THE EFFECT OF PATCH EDGE FUEL ASSIGNMENTS ON SIMULATED FIRE SPREAD IN THE CHEQUAMEGON NATIONAL FOREST, WI USA

Jacob J. LaCroix, Qinglin Li, Soung-Ryoul Ryu, Daolan Zheng, Jiquan Chen
Department of Earth, Ecological and Environmental Sciences, University of Toledo, Toledo, OH 43606-3390

1. AUTHOR BIOGRAPHY

Jacob LaCroix attended The University of Wisconsin at Stevens Point, WI were he got a BS degree studying Wildlife Management. He later attended Michigan Technological University, in Houghton, MI were he got an MS Degree in Ecology. His thesis was on stream ecology. He currently attends the University of Toledo in Toledo, Ohio, working on his PhD degree, studying Landscape Ecology. He uses the FARSITE model to isolate landscape structural elements to determine how they impact fire at the landscape level. Jacob has diverse work experience. He was a Woodland Fire Fighter. Then he worked as a Raptor Banding Biologist. He worked for the US Forest Service as a Wildlife Biologist studying the California Spotted Owl. He was a Biological Intern through the Student Conservation Association with the United States Navy in San Diego, CA. Then he worked for the US Fish and Wildlife Service, in Kodiak, Alaska.

2. ABSTRACT

Computer simulation is a useful tool for understanding the interaction of fire spread and landscape structure. FARSITE was used to simulate surfaces fires in the Chequamegon National Forest (CNF) in Northern Wisconsin. Our objectives were to use FARSITE to isolate and manipulate fuel in the Area of Edge Influence (AEI), when the edges are considered as a separate fuel category at the landscape level, to determine what impact these fuels will have on burned area and rate of fire spread. Next, to determine the level of the current landscape fuel loading without assigned edges to see where it fits in the range of edge fuel assignment scenarios. This data will allow us to make patch level inferences about other landscape features with high connectivity. Our approach, assigning all edge fuels together, allows us to keep the high connectivity of the feature in relation to other fuels on the landscape. We ran simulations on multiple landscapes, which had varying levels of fuel loadings in the edge structure. Edge depth was defined from recent literature and a Depth of Fuel Influence (DFI) was assigned as one distance resolution of the model (30m) for each side of the patch. We conclude that patch edge fuels do influence rate of fire spread and that our current classification without them is equivalent to a landscape loading that produces rates of fire spread and flame lengths between our medium and high-level edge loading scenarios. This data allows us to predict what may happen if similar or more landscape features with high connectivity are included in a landscape fuel classification. With this understanding forest managers can control fire spread through manipulating fuel in edges. Under our model conditions we show a range of approximately 1500ha by which fire spread is influenced with edge fuel manipulations alone.

3. INTRODUCTION

Forests are unique in structure and when researchers represent them, especially when using a Geographic Information System (GIS) model and remotely sensed data. It is up to the researchers to best represent the landscape with as many features as are necessary to adequately examine the dependant variable in question. We wanted to know what the impact would be if we isolated patch edge fuel structure in our FARSITE (Finney 1998) model simulations of fire spread in the Chequamegon National Forest (CNF) in Northern Wisconsin. This forest has a highly fragmented structure, due to its heavy use in both timer production and popularity for recreational activities (Bresee et al. 2004).

Patch edge dynamics are unique in space and time with lots of primary and secondary process and structural responses occurring, such as increases in decomposition, downed wood, recruitment, growth, mortality and under story cover, from the time forest edges are created from disturbance (i.e. natural or from clear cutting). As forest edges age the magnitude and distance of edge influence changes as the abiotic and biotic gradients between edge and interior seal, soften or expand (Harper et al. 2005). These edge dynamics result in situations were potential fuel in this location may be increasing or decreasing relative to the surrounding forest patches.

We hypothesis that edge fuel will influence fire spread and should reflect the level to which the fuel loading is assigned. This will tell us how the CNF incorporates this fuel structure into fire spread because each fire ignition location will have a different amount and configuration of edge structure within its burned perimeter after a fire.

