Forest Vegetation Simulation Tools and Forest Health Assessment

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Abstract.—A Stand Hazard Rating System for Central Idaho forests has been incorporated into the Central Idaho Prognosis variant of the Forest Vegetation Simulator to evaluate how insects, disease and fire hazards within the Deadwood River Drainage change over time. A custom interface, BOISE.COMPUTE.PR, has been developed so hazard ratings can be electronically downloaded directly to the District's GIS. Spatial and temporal evaluation of hazards can now be made when comparing management alternatives. GIS maps depicting hazard ratings through time generated from the FVS simulations provide ID team members with information to determine if landscape conditions are moving towards desired future conditions.

INTRODUCTION

Forest health is a major concern throughout much of the interior west. No where is this more apparent than on the Boise National Forest. During the past five years, the Boise National Forest has been occupied with the salvage of dead and dying trees from bark beetles, defoliators, and catastrophic wildfires.

Recently, the Boise National Forest Supervisor and the Lowman District Ranger challenged the Lowman Ranger District staff to develop and validate ecosystem management concepts using a landscape approach to address the forest health issue. The Lowman Ranger District has taken on that challenge, specifically within the context of the Deadwood Landscape (USDA, 1994a, USDA, 1994b).

The objective of the Deadwood Landscape Analysis and subsequent management activities is to restore and maintain the health and long-term sustainability of the Deadwood Landscape.

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No attempt will be made to define the term "ecosystem." Rather we will focus on how available tools and technology, including databases, vegetation simulation models, hazard rating systems, and geographic information systems can be used for understanding and characterizing ecosystem factors such as complexity, landscape attributes and viability, and resilience to stress.

DESCRIPTION OF PROJECT AREA

The Deadwood River Drainage is located in the west-central mountains of Idaho in Boise and Valley Counties. It encompasses approximately 153,000 acres and is roughly 32 miles long by 13 miles wide. Thirty percent of the Lowman Ranger District is contained within this drainage. The elevation ranges from 3680 feet, at the confluence of the Deadwood River with the South Fork of the Payette River, to 8696 feet at Rice Peak summit. The Deadwood river flows south, draining into the South Fork of the Payette River.

The Deadwood River Drainage has not recently had major disturbances from insect, disease, or wildfire. It is a diverse community containing both warm, dry sites of ponderosa pine, as well as cool, wet sites of subalpine fir. From pre-settlement times to the present, the warm, dry sites have changed from open stands of ponderosa pine to dense stands of douglas-fir. On the cooler sites, very dense stands of lodgepole pine are now dominated by subalpine fir. Considering recent events that have taken place in other parts of the forest, this existing combination of species composition and stand structure is a forest health concern. The Deadwood Landscape now appears to be susceptible to insect and disease epidemics and catastrophic wildfire.

MANAGEMENT OBJECTIVES

Within the general purpose of the Deadwood Landscape Analysis, specific objectives include: (1) restore and maintain the health and long-term sustainability of the Deadwood Ecosystem through silvicultural treatment of high risk/hazard stands, (2) maintain species diversity, (3) prioritize treatments where high risk from insects, disease, and wildfire are threatening neighboring low risk sites, (4) reduce the severity of potential fires, and (5) apply adaptive management techniques to ensure that treatments meet desired goals and objectives.

The project is an attempt to take full advantage of available tools and technology, allowing the District to analyze and evaluate silvicultural alternatives for restoring and maintaining the long-term health and integrity of the landscape.

The data manipulation and modeling procedures used in this analysis allows for both the assessment of current hazards and risks within individual stands and across the landscape, and more importantly, evaluation of how proposed management actions will affect those hazards and risks through time. Comparisons can then be made on how proposed actions will affect successional pathways due to the influences of disturbance agents and their associated changes to disturbance regimes.

It should be noted that the Boise National Forest in particular, and the National Forest Systems in general, are beginning to concentrate less on intensive forest management and more on "maintenance management" to utilize natural processes, whenever possible, to maintain desired future conditions. However, successful "maintenance management" must recognize when natural processes result in less than desirable conditions, and must dictate appropriate management actions to prevent such conditions from occurring.

