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Overview and Example Application of the Landscape Treatment Designer

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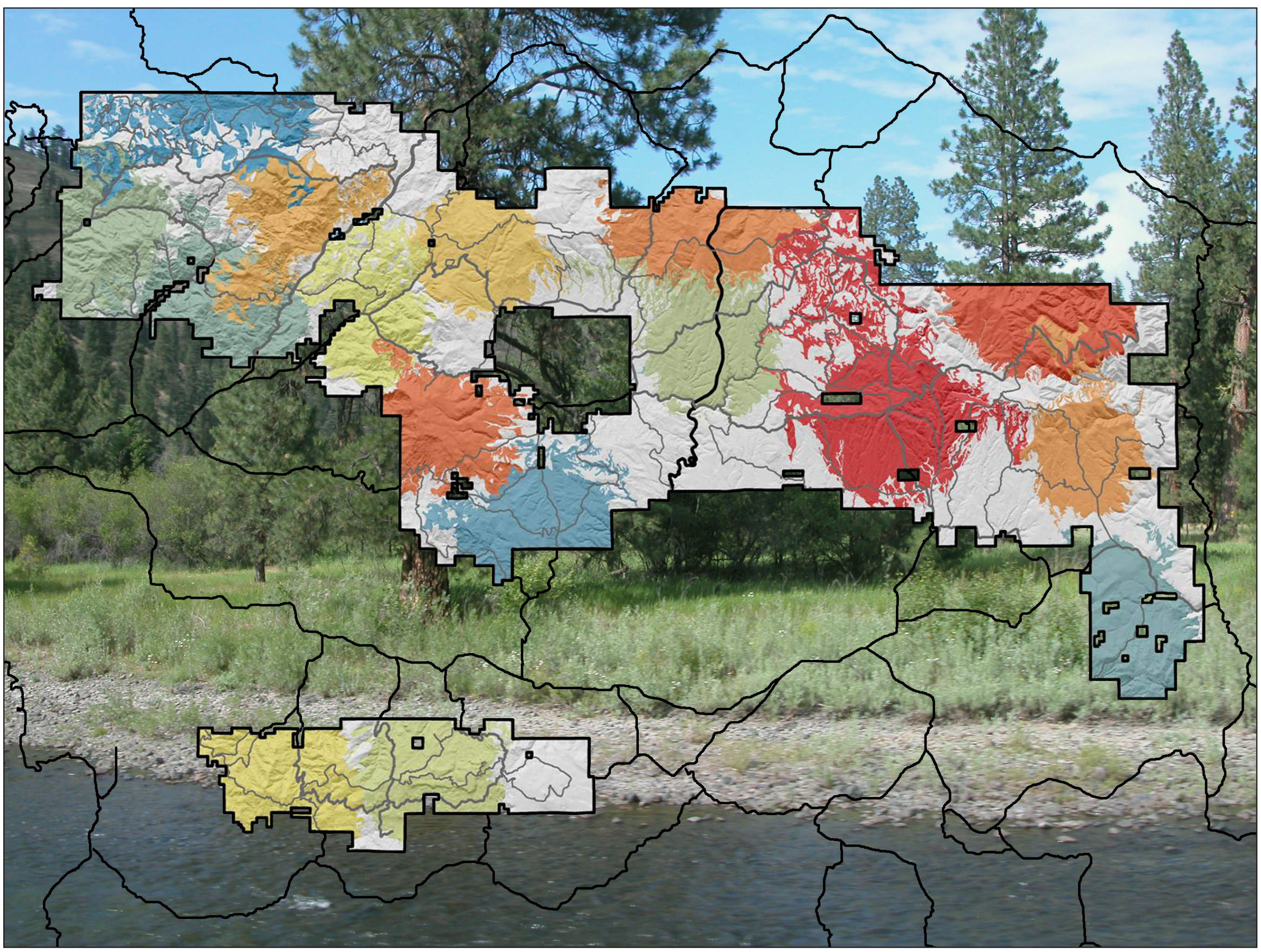

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Cover photograph by Frank Vanni.

Abstract

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The Landscape Treatment Designer (LTD) is a multicriteria spatial prioritization and optimization system to help design and explore landscape fuel treatment scenarios. The program fills a gap between fire model programs such as FlamMap, and planning systems such as ArcFuels, in the fuel treatment planning process. The LTD uses inputs on spatial treatment objectives, activity constraints, and treatment thresholds, and then identifies optimal fuel treatment locations with respect to the input parameters. The input data represent polygons that are attributed with information about expected fire behavior and the polygon's overall contribution to one or more landscape management objectives. The program can be used in a number of different ways to explore treatment priority and decision rules that manifest themselves on large (1 million ha) landscapes as spatially explicit treatment strategies. This report describes the LTD program and an example application on the Ochoco National Forest. Further information including program download and a tutorial can be found at http://www.fs.fed.us/wwetac/ltd.

