1934; McMurphy and Anderson, 1965; Towne and Owensby, 1984) yet either remained stable or increased from burning in other studies (Aldous, 1934; Anderson et al., 1970). The greatest dominance of Indiangrass, however, occurs from annual burning in late spring (Towne and Kemp, 2003; Towne and Craine, 2014). Little bluestem (*Schizachyrium scoparium* [Michx.] Nash) has declined from annual burning in autumn or early spring in some studies (McMurphy and Anderson, 1965; Anderson et al., 1970) but increased in other studies (Aldous, 1934; Towne and Owensby, 1984; Towne and Kemp, 2003; Towne and Craine, 2014). Apparently, the response of little bluestem to burning is strongly dependent on topographic position, increasing with autumn or early-spring burning on upland sites and remaining stable or declining on lowland sites.

Other components of the tallgrass flora are generally reduced by annual late-spring burning. In the Kansas Flint Hills, plant composition studies have indicated that sedges (*Carex* spp.) drastically decline with late-spring burning but increase with annual autumn or early-spring burning (Aldous, 1934; McMurphy and Anderson, 1965; Towne and Owensby, 1984). Perennial cool-season grasses generally respond similarly, but there are some differences among individual species. Prairie Junegrass (*Koeleria macrantha* [Ledeb.] Schult.), a native grass that grows predominantly on upland sites, increases with autumn or early-spring burning and is reduced with late-spring burning (Aldous, 1934; McMurphy and Anderson, 1965; Towne and Owensby, 1984; Towne and Kemp, 2003; Towne and Craine, 2014). The relatively high amount of Junegrass (20%) present in 1926 at the onset of the Aldous (1934) studies indicates a regional legacy of commonplace burning in fall, winter, and early spring (Towne and Owensby, 1984). In contrast to Junegrass, all plant composition studies in the Kansas Flint Hills have reported that Kentucky bluegrass (*Poa pratensis* L.) declines after burning, with the greatest decline from late-spring burning. Other perennial cool-season grass species in the Flint Hills have been too sparse in the research studies to determine with statistical confidence how they respond to season of fire, but they likely all decline with annual late-spring burning.

The response of most perennial forbs to prairie fire varies among species, but because their abundance usually is low and variable in time and space, there has been little consistency among the different studies. Most of the early studies considered all broadleaf forbs as “weeds” and unlikely to be grazed by livestock, so any increase in their abundance from burning was undesirable. Total perennial forb percentages were highest in plots burned in early spring and lowest in plots burned in late spring (Anderson et al., 1970; Towne and Owensby, 1984). However, studies that differentiated forb species have indicated

that only a few species are responsible for those response patterns. Heath aster (*Symphyotrichum ericoides* [L.] Nesom), aromatic aster (*S. oblongifolium* [Nutt.] Nesom), and white prairie clover (*Dalea candida* Michx. ex Willd.) all increase with annual autumn and winter burning but decline with burning in late spring (Towne and Kemp, 2003; Towne and Craine, 2014). In contrast, prairie lespedeza (*Lespedeza violacea* [L.] Pers.) and tall goldenrod (*Solidago canadensis* L.) can increase from burning in any season (Towne and Kemp, 2003; Towne and Craine, 2014). The response of many plants to time of burning has been obscure and varies among locations, but current evidence suggests that at least in ungrazed prairie, annual burning earlier in the spring increases cool-season graminoids and perennial forbs compared with late-spring burning and has little impact on warm-season grasses.