A hazard analysis will be done on the Deadwood Landscape to determine stands at high risk from wildfire, insects, and disease. Hazard ratings will be assigned to stands, and silvicultural prescriptions will be developed to alleviate these high hazards. A management schedule will be proposed to treat the high hazard stands over the next five years, and to treat stands with lower hazard ratings soon thereafter. All proposed treatments will be designed to maintain and/or restore structure, function, and diversity across the landscape.

SCOPE OF ANALYSIS

Over the past decade, more than 400,000 acres have burned in catastrophic wildfires on the Boise National Forest. Many of these acres were predisposed to intense wildfires due to prior insect and disease epidemics. These events killed trees on thousands of acres, and increased the hazard of catastrophic wildfire.

The vulnerability of individual forest stands (sites) to such events increases the hazard of converting diverse landscapes to homogeneous landscapes. Given the current paradigm that more diversity is better than less diversity, there exists a need to assess the health of forest stands and their associated hazards from agents of change. The juxtaposition of individual forest stands and their associated hazards will directly affect the hazard of the landscape as a whole.

The scope of this analysis considers about 153,000 acres in the Deadwood River Drainage and adjacent acreage of neighboring watersheds. This analysis will determine what management is needed over the next five to ten years, and where that management will occur.

To assess existing and future hazards due to management actions or lack thereof, the Lowman Ranger District is evaluating current and projected stand conditions using RMSTAND data (USDA, 1993), the Forest Vegetation Simulator (Wykoff, et al. 1982), a Stand Hazard Rating System for Central Idaho Forests (Steele, et al. 1994), and a geographic information system.

RMSTAND data is projected through time using the Forest Vegetation Simulator (FVS). FVS provides the ability to calculate hazard ratings on a stand by stand basis. Utilizing the FVS Event Monitor (Crookston, 1990), hazard ratings for individual stands along with other user-defined custom variables are calculated and then downloaded directly into the District's GIS database for further analysis and visual display.

Linking FVS output to the GIS, allows for landscape level analysis, using stand level simulation results. FVS output is downloaded into the GIS database as a unique layer, spatially linked to other existing GIS layers. GIS analysis models, such as wildlife habitat models and sedimentation models, use both vegetation data (FVS output) and other geographic information, such as roading and slope. These models are used to predict other ecosystem attributes, processes and functions for both existing and future conditions.

The National Forest Management Act (NFMA) portion of the Deadwood Landscape Analysis was completed in August 1994 (USDA, 1994a). Work is currently underway on the National Environmental Policy Act (NEPA) analysis to disclose the direct, indirect, and cumulative environmental impacts of the proposed action and other alternatives on the long-term sustainability of the Deadwood Landscape. The Deadwood Landscape Analysis will be the basis for future management activities. Hopefully, these activities will reduce the potential of catastrophic events taking place within the Deadwood River drainage.

SOURCES OF DATA

Vegetation data have been utilized from several sources to perform both a coarse filter analysis and a fine filter analysis.

The coarse filter utilized image processing and GIS analysis of Landsat Thematic Mapper Scenes along with USGS 1:24,000 scale DEM data. This coarse filter analysis is described in detail in the NFMA documentation (USDA, 1994a) and categorizes vegetation data by maturity class and density class.

The fine filter utilized RMSTAND/RMRIS (stand exam) data. Unfortunately, complete stand exam coverage for the drainage is not available. For acreages not covered by stand exam data, the District is utilizing The Most-Similar Neighbor (Moeur, et. al. 1995) procedure to assign surrogate stand attributes to non-inventoried stands. This methodology utilizes stand location, stand elevation, stand slope, and stand aspect derived from DEM data, plus the average and standard deviations of each of the seven LandSat bands within each stand. This will allow the District to perform FVS simulations on the entire landscape.

TOOLS

Many tools were utilized in the fine filter phase of the Deadwood Landscape Analysis. The following computer programs, databases, simulation models, and hazard ratings, form the core set of tools for the forest health assessment component of the analysis.

