DEVELOPMENT OF A WILDLAND FIRE COMPONENT FOR THE NED DECISION SUPPORT SYSTEM

B.T. Hemel[1], C.K. Routh[2], D.S. Buckley[1*], A.J. Long[3], H.M. Rauscher[4], W.G. Hubbard[2], and D.E. Nute[2]
[1]University of Tennessee, Knoxville, TN, [2]University of Georgia, Athens, GA, [3]University of Florida, Gainesville, FL, [4]USDA Forest Service, Southern Research Station, Asheville, NC. *Corresponding Author.

1. INTRODUCTION

Managers in the Southeast routinely choose between management alternatives and make decisions regarding the scheduling of various practices. A number of decision support systems (DSS) have been developed to assist managers in these endeavors (Rauscher 1999). Of the tools available, NED is one of the more popular and effective DSS. The NED DSS has been under development since 1994, and its aesthetics, ecology, forest health, timber, water and wildlife components have been field tested in several case studies (Twery et al. 2000). Since the inception of NED and development of its initial components, interest in tools for facilitating fire management decisions has increased substantially.

Evidence exists that fire has been an important part of the disturbance regime in wildland areas of the Southeast for millennia (Van Lear and Waldrop 1989). Approximately 80% of lightning-caused fires in the United States occur within the Rocky Mountain and Pacific Coast regions (Barnes et al. 1998), but wildfires ignited by lightning also occur in the eastern United States (Van Lear and Waldrop 1989). Thus, it is likely that wildfires were a component of the disturbance regime in the Southeast and elsewhere in the eastern United States well before the arrival of humans (Van Lear and Waldrop 1989). Accounts of early European explorers in the Southeast suggest that Native Americans used fire to drive game, create suitable habitat for game, prevent the redevelopment of woody vegetation in openings, and maintain open forest understories (Van Lear and Waldrop 1989). Fire was also used for various purposes in early European agriculture (Van Lear and Waldrop 1989), and prescribed burning has long been practiced in the management of certain Southeast forest types such as longleaf-slash pine (Brown and Davis 1973). The presence of species with special fire adaptations such as Table Mountain pine and longleaf pine (Della-Bianca 1990; Boyer 1990) and those that benefit from fire such as upland oaks (Abrams 1992) provides additional evidence for the long history of fire as an important factor on landscapes in the Southeast.

The occurrence of multiple, large, stand-replacing fires in the West and abundant wildfires in eastern states such as Florida over the past decade has brought the issue of wildfire to the forefront. Combined with ever-increasing development along the wildland-urban interface (Monroe et al. 2003), this recent fire history has increased the urgency for additional research, technology transfer, and practices to reduce risks to ecosystems, property, and human lives in the Southeast and other regions of the United States.

At the outset of this project in 2002, fire risk assessment and fuels management goals had not yet been implemented for NED or other general purpose DSS. Thus, the primary objective of this work was to develop fire risk and fuels management components relevant to the Southeast for incorporation into NED. Development of the wildland fire component is described here. Parallel work on the wildland-urban interface component in NED-2 is presented elsewhere in these proceedings (Long and Rauscher 2005).

2. METHODS

Development of the wildland fire component began with a survey of pertinent fire literature. Guidance for this process was provided by an advisory panel of fire experts working in different sub-regions throughout the Southeast. Once references were compiled and the information was synthesized, development of the wildland fire component proceeded in three main stages: 1) development of a wildland fire hazard rating system that managers could use to determine the potential for wildfire, 2) development of a new wildfire risk analysis agent and two geographic information system (GIS) agents that perform the various tasks needed for the user to obtain custom reports on wildfire risk and the consequences of implementing different management options, and 3) incorporation of these agents and their supporting models into NED-2.

During development of the hazard rating system, a guiding principle was to develop a system that was as comprehensive and straightforward as possible. NED-2 and earlier versions of this DSS generate reports based on inventory data supplied by the user. Whenever possible, the most practical and commonly measured variables obtained in forest inventories were utilized in the development of the hazard rating system. Variables selected for the hazard rating system included forest composition, landform, aspect, slope, canopy structure, fine debris, medium debris, and ladder fuels.