Keywords: Fuel treatment, spatial optimization, forest planning, forest restoration.

Contents

Introduction

The Landscape Treatment Designer (LTD) is a multicriteria spatial prioritization and optimization system to help design and explore landscape fuel treatment scenarios. The program fills a void between fire model programs such as FlamMap (Finney 2006) and planning systems like ArcFuels (Ager et al. 2011), in the fuel treatment planning process. The LTD uses inputs on spatial treatment objectives, activity constraints, and treatment thresholds, and then identifies optimal fuel treatment locations with respect to the input parameters. The input data represent polygons that are attributed with information about expected fire behavior and the polygon's overall contribution to one or more landscape management objectives. These can include nonspatial attributes such as stand conditions, or spatial attributes such as the distance to fire-susceptible landscape features like critical habitat or residential structures. The user supplies an activity constraint (e.g., area treated) that represents the maximum area that can be treated based on fuel treatment budget allocations or other constraints (fig. 1). The program can be used in a number of ways to explore treatment priority and decision rules as they manifest themselves on large (1 million ha) landscapes as spatially explicit treatment strategies. In a simple application, the program operates the same as sorting polygons based on fields of interest, and then selecting polygons from the sorted list until some total area limit is met. However, LTD automates the process and allows for combining several attributes in weighted combinations so that treatment alternatives can be quickly generated and mapped. The LTD also has an aggregation constraint option for coordinating treatments to build low-hazard fire containers (e.g., contiguous areas) that can serve as wildland-fire-use areas or large-scale prescribed fire treatment areas. The aggregation constraint forces the program to build patches within which threshold conditions at the stand level are not exceeded using the decision framework in figure 2. Stands that exceed fire behavior thresholds are treated until the treatment constraint is reached. For instance, to restore natural fire, treatments can be spatially allocated such that a large patch is created within which fire behavior thresholds are not exceeded, and the total area treated does not exceed a predetermined threshold. A nonadjacency problem would allocate treatments based on objective values regardless of their location relative to each other. Another implementation might use distance and azimuth objectives to allocate treatments around features of interest, such as a wildland-urban interface (WUI) or critical habitat for threatened and endangered species. Up to five objective values can be blended with weighting factors to build hybrid scenarios that allocate investments to multiple values of interest. For instance, a 50 percent weight could be put on treatments near the WUI and a 50 percent weight on treatments for restoration objectives. Because attribute values can include distance measures, scenarios with

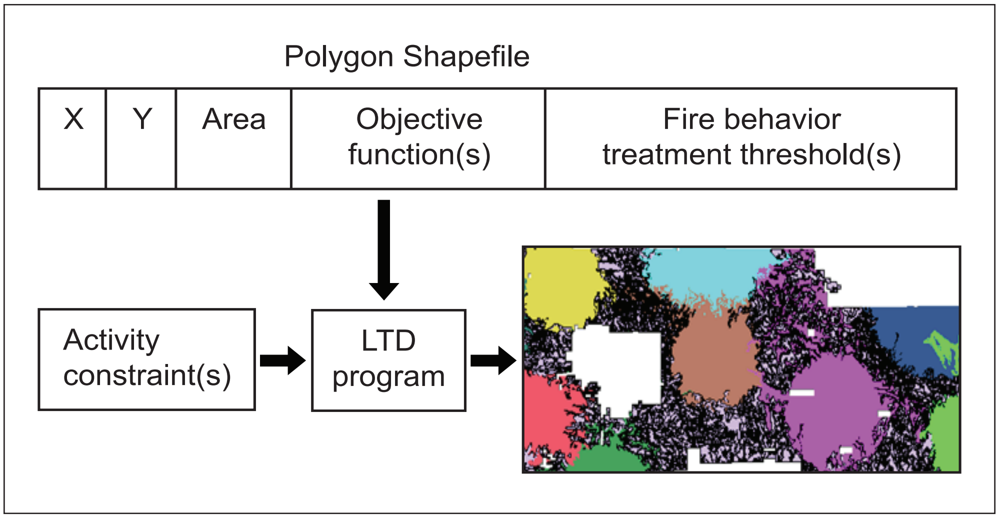

Figure 1—Diagram showing the input data and outputs of the Landscape Treatment Designer (LTD) program. Each record of the polygon shapefile contains data on (1) polygon XY centroid, (2) polygon area, (3) objectives, and (4) constraints. The latter two variables can be integer or real values. The outputs include a polygon shapefile that identifies the objective value for each polygon, and a code that specifies whether it was selected to be in a patch, and whether it was also selected for treatment.