### Woody Species

Burning in late April has been anecdotally promoted as the most effective time to kill woody species. Yet in research experiments, buckbrush (*Symphoricarpos orbiculatus* Moench) was the only woody species that eventually declined with burning in late spring, and that response occurred in ungrazed plots that were annually burned in early May (Aldous, 1934). In grazed pastures where fuel load and completeness of burns are lower than in ungrazed sites, fires conducted in the late dormant season can reduce structural dominance of buckbrush but burning at that time does not cause mortality (Scasta et al., 2014). For most woody species that invade and become established in tallgrass prairie, annual burning in either autumn, winter, or late spring will reduce their cover but not eradicate them (Towne and Kemp, 2003; Towne and Craine, 2014). There are, however, three notable exceptions in the Kansas Flint Hills—eastern redcedar, smooth sumac (*Rhus glabra* L.), and leadplant (*Amorpha canescens* Pursh). Burning at any time will kill eastern redcedar if there is a sufficient understory fuel load, although there is a decrease in fire effectiveness as tree height and crown cover increase (Buehring et al., 1971; Owensby et al., 1973; Engle and Kulbeth, 1992; Hoch et al., 2002). In contrast, smooth sumac either tolerates annual burning or is stimulated by fire at any time in the dormant season (Aldous, 1934; McMurphy and Anderson, 1965; Anderson et al., 1970). Burning in autumn will not reduce smooth sumac stem numbers, but it can reduce seed production (Hajny et al., 2011). Leadplant is also tolerant of fire at any time (Towne and Owensby, 1984; Towne and Kemp, 2003) and often increases from annual spring burning, particularly in pastures grazed by stocker cattle (Anderson et al., 1970; Towne et al., 2005). Frequent burning is the most important factor in forestalling invasion of woody plants (Bragg and Hulbert, 1976), but if woody species become established in native grasslands, there is no scientific data indicating that burning in late April is inherently superior in controlling them compared with burning at other times in the dormant season.

### Animal Performance

The primary impetus for many ranchers to routinely burn their prairie is based on improving animal performance. Stocker cattle gain more weight if a pasture is burned than if it is not burned (Owensby and Smith, 1979; Svejcar, 1989). However, only one study has compared animal performance in pastures that were burned at different times in the dormant season. In a 16-year grazing trial conducted in unreplicated pastures that were burned annually in early, mid-, and late spring, Anderson et al. (1970) concluded that monthly weight gains of steers were lower on a pasture burned in early spring than on a pasture burned in late spring. That conclusion solidified the traditional concept that Flint Hills pastures should only be burned in late spring.

Several aspects of that study, however, are problematic and raise questions about the veracity of their conclusions. As in other studies that formed the foundation for burning Flint Hills grassland in late spring, there was no spatial replication of the treatments and no

pretreatment data. In addition, there was a contradiction between the text and the graphics on how time of burning affected animal performance. The authors stated that “late-spring burning increased steer gains over early-spring burning” (p. 90), but their accompanying graph indicated that monthly gains throughout the grazing season did not statistically differ among any of the burned pastures when years were used as a statistical replicate. The only difference in monthly steer gains among treatments occurred between the pasture that was not burned and the other burned pastures (Fig. 1). In order to more emphatically illustrate differences in cattle gains from date of burning, the monthly data were subsequently revised and graphically presented in extension articles and conference proceedings as total gain over the entire grazing season (Owensby and Smith, 1972; Launchbaugh and Owensby, 1978; Ohlenbusch and Hartnett, 2000). In those reports, cattle gain was purported to average 10 kg more in a pasture burned in late spring than in a pasture burned in early spring. However, because the study was pseudoreplicated, any differences among treatments could have been due to site variation and there is no evidence that the differences in total weight gain were statistically significant. In addition, because interactions between individual years and burn treatments could not be tested, readers were led to assume that the average results for all treatments would be applicable every year. Yet it was subsequently acknowledged that results varied among years, including 4 years in which cattle weight gains in the unburned pasture were equal to or greater than the pasture burned in late spring (Smith and Owensby, 1972).

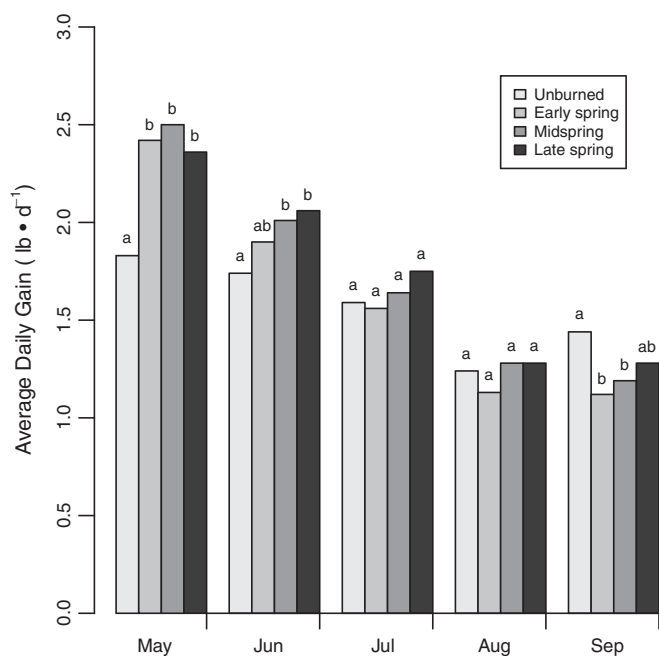
Another questionable issue in the Anderson et al. (1970) study was how the steers were managed both before and after the pastures were burned. Cattle were released on all pastures at the same time each year, thereby negating a potential benefit of burning early in the spring since the earlier emergence of high-quality forage was not being utilized. Although not reported in the Anderson et al. publication, in 12 years of the study, the animals were released on pasture 7 days or less after the late-spring burn (Kansas Agricultural Experiment Station Annual Livestock Feeders' Day Reports, 1951–1966). In 4 of those years, the animals were released the same day or the day after the late-spring burn, and in one year (1965) the animals were turned out