These variables were selected based on their influence on the likelihood of ignition and fire behavior. For example, differences in forest composition such as dominance by conifers vs. hardwoods substantially influences crowning potential (Chandler et al. 1983). Landform, aspect, and slope have important effects on insolation, hydrology, wind, and other site factors, which, in turn, affect fuel moisture and the likelihood of ignition (Chandler et al 1983; Barnes et al. 1998). Slope also influences rates of spread in many fires (Brown and Davis 1973). Canopy structure influences fuel moisture by affecting insolation and wind speeds, and determines the continuity of overstory fuels (Chandler et al. 1983). Finally, amounts and distribution of different fuel types such as fine debris, medium debris, and ladder fuels are of paramount importance in fire ignition and behavior (Brown and Davis 1973; Chandler et al. 1983).

A number of "if-then" rules were developed and built into NED-2 that use inventory and site data for each stand within a tract to determine the value of each variable used to evaluate the risk of fire. Once the values of variables are calculated, assessment of risk is obtained by matching a given combination of variable values to the appropriate row in a lookup table, which includes the hazard rating. At the outset, ratings for each potential combination of variable values in the lookup table were assigned based on output of BEHAVE, which employs similar variables to predict fire behavior. The complete set of possible qualitative hazard ratings includes very low, low, moderate, high, or very high. An example of a combination of variable values leading to a given risk assessment within the lookup table is the following:

Composition: Pine
Landform: Upper slope
Aspect: South
Slope: 30+ ^{o}
Fine debris: 3+ inches
Medium debris: Present
Ladder fuels: Present
Risk: **Very High**

The bulk of information and infrastructure concerning management options that produce changes in variables such as species composition, canopy structure, and various fuels was already present in NED at the time of development of the wildland fire component. As a result, this information and other pre-existing components were used to build and install components in NED-2 that have the capability of informing users of the consequences of implementing alternative treatment scenarios, including changes that can be expected in particular variables influencing the risk of fire. Interactive and reporting components of NED were adapted to provide users with reports indicating the risk of fire in each stand within a given management unit, and summary tables indicating changes that would be brought about with alternative management options at different points in time in the future. Currently, NED-2 provides projected outcomes of alternative practices, rather than providing treatment recommendations.

3. RESULTS AND DISCUSSION

Variables used in the wildland fire hazard rating system and their definitions were the following:

I. Forest composition
1. Hardwood
2. Pine
3. Mixed, more pine (% basal area of pine greater than or equal to % basal area of hardwoods)
4. Mixed, more hardwood (% basal area of hardwoods > % basal area of pine)

II. Landform
1. Valley floor
2. Lower slope
3. Upper slope
4. Ridge top

III. Aspect
1. South (135^{o}-315^{o})
2. North (0-134^{o} and 316-360^{o})

IV. Slope
1. 30+ (greater than or equal to 30%)
2. <30 (<30 %)

V. Canopy structure
1. Unclosed (hardwood stands <5 years old, or conifer stands <10 years old)
2. Closed (hardwood stands 5-119 years old and conifer stands 10-59 years old with 50% or greater canopy closure)
3. Closed with gaps (hardwood stands 120 years old and greater and conifer stands 60 years old and greater)

VI. Fine debris
1. 3+ (litter 3 inches deep and greater)
2. <3 (litter <3 inches deep)

VII. Medium debris
1. Present (transect data includes 1-3 inch diameter dead and down material)
2. Not present (transect data does not include 1-3 inch diameter dead and down material)

VIII. Ladder fuels
1. Present (fuels present in each of the ground, shrub, and midstory strata)
2. Not present (fuels not present in each of the ground, shrub, and midstory strata)

Definitions for each variable were initially developed based on the broad effects of particular ranges of the value of each variable on fire behavior, and further modified in certain cases to facilitate calculation of variable values in NED-2 based on the types of inventory data entered by users. Data obtained in forest inventories is often incomplete in some fashion, so the fire risk assessment component is designed to handle missing data and provide the user with the best possible information under the circumstances. If data for a given variable or set of variables are missing, the wildfire agent can return a worst-case scenario risk assessment.

The first step in using the NED-2 fire component is entry of vegetation inventory data and site descriptions for the land that is of interest to the manager. NED-2 is a goal-driven DSS, so in the next step, the user must select the fire risk management goal from the currently available set of goals such as visual quality, forest health, timber, and wildlife. The fire risk management goal resides under forest health. If information on fire risk under current conditions for a management unit is desired, NED-2 can generate a report indicating the degree to which overall fire risk management and several sub-goals are currently satisfied (Figure 1). In this case, this report would be based solely on the baseline information entered in the first step.