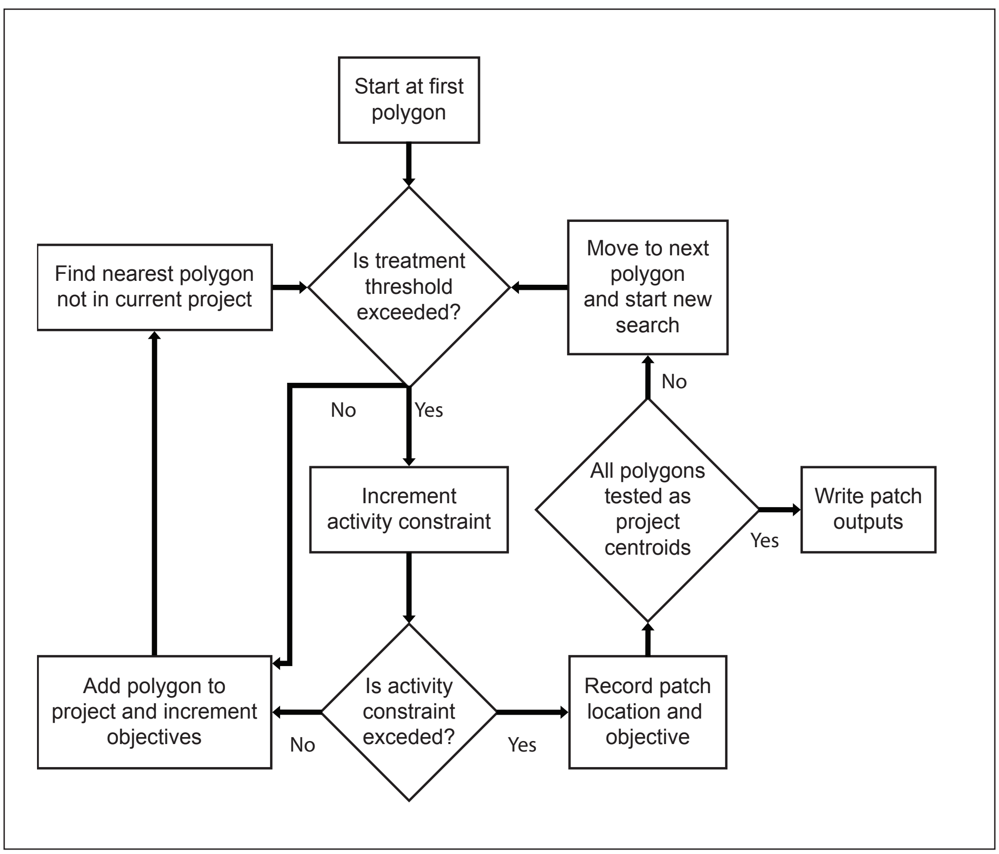

Figure 2—Flow chart of program control for the Landscape Treatment Designer program showing the decision framework for simulations that use the aggregation option.

spatial fidelity to particular landscape features (roads, WUI, etc.) can be used to drive treatment locations (e.g., Ager et al. 2010).

This paper describes the LTD program, including an example application on the Ochoco National Forest. Further information including program download and a tutorial can be found by following the links at http://www.fs.fed.us/wwetac/ltd/.

The LTD Program

Input

The LTD program uses an ArcGIS®[1] polygon shapefile containing forest stand boundaries and an attribute table with fields describing each stand's characteristics with respect to (1) treatment threshold (e.g., flame length, stand density index); (2) ecological, financial, or other objectives and respective weighting factors that are used for the objective function; and (3) investment or activity constraint (e.g., area or financial value required for treatment). The input data can be derived from Landfire (Rollins 2009), FlamMap (Finney 2006), the Forest Vegetation Simulator, and corporate spatial data. The stand value attribute can be represented by both relative spatial (e.g., distance to fire-susceptible landscape features like critical habitat or residential structures) and nonspatial attributes (e.g., stand density, crown fire potential). Attribute fields must include the polygon coordinates (centroid XY) and the area (fig. 3). The activity constraint entered by the user represents the total possible investment in the management activities based on budgets or other constraints. The treatment threshold is a constant that when exceeded by the value in a particular polygon, a treatment is triggered. Objective Direction can either be maximized (1) or minimized (0). The Check Availability option allows the user to only permit treatments in stands that are available for treatments. When checked, the program reads a user-specified field that indicates whether stands are available for treatments. The field is coded with 1 to indicate a stand is available for treatment, and a 0 otherwise.

