



Prescribed Fire Monitoring Report

*Tallgrass Prairie National Preserve (IQCS fire number:
218957, 219127, 220479)*

Natural Resource Data Series NPS/HTLN/NRDS—2013/425



ON THE COVER

The fireline at sunset at Tallgrass Prairie National Preserve.

Photograph by: Sherry Leis, Fire Ecologist filed in the HTLN archives.

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The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Acknowledgments

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List of Acronyms

<u>Term</u>	<u>Definition</u>
AAR	After-Action Review
ENGB	Engine Boss
FL	Flame Length
FDFM	Fine Dry Fuel Moisture
FEMO	Fire Effects Monitor (operational position)
FF	Fire Fighter
FIRB	Firing Boss
FZD	Flame Zone Depth
HTLN	Heartland Inventory and Monitoring Network
IC	Incident Commander
RAWS	Remote Automated Weather Station
RH	Relative Humidity
ROS	Rate of Spread
RxB2	Prescribed Fire Burn Boss Type 2
TAPR	Tallgrass Prairie National Preserve, also preserve
TNC	The Nature Conservancy

Burn Operations Summary

During the spring 2012 prescribed burn season at Tallgrass Prairie National Preserve (TAPR), 2,163 acres were burned. Burns at TAPR were coordinated with local US Fish and Wildlife Service (USFWS) fire staff and staff from The Nature Conservancy (TNC). Burns planned for spring 2012 were Big Pasture-Middle, Crusher Hill Pasture, East Traps, Two Section, Bottomland restorations, and the area around the bison handling facility (including West Traps North). Burns in the eastern pastures (East Traps and Two Section) were taken off the schedule due to site conditions and management constraints. Four successful days of burning occurred with one additional day where the test burn indicated poor burning conditions. This report will focus on the Big Pasture-Middle and Crusher Hill Pasture burns.

Big Pasture Middle (IQCS # 218957) March 30, 2012

Heavy dew was present in the morning until approximately 0930 hrs. A briefing occurred at 1100 hrs in the staging area in the lower parking lot near KS Hwy 177 at TAPR. Plans were to burn Big Pasture-Middle in two parts. Unit 1, the linear, western-most section, west of the tour road was to be completed first (Figure 1). As winds were predicted to shift during the day, burning would also shift to Unit 2, the largest portion of Big Pasture-Middle (Figure 1).

A test fire was ignited at the southwest corner of Unit 1 at 1222 hrs (Figure 1). A ring fire technique with stripping modifications was used. The west crew proceeded to the west, then north, along the pasture boundary fence. The east crew proceeded north along the two track road. The majority of grasses along the burn lines in the test fire area were green. As a result, burning began slowly. However, as flames reached greater fuel loads and dryer fuels, fire behavior increased. Fire and ash whirls were common along the western side of Unit 1. A spot fire resulted from one of these whirls. A quick response was initiated and the spot fire was kept to > 0.5 acre. The unplanned area burned was in Windmill Pasture, on the south side of the fence from Unit 1. Winds began to shift before Unit 1 was completed. Heavy smoke occurred on the fire lines at times.

Burning on Unit 2 started at 1620 hrs (Figure 1). A ring fire technique was applied to this unit as well. Smoke dispersal was good during much of the afternoon but varied with the amount of area actively burning area at any given time. A pyrocumulus cloud was observed above the smoke column during the afternoon. Staged water supply engines were moved to strategic locations throughout the burn. The east and southeast boundary of the unit presented some terrain challenges. The burn line had considerable relief and was rocky and included muddy stream crossings. The east firing crew on unit 2 had less difficult terrain to cover and reached drop point D well ahead of the west crew. The northward progression of the fire was impeded in places by a stream requiring additional ignitions from an utility terrain vehicle (UTV). Firing and perimeter mop-up was completed and crews held a brief after action review (AAR) before departing the preserve about 2400 hrs.

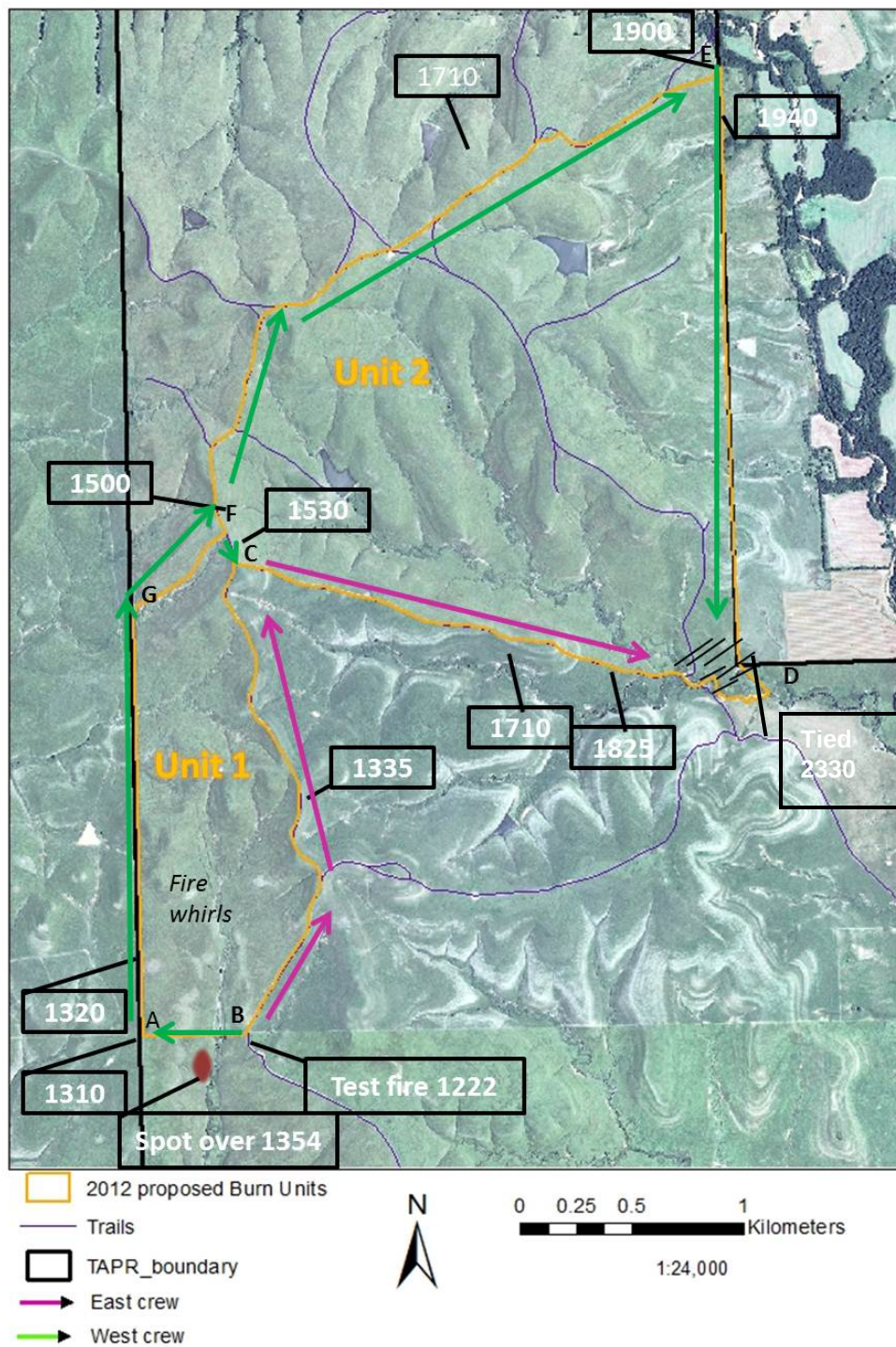


Figure 1. Ignition progression for Big Pasture-Middle Unit at Tallgrass Prairie National Preserve, Kansas on March 30, 2012. Pink arrows indicate path of east Team and green indicates west team. Hatching at point D indicates stripping.