- **RMSTAND** (Rocky Mountain Stand Exam Computer Program) generates reports of existing forest conditions. The program uses stand exam and/or forest inventory data as input. It is currently used by Regions 2, 3, and 4.
- **RMRIS** (Rocky Mountain Resource Information System) is an integrated data base. RMSTAND data is loaded into and extracted out of the RMRIS database. It is currently used by Regions 2, 3, and 4.
- **Forest Vegetation Simulator** (FVS) is an individual-tree, distance-independent forest growth model (see Appendix A). FVS projects forest stand exam and/or inventory data through time. Simulations can include management actions. FVS provides the capability for users to define, calculate, and output custom variables associated with forest structure, species composition, stand-level hazards, etc. . . . FVS output can be downloaded to a GIS database and to the Stand Visualization System (McGaughy, 1995), state-of-the-art forest visualization computer software.
- **Most Similar Neighbor Analysis** is used to find the "most similar" sampled parcel of land and use it as a surrogate for a parcel that does not have a detailed inventory available. The surrogate for an unsampled parcel is called its

Most Similar Neigbor (MSN), and the inventory attributes of the MSN parcel are subsituted for the unsampled parcel (Moeur, et al., 1995).
- **Stand Hazard Ratings for Central Idaho** "has been developed as a composite of eleven individual ratings in order to compare the combined and often different health hazards of different stands...(Steele, et al., 1994) . . . The composite rating includes Douglas-fir beetle, mountain pine beetle, western pine beetle, spruce beetle, Douglas-fir tussock moth, western spruce budworm, dwarf mistletoe, annosus root disease, armillaria root disease, Schweinitzii root and butt rot, and wildfire".
- **Landsat Thematic Mapper Scenes provided** estimates of forest cover type. Cover type consisted of maturity class (immature, mature, and undetermined) and density class (dense, medium, open, and undetermined). This data was utilized by the Most Similar Neighbor procedure.
- **U.S.G.S. Digital Elevation Model** (DEM) data provided estimates of slope, aspect and elevation which was utilized by the Most Similar Neighbor procedure.
- **Geographical Information Systems** (GIS) generate maps that display landscape elements, processes, functions and patterns. Examples of important landscape elements include the mosaic of stand structure, species composition, and stand density. Examples of important landscape functions include hiding cover and thermal cover. Maps displaying these and other landscape elements and functions are generated for both existing and future conditions.

VEGETATION DATA CLASSIFICATION

Vegetation can be classified using many different procedures. Several common methods of site and vegetation classification include habitat type, fire groupings, and vegetative structural stage.

- **Habitat types** (Daubenmire, 1966) were determined in the field for each stand during timber stand examinations. Habitat Type is a collective term for areas that support or can support the same plant association, or did support it prior to its destruction or modification by disturbance (Steele, et al. 1981).
- **Fire Group Classification** are aggregations of forest habitat types. Forest habitat types have been arranged into eleven fire groups based on the response of the tree species to fire and postfire succession (Crane and Fisher, 1986). Both habitat type and fire group indicate successional pathways, but they provide little indication of existing conditions. The landscape element that reflects existing vegetative conditions is the vegetative structural stage.
- **Vegetative Structural Stage (VSS)** is a composite of stand size (horizontal) class, stand canopy closure class, and vertical structure class. The rulebase for calculating structural class is based on algorithms imbedded in the RMSTAND software (USDA, 1992) modified slightly to coincide with the Boise National Forest Land & Resource Management Plan (USDA, 1990). Vegetative Structural Stage is also a variable often associated with wildlife habitat.

All three of these classification systems were utilized to evaluate the potential hazards and risk associated with insects, disease, and wildfire.

HAZARD RATING SYSTEM

Forest sucession in the central and northern Rocky Mountains is dramatically affected by disturbance. The primary disturbance agent for the past several centuries has been fire. Forests are also vulnerable to other major disturbance agents such as bark beetles, root rots, defoliators and pathogens.

