FUEL LOADING IN THE CENTRAL HARDWOODS

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1. ABSTRACT

We collected fuel loading data in the Southeast Missouri Ozarks to determine if aspect (protected, exposed, and ridge) has an effect on fuel loading in stands that will receive either thinning, prescribed fire, both prescribed fire and thinning, or no management (control). Stands chosen for the study had no management or documented fire for at least 30 years. Results indicate that total fuel loading varied between 1.42 and 2.24 kg/m^2 with higher total fuel loadings being typically observed on protected slopes. Most of the variation in total fuel loading between aspects occurred in the 1000-hour timelag class. There were no significant differences in 1, 10, 100-hour, and 1000-hour rotten fuels between aspects indicating that a single fuel loading value for each size category may reliably be used to predict fire behavior on any aspect. There was, however, a significant difference in 1000-hour solid fuels between aspects. With exception to 1000-hour solid, a single fuel loading value for each timelag class may be reliably used for fire behavior predictions on any aspect. Since finer fuels have the greatest effect on fire behavior total fuel loading measures may not accurately depict fire danger.

2. INTRODUCTION

Very little information is available on historic or current fuel loadings in the Central Hardwoods of the United States. A recent literature search for such information yielded less than five references that directly addressed the subject. Scowcroft (1965) and Grabner et al. (1999) examined fuel loading on unburned sites in the southeast Missouri Ozarks. Anderson (1982) reported general fuel loading values for oak/hickory forest of the eastern US which are used by BEHAVE to predict fire behavior. However, it is known that fuel loading and vegetative structure have been altered from pre-settlement conditions.

Most accounts of the Missouri Ozarks prior to settlement describe open woodlands with little to no underbrush (Ladd 1991, Nigh 1992). This open forest structure was the result of an anthropogenic fire regime, dominated by light surface fires, maintained by Native Americans. The mean fire-free interval (MFI) during the period of Native American depopulated (1580-1700) and repopulation (1701-1820) periods were MFI=17.7 and 12.4 years, respectively (Guyette and Cutter 1997, Guyette and Dey 1997).

Beginning in the early to mid 1800's, westward settlement began to have a substantial effect on the Missouri Ozarks. The MFI decreased to 3.7 years during the period of Euro-American settlement (1821-1940) (Guyette and Cutter 1997). A majority of the Ozarks was completely cutover in late 1800's and early 1900's to feed America's westward progression (Cunningham and Hauser 1992, Guyette and Dey 1997, Nigh 1992). By 1910, a majority of the Missouri Ozarks had been logged, especially shortleaf pine, without any regard to future forest (Cunningham and Hauser 1992, Guyette and Dey 1997, Guyette et al. 1999). Frequent fires and accumulations of slash, which resulted in intense fires that killed pine regeneration and stimulated oak sprouting, undoubtedly had an effect on pine regeneration and recruitment (Cunningham and Hauser 1992, Guyette and Dey 1997).

The composition of present day Ozark forests is much different from that of pre-settlement times. The second-growth forests are more dense and contains less pine than historic stands with hardwoods completely replacing pine in many places (Cunningham and Hauser 1992, Guyette and Dey 1997, Nigh 1992, Nigh et al. 2000). A 66-percent reduction in relative abundance of pine from historic levels (circa 1900) has

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been noted in some areas along with a reduction in range from an estimated 2,670,000 ha to only about 162,000 ha of pine and oak pine forest in 1976 (Cunningham and Hauser 1992, Guyette and Dey 1997). Fire suppression began in the 1930's which increased the fire rotation length from the period 1970-1989 to about 326 years statewide (Westin 1992). In the Arkansas Ozarks the MFI is greater than 80 years for the period 1921-2000 (Guyette and Spetich 2003). Suppression created favorable conditions for the development of dense oak forest and allowed for fuel loading to increase, unchecked by periodic fire.

