Determining Forest Fuel Treatment Levels for the Bitterroot Front using VDDT

Jim Merzenich[1], Werner Kurz[2], Sarah Beukema[2],
Mike Arbaugh[3], and Susan Schilling[3]

[1] Pacific Northwest Region, U.S.D.A. Forest Service, P.O. Box 3623, Portland, OR 97208, U.S.A.
[2] ESSA Technologies Ltd., #300-1765 West 8th Ave., Vancouver, B.C. V6J 5C6, Canada.
[3] Pacific Southwest Research Station, U.S.D.A. Forest Service, Canyon Crest Drive, Riverside, CA 92507, U.S.A.

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Abstract: The Vegetation Dynamics Development Tool (VDDT) simulates changes in vegetative composition and structure resulting from both management activities and natural disturbances. Vegetation is classified into discrete states and pathway diagrams portray progression between states. This paper describes the methods used to evaluate alternative forest fuel treatment strategies for the Bitterroot front region of western Montana using VDDT and discusses the general advantages and limitations of using this type of tool.

1. INTRODUCTION

Increasing forest stand density due to fire suppression has increased fuel loading and the associated risk of stand replacing wildfires throughout the western Unites States. Lower elevation sites in the Bitterroot drainage were historically dominated by open stands of ponderosa pine, Douglas-fir, and western larch maintained by frequent ground fires (Arno, 1996). Because of the combined effect of fire suppression and harvesting, these sites now mostly support overstocked mid-age stands highly susceptible to catastrophic wildfire and insect attacks.

Several tools are presently being examined to determine their use for predicting the effects of alternative levels of fuels treatments on forest composition and health, smoke emissions, and wildfire disturbance and intensity levels (Weise et al. 2000). This comparative study is funded through the Joint Fire Sciences Program (JFSP). Tools included in the study are being applied to eight locations, selected to represent the major forest and range fuel types contained on public lands. The Bitterroot front is one of these study areas. This paper describes the capabilities and limitations of using the Vegetation Dynamic Development Tool (VDDT) to evaluate the effects of alternative fuel treatment levels.

2. THE TOOL

The Vegetation Dynamics Development Tool (VDDT) examines the impact of landscape-scale disturbances while evaluating alternative management treatment levels (Beukema and Kurz 2000).

Combinations of cover type (dominant species) and structural stage define discrete states within each VDDT model. In the absence of disturbance, vegetation progresses from one state to the next in a time-dependent *successional pathway*. Natural or human caused disturbances also affect vegetation by altering the rate and possibly the direction of succession. For each state, the appropriate disturbances, their probability of occurrence and their expected impact are defined.

VDDT uses up to ten thousand pixels (grid cells) to simulate succession. Each pixel is assigned initially to a state and starting age. Based on the user-defined disturbance probabilities, VDDT calculates for each simulation year which pixels to disturb, using a random draw for each pixel. Disturbances typically cause a pixel to change vegetative state or to move forward or backward a set number of years within a state. VDDT applies disturbances to each pixel independently. VDDT models are thus non-spatial and are generally intended for large scale strategic planning

To allow sensitivity analysis, disturbances are categorised into groups that can then be enabled or disabled for each scenario. In addition, multipliers can be applied to selected disturbances to analyse the impact of varying disturbance probabilities. Line and bar graphs assist the interpretation of model results. VDDT also allows the user to make up to 300 simulations in a single run to obtain estimates of the range and variability of results that are affected by stochastic disturbances. Users can also vary disturbance probabilities from year to year to model infrequent episodic events and base the probability of one event on the time span since a previous event (Merzenich et al. 1999).

3. STUDY APPROACH

The study area contains approximately 400,000 acres on the west side of Montana's Bitterroot valley. Elevations range from about 3,500 to 10,000 feet. More than 50% of the area is within the Selway-Bitterroot wilderness and 67% of the area is forested.

