MODELING HISTORICAL AND CURRENT SUCCESSIONAL DYNAMICS ON THE HURON NATIONAL FOREST

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ABSTRACT. Historical and current successional dynamics were modeled on the Huron National Forest in northern Lower Michigan. Historical vegetative states, fire regimes, and catastrophic wind events were estimated using observations made by the General Land Office survey, which was conducted between 1837 and 1852 within the study area. Current vegetative states and disturbance regimes were based on federal and state records and maps of landcover. Ecological units classified and mapped using natural associations of landforms, soil properties, and potential natural vegetation were used for spatial analyses. The Vegetation Dynamics Development Tool (VDDT), a state-transition modeling system that simulates changes in vegetative composition and structure resulting from both management activities and natural disturbances, was parameterized and calibrated using these data and research results. VDDT models for ecological units categorized into six historical fire regime classes were built to evaluate historical and current successional trajectories, and alternative fuel treatment strategies on the Huron National Forest.

Key words: VDDT, succession, Michigan national forests

INTRODUCTION

The U.S. Forest Service, Pacific Southwest Station, conducted a study comparing landscape-scale fuel treatment models at seven major locations in the United States including the Huron-Manistee National Forests in Michigan (Weise et al. 1999; Weise et al. 2003). A major purpose of this study was to simulate a set of fuels treatments and evaluate model results with regard to wildland fire occurrence, smoke emissions, and vegetation distribution. This analysis of the Huron National Forest was done as part of this broader study. Additional reports describing the use of VDDT in conjunction with this study are available (Arbaugh et al. 2001; Merzenich et al. 2001; Merzenich and Frid 2005). Analysis using VDDT is being used to support land planning throughout North America (Hemstrom 2001, Forbis 2006).

The Huron National Forest is located in the north central portion of the lower peninsula of Michigan. Northern Lower Michigan is typified by fire-resistant northern hardwood forests growing on fine textured morainal or low-energy glacial lakebed landforms. In contrast, the Huron National Forest and nearby state forests are largely composed of high-energy sandy outwash plains or ice-contact topography supporting fire adapted vegetation. The dominant forest types include jack and red pine (*Pinus banksiana* and *Pinus resinosa*), red maple (*Acer rubra*), white, black oak, and pin oak (*Quercus alba, Quercus velutina, Quercus ellipsodalis*), and big tooth aspen (*Populus grandidenta*). The history of federal land acquisition due to tax abandonment in the early twentieth century resulted in areas composed of the poorest soils reverting to federal or state ownership. As a consequence, the Huron National Forest is composed of vegetation and fuel types that pose a serious fire hazard (Haight et al. 2004).

Jack pine is especially prone to intense stand replacing fires, which historically burned with fire rotations of approximately fifty years (Cleland et al. 2004, Maclean and Cleland 2003). This forest type is the dominant community within the Huron-National Forest, providing habitat for the federally listed endangered Kirtland's warbler (*Dendroica kirtlandii*). Continued management for the Kirtland's warbler and jack pine is therefore a mandate for National Forest managers, and as a consequence large acreages will be maintained in conditions posing a high crown fire hazard. This hazard is compounded by the intermingling of private lands and homes within the proclamation boundary of the Huron National Forest. Of the 594 thousand acres occurring within the Forest's boundary, 264 thousand acres are private land. Therefore improving our understanding of historical and modern successional dynamics and fire regimes is important for meeting multiple-use goals of providing for species, maintaining or restoring ecosystems, and managing fire hazards.

The purpose of this paper is to describe the Vegetation Dynamic Development Tool (VDDT) modeling process and results for the Huron National Forest. Model assumptions, development and calibration are presented first. Management scenario results and discussion follow.

MODELING

VDDT is a state-transition model used to project landscape-scale vegetative conditions over long time frames (Beukema et al. 2003, Merzenich et al. 1999). VDDT was developed jointly by ESSA Technologies, Ltd. and the USDA Forest Service. VDDT models the effects of alternative levels of management treatments on vegetation as influenced by stochastic disturbances such as wildfire. VDDT provides a common platform for specialists to collectively define the roles of management treatments and natural disturbance agents at the coarse-scale. VDDT allows for rapid testing of the sensitivity of the system to changes in assumptions thus enabling learning and communication (Kurz et al. 2000).

Discrete states are defined in VDDT on the basis of a vegetative cover type and structure class. Simulation units are assigned to states based on the proportion of area contained in those states. These simulation units then progress along time-dependent successional pathways or change states in response to probabilistically applied disturbances or management treatments. VDDT projects the proportion of units (or area) contained in each state and the levels of disturbances that may be expected. VDDT is a non-spatial model and does not consider the effect of contagion in time or space. For this analysis, VDDT models were built for each historic fire regime class as described by Cleland and others (2004). These fire regime classes were developed by aggregating ecological landtype phases (Cleland et al. 1994) into relatively homogenous categories with respect to dominant historical vegetation and crown fire regimes. Table 1 displays fire regime classes on the Huron National Forest.

