

Overview of Developing Desired Conditions: Short-Term Actions, Long-Term Objectives

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Abstract—A number of modeling tools are required to go from short-term treatments to long-term objectives expressed as desired future conditions. Three models are used in an example that starts with determining desired stand level structure and ends with the implementation of treatments over time at a landscape scale. The Multi-Aged Stocking Assessment Model (MASAM) is used for assessing sustainable stand structures. Simulating Vegetative Patterns and Processes at Landscape Scales (SIMPPLLE) is initially applied to assess risks from disturbance processes on the current landscape without management treatments, but with fire suppression. The frequencies of process occurrence from these simulation results are input into the Multi-resource Analysis and Geographic Information System (MAGIS), an optimization modeling system, for scheduling activities that reduce these risks and address other management objectives while trying to attain desired future conditions. The derived treatment schedules are used in additional SIMPPLLE simulations to examine the change in risk of natural processes. The resulting economic impacts associated with trying to achieve the long-term desired future conditions are finally quantified by putting not only the final treatment schedule, but also the changes from disturbance processes from the final set of SIMPPLLE runs into MAGIS.

Introduction

Desired future conditions have been quantified for some time at the individual stand level. From the beginning of the requirement for silvicultural prescriptions we have developed means to quantify desired future conditions, to communicate them to others, and to identify what treatments are necessary to achieve and maintain them. These have always been tailored to management objectives. As our management objectives have changed so have our desired future conditions. As our objectives have changed to a focus of restoring ecosystem health and functioning, we have changed to scales above the individual stand. We have expanded our definition of desired future conditions to include the level of disturbance processes that are acceptable and necessary to achieve them. Our techniques and tools for describing and defining desired future conditions have improved to enable us to move from the stand level to the landscape level.

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In addition to considering treatment alternatives for individual stands, we need to consider strategies for applying the treatments at landscape scales. Given the number of acres involved and limited budgets, it is clear that treatments cannot be accomplished in all areas in which they are needed. Are some strategies more effective than others? Is it more cost-efficient to first treat the plant communities where it takes the least intervention to achieve desired future conditions, or to treat those that need more treatments and costs may be higher? Is it better to treat stands whose degree of departure from the desired future condition results in a high probability for a disturbance process versus one that has a low priority for a disturbance event regardless of how far it is from the desired future conditions?

Models and decision support systems can provide information and analyses to aid managers in addressing these questions (Mowrer 1997). Our objective of this paper is to give an overview of a set of models/tools that can help in designing and applying treatments to achieve desired future conditions.

Our overview uses one stand level model and two landscape models, one for simulation and one for optimization. The stand level model is "Multi-Aged Stocking Assessment Model" (MASAM) for Western Montana ponderosa pine (*Pinus Ponderosa* Laws.) (O'Hara 1996). The landscape simulation model is "Simulating Vegetative Patterns and Processes at Landscape Scales" (SIMPPLLE) (Chew 1995 1997). The optimization model is the "Multi-resource Analysis and Geographic Information System" (MAGIS) (Zuuring and others 1995).

Model Descriptions

The stand level model, MASAM, is used to help quantify and evaluate a variety of multiaged ponderosa pine structures. MASAM was developed from a study of data from western Montana and central Oregon to quantify the dynamics of multiaged stands and to assess stand growth stocking relationships. The methodology differed from previous whole-stand approaches in several respects: it defined the total available three-dimensional growing space with leaf area index (LAI); it incorporates age structure by dividing stands into cohorts and determining appropriate growing space requirements for each cohort rather than for the entire stand; and it provides flexibility to assess a wide variety of stocking alternatives.

MASAM is a spreadsheet model that requires the user to specify a number of variables, which describe the desired future structure condition. These variables include: number

of cohorts, or age classes, total leaf area index (LAI), number of trees per cohort, and percent of LAI per cohort. The values assigned are a function of management objectives and forest health considerations. MASAM helps a user to determine if a desired structure is sustainable for a given annual growth rate for a particular site, cutting cycle length or ownership objective. If the cutting cycle is too short to regrow the harvested volume, the system is not sustainable. If sufficient growing space is not created during the reproduction method treatments, then replacement cohorts will not regenerate and the desired structure is not sustained.

