COMPUTER VISUALIZATION OF FOREST CHANGE TO COMMUNICATE FIRE-RELATED ECOLOGICAL CONCEPTS

Jed H. Andrews[1]
Big Sky High School, Missoula, MT 59804

Patricia L. Andrews
Intermountain Fire Sciences Laboratory, Rocky Mountain Research Station, U.S. Department of Agriculture, Forest Service, P.O. Box 8089, Missoula, MT 59807

ABSTRACT

A computer program, called DYNAMICS, was developed to illustrate changes in a forest type adapted to short-interval fire. Management options include natural fire occurrence, fire exclusion, and a silviculture-fire management approach. During a 500-year simulation, fire occurrence and intensity, tree growth, and tree mortality are shown in an animated display. The dynamic, visual display of the stylized, 10-tree forest and fire is presented as a way to communicate fire-related ecological concepts.

Citation: Andrews, Jed H., and Patricia L. Andrews. 1998. Computer visualization of forest change to communicate fire-related ecological concepts. Pages 57–60 *in* Teresa L. Pruden and Leonard A. Brennan (eds.). Fire in ecosystem management: shifting the paradigm from suppression to prescription. Tall Timbers Fire Ecology Conference Proceedings, No. 20. Tall Timbers Research Station, Tallahassee, FL.

INTRODUCTION

Wildland fire is a vital ecological process that profoundly influences the composition, structure, and function of forests and grasslands. Portraying alternative fire management decisions, describing possible future conditions, and communicating ecological concepts are complex challenges (Williams et al. 1994). Temperate forests change slowly, thus impacts of various fire management strategies on them become evident only with the passage of considerable time. The ability of the public to understand such systems can be aided by the use of computer modeling accompanied by visualization of the resulting predicted changes (Orland et al.1993, Burk and Nguyen 1992). Computer visualization is increasingly used to communicate the implications of natural and management changes in biological systems in wildland areas such as national parks and forests. Visualization techniques can be used by scientists, managers, and the public to interpret dynamic changes, and to evaluate the range of outcomes that most likely will result from different management strategies (Orland 1993).

Williams et al. (1994) proposed a decision tree analysis as a method to portray a better understanding of the risks, benefits, costs, and consequences that may result from an array of fire management options. A diagram was developed to show some commonly observed successional pathways. The permutations of potential successional pathways, however, are virtually limitless. The DYNAMICS program described here includes features that are not possible in such a static diagram. Probabilities are used to determine fire occurrence, fire intensity, tree mortality, and seedling establishment. The user is able to choose a management option and observe the simulated effect on the forest. Like the real world, the simulation produces a different result with each run.

Figure 1 shows sample screens indicating how the DYNAMICS program displays forest change. This representation cannot, however, do justice to the animated, color display produced by the actual computer simulation.

FOREST AND FIRE DYNAMICS

The vegetation type used in the DYNAMICS computer program is a long-needle pine stand that was once maintained by periodic surface fire. Long-needle pine, such as ponderosa pine (*Pinus ponderosa*), and other similar species is a common forest type adapted to short-interval fire (Williams et al. 1994). Frequent low-intensity fires maintain open-grown pine stands by limiting the establishment and growth of tree regeneration. With fire removed from the ecosystem, dense understories of small trees (*Abies* and *Pseudotsuga* fir species) develop, increasing the likelihood of high-intensity stand-replacement fires.

From interpretations of historic photos, maps, and journals, we know that stands looked much different 100 years ago than they do today (Gruell 1983). They were once maintained in an open condition by frequent surface fire that favored ponderosa pine. Since the early 1900's land management activities and public uses began to influence the landscape. Perhaps the most apparent changes were the result of successful fire control practices. When these changes took hold, frequent

[1] Present address: Montana State University, Bozeman, MT 59717.