Crusher Hill Pasture (IQCS # 219127) March 31, 2012

Crews planned to burn Crusher Hill Pasture in the afternoon, because adjoining property owners planned to burn that day. The burn was declared an “incident”, designed to protect the preserve from probable trespass fire. Ignition began from the northeast corner of Crusher Hill Pasture near KS Hwy 177. While fuels were burnable, high winds and low moisture made it difficult to control the fire. At the urging of the incident commander, both the fire on the preserve and adjoining private land were extinguished.

Crusher Hill Pasture (IQCS # 220479) April 10, 2012

A briefing was held at 1530 hrs near the Ranchhand House. Because of the predicted weather for the day and features of the unit, only the eastern two-thirds of Crusher Hill Pasture were burned. A creek entered the unit from the south side of the property running northwards to a limestone chipped trail. The trail could then serve as the fire line up to the pasture gate where the fire would be lit on the south side of the pasture fence (bordering Crusher Hill and Red House Pastures) along a mow line to KS Hwy 177. Operations included an ignitions crew and suppression crew. The group worked only one fireline at a time rather than the usual ring fire technique (Figure 2). The south side of the pasture was very green and the moist riparian area held the fire. Despite the sinuosity of the creek, it served as an adequate fireline. Care was taken in switchback areas to avoid sending unwanted head fires towards sensitive areas (firelines or crews). Areas along the creek bed contained damaged trees with potential for falling branches. Extra precaution was taken in these areas. A lookout was posted near the southwest portion of the fireline until the area was safe.

Once ignitions reached a safe portion of the limestone chipped trail the cattle Lessee’s land manager led ignitions using an ATV (all-terrain vehicle) mounted firestick (Figure 2). Agency ignitions crews followed up to improve the flame front and black safe zone. Suppression forces worked diligently to put out smoking cow pies as they have been known to start unwanted fires. Once the eastern boundary of the preserve was reached, ignitions proceeded south along the fence running parallel to KS Highway 177 and along trails in the interior of the unit. Neighboring fires crossed onto the preserve along the south and southwest border of the pasture.

An AAR was conducted when the unit was declared safe to leave at 2020 hrs. The IC noted communication would have been improved if all igniters had a radio. The IC also related that he became more comfortable with the western fireline (creek) as ignition progressed, and crews agreed that ignition along the draw was more effective than anticipated. The ignition crew was effective at spotting hazards and situations that required adjustment. The TAPR UTV pump unit requires repair, but other equipment operated normally.

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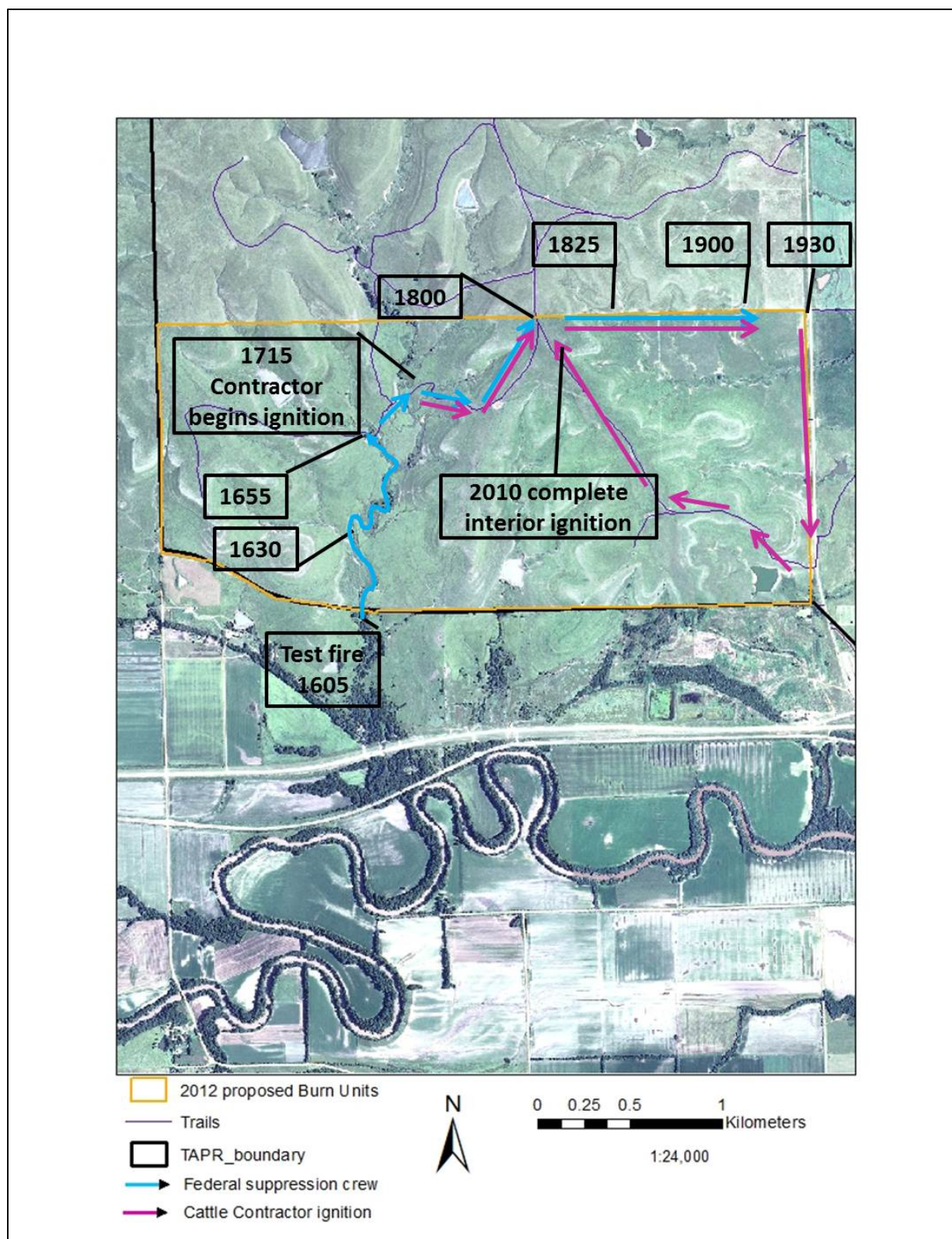


Figure 2. Ignition progression for Crusher Hill Pasture at Tallgrass Prairie National Preserve, Kansas on April 10, 2012. Blue line indicates ignition and suppression by federal crews. Pink pathway indicates ignition lead by cattle contractor.