The simulation model SIMPPLLE is a stochastic model that predicts changes in vegetation over time and space by using a vegetative state/pathway approach. A vegetative state is defined by dominant tree species, size class/structure, and density. These states are grouped by an ecological stratification of habitat type groups (Pfister and others 1977). The change between vegetative states is a function of natural disturbance processes, including insects, disease, and fire, and management treatments. The probability of a natural process occurring in a given plant community is determined by attributes of the state it is in, its past processes and management activities, the vegetative pattern as identified by its neighboring communities and their past processes. The probabilities determined for each plant community in a landscape are used in a classical monte carlo method (McMillan and Gonzales 1965) to simulate the location and timing of process occurrence. Once a process occurs for a plant community, logic is used to model its spread to neighboring plant communities.

SIMPPLLE helps in understanding landscape interaction between disturbance processes, plant community conditions, and patterns of communities. The system helps us to predict probable scenarios of the location and probability of insect, disease, and fire processes on the landscape. Treatments can be scheduled to change existing conditions and the pattern of conditions thus having an impact on the probability, the origin, and the spread of processes. This information can be used to help identify if the desired future conditions for a large number of stands are sustainable.

The optimization model MAGIS is a spatial decision support system for planning land management and transportation-related activities on a geographic and temporal basis in the presence of multiple and sometimes conflicting objectives (Zuuring and others 1995). An objective to maximize or minimize and other objectives as constraints that must be achieved are specified, and the system selects the location and timing of activities that best meets these specifications and calculates the effects. The objective and constraints are selected from the management relationships within MAGIS, which tabulate output quantities, acres with specified characteristics, miles with specified characteristics, costs, and net revenues. Management relationships can be calculated for an entire planning area, or specific portions such as individual watersheds.

Example Application

The area used for this example is a 58,038-acre planning unit, Stevensville West Central, in the Bitterroot National Forest in Western Montana. The area extends from the

Bitterroot River upward to the Bitterroot Range divide in the Selway-Bitterroot Wilderness. Species composition ranges from ponderosa pine, Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), and western larch (*Larix occidentalis* Nutt.) mixtures at the lower elevations, to lodgepole pine (*Pinus contorta* Doug.), whitebark pine (*Pinus albicaulis* Engelm.) and alpine larch (*Larix lyallii* Parl.) at the upper elevations. For this application example we have selected the drier, warmer habitat types in the Douglas-fir series (Pfister and others 1977) to focus on. These are habitat types in which ponderosa pine is a major seral species, but Douglas-fir is the climax species. The current composition of the species in this area has only 1 percent in pure ponderosa. A mixture of ponderosa pine with Douglas-fir comprises 44 percent of the stands. Thirty six percent of the area is nonstocked and the remainder is in mixtures of larch, Douglas-fir and ponderosa pine. Within these acres 29 percent of the area is in pole size classes. Thirty six percent are nonstocked. Multistory conditions exist on 17 percent of the area that correspond with the mixture of ponderosa pine and Douglas-fir species composition. None of the multistory structure is pure ponderosa pine.

Step 1

The first step in the applications of these tools is the identification of what structure is not only desired but also sustainable at the stand level. Our concept of desired conditions for these habitat types that are ecologically sustainable are multiaged ponderosa pine stands. Arno and others (1996a,b) reported presettlement ponderosa pine stands in western Montana consisted of low densities in intermediate and large size classes, with very little representation in size classes below about 4 inches. This age structure was the result of localized disturbance/regeneration events that allowed small even-aged groups of trees to become established, and frequent low severity, low intensity surface fires that periodically killed or reduced the density of the lower canopy while leaving the upper canopy relatively unharmed (O'Hara 1996). A MASAM display for a four cohort structure designed for the moderately warm and dry habitat types within the planning area is shown in figure 1. There are currently no areas within the habitat types that meet these desired future conditions.