Three VDDT models with separate pathway diagrams were developed based on habitat type and species grouping to analyse this area. The *WarmDry* model applies to lower elevation sites mostly available for timber management. These sites were historically maintained by frequent ground fires and primarily contain ponderosa pine and Douglas-fir. The *CoolMoist* model applies to mid elevation sites that contain a mixture of Douglas-fir, true firs, and western larch. The *ColdDry* model reflects higher elevation subalpine and alpine species contained primarily in the Selway-Bitterroot wilderness. Within each of these three models disturbance probabilities also vary by three management regions. These regions are 1) *private*, 2) *general-forest (public)*, and 3) *wilderness*.

Within each species grouping vegetation is classified into three size and two density classes. The size classes are *seedling/sapling*, *pole*, and *large*. The models also contain multi-story classes for the pole and large size classes. The density classes are *low* (< 50% canopy closure) and *high* (>50% canopy closure).

In these models density class was used as a proxy for fire risk. Pixels move from the low to the high-density (high-risk) states after periods ranging from 30 to 75 years, if no intervening disturbance or treatment occurs. The time span to move from a low to a high-risk state varies based on the model and species. VDDT tracks the time span since a *fuel reducing treatment or disturbance* (as defined by the user), and allows the user to vary future disturbance probabilities based on the values of this variable. Management treatments, in contrast, move vegetation from high to low-risk states.

The successional and disturbance pathways used in these models were derived from SIMPPLLE models developed for the Bitterroot Forest (Jones et al. 1999). The disturbances included in the model are stand-replacement (hereafter called lethal) wildfire, moderate wildfire, and low-intensity wildfire (underburn). The pathways for mountain pine beetle, spruce budworm, and root disease are contained in the VDDT models but no probabilities were assigned.

The historic (pre-European settlement) wildfire probabilities included in these VDDT models were derived from probabilities used in the ICBEMP (Interior Columbia Basin Ecosystem management plan) process (Long et al. 1998, Quigley and Arbelbide 1997). An exact match to the ICMEMP data could not be made since the vegetative classification systems differed. Table 1 shows the assumed historic fire regime for the ponderosa pine (PP); mixed ponderosa pine and Douglas-fir (PP/DF), and dry Douglas-fir (DD) species groups of the *WarmDry* model.

Table 1. Assumed Historic Fire Regime: *WarmDry* model.

Model/Species	Stand Replace.	Moderate Inten.	Low Inten.	All Fires
WarmDry (PP)				
Annual Prob.	.002	.008	.03	.040
Fire Interval (yr.)	500	125	33	25
Percent of Fires	5	20	75	100
WarmDry (DF)				
Annual Prob.	.004	.008	.028	.040
Fire Interval (yr.)	250	125	36	25
Percent of Fires	10	20	70	100

Data for 28 wildfires that occurred in the study area during the 20-year time period from 1975 to 1994 were used to estimate wildfire parameters reflective of current conditions. Data are incomplete for fires that occurred prior to 1975 or after 1994. These data demonstrate the episodic nature of wildfires on the Bitterroot. 58% of the total burned acreage was contained in just three large fires. 78% of the total occurred in 1988, the year of the Yellowstone fires. A total of 20% of the burned acreage occurred in 3 other years and only 2% occurred in the other 16 years (Table 2). Data are unavailable on wildfire severity.

Table 2. Summary of 20-year wildfire history for the Bitterroot Front.

Number of Years	Burn Acres	Burn %	Relative Area Burned/yr.
1	23,152	78.3%	663
3	5,838	19.8%	56
16	562	1.9%	1

To portray the episodic nature of wildfires using VDDT, years are classified into three types (up to five types could be used) and the relative probability of experiencing each type of year is given as input. The tool generates random sequences of fire years, based on these probabilities and these *Year Sequence Group* (YSG) data are written to files that are subsequently read by VDDT with each simulation. Users can also modify these files to model any sequence of year groups that they desire to test. Using the 20-year historic fire data, the distribution of fire years for this analysis was assumed to be *Normal* (80%), *High* (15%), and *Severe* (5%).