Table 1: Summary of Fire Regime classes for the Huron National Forest

Class	% of Area	Soils	Dominant Vegetation	Landform
FRC1	40	Coarse sands	Jack pine	Outwash plain
FRC2	22	Medium sands	Mixed pine	Ice-contact hills
FRC3W	12	Fire prone wetland	Wetland conifers	Glacial lakebeds
FRC3	10	Silt-loam	Hemlock-white pine	Moraines and lakebeds
FRC4	9	Deep loam	Maple, beech, hemlock	Moraines
FRC4W	6	Fire resistant wetland	Wetland hardwoods	Glacial lakebeds
Water	1			

Model Assumptions

Model assumptions were based on published research that was conducted within the study area (Cleland et al. 2004). In this research, data from General Land Office (GLO) surveys, carried out between 1837 and 1852, were used to estimate historic stand replacement (lethal) wildfire rotations for each fire regime class, and compare them to current (1985-2000) fire rotations using data from northern Lower Michigan. The authors reported that current stand replacement fire rotations are an order of magnitude greater than historic rotations. The wildfire acreage burned in VDDT under current conditions is thus assumed to be one-tenth that of historic levels (Table 2). By analyzing the GLO survey data, the authors also estimated the relative historic abundance of each major tree species. Comparisons between historic and current conditions are based on these estimates.

Table 2: Historic and current wildfire and windthrow rotations in years.

	Stand replacement (lethal) fire rotations		**VDDT fire rotations (based on historic)**		**VDDT windthrow rotations (based on historic)**	
Class	**Historic**	**Current**	**All fires**	**Lethal only**	**Annual rate**	**Rotation (yrs)**
FRC1	59	870	30	60	.0046	217
FRC2	107	1,162	30	100	.0038	263
FRC3W	120	7,192	60	120	.0087	115
FRC3	473	4,264	210	400	.0018	555
FRC4	1,385	19,137	1,400	1,400	.0073	137
FRC4W	684	9,456	360	700	.0065	154

** These are averages. In VDDT wildfire rates vary by cover type, structure class and other criteria. Fire and windthrow rotations reflect the relative frequency of stand replacing events.

The other major natural disturbance is catastrophic windthrow caused largely by tornados. Windthrow patches may exceed ten thousand acres, and historically more than 50 per cent of patches were one-thousand acres or larger (unpublished data). It was assumed that most large windthrow areas subsequently burned. To develop probabilities for VDDT, we also assumed that pole-timber and larger stands are susceptible to windthrow and that the recognition window for windthrow by the GLO surveyors was 20 years. Wetland areas tend to be most susceptible to windthrow. The average windthrow rotation calculated by this method from the GLO survey data varied from 115 years in class FRC3W to 555 years in class FRC3 (Table 2). In VDDT windthrow areas are transferred to special classes for 10 years where they have highly elevated wildfire risks. If no wildfire occurs within this timeframe they succeed to seedling/sapling stands. Windthrow fires are modeled separately from normal wildfires. Rapid salvage of windthrow areas eliminates the risk of fires in these areas.

VDDT succession classes are defined according to a cover type and structural stage. Cover types are based on the predominant overstory and understory tree species. Structural stages are defined based on tree size and density. For this study, the stages are seedling/sapling, pole, and mature. In addition conifer and oak stands are identified as having low or high stocking. Areas with less than 10 percent tree canopy coverage are defined as barrens. On private lands, Gap Analysis Project (GAP) data were used to define cover types. Structural stage data were not readily available from GAP for private lands, so the dominant structural stage, as calculated by fire regime and cover type for Forest Service lands, was applied to private lands.

Model Development

Separate VDDT models were developed for each fire regime class. Each VDDT model was calibrated by using assumed historic wildfire and windthrow disturbance rates, and then comparing the long-term results with the data estimated from the General Land Office (GLO) survey data. An iterative process was used to calibrate the models by refining succession and disturbance pathways. A general description of the models and processes follows. The actual models and more complete documentation are available from the authors.

*Fire regime class 1 (FRC1)***.** FRC1 comprises 40 percent of the Huron National Forest. These ecosystems occur on high-energy glacial outwash plains consisting of xeric coarse sandy soils classified as Typic Udipsamments at the subgroup level of Soil Taxonomy. The major cover types modeled are jack pine, red pine, oak (primarily *Quercus ellipsodalis*), and aspen/birch (*Populus spp*. and *Betula spp*.). The annual probability of a wildfire was assumed to be four percent with the caveat that a wildfire will not occur until five years have elapsed since a previous fire. This is analogous to a wildfire return interval of 30 years (Table 2, FRC1 fire rotation for “all fires”). Lowland forest inclusions are wetter and tend to burn under only severe conditions. In this analysis they are assumed to burn at one-third the rate of surrounding lands.

Most fires in jack pine are stand-replacing (lethal), and burned areas quickly regenerate to jack pine. Jack pine must be at least 10 years old to produce viable seed, however, and lethal wildfires in young stands result in barrens. Jack pine barrens slowly regenerate to jack or red pine. Low-stocked stands move to a well-stocked condition after 50 years without a wildfire. Unburned jack pine stands generally die by age 100.

