Demonstrating Vegetation Dynamics using SIMPPLLE

Glenda Scott and Jimmie D. Chew[1]

Abstract.—Understanding vegetation dynamics, both spatially and temporally, is essential to the management of natural resources. SIMPPLLE has been designed to help us quantify and communicate these concepts: What levels of process, i.e., fire or insect and disease, to expect; how they spread; what the vegetative distribution and composition is over time; and how silvicultural treatments affect the processes driving vegetative change. SIMPPLLE is applied in two forest types and used to communicate interaction of processes and vegetative patterns on specific landscapes and evaluate silvicultural strategies. Impacts on species, stand structure and probability of fire are displayed and compared to desired landscape conditions.

INTRODUCTION

Understanding vegetative dynamics is key to managing our ecosystems. SIMPPLLE is an acronym taken from **SIM**ulating Vegetative **P**atterns and **P**rocesses at **L**andscape Sca**LE**s; it is a management tool to facilitate the understanding of landscape dynamics. SIMPPLLE integrates existing knowledge of vegetative change and the processes driving change. Useful at multiple scales, from mid-scale to project level, where spatial relationships are important, it provides a bridge for analyzing stand level treatments to landscape level effects.

The model was developed as technology transfer addressing the needs of Region 1. Work was initiated during the Sustaining Ecological Systems program in the early 1990s and has evolved with the Region's current approach to Ecosystem Management. The protocol for revising Forest Plans in Region 1 recommends SIMPPLLE be used in the pattern and process assessment. Foresters with the State of Montana, BLM, and Forests in neighboring Regions have also expressed interest in this model.

PATTERN AND PROCESS

A key concept associated with SIMPPLLE is the interaction of pattern and processes. Vegetation patterns across the landscape influence the processes that will occur; likewise, process results in changes in pattern. Pattern is described as the mosaic of patches that are different in vegetation based on species, size and structure class, and density. The size and arrangement of patches becomes important in this assessment.

Succession is the most common vegetative process affecting composition and structure; however, fire was and will continue to be, a major disturbance agent in the Inland West (Camp 1996). In that context, fire suppression is also shaping vegetation. Other processes including insect outbreaks, root pathogens, windthrow and winter desiccation can be influential effects. To understand vegetation dynamics, it is important to consider these types of processes and the probability for occurrence. Low probability events commonly have the largest effect on shaping the vegetative mosaic.

The temporal effects on vegetation is an important aspect of the pattern and process assessment. Current and historic photographs such as those in *Fire and Vegetative Trends in the Northern Rockies* (Gruell 1983) help to communicate vegetation changes. These provide documentation of the effects of processes and the resulting patterns that have occurred. Photo records, however, fall short in predicting the look of the landscape in the future.

SIMPPLLE simulates the interaction of patterns and processes over time to predict future landscape conditions and the levels of processes, and to establish the range of variation.

COMPONENTS OF SIMPPLLE

There are four basic interacting model components used in SIMPPLLE: existing vegetation; processes that change vegetation; vegetative pathways and all possible vegetative states; and, silvicultural treatments.

Existing Vegetation

Existing vegetation conditions establish the starting point of each polygon modeled on the landscape. The following attributes are used to describe existing condition: 1) dominant species or species mix; 2) structure as an indication of developmental stage; and, 3) density. Data for the existing condition stems from attributes in inventory data bases. A GIS coverage for the existing vegetation is needed to provide the spatial attributes of adjacent polygons.

Vegetative Processes

Vegetative processes currently assessed in the model are succession (stand development), mountain pine beetle, western spruce budworm, root disease and fire. The probability of occurrence for the various processes stems from a combination of experts' judgments (as in the case of fire) and available hazard rating systems (as for mountain pine beetle). The probability of occurrence is based on an initial probability that depends on individual polygon attributes, and adjusted by both the vegetative condition and the processes in adjacent polygons. This influence of adjacent polygons provides for an interaction between specific vegetation patterns and the processes. SIMPPLLE also allows for the spread of processes. Thus a polygon with low fire probability may burn in the simulation due to fire spread from an adjacent polygon. The systems user interface

[1]Forest Silviculturist, USDA Forest Service, Lewis and Clark National Forest, Great Falls, MT 59401and Forester, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT, respectively.

allows users to alter probabilities and resulting states and lock-in the processes to be simulated.

Vegetative Pathways

A sequence of potential vegetative states, with processes being the agents for change from one condition to another, is called a pathway. These potential states are stratified by ecological classifications such as habitat types or groups of habitat types. The potential states represent different conditions for species, structure or density. The specific combinations used depends on what is needed to capture the dynamics of processes and to provide detail to address the planning issues.

Silvicultural Treatments

Silvicultural treatments in SIMPPLLE are separate from the processes in the pathways. A treatment alters the state by changing the species, structure or density. It may also alter the probability of processes occurring even without changing the state.

SIMPPLLE MODELS VEGETATIVE CHANGE

Two examples of forest types in Montana were used with SIMPPLLE to model vegetative change. The data used was from Forest projects; however, the activities have been modified and management considerations simplified for this presentation. These types of simulations can be valuable in communicating historic range of conditions, the trends of the existing vegetation, and to understand the influence of silvicultural treatments in moving towards desired landscape conditions.

Ponderosa Pine Forest

Forest condition. The lower east slopes of the Bitterroot Mountains are ponderosa pine (*Pinus ponderosa* Dougl. ex. Laws.) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn) Franco) forests. Ponderosa pine is climax at the lower limits of coniferous forests and seral in higher elevations. Along the Bitterroot face, it is a long-lived seral. Commonly, Douglas-fir grows in association with ponderosa pine as elevation increases. Ponderosa pine, and to a lesser extent Douglas-fir, possesses thick bark that offers it protection from fire damage. Young ponderosa pine, Douglas-fir, and other competing species are less fire tolerant. In low elevations, and with historic fire cycles, ponderosa pine was maintained in open conditions over large areas. Observations from the Selway-Bitterroot Wilderness study indicate that the most common fires were low intensity with variable severity (Saveland 1987). These fires thinned the stand from below, favoring larger ponderosa pine. On the higher slopes, Douglas-fir may have been more dominant but they were also in open stand conditions.

Without fire or other disturbance mechanisms, ponderosa pine stands tend to increase in density and develop multiple canopies. A shift to more tolerant species also tends to occur. With these changing stand conditions, the occurrence of stand replacing crown fires increases, replacing the light or mixed intensity fires in frequency and acres burned. This shift in fire regime also affects understory vegetation, litter composition, and nutrient availability.

