Using a Multichange Agent Approach with the Forest Vegetation Simulator on the Boise National Forest, Idaho

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Abstract—Permanent plots from the Boise National Forest, Idaho, were established in 1982 and remeasured in 1987 and 2000 for monitoring the effects of western spruce budworm (*Choristoneura occidentalis*) on mixed conifer stands of grand fir (*Abies grandis*), Douglas-fir (*Pseudotsuga menziesii*), subalpine fir (*Abies lasiocarpa*), and Engelmann spruce (*Picea engelmannii*) tree species. The central Idaho variant of the Forest Vegetation Simulator was used to make two simulations that were then compared to the actual data. A simulation without change-agent impacts causes an underestimation of mortality and overestimation of growth. A multichange agent approach using a variety of pest model models and fixed mortality functions simulates impacts from western spruce budworm and a variety of bark beetles. This simulation more closely represents the mortality and growth indicated by the actual data.

Modeling the process of change in forests is challenging. To assist in this task, forest managers use the Forest Vegetation Simulator (FVS) to simulate changes in stand structure and composition over a specified timeframe. Traditionally, simulating disturbances, referred to as change agents (Steele and others 1996), is accomplished by linking one pest model to the main FVS model. If Douglas-fir beetle (*Dendroctonus pseudotsugae*) is the primary change agent, then one will use the model with the Douglas-fir beetle model. Similarly, other independent pest models are available for western spruce budworm (*Choristoneura occidentalis*), mountain pine beetle (*Dendroctonus ponderosae*), and Douglas-fir tussock moth (*Orgyia pseudotsugata*). Only impacts from dwarf mistletoes (*Arceuthobium* spp.) are simulated as part of the main FVS model. Unfortunately, no single change agent can adequately reflect the total actual mortality and growth impacts on vegetation. Only a multichange agent approach can lead us closer to simulating change.

Since 1991 a multichange agent scenario has been available for use with the central Idaho variant of FVS. The Southwest Idaho Ecogroup Team has utilized it in landscape and project planning on the Boise and Payette National Forests in Idaho. For this analysis, permanent plot data collected on the Boise National Forest in 1982 and remeasured in 1987 and 2000 were used to evaluate the multichange agent scenario. The outputs from the actual data were compared to a no-change agent (nopest) simulation and a multichange agent (pestadj) simulation.

Methods

To evaluate this multichange agent procedure, 88 permanent plots established in 17 stands in the Boise National Forest in 1982 were analyzed. These stands were established to monitor the impacts of defoliation by western spruce budworm on mixed conifer stands where an outbreak event started in some stands as early 1971. The outbreak grew and continued through 1987 when some unknown event ended the outbreak in all stands. Species composition includes grand fir (*Abies grandis*), Douglas-fir (*Pseudotsuga menziesii*), subalpine fir (*Abies lasiocarpa*), and Engelmann spruce (*Picea engelmannii*). Ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), and lodgepole pine (*Pinus contorta*) tree species are also present but are not primary hosts of western spruce budworm.

Originally, stands were selected based on presence of defoliation, size of stand (20 to 65 acres), stand accessibility, land base stratification, and defoliation stratification (Beveridge and Cahill 1984). Remeasurements were taken on stands in 1987 and 2000. Although these stands are maintained to monitor impact from western spruce budworm, their species composition makes them suitable for a multichange agent evaluation.

To prepare stand data for entry to the FVS model, the tree data were compared in each year to correct small discrepancies in tree species and find unreasonable growth measurements. Stands were not included if trees grew smaller or could not be found in every measurement. In the 17 stands that were selected, only trees that were measured in all three measurements were included in the simulated data sets. Additionally, only trees equal to or greater than 1 inch in diameter were included.

The following computer programs and files were used to complete the project:

- Suppose Version 1.14—(Crookston 1997)
- Forest Vegetation Simulator—CIX.EXE (Wykoff and others 1982; David 2001)
- Multichange agent keyword set (Roberts and Weatherby 1997)
- Event Monitor (Crookston 1990)
- Compute2 post processor (Van Dyck 2001)
- Excel spreadsheet—graphics (Microsoft© Excel™2000)

The CIX.EXE program offers the user a multilinked version of FVS. In this version, the Douglas-fir beetle model, the mountain pine beetle model in lodgepole pine, and the

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western spruce budworm model are all available to the main FVS program. Due to the low occurrence of mistletoe in these stands, mistletoe was not included in the evaluation.