Red pine stands also occur within FRC1 with white pine (*Pinus strobus*) as a minor component. The susceptibility of red pine stands to lethal wildfire increases with stocking but decreases with age. The lethal wildfire percent varies from 80 percent for well-stocked young stands to two percent for mature low-stocked stands. Red pine must be 50 years old to produce viable seed. Younger stands that burn in a lethal fire revert to barrens. Low-stocked red pine stands move to a well-stocked condition after 40 years without a fire. On these droughty sites mature red pine stands die after about 150 years and revert to a dead class. This prevents the buildup of mature stands.

Historically less than two percent of the tree composition on FRC1 lands consisted of oaks. Due primarily to selective removal of pine, oaks now dominate approximately 18 percent of the Huron landscape. However sites are too dry to support old growth oak and trees usually die by age 100. Beyond age 50 most oaks are unable to sprout following a fire and revert to barrens if burned. Younger stands sprout and remain in oak. Oak barrens regenerate slowly to oak, jack pine, or red pine.

Aspen/birch stands exist as small patches in a matrix of jack and red pine and are assumed to burn at the same rates. Following a fire, aspen/birch sprouts. Without disturbance aspen/birch succeeds to jack pine or red pine.

Fire regime class 2 (FRC2). These ecosystems occur on ice contact topography consisting of dry sandy soils classified as Entic Haplorthods at the subgroup level of Soil Taxonomy. They are intermingled or adjacent to FRC1 areas, and are better able to support red and white pine due to higher moisture holding capacity associated with stronger podzolization (presence of iron oxide coatings on sand grains) and slightly finer soil textures. While the overall frequency of wildfires is assumed to be the same as for FRC1, crown fires in mature red and white pine stands tend to be low or mixed severity rather than stand-replacing. Many assumptions mimic those for FRC1, significant differences are highlighted.

Jack pine stands are modeled as in FRC1, except succession times are faster and low-stocked stands become well-stocked after 40 years without a wildfire. Assumption similarities for this type in FRC1 and FRC2 are due to the equivalency of the primary fuel, the volatile foliage of jack pine and resulting severe crown fires.

Four cover types represent stands with red or white pine. The *red-pine* cover type represents single-story red pine stands. The red pine/hardwood cover type represents stands with a red pine overstory and an understory composed generally of oak (*Quercus alba; Quercus rubra*), red maple (*Acer rubra*), and aspen. Stands with the red pine/white pine cover type have a white pine understory. Over time these stands succeed to a *white pine* cover type.

Mature red and white pine stands are maintained by frequent surface fires and are resistant to lethal wildfire. Only two percent of fires in low-stocked stands are lethal. Low-stocked stands move to well-stocked after 30 years without a wildfire. Transitions are to dense red pine or to red pine with a hardwood understory. Red and white pine stands do not experience age-related stand mortality as in FRC1. This allows for the development of more mature stands.

The oak/hardwood cover type, primarily composed of white and red oak (*Quercus alba*; *Quercus rubra*) and red maple, and the aspen/birch cover type have both increased substantially from historic levels. Based on the GLO survey data, eight percent of the historic tree composition on FRC2 lands consisted of oaks or red maple and six percent was aspen/birch. Currently oaks and red maple dominate 35 percent and aspen/birch dominates 33 percent of FRC2 lands.

White pines are more shade tolerant than red or jack pines and develop as an understory in low-stocked pine and hardwood stands. These mixed species stands eventually succeed to white pine. White pine may also colonize barren areas. The wildfire assumptions for red pine were applied without modification to white pine.

Six percent of FRC2 areas are in lowlands containing conifers and hardwoods. These areas often provide natural fire breaks and burn only under severe conditions. The wildfire rotation is assumed to be one-third that of pine and oak stands and all wildfires are considered lethal.

Fire regime class 3 (FRC3). Historically fires were relatively infrequent in these areas with an annual wildfire probability of less than 0.005. This corresponds to an average wildfire rotation of 210 years and an average stand replacement rotation of about 400 years. All pine, oak, and aspen/birch cover types are assumed to burn at this rate. Lowland and northern hardwood forests are assumed to burn at one-half this rate. Jack pine is a minor cover type and wildfire effects are assumed to be the same as in FRC2.

The red pine cover type succeeds to red pine/white pine and then to white pine. The susceptibility of pine stands to lethal wildfire is the same as on FRC2. When wildfires occur they tend to be more severe because of a greater proportion of acreage in dense stands.

The oak/hardwood cover type, primarily composed of white and red oak and red maple, and the aspen/birch cover type have both increased substantially in extent from historic levels. Ten percent of the historic tree composition on FRC3 lands consisted of oaks or red maple and three percent was aspen/birch. Currently oaks and red maple dominate 23 percent and aspen/birch dominates 54 percent of FRC3 lands.

White pines develop as an understory in low-stocked red pine or oak/maple stands. These mixed species stands eventually succeed to white pine. White pines do not produce large quantities of viable seeds until age 50. A stand replacing wildfire in young white pine stands converts these stands to either aspen/birch or oak/hardwoods. Without disturbance white pine develops a hemlock understory and moves to the white pine/hemlock (*Pinus strobus/Tsuga canadensis*) cover type. Wildfires in white pine/hemlock revert these stands back to white pine.

