PROJECTING LANDSCAPE CONDITIONS IN SOUTHERN UTAH BY USING VDDT

James Merzenich[1] and Leonardo Frid[2]

ABSTRACT

The Vegetation Dynamics Development Tool (VDDT) is a state-transition modeling system that integrates the effects of succession and natural disturbances such as wildfire with management treatments. VDDT is used to evaluate the response of non-spatial indicators to management actions. This study used VDDT to project changes in vegetation in response to different management scenarios for a mixed forest and range watershed in southwest Utah. The vegetative composition of this landscape has been significantly altered because of the effects of fire suppression and grazing. Pinyon-juniper acreage has increased from historic levels while aspen, sage, and oak habitats have declined. Key environmental factors projected by VDDT include the percent of area dominated by open shrubs, pinyon-juniper, and aspen, and the percent of dry-site conifer acres at high risk of uncharacteristically severe wildfire. The analysis shows that an aggressive vegetation treatment schedule is needed to reverse current trends and restore ecological conditions and processes in this area.

KEYWORDS: Landscape modeling, natural disturbance, simulation, forest dynamics, vegetative succession.

INTRODUCTION

The Vegetation Dynamic Development Tool (VDDT) is a simulation model used to project landscape-scale vegetative conditions over long time frames (Beukema and others 2003; Merzenich and others 1999). VDDT models the effects of alternative levels of management treatments on vegetation as influenced by stochastic disturbances such as wildfire.

Discrete states are defined in VDDT on the basis of a vegetative cover type and structure class. In each model run VDDT uses up to fifty thousand simulation units to project change. Simulation units are initially assigned to states based on the proportion of area contained in those states. These simulation units then progress along time-dependent successional pathways or change states in response to probabilistically applied disturbances or management treatments. VDDT projects the proportion of units (or area) contained in each state and the levels of disturbances that may be expected.

The U.S. Forest Service, Pacific Southwest Station, is conducting a study comparing landscape-scale fuel treatment models at seven major locations in the United States (Weise and others 2001). Two reports describing the use of VDDT in conjunction with this study are available. In a retrospective analysis, VDDT models were used to predict stand replacement fires between 1937 and 1996 in Yosemite national park (Arbaugh and others, 2001). In the Bitterroot front of western Montana VDDT was used to estimate the level of fuel treatments needed to restore ecological conditions and reduce the risk of uncharacteristic stand-replacement wildfires (Merzenich and others, 2001). This paper presents the results of applying VDDT to the Beaver River drainage, an area of mixed range and forest, in southwest Utah.

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[1] James Merzenich is an analyst, U.S. Forest Service, Pacific Northwest Region, P.O. Box 3623, Portland, OR 97208. [2] Leonardo Frid is a systems ecologist, ESSA Technologies Ltd., #300-1765 West 8th Ave., Vancouver, B.C. V6J 5C6.

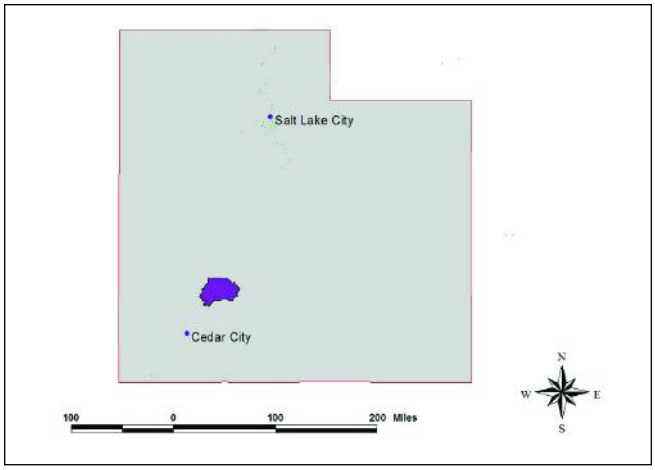

Figure 1—Map of Utah. Shaded area represents Beaver River drainage.

