

Biosketch of Dr. Hong S. He

Dr. He is an assistant professor at the University of Missouri-Columbia. Dr. He primarily works in the field of landscape ecology and geographical information systems, spatially explicit forest landscape modeling, and GIS and remote sensing data integration. Dr. He has been one of the principal model developers and code master of LANDIS since 1994. He is the principal investigator of the LANDIS 4.0 project supported by National Fire Science funding.

Spatially explicit assessment of the landscape-scale effects of various fuel treatment on fire risk in Missouri Central Hardwoods using LANDIS 4.0

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Introduction

Forest Plans of National Forests provide broad guidance for periods of 10-15 years. Within the framework of the Forest Plan, site-specific projects and activities are proposed, analyzed and carried out for each management area. The National Forest Management Act of 1976 (NFMA) requires that plans be maintained, amended and revised to address new land conditions, public demand, and scientific development. Planners, managers, scientists and the public increasingly realize the need to understand the long term effects of the cumulative management decisions at the landscape-scale and revise the plan to minimize the negative effects. Such a task is challenging because practical constraints such as large spatial extents, long timeframes involved, and high human and economic costs often make it difficult to evaluate these management effects using descriptive studies or field experiments. Consequently the long-term effects often are not studied. Models are an important tool for analyzing large-scale, long-term, cumulative effects. Forest landscape models, in particular, can provide guidance about spatial and temporal allocation of various management practices and evaluate their effects on species compositions, spatial patterns, wildlife habitat, and fire risk.

LANDIS 4.0 is a forest landscape disturbance and succession model that was developed with funding from the National Fire Plan. Its strength is the ability to predict the effects of interacting disturbances (including timber and fuel management, insect outbreaks and human fire ignitions) on many forest properties, including forest composition, spatial pattern of fuel loads and fire risk. It operates at large scales (e.g., an entire National Forest) to simulate management strategies and multiple natural disturbance processes with tree species-level realism. There are few landscape models that explicitly account for interactions among so many phenomena. LANDIS development has been underway for more than a decade. It has been used by more than

200 individual groups worldwide and about 20 of those currently have ongoing interactions with the developers. The model can be adapted to a wide range of species and environmental settings, and it has been parameterized for major forest ecosystems in the eastern U.S. LANDIS is being used to assist forest planning in several National Forests in eastern U.S.

In this study we discuss the design and functionality of LANDIS and present a case study applying LANDIS 4.0 to the Central Hardwood forests of Mark Twain National Forest (MTNF) in Missouri. Specifically, we assess the long-term effects of various fuel treatments on fuel loads, fire risk, tree species composition and age classes.

Materials and Methods

Study area and issues of fuel and fire management

Our study area is Mark Twain National Forest (MTNF) in the Missouri Ozark Highlands. The study area includes approximately 400,000 ha and encompasses the typical Central Hardwood forests comprised primarily of white oak (*Quercus alba* L.), post oak (*Q. stellata* Wangenh.), black oak (*Q. velutina* Lam.), scarlet oak (*Q. coccinea* Muenchh), short leaf pine (*Pinus echinata* Mill.), and hickory. Sugar maple (*Acer saccharum* Marsh.) and red maple (*A. rubrum* L.) have increased in abundance due to their shade tolerance and decades of fire suppression.

Similar to other National Forests, over a half century of fire suppression on the MTNF has resulted in the build-up of hazardous fuels and consequently, the increase of fire intensity. The major portion of MTNF is intersected with over 10,000 non-industrial private forestlands and residential areas, minimizing the risk of wildfire at these wildfire urban interface (WUI) is of a great concern. Currently, MTNF treats about 0.06% of the total area per year for surface fuel reduction using prescribed burning. In the recently completed management plan, 0.6% per year of fuel treatment is suggested as the new target treatment size and 2.4% per year of fuel treatment is identified as a desired level of fuel treatment. However, how extensively fuel treatment should be expanded and to what degree other types of fuel treatment methods such as coarse woody debris reduction should be applied are of great interest to the planners and managers.

The LANDIS model presents a useful tool for answering these questions. Fuel treatment sizes and fuel treatment methods (prescribed burning and coarse woody debris reduction) can be simulated using a factorial design in LANDIS and key variables such as fuel loads, fire risks, species composition and age classes can be used as response variables to quantify the effects of each fuel treatment scenario. The effects of these treatments can then be statistically compared.