Fire Regime class FRC3W. The FRC3W wetland ecosystems typically occurs within or adjacent to fire prone landscapes and historically burned with a fire rotation of about 120 years. Historic wildfires are assumed to occur across both surface and crown fire classes on a 60-year cycle. Windthrow was relatively frequent in these areas with an estimated windthrow rotation of 115 years. Successional pathways for FRC3W are identical to those for FRC3.

Fire Regime FRC4. These areas seldom burn and present little risk. The historic fire rotation was 1,385 years and the current (1985-2000) rotation is nearly 20,000 years. All areas succeed to northern hardwoods and hemlock given sufficient time. Windthrow followed by wildfire was the major disturbance event.

Historically red pine, aspen, and oak/maple stands were rare in FRC4. Red pine is currently confined to artificial plantations. Aspen/birch stands now occupy 25 per cent of FRC4 areas largely as a result of harvesting and its preference as a commercial species, as well as abandoned field succession. Oak/red maple stands now occupy about 10 percent of FRC4 areas. Without disturbance these areas succeed to northern hardwoods.

White pine is more shade tolerant than red pine and can regenerate in gap disturbance areas or areas of intensive windthrow and fire. Historically about five percent of FRC4 areas were dominated by white pine. These stands succeed to white pine/hemlock then northern hardwood/hemlock stands.

The northern hardwood cover type is composed primarily of beech and sugar maple (*Fagus grandifolia; Acer saccharum*). After a windthrow event, without a subsequent fire, these stands succeed directly back to northern hardwoods. If a fire occurs following blowdown, affected areas succeed to earlier seral species such as aspen and white pine. Northern hardwood stands eventually develop a hemlock component and in the absence of disturbance succeed to a hemlock-white pine cover type.

Fire Regime class FRC4W. These areas are similar in composition to FRC3W areas but occur within or adjacent to fire resistant landscapes. The historic stand replacement fire rotation was about 700 years.

Calibrating VDDT Models

Thousand-year VDDT runs were made to estimate the historic composition of cover types within each fire regime class. The time period, using natural disturbances only, should allow the ecosystems to return to composition patterns similar to GLO patterns (Tables 3a and 3b). These results were then compared to relative tree abundance data gleaned from the GLO survey notes. Many sensitivity runs were made to calibrate each model.

Table 3a shows the current and projected area by cover type for fire regime classes one through four. The wetland classes (3W and 4W) are not shown since these areas contain mostly lowland species that are not well-differentiated in the VDDT models. These projections are based on runs of the VDDT models using historic wildfire and windthrow assumptions. Projections are compared to the historic percentage of trees by species group as determined from the GLO data.

Table 3a: Percent of forested area by cover type (Current; projected)

Class	Cover Type	Current	Projected	GLO data**
FRC1	aspen/birch	8	3	2
FRC1	jack/red/white pine	81	92	97
FRC1	Oak/red maple	11	0	1
FRC2	aspen/birch	35	7	5
FRC2	red/jack/white pine	27	83	86
FRC2	oak/red maple	38	11	9
FRC3	aspen/birch	61	1	3
FRC3	white pine/hemlock	7	73	71
FRC3	northern hardwoods	3	14	15
FRC3	oak/red maple	28	13	10
FRC4	aspen/birch	49	8	1
FRC4	northern hardwoods	40	82	63
FRC4	oak/red maple	6	1	3
FRC4	white pine/hemlock	6	9	33

*** GLO data are based on the percent of trees in the upper 90% of the canopy. Lowland hardwoods and conifers were factored out to make these estimates. Totals may not add up to 100 percent due to rounding.*

Table 3b: Percent of area in barrens (Current; projected)

Class	Current	Projected	GLO data**
FRC1	4	25	20-30
FRC2	2	18	20-30

ANALYZING ALTERNATIVE MANAGEMENT SCENARIOS

Following initial development, the VDDT models were used to analyze different management scenarios for the Huron National Forest. Five different VDDT land-use classes based on land management objectives for this area were identified (table 4).

Table 4: Huron National Forest management Regions

Abbreviation	**MGT regions**	**Net acres****	**Percent**
GFOR	General forest	307,777	49
KW	Kirtland’s warbler	70,534	11
FB	Fuel break	15,151	2
FSWUI	Forest Service wildland-urban-interface	33,804	5
PVT	Private land	206,196	33

*** net acres excludes water, agricultural cropland, and urban areas*

Management treatments were designed to treat fuels and produce commercial products while restoring ecological conditions. All scenario runs were made using annual time steps for 150 years, with special emphasis placed on what could be accomplished in the next 50 years. The treatments include prescribed burning, regeneration harvest of mature stands, removal cuts to create barrens and fuel breaks, thinning to control stand density, and salvage of windthrow areas.

Natural regeneration assumptions contained in the original VDDT models reflected historic conditions. Prior to European settlement most of the area within barrens was located away from available seed sources and regenerated slowly. Most newly created barrens, in contrast, either regenerate from the existing seedbank or regenerate from windborne seed within 10 years of burning. Natural regeneration probabilities were increased five-fold over historic levels to reflect this current condition. VDDT’s trend lines are then used to gradually reduce the amount of natural regeneration in barrens to the historic rate as the acreage in barrens approaches historic levels. Thus as the acreage in maintained barrens increases the natural regeneration rate decreases. These trend lines thus vary by scenario.