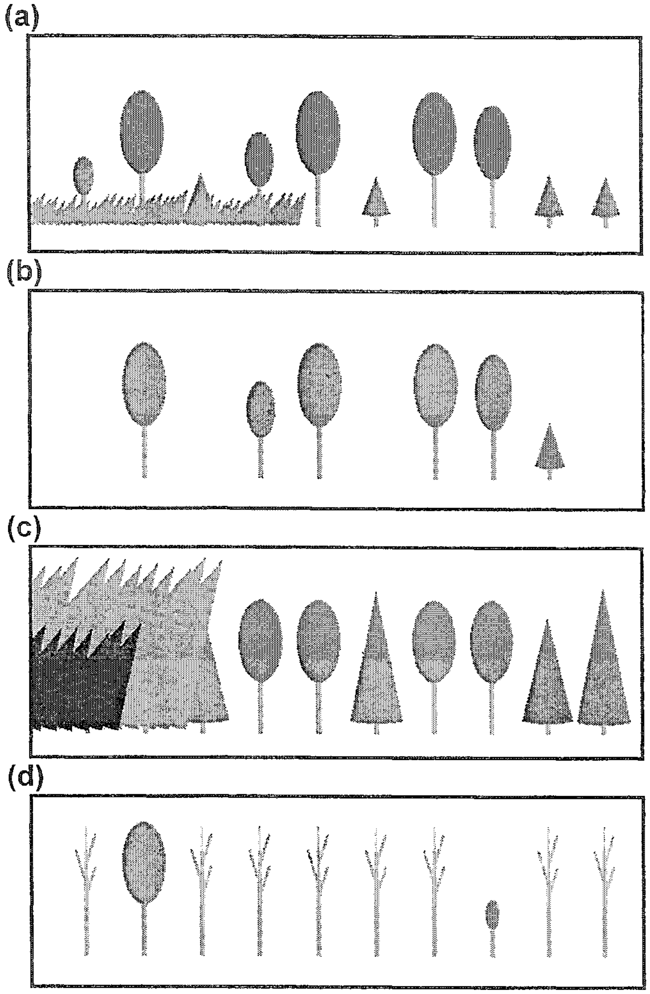

Figure 1. Sample screens from DYNAMICS' color, animated display: (a) a low-intensity surface fire through a forest of mostly large ponderosa pine and small Douglas-fir; (b) the forest shortly after the low-intensity fire, which has killed most of the small trees; (c) a high-intensity crown fire through the forest after a period of fire exclusion; (d) the forest shortly after the high-intensity fire, which has killed most of the trees, including large ponderosa pines.

fires and related ecological processes were disrupted and species composition gradually changed to include more Douglas-fir (*Pseudotsuga menziesii*). Denser, multi-storied, uneven-aged stand characteristics also developed (Figure 2).

A common misconception among many members of the public is that we will see the same forest tomorrow as we see today. In fact, forests are dynamic. Although change may be slow, it is certain. A forest cannot be "preserved" by excluding forest fires. When fires do not occur in the ponderosa pine type for a long period of time, fuels build up and firs grow among the pine, making a high-intensity fire more probable. When fires reach a high intensity, they cannot be suppressed. A stand-replacement fire then kills most of the trees. In stands where fire has been excluded for some time, the potential for high-intensity fire can be reduced by thinning the Douglas-fir (or removing most of the understory) and periodically burning with prescribed fire to maintain an open ponderosa pine stand (Arno 1988).

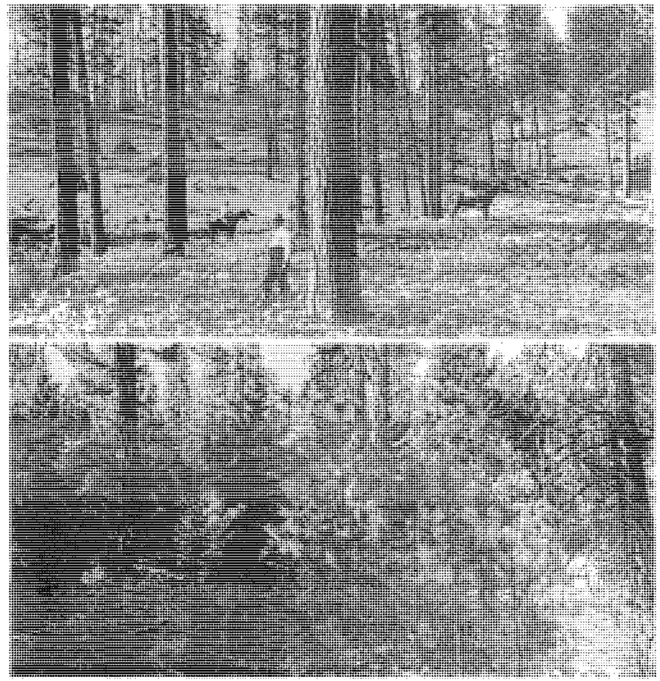

Figure 2. (top) 1909—Lick Creek timber sale, Bitterroot National Forest, Montana. Fire scar samples showed a mean fire interval of 7 years between 1600 and 1900. (bottom) 1979—Same camera point 70 years later. The large ponderosa pine in center-foreground in the 1909 view was cut in 1952. (from Gruell 1983).