Currently federal and state agencies, as well as private organizations and individuals, are using prescribed fire, thinning, harvesting, or combinations of these treatments as management tools. In many cases these treatments are used for restoration of habitat and biodiversity. In 2002, state and federal agencies as well as private organizations applied prescribed fire to more than 24,000 ha throughout Missouri. There is evidence that fire exclusion and timber harvest have increased fuel loadings (Guyette 1999). However, the effects of management activities on fuels are poorly understood. Even baseline loadings in mature oak-hickory and oak-pine stands are not known for the area.

We collected fuel loading data in southeast Missouri as part of a cooperative study funded by the Joint Fire Science Program. The project cooperators include the USDA Forest Service North Central Research Station, U.S. Geological Survey Northern Prairie Wildlife Research Station, University Of Missouri - Columbia, and the Missouri Department of Conservation. The purpose this study is to determine existing fuel loads and whether aspect (exposed, ridge, and protected) has an effect on fuel loading in stands that will receive thinning, prescribed fire, both thinning and prescribed fire, or no management (control). This study is the most ambitious of is kind in this area.

3. STUDY AREA

The study area is located in the southeastern Missouri Ozarks near Ellington, MO, USA, on land managed by the Missouri Department of Conservation (Figure 1).

3.1 Ecological Classification

Study sites were all installed within the Black River Hills Landtype Association. This was done to minimize variation caused by potential vegetative differences among landtype associations (LTAs) (Meinert et al. 1997, Nigh et al. 2000). LTAs are landscape scale ecological units, 10-1000s of square kilometers in size, that lie in the lower levels of the hierarchical Ecological Classification System. LTA delineation is based on variations in local landform, relief, geologic parent material, soils, and vegetation patterns which make them appropriate for local planning and assessment, i.e. counties, watersheds, ranger districts (Nigh and Shroeder 2002). The Missouri Ecological Classification System utilizes the US Forest Service National Hierarchy of Ecological Units for landscape classification (Meinert et al. 1997, Nigh and Shroeder 2002).

3.2 Vegetation

The Black River Hills LTA is characterized by strongly rolling to hilly lands with steep slopes and flat land found only in creek and river bottoms. Historically oak and oak-pine woodlands and forest comprised the area. These forests types still dominate, however, woodlands are second growth and have grown less open due to fire suppression (Nigh and Shroeder 2002). Lying within the Current River Hills Subsection, the Black River Hills LTA is in the center of one of the largest blocks of forest in the Midwest which also supports a substantial timber industry (Nigh et al. 2000).

4. METHODS

4.1 Site Selection

Stands chosen for the study had no management or documented fire for 30 years. All stands were fully stocked and composed primarily of oak-hickory and oak-pine forest types. The study was replicated across three complete blocks of 12 stands (3 aspect classes X 4 treatments) with each stand being an aspect/treatment unit. Aspect classes included exposed backslopes (135-315 degrees), ridge, and protected backslopes (315-135 degrees) (Nigh et al. 2000). Treatments were randomly assigned and included thinning, prescribed fire, both thinning and prescribed fire, and no treatment (control).

4.2 Data Collection

Data were collected from 15 points within each stand. These points were along a main transect placed at a random azimuth in each stand. The 15 points were installed at randomly-chosen 20-meter intervals along the main transect.

Fuels were inventoried from each of the 15 sampling points using a modified transect intercept method. Woody fuels were separated into four size classes: 0.0 to 0.64 cm (1-hour), 0.64 to 2.5 cm (10-hour), 2.5 to 7.6 cm (100-hour), and greater than 7.6 cm (1000-hour). 1000-hour fuels were further separated into rotten and solid categories. From each sample point, 1 and 10-hour fuels were inventoried along a 1.8 m segment, 100-hour fuels along a 3.7 m segment, and 1000-hour fuels along the entire 15.2 m length of the transect. Fuel height, litter and duff depths were measured at 1.5 m intervals along the fuel transect starting 0.3 m from the origin (Anonymous 2001, Brown 1974, Brown et al. 1982, Grabner 1996). Litter and herbaceous samples were collected from a 0.2-m^2 clip-plot located at the end of each fuel transect. Samples were then dried to a constant weight at 60° C and reported on a dry-weight basis (Grabner 1996).