The Bitterroot Valley is composed of agricultural lands at lower elevations, a portion of which was once ponderosa pine forests. Today, private lands border the Bitterroot National Forest. Homes and other urban developments are creeping into the dense forested lands, creating an urban interface fire risk that concerns the public and Forest managers.

Based on these forest conditions and concerns, an aspect of the Desired Condition is to reduce fire risk and provide better protection potential to homes, and protect the viewshed from wildfire. The following SIMPPLLE simulations display the stand level conditions on the landscape, vegetation trends, and the effects of silvicultural strategies on the landscape conditions.

Displays using SIMPPLLE. The Stevi West Central project area covers approximately 60,000 acres (24,282 hectares). SIMPPLLE was used to compare cover types, density levels, and size and structure composition across the landscape at various time periods. Although it was not obvious when viewing the maps, there was an increasing trend of tolerant species in the next 50 years, from 11 percent to 15 percent and increasing density. More obvious, however, was the change in size and structural stages.

The current size and structure distribution is displayed in figure 1 and future structure in 50 years is shown in figure 2. The only management action simulated was the current practice of fire suppression.

As a comparison, the reference condition size and structure class are displayed in figure 3. In this simulation, a reference condition was identified by projecting the current condition into the future to a point where the effects of fire suppression were eliminated and natural processes had returned, thus representing the range of variation under historic fire regimes. Numerous stochastic runs would establish a range of conditions, which would be useful in establishing a context for desired conditions.

Further analysis would help quantify the changes in pattern and patch sizes of the landscape conditions. It appears that there are more continuous patches of multi-story and two story stand conditions in the future condition simulation than in either the current or reference condition. This is consistent with the stand development expected in ponderosa pine relative to fire regimes.

The relative composition by size and structure class is shown in figure 4. The current condition shows 13 percent multi-storied stands; in 5 decades that would increase to 31 percent (multi- and two storied stands) based on one simulation.

SIMPPLLE also can be used to predict the level of processes likely to occur under different scenarios. Based on numerous runs, fire levels are predicted over time and displayed in figure 5. The current regime is represented in about the first 15 decades. After that, the effects of fire suppression decline, and by decade 40 it appears that stand conditions have returned to historic conditions and historic fire regimes are functioning. Fewer acres are burned by stand replacement fire however, significantly more acres are burned by mixed intensity fires. The management goal is not to mimic this fire cycle per se, but to move towards conditions that were maintained by these fire regimes. A fire start in these conditions will more likely be less intense and more controllable.

Based on an understanding of the processes and vegetative conditions, silvicultural treatments were designed to increase diversity and lower fuel loads along the lower slopes. Although a mix of stand conditions is desirable, this example emphasizes treatment in the ponderosa pine forest types to reduce canopy layers and ladder fuels. These types of stands are most dominant on the eastern portion of the landscape, west of the large non-stocked agricultural lands. The target stands would be open grown, dominated by larger ponderosa pine and Douglas-fir. There would be small areas of young trees, but stand replacement fire would be low risk.

Silvicultural treatments include thinning from below and underburning to favor large ponderosa pine and repeated to maintain conditions similar to the historic fire regimes. The level of treatments that were simulated are shown in figure 6. Thinning was accomplished on all stands that would benefit in the first decade. Underburning, however, was repeated in the following five decades to maintain the desired stand conditions.

The resulting size and structure class composition of the landscape (figure 7) is compared with the simulation of future condition with only fire suppression in place (from figure 4). The result is a 6 percent decline in the combination of multi-storied and two-storied conditions. Assuming this provides a mosaic of size and structure types, it is observed that silvicultural treatments are moving the landscape towards the desired condition. It is also observed that major changes to landscape conditions require rather intensive levels of management activities.

Lodgepole Pine Forest

Forest condition. Lodgepole pine (*Pinus contorta* Doug.) grows in association with many western conifers. It tends to dominate in even-aged stands. In this example on the Helena National Forest, lodgepole pine is seral to more tolerant alpine fir and other species, however it will maintain site dominance for over 100 years. Large expanses of lodgepole pine were historically common, with a mosaic of young and later successional lodgepole pine patches as a result of varying disturbances. The current trend, however, is a decline in diversity with large expanses of lodgepole pine being similar in structure and density. It is not uncommon to see entire drainages moving in this direction. In short, the historic mosaic that provided resiliency and diversity is being lost.

Mountain pine beetle (*Dendroctonus ponderosae* Hopk.) has played a historic role in lodgepole pine ecology. When

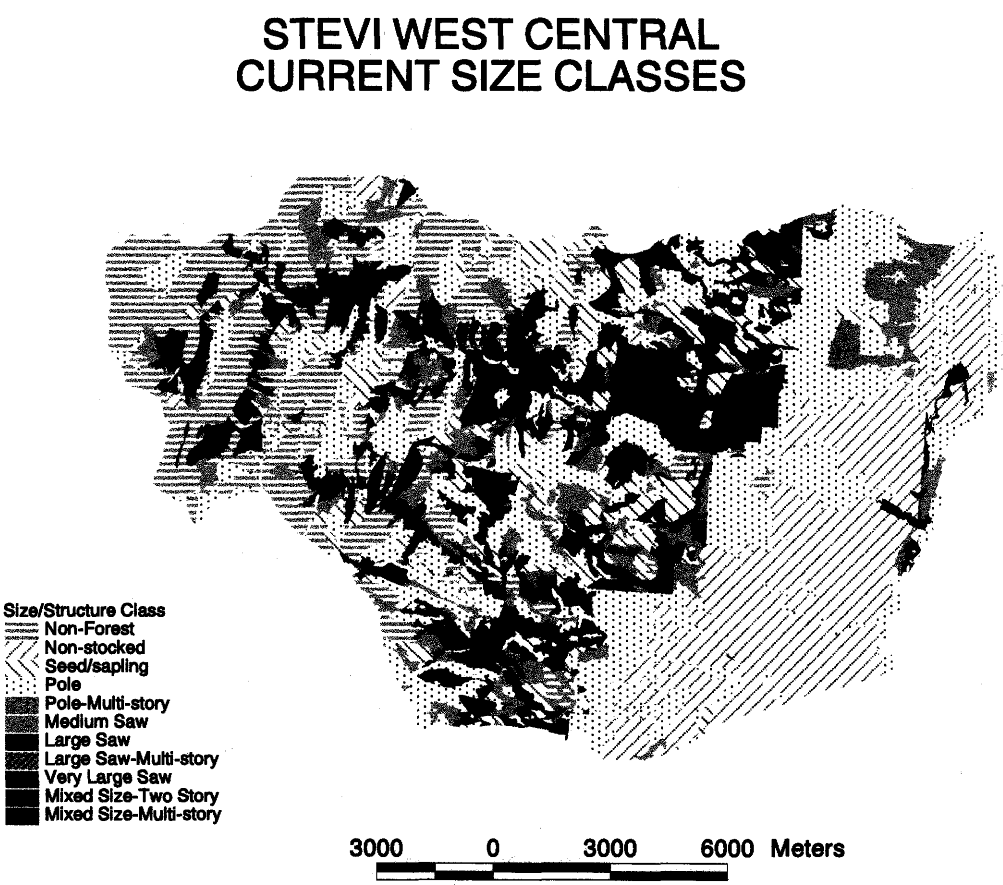


Figure 1.—Distribution of the Current Condition size and structure classes in the Stevi West Central project area. (Single story structure except as noted in legend.)

