

# Applying TELSA to Assess Alternative Management Scenarios<sup>1</sup>

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**ABSTRACT:** The Tool for Exploratory Landscape Scenario Analyses (TELSA) is a spatially explicit simulation model that represents the interactions of succession, natural disturbances and management in forested landscapes. Vegetation dynamics are defined using successional pathway diagrams created with the Vegetation Dynamics Development Tool (VDDT). TELSA was applied here to demonstrate a simple example of management scenarios designed to emulate historic natural disturbance regimes in a 45,000 ha landscape. The results demonstrate the need to account for both management and natural disturbance impacts, and to assess future landscape characteristics in terms of spatial and non-spatial indicators.

## 1. INTRODUCTION

As more of the forests of North America are affected directly or indirectly by human activity, forest managers are increasingly expected to manage the forests for a variety of objectives. These objectives can include a

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combination of timber production and non-timber values such as wildlife habitat (e.g., BC Ministry of Forests 1995). Most managers have knowledge or models to predict how the forest is expected to change over time (e.g., volume over age curves), and how it will respond to various management activities. In most cases, however, natural disturbances such as fire or insects, operate in the managed areas and tools are required that address the interactions of management and natural disturbances.

In an effort to maintain the historic range of conditions in the landscape, some managers are interested in using management to emulate the natural disturbance regime, i.e., to substitute some natural disturbances with partial cutting, and stand replacing disturbances with clear cutting. This requires knowledge of the historic range and variability of natural disturbances, and methods for testing whether the proposed management plans will maintain landscape indicators within this range. Indicators that could be evaluated include area affected by different types of disturbances (i.e., stand replacing or partial), and the amounts and distributions of seral stages, age classes, cover types, patch sizes and interior forest habitat.

Tools are needed to analyse the effect of different management scenarios on each of the desired indicators, and to compare their values to the designated goals and guidelines. Models that address these complex problems should simulate both management and natural disturbances because their interactions determine future landscape characteristics. The Tool for Exploratory Landscape Scenario Analyses (TELSA) is a spatially-explicit model that simulates forest succession, natural disturbance regimes and various management actions, to predict alternative future conditions in terms of a variety of spatial and non-spatial indicators (Kurz et al. 2000). This paper describes a simple example application of TELSAs to the issue of substituting management actions for natural disturbances.

## **2. THE TOOL**

TELSA is a spatially explicit, strategic planning tool designed to project the consequences of alternative management and natural disturbance scenarios at the scale of landscape units (up to about 250,000 ha or about 100,000 polygons) over time frames of decades to centuries. TELSAs represents forest succession and the impacts of natural disturbances and management as changes in species composition, age, and structural stages of stands, using successional pathway diagrams (SPD) developed within the Vegetation Dynamics Development Tool (VDDT; Beukema and Kurz 2000, Merzenich et al. this volume). Such pathway diagrams can easily be developed for any type of forest and other vegetation.

Natural disturbances are represented in the model using the probabilities and pathways defined in the SPD, as well as additional information about the size-class distribution of the disturbances, the annual variation (e.g., to represent weather variation), and long-term trends (e.g., increasing fire suppression or global change). Management impacts are also defined in the pathway diagrams. Various management options are combined into management systems that define the sequence of activities to be applied to a polygon, the stand age for the activities, and various constraints on the size of management units (treatment blocks), adjacency (green-up), or on the total area affected by a management activity.

In addition to the main simulation model, the TELSA toolbox includes a tessellation tool which creates simulation polygons; a management unit building tool which groups and assigns polygons to management systems; a spatial analysis tool which calculates patch-size distributions, interior old-growth habitat, and border lengths; and user interfaces for editing the database or for viewing graphs, tables, and maps of the simulation results (Kurz et al. 2000).

### 3. METHODS

Using the VDDT, we developed a successional pathway diagram for a hypothetical landscape containing two tree species. Each species existed alone or in combination with the other species. These forests consisted of four different structural stages: stand initiating, young stem exclusion, young multistory, and old multistory. Although several other attributes can be assigned to successional classes, none were used for this simple example.

