5C.3 HUMAN INFLUENCE ON FIRE DISTURBANCE IN NORTHERN WISCONSIN

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1. INTRODUCTION

Historically, fire disturbance played a major ecological role in the structure and function of many forested ecosystems of the upper Midwest. Human activity patterns have since disrupted the historic fire regime following human settlement. Human-related activity is currently responsible for igniting approximately 97% of all fires in the region (Cardille et al. 2001), but all fires are actively suppressed. The resulting fire regime is therefore dominated by very frequent but small fires (Fig. 1a). Nonetheless, large fires are ecologically important because they contribute a disproportionate area to the total area burned each year (Fig. 1b).

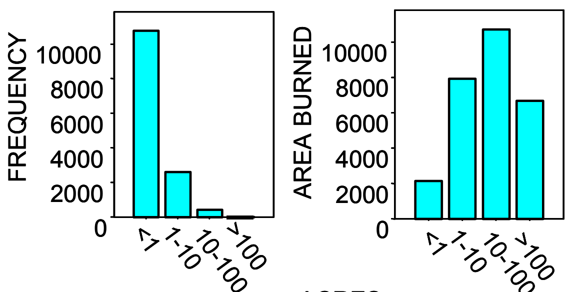

Figure 1. Fire frequency and area burned by fire size in northern Wisconsin (1985-2000).

Two characteristics of fires are essential to understanding fire patterns across landscapes: fire *ignition*, which affects fire frequency, and fire *spread*, which affects fire size. Each characteristic may be influenced by both human and ecological factors. Humans influence the spatial pattern of ignitions through activity associated with development, infrastructure and recreation (Cardille et al. 2001). However, the likelihood of a successful ignition is also dependent in part on ecological factors such as soil moisture, climate, and the relative flammability of vegetation and litter (Frelich and Reich 1995, Cleland et al. in press). Humans affect fire spread through fire suppression, and their efforts may vary in space because of road access and/or priorities associated with human dwellings. Nonetheless, ecological factors still influence the ability of a fire to spread to adjacent vegetation. For example, deciduous tree species lack the volatile chemicals present in coniferous foliage that allow coniferous canopies to burn. This makes coniferous stands susceptible to high-intensity fires that are difficult to suppress.

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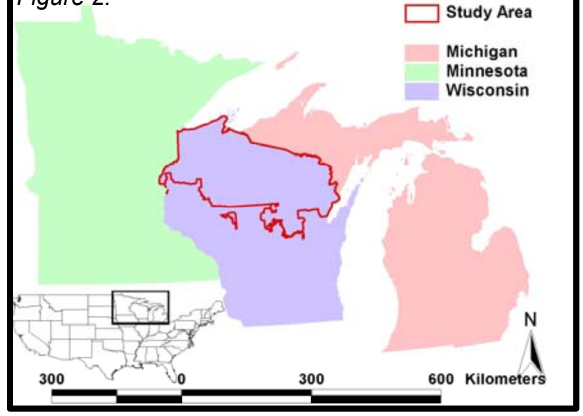
In this paper, we evaluated the relative importance of human versus ecological influence on fire ignitions and fire size in a 75,000 square km region of northern Wisconsin using a 16-year fire record database.

2. METHODS

2.1 *Study Area*

We focused on the Laurentian Mixed Forest Province within Northern Wisconsin, where either the Wisconsin Department of Natural Resources or the USDA Forest Service had primary wildfire attack responsibility (Fig. 2). The area is primarily forested, with scattered residential areas, seasonal lakeshore development, and low to moderate levels of agricultural activity.

Figure 2.



2.2 *Wisconsin Fire Database*

A total of over 13,185 fires were recorded in the study area by either the Wisconsin Department of Natural Resources or the US Forest Service between 1985 and 2000. Each fire record includes data such as fire size in acres, the date and time the fire was observed, the estimated cause of the fire, and the cover type at the origin of the fire. Each fire was assigned to a square mile area corresponding with a section of the Wisconsin General Land Office survey. Forest fires were separated from the rest of the database using the recorded cover type, and the section boundaries were used to calculate mean values for the independent variables used in the analyses, described below.