In order to assess the current and future hazards associated with these disturbance agents within the Deadwood Landscape, hazard rating algorithms were incorporated into the FVS stand-level projections based on the Hazard Rating System for Central Idaho (Steele et al. 1994). The term hazard implies a relative measure of predisposing conditions for damage (Paine et al., 1993). The rating is a relative measure, usually ranging from one to ten. This rating represents the expected percent mortality of the host species if an insect or disease infestation and/or fire occurred. A hazard rating of three would indicate a potential for 30 percent mortality in the host species.

Hazard rating algorithms were coded directly into the FVS keyword files using variables available in the Event Monitor (Crookston, 1990). The keyword files were then used for projecting stands through time with FVS. As each stand was projected through time, the Event Monitor would calculate variables such as the average diameter of a host species, stand basal area, percentage of a host species in the stand, stand structure, site index, crown scorch volume, scorch height, tons of slash, etc. . . . (keyword files, are available from the ESAT Information Center in Fort Collins).

For some of the hazard ratings, all of the required predictor variables were available within FVS. When this was the case, the Event Monitor would calculate the actual hazard rating and output the results in the report created by BOISE.COMPUTE.PR (an FVS Post-Processor developed by the Fort Collins Service Center for this analysis). Some of the hazard ratings required variables not available to FVS, and so the custom report would contain a subset of the required predictor variables necessary for calculating the hazard rating. The final hazard rating would be calculated within the GIS once the custom report had been downloaded into the GIS database.

LINKING FVS SIMULATION RESULTS TO GIS

Using RMSTAND data as input to the model, FVS is used to generate information on existing and future stand conditions. Future conditions are based on simulations that take into consideration insects, disease, fire, management activities, and other processes that affect the growth and mortality of the vegetation on the site.

Information on specific landscape attributes, identified by the ID Planning Team as being relevant to the analysis, such as stand structure, species composition, and hazard ratings, are transferred directly from FVS into the Lowman Ranger District's GIS via a custom report. The Fort Collins Service Center worked with the Lowman Ranger District to facilitate this transfer of data as efficiently as possible. This custom report contains the simulation results for all stands and is used to populate a new GIS database layer. The information stored in the GIS database are then used for creating maps that display the spatial and temporal characteristics of those landscape attributes.

The use of site-specific simulations and the resulting attribute files, combined with the spatial analysis and display functionality of GIS, allows us to bridge the gap between site-specific management prescriptions and activities, and the resulting effects on future landscape-scale desired future conditions.

Simulations projecting the no-management alternative allows us to evaluate the short and long-term consequences of not actively managing the Deadwood Landscape. Simulations incorporating the calculation of site-specific hazards for fire, insects, and disease, allows us to observe how those site-specific hazards may be expected to change with time. Maps are then generated to view the pattern of the predominant vegetation (matrix), patches and corridors, structural stage, fire groups, wildlife habitat, and insect/disease/fire hazards.

Additional simulations will be used to evaluate the short and long-term consequences of actively managing the Deadwood Landscape under a variety of management regimes. Algorithms for calculating and predicting site-specific hazards and the mangement strategies for addressing those hazards, will be incorporated into the FVS simulations. Mapping the results of those simulations provides both a temporal and spatial perspective of the consequences of the no management alternative versus proposed management alternatives.

The Lowman Ranger District is now in the process of defining those alternative management actions and will soon be performing the simulations to begin analyzing the effects. The results of that analysis will be published within the context of the NEPA documentation.

CONCLUSIONS

The combination of tools now available to our agency, allows us to bridge the gap between site specific management and landscape level analysis. Although this methodology is both data and computationally intensive, it allows us to continue using concepts and methods we are familiar with.

It also points out that stand level management can play an important role in landscape "ecosystem" management. The Deadwood Landscape Analysis is an excellent example of this approach to landscape management.