Types of Scenarios

Several types of scenarios can be performed with a given set of input data. Options include (1) **aggregation**, (2) **iterate** until all treated, and (3) **sensitivity** runs. When the first option is invoked, LTD builds a contiguous patch that maximizes the objective function while not exceeding the investment constraint. Stands that exceed the established treatment threshold count against the investment constraint. Without the **aggregation** option, LTD simply locates the polygons that maximize the objective

[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

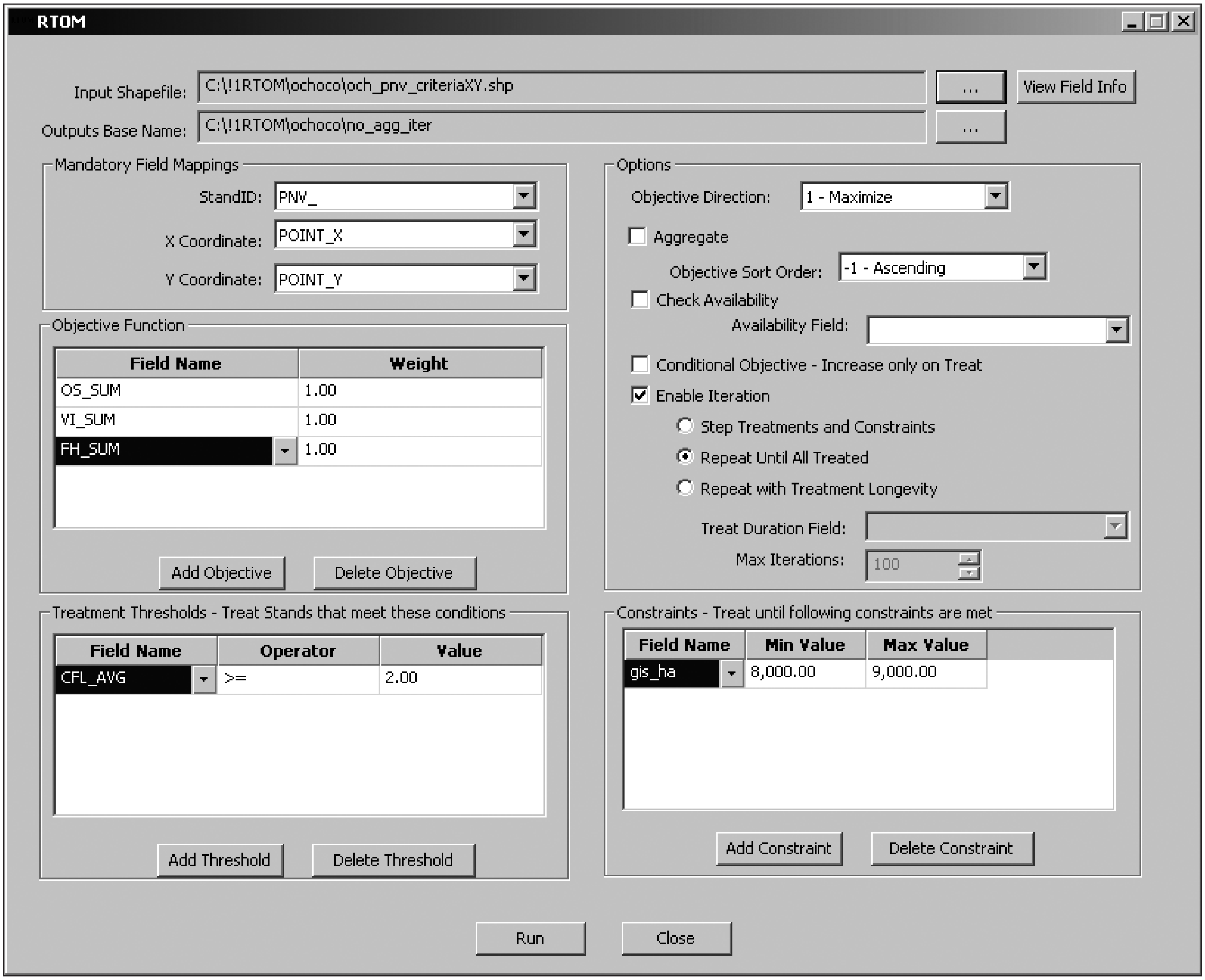

Figure 3—Screen capture of the Landscape Treatment Designer program showing the run parameters for example run No. 1 described in the text. The input parameters call for maximizing indices that describe stand size class, and structure, and fuel hazard (table 2, OS_SUM, VI_SUM, FH_SUM) while treating polygons that have a predicted flame length that exceeds 2 m. The activity constraint is set at 9000 ha, meaning each patch can include a maximum of 9000 ha that exceed the treatment threshold.

function within the activity constraints, irrespective of their spatial relationships. The **iteration** option repeats the process of maximizing the objective function to create multiple planning areas, until all stands in the landscape have been either treated or included in a patch. With the **aggregation** option enabled, this process creates multiple patches (i.e., planning areas) of decreasing treatment priority. The **sensitivity** option allows the user to specify floor, ceiling, and an interval for input parameters that LTD will use to simulate multiple runs to see how changing input parameters affect the outputs.

Outputs

Three types of output files are generated with each run: (1) a text file with all the input data with treatment locations indicated, (2) a summary text file of input parameters and output results, and (3) a shapefile with an attribute table that identifies patch locations and stands selected for treatments.