In each type of year relative multipliers are applied to each affected disturbance type. Probabilities are then adjusted such that averages calculated over all types of years remain the same. This (optional) normalisation process insures that these adjusted probabilities will only affect the temporal distribution of disturbances, not the absolute amount. The 20 years of data show that for every acre burned in a normal year, 56 acres burned in a high year, and 663 acres burned in a severe year. Since the total fire acreage was most likely underreported in the normal years (for example no acreage is reported as being burned from 1976 to 1982), the following VDDT relative multipliers were applied to normal, high, and severe years, respectively: *Lethal fires*: 1: 25: 250; *Moderate-Intensity fires*: 1: 10: 50; and *Low-Intensity fires*: 1: 5: 25.

On the National Forest 0.41% of the landscape burned per year for the 20-year period from 1975 to 1994 and 0.76% burned per year for the 10-year period from 1985 to 1994. During the same 10-year period only 0.04% of the private forested acreage burned per year. Based on this preliminary analysis we assumed that with fire suppression 1% of the National Forest and 0.5% of the forested private land would be expected to burn in a wildfire per year. The 1% rate for National Forest lands is somewhat larger than would be indicated by the 20-year historic data but consistent with trends. The forested private acreage in the study area is only 54,000 acres and we did not feel that the low historic burn rate was indicative of current risks.

Probabilities for each wildfire type were adjusted to reflect differences due to stand structure and density. In low density stands the mix of lethal, moderate, and low-intensity wildfire was assumed to be the same as under historic (pre-European settlement) conditions. The proportion of lethal fires was increased in the high density and multi-story stands. Table 3 shows how probabilities were varied by density class in the *WarmDry* model.

Table 3. Existing fire probabilities (percent); WarmDry (Ponderosa pine) model.

Size	Density	% Prob. Stand Replacement	% Prob. Moderate	% Prob. Low Intensity	% Prob All Fires
Seed/Sap.	All	1.000	.000	.000	1.00
Pole	Low	.050	.200	.750	1.00
Large	Low	.050	.200	.750	1.00
Lg. Multi.	Low	.340	.330	.330	1.00
Pole	High	.750	.125	.125	1.00
Large	High	.340	.330	.330	1.00
Lg. Multi.	High	.750	.125	.125	1.00

4. SCENARIOS

As participants in the JFSP comparative study we were asked to analyse *no treatment*, *prescribed fire*, and *final harvest only* scenarios over 50 years (Weise et al. 2000). The prescribed fire scenario assumed that pole and larger stands in the ponderosa pine, Douglas-fir, western larch, and lodgepine cover types would be burned at rates varying from 2 to 5% per year. The harvest scenario assumed that poles and larger stands outside of existing wilderness would be harvested at rates of 2% per year. These scenarios were established to make comparisons of the tools included in the JFSP study and do not represent realistic fuel treatment strategies.

To reduce the number of computer runs all of the succession classes (states) of the three original models were combined into a single large VDDT model that also contained separate states to represent each region. The resulting model contains 282, out of an allowable 480, states. This reduced the number of necessary runs by a factor of 9 without losing data detail. By including probabilities for all prescribed burning and harvest treatments, and disabling selected treatments, all scenarios could be analysed with a single model.

VDDT can perform up to 300 simulations in one run and calculate statistical summaries. We defined the model with 10,000 pixels and did 50 simulations per scenario (unless otherwise stated). Separate runs were made using average probability data only and using the fire-year data that vary probabilities from year to year.

In the first set of scenarios, prescribed fires were assumed to reduce wildfire severity but not the area burned by wildfire. A sensitivity analysis explored the impact of changes to assumptions. All wildfire probabilities in areas treated with prescribed fires were reduced. The response to several levels of prescribed burning was also analysed.

5. RESULTS

Figure 1 shows the projected total acreage burned in lethal wildfires under the three scenarios. Note that both the *no treatment* and the *final harvest only* scenarios show an increase in lethal wildfires over time, while the *prescribed fire* scenario maintains the acreage burned near current levels. The change in area burned by lethal wildfires is a result of changes in the vegetation composition of the landscape.

In general, lethal wildfire probabilities were estimated to be higher in younger age stands than in older stands. Since the *final harvest only* scenario converts sites to younger age stands without any associated fuel treatments, this scenario increased rather than decreased the average level of lethal wildfire. No further analysis of this scenario was made.

