SIMULATING FIRE RISK WITHIN A MIXED-OWNERSHIP, FIRE-PRONE LANDSCAPE OF NORTHEASTERN WISCONSIN: INTERACTIONS BETWEEN HUMAN IGNITIONS AND FOREST DYNAMICS.

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1. INTRODUCTION

The risk of wildfire in northern Wisconsin depends on the interaction between human-caused ignitions and relative flammability of the vegetation and fuels where they occur. In particular, Wisconsin pine barrens contain extensive areas of pine and oak forests that are prone to high intensity fires, but these systems are embedded within a largely fire-resistant northern hardwood region (Figure 1). Since humans are the primary cause of fire in the Lake States (Cardille et al. 2001), the greatest risk of severe fires occurs where fire-prone ecosystems overlap the Wildland Urban Interface (WUI), the intersection of human development and natural vegetation (Haight et al. 2004). Because ecosystem properties, vegetation treatments, natural disturbance, and the presence of people in wildland areas interact to determine fire ignition and spread across landscapes, it is critical to understand these interactions in a spatial context when developing fire mitigation strategies.

The Chequamegon-Nicolet National Forest (CNNF) sought guidance for developing strategic fire and fuel mitigation plans in a 780-km^2 area (Lakewood subdistrict, Fig. 1) of their forest experiencing rapid development of its WUI that partially overlaps with fire-prone landscape ecosystems. We used the forest landscape succession and disturbance model, LANDIS 4.0 (He et al. 2005), to simulate interactions between current human ignition patterns, ecosystem constraints (e.g., soil texture), forest management, and succession to estimate long-term fire risk in the Lakewood subdistrict under alternative fire mitigation scenarios.

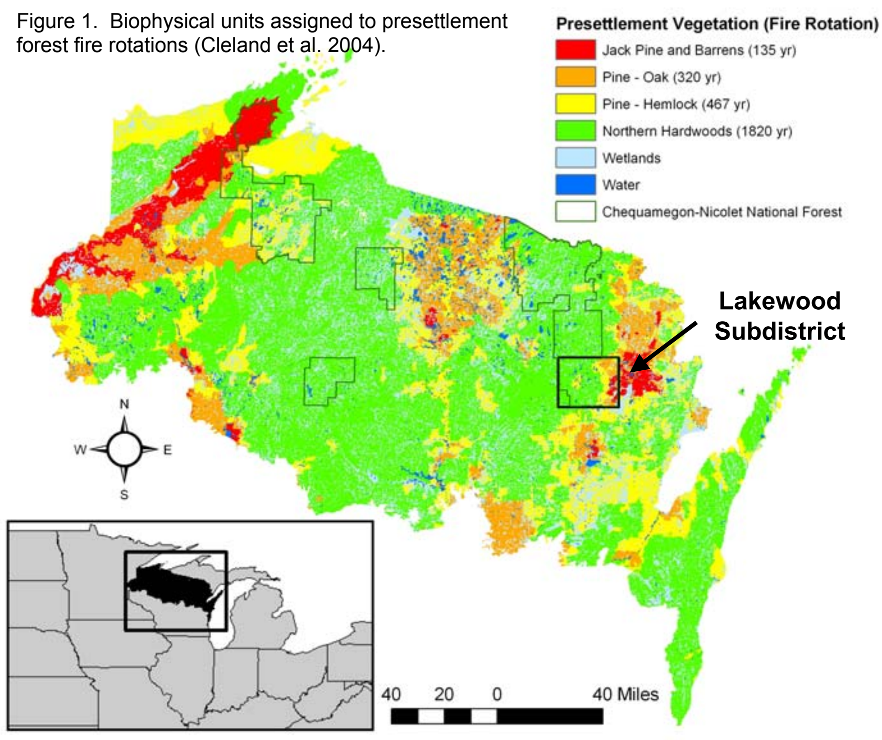


Figure 1. Biophysical units assigned to presettlement forest fire rotations (Cleland et al. 2004).

2. METHODS

LANDIS simulates spatial forest dynamics including forest succession, forest harvesting, seed dispersal, species establishment, natural disturbance, and their interactions across large landscapes (10^4 to 10^7 ha) and long time scales (50 to 1000 years) (He and Mladenoff 1999, Gustafson et al. 2000). We first developed a base scenario that simulated (1) harvest patterns and prescriptions defined by the CNNF forest plan, (2) a spatial distribution of fire ignitions affected by the current distribution of residential development and road networks, and (3) realistic burn patterns affected by spatial configurations of fuels and both natural and man-made fire breaks. Management area-specific harvest prescriptions were implemented in the harvest module of LANDIS based on Gustafson et al. (2000) and verified by CNNF silviculturalists and forest planners. A 16-year fire database for northern Wisconsin (Cardille and Ventura 2001) was used to parameterize the fire regime expected under current fire suppression policies. Modern fire size distributions were estimated for each biophysical unit (Cleland et al. 2004), whereas ignition rates were parameterized using current housing density in combination with biophysical unit (Sturtevant and Cleland 2003) (Fig. 2, Table 1). Mean fire rotations were then calculated using the resulting combination of ignition density and mean fire size.