2.3 Ecological Factors

Cleland et al. (in press) classified ecological land type associations (**LTA**) into six fire rotation (FR) categories based on common soil characteristics, current and presettlement vegetation. For example, FR1 LTAs were historically dominated by jack pine systems underlain by coarse-textured sandy soils and experienced frequent, large catastrophic stand-replacing fires (Table 1). In contrast, FR4 LTAs were historically dominated by northern hardwood systems, underlain by fine-textured sandy loam to heavy clay and silt loams soils, and experienced very infrequent stand-replacing or surface fires (Table 1). While fire suppression by humans has increased fire rotations by roughly an order of magnitude, the rank order of the FR classification has remained consistent (Cleland et al. in press).

Table 1. Ecological Land Type Associations ranked according to their historic fire return interval, (FR1 = shortest, FR4 = longest), where a "W" indicates a wetland-dominated ecosystem (Cleland et al. in press).

Fire Rotation Classification	Soil Moisture	Dominant Presettlement Vegetation	Presettlement Fire Rotation (yrs)
FR1	xeric	jack pine and barrens	135
FR2	less xeric	red & white pine, oak	320
FR2W	hydric	wetlands adjacent xeric LTAs	490
FR3	dry mesic	white pine - hemlock	467
FR4	mesic	northern hardwoods	1820
FR4W	hydric	wetlands adjacent mesic LTAs	2925

Current vegetation was estimated from classified TM imagery (WISCLAND). The percentage of 4 major cover types within each section was calculated: Agricultural and Grassland (**AG**), **Forest**, **Water**, and **Wetland**. Forest vegetation was further rank-ordered according to a flammability scale (1 = most flammable, 5 = least flammable) comparable to the LTA FR classification shown in Table 1 (Table 2). This ordinal scale was assigned to each 30x30m pixel of the classified imagery, and averaged across all forested pixels in a given section (**RelFireResist**).

Table 2. Forest vegetation flammability scale.

Fire Risk Class	WISCLAND Cover Types	Expected Fire Behavior
1	coniferous, jack pine, red pine	Pine-dominated systems with greatest crown fire risk
2	white spruce, mixed/other coniferous	Moderate crown fire risk
3	aspen, oaks, lowland mixed/other conifer	Surface fire risk or low crown fire risk
4	coniferous and mixed wetlands	Crown fires rare but possible
5	maple, mixed/other broad-leaved, broad-leaved wetlands	Lowest surface fire risk

Other ecological variables included the available water-holding capacity (**AWC**) of the soil as estimated from the national STATSGO soils database, and three mean climatic variables that were shown to be important indicators of fire risk in an earlier study (Cardille et al. 2001): mean maximum August temperature (**AugMaxT**), mean March precipitation (**MarPrecip**), mean June precipitation (**JunPrecip**).

2.4 Human Factors

Block-level census data from the 1990 U.S. census was used to calculate 4 variables associated with human development: population density (**PopDens**, residents/sq. km), housing density (**HouseDens**, # homes/sq. km), percent of homes occupied by owners (**PropOwn**), and percent of seasonally occupied homes (**PropSeas**). Each of these variables was calculated as an area-weighted average of the blocks within a section. Four additional measures of infrastructure were also used: distance to nearest road (**DistRoad**, meters), road density (**RoadDens**, linear km/square km), distance to nearest railroad (**DistRail**, meters), and railroad density (**RailDens**, linear km/ square km).

2.5 Statistical Analysis

We applied classification tree analyses to binary (fire/nonfire) section observations using the RPART extension (Atkinson & Therneau 2000) to SPLUS 2000 Professional (Release 3). Forest fire observations were analyzed in comparison with all fire observations in each of three minimum size classes: All fires (ignitions), fires >= 1 acres, and fires >= 10 acres. Trees were pruned using the cross-validation procedures of Atkinson & Therneau (2000), and 50% of observations were reserved for validation.

3 RESULTS

The classification trees shown in this paper can be interpreted as a dichotomous key, where the decision variable is shown at each split, true statements flow to the left, and the length of each branch reflects the variation explained by the split. In all of the following classification trees, nonfire predictions (0) follow the left branch (i.e., true statements), and fire predictions (1) follow the right branch. The likelihood of a fire prediction therefore increases from the left to the right of each tree.