The initial distribution of forested polygons in the landscape was created from an existing 45,169 ha forest cover map. Rules were developed that mapped the current species in each polygon to one of the four species combinations used in this example, and that assigned structural stages based on age class.

Existing forest cover polygons averaged 24 ha with a maximum size of 2400 ha. Many natural disturbances do not follow polygon boundaries and can affect partial polygons. To simulate such disturbances, TELSA first partitions forest cover polygons into smaller simulation polygons, which are created by an automated tessellation algorithm with user-defined parameters (Kurz et al. 2000). For this example, the landscape was tessellated using a 300x300m point scatter, with random variation around each point location. No additional planning zones were used. The resulting landscape map consisted of 9,967 polygons, ranging in size from  $<1\text{m}^2$  to 13.2 ha, with an average size of 4.5 ha. The very small polygons originated from the forest

cover map as the tessellation algorithm does not create new polygons below a user-defined size threshold (1 ha in this example).

We assumed that the landscape could be disturbed by two types of natural disturbances: stand replacing wildfire (SRF), and underburns (UB), and two corresponding types of management: clear cuts (CC), and partial cuts (PC). Each of these can occur in more than one structural stage (Table 1). Other natural disturbances such as insects, diseases or severe weather events, and more detailed management options, such as different types of partial cutting, planting, etc., were ignored for this example. They can easily be accommodated in both VDDT and TELSA.

*Table 1.* Summary of assumptions about structural stages in the VDDT.

Structural stage	Approximate ages	Potential disturbance	Resulting stage
(1) Stand initiating	0-30	Wildfire	Stand initiating
(2) Young stem exclusion	31-80	Wildfire	Stand initiating
(3) Young multistory	81-150	Underburns, PC	Young multistory
		Wildfire, CC	Stand initiating
(4) Old multistory	151+	Underburns, PC	Young multistory
		Wildfire, CC	Stand initiating
		Underburns	Young multistory
		PC	Old multistory

We assumed that, on average, SRF would burn 0.5% and underburns 1% of the landscape each year. In runs that combined fires and management, we assumed that fire suppression efforts reduced the areas burned to 20% of the initial values.

TELSA uses information on the expected size-class distribution of natural disturbances and on any variation that occurs for reasons other than changes in vegetation. We approximated a negative exponential size-class distribution for SRF, and a slightly decreasing distribution for underburns. Annual variation for SRF was calculated based on data containing 45 years of annual fire statistics. Underburns were assumed to occur with no additional variation.

Three different management systems were defined: partial cutting, small clear cuts, and large clear cuts (Table 2). Management scenarios combined partial cutting with either small or large clear cuts. The two management systems used in a scenario were distributed randomly in the landscape (Fig. 1). Adjacency or green-up constraints were not used in this example.

Table 2. Summary of the management systems used in the model runs

Management System	Eligible age / structural stage	Size range
Small clear cuts	100+ years / stages 3-4	10-40 ha
Large clear cuts	100+ years / stages 3-4	50-200 ha
Partial cuts	50+ years / stages 2-4	10-40 ha