There is no programmed interaction between the pest models. They run independently and in a sequence. Growth is adjusted and mortality is applied according to each model's specifications. In addition, three mortality functions have been defined to simulate mortality caused by fir engraver beetle in grand fir (Schenk and others 1977), western pine beetle in ponderosa pine (Stevens and others 1980), and spruce beetle in spruce (Schmid and Fry 1976). These functions are executed from the multichange agent keyword set.

All instructions for determining vulnerability of trees to a change agent are also included in the multichange agent keyword set. A set of hazard rating rules is applied to each stand using the event monitor. If the vulnerability is high, based on these rules, the associated change agent model or function is called. For the western spruce budworm model, the Douglas-fir beetle model, and the mountain pine beetle model, the tree mortality caused by the change agent is checked against the background mortality computed by the FVS model. The larger of the two is applied (Marsden and others 1994). On the other hand, the fixed mortality functions for spruce beetle, fir engraver beetle, and western pine beetle add mortality to the background mortality.

Two simulations were compared to the actual data in this evaluation. Data from the actual measurements collected in years 1982, 1987, and 2000 were submitted to FVS for computing the initial stand characteristics for each stand for each measurement year. Then a simulation that contained no-change agent impacts (nopest) was made starting with the 1982 actual data. The simulation grew each stands forward to 1987 and then to 2000. The second simulation (pestadj) started with the 1982 actual data and grew the stands forward applying the rules, models, and functions from the multichange keyword set. Both mortality and growth are impacted by the change agents. The stand summary data displayed in the Summary Statistics Table of the FVS output were used as indicators for comparing differences between the simulations and the actual data. These summary data are recreated in tabular format using the ECHOSUM keyword in the FVS and stored in an output file (.sum).

The stand indicators that were compared are trees per acre, basal area, stand density index, dominant height, quadratic mean diameter, volumes, crown competition factor, and mean annual increment. Additionally, some indicators that were evaluated by species and tree size class include trees per acre, basal area, quadratic mean diameter, and dominant height. These outputs were produced using the event monitor, which is a part of the FVS model. The event monitor keyword SPMCDBH was used to extract the indicator information by species and diameter class. The diameter classes consist of small trees between 1 and 5 inches and large trees greater than 5 inches. Two output files were created using the postprocessor of Suppose. The data from both output files were imported into a Microsoft Excel® spreadsheet program. Using the spreadsheet's pivotal table function and graphing capabilities, the data were summarized and displayed.

Results

In this paper, the basal area indicator will be discussed in detail. By looking at the average basal area by species in figures 1 and 2, it becomes clearer how the change agents have impacted the stands. The bottom bar on the chart represents the actual data, the middle bar is the multichange agent simulation (pestadj), and the top bar is the no-change agent simulation (nopest.) There is a decline in basal area in all species from 1982 to 2000. The largest change in stand species composition was in the subalpine fir species, which declined from 17 percent in 1982 to 13 percent in 2000. Grand fir, the largest component of this mix, remained relatively unchanged, while both Engelmann spruce and Douglas-fir improved position due to the decline in subalpine fir.

The average basal area for the no-change agent simulation (nopest) and the actual data are displayed in figure 3. This no-change agent simulation might be viewed as the best-case scenario. As each change agent is added as a line on the graph, notice the move from the no-change agent scenario toward the actual data. Modeling the change agents explains some of the difference between a no-change agent run and the actual data. Change agents that are not modeled might explain some of the remaining difference. These might include other insects, diseases, and impacts from weather, drought, animals, or humans. Another factor that might influence the remaining difference is in growth rates used in the model. Unadjusted rates may be growing trees faster than the actual growth rates, causing the basal area