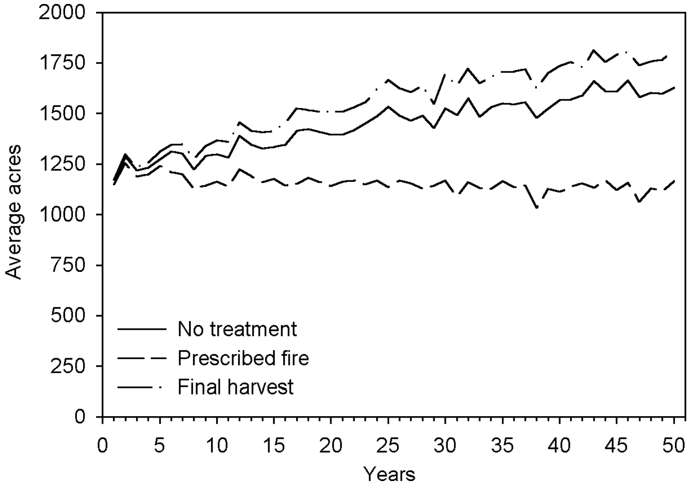

Figure 1. Average lethal wildfire acres for 3 scenarios.

The largest immediate benefit from prescribed burning and other fuel treatments can be achieved on lower elevation sites represented by the *WarmDry* VDDT model. The non-wilderness National Forest portion of the *WarmDry* model contains approximately 64,000 acres or 23% of the forested total. This area is conducive to active management and together with the adjoining private land comprises most of the wildland-urban interface on which excessive fuel buildup is a significant social risk. The remainder of this analysis focuses on this non-wilderness National Forest acreage.

The decline in lethal wildfire acres depicted in Fig. 1 is a result of reducing the average wildfire intensity through prescribed burning. No reduction in total wildfire acres was assumed in the initial analysis. Any reduction in lethal fires was thus offset by an increase in moderate or low-intensity wildfires. In at least the long term, fuel treatments coupled with suppression should reduce the total acres burned by wildfire.

To analyse this question, two additional scenarios were prepared using the multipliers feature of VDDT on all lethal, moderate, and low-intensity wildfire probabilities. For one scenario, these probabilities were multiplied by 0.5 (50% reduction) on low-risk (low-density) areas, and for the second scenario they were multiplied by zero (100% reduction) in low-risk areas. Fig. 2 shows the potential influence of this reduction in wildfire risk after prescribed burning on lethal burn acres. Note that prescribed burning is not applied until stands are 60 or more years of age and these younger stands are often in the high-risk category. This accounts for a base level of lethal wildfires in all scenarios. Also note that the acres burned in year 1 varies substantially with each run. Initially 60% of the acres in the *WarmDry* model are in the low-risk class. Changes in the assumptions on the burn rates in the low-risk class thus have an immediate effect on the solution.

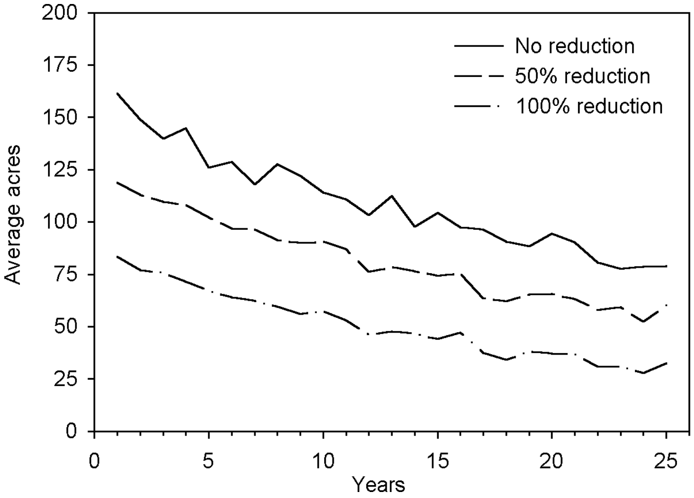

Figure 2. Lethal wildfire projections based on 3 assumptions of prescribe fire effectiveness.