4 days before the pasture was burned (Table 1). This raises questions of what the cattle were eating in the late-spring burned pasture before the new spring growth emerged. Depending upon precipitation and temperature, it usually requires 10–14 days after burning before there is sufficient new growth to support grazing at a moderate stocking rate (E.G. Towne, personal observations). Whether the animals were surreptitiously supplemented or subsisted by picking from remnant forage in small unburned patches before growth of the warm-season grasses is unknown. Either way, animal performance in the pasture burned in late spring likely would have been negatively affected in the early part of the growing season in many of the years. Although research on time of burning in grazed prairie is sparse and potentially misleading because of insufficient statistical analyses, claims that cattle gains will be reduced if pastures are burned early in the spring cannot be substantiated.

### Challenges to the late-spring burning tradition

Following the Anderson et al. (1970) publication, the issue on time of burning was considered resolved and further research ceased except for an updated summary of treatment means in the Aldous plots (Towne and Owensby, 1984). The concept that late April was the only acceptable time to burn tallgrass prairie went unchallenged and became embedded in the cultural practices of grassland management for the Kansas Flint Hills. Rhetoric from university outlets, local media, and the popular press reinforced public perception on the “best” time to burn with continual cautions of dire consequences if burning was conducted earlier in the spring (Owensby and Smith, 1972; Smith and Owensby, 1972; Launchbaugh and Owensby, 1978; Ohlenbusch and Hartnett, 2000; Blocksome, 2011).

By the turn of the 21st century, however, statistically supported research indicated that annual burning in autumn (November) or winter (mid-February) did not cause the adverse repercussions on biomass production and species composition compared with burning in late spring that had been predicted in all previous studies (Towne and Kemp, 2003). These results challenged the traditional tenet that late spring was the best time to burn prairie, and a subsequent 20-year study on annual burning confirmed that there were no differences in biomass production among autumn, winter, and late-spring burn treatments on either upland or lowland topographic positions (Towne and Craine, 2014). Many landowners, however, are hesitant to adopt rangeland management practices that differ from tradition (Morton et al., 2010), and because those studies were conducted on ungrazed prairie, their relevance to most Flint Hills pastures generally has been repudiated. Nevertheless, almost all research comparing the



**Fig. 1.** Monthly cattle gains in unreplicated pastures burned in early spring, midspring, and late spring compared with an unburned pasture over 16 years, as reported in Anderson et al. (1970). Weight gains for treatments with the same letter above the bar do not differ significantly ( $P > 0.10$  when using years as a replica).

**Table 1**

Burn dates for the early-spring (ES) burned pasture, midspring (MS) burned pasture, and late-spring (LS) burned pasture, and the date cattle were released in the Anderson et al. (1970) study. Dates were not reported in the study but were derived from Kansas Agricultural Experiment Station Livestock Feeders' Day annual reports.

Year	ES burn	MS burn	LS burn	Cattle released
1950	24 Mar	13 Apr	2 May	8 May
1951	22 Mar	13 Apr	25 Apr	10 May
1952	26 Feb	7 Apr	28 Apr	5 May
1953	13 Mar	9 Apr	30 Apr	4 May
1954	23 Feb	10 Apr	24 Apr	11 May
1955	8 Mar	1 Apr	25 Apr	28 Apr
1956	8 Mar	10 Apr	28 Apr	29 Apr
1957	16 Mar	10 Apr	1 May	11 May
1958	21 Mar	11 Apr	1 May	1 May
1959	21 Mar	10 Apr	30 Apr	5 May
1960	7 Apr	7 Apr	4 May	4 May
1961	3 Mar	6 Apr	28 Apr	3 May
1962	19 Mar	10 Apr	2 May	2 May
1963	14 Mar	8 Apr	25 Apr	7 May
1964	31 Mar	8 Apr	30 Apr	5 May
1965	7 Apr	7 Apr	3 May	29 Apr

effects of burning at different times in the dormant season has been conducted in ungrazed prairie.