STEVI WEST CENTRAL
FUTURE CONDITION SIZE CLASSES

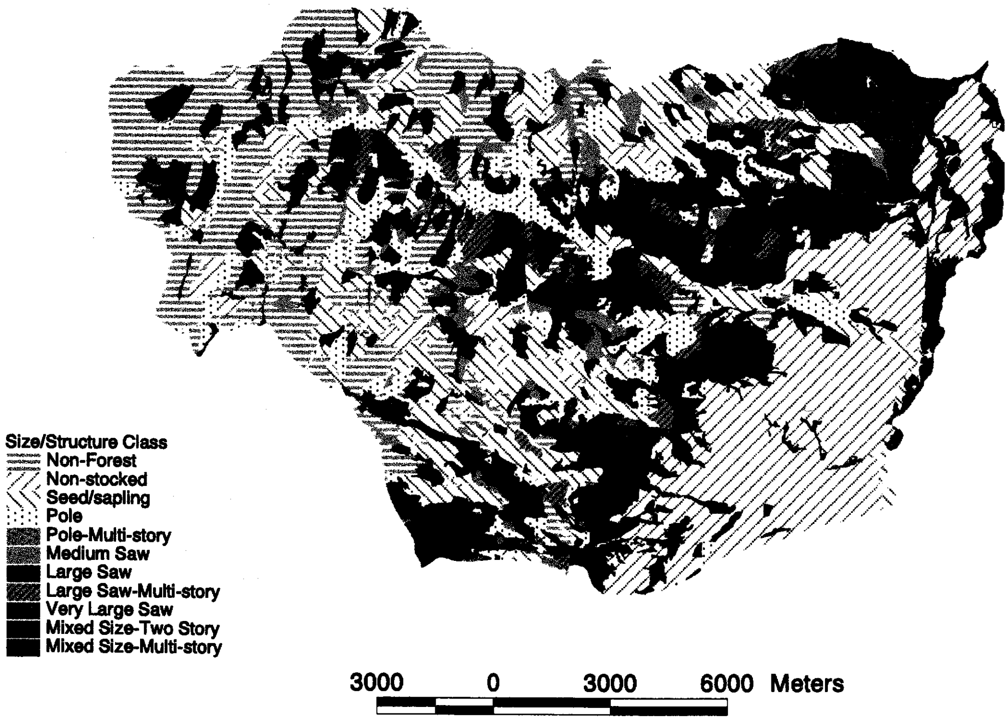


Figure 2.—Simulation of Future Condition in 50 years displaying size and structure classes with the only management activity being the current fire suppression. (Single story structure except as noted in legend.)

STEVI WEST CENTRAL
REFERENCE CONDITION SIZE CLASSES

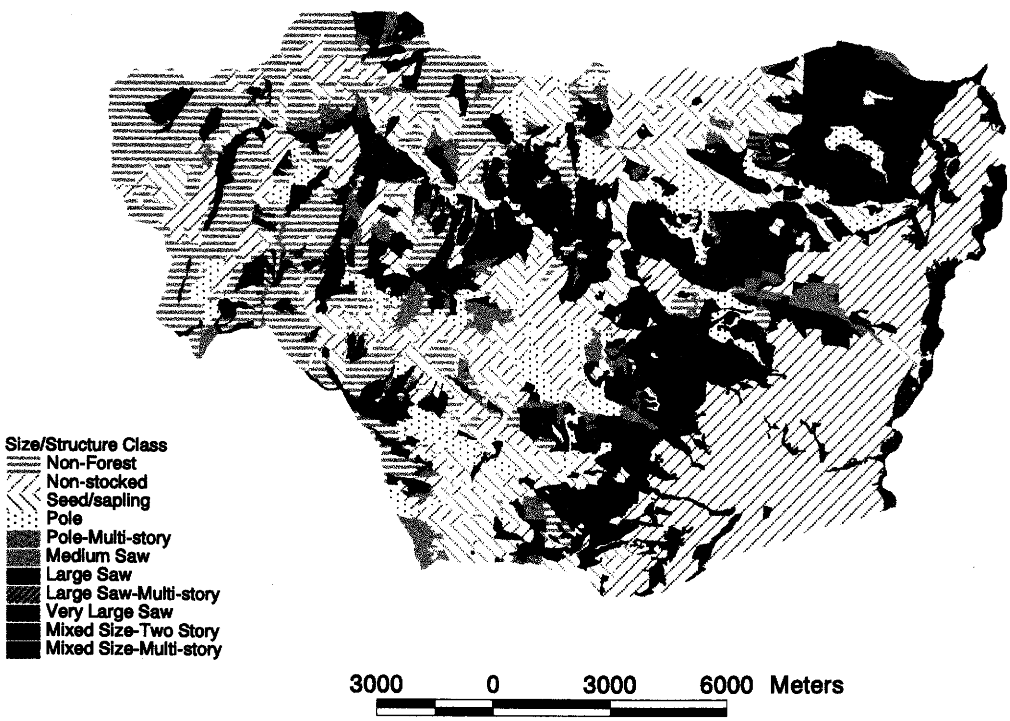
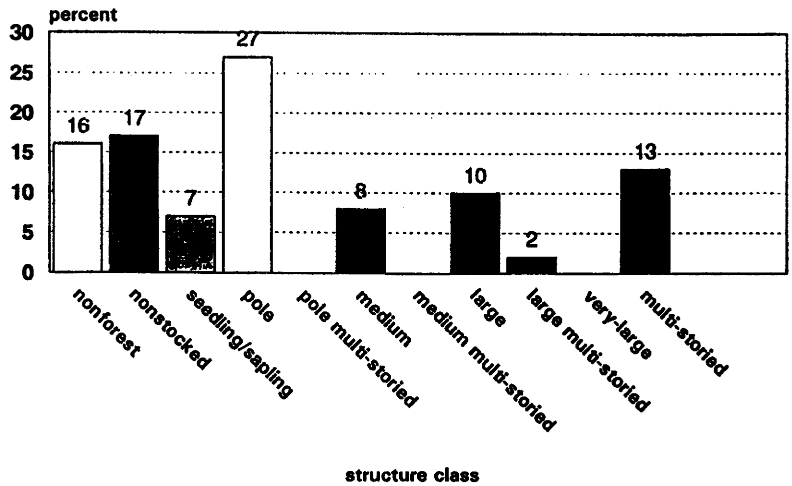
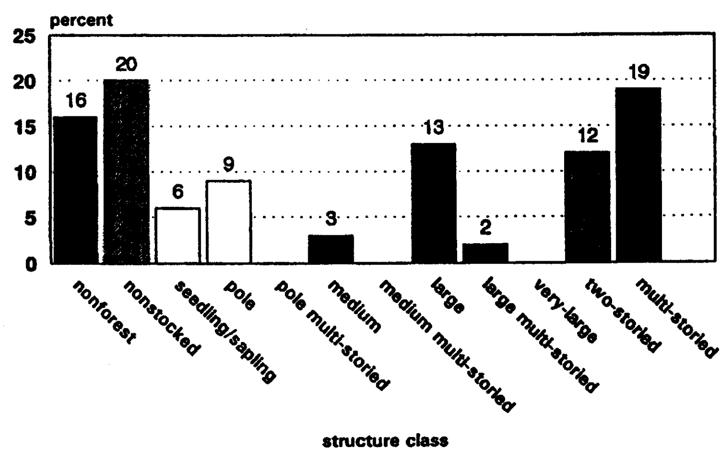