Our overall objectives with this study was to use FARSITE to examine a patch edge structural feature with scenarios from three levels of edge fuel loading to determine: 1) what impacts fuels in edges will have on fire spread, and 2) the level of fire spread produced by our current landscape fuel classification without the edge feature. This data will help us to make inferences about other landscape features with high connectivity, which may be included in a hypothetical landscape, for example roadsides, power line corridors, railroads, trails, timberline, meadows or riparian zones.

4. METHODS

Study area

The study area is located in the Washburn Ranger District of the CNF in Northern Wisconsin (46o 30'- 46o 45' N, 91o 02'-91o 22' W) USA. We used the 2001 Landsat image from Breese et al. (2004) to derive the three topographic layers needed for FARSITE. The imaged portion is approximately 39,381 ha in size. The major habitats were reclassified into four nationally recognized fire fuel categories 5, 8, 10 and 11 (Anderson 1982), which FARSITE was designed to use without adjustment. The 16 fire ignition locations were systematically placed on the landscape to cover as much area as possible. The area's topography is flat with gently rolling hills with elevations ranging from 232 – 459 m. This relatively flat topography helps eliminate elevational influences on fire spread and allows us to emphasize the effects of landscape structure (Figure 1).

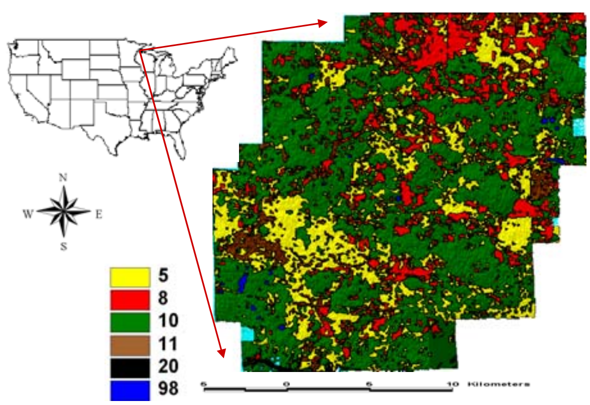

Figure 1. Study site location in the Chequamegon National Forest, WI showing the GIS map with its fuel categories. 5 represents brush, 8 is pine, 10 is hardwood, 11 is slash, 20 is edge, and 98 is water.

Model

FARSITE was used to simulate seven daylong surface fires for 16 ignition points systematically located across the landscape. Five gridded variables are required for model simulations: elevation, slope, aspect, canopy openness, and fuel type. The first three layers were obtained from the Digital Elevation Model (DEM); the fourth layer was derived by rescaling the Normalized Difference Vegetation Index (NDVI) values (0-1), calculated from the red and infrared channels of Landsat 7 data (Rouse et al. 1973) to 0 – 100%. The fifth layer is a fuels assignment that was created by reclassifying the major habitats at the CNF from Breese et al. (2004) into four nationally recognized fire fuel categories.

Manipulating the fuel layer from the model we absorbed all patches that were equal to or less than 60m^2 in size with an algorithm that assess pixel assignment with a moving 9 x 9 pixel window. The resolution in our model is 30m^2. We kept this as the control landscape with no edge structure defined. Taking the absorbed fuel layer we added a 30m-edge buffer to both sides of the patches and added this to the other four GIS layers to create another landscape with the edge defined as a 60m belt on the landscape, this is why we absorbed patches smaller than 60m. We assigned the edge feature with three different custom fuel model numbers 20, 21, and 22 that we created using FARSITE's custom fuel editor. This gave us a total of four landscapes, the no edge landscape classification with larger size patches but no edge fuel defined having a total of 4 different fuels and three landscapes with the same fifth edge fuel structure but each one assigned a different custom fuel model number (Table 1).

The custom fuels were based off of models 8, 9 and 10 respectively, since we were using 8 and 10 in our classification. The initial fuel moistures and the other characteristics were the same however, 8 was tuned down by .5 to produce the 1, 10 and 100hr fuel loadings we used in 20, 9 was tuned down by .5 to produce the loadings we used in 21, and 10 was tuned up by 1.5 to produce the loading in 22. The loadings are not necessarily low, medium or high to each other but the resulting fire spread and flame lengths are, relative to the forest without the edge structure (Table 2).