4.3 Data Analysis

For analysis, the pretreatment fuel data was organized into the following categories: litter, 1-hour, 10-hour, 100-hour, all fuel < 7.6 cm, 1000-hour solid, 1000-hour rotten, total fuel load, fuel height, litter depth, and duff depth. Reliable fuel loading constants, specific gravities and squared average-quadratic-mean diameters, could not be found for species in the Central Hardwoods. To compute fuel loadings in the 1, 10, and 100-hour time lag classes, we used fuel loading constants for northern red oak (*Quercus rubra* L.) (Fire Management Handbook Software, USDI National Park Service). For 1000-hour rotten fuels, the average specific gravity for northern red oak decay classes 1-3 (Adams and Owens 2001) were used. We used these constants because the specific gravity of northern red oak is similar to black oak (*Q. velutina* Lam.), the most abundant species in our study area.

Analysis of variance was utilized to determine if differences in fuel loading were related to aspect. Data was analyzed using the MIXED procedure in SAS. This procedure was used because it allows covariates to vary within a subject (Wolfinger and Chang 1995). A p-value of 0.05 or less was considered significant.

5. RESULTS and DISCUSSION

Fuel loading by timelag categories and vertical structure did not substantially vary between aspects. The 1000-hour solid fuels were an exception. 1000-hour solid fuels were significantly greater ($p<.05$) on protected slopes as compared to both ridges and exposed slopes. On average there was a progression of increasing total fuel load from exposed, to ridge, and finally to protected slopes (Figure 2), which could be caused by slower decomposition on protected slopes. Litter, 1, 10, 100-hour, 1000-hour rotten, and the sum of all fuels < 7.6 cm did not vary greatly between aspects (Figure 2 and Table 1). However, some differences worth noting occurred between exposed slopes and ridges in 10-hour fuels, exposed and protected slopes in total fuel loading, between exposed and protected slopes as well as exposed slopes and ridges in fuel height, and exposed and protected slopes in litter depth (Figure 2 and Table 1). Since finer fuels primarily drive fire behavior, particularly rate-of-spread, (Anderson and Brown 1987, Brown and Davis 1973, Brown 1970, Davis 1959), total fuel loading probably is not the best indicator of potential fire behavior.

The increased levels of 1000-hour solid fuels could increase residence time and overall intensities on protected slopes. Anderson (1969) found that residence was approximately 3.15 times the fuel particle diameter or thickness in centimeters. The burnout of the larger fuels can result in two waves of heat passing over an area with the second wave possibly having a greater effect than the initial (Brown 1972, Rothermel and Deeming 1980). An increased risk of mortality or damage to standing timber may exist on protected slopes.

We compared our fuel loading estimates to those reported by Scowcroft's (1965) and Grabner (1999). Unfortunately sample sizes were small, n=5 and n=30 respectively, and Scowcroft was unable to utilize modern sampling techniques. Fuel loading estimates and vertical structure were similar (Table 2). However, Scowcroft attributed about twice as much of the total fuel loading to litter as we did (Table 2). Grabner had similar results in most categories. We found nearly 1.75 times more litter and 10 times more 1-hour fuels which explains the reduction observed in total fuel loading (Table 2).

We also compared our fuel loading estimates to those used in the BEHAVE model for hardwood leaf litter, Fire Behavior Fuel Model 9. We found that fuel loading in the 1-hour timelag class was similar (Table 3). However, we found fuel loading in the 100-hour and smaller category to be nearly 1.5 times greater than is assumed by the BEHAVE model (Table 3). This discrepancy could cause an underestimation of both flame length and rate-of-spread by BEHAVE when using Fuel Model 9 in hardwoods of the Missouri Ozarks that have not been recently burned.

6. CONCLUSION

The results from this study indicate that aspect does not significantly affect total fuel loading, but does affect 1000-hour fuel loading under fully stocked forested conditions in the Central Hardwoods of Missouri. With exception to 1000-solid solid fuels, a single fuel loading value for each timelag class may reliably be used to predict fire behavior on any aspect. However, significant changes in fuel loading due to position in the landscape may exist at smaller scales of ecological classification. Further research is also needed in developing constants for calculating fuel loadings in the Central Hardwoods Region.