Burn Unit Measurements

Big Pasture-Middle Unit Measurements (IQCS # 218957)

Date: 3/30/12

Size: Total planned acres = 1392.0

Total burned acres = 1379.8

Vegetation type: (Beacham 2011, based on Scott and Burgen 2005): Tallgrass prairie (fuel models GR5, GR6)

Personnel: (see Acronyms for qualification definitions):

Burn Boss: Jason Pankratz RXB2

FEMO: Sherry Leis, Chris Kopek FEMO

East team: Deon Steinle, Team Leader, FIRB

Ignitions: Darin Raditz, Iain Mason, Vanessa Brooks, Josh Meggers, Adam Throckmorton

Suppression: Dustin Jacob UTV lead, Vic Elam UTV, Brian Obermeyer ATV, TJ Cooper UTV, Cole Starkey UTV,

Mobil refill: Daniel Tuthill

West team: Tim Menard, Team Leader, FIRB

Ignitions: Erik Lindsay, Mathew Bernhardt, Chris Mouzacitis, D. Pieknik

Suppression: Dave McCauley UTV lead, Taylor Easley UTV, Kristen Hase UTV, Bruce Childers UTV

Mobil refill: Paula Matile and Jim Hays

Crusher Hill Pasture Measurements (IQCS #219127, and 220479)

Date: 4/10/12

Size: Total planned acres = 1339.1

Total burned acres = 723.1

Vegetation type: Tallgrass prairie (fuel models GR5, GR6)

Personnel: (see Acronyms for qualification definitions):

IC: Jason Pankratz

FEMO: Sherry Leis

Ignitions: Chris Kopek FFT1(t), Daniel Tuthill FF, Lessee Contractor

Suppression: Kristen Hase, Tim Menard FF, Dustin Jacob FF, Brian Obermeyer FF.

Mobil refill: Paula Matile

Burn Unit Goals

Goals were taken from the burn plan (Beacham 2011).

1. Increase biological diversity by promoting varied plant structure to improve wildlife habitat by implementing a varied fire and grazing regime.
2. Secondary objectives include controlling woody and undesirable vegetation, removing dead or old growth vegetation build-up, promoting re-growth of warm season grass species, and increasing native plant diversity.

Prescription

Table 1. Tallgrass Prairie National Preserve 2012 prescribed fire environmental prescription. The full prescription can be found in the burn plan (Beacham 2011).

Variables	Low Fire Intensity	Desired Fire Intensity	High Fire Intensity
Relative Humidity	60	30-45	25
Wind Direction	N/A	Keep smoke off K-177, US 50 and Strong City	N/A
Wind Speed (midflame)	5	7-10	15
Fuel Moisture (%) 1-hour	12	8	6
Live Fuel Moisture	75	60	30
Minimum mixing height	2,000 ft above ground level		

Table 2. Tallgrass Prairie National Preserve 2012 prescribed fire behavior prescription. The full prescription can be found in the burn plan (Beacham 2011).

	Fuel Model	
	GR5 (#105)	GR6 (#106)
Surface Rate of Spread (ch/h)	370	581
Headfire Flame Length (ft)	24	33
Backfire Flame Length (ft)	3	4
Backfire Rate of Spread (ch/h)	5	7

Methods

Fire ecology monitoring has occurred at TAPR since 2010. Monitoring involves collecting a suite of data that are used to evaluate the effectiveness of fire use on the landscape. Monitoring includes documenting the fire environment (weather, fuels, topography), fire behavior (manner and rate of spread, flame length, etc.), and fire effects (percent of fuels consumed, changes in plant and animal community composition and structure, etc.). Data collected include fuel load, fuel moisture (1-hr and 10-hr), soil moisture, burn day weather, fire behavior, smoke observations, and fire severity. Sampling methods for fire ecology monitoring are described in detail in Fire Ecology Monitoring Protocol for the Heartland Inventory and Monitoring Network (Leis et al. 2011).

Fuel load monitoring was conducted on July 27, 2011 for Big Pasture-Middle (6 sites), Crusher Hill (5 sites), East Traps (3 sites), and Two Section (5 sites) pastures (Leis et al 2011; SOP 7) (Figure 5 and Appendix A). We expect a 10-20% degradation of the fuel bed over the winter months; however, the anticipated degradation is within the measurement error of most pastures at TAPR (personal communication C. Owensby 2010). Because of varying firing and grazing management practices by pasture, a one way Analysis of Variance (ANOVA) was used to determine if there were differences in fuel loads among pastures, followed by an evaluation of all possible pairwise comparisons of pastures using the Least Significant Difference criterion in SPSS (SPSS Inc. 2008)

Fuel moisture data was collected pre-burn on March 30, 2012 for Big Pasture-Middle and April 10, 2012 for Crusher Hill Pasture. Fuel moisture sampling for Big Pasture-Middle was modified because of site conditions and time constraints. Thus, only one site was sampled for fuel moisture and the mean moisture for that site was used to gauge the 1-hr fuel moisture levels for that day.

Soil moisture is not as sensitive to dew and does not adjust as rapidly to atmospheric conditions, so we were able to collect it on all visited sites both days. Pre-burn monitoring for the Crusher Hill incident occurred on the morning of April 10, 2012. 10-hr fuel moisture values were taken from both the Remote Automated Weather Station (RAWS) (March 30, 2012) and 10-fuel stick (April 10, 2012).

Burn day weather and fire behavior data were collected by the designated FEMO (see Burn Unit Measurements section). Data collected included temperature, relative humidity, and wind speed and direction (Table 7, 8). A Remote Automated Weather Station (RAWS; TGSK1) is located at the preserve and was cross referenced for accuracy of field measurements.

GPS collection of the preserve-wide burn perimeter was completed by preserve staff between April 6 and 27, 2012 (Figure 5). Minimum mapping units were set at 1-acre (SOP 3, Leis et.al. 2011). Burn perimeters were walked or driven (UTV) as soon after burning as possible, depending mostly on staff availability. GPS coordinates were taken using a Garmin Map 60Cx. The coordinates were recorded in a geodatabase using the Fire Incident Management Tool (USDA Forest Service 2007).

Fuel moisture affects fire behavior and potentially fire severity. Simple linear regression analyses were used to determine relationships of the response variable fire severity to predictor variables fuel moisture, soil moisture, and fuel load (SPSS Inc. 2008). Alpha was set at 0.05 for determination of significance on all tests and a Bonferroni adjustment was applied to correct for multiple comparisons where needed (SPSS Inc. 2008).

Post-burn monitoring was completed on March 31 and April 11 for Big Pasture-Middle and Crusher Hill Pasture, respectively (Leis et al. 2011; SOP 13) (Appendix A). Mean fire severity rankings for each site were used to infer fuel reduction. Proportions of categories for severity were assigned a fuel reduction percent and the sum for all the sites was converted to percent. Substrate fuels (litter, duff, soil surface) considered to be eliminated were in severity class 1, 2, and 50% of class 3; while vegetation fuels (standing plant matter) in severity class 1, 2, and 75% of class 3 were considered eliminated. The sum total for all sites was converted to a percentage for both substrate and vegetation to infer fuels reduced.

Results

Fuel Load

The 2012 preserve-wide mean fuel load was 0.4 tons/acre less than in 2011 but within measurement error (Table 3). However, East Traps and Two Section were 0.8 and 1.0 tons/acre less than in 2011 (Figure 3). Interestingly, Crusher Hill had greater fuel loads in 2012 than when previously measured in 2010 (Figure 3). Mean fuel loads differed significantly among pastures (ANOVA results: $P < 0.0001$, $F = 34.44$, $df = 75$) and were lower in the east pastures (East traps and Two Section) than in the west pastures (Big Pasture-Middle, Crusher Hill Pasture) of the preserve in 2012 (Table 4). All pastures were significantly different from each other by the multiple comparisons procedure with the exception of East Traps and Two Section (Table 5).

Table 3. Fuel load trends for Tallgrass Prairie National Preserve, Kansas (2010 – 2012).