Table 1. Fire regime attributes (see Figure 2). LD and HD refer to housing density less than and greater than 4.4 homes/km^2, respectively, a threshold that affects fire ignition rates.

Biophysical Unit	Mean Fire Size (ha)	Fire Rotation LD	Fire Rotation HD
FR1	3	4700	1250
FR2	1.1	12100	4800
FR3	1	20900	5600
FR4	1.8	18500	6150
Wetland	3.3	10700	5550
Open	1.2	5050	3100

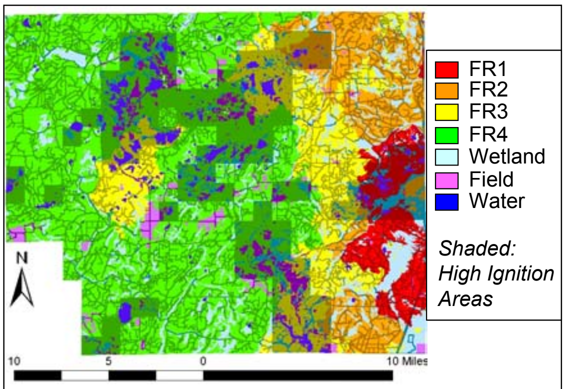


Figure 2. Mapped fire rotations (FR). See Table 1 for corresponding fire regime attributes.

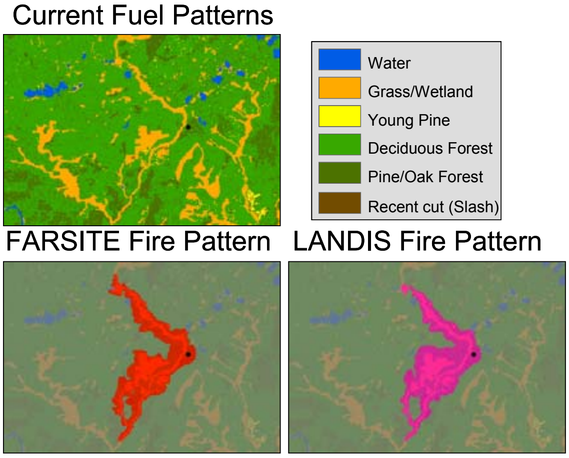
Mapped road networks functioned as firebreaks, where the likelihood of a fire breaching a road was a function of the road size class and the spread characteristics of the fire. Ignition rates along 30m buffers adjacent roads were assumed to have the same ignition rates estimated for areas with high housing density.

Evaluating the effects of alternative fire mitigation strategies on the area and spatial pattern of wildfires required understanding of fire response to the spatial arrangement of locally relevant fuel types. Given the paucity of data available on actual fire burn patterns in the region, we calibrated the fire spread patterns generated by LANDIS to that predicted by the fire behavior model FARSITE (Finney 1998). Working with fire management officers, we translated the LANDIS fuel classes into BEHAVE fuel models (Anderson 1986) they have applied successfully within the CNNF. Basic fuel types in increasing order of spread rates included forest other than pine and oak (BEHAVE Class 8), pine older than 20 years and oak (BEHAVE Class 9), young pine plantations (BEHAVE Class 4), and open grassland and wetland (BEHAVE Class 1). With the exception of young pine plantations, the spread rates are based on surface fire behavior that dominates the local fire regime. The minimum travel time algorithm (Finney 2002) was implemented in the LANDIS fire module to generate a fire spread cost surface based on elliptical fire spread behavior from an ignition point in response to wind direction, wind speed, and fuel type configuration. Fire season (i.e., April and May; Cardille and Ventura 2001) wind statistics were used to define probabilities of different wind directions and relative wind speeds for a given fire event. Actual burn perimeters simulated within LANDIS were then determined by specifying a "cut-off" point in spread cost that could be defined either by a predetermined fire size or fire duration (Fig. 3).

3. STUDY DESIGN

The fire risk and ecological implications of four mitigation strategies and their interactions were investigated relative to the base scenario using a replicated factorial study design with the

Figure 3: LANDIS fire pattern calibrated to FARSITE output (dot indicates ignition point)



following factors: (1) additional permanent firebreaks within fire-prone biophysical units, (2) redistributing pine and oak community types to areas of the forest more isolated from housing developments, (3) reducing fire ignitions within the WUI by changing policy on debris burning, and (4) reducing fire ignition rates on roadsides through vegetative management on NF lands. Key response variables included landscape-scale area burned, area burned within the WUI, and changes in forest composition relative to the ecological goals specified by the CNNF forest plan. Spatial maps of fire risk, estimated as the cell-scale probability of burning during 50 replicate simulations, were created for the base scenario and some selected fire management alternatives that showed the greatest departure from the base scenario.

4. RESULTS & CONCLUSIONS

Eliminating debris burns had the greatest influence on the landscape area burned over a 250-year period, both inside and outside of the WUI. Debris burns accounted for roughly 25% of the total fire ignitions in the northern Wisconsin fire database, a percentage that increased within high density housing areas. This result suggests that fire prevention and education remains an important strategy for reducing fire risk within the Lakewood area. Given the current development trends, however, housing density and landscape-scale fire risk are expected to increase over time. Future research will incorporate human development projections to evaluate how an expanding WUI may influence the relative success of fire and fuel mitigation strategies within this landscape.