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9. FIGURES AND TABLES

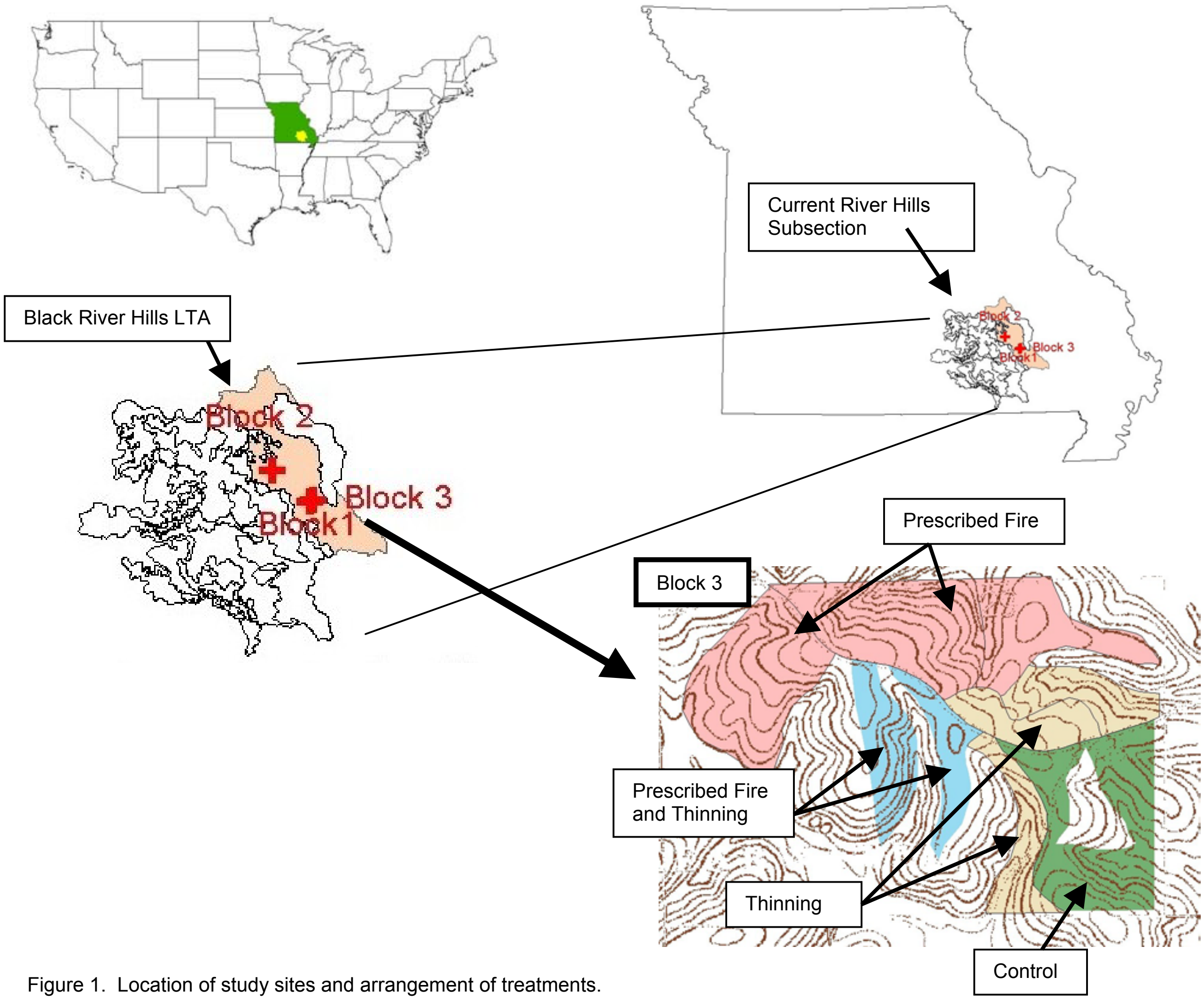

Figure 1. Location of study sites and arrangement of treatments.