The three scenarios analyzed were: 1) Scenario *S1* aggressively applies fuel and restoration treatments to the Huron forest in conjunction with the goals of the forest plan; 2) Scenario *S2* applies treatments at approximately half the annual rate as scenario *S1* and reflects probable budget limitations; and 3) Scenario *NoTrt (no treatment)* projects outputs when no management treatments, aside from wildfire suppression, are applied.

Kirtland’s warbler (*Dendroica kirtlandii*), an endangered species, requires a matrix of young jack pine and openings to survive. Over 90 percent of the identified habitat for this bird species is within jack pine in FRC1 areas. Critical Kirtland’s warbler habitat is included in a special management area. These Kirtland’s warbler blocks are cut and replanted to jack pine on approximately a 50-year rotation. In addition four thousand acres of barrens are maintained within Kirtland’s warbler habitat. Since this management for Kirtland’s warbler is required by the Endangered Species Act, it is included in all of the scenarios.

Forest Service stands in the wildland-urban interface (WUI) are treated as in general forest, but fuel treatments that reduce wildfire risk (thinning, prescribed burning) are applied at approximately double the annual rate. For example if five percent of dense stands are thinned annually in general forest, ten percent would be thinned in WUI.

Scenario *S1* aggressively treats fuels to restores ecological conditions on all lands and reduce wildfire effects in the wildland-urban interface (WUI). In the *general forest* management area barrens, jack pine, red pine, aspen/birch, and oak stands under 10 years of age are burned on a 10-year cycle to promote barrens; open mature stands are burned or thinned on a 40-year cycle; dense red pine, white pine, and oak stands are thinned at a five percent rate per year; mature stands of jack pine, red pine, aspen/birch, and oak/maple stands are harvested and regenerated at rates varying from two to five percent per year; and 20 percent of recently windthrown stands are salvaged per year.

Fuel breaks are created and maintained as barrens or seedling/sapling stands. The Huron forest has identified one large fuel break containing 7,700 acres. Additional scattered fuel breaks comprise approximately 7,500 acres. The treatment is to harvest all pole and larger stands with a "removal" cut, then to prescribe burn barrens and seedling/sapling stands at a 10-year interval to maintain the barrens.

Scenario *S2*, which reflects budget realities, uses the same acreage base as scenario *S1*. The major differences are in the transitions time used to create barrens and treat high risk fuels and the amount of mechanical treatment and prescribed burning that is done. In general treatments are done at approximately half the rate of scenario *S1*.

Scenario *NoTrt* includes only the treatments required to maintain Kirtland's warbler habitat. Wildfire suppression at current levels is assumed in both this and the two treatment scenarios.

RESULTS

Two important objectives of the Huron-Manistee's Forest Plan are to restore ecosystems to be within historical bounds and to reduce the risks associated with wildfires. Two significant trends evident in our analyses relative to these objectives are:

1. Wildfire suppression has resulted in a substantial decline in barrens in fire prone areas (classes FRC1 and FRC2).
2. The current levels of aspen/birch and oak are substantially greater than historic levels within all fire regime classes due to extensive harvesting in the late 1800s and early 1900s and continued harvesting in recent decades. Conversely, the extent of white pine and northern hardwoods has decreased.

Barrens provide crucial habitat for many threatened animal and plant species and represent one of the most highly imperiled plant communities in North America (Heikens and Robertson 1994; Houseman and Anderson 2002). Barrens also are effective at reducing crown fire hazard by altering fuel structure and providing areas within which less severe surface fires can be more easily contained. Within the jack pine type, the only effective landscape treatment for reducing crown fire is the creation of openings, since thinning is not an economically practical and also degrades habitat quality for the Kirtland's warbler.

The Huron National Forest management plan provides direction to create and maintain barrens within general forest areas. Historically, barrens comprised 10 to 25 percent of fire regime classes FRC2 and FRC1 lands, whereas today less than one percent of these areas are in barrens.

Figure 1 shows the projected percent of general forest area in barrens. After 50 years approximately nine percent of general forest areas are barrens under scenario S1, while scenario S2 has less than four percent of the area as barrens. In scenario *S1* barrens and young seedling/sapling stands are burned on a 10-year interval. Scenario *S2* burns these stands on a 20-year interval, allowing more stands to revert to jack pine. Note that more than twice as many acres are maintained as barrens when the rate of treatment is doubled.