The study area contains 350,000 acres (142,000 ha.) located primarily on the Fishlake National Forest and adjoining Bureau of Land Management land (fig. 1). Elevations vary from approximately five to twelve thousand feet (1500 to 3700 meters). The study area contains acreage associated with nineteen of twenty-four VDDT models developed for potential vegetation types in southern Utah (Long and Merzenich, 2004). The major vegetation types represented by these models are Wyoming big sage (*Artemesia tridentata var. wyomingensis*), mountain big sage (*Artemesia tri-dentata var. vaseyana*), Gambel oak (*Quercus gambelii*), ponderosa pine (*Pinus ponderosa*), montane fir (mix of *Pseudotsuga menziesii* and *Abies concolor*), and Spruce/fir/aspen (*Picea engelmannii*, *Abies lasiocarpa*, and *Populus tremuloides*).

A combination of wildfire suppression and livestock grazing has significantly altered the vegetative composition of the study area over the past 150 to 200 years (Campbell and others, 2003). At lower elevations, a mosaic of grass and shrublands has been replaced by vast areas of dense shrubs and non-native annuals such as cheat grass and red brome (*Bromus tectorum; Bromus rubra*). On more mesic sites pinyon pine (*Pinus edulis*) and juniper (*Juniperus* spp.) are replacing sage and perennial grasses. Mid-elevation mixed pine and fir forests, once maintained by frequent ground fires, now have unnaturally high levels of easily combustible fuel and are at high risk of catastrophic wildfire (Bradley and others 1992). Quaking aspen stands, dependent upon fire disturbance for regeneration and detrimentally affected by livestock browsing, are being replaced by shade tolerant spruce and subalpine fir (Bartos and Campbell, 1998).

The objectives of this study were to track the response of key indicators, such as aspen, ponderosa pine and piny-on-juniper acres, to management scenarios that represent: 1) no management; 2) management at levels commensurate with current funding; and 3) management at a higher level believed necessary to restore ecological conditions.

METHODS

Historically fires were common within most vegetative types in the Beaver River drainage with estimated fire frequencies ranging from every 5-25 years for ponderosa pine stands to 50-80 years for spruce/subalpine fir stands (Campbell and others, 2003).

Data on the acreage burned by individual wildfires for the modern period are available for this drainage for the years 1970 to 2002. Because of active fire suppression and the reduction of fine fuels due to grazing, there has been a decrease in the acres burned during this modern period, as compared to historic. The average area burned per year in wildfires was about two hundred acres for the period 1970 to 1991 and two thousand acres for the period 1992 to 2002. The burn data for this latter period (1992-2002) are believed to be more reflective of current fuel and climatic conditions and were used to estimate annual wildfire probabilities for VDDT. Based on these data, the average fire return interval is now 175 years with 0.57 percent of the area burned per year.

The wildfire acreage burned per year varies based on ignitions, climatic conditions, and resources available to suppress fires. Options available in VDDT to vary wildfire disturbance probabilities temporally, by type of fire year, were not used in this analysis.

Most wildfires in the last decade have occurred in the grass/shrub and woodland classes. In this analysis average fire return intervals are estimated to be 150 years (0.0067 annual probability) for grass/shrub and woodland, 200 years for dry forest, and 300 years for high elevation spruce/fir and aspen areas. These fire return intervals and annual probabilities correspond to an expected acreage burned per year for the entire study area of about 2,000 acres. This is consistent with the burn data for the period 1992 to 2002.

Wildfire probabilities also vary according to the succession class. For example, on areas dominated by annual grasses or high-risk conifer stands wildfire probabilities are increased, while on low-risk stands they are decreased. For each vegetative class both stand-replacement and low intensity (underburns and mixed severity) fires are modeled.