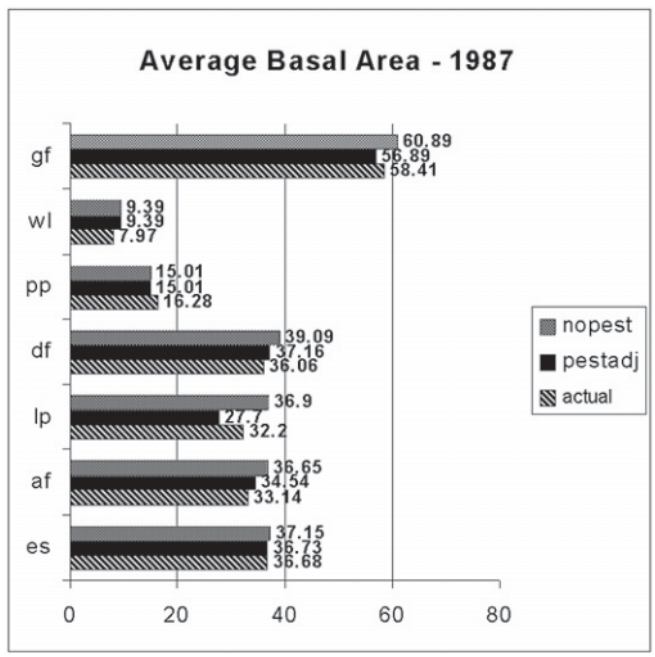


Figure 1—Total basal area (ft^2) and average basal area (ft^2) by species by simulation for 1982 to 1987 cycle. Species codes are: gf = grand fir; wl = western larch; pp = ponderosa pine; df = Douglas-fir; lp = lodgepole pine; af = subalpine fir; es = Englemann spruce.

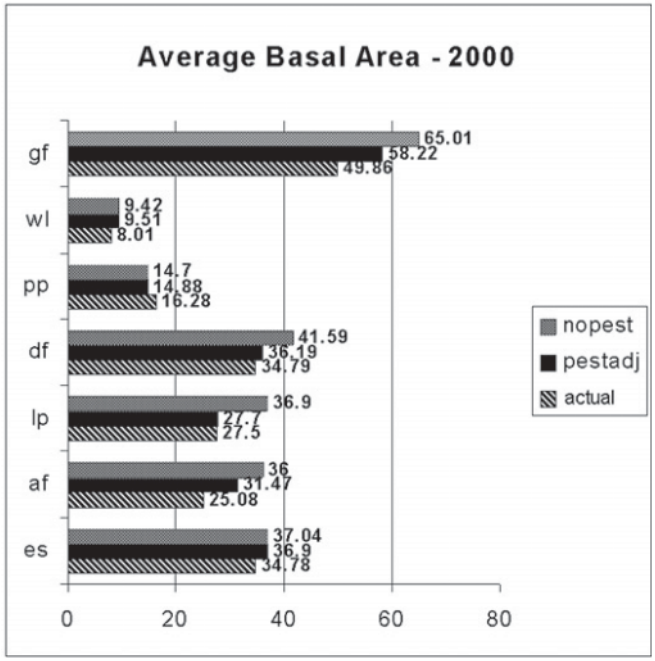
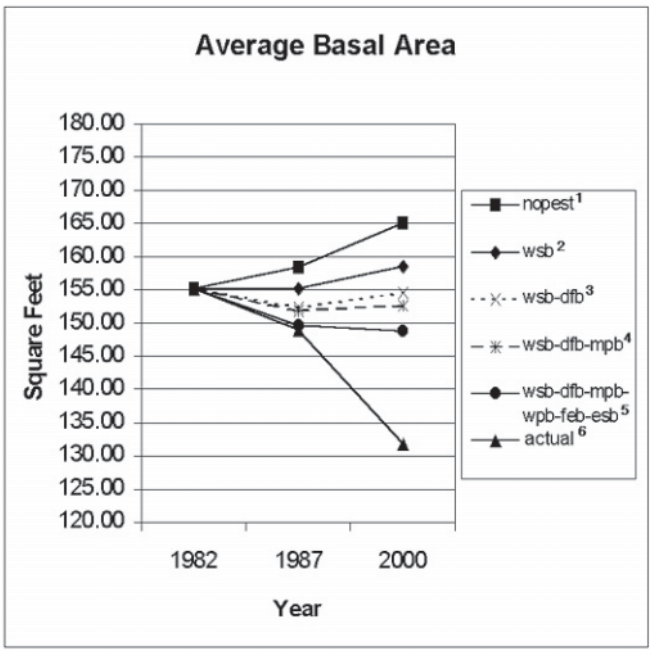


Figure 2—Total basal area (ft^2) and average basal area (ft^2) by species by simulation for 1987-2000 cycle. Species codes are the same as used in figure 1.