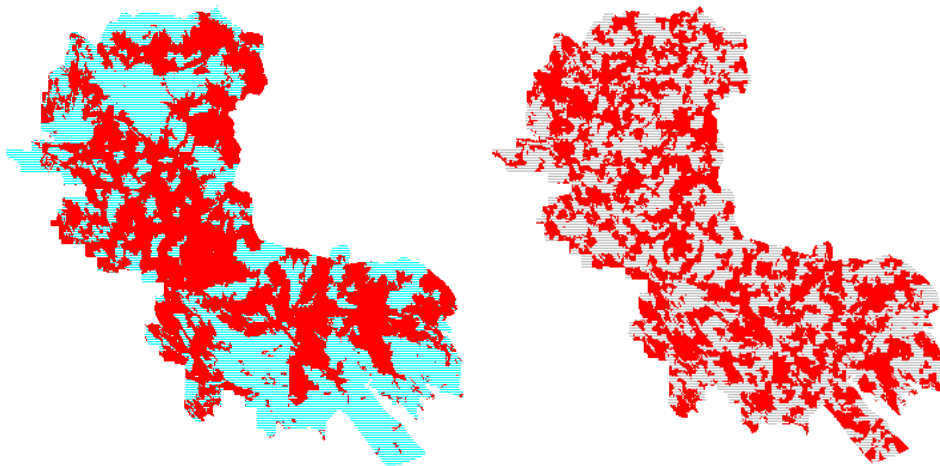


Figure 1. Maps showing the distribution of the two different management systems, under the different clear cut size scenarios. Light areas are eligible for partial cut, and dark are for clear cuts. Left: Large clear cuts. Right: Small clear cuts.

We analysed five scenarios that combined different assumptions about natural disturbances and management (Table 3). Each scenario was simulated in annual time steps for 100 years. Scenarios with disturbances were simulated for five Monte Carlo runs to assess the range and variability of the results. Spatial analyses were done at 25-year intervals for Monte Carlo 1 of each scenario, and in years 50 and 100 for all Monte Carlo runs. Patches were defined using the age ranges in Table 1, and interior old growth was calculated from patches older than 150 years with a 200 m buffer. While numerous indicators are available, only four are presented here, all for year 100 of the simulation: cumulative area disturbed, area in each 20-year age class, patch-size distribution, and interior old growth.

Table 3. Summary of the scenarios simulated by TELSA

Scenario	Disturbances	Clear cuts	Partial cuts
1	Historic (full level)	None	None
2	None	Large CC	Yes
3	None	Small CC	Yes
4	Managed (20% only)	Large CC	Yes
5	Managed (20% only)	Small CC	Yes

## 4. RESULTS

Scenario 1 with historic disturbances shows little annual variation in the area of underburn, and a highly variable amount of SRF. Although the average area burned was the same in all Monte Carlo simulations (228.9 - 229.4 ha / year), the area burned in a single year ranges from 1 to 9,464 ha, and is highly variable between simulations.

In all scenarios with management, the area harvested closely emulated the corresponding disturbance levels from the scenario with historic disturbances (Fig. 2). Management scenarios with large clear cuts were slightly below the harvest target, because the 50-200 ha cut blocks constrained the model's ability to meet and not exceed the area limit.

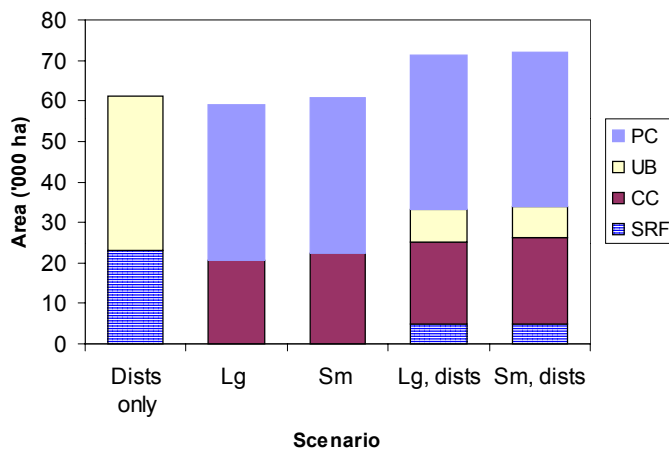


Figure 2. Cumulative area disturbed by fire or management in each of the 100-year scenarios.

Scenarios with and without management show very different age-class distributions. With historic disturbances, a large amount of area is in the older age classes. With management, very little area is older than 120 years (Fig. 3). Management scenarios with disturbances have more area in the youngest classes than those with no disturbances, because of the wildfires that are not suppressed. The large amount of area in the middle age classes is a result of the partial disturbances: partial cutting or underburns, which maintain those classes.