Fire-related ecological concepts that are illustrated by the DYNAMICS program are as follows:

- Fire is an important part of the ecosystem.
- Forests do change; they are dynamic, not static.
- Forests cannot be "preserved" by fire exclusion.
- The species and structure of a forest influence fire intensity. In open ponderosa pine forests, for example, low-intensity surface fires are more likely than high-intensity crown fires.
- Thinning and prescribed burning are viable fire management options.

STOCHASTIC SIMULATION

The simulation presented in DYNAMICS is based on stochastic relationships for fire occurrence, fire intensity, tree mortality, and seedling establishment. Mathematical models are available for fire behavior, tree mortality, and forest succession (Andrews 1986, Ryan and Reinhardt 1988, Keane et al. 1990). They are not used in this application because the ecological concepts can be communicated effectively by means of a simple, stylized forest, with dynamics based on simplified probabilities.

Arno et al. (1985) state that pre-1900 low- to medium-intensity surface fires occurred at about 5- to 30-year intervals. Keane et al. (1990) used an 8-year mean fire interval in their simulation. In DYNAMICS, the probability of a fire each year is 0.10 based on a random number uniform frequency distribution. DYNAMICS uses two levels of fire intensity: low-intensity surface fire and high-intensity crown fire. The probability of a crown fire is a function of tree sizes and the relative numbers of pine and fir. Crown fires can occur even under the option of fire exclusion. The probability of a ponderosa pine surviving a low-intensity fire is higher than that for Douglas-fir. Few trees of either species are able to survive a high-intensity crown fire. A low probability of surviving a crown fire was, however, assigned to large ponderosa pine trees. The probability of ponderosa pine seedling establishment after a fire was set to be lower than for Douglas-fir.

DISCUSSION

The user of the DYNAMICS computer program is allowed to simulate management decisions and observe the consequences. The simulation runs from 300 years in the past to 200 years in the future. Four fire management options are offered. Option (1) is periodic fire occurrence with no fire suppression for all 500 years of the simulation. The other three options start with periodic fire without suppression action for the first 200 years, followed by fire exclusion from 100 years ago until the present. The user can then choose (2) no fire exclusion, (3) fire exclusion, or (4) thinning by removing all Douglas-fir and then burning with prescribed fire every 10 years.

Figure 3 shows the screen after two runs of a 500-year simulation. The difference is due to the stochastic nature of the simulation. The labels under the time line indicate the management option that was chosen, in this case option 4: thinning and prescribed burning after a period of fire exclusion. Ponderosa pine are indicated by elliptical crowns and Douglas-fir by triangular crowns. The graph below the forest diagram gives a history of the simulation. The lines indicate the relative number and size of the pine (PP) and fir (DF) in the stand. This is a visual surrogate for basal area or stems per acre, which can't be used because of the simple 10-tree forest. The timeline shows the fire occurrence; low-intensity fires are indicated by short bars and high-intensity fires by taller bars. In figure 3b note the high-intensity crown fire about 120 years in the past, and the resulting drop of the curves due to tree mortality. In both cases, the PP and DF lines increased as the trees grew during the period of fire exclusion; the DF line then drops to zero at time zero (present) when the Douglas-fir are harvested.