The primary variable affecting the likelihood of a section experiencing a fire was population density, which explained roughly 40% of the variation in the data (Fig. 3a). Proximity to roads and railroads also increased the likelihood of a fire ignition, but explained far less variation in the data. Similarly, forest fire ignitions were predicted primarily by housing density, a strong correlate of population density (Fig. 3b). Ecological variables were less common in the classification trees for fire ignitions.

As the fire size threshold was increased, ecological variables described more of the variation in the data. For fire occurrences greater than 1 acre, the presence of agriculture or grassland cover types was the most important predictor (Fig. 3c). For forest fires greater than 1 acre, the historic fire rotation of the land type association explained the most variation (Fig. 3c). Forest fires greater than 10 acres were most likely to occur in FR1 LTAs, relatively flammable vegetation (RelFireResit < 3.1), or close to railroads. Applications of the classification trees to the geographic data show that the spatial interpretations of fire risk change dramatically when evaluating the risk of fire ignitions (Fig. 4a) versus the risk of large fires (Fig. 4b).

Figure 3. Classification tree results. Zeroes indicate non fire observations and ones indicate fire observations.

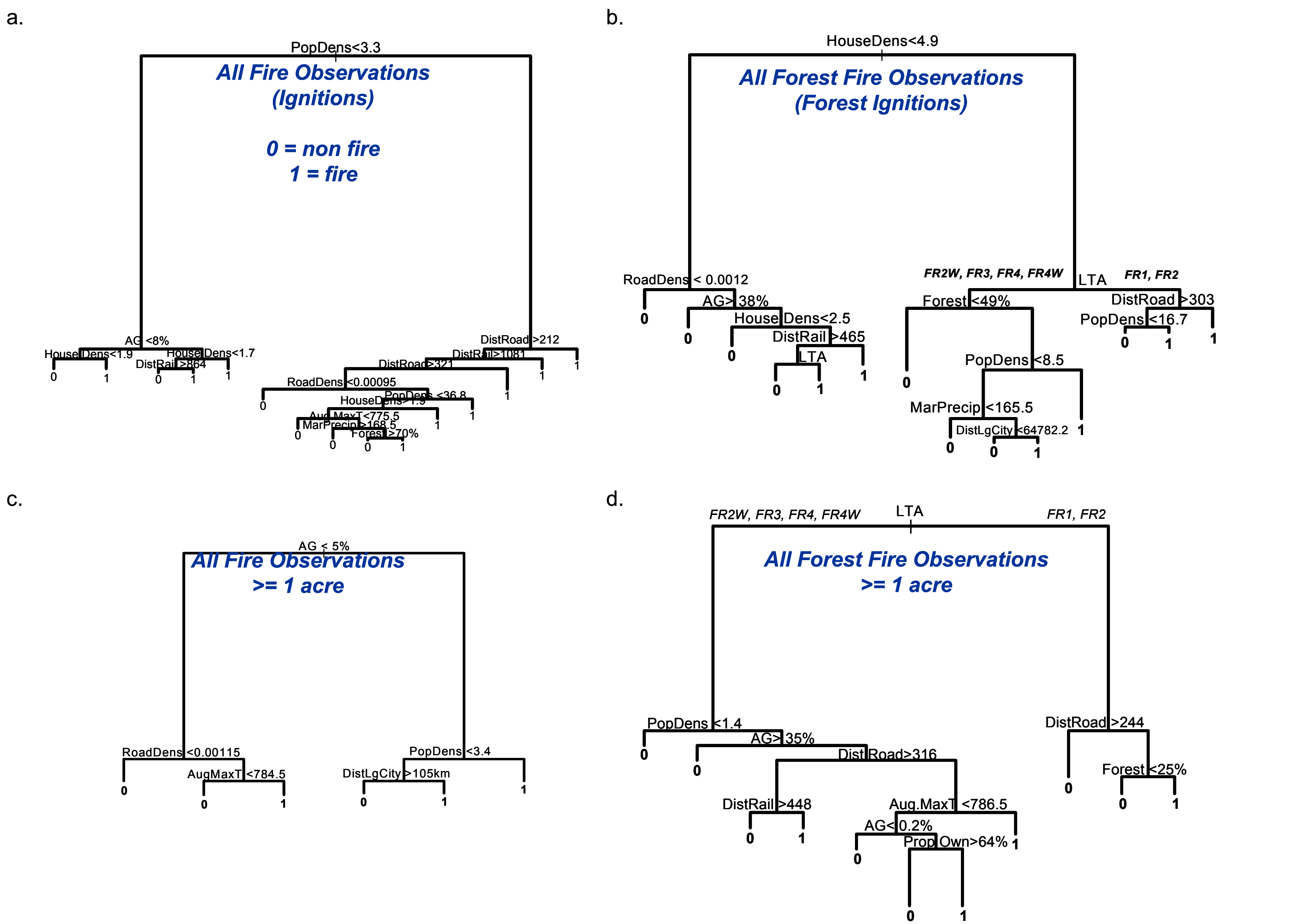
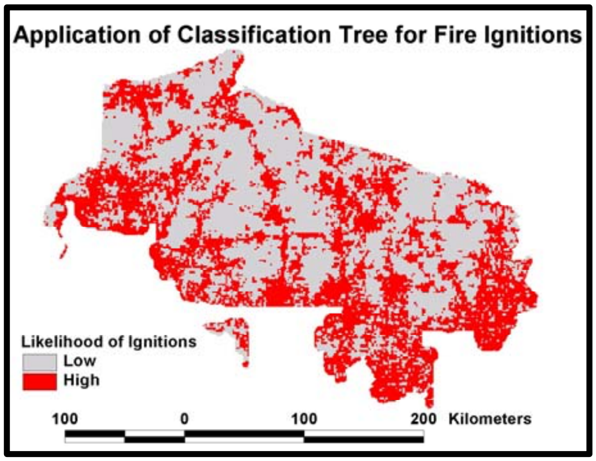
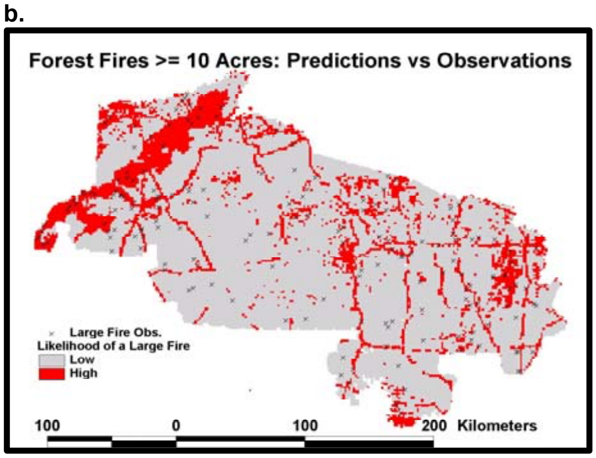