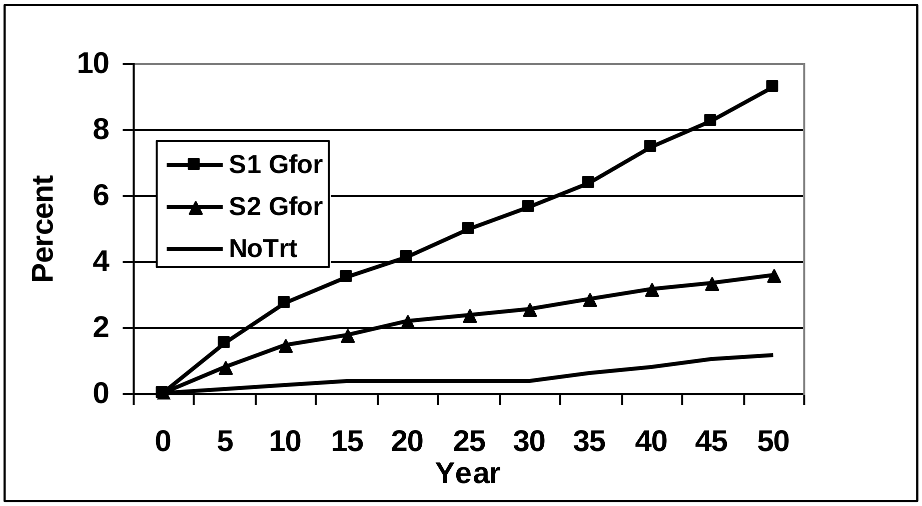

Figure 1. Comparison of scenarios: percent of landscape in barrens.

Dense stands are most susceptible to stand replacing fire. Figure 2 shows projected acres in the high density class for the three scenarios. Initially 118 thousand acres are defined as being dense. After 50 years, this increases to 140 thousand acres in the *NoTrt* (no treatment) scenario. In the treatment scenarios the dense acreage declines to about 67 thousand acres in scenario *S1* and 91 thousand acres in scenario *S2.* The majority of dense acres that remain in the *S1* scenario are in jack pine stands that are never thinned. Commercial thinning and prescribed fire are the primary tools used to maintain stands in the low density class for remaining communities. Figure 3 compares the area that would be treated annually under the two scenarios. Note that with both scenarios, the annual acres treated declines as more acres attain the desired condition.

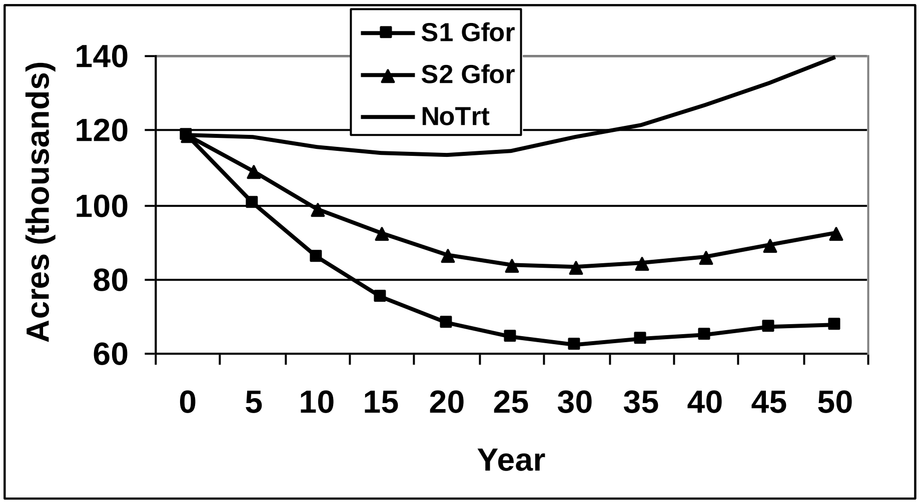

Figure 2. High density acres by scenario.

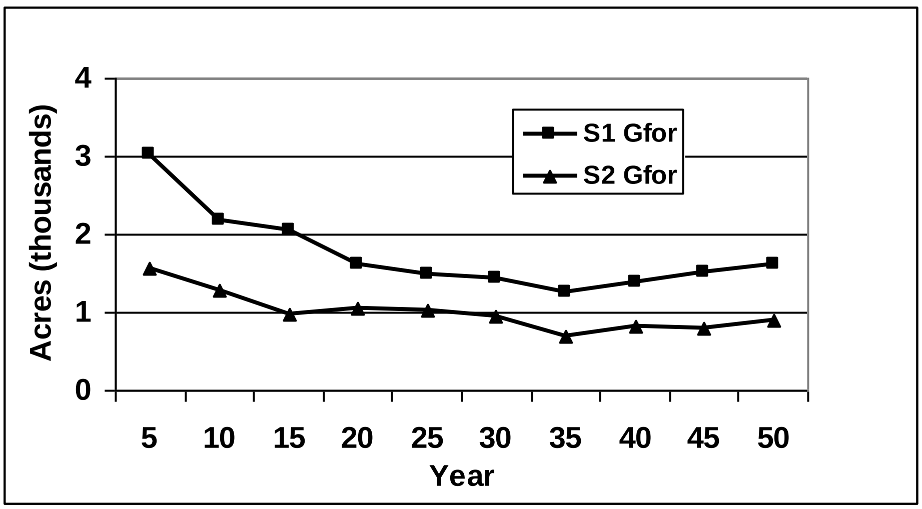

Figure 3. Fuels treatment acres.

Another species of interest to the forest is white pine. Due to 19th century harvesting followed by fires and white pine blister rust, white pine that once dominated a large portion of the landscape now occurs on only one percent of general forest. Figure 4 shows that white pine acreage should increase substantially under all scenarios, with the largest increase occurring when no treatments are applied. White pine is relatively shade tolerant and succeeds to early seral species when wildfires are suppressed. Treatments used to create barrens, control stocking, and reduce fuels decrease the potential acreage in white pine. More research is needed to develop strategies that promote white pine while reducing fuels.