Preserve mean fuel load Tons/acre	Sample year	Burn year
2.0 (± 1.0)	2011	2012
2.5 (± 0.4)	2010	2011
1.6 (± 0.7)	2010	2010

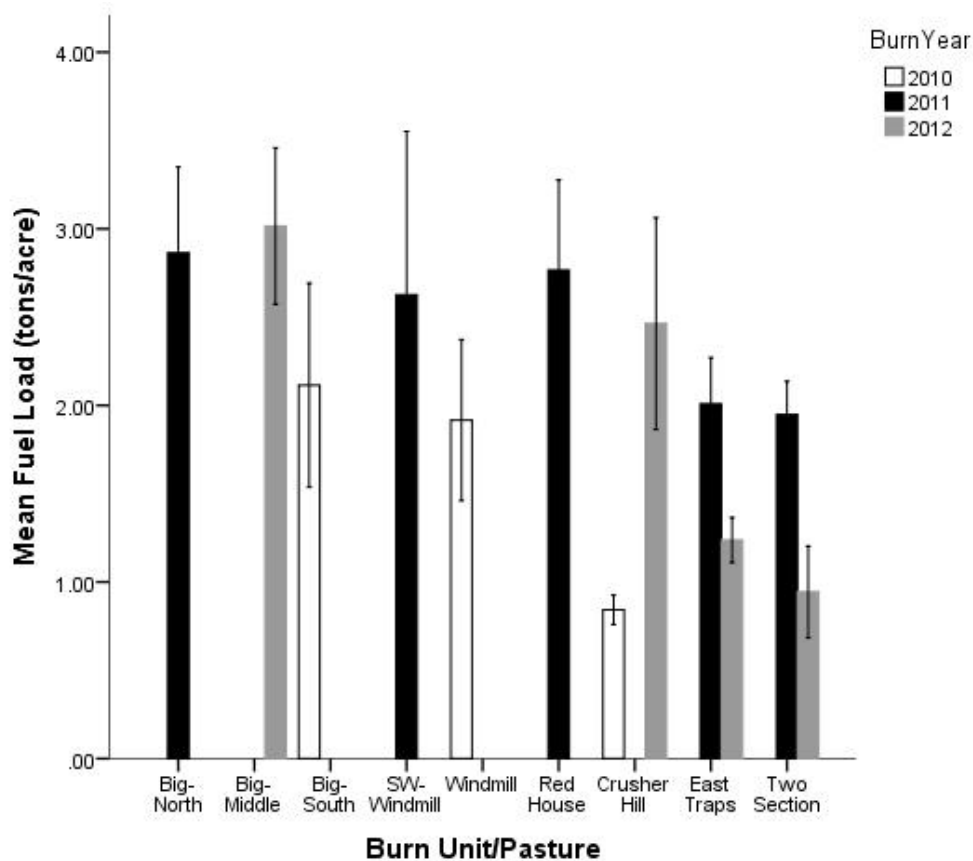


Figure 3. 2010-2012 fuel loads for burn units at Tallgrass Prairie National Preserve, Kansas. Error bars are ± 1 SD.

Table 4. Estimated 2012 mean fuel load values by burn unit for Tallgrass Prairie National Preserve, Kansas. Fuel load includes standing live, standing dead, as well as litter, and duff. Samples were taken in August 2011.

Burn Unit	Time since last burn (yrs)	N	Mean ton/acre	Stdev (ton/acre)
Big Pasture-Middle	2.7	6	3.0	0.4
Crusher Hill	1.7	5	2.5	0.6
East Traps	0.7	3	1.2	0.1
Two Section	0.7	5	0.9	0.3
Preserve		19	2.0	1.0

Table 5. Least significant difference comparisons for fuel load values by burn unit for Tallgrass Prairie National Preserve, Kansas, 2012.

(I) Pasture	(J) Pasture	Mean Difference (I-J)	Std. Error	Sig.
Big-Middle	CrusherHill	0.55	0.23	0.02
	EastTraps	1.78*	0.27	0.00
	TwoSection	2.07*	0.23	0.00
Crusher Hill	BigMiddle	-0.55	0.23	0.02
	EastTraps	1.23*	0.27	0.00
	TwoSection	1.52*	0.24	0.00
East Traps	BigMiddle	-1.78*	0.27	0.00
	CrusherHill	-1.23*	0.27	0.00
	TwoSection	0.29	0.27	0.29
Two Section	BigMiddle	-2.07*	0.23	0.00
	CrusherHill	-1.52*	0.24	0.00
	EastTraps	-0.29	0.27	0.29

*. The mean difference is significant at the 0.05 level, with Bonferroni correction $\alpha = 0.004$.

Soil Moisture

Soil moisture may affect fire severity by contributing to moisture within the duff and litter layers. Soil moisture was relatively consistent throughout the preserve in spite of the difference in time between sampling dates. Soils were moist, but not saturated (Table 6). Soils were slightly drier in 2011 (mean: 34.7% (± 5.2); Leis and Kopek 2012).

Table 6. Soil moisture prior to prescribed fires on March 31 and April 10, 2012 at Tallgrass Prairie National Preserve, Kansas. Volumetric soil moisture of 50% is considered a saturated condition, while 25% is the field capacity for plant available water and 10% indicates the permanent wilting point for plants.

Sample Date	Burn Unit	N	Mean Volumetric Moisture (%)	Stdev
March 31, 2012	Big Pasture-Middle	5	36.9	9.1
April 10, 2012	Crusher Hill	5	39.6	8.9
	Preserve	10	38.3	8.6

Fuel Moisture

Fuel moisture in Big Pasture-Middle was only collected at one site because of time and weather constraints (Table 7). While drawing conclusions from one sample site would be tenuous, moisture at this site was in the low fire intensity range of the prescription (Table 1; Beacham 2011). The most recent measureable precipitation prior to the burn was 11 days prior, but heavy fog occurred the morning of the Big Pasture-Middle burn.

Fuel moisture in Crusher Hill Pasture was much greater than the prescription for 1-hr fuels required, however, informal estimates of the percent cover of green fuels in sample plots varied from 5-60%. While green fuels were not measured separately, they likely contributed to greater moisture values. Additionally, the most recent rain was three days prior to the burn, which contributed to the higher fuel moisture values.

Table 7. 1-hr fuel moisture prior to prescribed fires at Tallgrass Prairie National Preserve, Kansas 2012. Fuel moisture samples included both live and dead materials from the standing and litter portions of the fuel bed.

Sample Date	Site	N	Mean moisture (%)	Stdev
March 31, 2012	Big Pasture-Middle	1	14.4	3.6
April 10, 2012	Crusher Hill	5	31.3	12.5
	Preserve	6	28.5	13.1

- 10 hr fuel moisture via RAWS station March 30 at 1200: 9.6%
- 10 hr stick April 10th at 1330: 10%.

Weather Observations

For both burn days, onsite weather observations (relative humidity (RH) and winds) during the burns (Table 8, 9) fell in the desired range of the environmental prescription model (Table 1;

Beacham 2011). Winds were favorable for controlling the fire and keeping smoke off of highways and sensitive areas both days.

However, Fine Dead Fuel Moisture calculated from weather variables varied from the low to desired ranges for Big Pasture-Middle, but were mostly in the high range for the Crusher Hill Pasture burn. The calculated fuel moisture likely varied considerably from the sampled fuel moisture for the Crusher Hill Pasture burn because of the increased proportion of live fuels (Table 6, 8). Sampled fuel moisture collected the morning of the Crusher Hill Pasture burn was 27% greater than values calculated by the FEMO during the burn. Samples were estimated to include a range of live fuels from 5-60%.

Table 8. Weather observations on March 30, 2012 during the Big Pasture-Middle burn at Tallgrass Prairie National Preserve, Kansas. FDFM was calculated using the Fire Line Manual Appendix B (2006). Refer to fire the progression map (Figure 1) for location reference points.