Despite long-standing recommendations that prairie burning should only occur in late spring, there are some disadvantages to burning at that time that were never addressed in the studies that promoted it: 1) Burning in late April logistically restricts the rancher to burn within a narrow window of time when environmental conditions may not always be favorable. For example, wet or windy weather could extend burning into May, or a warm April may stimulate early grass growth to the point where any burning becomes impractical. Weather in late spring is often volatile, and there are only a limited number of days when conditions are favorable for burning (Weir, 2011). Thus conducting burns earlier in the season would increase the number of potential burnable days and ensure that burning gets done. 2) Burning in late April often negatively affects ground-dwelling wildlife. Snakes and tortoises normally have emerged from hibernation in late April, and they, as well as clutches of ground-nesting birds, are susceptible to mortality from fire at that time (Erwin and Stasiak, 1979; Robel et al., 1998; Hailey, 2000; Reinking, 2005; Augustine and Sandercock, 2011). In contrast, herpetofauna are protected within hibernacula from fires that occur earlier in spring (Cavitt, 2000). 3) By blackening the soil surface, burning earlier in the spring can create a microenvironment that is favorable to earlier emergence of grass tillers (Old, 1969; Knapp, 1984; Ojima et al., 1994), thereby lengthening the growing season and potentially allowing cattle to be turned out sooner. 4) Although the early studies on plant composition from burning early in the spring considered any increase in sedges, cool-season grasses, and perennial forbs as undesirable, that response could actually be beneficial. Promoting greater phenological diversity by not burning exclusively in late spring potentially could provide high forage quality for livestock, both early and late in the growing season. 5) Since the 1970s, recommendations have been to burn when the dominant warm-season grasses have emerged 1.25–5 cm above the soil (Ohlenbusch and Hartnett, 2000; Blocksome, 2011). Yet burning at that time removes highly nutritious new grass and represents lost productivity and forage quality (Rao et al., 1973). 6) Lastly, burning in late April after the new grass has emerged can exacerbate air pollution emissions because green vegetation has higher moisture and nitrogen content than senesced biomass, which facilitates ozone production when burned and combined with warmer temperatures and insolation (Kuhlbusch et al., 1991; Lacaux et al., 1996; Andreae and Merlet, 2001). With recommendations to burn only in late April, numerous ranchers throughout the Flint Hills burn their pastures in unison within a narrow time frame. The resultant concentrated smoke production often causes ozone levels in downwind cities to exceed threshold levels that foster antiburn sentiments in urban communities (Kansas Department of Health and Environment, 2010; Liu, 2014; Kansas Flint Hills Smoke Management, 2015).

### Management implications

The research studies from the 1930s through 1970, which were the foundation for the current recommendation on time of burning in the Kansas Flint Hills, all represented experiments that were not sufficiently replicated for meaningful statistical analysis. We are unaware of any other studies in the rangeland ecology and management literature, or other natural resource disciplines, where data from unreplicated treatments from more than 40 years ago has been so readily accepted and has had such an enduring impact on management recommendations. Revealing some of the inherent limitations in the historical studies should help generate questions about current management practices and stimulate additional research into burning tallgrass prairie at times that are different than what has been traditionally recommended. With the advent of long-term replicated research on burning, there is sufficient evidence to conclude that previous condemnation of early-season burning is not justified, and there is not a “best” time to burn Flint Hills prairie. Yet burning earlier in the year has not been commonly

accepted as a potential option in managing smoke emissions because of deep-rooted tradition and fear of potential biological or economical repercussions. Although the objective of this review was to critique the burn research from decades ago, it also reveals that there is a paucity of information on burning at alternative times in grazed pastures, especially on animal performance measurements. In stark contrast to the prevailing philosophies on time of burning in Kansas, burn recommendations in the Oklahoma Flint Hills have long recognized a less ardent attitude on when pastures should be burned (Engle and Bidwell, 2001; Bidwell et al., 2013a, 2013b). Burning earlier in the spring may be a potential viable option in Flint Hills prairie management that could increase flexibility in managing grasslands, promote biodiversity, and help minimize air quality issues. However, the limitations and subjective conclusions of the old studies cannot be regarded as a reliable metric for when tallgrass prairie should or should not be burned.

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