Figure 3.—Simulation of Reference Condition displaying distribution of size and structure classes. (Single story structure except as noted in legend.)

STEVI WEST CENTRAL
STRUCTURE CLASSES
CURRENT CONDITION



FUTURE CONDITIONS



REFERENCE CONDITION

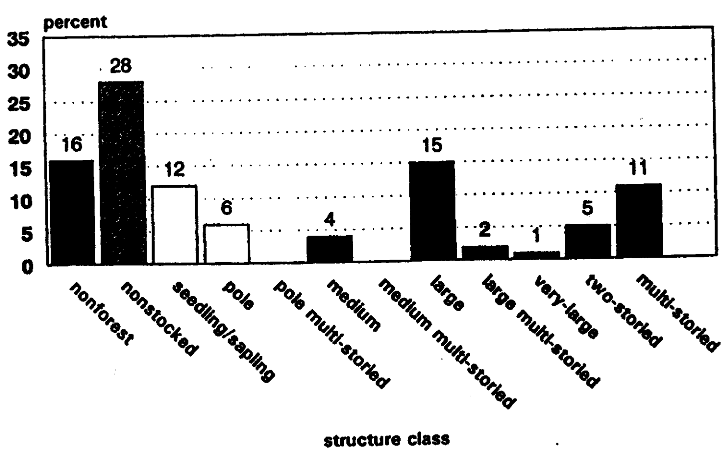


Figure 4.—Comparison of the size and structure classes in the three conditions: Current, Future (fire suppression only), and Reference Condition.

STEVI WEST CENTRAL
ACRES OF PROCESSES

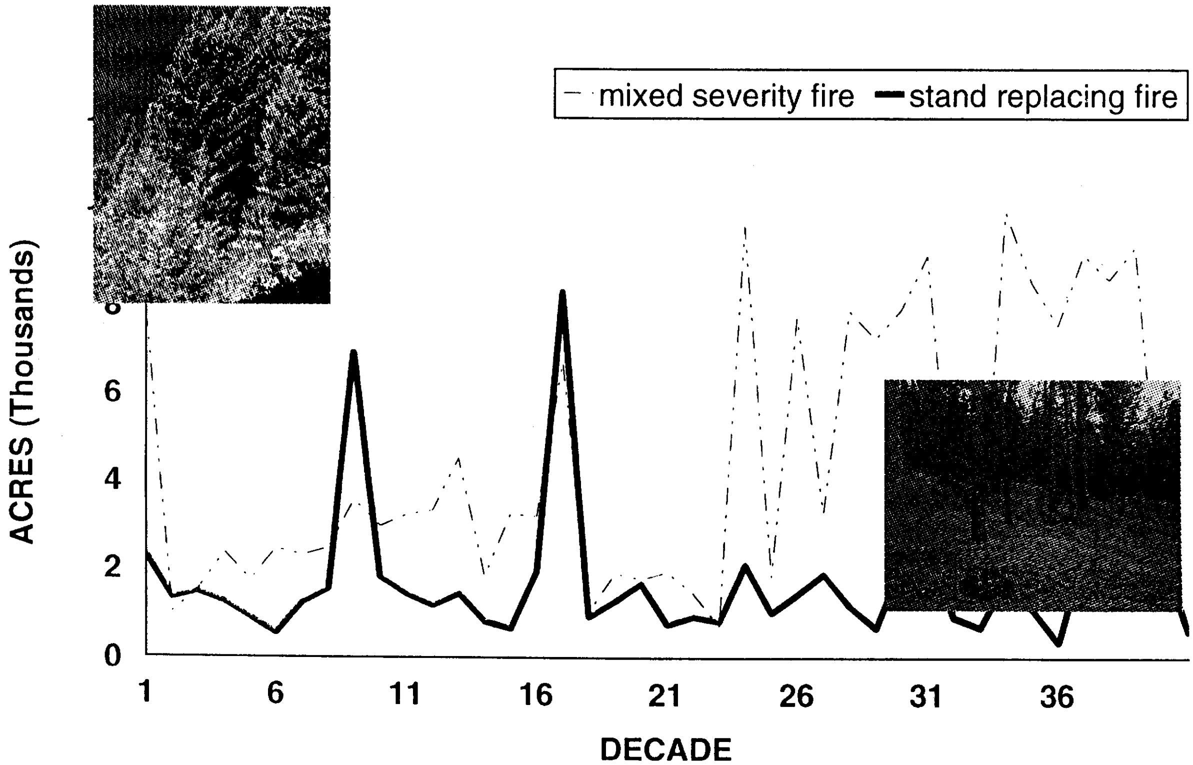


Figure 5.—Prediction of fire levels for 40 decades with fire suppression not in practice. The effects of past fire suppression are greatest in the first 10 to 15 decades. By the 40th decade, historic fire regimes are assumed to be functioning.