Example Application

The example application was derived from the Ochoco National Forest where a vegetation action plan[2] identified vegetation management priorities for the forest. It represents a typical approach used by national forests to prioritize vegetation management activities and develop strategic plans for restoration and fuel management. The priority schema was based on forest stand structure, overstocking, and fuel hazard (tables 1, 2). The above three indices were then combined into an objective function with equal weights. The stand structure index identified multilayer stands with large trees and overstocked conditions according to the stand density index (table 2). Fire hazard rating was developed from a combination of flame length and crown fire activity derived from FlamMap runs (table 1). Overstocked condition was measured by comparing the current stand density with the maximum as specified by the stand density index (table 2). The stand structure and density indices were calculated by processing gradient nearest neighbor data (Ohmann and Gregory 2002) through the Forest Vegetation Simulator.

To trigger a treatment, we identified a treatment threshold as the average flame length for the stand as determined from a FlamMap (Finney 2006) simulation. We then set a treatment threshold at 2 m, which represented minimum conditions where

Table 1—Definition of fuel hazard used for the Ochoco National Forest example[a]

	Crown fire potential		
Flame length	**Surface**	**Passive**	**Active**
Feet (meters)			
0–2 (0–0.6)	Low	Low	Low
2–4 (0.6–1.2)	Low	Low	Medium
5 (1.5)	Low	Medium	Medium
6 (1.8)	Medium	Medium	Medium
6–8 (1.8–2.4)	Medium	High	High
8–11 (2.4–3.4)	High	High	High
11–20 (3.4–6.1)	High	High	High
20+ (6.1+)	High	High	High

[a] See Finney 2006 for crown fire definitions.

[2] Owens, D. 2011. Unpublished report. On file with: Ochoco National Forest Supervisors Office, 3050 NE Third St., Prineville, OR 97754.

Table 2—Vegetation scoring system to determine treatment and restoration priorities for the Ochoco National Forest example[a]

Variable	Specification	Objective score
Stocking	Overstocked stands 3+ in (8 cm) dbh at or above lower stand density index management zone	1
	Overstocked stand 8 to 20.9 in (20 to 53 cm) dbh at or above the lower stand density index management zone	2
Structure size class	Grass/forbs/shrubs	0
	Seed/saplings	0
	Poles (4 to 8.9 in [10 to 23 cm] dbh)	1
	Small (9 to 20.9 in [23 to 53 cm] dbh)	2
	Med/large (21+ [53+ in [53+ cm] dbh)	1
Fuel hazard	Low	0
	Medium	1
	High	3

[a] Fuel hazard is defined in table 1. Dbh is diameter at breast height.

fire behavior would likely result in a significant loss of ecological and economic value in the stand. The total area assigned for management activity, the activity constraint, was set at a minimum of 6000 ha and a maximum of 9000 ha. Although this level of activity is relatively high for a typical fuel treatment project, we chose the higher value for illustration purposes as described below.

We performed two simulations to demonstrate LTD. The first run (figs. 3 and 4) maximized the objective function with aggregation, meaning that the LTD program identified a contiguous patch on the landscape that contained the largest objective function value (maximizing area of stands that are overstocked and have high fuel hazard), treating those polygons that exceeded the flame length threshold (>2 m, fig. 2). Note that polygons that did not exceed the treatment threshold were also included in the patch. The run also used the iteration feature (Enable Iteration), such that successive patches were created that each maximized the objective given that the previous patches were not available for consideration. The resulting output (fig. 4) identified 16 patches in order of decreasing priority. These represent potential project areas that best meet the intent of the forest restoration and treatment objectives.

The second run (figs. 5 and 6) maximized the same objective function without the aggregation constraints. The result was the identification of stands that maximized the objective function and had flame lengths >2 m (exceeded the treatment threshold). For clarity, only the first four sets of stands identified in the run are shown in figure 6. The solution shows the location of the stands that best satisfy the objectives under the treatment threshold and constraints.