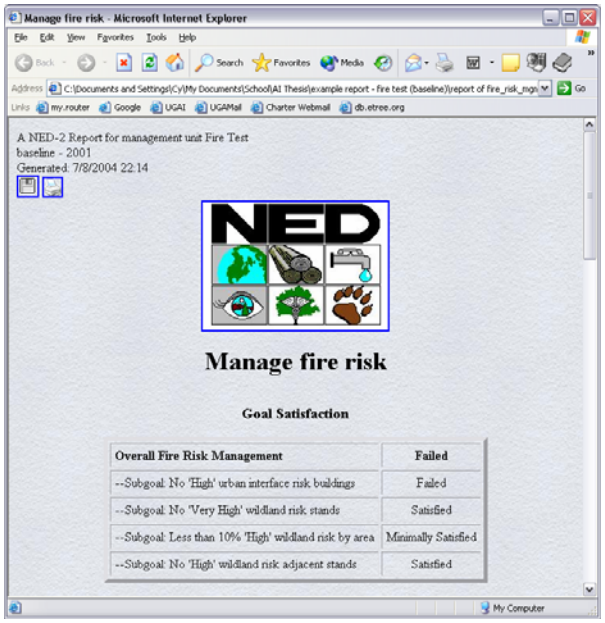

Figure 1. Goal satisfaction table within the manage fire risk goal report.

A breakdown indicating numbers and percentages of stands (and buildings) with a given risk assessment according to the wildland and wildland-urban interface models is also generated for the management unit (Figure 2). A management unit is comprised of multiple stands, and can also contain multiple buildings.

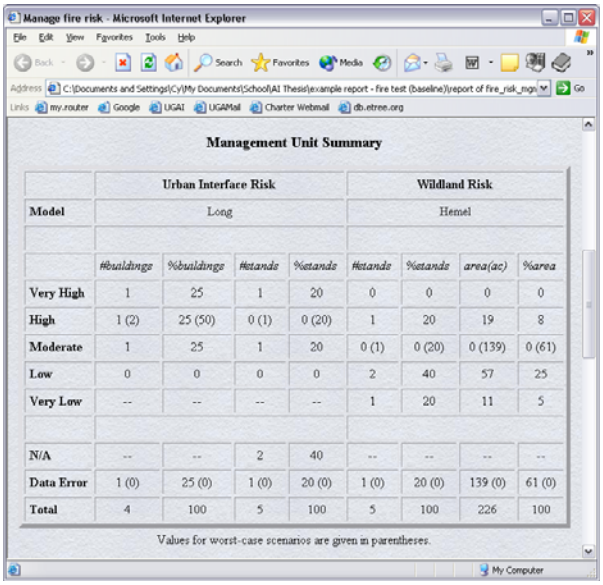

Figure 2. Management unit summary table within the manage fire risk goal report.

Detailed risk information for individual stands is included in a stand summary (Figure 3). Additional summaries of missing data can also be generated as part of the manage fire risk goal report.

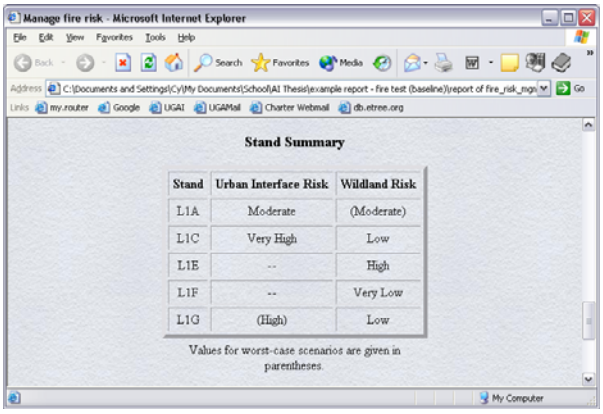

Figure 3. Stand summary table within the manage fire risk goal report.

Once the user learns of the risks by management unit and stand under current conditions, it is possible to follow up by developing custom management plans for each stand. Management plans can be developed within NED-2 by choosing among an array of alternative treatments, and selecting the timing of treatment implementation. It is assumed that the user

is a manager familiar with the effects of various treatments and management options. Once a given plan is formulated by the user, NED-2 will simulate growth and development into the future, and it is possible to request subsequent reports on the manage fire risk goal or other goals based on the projected future condition of the stands and management units.