Model experimental design

We designed eight simulation scenarios (A-H) reflecting combinations of treatment size (percent/yr) and treatment methods (prescribed burning vs. CWD reduction) (Table 1). Scenario A is the current treatment, scenario B is the target treatment size, scenario D is the desired level of fuel treatment size. Others are hypothetical fuel treatment scenarios that facilitate the comparisons.

Table 1. Factorial design of fuel treatment in MTNF
(PB = prescribed burning; PB+CWD = prescribed burning and coarse woody debris reduction in equal measure)

		Treatment Size (<i>percentage /yr</i>)					
		0.06	0.12	0.6	1.2	2.4	4.8
Treatment Method	PB	A		B	C	D	
	PB+CWD		E		F	G	H

Model simulation and data analysis

LANDIS model simulations use the existing data on species/age and land types already parameterized in previous studies. The current fire regime under aggressive suppression was simulated as mean fire size 3.5=ha (SD=1.8 ha) and fire cycle 300 yrs on southwestern slopes and 450 yrs on northeastern slopes. Harvest was simulated as even/uneven aged harvesting on oldest forest (>100 yrs) and “thinning” on young forest (<30 yrs), 0.4% /yr. Each treatment was simulated to 200 years with 10 replicates. Overall treatment effects were analyzed using multivariate analysis of variance (MANOVA) and treatment pair comparisons was analyzed using ANOVA. Response variables included percent pixels (% landscape) by simulated fire intensity classes (ground fire, low damage, medium damage, severe damage, and stand-leveling fire), four species groups (black oak, white oak, shortleaf pine, and maple), and five age classes (seedling, sapling, pole, sawlog, and old-growth).

Results and Discussion

Simulated low and mid intensity fires will change to severe stand damaging (class 4) or stand leveling (class 5) fires under the scenarios of low fuel treatment (e.g., 0.6%/yr) in the Central Hardwood forests. Simulated total area of wildfires decreases with increasing treatment intensities (size and method) except for scenario A and E in which treatment sizes are relatively low (<0.6%/yr). Fuel treatments reduce fire occurrence, prolong fire cycle, and reduce the area of high intensity fires. Wildfire cycles extend from current 300-450 years to over 1,000 years depending upon treatment methods. Total sites burned by high intensity wildfires are reduced from 11% to 1% of the study area.

Fuel treatment size exhibits threshold effects in the study area. Our results suggest that when treatment size is small (e.g., <0. 6% per year (treatment B), treatment methods have little effect in terms of reducing fire severity.

CWD reduction in combination with prescribed burning is more effective in reducing fire severity. Comparison of scenario F with scenario D suggests that treating only 0.6% of the area with prescribed burning and 0.6% with CWD reduction is more effective than treating 2.4% of area with prescribed burning (Fig. 1).

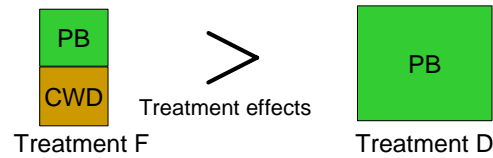


Figure 1. Treatment effects comparison

Similarly increasing treatment size from 1.2%/yr (F) to 2.4% /yr (G) reduces severe stand damaging fires from 2.4% to 0.5%. Further increasing treatment size to 4.8% (H) had only small effects (although statistically significant) on high severity fires. These results may have important implication for the forest planners and managers in MTNF in designing fuel treatment strategies and allocating efforts. The planners and managers should consider a balanced approach in terms of treatment size and treatment effects.

Fuel treatment effects on species composition and age class are statistically significant, except when treatment size is small (e.g., <0.6%). However, such effects are secondary to the effects of fire suppression on species composition and age structure (result not shown).

We showed that LANDIS is an effective model for evaluating long-term and large spatial effects for the identified scenarios. However, LANDIS is not a predictive model. The actual future is only one realization of numerous possible simulation scenarios. Nevertheless, the model is useful since it can provide insights on the large-scale and long-term effects which would otherwise be impossible to assess.