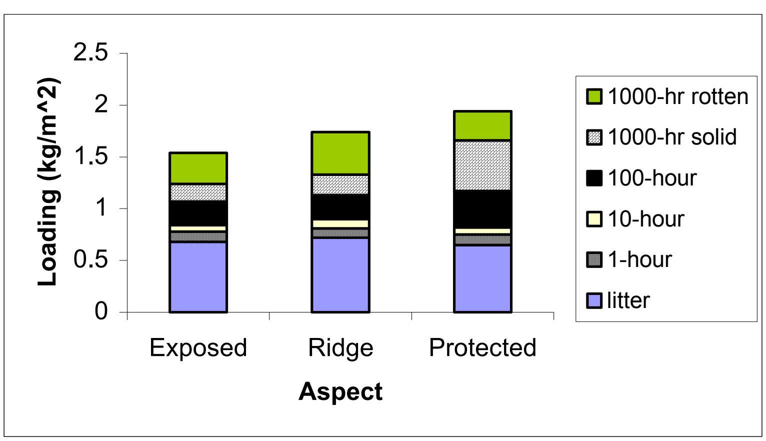

Figure 2. Fuel loading by size class and aspect

Table 1. Fuel loading and vertical structure by aspect.

	Fuel Loading (kg/m^2)							Vertical Structure (cm)		
	Litter	1-hour	10-hour	100-hour	1000-hour Solid*	1000-hour Rotten	**Total**	Fuel Height	Litter Depth	Duff Depth
Blk 1 E	0.69	0.10	0.04	0.21	0.10	0.35	**1.48**	6.5	6.0	0.9
R	0.62	0.09	0.07	0.23	0.13	0.99	**2.24**	7.3	6.6	1.4
P	0.64	0.10	0.05	0.27	0.53	0.45	**2.04**	7.8	6.7	1.5
Blk 2 E	0.76	0.12	0.09	0.28	0.13	0.34	**1.69**	6.1	5.7	2.1
R	0.79	0.10	0.09	0.22	0.22	0.10	**1.50**	6.1	5.9	2.0
P	0.65	0.11	0.10	0.35	0.61	0.10	**1.92**	6.6	6.3	2.4
Blk 3 E	0.59	0.09	0.05	0.19	0.28	0.22	**1.42**	6.4	5.8	1.4
R	0.74	0.08	0.11	0.24	0.27	0.14	**1.57**	9.8	7.9	2.1
P	0.68	0.08	0.05	0.43	0.31	0.29	**1.85**	8.3	7.8	1.6
Overall Average										
Exposed	0.68	0.10	0.06	0.23	0.17	0.30	**1.53**	6.3	5.8	1.4
Ridge	0.72	0.09	0.09	0.23	0.20	0.41	**1.77**	7.7	6.8	1.8
Protected	0.65	0.10	0.07	0.35	0.49	0.28	**1.93**	7.5	6.9	1.8

*significant difference among aspect found only in 1000-hour solid (p=0.007).

Table 2. Comparison of fuel loading by size class with previous studies.

	Fuel Loading (kg/m^2)						Vertical Structure (cm)		
	Litter	1-hour	10-hour	100-hour	1000-hour	**Total**	Fuel Height	Litter Depth	Duff Depth
Scowcroft (1965)	1.21					**1.48**		7.39	
Grabner (1999)	0.40	0.01	0.09	0.16	0.53	**1.19**		4.52	
This Study*	0.68	0.10	0.07	0.27	0.62	**1.75**	7.20	6.51	1.68

*All aspects averaged for each time lag category

Table 3. Comparison of fuel loading by size classed used in BEHAVE

	Fuel Loading (kg/m^2)	
	< .64 cm (1-hr) and litter	<7.6 cm (100-hr)
Anderson (1982)		
	0.65	0.78
This Study		
E	0.78	1.07
R	0.80	1.13
P	0.75	1.17

E = exposed, R = ridge, P = protected