Furthermore, for landscapes where on-the-ground inventory or stand-exam data is not available, methods are now being developed and fine-tuned to allow for the objective substitution of data. Moeur et al. (1995) have developed one such approach which was used in this analysis. This substitution of data enables the ID Team to consider every acre within the landscape even though measured field data is only available for a subsample of the landscape.

A single landscape analysis tool which will answer all of the questions, interested citizens and ID Team Members are asking, has yet to be developed. Until such a tool exists, it will be necessary for each Forest Service District to utilize to the best of their ability, the tools currently available to them. Utilization of these tools within the context of landscape analysis, requires the professional experience of Resource Specialists, working together with Operation Research Analysts and Computer Scientists to develop new ways to take advantage of these tools.

Using these tools, we can demonstrate how landscape structure, function, and diversity can be expected to change with time. By identifying desirable landscape attributes and functions, we can begin to predict the affect that changing vegetation structure and composition will have on identified desired future conditions. Welcome to a preview of landscape "ecosystem" management analysis in the 21st century.

REFERENCES

Crane and Fisher. 1986. *Fire ecology of the forested habitat types of Central Idaho.* Gen. Tech. Rep. INT-218. Ogden, UT: USDA, Forest Service, Intermountain Research Station. 00 pp.

Crookston, Nicholas L. 1990. *User's guide to the event monitor: part of Prognosis Model Version 6.* Gen. Tech. Rep. INT-274. Ogden, UT: USDA, Forest Service, Intermountain Research Station. 21 p.

Daubenmire, R. 1966. *Vegetation: identification of typical communities.* Science 151:291–298.

McGaughy, B. 1995. *Stand Visualization System.* Gen. Tech. Rep. PNW-___. Portland, OR: USDA Forest Service, Pacific Northwest Research Station (in press).

Moeur, Melinda, Crookston, N.L., and Stage, A.R. 1995. *Most similar neighbor analysis: A tool to support ecosystem management.* In: Proceedings of the Analysis Workshop III: Analysis in Support of Ecosystem Management. April 10–13, 1995. Fort Collins, CO. USDA, Forest Service (in press).

Paine, T.D., Stephen, F.M., and Mason, G.N. 1983. *A risk population level in: The role of the host in population dynamics of forest insects.* Victoria, B.C., Canadian Forest Service. p. 201–212.

Steele, Robert, Pfister, R.D., Ryker, R.A., and J.A. Kittams. 1981. *Forest habitat types of central Idaho.* Gen. Tech. Rep. INT–114. Ogden, UT: USDA, Forest Service, Intermountain Research Station. 138 p.

Steele, R., Williams R.E., Weatherby, J.C., Reinhardt, E.D., Hoffman, J.T., and Thier, R.W. 1994. Draft: *A stand hazard rating system for Central Idaho forests.* U.S. Department of Agriculture, Forest Service, Intermountain Research Station and Forest Pest Management, State and Private Forestry; Boise, ID.

USDA, 1990. *Final Environmental Impact Statement for the Boise National Forest Plan.* Boise National Forest, Boise, Idaho.

USDA, 1992. *Vegetative structural stages description and calculations.* U.S. Department of Agriculture, Forest Service, Southwestern Region. Unpublished Report. ESAT Information Center, Fort Collins, CO. 8 pp.

USDA, 1993. *RMSTAND and RMRIS User's guide.* Forest Service Intermountain Region, Ogden, UT.

USDA, 1994a. *Deadwod Landscape Analysis (NFMA).* Forest Service Intermountain Region, Boise National Forest, Lowman Ranger District.

USDA, 1994b. *Deadwood Landscape Analysis Process (Scoping Package).* Forest Service Intermountain Region, Boise National Forest, Lowman Ranger District. 17 pp.

Wykoff, William R.; Crookston N.L; Stage, A.R. 1982. *User's guide to the Stand Prognosis Model.* Gen. Tech. Rep. INT-133. Ogden, UT; USDA, Forest Service, Intermountain Forest and Range Experiment Station; 112 pp.