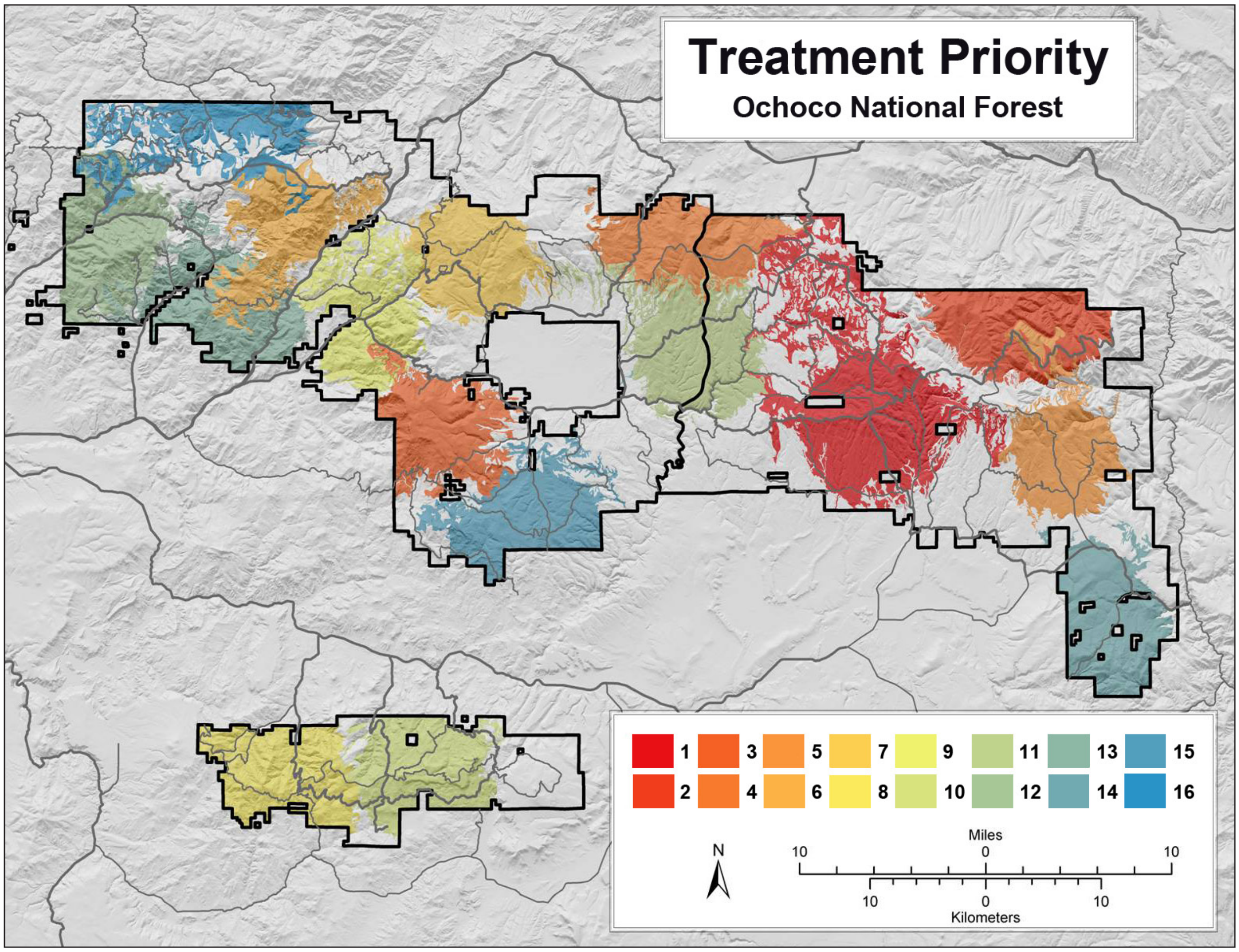

Figure 4—Map of outputs from example run No. 1 for the Ochoco National Forest as described in figure 3. Increasing patch numbers represent decreasing treatment priority based on the objective function value. For example, patch No. 1 (red) contained a set of contiguous stands that collectively maximized the objective function with the specified treatment area constraint. The black lines represent major roads on the forest.

Additional Options in LTD

Many other options are available in LTD to experiment with treatment strategies. The reader is referred to the tutorial for more detailed examples. Selected options are described below.

Enable iteration—

***Step treatments and constraints*—**This option allows the user to perform a batch run where the activity constraint and treatment threshold is incremented by fixed amounts. The option can only be used for runs where a single threshold and constraint is specified.