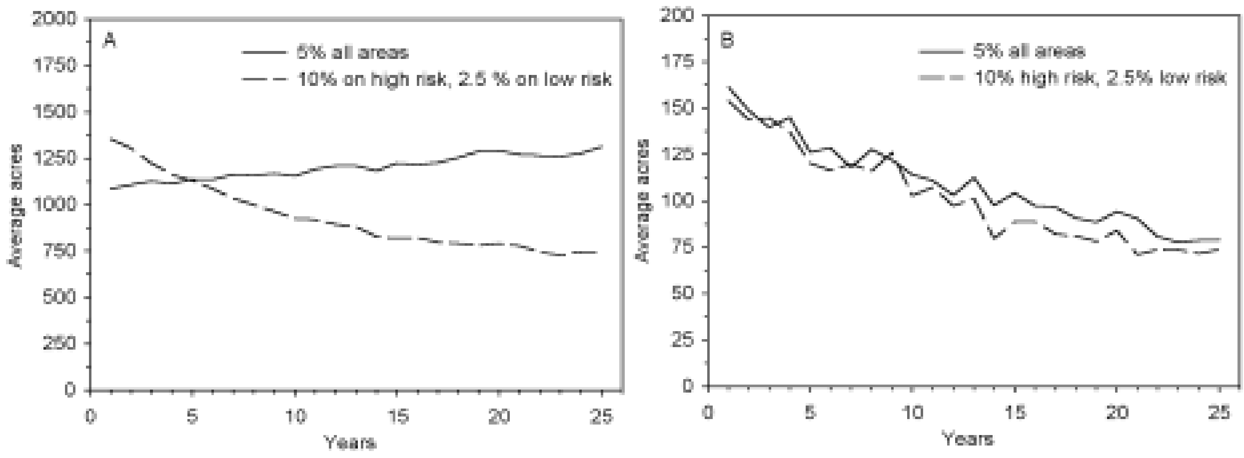

Figure 3. A: Prescribed burn acres under two options.
B: Lethal wildfire acres under two options.

Additional scenarios demonstrate the effect of varying the level of fuel treatments over time. In the original prescribed fire scenario for the *WarmDry* model, 5% of the pole and larger stands were treated per year. This rate was applied to all pixels regardless of their current risk level. A more realistic strategy would be to selectively treat the high-risk pixels or to treat these pixels at a higher rate. Figures 3a and b show the prescribed fire and lethal burn acres under two options. The first scenario applied the 5% treatment rate to all pixels regardless of existing condition. The second scenario treats high-risk pixels at double the rate (10%) and low-risk pixels at half the rate (2.5%). Although the second scenario treats substantially fewer acres, it results in a greater reduction in lethal wildfire acres.

Because the acres in the high and low-risk state change with time, it is impossible to set a rate that both treats the high-risk pixels first and also results in a predictable level of treatments over time. To correct this we are adding an option in VDDT that will allow the user to place upper and lower limits on the amount of each treatment allowed per year. The tool will then adjust the relevant probabilities in each year to stay within the bounds. By applying treatment probabilities preferentially to the high-risk pixels and using this option, alternative treatment levels can be more efficiently assigned and evaluated.

The greatest proportionate reduction in lethal fires is projected in the ponderosa pine and mixed ponderosa pine Douglas-fir species types contained in the *WarmDry* model. The following figures describe the difficulty of addressing just this single management issue.

Fig. 4A shows the projected lethal fire acreage based on one simulation with no between-year fire variability and 10,000 pixels used to represent the problem. Note that the wildfire acreage appears to trend downward from about 350 to 200 acres per year over the 50-year time frame. Fig. 4B is based on the same assumptions and 300 model simulations. This figure shows the mean expected burned acreage plus or minus one standard deviation. The apparent decline in burned acreage is less dramatic than in Fig. 4A.