Step 2

SIMPPLLE helps to provide the basis at the landscape scale for understanding the difference between current vegetative conditions and the desired future condition. SIMPPLLE was used to model the disturbance processes of light and severe western spruce budworm (*Choristoneura occidentalis* Freeman), mountain pine beetle (*Dendroctonus ponderosae* Hopkins) in both lodgepole pine and ponderosa pine, root disease (*Armillaria* sp.), and three intensities of wildfire: light-severity fire, mixed-severity fire, and stand-replacing fire. Two sets of 20 stochastic simulations of 5 decades were made starting with the current vegetative conditions. One set was made with the only management activity being fire suppression, the second set without fire

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2	TOTAL Leaf Area Index (LAI)	6								
3		Cohort 1	Cohort 2	Cohort 3	Cohort 4	TOTAL				
4	Number of Trees/Cohort	18	24	30	36	108				
5	Percent of LAI/Cohort	40	30	20	10	100				
6										
7		DIAGNOSTIC INFORMATION								
8		Cohort 1	Cohort 2	Cohort 3	Cohort 4	TOTAL				
9	Leaf Area Index/Cohort ECC	2.4	1.8	1.2	0.6	6.0				
10	Leaf Area Index/Cohort BCC	1.4	1.0	0.5		2.8				
11	BA/Cohort (ft ² /ac) ECC	52.6	36.4	20.9	12.6	122.5				
12	BA/Cohort (ft ² /ac) BCC	27.3	16.7	10.5		54.5				
13	Avg. Growth/CC (ft ³ /ac)	21.9	15.0	9.9	2.0	48.8				
14	Avg. Tree Growth/CC (ft ³ /yr)	1.2	0.6	0.3	0.1					
15	Quadratic Mean DBH/Cohort	23.2	16.7	11.3	8.0					
16	Tree Vigor (in ³ /ft ² /yr)	59.9	42.8	63.1	30.5					
17	ECC SDI	69.0	54.4	36.5	25.2	185.1				
18	BCC SDI	40.8	29.2	21.0		91.0				
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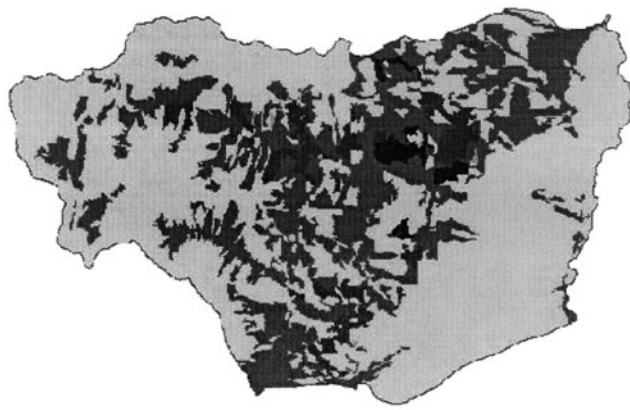
suppression. Two additional sets of simulations were made starting with all of the acres in the selected area in the desired future conditions. No management activities are scheduled to keep them in this condition. Fire suppression was applied in one set of simulations and removed in another set. The levels of processes are displayed for all four sets of simulations in table 1.

Table 1—Average acres of processes per decade across five decades.

Conditions	Stand replacing fire	Mixed severity fire	Light severity fire	Root disease
Current with fire suppression	1877	1198	417	2835
Current without fire suppression	5728	6398	5119	639
Desired with fire suppression	306	542	559	1281
Desired without fire suppression	2875	5702	7478	360

Current conditions without fire suppression result in approximately equal amounts of stand replacing fire, mixed severity fire and light severity fire. Under desired conditions, the level of stand replacing fire is considerably less than that under current conditions. The relationships between the types of fire processes change from the current to desired conditions. Under desired conditions, light severity fire is the most dominate type followed by mixed severity fire and stand replacing fire being the least. Root disease under desired conditions is approximately half of what it is under current conditions with and without fire suppression.