Table 1—Wildfire frequencies and treatment levels for Full_mgt scenario (Campbell and others, 2003)

Vegetation type	Fire freq. (historic)	Fire freq. (current)	Treatment	Trt freq Ann rate	Targeted classes
Wyo. Sage	40-60	150	Mech/Pres burn	50 (2%)	All stands with pj or closed shrub
Mtn. Sage	20-40	150	Mech/Pres burn	30 (3.3%)	All stands with pj or closed shrub
Oak woodland	20-50	150	Pres burn	50 (2%)	All but seedlings
Dry forest	5-25	200	Pres burn	30 (3.3%)	Pole and larger open
			Thin/burn	50 (2%)	Mature dense
Sprucefir/aspen	50-80	300	Pres burn	50 (2%)	All mature/old
			Regen harv	100 (1%)	Mature sprucefir/aspen

Three scenarios were developed to estimate the effect of alternative levels of management treatments over a 50-year time frame. This time frame was chosen to make this analysis consistent with other analyses comparing landscape-scale fuel treatment models (Weise and others 2001). The VDDT models for this area are actually designed to allow projections for 300 or more years.

The following assumptions apply to all scenarios: active wildfire suppression will continue; regeneration harvest is used to promote aspen; partial harvests are used to reduce fuels and promote early seral species; and livestock grazing will continue at current levels. The three scenarios are described as follows.

1) **No_mgt:** No management except fire suppression and grazing
2) **Full_mgt:** Management at a level designed to restore and maintain ecological function as quickly as practicable.
3) **Current_mgt:** Management at a level commensurate with current funding. The treatment level is assumed to be one-third that of the full-management scenario.

An explanation of the full-management scenario (scenario 2) as it applies to the major vegetation types follows. Table 1 shows projected treatment levels associated with this scenario along with the estimated historic and current fire return intervals.

Grass and Shrublands: Approximately 42 percent of the study area was historically dominated by perennial grass and sagebrush. Two major management issues in these vegetation types are the proportion of acres in which pinyon-juniper is dominant and the amount of open versus closed shrub. Pinyon pine and juniper develop slowly and are susceptible to mortality by wildfire. Historically pinyon-juniper stands were mostly confined to rocky outcrops or other areas that frequently escaped wildfire (Bradley and others 1992). The area dominated by pinyon-juniper is presently at least three times higher than the historic level (O'Brien 1999). Pinyon-juniper stands reduce water yield and streamflow through evapo-transpiration, and retard the growth of grasses, forbs and shrubs. Pinyon-juniper stands are often fire resistant due to the lack of fine fuels in the understory.

Most sage stands are presently closed canopied. Natural sagebrush areas maintained by fire would have nearly equal acreage in perennial grass, open shrub, and closed shrub.

Few large wildfires presently occur in this landscape. An average fire return interval of 150 years was applied to areas dominated by perennial grass, shrubs and pinyon-juniper. On areas dominated by annual grasses (e.g. red brome or cheatgrass) the assumed fire return interval is 50 to 75 years. If large areas of contiguous annual grasses were to develop wildfire probabilities could dramatically increase. In cheatgrass dominated landscapes in southern Idaho average fire-return intervals are now less than 10 years (Paysen and others, 2000).

The primary prescription is to apply mechanical treatment (Dixie harrow, brush choppers, cut and burn) and prescribed fire to closed shrub classes and classes containing pinyon-juniper at a ratio of 75 percent mechanical treatment to 25 percent prescribed fire. This is done at a 50-year return interval for Wyoming sage and a 30-year interval for mountain sage areas. These treatments include seeding annual grass areas to perennial grass where appropriate with an assumed success rate of 50 percent. The purpose of these treatments is to remove pinyon-juniper and to lower the density of sage. The closed shrub and pinyon-juniper classes younger than 200 or 250 years are the target areas to be treated. Some non-target areas are burned with prescribed fire, however. When applying prescribed fire we assumed that perennial grass, annual grass, and open shrub areas

will be burned at a ratio that is approximately one-third that of the other classes. Thus, if targeted states were burned at a rate of 3 percent per year, these non-target states would be burned at a rate of 1 percent per year.