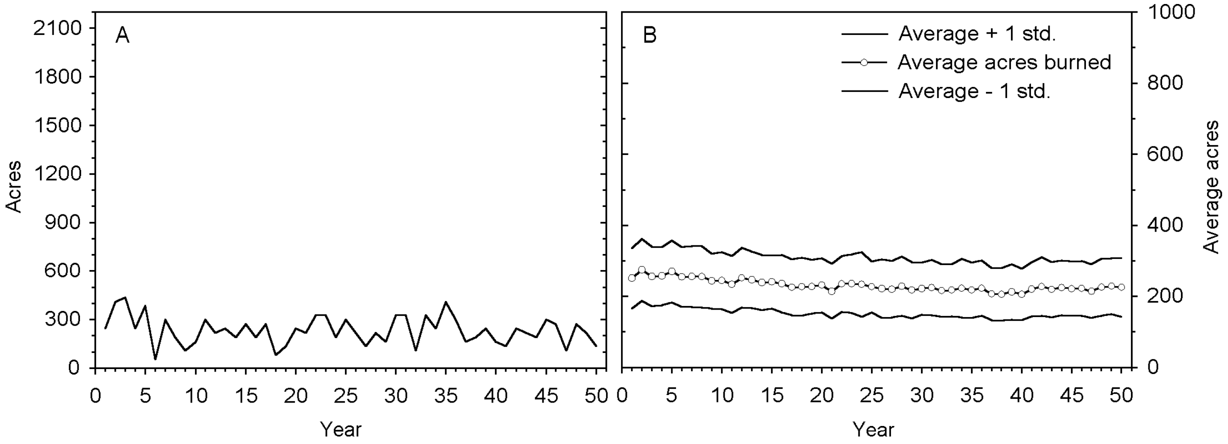

Figure 4. A: Average acres burned in lethal fire based on one simulation and no between-year variability.
B: Average and standard deviation of acres burned in lethal fire based on 300 simulations and no between-year variability.

In reality wildfires are episodic and this should be considered in any analysis. Fig. 5A shows the acreage burned per year based on one simulation taking into account variable fire years. Fig. 5B shows the statistical summary of 300 simulations with between-year fire variability. The average area burned in Fig. 5B is similar to that in Fig. 4B. The standard deviations of the predictions increase from around 100 to 500–800 acres per year when the episodic nature of fire is accounted for in the model.

Any single simulation will not give an accurate portrayal of the effects of fuel treatments on a given disturbance. For example, the simulation portrayed by Fig. 4A, overestimates the average expected reduction in burn acres as shown in Fig. 4B. While the projections of Fig. 5A may be more realistic, the extreme fluctuation in wildfire acreage makes it nearly impossible to visualise any trends. The high standard deviations associated with Fig. 5B demonstrate the high uncertainty of realising any benefits from fuel treatments over 50 years within this relatively small geographic area.

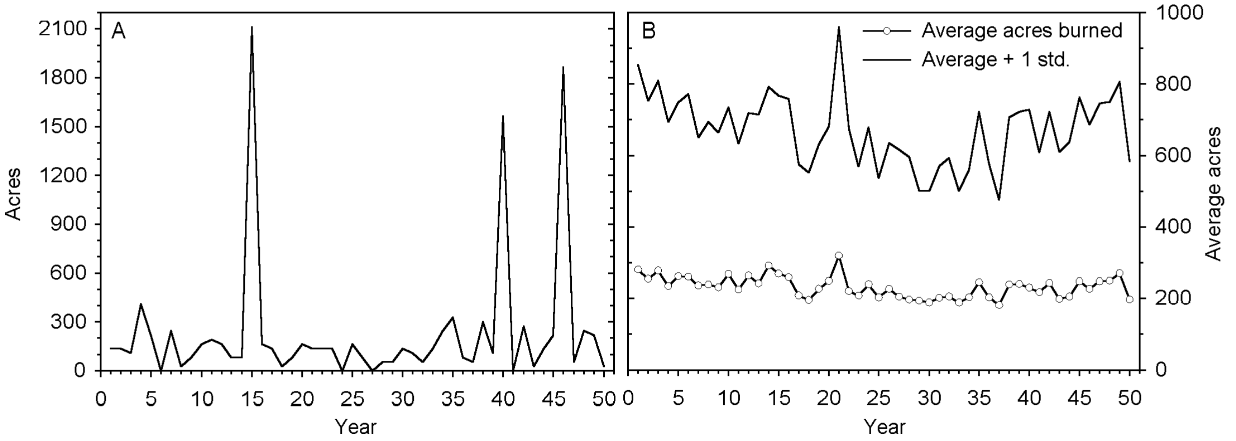

Figure 5. A: Average acres burned in lethal fire based on one simulation, between-year variability included.
B: Average and standard deviation of acres burned in lethal fire based on 300 simulations, between-year variability included.