The frequency of occurrence over five decades for each process is kept track of for each plant community. We can use this simulated frequency to represent an estimate of the risk of these natural processes occurring on an individual stand over that period of time. An interpretation is made of what frequency of processes represent the greatest risk to achieving desired future conditions. For example a high risk for mixed severity and light severity fire may not be considered as a potential problem. These processes by removing understory vegetation can help achieve the desired future condition sooner. A high probability of western spruce budworm may be viewed as a greater risk because it is associated with



Risk values		
0	light spruce budworm	>= 50%
1-2	mountain pine beetle	>= 50%
3-4	stand replacing fire	<= 10%
5-6	severe spruce budworm	>= 50%
7-8	stand replacing fire	11-20%
10	stand replacing fire	>= 21%

Figure 2—Example of a risk map for disturbance processes.

stands that have multistory structures composed of tolerant species. An example of a risk map is displayed in figure 2.

Step 3

In Step 3, MAGIS is used to develop a schedule of treatment activities for the landscape using treatments necessary to move the plant communities to the desired future conditions. In addition to the values from a risk map, management relationships for other issues, sediment production, big game hiding cover, and pine marten habitat by drainages, and net revenues are utilized. However in these MAGIS runs, the only change in plant communities, other than the treatments, is stand development, succession. The results from this step are treatment scenarios that are both spatially and temporally specific, and are responsive to both costs and resource effects. One map of treatments by decade is shown in figure 3. This is only one scenario. Many other scenarios could be developed using different combinations of resource objectives.

Step 4

In Step 4, this schedule of stand treatments proposed by MAGIS is incorporated into SIMPPLLE. Stochastic simulations are ran to predict the frequency of the natural processes occurring on the landscape, given this proposed schedule of treatments. The impact of the treatments on the disturbance processes can be quantified. However all the treatments are often not achieved. Sometimes the occurrence of a disturbance process will change stand conditions prior to a scheduled treatment being applied. A treatment schedule that has little impact on disturbance processes may

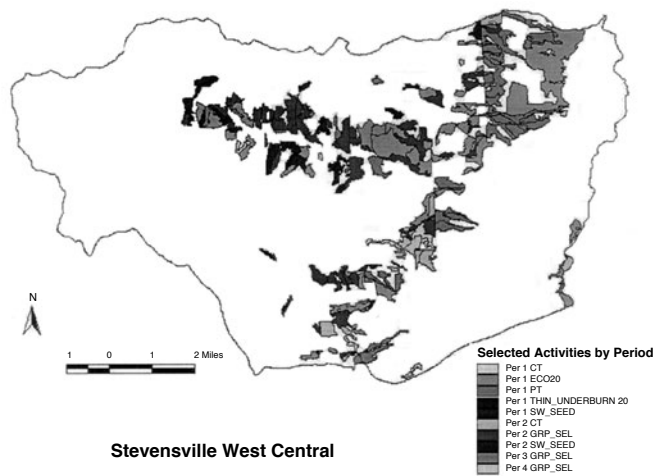


Figure 3—Example of scheduled treatment developed from MAGIS.

turn out to be difficult to implement before processes change stand conditions.

Step 5

To complete the analysis, one of the SIMPPLLE simulations, the resulting treatments that did get applied and the change in stands as a result of all processes are put into another MAGIS run. In this application, all decisions are fixed into the model, and MAGIS is simply used to compute the results. These results include fire suppression costs computed from the predicted fire processes, the treatment costs and benefits, and benefits and costs to other resources such as water quality and wildlife habitat. The results of these simulations can be compared with the results of the “no action” simulations to measure the effectiveness of the treatment scenario. These computations include the effects of the natural processes as well as the management treatments, and provide estimates of the resource impacts associated with “no action” as well as with the treatment scenario.

Discussion

The choice of desired future conditions at both a stand and landscape level must be conditions that can be sustained within a dynamic landscape. The decision must be made by looking at tradeoffs between where we can go within landscape patterns and what we can maximize while working with limited budgets and multiple resource objectives. Often resource effects of trying to get to desired future conditions are based only on the proposed treatments, and the effects of the interaction of the treatments and natural processes ignored.

More than one tool/modeling system is needed. Three tools, developed independently, have been used in a complementary fashion to accomplish designing desired future conditions for individual stands and extending them to

landscape scale applications. The integration of stand level tools and landscape level simulation and optimization models such as SIMPPLLE and MAGIS have the potential for developing spatially-specific scenarios for achieving desired future conditions and providing quantification to use in trade-off analysis at landscapes scales. This provides the opportunity to better understand, manage, and monitor landscapes.

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