Landscape Comparisons

	% Area in each classification						
	Anderson's fuel model #'s				Custom fuel model #'s		
	Brush	Red Pine	Hardwood	Slash	Low	Medium	High
Landscapes Scenarios	5	8	10	11	20	21	22
Control No Edge Fuel	24.5	14.5	52.5	8.5	0	0	0
Edge Low Fuel Loading	15.2	8.9	42.3	4.4	29.2	0	0
Edge Medium Fuel Loading	15.2	8.9	42.3	4.4	0	29.2	0
Edge High Fuel Loading	15.2	8.9	42.3	4.4	0	0	29.2

Table 1. Comparison of landscape structure between the four landscapes generated from assigning different custom fuels to 60m combined patch edges. Control has no edge fuels. The three edge landscapes were

created using a 30m buffer inside and outside of the patches. Area was taken away from the four main patch types and put into the edge category. Categories 5, 8, 10 and 11 are Anderson's (1982) fuel types and categories 20, 21, and 22 are custom fuels created using the FARSITE custom fuel editor to create fuel loadings that represented low, medium and high timber fuel loadings.

Fuel Assignment Comparison

Model #		Fuel Loading tons/ac 1hr	10hr	100hr	Rate of Spread ft/min	Flame Length ft
5	Brush	1.00	0.50	0.00	14.0	3.5
20	Low Edge	0.75	0.50	1.25	1.0	0.6
8	Red Pine	1.50	1.00	2.50	2.2	1.1
21	Medium Edge	1.46	0.20	0.07	4.9	1.6
11	Slash	1.50	4.51	5.51	6.7	3.5
10	Hardwood	3.01	2.00	5.01	8.2	4.8
22	High Edge	4.51	3.00	7.51	12.4	7.0

Table 2. Fuel loadings for all the fuels used in the simulations. All calculations are from the FARSITE custom fuel editor at moderate fuel moisture levels and midflame winds speeds of 5 mph, in English units.

Weather

We applied one weather input in this study. The data for the file came from a weather station located in the mixed northern hardwood habitat. This was the most dominant habitat type in the CNF. The weather data was recorded on site for the month of April 2004, it included temperature, precipitation, and relative humidity. We used wind speed and direction at noon similar to Bessie and Johnson (1995). There was no precipitation during this seven-day period from April 3rd to the 10th. This eliminated any rain effects. No roads, streams, barriers or fire attacks were used to impede the spread of the fire in our simulations. The location points were kept constant in every landscape to allow for direct comparisons between the 16 fire locations in each of the four landscape scenarios.

The simulated burned areas were analyzed with ANOVA to detect if the burned area was significantly affected by landscape and location after 7 days, with a 24-hour burn period.

Assumptions

There are three main assumptions with this study. First, we froze edge dynamics at one point in time and we created a potential Depth of Fuel Influence (DFI) in patch edges as a structural element for the FARSITE model fuel layer. The dynamics that we froze are those that could increase or decrease potential fuels that occur at new forest edges. Secondly, we are not simulating any fuel or other gradients that probably occur in patch edges. We took the entire define DFI as one fuel structure. Lastly, a 30m DFI to one side of an edge is likely smaller than the entire Distance of Edge Influence (DEI) (Zheng and Chen 2000) so it is not meant to represent all edge processes but only help us see how fire might respond to fuel in patch edges. Along with this we have some model constraints because 30m is the smallest distance resolution of our GIS coverage. However, it is not unrealistic as a DFI. From the literature, Harper et al. (2005) reports a synthesis of literature that measured, among other variables, snag or log abundance in edges, an important fuel, as having mean DEI's of between 5 and 125m. Harper and McDonald (2002) reported a range for this in another study as being between 10 and 20m. Further, we made the DFI equal on both sides of the edge and since we are looking at it as all one custom fuel structural unit, it forms a uniform 60m belt on the landscape.