Time	Location	Temperature (°F)		Dew Point	RH	Wind (mph)		Fine Dead Fuel Moisture (%) (Unshaded)	Prob. Of Ignition %	Comments
		Dry	Wet			Speed*	Direction			
0730	Near pond by sites 61, 57	55	55	55	100	5.4 (9)	NW	17	10	
0820	Hillside by site 57	59	57	56	89	2.1(7.7)	NW	16	10	
0908	Above pond by site 68	60	58	57	88	5.1(6.6)	N	16	10	
1200	Test fire	75	61	52	44	5(9.5)	NW	11	30	
1300	.	79	61	49	35	5(6)	N	9	40	
1400	E line before pt C	90	60	46	30	6.7(9.2)	NE	9	40	
1500	E line 300 m before pt. C	81	60	45	28	4(6.7)	E	8	40	
1600	Pt. C	82	60	44	27	3.5(4.7)	E	8	40	
1710	Half way to pt E	79	61	61	35	4.5(6.6)	E	9	40	
1800	Final intersection before pt. E	72	60	52	50	6.3(8.8)	SE	11	30	Inaccurate reading.
1900	Corner that heads E	75	60	50	42	5.0(6.6)	SE/E	10	30	
2000	Pt. E	68	57	49	51	.	.	11	20	

*Wind speed given as mean speed (gust).

(.)Indicates missing data

Table 9. Weather observations on April 10, 2012 during the Crusher Hill pasture burn at Tallgrass Prairie National Preserve, Kansas. FDFM was calculated using the Fire Line Manual Appendix B (2006). Refer to fire the progression map (Figure 2) for location reference points.

Time	Location	Temperature (°F)		Dew Point	RH	Speed*	Wind (mph) Direction	Fine Dead Fuel Moisture (%) (Unshaded)	Prob. Of Ignition %	Comments
		Dry	Wet							
1140	Windmill gate	61	47	31	33	8-9(11)	E	6	50	
1300	Windmill gate	64	48	30	28	9-10(13)	E	6	50	
1410	Windmill gate	64	49	33	31	2-3(5)	E/NE	6	50	
1602	Test fire	67	51	39	36	5(7)	E	7	50	
1702	Half way to E turn	67	50	32	28	5.1(8)	NE	6	50	No shade
1800	.	62	49	36	38	2.7(5.5)	NE	7	50	
1900	W of last drainage on N line	60	48	36	40	3.9(5.3)	NE	7	50	

*Wind speed given as mean speed (gust).

(.)Indicates missing data

Smoke Observations

Smoke was within the desired environmental prescription of the burn plan (Beacham 2011). Smoke was heavy on the firelines at times, but did not impact sensitive resources such as roads and communities either burn day (Table 10, 11). Elevation of the smoke column is difficult to estimate. Some estimates were made relative to the cloud deck which is related to the mixing height where upper level winds carry smoke away. Mixing height was predicted to be 300-1900 ft in the morning and late evening hours, increasing to 4200-4700 ft in the afternoon and early evening.

Table 10. Smoke observations during the Big Pasture-Middle burn at Tallgrass Prairie National Preserve, Kansas on March 30, 2012.

Time	Location	Elevation of smoke column	Column direction	Fireline visibility	Roadway visibility	Comments
1245	N of pt. B	~100 ft, low	S/SE	30 ft	No impact on highway	Dispersion away from line.
1300	Half way to tour loop	1000 ft	SE	100ft	Same	
1320	Near pt. A, west line	Near cloud base	SW	Varies depending on wind gusts	Same	Column not well formed.
1340	.	At cloud base			Same	Column formed vertically
1540	N of extension	Mixing height	W	Varies on west line	Same	
1635	N of pt. C, Main Unit	Not well formed	NW	50ft	Same	
1815	Spur to complete N line to pt. E.	Mixing height	NW	Unlimited	Same	
1837	250 yd from pt. D	Cloud height	NNW	Unlimited	Same	Pyrocumulus cloud
2008	200 yd N of pt. D	1500	WNW	Unlimited	Same	

Table 11. Smoke observations during the Crusher Hill Pasture burn at Tallgrass Prairie National Preserve, Kansas on April 10, 2012.

Time	Location	Elevation of smoke column	Column direction	Fireline visibility	Roadway visibility	Comments
1615	Test fire	Low, <100 ft	W	Unlimited	No roadway in unit	Column poorly formed.
1655	Half way to E turn	Just below cloud deck	W/SW	Unlimited		Good dispersal
1735	Near trail marker	~500 ft	W			Column poorly formed
1745	.	Cloud level				Column formed
1835	Before drainage along N unit boundary	~500 ft	W			Column is formed in a line

Fire Behavior

Surface rates of spread (ROS; Table 12, 13) for both fires were less than the prescribed model and backfire rates of spread were within prescription with two exceptions (Table 2; Beacham 2011). Flame lengths (FL) for headfires of both burns were shorter than the model prediction. Backfires varied from 1 to 6 ft during the Big Pasture-Middle burn (March, 30, 2012, but only one backfire flame length was taken during the Crusher Hill Pasture burn April 10, 2012. Despite many of the mild ROS readings, fire and ash whirls were seen throughout the Big Pasture-Middle burn, especially during the first two hours. These whirls may have resulted from a combination of adequate fuel loads and shifting winds along the hilly topography. The fire intensity calculations depict a great deal of variability which included both high and low intensities. Furthermore, enough heat was generated over a long enough period to temporarily support the formation of a pyrocumuluous cloud. The Crusher Hill Pasture burn was also variable, but was less intense overall (Table 13).

Table 12. Fire behavior for Big Pasture-Middle burn at Tallgrass Prairie National Preserve, Kansas March 30, 2012. Intensity was calculated using the formula $3(10FH)^2$. All measurements were taken in fuel models GR 105, 106.

Time	Location	Fire type	ROS (Ch/hr)	FL (ft)	FH (ft)	FZD (ft)	Fuel model	Intensity (Btu/ft/s)
1220	N of pt. B	B/F	4.5	2	1-2	<1	GR105/6	346.7
1255	Pt. B-C	B	3.6	4-6	6	2		3120.1
1304	Pt. B-C	H	54.5	10	10-12	15		12480.2
1305	Near tour rd loop	B	0.9	1	<1	<1		86.7
1320	W line near pt A	B	3.6	2-3	2-3	2		780.0
1327	Half way to C	B	2.7	4	3	1		780.0
1340	N of tour rd	H	2.7	3	2-4	2-3		1386.7
1400	SPOT	B	22.7	3-4	1-2	1		346.7
1436	300 yds from pt. C	B	2.7	4	3	1		780.0
1500	E line 300 yds before pt. C	F	.	7-10	6-10	3-5		8666.8
1500	150 yd from pt. C	B	1.8	4	3	1		780.0
1526	Pt. C	B	2.7	4-6	5	2		2166.7
1535	Pt. F	H	72.7	15-20	12	30		12480.2
1540	N line of extension	F	2.7	2-3	2-3	1-2		780.0
1645	Main unit N of pt. C	F	1.8	1-2	2	1		346.7
1654	Pt. C	H	13.6	12	10	10		8666.8
1720	N line near pt. C	B	2.7	3	2-3	2		780.0
1735	Between pts. C and D	H	18.2	12	8	10		5546.8
1742	Between pts. C and D	H	27.3	12	10	12		8666.8
1745	Between pts. C and D	F	2.7	3	2	>1		346.7
1800	300 yd from pt. D	B	1.8	2	1	>1		86.7
1835	200 yd from pt. D	F	1.8	2	1	1		86.7
1845	Mowed line W of pt. E	B	2.7	2-3	2	1		346.7
2030	Pt. E	B	5.5	3-4	3	3		780.0
2133	Pt. D	H	13.6	6-8	6	10		3120.1
2145	300 yd N of pt. D	B	0.9	2	1	>1		86.7

ROS - rate of spread, FL - flame length, FZD - flame zone depth

Table 13. Fire behavior for Crusher Hill Pasture burn at Tallgrass Prairie National Preserve, Kansas April 10, 2012. Intensity was calculated using the formula $3(10FH)^2$. All measurements were taken in fuel model GR 105, 106.