[1]A simulation that does not include any change agent impacts.
[2]Impacts from western spruce budworm have been added.
[3]Impacts from western spruce budworm and Douglas-fir beetle have been added.
[4]Impacts from western spruce budworm and Douglas-fir beetle, and mountain pine beetle have been added.
[5]Impacts from western spruce budworm and Douglas-fir beetle, mountain pine beetle, western pine beetle, fir engraver beetle and spruce beetle have been added.
[6]Actual data

Figure 3—Illustrates the change in basal area from 1982 to 2000 for each of the simulations and the actual data.

of the simulations to be higher. Other factors such as competition of trees less than 1 inch that are not included in the simulations might also have an impact.

Western spruce budworm, which impacts Douglas-fir, Engelmann spruce, grand fir, and subalpine fir, causes diameter growth loss, top kill, and mortality due to defoliation in host species (Beveridge and Cahill 1984). In the multichange agent simulation, this is the only agent impacting subalpine fir. By year 2000, the overall difference in subalpine fir from the no-change agent simulation to the actual is 30 percent, of which 13 percent is attributed to western spruce budworm. The remaining mortality in subalpine fir can be attributed to a complex of insects, pathogens, and environmental factors (Bennett and others 2001).

In addition to western spruce budworm, the Douglas-fir beetle model in the multichange agent simulation moved Douglas-fir basal area close to the actual data. There is a 16 percent difference in the actual basal area from the no-change agent simulation but only a 4 percent difference between the multichange agent simulation and the actual data in Douglas-fir.

The impacts from mountain pine beetle in lodgepole pine move the 1987 basal area slightly lower than the actual data. A study of the simulation indicates that outbreaks for mountain pine beetle rated high in some stands in 1982, which triggered an outbreak during the 1982 to 1987 growth cycle. A study of the actual data shows that a large number of lodgepole pine trees actually died during the 1987 to 2000 cycle.

Although a stand may be vulnerable to an attack, it is most difficult to predict when an outbreak might occur. During a simulation using 10–year cycles, mountain pine beetle might have an outbreak in highly vulnerable stands sometime within a 20–year period. Which cycle the outbreak will occur can only be simulated, not predicted. Although the length of reoccurrence is different for different change agents, the problem of predicting when an outbreak will occur applies to all change agents.

In Engelmann spruce, the actual data show that the basal area in this species declined only slightly and increased in percentage composition from 17 percent in 1987 to 19 percent in 2000. Although spruce is present in the majority of stands, no individual stand contained enough contiguous spruce to trigger an epidemic event by spruce beetle. The minor difference in basal area is caused by western spruce budworm.

Overall, grand fir had the largest difference of 24 percent between the no-pest simulation and the actual data by 2000. Of this, only 11 percent is modeled as fir engraver beetle. A fixed mortality function based on risk ratings from Schmid and Frye (1976) has been used to compute vulnerability and outbreak mortality. The remaining mortality can be attributed to other change agents and environmental factors not modeled.

There is minimal impact from western pine beetle as ponderosa pine is a minor component in the stands. Western larch is also a minor component, and although mistletoe is modeled for this species, not enough mistletoe was present to trigger an event. By year 2000, only 55 percent of the difference in basal area between no pest and actual has been explained by change agents. The remaining 45 percent represents mortality that cannot be explained or are impacts by change agents not simulated.

Conclusions

In a no-change agent simulation, the model overestimates indicators used in this analysis. In the actual data, certain tree species were disturbed by some kind of change agent that caused mortality and reduction in growth. Some of this is explained by the individual change agents modeled in the keyword set that processes the models and mortality functions in an independent and sequential procedure. In reality, change agents do not work independently and are in concert with many other change agents including weather, fire, and other insects and diseases (Weatherby and others 1997) not simulated in our analysis. This leaves some unexplained difference between the actual data and our change-agent simulation. Still, a multichange-agent approach offers the modeler a simulation closer to actual change than does a no-change agent approach.

There are several multichange agent methods available besides the multichange agent keyword set used in this analysis. The Western Root Disease Model (Frankel 1998) and the Westwide Pine Beetle Model (Smith 1999) are also available. Modelers are encouraged to work with insect and disease modeling specialists who can assist in using a multichange agent approach.

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