Woodlands: Oak and associated woodlands comprise about 29 percent of the Beaver River landscape. Historically fires occurred in these areas every 20 to 50 years (Campbell and others, 2003). Pinyon-juniper now dominates a majority of this acreage. The major issue is controlling the amount of pinyon-juniper and maintaining young oak stands commensurate with the historic fire return interval. The assumed current fire return interval for these areas is 150 years. The primary treatment is to prescribe burn these areas at a rate of 2 percent per year.

Dry Forest: Approximately 10 percent of the study area is comprised of dry forest comprised mostly of ponderosa pine, Douglas fir, and white fir. These stands often have an aspen associate. The historic fire return interval is 5 to 25 years (Campbell and others, 2003). Wildfires in dry forests are now uncharacteristically severe and most areas that were dominated by ponderosa pine and aspen are now overstocked with white fir and Douglas fir. Major issues are the decline of aspen and ponderosa pine. Fuel treatments are needed to restore the natural role of fire. The assumed current fire return interval for these areas is 200 years. The primary treatment is to apply a salvage treatment (partial harvest and burn) to the mature and old high-risk classes at a rate of 2 percent of these areas per year. This treatment should transform these stands to the low-risk class. Immature, mature, and old low-risk stands are then prescribed burned every 30 years to maintain them in an open-canopied low-risk state.

High Elevation SpruceFir/Aspen forests: Approximately 12 percent of the study area is comprised of higher elevation forests. Dominant cover types are subalpine fir, Engelmann spruce and aspen. Historically fires occurred in these areas every 50 to 80 years, maintaining about 80 percent of the area in aspen (Campbell and others, 2003). Presently most acres are dominated by spruce and fir. The major management issue is the decline in the acreage and vigor of aspen. The primary treatments are to prescribe burn the mature aspen and spruce/fir stands capable of supporting aspen at a rate of 2 percent per year and to apply regeneration harvest to mature spruce/fir stands still containing an aspen component at a rate of 1 percent per year. These treatments restore aspen and reduce the amount of overage spruce/fir. In southwest Utah all aspen reproduction is by vegetative sprouting usually triggered by disturbance (Bartos and Campbell 1998).

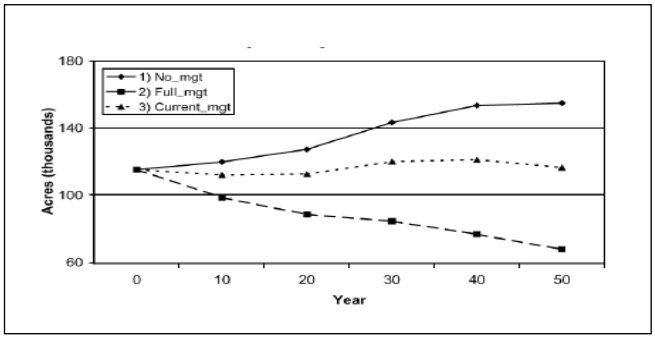

Figure 2—Scenario comparison: Pinyon-Juniper dominant acres

RESULTS

Four key environmental variables are used to compare the results of each scenario over the next 50 years.

1) **Acres dominated by pinyon–juniper** within both the grass/shrub and woodland models. Pinyon-juniper acreage has increased at least three fold from historic levels. The treatment objective is to reduce this acreage.
2) **The acres of open versus closed shrub** in grass/shrub areas. A relatively even proportion of open and closed shrub provides near optimal sage grouse habitat and is more reflective of historic conditions. Presently nearly 90 percent of sage stands are closed.
3) **Acres dominated by aspen** in forested areas. The intent of the treatments is to increase the aspen acreage at the expense of montane fir and spruce/fir.
4) **Acres of low-risk stands** in dry forest areas. These are the poletimber and larger stands historically maintained by frequent surface fires. Most dry forest stands are presently at high-risk for a stand replacement wildfire due to missed fire cycles and the associated fuel buildup.