Time	Location	Fire type	ROS (Ch/hr)	FL (ft)	FH (ft)	FZD (ft)	Intensity (Btu/ft/s)
1500	Test fire	F	3.6	2	2	1	346.7
1630	1 st dogleg in stream	H	136.4	3-4	3	15	780.0
1712	Near 2-track	F	2.7	2-4	3-4	1-2	1386.7
1735	Trail marker	B	0.9	1-2	2	2	346.7
1745	Pt. H	F	5.5	3-5	3-5	5-8	2166.7
1830	W of drainage on N boundary	F	1.8	2-4	2-3	1-2	780.0

Fire type (H:head, B:back,F:flank);ROS - rate of spread; FL - flame length; FZD - flame zone depth.

Fire Severity

One plot in the Crusher Hill Pasture unit was unburned at the time of measurement because it was excluded from the burn unit. Therefore, it was not included in the analysis. Mean fire severity as measured in the monitoring plots in both Big Pasture-Middle and Crusher Hill Pasture was moderate for standing vegetation and light for substrate (duff, litter, soil surface; Table 14). A one-way ANOVA test showed no significant differences between pastures for vegetation ($P = F=2.98$, 0.12, $df = 9$) or substrate severity ($F=0.001$, $P = 0.97$, $df = 9$). Preserve staff desired a clean and complete burn to prepare for a remote sensing project (personal communication Kristen Hase). The severity results were consistent with this intention. Furthermore, the desired fire intensity model outlined in the prescription was also moderate (Table 1 and 2; Beacham 2011). Areas of high intensity were observed especially in areas where fire would have swept upslope (indicated by white fluffy ash and fully consumed plant and litter material). Sampled fire severity for the Crusher Hill Pasture unit was more variable, perhaps owing to greater fuel moisture.

Table 14. Fire severity values by pasture for prescribed fires at Tallgrass Prairie National Preserve, Kansas March 30 and April 10, 2012. Values in parenthesis are ± 1 std error. Vegetation severity refers to standing live and dead plants while substrate refers to litter, duff, and soil surface.

Pasture	N	Mean Severity Class Vegetation	Mean Severity Class Substrate
Big Pasture-Middle	6	2.1(0.3)	2.9 (0.3)
Crusher Hill	4	2.5(0.6)	2.9 (0.5)
Preserve	9	2.3 (0.4)	2.9 (0.4)

Severity classes: 0 = NA, 1 = heavy, 2 = moderate, 3= light, 4 = scorched, 5 = unburned.

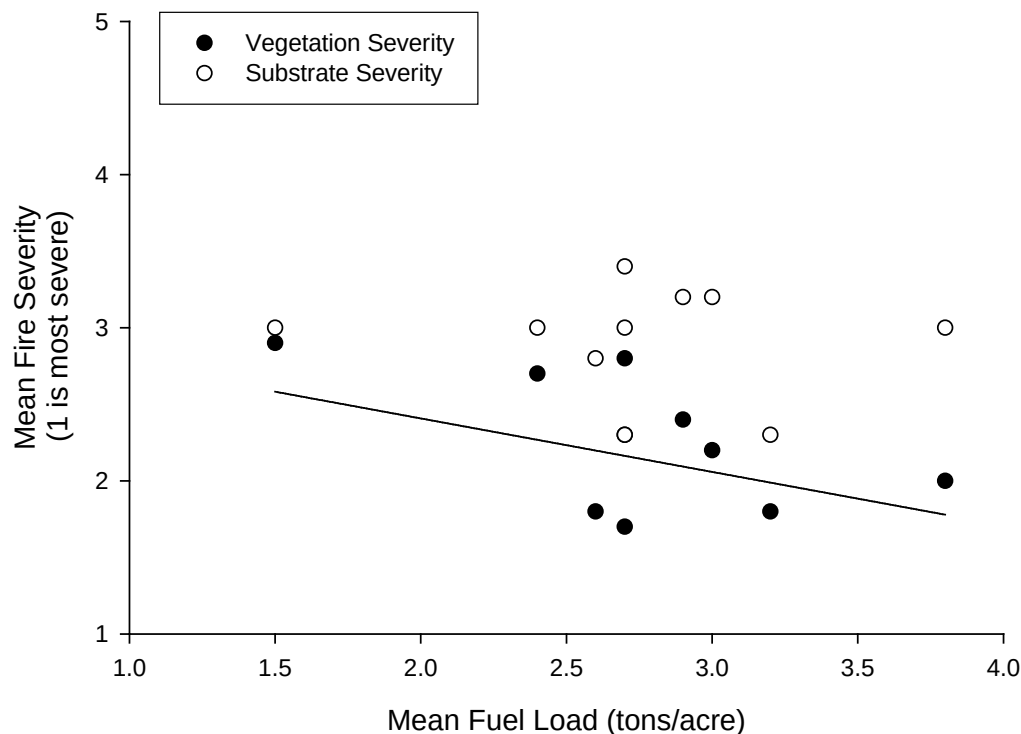


Figure 4. Vegetation fire severity was marginally related to mean fuel load 2012 ($r^2=0.36$, $P = 0.065$, $df = 9$), but substrate severity was not significant ($P = 0.71$) in 2012 at Tallgrass Prairie National Preserve, Kansas. Severity classes: 0 = NA, 1 = heavy, 2 = moderate, 3= light, 4 = scorched, 5 = unburned.

We previously hypothesized that fuel load is a contributing factor in determining fire severity and that relationship was supported for vegetation severity in the previous two years (Leis and Kopek 2011). As fuel load increased, fire severity also increased. The linear relationship between fuel load and vegetation fire severity was marginally significant in 2012 ($r^2=0.36$, $P = 0.065$, $df = 9$, Figure 4), but not significant for fuel load and substrate severity ($P = 0.71$; Figure 4).

Regression analysis indicated no significant relationships between fuel moisture and soil moisture with fire severity (Fuel moisture: Vegetation severity $P = 0.13$, substrate severity $P = 0.60$; soil moisture: vegetation severity $P = 0.30$, substrate severity $P = 0.70$).

Hazard fuel reduction is often a concern for natural resource managers and an objective for conducting burns. The combined proportion of fuels reduced during the Big Pasture-Middle and Crusher Hill Pasture burns was estimated using the fire severity data (see Methods section).

Substrate fuels in both burned units were reduced by 55% and *vegetation* fuels were reduced by about 89% in the burned portion of Crusher Hill Pasture. Notably, the Big Pasture burn reduced standing fuels by 93% in that unit. The values for substrate and vegetation cannot be combined because the proportion of the fuel load contributed by both elements is not known. The proportion of fuel reduction calculation is an indirect analysis and should be used cautiously.