In spite of the large size of some fires, the average size of patches in the landscape is smaller in scenarios that include disturbances. Average patch size in these scenarios range from 48-67 ha. The patch size in scenarios without disturbances averages 72 ha with small clear cuts, and 111 ha with large clear cuts. This counter-intuitive result is due to the impact of partial cutting, which maintains large areas (Fig. 1) in the same structural stage.

These areas create many of the large patches. In addition, since green up constraints were not used, clear cuts may occur next to each other and create a large patch of similar structural stage. When disturbances are added, SRF may occur any place in the landscape and potentially break up these large patches. The resulting spatial arrangement of the patches differs widely between scenarios even when the average patch size is similar (Fig. 4).

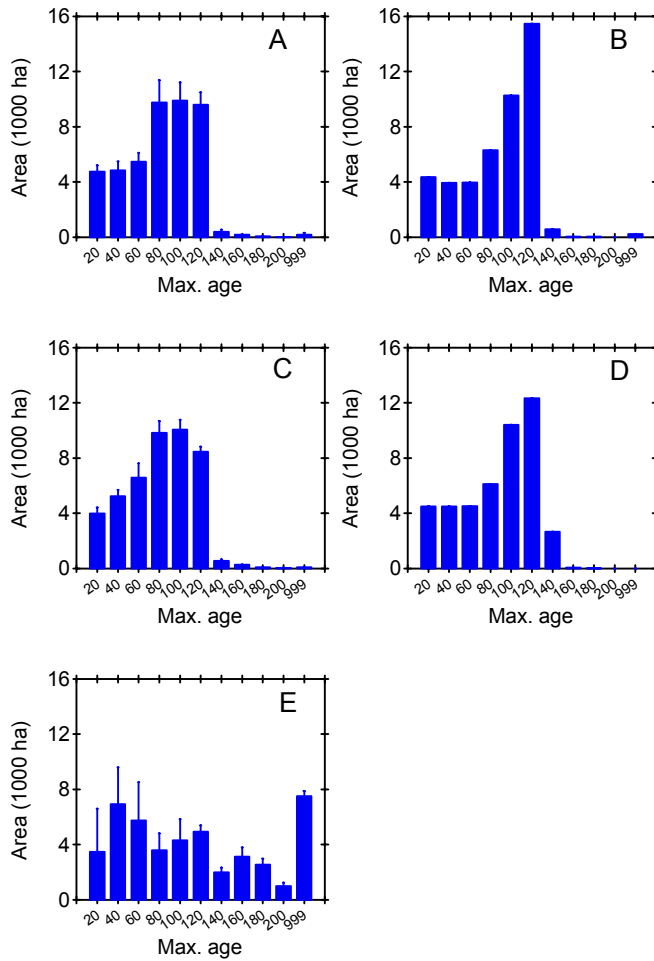


Figure 3. Age class distribution in year 100 for each of the scenarios. Error bars indicate one standard deviation, and are only present on the runs with disturbances. A: Large CC with disturbances. B: Large CC only. C: Small CC with disturbances. D: Small CC only. E: Disturbances only.