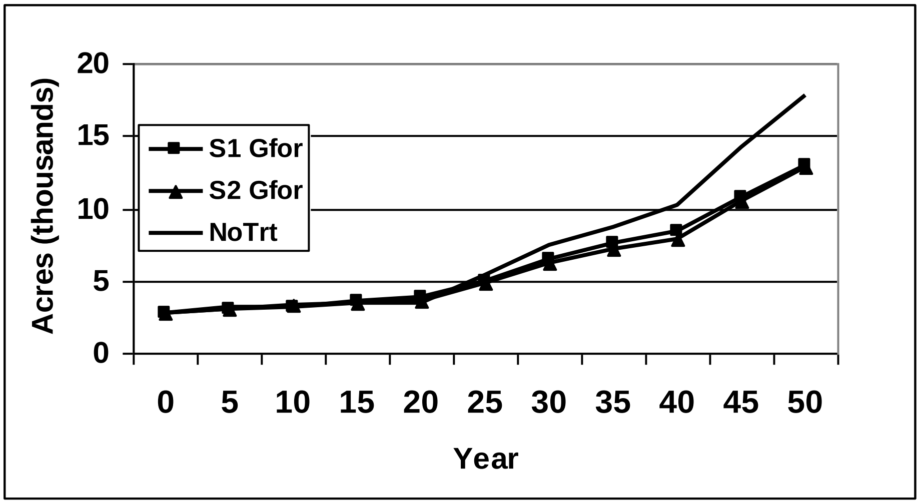

Figure 4. White pine dominant acres.

Historically less than 10 percent of the dominant trees on the Huron National Forest were aspen/birch. These species now dominate greater than 26 percent of the general forest landscape. Figure 5 shows a projected decline in aspen/birch for the three scenarios. Aspen and birch are early successional species requiring stand replacing disturbance to get established. The *NoTrt* scenario thus projects the greatest decline in aspen/birch. Aspen/birch stands are not a significant fire hazard and are not treated to reduce fuels. Five percent of mature aspen/birch stands are harvested and regenerated annually under both treatment scenarios. With this level of harvest aspen/birch declines to about 17 percent of the area in 50 years and nine percent of the area in 150 years. These numbers are consistent with the historical levels of aspen/birch on this forest.

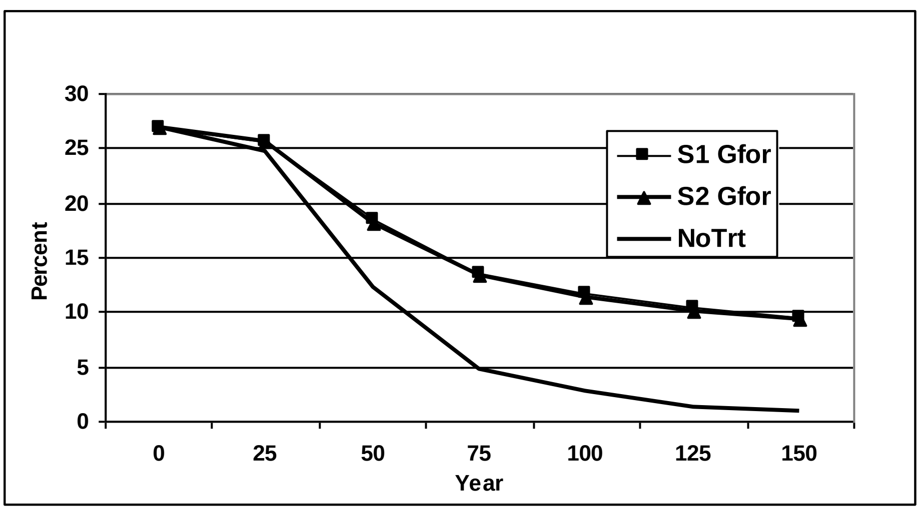

Figure 5. Scenario comparison: percent of area in aspen/birch projected for 150 years.

Approximately eight percent of the Huron Forest is identified as Wildland-Urban-Interface (WUI). These are the areas where fuel treatments are the first priority and the risks to property and life from uncontrolled fires are most severe (Hemstrom 2006). The same basic fuel treatments (thinning and burning) are applied in WUI as in general forest with the rates of treatment increased two-fold. This results in a more rapid reduction in the acreage susceptible to wildfire. Dense stands are mechanically treated (thinned and burned) to create open stands. These open stands are then periodically maintained by prescribed burning. Figure 6 shows the level of mechanical treatment and prescribed burning projected for 50 years. Note the decline in acres receiving mechanical treatment as the acreage in dense stands is decreased. Conversely, as more stands become open and are safe to treat with prescribed fire, the acreage of prescribed burning increases.