5. RESULTS

The four landscapes have different structures. The 60m-edge buffer took away a percentage from each of the four fuel classes. Into this fifth fuel class we placed one of the three custom fuels (Table 1). Custom fuels had different scenarios for fuel loading, fire spread and flame length output (Table 2). Fire responded to landscape structure and spread significantly ($P < 0.0001$) different in the four landscapes (Table 3) with changes in structure coming from the edge feature and its fuel loading (Figure 2).

ANOVA

Source	DF	Sum of Squares	Mean Square	F-Value	P-value
Model	18	17,880,234	993,346	34.34	< 0.0001
Error	45	1,301,820	28,929		
Corrected Total	63	19,182,054			

R - Square = 0.932

Source	DF	ANOVA SS	Mean Square	F-value	P-Value
Landscape	3	14,238,072	4,746,024	164.06	< 0.0001
Location	15	3,642,162	242,810	8.39	< 0.0001

Table 3. Results of ANOVA for the main effects of landscape and location on area of fire spread. Dependent variable: Fire area.

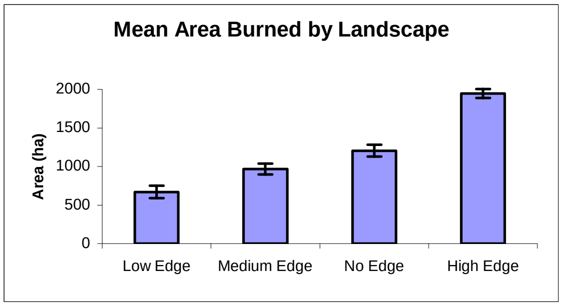

Figure 2. Burned area (ha) for each of the four landscapes after seven days. The error bars represent one standard deviation.

The mean burned area (ha) for each of the 16 locations was also calculated on a per day basis for each landscape and a daily rate of spread was plotted to show the rate of spread for each landscape as well (Figure 3).

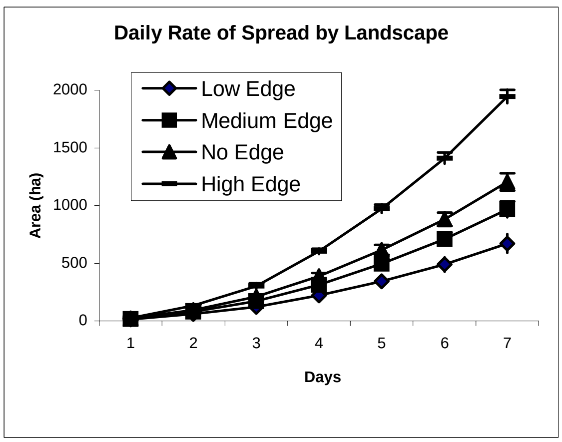

Figure 3. Burned area (ha) per day for each landscape. The error bars represent one standard error.

6. CONCLUSIONS

Our non-edge structure landscape produced fires with burned areas between our high and medium edge loading scenarios. Including it in our model improved our ability to predict fire spread. With this data we can also predict what might happen if forest fires encounter other fuel sources with high connectivity.

Burned area was different by landscape. This suggests that management decisions that focus on manipulating fuel in edges would be successful in attenuating fire spread. Edges are potentially a controlling fire fuel source at the landscape level, especially if the high connectivity is realized on a large portion of the edges between patches. Our simulations show a 1500 ha range for which managers could influence the 7-day outcome of fire spread by managing edges fuels alone. Carrying out the manipulation of fuel loading in patch edges could be done at the same time as normal harvesting operations. Edge fuel structure may not be changeable in a highly fragmented forest like the CNF but the loading that occurs in them over time can be changed to increase or decrease fires spreading potential.

Through this study we demonstrated that edge fuel manipulation was one activity that influenced fire spread. When looking for ways to manage landscape-scale forest fuel loads, edge manipulation could reduce fire spread and thereby reduce the possibility of stand replacement fires and their associated ecological and social impacts on the potential loss of life and property (Stratton 2004).

7. REFERENCES

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