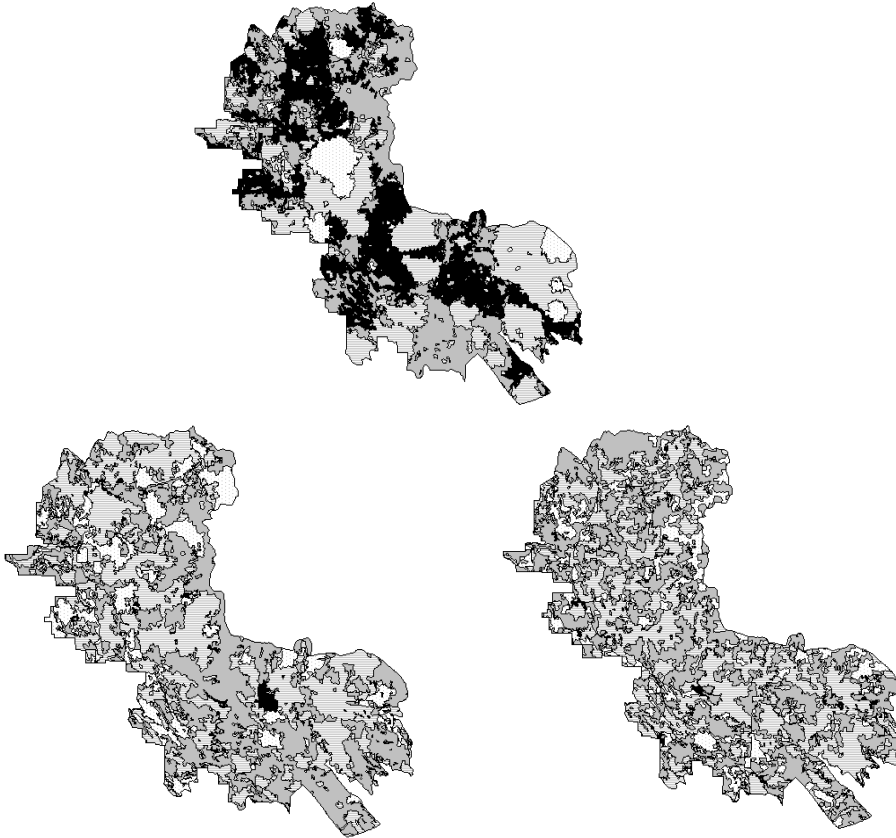


Figure 4. Maps of the patch-size distribution of the landscape in year 100. Patches are colored according to their age, with darker patches being older ages. Top: Disturbances only. Left: Large clear cuts with disturbances. Right: Small clear cuts with disturbances

The biggest difference between scenarios with and without management is in the area of interior old growth (IOG). The scenario with historic disturbances contains 2,460 to 2,580 ha of IOG, depending on the Monte Carlo simulation. In contrast, only the scenarios with large clear cuts contained any IOG, and it only covered 19 to 69 ha.

## 5. DISCUSSION

Those tasked with managing forest landscapes to meet specified future desired landscape conditions, such as the distribution of seral stages, forest cover types, age classes, patches and interior old-growth habitat, require tools with which to assess and demonstrate the outcomes of their proposed actions in terms of spatial and non-spatial indicators. Ideally, such tools

should address the interactions of management, succession, and natural disturbances and estimate the range and variability of the future conditions.

One such tool, TELSA, was used here to demonstrate one approach to addressing these issues through simulation of alternative scenarios that combine assumptions about succession, natural disturbances and management actions. Due to the space limitations of a journal publication, we have chosen a very simple example, selected only a small number of indicators, and presented results for only one point in time. TELSA is capable of significantly more complex applications and it generates results over time for a large number of indicators (Kurz et al. 2000). For example, applications in the interior of British Columbia simulated 26 different management systems, numerous natural disturbances and salvage logging on a landscape with multiple ecosystem types and planning zones.

This simple example demonstrated some of the consequences of management scenarios designed to emulate natural disturbance regimes. While the area affected by comparable disturbance types was quite similar to the historic disturbance regime, the resulting landscape characteristics were rather different, because management actions such as clear cuts act differently than wildfire. In this example, clear cutting targets older stands with merchantable timber, while wildfires can affect forest types of any age. Thus, wildfires may burn some areas repeatedly and let other stands “escape” and grow old. In addition, wildfire can burn stands previously affected by an underburn, while, in these scenarios, stands in a partial cut system were not eligible for clear cutting. TELSA has previously been used to explore the interactions between management and disturbances in more detail. For example, Klenner et al. (2000) demonstrated the need to account for natural disturbance impacts when trying to meet specified targets of old-growth area through old-growth reserves.

The TELSA toolbox allows users to define forest types, succession pathways, disturbances and management. TELSA can therefore be used to simulate a wide range of forest types and scenarios. TELSA has been applied to areas in BC’s dry southern interior and wet northern coast, the boreal forest in Alberta, and various forests in California, Montana, and Oregon. TELSA is currently part of a model comparison in which several models will be applied to eight different forest and range types across the US (Weise et al. 2000).

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