Burn Extent

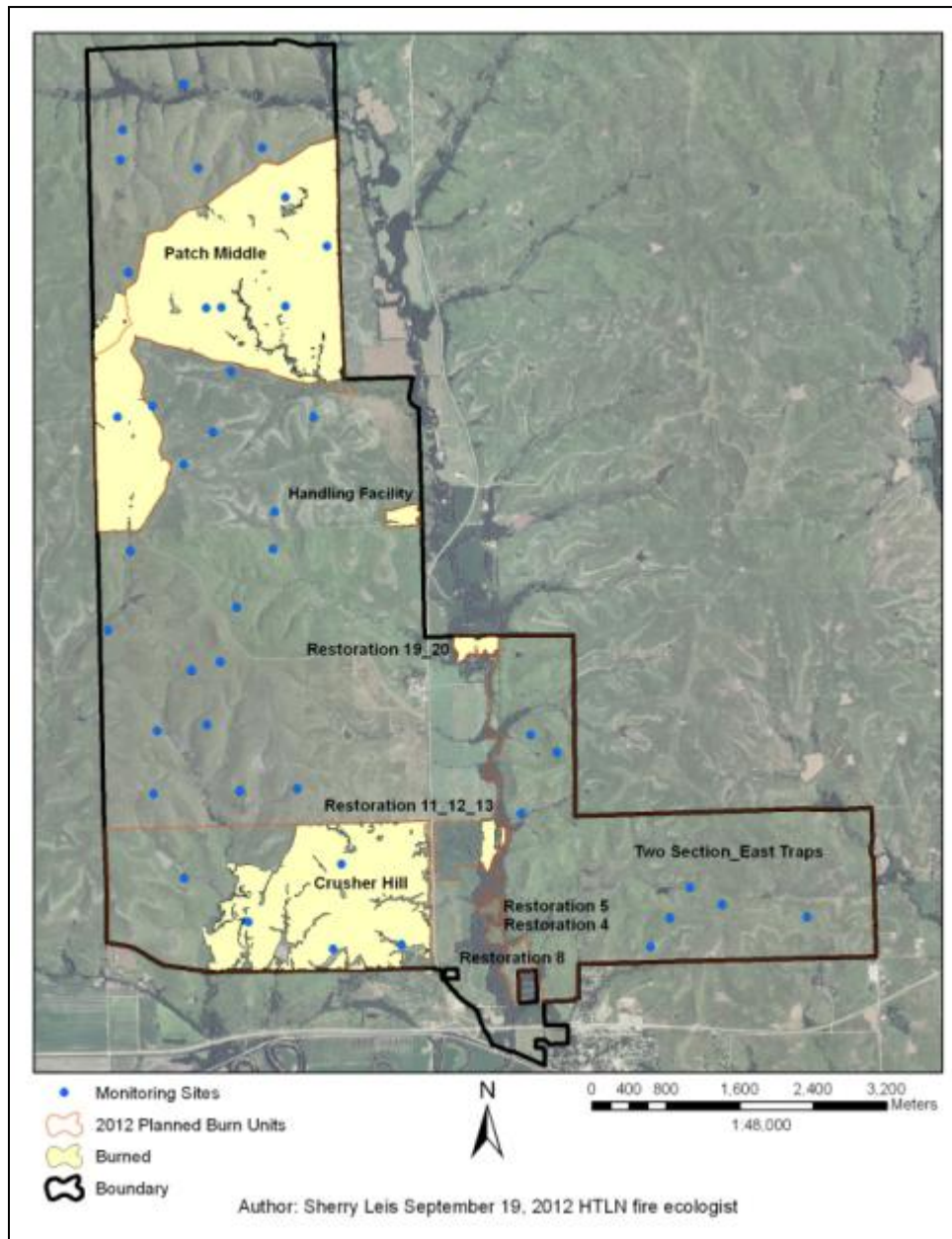


Figure 5. Areas burned at the Tallgrass Prairie National Preserve, Kansas in spring 2012. This report focuses on the prescribed burns in Big Pasture-Middle and Crusher Hill Pasture.

The total number of acres burned in 2012 was 2163.3, 43.6% of the planned area (Figure 5). The additional planned areas were not burned for a variety of reasons. The eastern pastures were rested from fire because neighboring ranches did not burn as expected. Only two-thirds of Crusher Hill Pasture was burned because of available weather conditions. A north/south running creek along with a secure eastern pasture boundary provided adequate fire breaks for the Crusher Hill Pasture burn. Additional acres in the bottomland restorations were not burned because appropriate weather conditions did not coincide with available resources.

Summary

Prescribed fire was applied on several different days at TAPR this spring. Big Pasture-Middle was burned first followed by two attempts to burn Crusher Hill Pasture. Additional burn days were added to complete burns in the bottomland restorations and in the West Traps area for the new bison handling facility. This report focused on the Big Pasture-Middle and Crusher Hill Pasture units, although spatial data (burned area) is presented for the preserve as a whole. All burns were conducted safely with regard to fire fighters and the public.

The primary goals for prescribed fires in 2012 were exclusively natural resource related (Beacham 2011). Although not explicitly stated as a goal, completing the prescribed fires within the criteria set by the prescription was important to the operations. As practitioners of prescribed fire know, the ability to meet objectives is balanced with staying within the defined prescriptions. The prescription was flexible enough to allow operations to continue safely during variable weather conditions while meeting burn objectives. (Note: revised objectives have been drafted.)

Spring fire season in the Flint Hills can be unpredictable with regard to ever-changing weather conditions. The goal of implementing a varied fire regime owes much to this and can be accounted for with consistent moderately, moist soils, high but variable fuel moistures in Crusher Hill Pasture, and fire behavior that varied considerably from mild to extreme (Goal 1, see Burn Unit Goals). High proportions of live fuel contributed to greater fuel moisture and reduced fire behavior in Crusher Hill Pasture. Fuel moisture was low for the Big Pasture-Middle burn and fire behavior was extreme at times, but often below expectations outlined in the burn plan. Despite the differences in conditions for the two pastures, fire severity was similar.

Fuel loads have remained fairly stable from 2010-2012, even though precipitation was quite variable through that period. In 2011, precipitation was about 6 in. less than the 30-yr average (National Climatic Data Center 2011, RAWS Tallgrass Prairie (2011 data)). That stability may be a testament to the preserve's management philosophy of heterogeneity as well as the resiliency of the prairie, because we normally expect precipitation to affect biomass accumulation (Milchunas and Lauenroth 1993). On the pasture scale in 2012, fuel loads in the eastern pastures were less than those of the western pastures. In comparison to fuel loads presented in this report, a 10-year average of live peak biomass in burned upland sites at Konza Prairie, Kansas was 1.6 tons/acre, somewhat less than the mean tons/acre at TAPR the past two years (Abrams et. al. 1986). However, the maximum in the Konza study, about 2.7 tons/acre was similar to the fuel loads in the western pastures in 2010 (Table 5). Measurements in this report reflect a combination of both live and dead biomass and so are expected to be greater than the Konza study, but the preserve has demonstrated greater variability than the Konza study. A long-term analysis of preserve-scale fuel loads could be considered in the future.

Fuels within pastures are variable and may be the result of inherent differences such as topography and soils and/or grazing and burning treatments. Fuel loads were substantially reduced by the burns in the monitored pastures (Big Pasture-Middle and Crusher Hill Pasture). Although only marginally significant in 2012, since 2010 we have seen a positive relationship between post-burn vegetation severity and fuel loads. Greater fuel moisture for the Crusher Hill Pasture burn could be attributed to greater live fuels resulting from early green-up. However, we

were unable to find a relationship between fuel moisture and fire severity. Further understanding these relationships could be useful in aiding in the development of burn plans. To achieve a desired severity, for example, the fuel load could be manipulated through grazing or deferment and/or burning on a day with particular fuel moistures.