Figure 4. Applications of classification tree results to a. fire ignition data, and b. forest fires greater than 10 acres.

a.



b.



4 Conclusions

Results suggest that fire ignitions are related primarily to factors associated with human populations. Less important indicators of ignition risk include variables associated with human access, such as distance to nearest road or railroad. However increasing the minimum fire size increases the importance of ecological indicators of fire risk. For example, vegetation within agricultural and grassland areas are susceptible to fire at certain times of the year, as indicated by the importance of that cover type in predicting fire observations greater than 1 acre in size. Similarly, landtype association is the most important indicator of forest fire observations greater than one acre. This suggests that the LTAs historically prone to fires are still susceptible to fires today, despite an aggressive fire suppression policy practiced throughout the region. Collectively, our results indicate that while humans factors dominate the probability of fire ignitions, ecological factors constrain the ability of those fires to spread. These results have strong implications for forest dynamics and fire risk at the human-wildland interface in the upper Midwest.

5 Acknowledgements

We thank the Wisconsin Department of Natural Resources and the US Forest Service offices responsible for recording and compiling the Wisconsin fire database. Thanks also to Maureen Mislivets for her assistance in compiling the spatial datasets, and both Jeff Cardille and Sari Saunders for their expertise and guidance with fire data analyses. This research was funded through the National Fire Program.

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