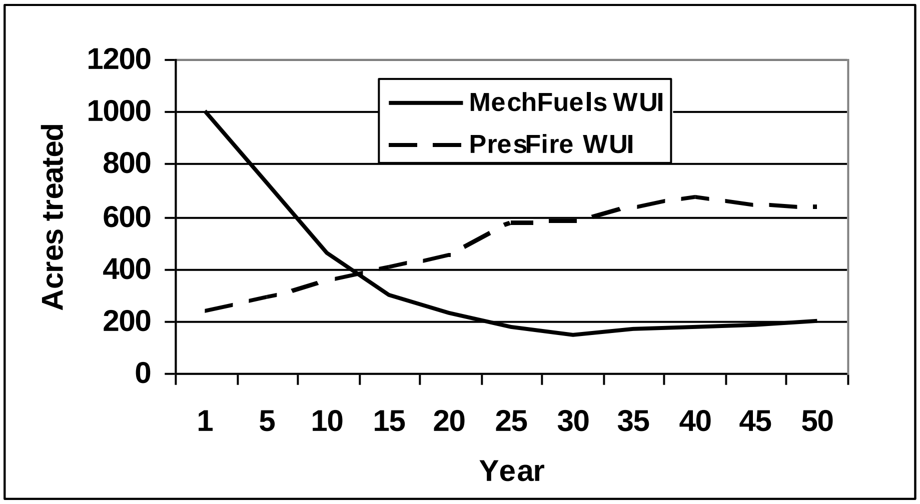

Figure 6. S1: mechanical fuels treatment versus prescribed burn acres on WUI.

DISCUSSION

The wildfire probabilities used in this model for the current period are based on burn data for the years 1985 to 2000. During this period approximately one thousand acres, or 0.3 percent of the area, burned in uncontrolled wildfires per year. These numbers do not reflect the potential for wildfire in this area since approximately ten times as many acres burned prior to European settlement (Cleland et al. 2004). These results also do not consider the stochastic nature of fire and the interaction of fire behavior with weather and human ignition, detection, and suppression. While many fires start on the forest each year, they are actively suppressed and seldom exceed a few acres in size. In contrast, wildfires that escape under extreme weather conditions can be explosive. The Mack Lake fire in 1980 burned over 24 thousand acres. In the first 3 ½ hours the fire advanced 7 ½ miles and consumed approximately 20 thousand acres of forest land (Simard et al. 1983). In the past five years, three fires that were eventually suppressed burned more than 5 thousand acres. Without an effective fire fighting capacity, these fires may have reached or exceeded the size of the Mack Lake fire.

It is not feasible from a fire management perspective or socially acceptable from a public risk management perspective to attempt to restore wildfire as a natural process in an area like the Huron National Forest, which consists of intermingled public and private ownership embedded within explosive fuels. Through fuel treatments and the creation of semi-permanent fuel breaks, however, managers can mimic the spatial and temporal patterns of wildfire while reducing the chance of a catastrophic fire and restoring critically imperiled barrens habit.

Using the model Farsite, Finney (2000) has estimated that significant reductions in wildfire spread rates and the resultant acreage burned can be achieved by strategically locating fuel treatments and fuel breaks. On the Huron National Forest, the potential for large catastrophic fires can be reduced by creating barrens of sufficient size to accommodate spotting of crown fires, and placing fuel breaks in strategic locations. The National Forest is actively engaged in creating fuel breaks for this purpose.

The *Landscape Condition Feedback* option of VDDT allows the user to apply disturbance multipliers based on the average condition of the landscape. Once a critical proportion of the landscape was treated for fuels, wildfire disturbance probabilities could be scaled down to simulate the effect described by Finney. VDDT also contains a *variations* option which allows the user to more realistically model stochastic events such as large escaped wildfires or insect outbreaks. Due to time, personnel, and budget constraints these options were not used in this coarse-scale analysis.

Model results described herein have not been discussed in detail with resource specialists on the Huron-Manistee Forest. This initial analysis was intended to demonstrate the capabilities of the VDDT tool. A next logical step will be to review these models with the Forest staff and interested stakeholders. In particular, better initial conditions data and management assumptions for private lands are needed.

The main advantage of VDDT is that models can be easily built by non-experts, with assumptions easily changed for additional runs given the transparency of the system. Model users must supply all the successional pathways, disturbance probabilities, and modeling relationships contained in VDDT. Thus the model and model results are dependent on correctly estimating successional and disturbance relationships, and disturbance and weather probabilities. The model is not intended for those desiring to model detailed fine-scale ecological, disturbance, or fire behavior dynamics, however.

Application of research results and use of historical information on community composition and fire and wind regimes rendered through analysis of GLO data allowed us to calibrate VDDT models based on the actual historical range of variability. The use of historical data also enabled us to more confidently project changes into the future by looking backward in time at least 150 years. The Huron National Forest's map of ecological landtypes also facilitated characterization of historical and current ecological processes and conditions, and allowed spatial extrapolation of modeling results in future planning and management.

VDDT is a non-spatial model, intended largely for broad scale analysis. Depending on the scale of analysis and questions being asked, a spatially explicit model may be required to produce meaningful results. The Tool for Exploratory Spatial Analyses (TELSA) was developed to address these spatial concerns (Kurz et al. 2000). TELSA uses VDDT model data plus spatial map data as input and simulates analyses of alternative management scenarios. The VDDT software, manual, and tutorial exercises can be obtained from the ESSA website at www.ESSA.com.

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