STEVI WEST CENTRAL
SILVICULTURAL TREATMENTS

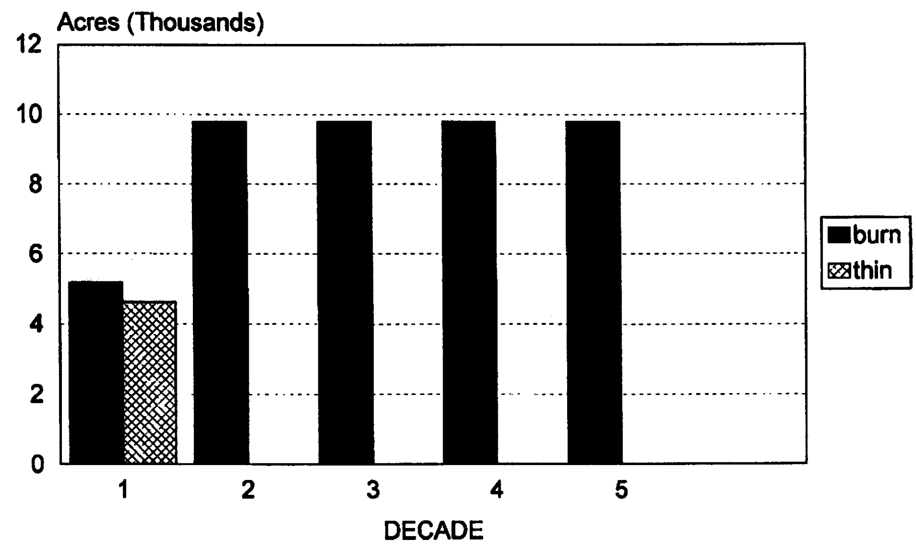


Figure 6.—Levels of silvicultural treatments applied in the ponderosa pine forest types to alter stand structure and composition. All "necessary" thinning is accomplished in the first decade. Underburning activities applied for 5 decades.

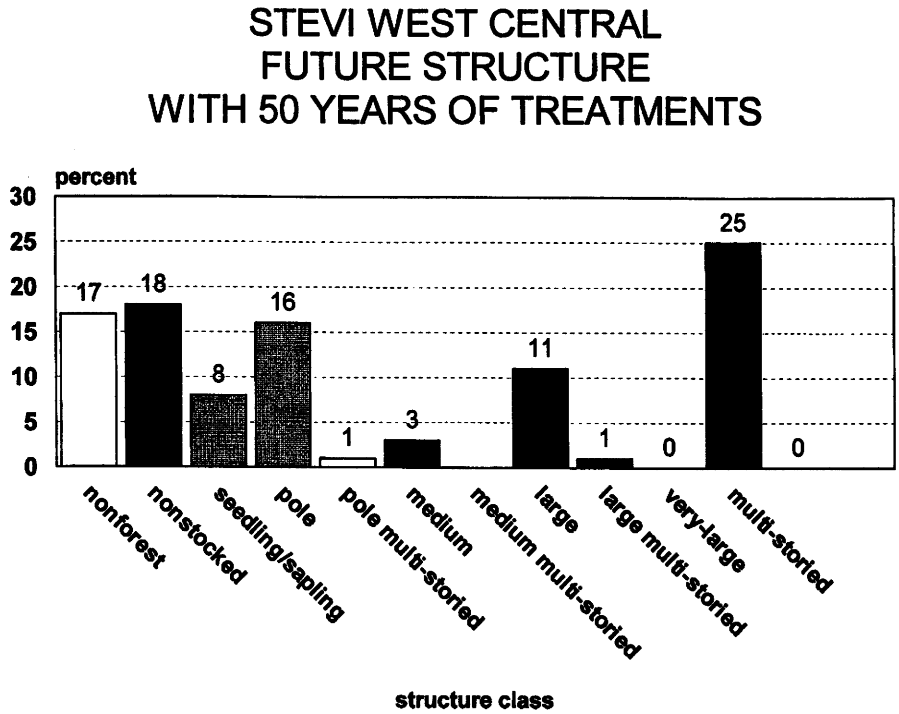


Figure 7.—Simulation of Future Condition in 50 years with the thinning and underburning activities applied.

weather conditions are favorable, susceptible stands of lodgepole pine can be infected by mountain pine beetle. Depending on the continuum of susceptible stands and other factors, the mortality may be endemic or at epidemic levels. The more continuous the susceptible stands, the greater the areas of mortality.

Fire is also common in lodgepole pine forests with or without mountain pine beetle mortality. With heavy mortality from mountain pine beetle, however, the fuel loads build up even greater. Aging lodgepole pine forests compile fuels as canopies break apart and alpine fir develops as an understory ladder fuel. Eventually, built up fuels are consumed by fire. Favorable conditions for lodgepole pine regeneration is created and it is likely that lodgepole will revegetate the site at the expense of other species. The pilot study by Arno and others (1993) showed that pre-1900 fires were relatively frequent but patchy, resulting in a fine grained mosaic of young and mixed-aged lodgepole pine communities with few late successional stands dominated by fir. A decline in fire frequencies (resulting from fire suppression) across the landscape sets the stage for larger stand replacing fire events, and a coarser grained mosaic.

The continual mountain pine beetle mortality and fire cycle can be simulated with SIMPPLLE (figure 8). Mountain pine beetle mortality peaks one to two decades prior to stand replacing fire peaks.

Fire control and management activities cannot change the mountain pine beetle and fire cycle, but they can affect the patterns that these processes affect. The more continuous areas of susceptible forest result in larger areas of mortality and eventually more intense fires.

In many drainages, concerns about sensitive fish species exist. In drainages, such as Poorman Creek on the Helena National Forest, an aspect of the desired condition is to reduce the risk of catastrophic mortality to protect long term watershed conditions. Heavy mortality would intensify concerns in already stressed watersheds.

Displays using SIMPPLLE. The distribution of current vegetation conditions is displayed in figure 9 for the Poorman Implementation area; an area of 30,000 acres (12,141 hactares). This map of size and structure classes shows large expanses of lodgepole pine of varying patch sizes. The simulation of conditions in 50 years (figure 10) with fire suppression being the only management activity, shows the trend toward larger expanses of older age classes, which will result in a trend of larger fires with greater intensity.

Using SIMPPLLE, the level of fire over the next 50 years is simulated based on current stand conditions and fire suppression practices. The result is a landscape with a majority of the area likely to burn in the next 50 years (figure 11). The SIMPPLLE output report identifies poygons where fire starts occur versus polygons burned by fire spread. The polygons of fire start would be likely candidates for silvicultrual manipulation to lower the fire risk.

The overall silvicultural strategy to achieve the desired condition is to breakup the continuum of even-aged lodgepole pine (increase mosiac), improve stand vigor, and reduce ladder fuels for decreased fire risk. A combination of silvicultural treatments were simulated across the landscape including underburning and broadcast (stand replacement) burning, regeneration and intermediate harvests (figure 12).