Figure 2 shows the projected acreages dominated by pinyon-juniper for the three scenarios. In the full-management scenario pinyon-juniper dominated acres decrease 41 percent from 115 to 68 thousand acres over the next 50 years. With no treatment this acreage would increase 35 percent to 155 thousand acres over this same period. At current treatment levels pinyon-juniper acres are relatively constant.

The ratio of open to closed shrub area is graphed in figure 3. This ratio increases substantially with the full-management scenario and slightly when no treatments are applied. Changes in the no-treatment option are in response to projected wildfire acreage. If wildfires continue at the

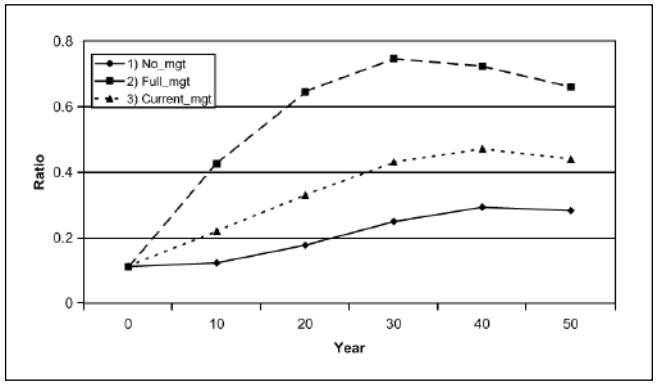

Figure 3—Scenario comparison: Ratio of open/closed shrub

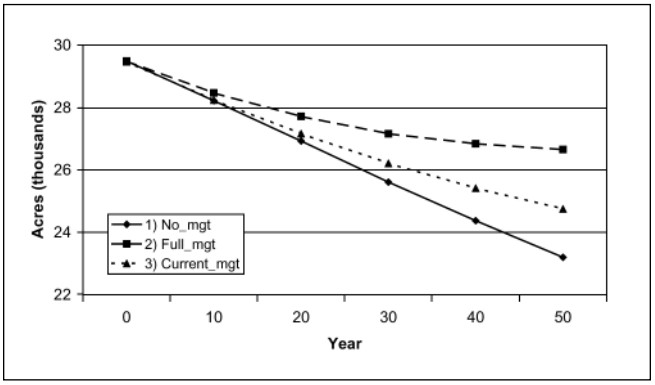

Figure 5—Scenario comparison: Acres with aspen present

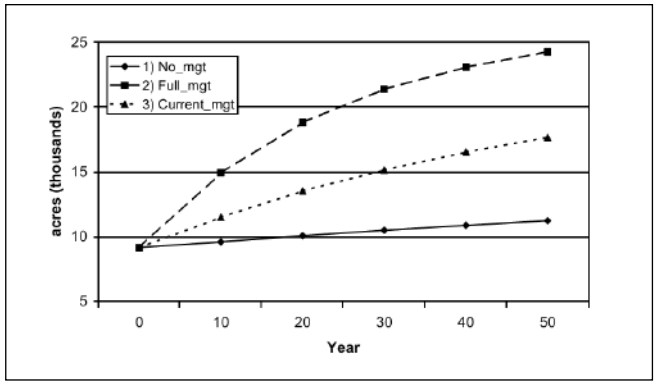

Figure 4—Scenario comparison: Dominant aspen acres

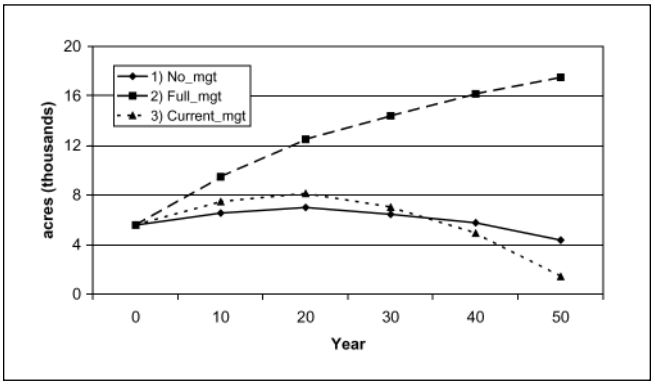

Figure 6—Scenario comparison: Dry Forest, low risk acres

rate of the past 10 years, there may be an increase in open shrub areas, regardless of whether management treatments are applied.