APPENDIX

The Forest Vegetation Simulator (FVS) is a distance independent growth and yield model. FVS was originally called PROGNOSIS and was developed for North Idaho by Al Stage and other researchers at the Intermountain Forest and Range Experiment Station in Moscow, Idaho. The PROGNOSIS model was used extensively in the Northern Region of the Forest Service throughout the 1980's. It was used in both strategic planning and project level planning. Over the past ten years, the Forest Management Service Center staff in Fort Collins, Colorado, have calibrated sixteen additional "variants" of the model to specific geographic areas throughout the west, midwest, and northeastern United States. The Central Idaho Prognosis variant of FVS was used for the Deadwood Landscape Analysis.

There are now FVS geographic variants for (1) Southern Oregon/North Central California (SORNEC), (2) Utah, (3) the Tetons, (4) Southeast Alaska (SEAPROG), (5) Eastern Montana, (6) Western Sierras (WESSIN), (7) Blue Mountains, (8) East Cascades, (9) West Cascades, (10) Central Idaho, (10) Northern Idaho, (11) Central Rockies, (12) Klamath Mountains, (13) Black Hills, (14) Northeastern United States, (15) Lake States, and (16) Central States. In 1996 three new variants: Pacific Coast Range, Northern California, and Southeastern United States, are scheduled for release.

The Forest Management Service Center in Fort Collins, Colorado, maintains the current variants, develops new variants, and provides user support and training. Information on FVS can be obtained from the ESAT Information Center (ESAT:W04A).

FVS extensions include: (1) insect and disease models, to simulate growth reductions, damage, and mortality due to bark beetles, dwarf mistletoe, defoliators, and root disease; (2) a REGENERATION/ESTABLISHMENT model, to incorporate new seedlings into the simulation; (3) the Parallel Processor, where multiple stands are projected simultaneously incorporating inter-stand effects; (4) a COVER model, for predicting the development of understory vegetation; and (4) the Event Monitor, which allows for the conditional scheduling of activities based on changing stand conditions.

Stand management activities are often contingent upon many factors. A harvest may be scheduled if a stand is too dense or if a certain condition predisposes it to particular insect or pathogen damage. Hazard ratings are often used to assess those conditions. Usually, forest growth simulation models must be able to foretell the occurrence of stand conditions that require management actions and preschedule the program options that represent those actions. Not so with the FVS model.

The FVS Event Monitor offers an alternative method of scheduling activities. The user specifies a set of conditions that must occur. This condition is called an event. The user also specifies a set of mangement activities for the model to simulate if and when the event occurs.

For example, suppose you wish to reduce the density of a stand by scheduling a thinning when the hazard rating for bark beetles exceeds a certain value. The Event Monitor is designed to facilitate such a scenario. Taken together, the event and it's associated management activity may be viewed as a mangement rule. There are no limits to how many management rules can be incorporated into a single simulation.

It is also the Event Monitor that provides the capability to calculate user-defined, "custom," stand and tree level variables. These "custom" variables are then incorporated into algorithms used to calculate stand hazards, vegetation structural stage, and other stand level attributes of interest.

Two types of input data are required by FVS. First is a data file in the form of tree records commonly obtained from various inventory methods. Second is a keyword file consisting of FVS keyword records and their associated parameters which provide the model with operating instructions. Keywords provide information about the inventory sample design, geographic location, length of projection, and a whole set of other parameters needed to define the projection.

Keywords can also be used for calculating custom variables. This method of creating variables is facilitated via the use of the Event Monitor's COMPUTE option. The COMPUTE option allows the user to define variables that can be used in logical expressions, in other COMPUTE options, and as parameters on keyword records.

For the Deadwood Landscape Analysis, the COMPUTE option was used during the FVS simulations to calculate vegetation structural stage, and a series of hazard ratings. The Forest Management Service Center working with the Lowman Ranger District developed a Post-Processor called BOISE.COMPUTE.PR to generate custom reports containing the results of these internal calculations. This custom report was then used as input into the District's Geographic Information System (GIS) for developing additional map layers for the analysis. Individuals, interested in obtaining more about FVS can contact the Forest Management Service Center at 970-498-1772.