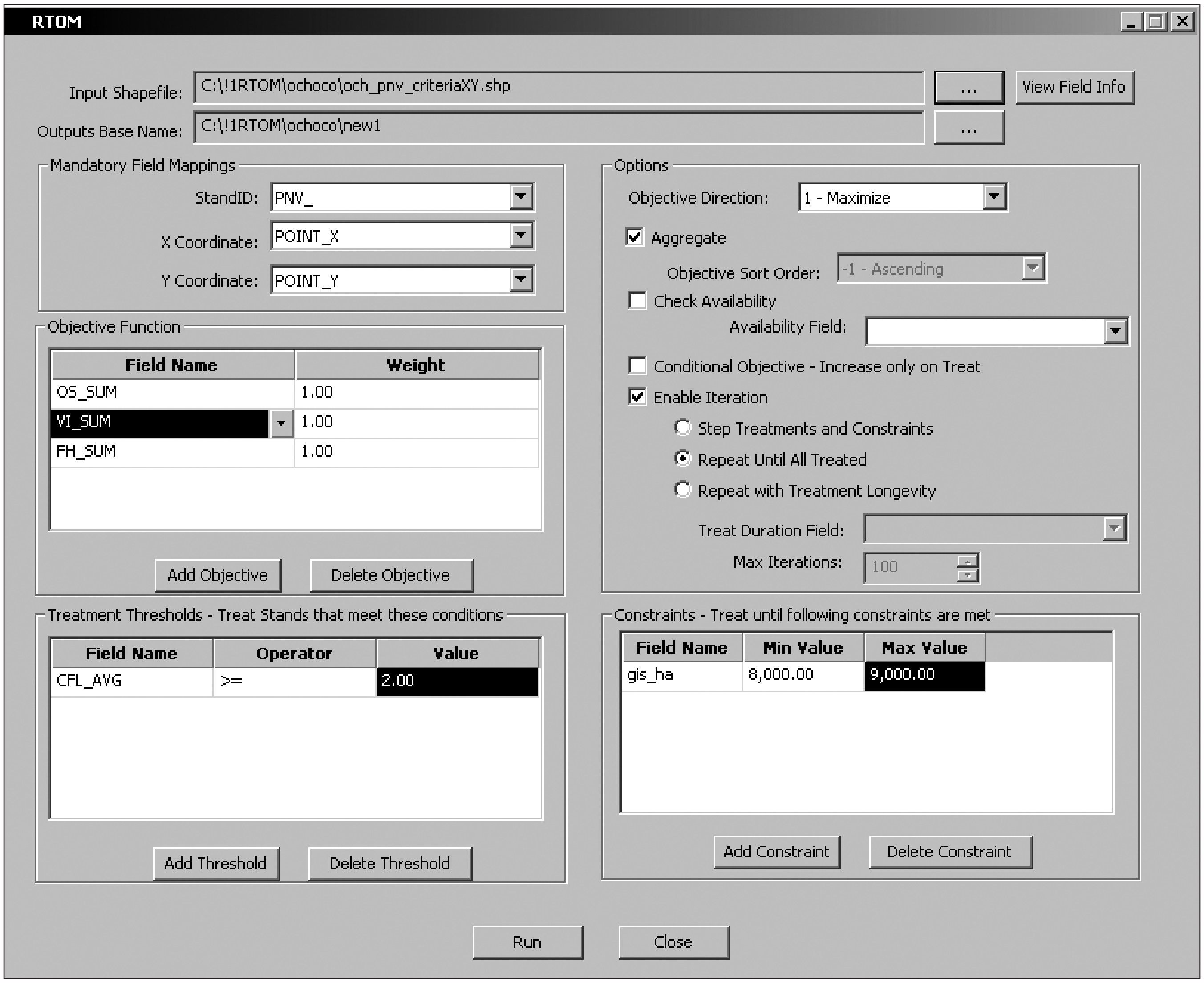

Figure 5—Screen capture of the Landscape Treatment Designer program showing the run parameters for the example run No. 2 described in the text. The input parameters call for maximizing indices that describe stand size class, and structure, and fuel hazard (table 2, OS_SUM, VI_SUM, FH_SUM) while treating polygons that have a predicted flame length that exceeds 2 m. The activity constraint is set at 9000 ha, meaning that sets of stands that maximize the objectives are identified until the constraint is met, and the process repeated until less than 8000 ha (minimum value) of stands needing treatment are remaining.

Disable shapefile outputs—

Disabling the point shapefile outputs is used for batch runs to reduce the volume of output files.

Conditional objective—

***Increase only on treat*—**This option is intended for runs that use the aggregation option where the objective is not incremented for stands that are added to a patch unless they exceed the treatment threshold. Thus the objective is not realized unless a treatment is allocated to the stand.