After numerous stochastic runs, the SIMPPLLE output showed lower levels of stand replacement fire with the

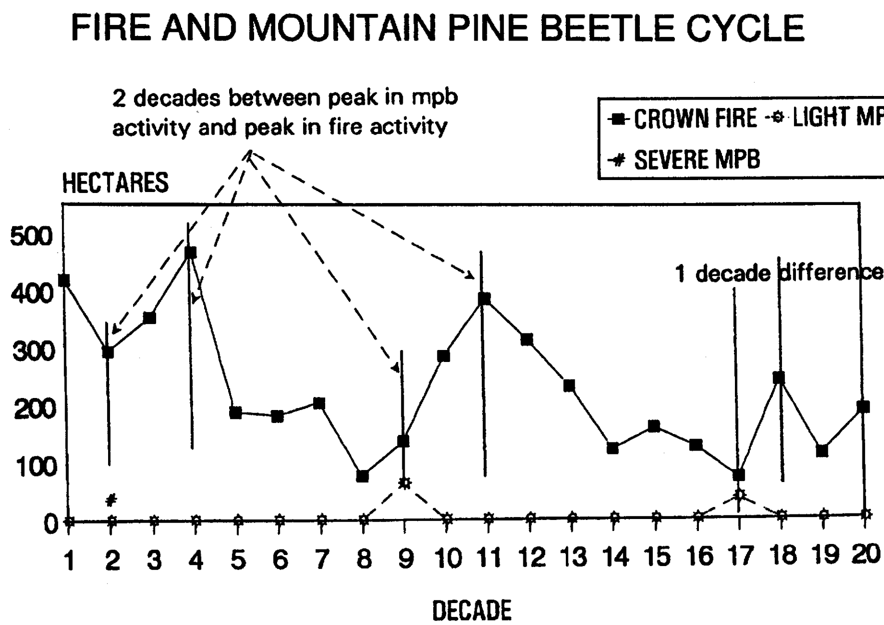


Figure 8.—Prediction of crown fire (stand replacing) and mountain pine beetle (MPB) cycles on the Coram Experimental Forest.

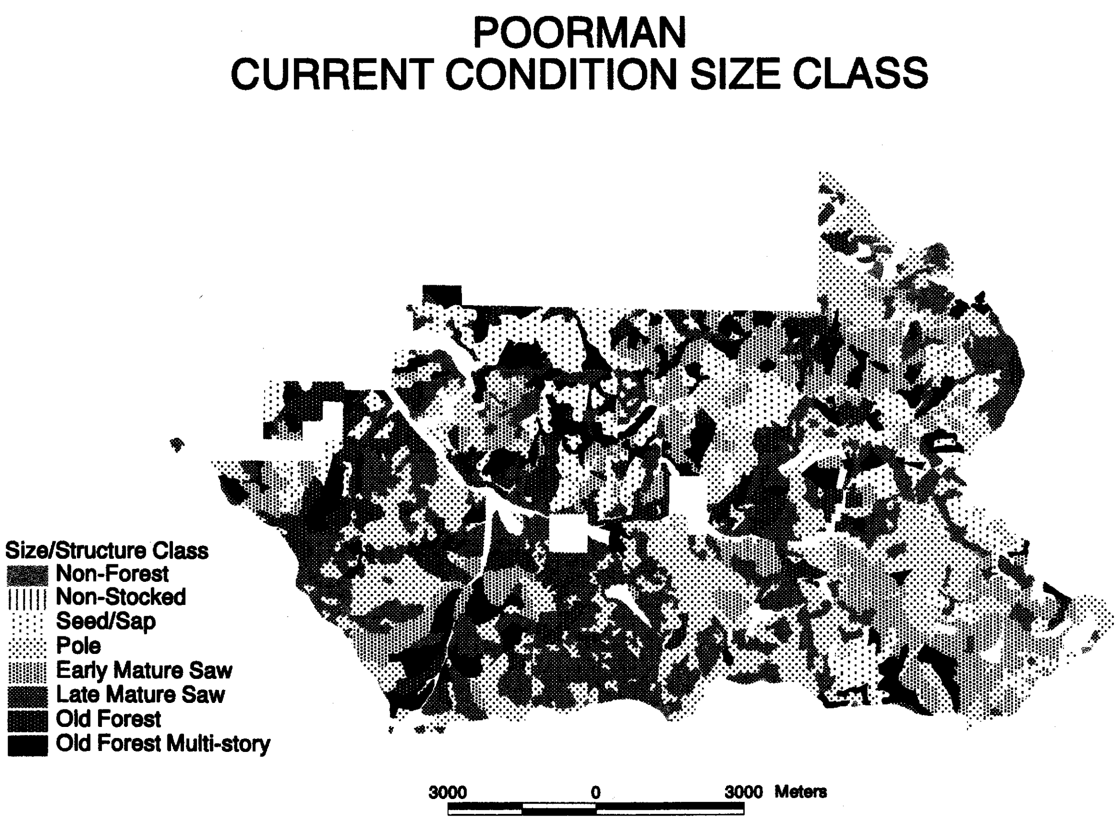


Figure 9.—Distribution of Current size and structure classes in the Poorman Project Area which is dominated by lodgepole pine. (Single story structure except as noted in legend.)

POORMAN
FUTURE CONDITION SIZE CLASS
NO TREATMENT

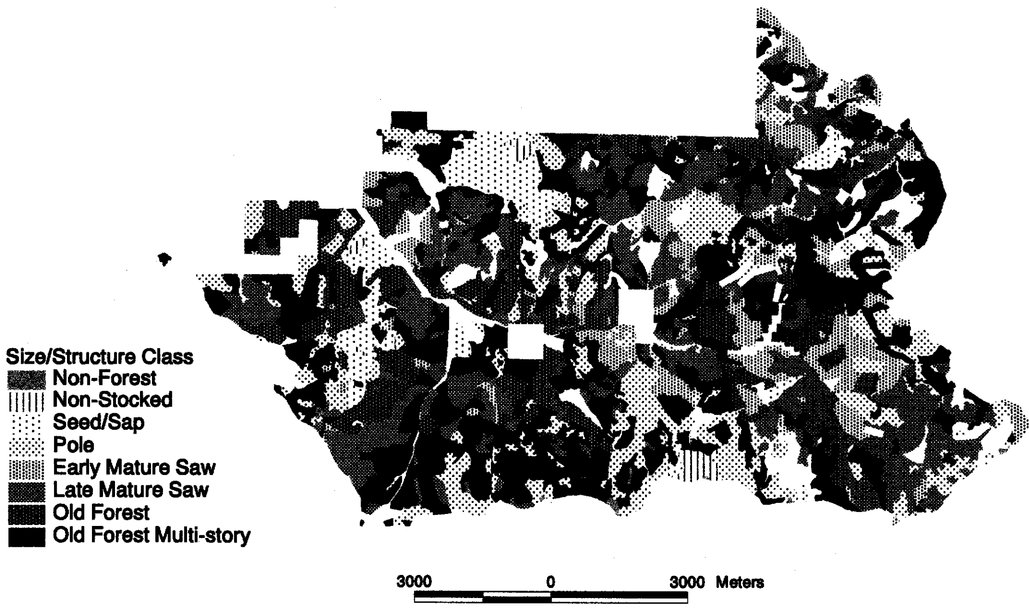


Figure 10.—Simulation of the future condition in 50 years with fire suppression being the only management activity. (Single story structure except as noted in legend.)