Acres dominated by aspen over the 50-year period are graphed in figure 4. Dominant aspen acreage increases from 9 to 24 thousand acres with full management and from 9 to 17 thousand acres at current treatment levels.

The increase in dominant aspen acreage associated with the no-treatment scenario (from 9 to 11 thousand acres) results from projecting the wildfire rates from the past decade for the next 50 years. Presently there are approximately 17 thousand acres of spruce/fir forests that contain aspen. Aspen is presently dominant on only 3 percent of this area (500 acres). Since wildfires in sprucefir/aspen stands normally result in an aspen dominated stand, the acres of dominant aspen acreage increases over the next 50 years even at a burn rate of 0.33 percent per year. Prior to European settlement, aspen was dominant on about 35 thousand acres in the Beaver River drainage (Campbell and others, 2003).

Aspen reproduces primarily by suckering from the parent root system. This suckering is normally in response to a disturbance such as wildfire. When aspen are lost from the landscape they will not reseed an area, as do conifers (Bartos and Campbell 1998). Overtopping by conifers, and reduced vigor caused by grazing, is gradually causing aspen to die out of many stands. Figure 5 shows the projected acreage in which aspen is present, but not necessarily dominant. Because all at-risk stands containing aspen cannot be immediately treated, the acres containing aspen declines with all three scenarios.

Figure 6 compares the projected acres of dry forest that are at a low risk for uncharacteristic stand-replacing fires. These are the open ponderosa pine and mixed ponderosa pine and Douglas fir stands. The acreage of low-risk stands steadily increases with the full-management scenario but ultimately decreases with the no-treatment and current-management scenarios.

Management treatments in this study area are generally designed to restore ecological conditions and reduce the

intensity of wildfire. In range areas within the Beaver River drainage these treatments result in a slight increase in potential wildfires. This is due to the increased acreage of annual and perennial grasslands, which are more prone to fire. In forested areas management results in a small decline in potential wildfire acres. The net result of these two factors is that the total wildfire acreage is projected to be nearly the same for the three scenarios.

DISCUSSION

VDDT is a non-spatial model intended mainly for broad scale analysis. VDDT projects changes in vegetative conditions in response to succession, disturbances, and management treatments. In the Beaver River drainage key indicators are used to estimate environmental conditions under different management scenarios, as projected by VDDT.

Major shifts in vegetative composition have occurred as a result of fire suppression and grazing. Historically fires burned vegetative types within the Beaver River area at frequencies ranging from every 5 to 80 years. In the past decade only 0.57 percent of this area burned per year for an average fire frequency of 175 years. In the previous two decades (1973 – 1992) virtually no acres burned. Current conditions in this drainage are reflective of conditions on the Fishlake National Forest as a whole. On the Fishlake National Forest spruce and fir acreage are estimated to have increased 238 percent from historic levels, while aspen has declined 259 percent. Pinyon-juniper acreage is believed to have increased 357 percent, while sage/grass/forb acreage has declined 295 percent (Campbell and others, 2003). These changes result in reduced streamflows caused by increased coverage of conifers including pinyon-juniper, reduced habitat for sage and aspen dependent wildlife species, and increased risk of uncharacteristically severe wildfires in dry forest areas.

This analysis suggests that if management treatments are maintained at current levels, vegetative conditions will most likely stabilize or decline further over the next fifty years. Active management, with treatment levels designed to mimic natural processes, would be necessary to restore this area and reverse current environmental trends.

The VDDT software, manual, and tutorial exercises can be downloaded from the website http://www.essa.com.

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