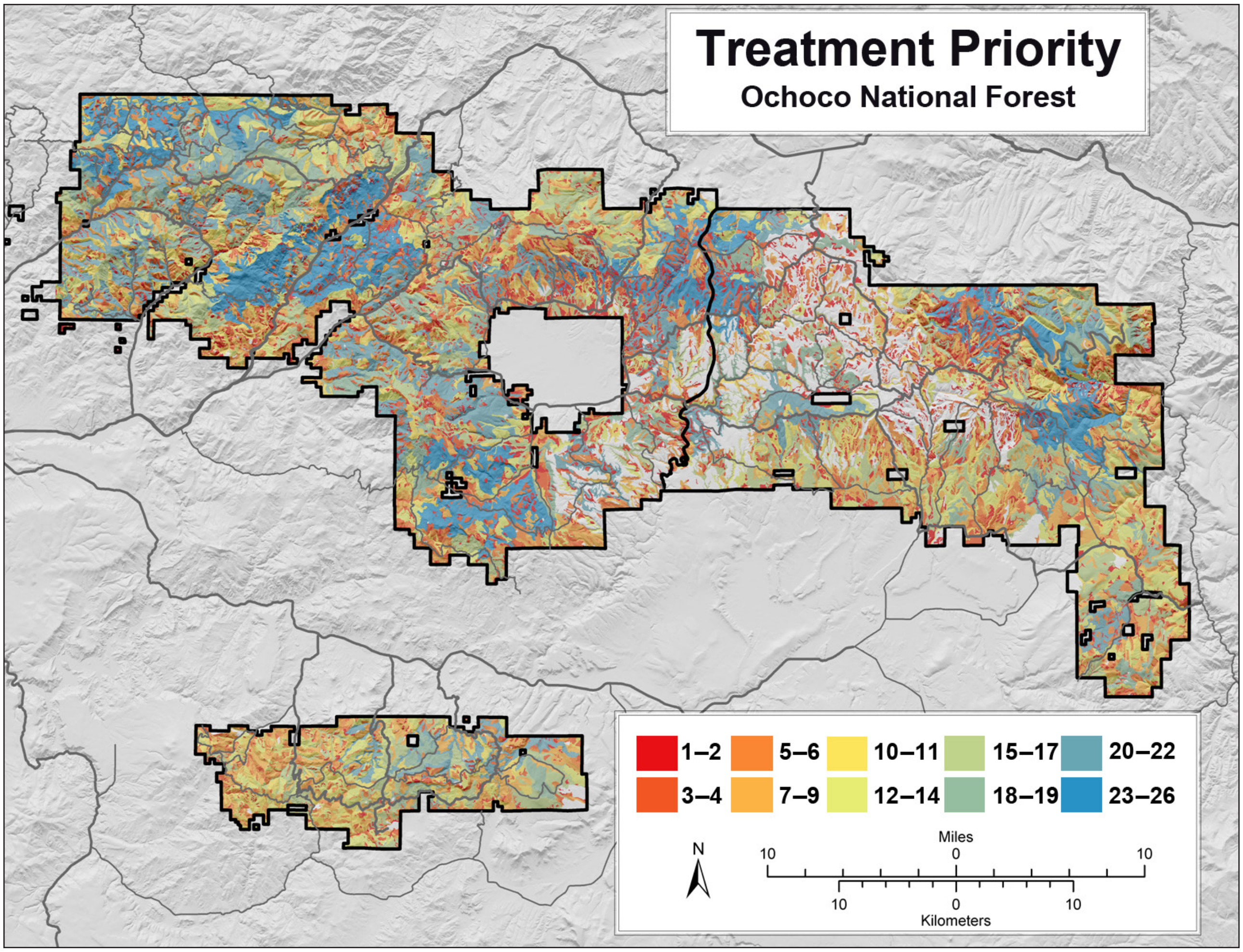

Figure 6—Map of outputs from example run No. 2 for the Ochoco National Forest showing stand treatment priority without the use of the aggregation feature. The colors identify groups of stands of decreasing treatment priority based on the objective function. The run parameters are shown in figure 5.

Check availability—

This option is available for landscapes where treatments are not allowed on specific land allocations like wilderness and conservation reserves. A user-defined integer field (0/1) allows users to specify which stands can be treated.

Objective direction—

Allows the user to minimize or maximize the objective function.

Treatment efficiency—

The treatment efficiency option was added to allow the creation of patches with variable fire severity. A specified percentage of stands are not treated, despite the fact that they exceed the fire behavior threshold. The stands are chosen at random. This option was added to address research aimed at creating landscapes that retain a mix of potential fire behaviors.

Downloads and Other Documentation Information

To obtain the LTD program, go to http://www.fs.fed.us/wwetac/ltd/. Demonstration data are available to download for LTD at the Web site and tutorial (Vaillant and Ager 2011).

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English Equivalents

When you know:	Multiply by:	To find:
Centimeters (cm)	0.394	Inches
Meters (m)	3.28	Feet
Kilometers (km)	0.621	Miles
Hectares (ha)	2.47	Acres

References

Ager, A.A.; Vaillant, N.M.; Finney, M.A. 2011. Application of fire behavior models and geographic information systems for wildfire risk assessment and fuel management programs. Journal of Combustion. Vol. 2011, Article ID 572452. 19 p.

Ager, A.A.; Vaillant, N.M.; Finney, M.A. 2010. A comparison of landscape fuel treatment strategies to mitigate wildland fire risk in the urban interface and preserve old forest structure. Forest Ecology and Management. 259: 1556–1570.

Finney, M.A. 2006. An overview of FlamMap fire modeling capabilities. In: Fuels management—how to measure success. Proceedings, RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 213–220.

Ohmann, J.L.; Gregory, M.J. 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest-neighbor imputation in coastal Oregon, USA. Canadian Journal of Forest Research. 32: 725–741.

Rollins, M.G. 2009. LANDFIRE: a nationally consistent vegetation, wildland fire, and fuel assessment. International Journal of Wildland Fire. 18: 235–249.

Vaillant, N.M.; Ager, A.A. 2011. Tutorial for the Landscape Treatment Designer. Unpublished paper. http://www.arcfuels.org/ltd/download.shtml. (October 1,2011).

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