POORMAN
PROCESSES WITH HIGH PROBABILITY OF OCCURRENCE IN NEXT 5 DECADES

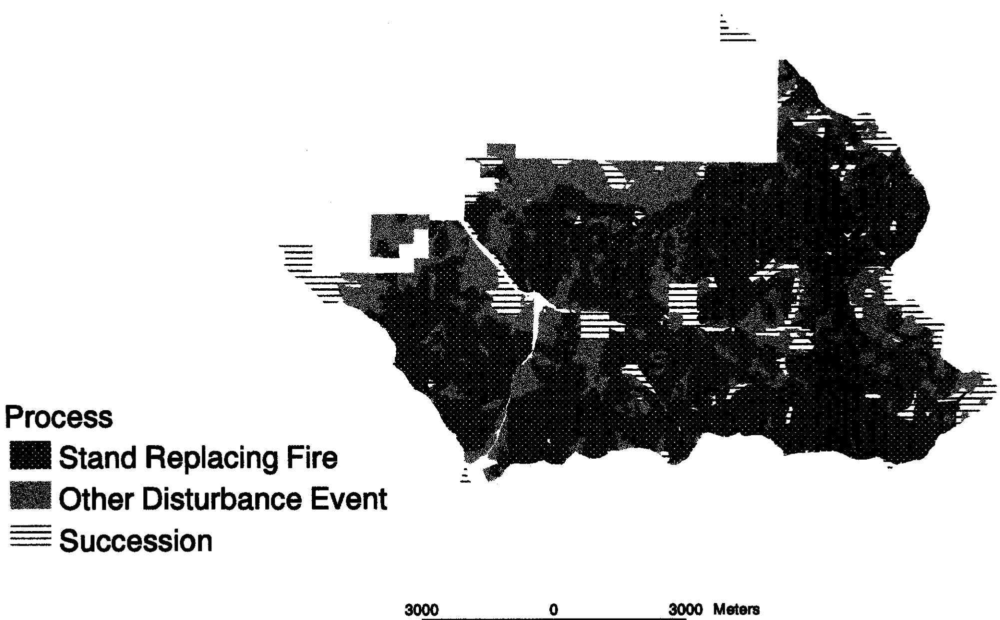


Figure 11.—Level of fire predicted over the next 50 years based on current stand conditions and fire suppression practices in place. Shaded areas represent the areas with greater than 90 percent likelihood of burning.

POORMAN
ALTERNATIVE B TREATMENTS

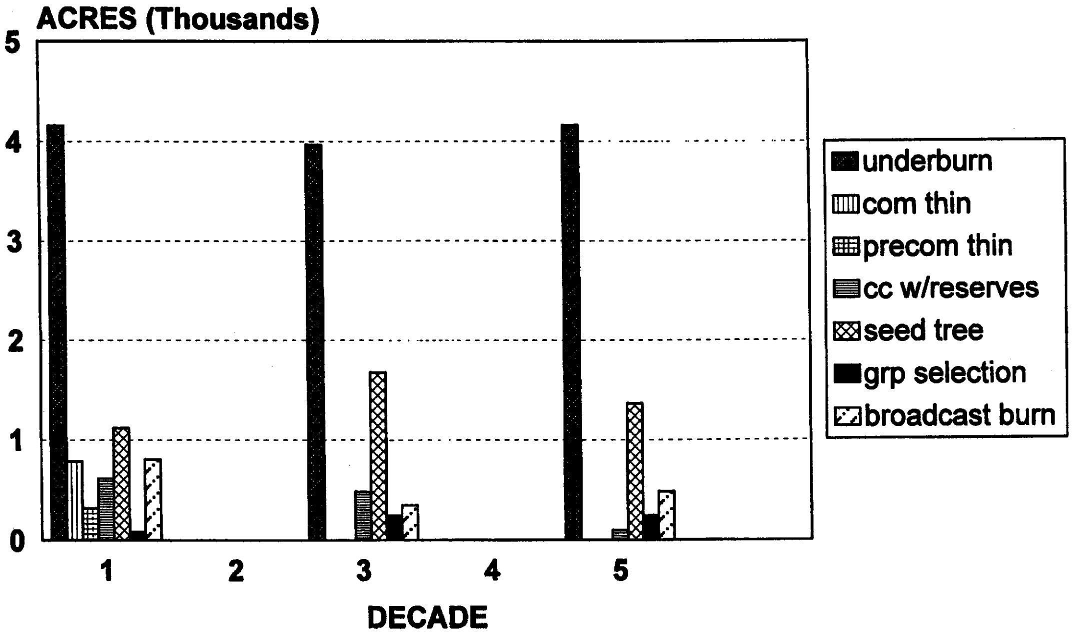


Figure 12.—Level of silvicultural treatments applied to modify stand species and size class to move towards the desired vegetative conditions. This is alternative B in the Poorman project.