Redistributing pine and oak communities had the next greatest influence on the cumulative area burned within the study landscape. Interestingly, this alternative had a negligible effect on the ecological goals outlined within the CNNF forest plan. We suggest that such landscape-scale management strategies can offer viable solutions for mitigating long-term fire risk in the face of increased development of private in holdings. Reducing fire ignitions along roadsides also reduced the landscape area burned, but this effect was most evident outside of WUI areas.

Strategic firebreaks did not significantly influence the cumulative area burned at the landscape scale, though they did appear to reduce fire risk in localized areas. Firebreaks are designed to restrict the spread of very large fires. Given modern suppression policies, such fires are rare events within northern Wisconsin. Nonetheless, large fires on the order of 1,000 – 10,000 acres have occurred in the past (Radeloff et al. 2000). Reducing the risk of low probability but catastrophic events is a problematic area of risk assessment that requires further study.

Despite relatively small fires predicted under current suppression policies, landscape context was an important determinant of fire risk – the probability of fire was higher on or adjacent to the most fire-prone biophysical units, including open and wetland systems. Results from this study provide insight into the relative impacts of different fire mitigation strategies. Our study also illustrates the importance of human-ecological interactions when addressing fire risk within the WUI.

5. REFERENCES

Andrews, P.L., 1986. BEHAVE: Fire behavior prediction and fuel modeling system-BURN subsystem, part 1, Gen. Tech. Rep. INT-194. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 130p.

Cardille, J.A., Ventura S.J., and Turner M.G.

2001. Environmental and social factors influencing wildfires in the Upper Midwest, United States. Ecological Applications 11: 111-127.

Cardille, J.A. and Ventura, S.J. 2001. Occurrence of Wildfire in the Northern Great Lakes Region: Effects of Land Cover and Land Ownership Assessed at Multiple Scales. International Journal of Wildland Fire 10: 145-154.

Cleland, D.T., T.R. Crow, S.C. Saunders, D.I. Dickmann, A.L. MacLean, J.K. Jordan, R.L. Watson, A.M. Sloan, and K.D. Brosofske. Characterizing historical and modern fire regimes in Michigan (USA): A landscape ecosystem approach. Landscape Ecology 19: 311-325.

Finney, M.A. 1998. FARSITE: Fire Area Simulator - Model development and evaluation. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. Research Paper RM-4.

Finney, M.A. 2002. Fire growth using minimum travel time methods. Canadian Hournal of Forest Research 32: 1420–1424.

Gustafson, E.J., S.R. Shifley, D.J. Mladenoff, H.S. He and K.K. Nimerfro. 2000. Spatial simulation of forest succession and timber harvesting using LANDIS. Canadian Journal of Forest Research 30:32-43.

Gustafson, E.J., Zollner, P.A., Sturtevant, B.R., He, H.S., and Mladenoff D. J., 2004. Influence of forest management alternatives and landtype on susceptibility to fire in northern Wisconsin, USA. Landscape Ecology 19:327-341.

Haight, R.G., D.T. Cleland, R.B. Hammer, V. C. Radeloff, and T. S. Rupp2004. Assessing Fire Risk in the Wildland-Urban Interface. Journal of Forestry 104: 41-48.

Pennanen, J. and Kuuluvainen, T. 2002. A spatial simulation approach to natural forest landscapedynamics in boreal Fennoscandia. Forest Ecology and Management 164: 157-175.

He, H.S. and D.J. Mladenoff. 1999. Spatially explicit and stochastic simulation of forest-landscape fire disturbance and succession. Ecology 80:81-99.

He, H. S., Shang, Z. B., Crow, T. R., Gustafson, E. J., and Shifley, S. R. 2004. Simulating forest fuel and fire risk dynamics across landscapes—LANDIS fuel module design. Ecological Modelling 180: 135-151.

Radeloff, V.C., D.J. Mladenoff, and M.S. Boyce. 2000a. Effects of interacting disturbances on landscape patterns: Budworm defoliation and salvage logging. Ecological Applications 10: 233-247.

Sturtevant, B.R. and D.T. Cleland. 2003, Human influence on fire disturbance in northern Wisconsin. Proceedings of the 2nd International Wildland Fire Ecology and Fire Management Congress, November 18-20, Orlando, Florida.

Yang, J., He, H. S., Gustafson, E. J. 2004. A hierarchical fire frequency model to simulate temporal patterns of fire regimes in LANDIS. Ecological Modelling 180: 119-133.

BIOSKETCH

Brian Sturtevant is a Research Ecologist with the North Central Research Station of the Forest Service, located in Rhinelander, Wisconsin, along with co-authors Brian Miranda and Eric Gustafson. All have research interests in landscape-scale interactions between forest succession, natural disturbances including insects and fire, and forest management patterns. Hong He is an associate professor in the Forestry Department of the University of Missouri-Columbia, and a primary developer for LANDIS 4.0. The National Fire Plan funded this research.