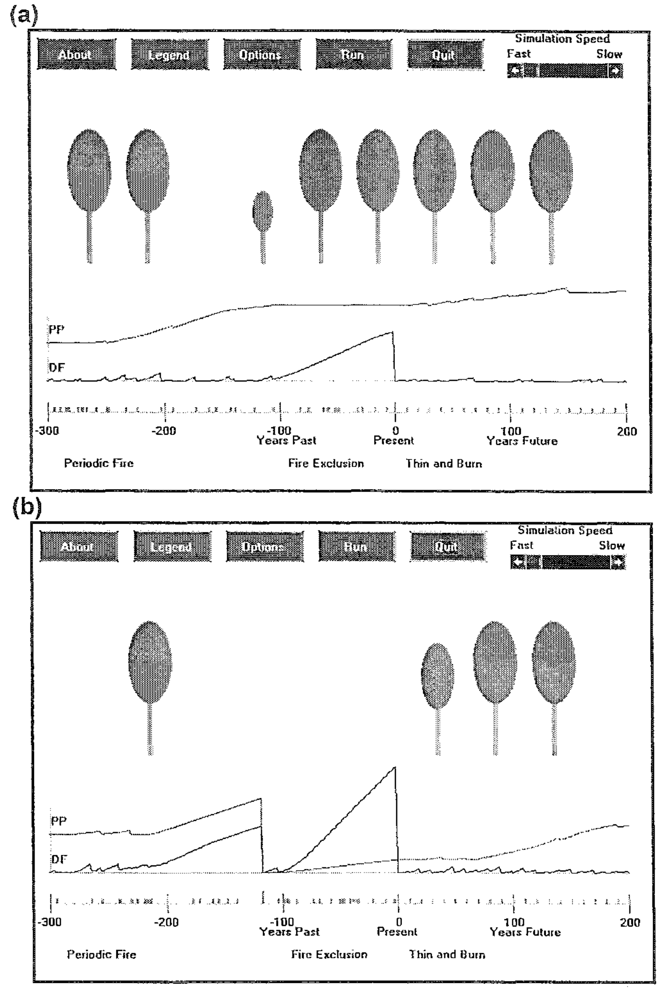

Figure 3. Two results of the simulation under management option 4: (a) periodic fire without suppression for 200 years, followed by 100 years of fire exclusion, and followed by (b) removal of Douglas-fir and prescribed burning for 200 years. Differences in (a) and (b) are due to the stochastic nature of the simulation.

CONCLUSIONS

Usefulness of the DYNAMICS program is indicated by the positive reaction to demonstrations by members of the general public as well as fire researchers and land managers. Comments and suggestions on enhancements emphasize the potential of this approach to communicating ecological concepts. DYNAMICS is fun to use. It promotes active participation in a discussion of concepts.

It is a challenge to communicate concepts related to forest change that occur over the span of one or more human lifetimes. A shift in the fire management paradigm from fire exclusion toward the use of prescribed fire makes it even more important that the public and non-fire specialists understand fire-related ecological concepts.

ACKNOWLEDGMENTS

Jed Andrews designed and developed the DYNAMICS program as a Forest Service volunteer and as a sophomore in an Advanced Problems in Science course (1994–95) at Big Sky High School, Missoula, Montana under learning facilitator Jim Harkins and technical advisor Pat Andrews. The authors thank Jim Brown and Steve Arno for advice and encouragement on this project, and Steve Arno, Mick Harrington, and Jane Kapler-Smith for review of the manuscript.

LITERATURE CITED

Andrews, P.L. 1986. BEHAVE: Fire behavior prediction and fuel modeling system—BURN subsystem, Part 1. General Technical Report INT-194, U. S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT.

Arno, S.F. 1988. Fire ecology and its management implications in ponderosa pine forests. Pages 133–139 *in* D.M. Baumgartner and J.E. Lotan (compilers). Ponderosa pine: the species and its management. Office of Conferences and Institutes, Cooperative Extension, Washington State University, Pullman.

Arno, S.F., D.G. Simmerman, and R.E. Keane. 1985. Forest succession on four habitat types in western Montana. General Technical Report INT-177, U. S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Burk, T., and M.V. Nguyen. 1992. Visualizing the operation of a distance-dependent tree growth model. The Compiler 10: 10–19.

Gruell, G.E. 1983. Fire and vegetative trends in the northern Rockies: interpretation from 1871–1982 photographs. General Technical Report INT-158, U. S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Keane, R.E., S.F. Arno, and J.K. Brown. 1990. Simulating cumulative fire effects in ponderosa pine/Douglas-fir forests. Ecology 71:189–203.

Orland, B., J. Obermark, J. LaFontaine, and T. Suter. 1993. Model and data-driven visualization of forest health dynamics. Pages 65–72 *in* A.M. Liebhold and H.R. Barrett (eds.). Proceedings: spatial analysis of forest pest management. General Technical Report NE-175, U. S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Radnor, PA.

Ryan, K.C., and E. Reinhardt. 1988. Predicting post-fire mortality of seven western conifers. Canadian Journal of Forest Research 18:1291–1297.

Williams J.T., R.G. Schmidt, R.J. Lasko, R.A. Norum, P.N. Omi, and R.G. Lee. 1994. Communicating fire-related considerations along successional pathways using decision tree analysis. Proceedings of the 12th Conference on Fire and Forest Meteorology 12:299–304.