POORMAN
LEVEL OF STAND REPLACING FIRE

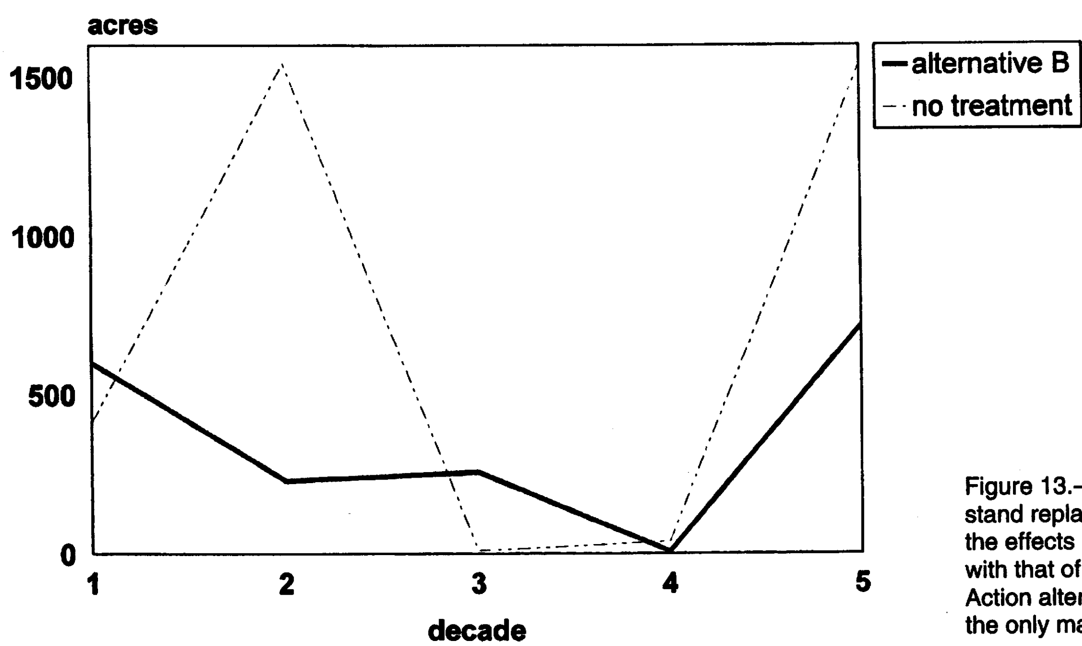


Figure 13.—Prediction of the levels of stand replacement fires comparing the effects of applying Alternative B with that of No Action. Under the No Action alternative, fire suppression is the only management activity.

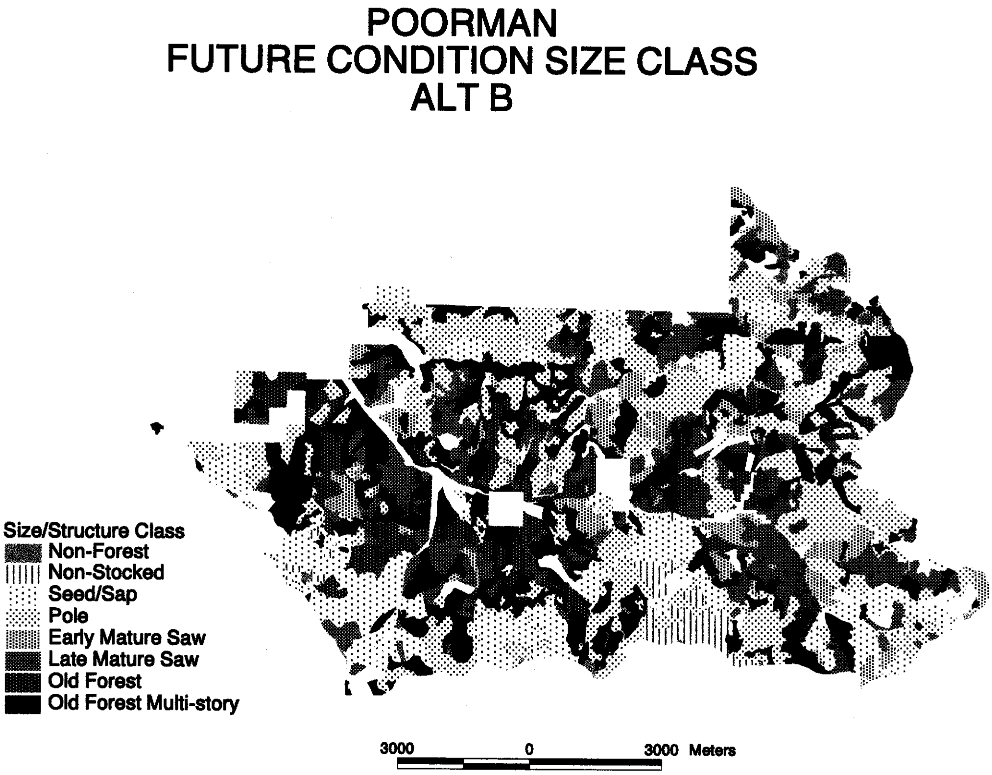


Figure 14.—Simulation of resulting Size and Structure Composition 50 years in future with the silvicultural practices applied. (Single story structure except as noted in legend.)

silvicultural activities applied. As see in figure 13, fewer acres are predicted to burn each decade.

The resulting structural diversity displayed in figure 14 is also more desirable, representing the patchy distribution common during historic fire regimes. The silvicultural activities increased the compostion of young and middle age classes. As in the pondersoa pone example, affecting change on the landscape requires treating a large number of acres. However, even when treating only a third of the acres described in this example, we see the landscape moving towards desired conditions.

SIMPPLLE STATUS

The silviculturists and other resource managers in Region One are becoming familiar with the use of SIMPPLLE and are refining the logic and probabilities of the pathways and processes. The current SIMPPLLE version is linked to ARCINFO; information can be passed on to other models to quantify the fragmentation based on patch sizes, to define parameters for optimization or scheduling models, to evaluate habitat function over time and to make volume projections. The SIMPPLLE design allows for the incorporation of non-forested communities, and work has begun to incorporate a future version that will capture the interaction of vegetation and the aquatic components of the landscape.

SUMMARY

The ponderosa pine and the lodgepole pine forest examples are used to display the dynamics of forest vegetation and the effects of stand level prescriptions across the landscape using SIMPPLLE. The simulations provide a quantification of the concepts that help in understanding and communicating the range of variation of processes, the change in vegetation over time, the interaction of pattern and process, and the effects of silvicultural strategies within the context of forest ecology.

LITERATURE CITED

Arno, Stephen F.; Reinhart, Elizabeth D.; Scott, Joe H. 1993. **Forest structure and landscape patterns in the subalpine lodgepole pine type: a procedure for quantifying past and present conditions.** General Technical Report INT-294. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest Experiment Station. 17 p.

Camp, Ann B.; Hessburg, Paul.; Everett, Richard L. 1996. **Dynamically incorporating late-successional forest in sustainable landscapes.** In: The use of fire in forest restoration. General Technical Report INT-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 20-23.

Gruell, George E. 1983. **Fire and vegetative trends in northern rockies: interpretations from 1871-1982 photographs.** General Technical Report INT-158. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest Experiment Station. 117 p.

Saveland, James M.; Bunting, Stephen C. 1988. **Fire effects in ponderosa pine forests.** In: Ponderosa pine: the species and its management, Symposium Proceedings. Office of Conferences and Institutes. Washington State University, Pullman: 125-131.