6. DISCUSSION

VDDT projections are most reliable when applied over large geographic areas and long time frames. The distribution of vegetation across the landscape and its relationship to terrain and natural fuel breaks also have a significant influence on the expected acreages burned and the presumed benefits of fuel treatments. Care must be taken to insure that the disturbance probabilities included in VDDT consider these factors.

Extreme topographic relief makes the Bitterroot front less prone to catastrophic fire than other portions of the Bitterroot forest. The study area mostly consists of west to east trending glaciated valleys separated by high elevation barren areas. The relative discontinuity of fuels accounts for the relative low acreage that burned during the period 1975 to 1994, and the small size of the largest wildfire (6,000 acres). In the extreme summer of 2000, only 10,000 acres burned in the study area while several hundred thousand acres burned in nearby areas of the forest with gentler terrain and more contiguous fuels.

The landscape scale fuel problems and relative continuity of fuels that exist now have never existed in the past. With continued fire suppression and little fuels management, fuel levels and associated wildfire risks have continually risen. Is the fire history for the past 10 or 20-year period a good indicator of existing risks? What is the appropriate geographic area on which to base disturbance probabilities? It is our opinion that a combination of empirical fire data and professional judgement is necessary to derive reasonable fire probability estimates for these types of models. Other more empirically based tools such, as the Fire Effects Tradeoff Model (FETM) (Schaaf et al. 1999) may be useful for estimating disturbance probabilities. Stand growth and projection models such as the Forest Vegetation Simulator (FVS) can be used to temporally portray successional pathways (Wykoff et al. 1982).

Using the model Farsite, Finney (2000) has estimated that significant reductions in wildfire spread rates and resultant wildfire sizes can be achieved by strategically creating overlapping fuel breaks in a block pattern. In areas with large patches of contiguous high-risk fuels, treatments will initially have little effect on reducing the total acreage burned. Once a critical mass of fuel treatment areas is established and maintained, however, there should be a significant reduction in total acres burned by wildfire.

The *Landscape Condition Feedback* option of VDDT allows the user to apply disturbance multipliers based on the average condition of the landscape. Once a certain percentage of the landscape became treated for fuels, wildfire disturbance probabilities could be scaled down to simulate the effect described by Finney.

Because of time and budgetary constraints the modelling assumptions developed here were not developed collaboratively with resource specialists on the Bitterroot Forest or elsewhere. This initial analysis was intended to show the capabilities of the tool only.

The next logical step is to review these models with the Forest staff and to modify the assumptions as appropriate. For example, both the treatment and wildfire assumptions should vary greatly between wilderness and non-wilderness areas. Realistic fuel treatment options must be developed for all areas and more accurate estimates of current fuel loadings, as compared to historic conditions, must be developed. Probabilities for key insect and disease and other weather-related disturbances must also be estimated and integrated into the models.

The main advantage of VDDT is that models can be easily built from scratch by non-expert modellers. Because of this emphasis, the model is not intended for those desiring to model detailed fine scale ecological, disturbance, or fire behaviour dynamics. The user must supply all the successional pathways, disturbance probabilities, and modelling relationships contained in VDDT. Thus the model and model results are dependent on correctly estimating successional and disturbance relationships, and disturbance and weather probabilities.

VDDT is a non-spatial model, intended largely for broad scale analysis. Depending on the scale of analysis and questions being asked, a spatially explicit model may be required to produce meaningful results. The Tool for Exploratory Spatial Analyses (TELSA) was developed to address these spatial concerns (Kurz et al. 2000). TELSA uses VDDT model data plus spatial map data as input and simulates analyses of alternative management scenarios.

The VDDT software, manual, and tutorial exercises can be obtained from either the internet site http://www.essa.com/forestry/vddt/ or the USFS intranet site http://fsweb.r6.fs.fed.us/sp/analysis/.

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