4. CURRENT AND FUTURE WORK

Although a great deal has been accomplished over the past three years, the wildfire risk management component of NED-2 remains a work in progress. Testing and evaluation of both the wildland and wildland-urban interface risk assessment models by managers and fire experts is a planned and crucial process, and is scheduled to begin shortly. Several areas of expansion and refinement have already been identified in the development of the current version of the wildfire risk management component, and additional work involving these improvements is anticipated. Examples include: 1) more detailed reports of specific factors that led to the risk assessment returned for a particular stand, 2) incorporation of wildfire risk models and components tailored to other regions of the United States, 3) additional treatment options that will directly address certain fuel types such as slash, down material, and litter, and 4) implementation of components that can simulate future development of living and dead fuels in the understory following treatments. Development of an understory simulator in NED-2 is important for improving the reliability of long-term wildfire forecasting, and would also improve the ability to assess future understory habitat components affecting wildlife goals. Our ability to develop a simulator of understory succession and development for NED-2 is currently hampered by a lack of models addressing changes in understory herb and shrub species composition and structure over time following overstory manipulations. The modelling of these dynamics is an important area for future research.

5. ACKNOWLEDGEMENTS

This work was made possible by a grant from the Joint Fire Science Program.

6. REFERENCES

Abrams, M.D., 1992: Fire and the development of oak forests. BioScience, **42**, 346-353.

Barnes, B.V., D.R. Zak, S.R. Denton, and S.H. Spurr, 1998: Forest ecology. 4th Ed. Wiley and Sons, New York. 774 pp.

Boyer, W.D., 1990: *Pinus palustris* Mill. Longleaf Pine. Pp. 405-412 *in* Burns, R.M., and B.H. Honkala, Eds. Silvics of North America Volume 1, Conifers. USDA Forest Service Agriculture Handbook 654. 675 pp.

Brown, A.A., and K.P. Davis, 1973: Forest fire control and use. 2nd Ed. McGraw-Hill, New York. 686 pp.

Chandler, C., P. Cheney, P. Thomas, L. Trabaud, and D. Williams, 1983: Fire in forestry Volume 1 Forest fire behavior and effects. Wiley and Sons, New York. 450 pp.

Della-Bianca, L., 1990: *Pinus pungens* Lamb. Table Mountain Pine. Pp. 425-432 *in* Burns, R.M., and B.H. Honkala, Eds. Silvics of North America Volume 1, Conifers. USDA Forest Service Agriculture Handbook 654. 675 pp.

Long, A.J., and H.M. Rauscher, 2005: Enhancing the NED decision support system with wildfire risk assessments in the WUI. Eastfire Conference Proceedings, May 11-13, George Mason University, Fairfax, VA.

Monroe, M.C., A.J. Long, and S. Marynowski, 2003: Wildland fire in the Southeast: Negotiating guidelines for defensible space. Journal of Forestry, **101**, 14-19.

Rauscher, H.M., 1999: Ecosystem management decision support for federal forests in the United States: a review. Forest Ecology and Management, **114,** 173-197.

Twery, M. J., H.M. Rauscher, D.J. Bennett, S.A. Thomasma, and others. 2000: NED-1: integrated analyses for forest stewardship decisions. Computers and Electronics in Agriculture, **27,** 167-194.

Van Lear, D.H., and T.A. Waldrop, 1989: History, uses, and effects of fire in the Appalachians. USDA Forest Service Southeastern Forest Experiment Station Gen. Tech. Rep. SE-54. 20 pp.

7. AUTHOR BIOGRAPHIES

During completion of this work, Brian T. Hemel and Cy K. Routh were M.S. candidates at the University of Tennessee and University of Georgia, respectively. David S. Buckley is an Associate Professor of forest ecology and silviculture at the University of Tennessee. Alan J. Long is an Associate Professor of forest operations, fire, and extension at the University of Florida. H. Michael Rauscher is a Research Forester with the USDA Forest Service, Southern Research Station. William G. Hubbard is a Southern Regional Extension Forester with the University of Georgia, and Donald E. Nute is currently Professor Emeritus of philosophy of language, logic, automated reasoning, and knowledge-based systems at the University of Georgia.