An evaluation of the primary objective of promoting varied vegetation structure (horizontal structure) has been submitted for publication (Leis et.al. *in review*). The analysis shows horizontal vegetation structure differs by time since burn as hypothesized. However, plant structure within the first 0.25 m recovers within one year, and structure 0.25-0.5 m recovers by two years post-burn. A difference in height was detected between the most recently burned patch and the other patches, but no difference was found between patches >1 year since burn. These results indicate that the preserve is meeting their structural heterogeneity goal and that the grass canopy response is more complex than previously thought.

The evaluation of objectives concerning the improvement of nesting bird habitat, control of woody and undesirable vegetation, and increasing native plant diversity will be addressed in HTLN project reports (Goal 1, see Burn Unit Goals). The most recent plant community report (James 2011) indicated a positive trend towards increased structural heterogeneity and consistent community level diversity (beta diversity). Conducting prescribed burns in this region, with its unique cultural legacy of landscape-style burning and grazing also satisfies management objectives of controlling woody vegetation, removing old growth thatch, and promoting re-growth of native warm season plants (Goal 2, see Burn Unit Goals) (James 2011).

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Appendix A: Sample Site Photographs

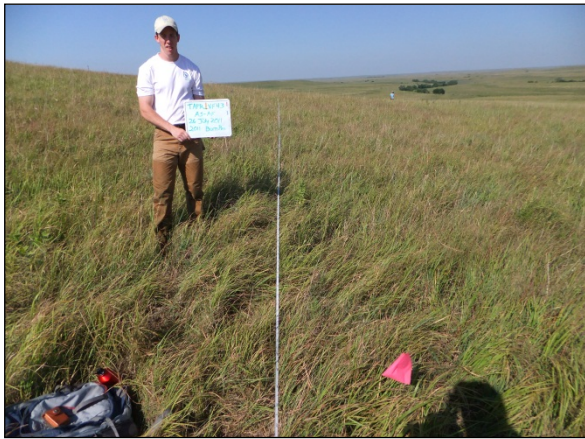


Figure 6. Big Pasture- Middle, Tallgrass Prairie National Preserve, Kansas, August 2011. Pre-burn Site V43 AS-AF.

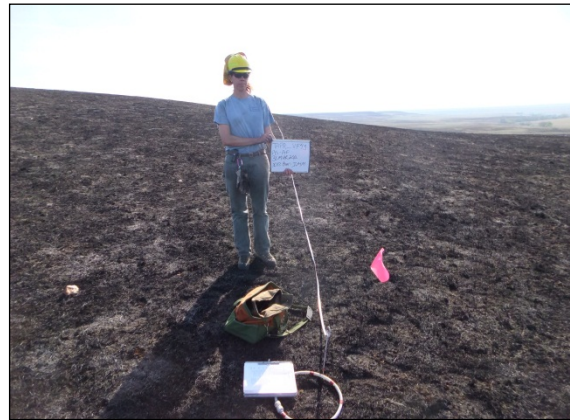


Figure 7. Big Pasture- Middle, Tallgrass Prairie National Preserve, Kansas, April 2012. Post-burn Site V43 AS-AF.

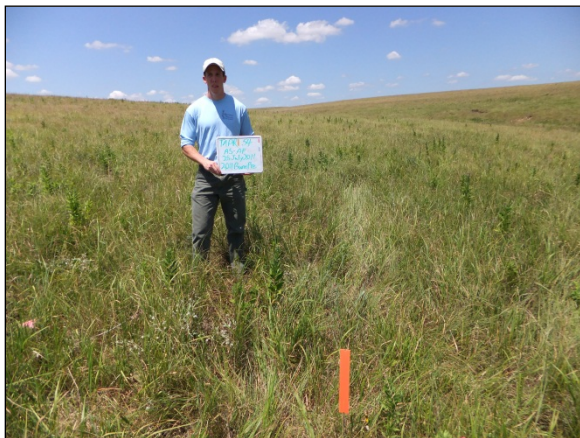


Figure 8. Big Pasture-Middle, Tallgrass Prairie National Preserve, Kansas, August 2011 Pre-burn Site 54 AS-AF.



Figure 9. Big Pasture-Middle, Tallgrass Prairie National Preserve, Kansas, April 2012. Post-burn Site 54 AS-AF.



Figure 10. Crusher Hill Pasture, Tallgrass Prairie National Preserve, Kansas. August 2011. Pre-burn Site 42 AS-AF.

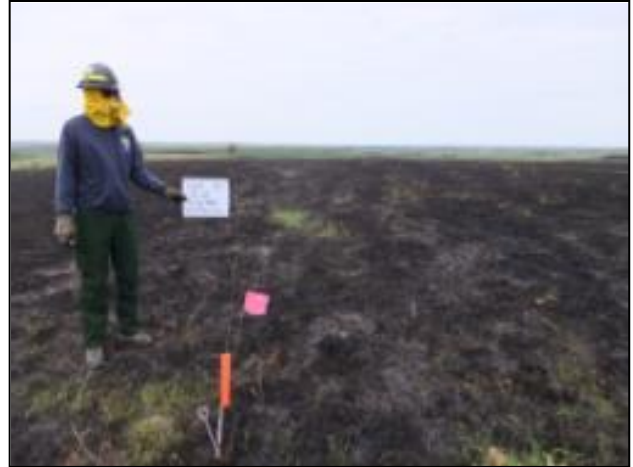


Figure 11. Crusher Hill Pasture, Tallgrass Prairie National Preserve, Kansas. April 2012. Post-burn Site 42 AS-AF.



Figure 12. Crusher Hill Pasture, Tallgrass Prairie National Preserve, Kansas. August 2011. Pre-burn Site 44 AS-AF.

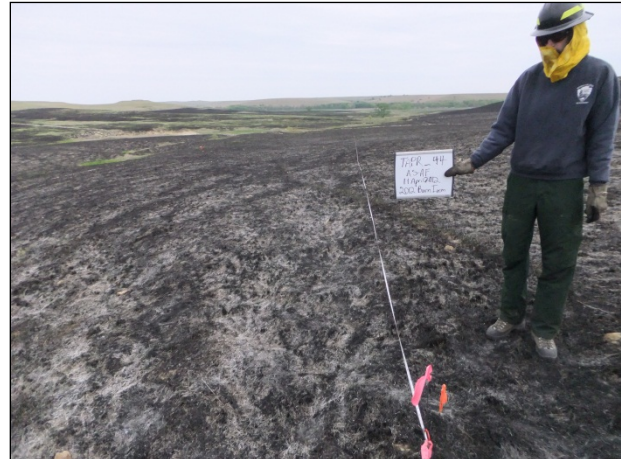


Figure 13. Crusher Hill Pasture, Tallgrass Prairie National Preserve, Kansas. April 2012. Post-burn Site 44 AS-AF.



Figure 14. Crusher Hill Pasture, Tallgrass Prairie National Preserve, Kansas. Post-burn, substrate severity 3 and vegetation severity 3.



Figure 15. Crusher Hill Pasture, Tallgrass Prairie National Preserve, Kansas. Post-burn, substrate severity 2 and vegetation severity 2.



Figure 16. Big Pasture-Middle, Tallgrass Prairie National Preserve, Kansas. March 30, 2012. Excellent smoke dispersal and active fire behavior were common throughout the day.



Figure 17. Crusher Hill Pasture, Tallgrass Prairie National Preserve, Kansas. The western boundary of the unit was marked by a sinuous creek.