Chapter 10: Geographic Information System Landscape Analysis Using GTR 220 Concepts

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Introduction

Forest Service General Technical Report "An Ecosystem Management Strategy for Sierran Mixed-Conifer Forests" (hereafter GTR 220) (North et al. 2009) emphasizes increasing forest heterogeneity throughout a range of spatial scales including within-stand microsites, individual stands, watersheds, and entire landscapes. For fuels reduction, various landscape strategies have been proposed and modeled, but there are few conceptual models for integrating forest restoration and wildlife habitat at larger scales. General Technical Report 220 proposes varying forest structure, composition, and fuels based on topographic characteristics, particularly slope position and aspect. The concept is an effort to emulate how frequent fire might have created landscape-scale forest heterogeneity and by inference increased forest resilience and habitat connectivity. In this chapter, we describe a raster-based geographic information system (GIS) tool developed to parse a landscape into basic topographic categories. The Landscape Management Unit (LMU) tool has two versions. An initial version closely follows the methods described in Underwood et al. (2010), binning the landscape into three slope positions crossed with three aspects (resulting in nine total categories). A second version addresses application considerations that managers have identified within the U.S. Forest Service. It condenses some of the topographic categories present in version 1 while adding a category based on mechanical operation limitations that usually occur around >30 percent slopes, resulting in six total categories. The second version also allows for more user modification. The user can change how topographic categories are defined, allowing managers to more closely parameterize the GIS tool for a project's particular topographic conditions.

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Summary of Findings

1. **Two versions of a GIS tool have been developed for analyzing and binning a forested area into landscape management units (LMUs) based on topography using DEMs.**
2. **The first version divides an area into nine LMUs resulting from three slope positions (canyon bottom/drainage, midslope, ridge) and three slope aspects (Southwest, Northeast, and neutral) following earlier published work.**
3. **A second version divides an area into six LMUs (ridge, canyon bottom/drainage, Southwest mid-slope <30 percent, Southwest mid-slope >30 percent, Northeast mid-slope <30 percent, and Northeast mid-slope >30 percent) following feedback from forest managers.** This version also allows the user to modify three parameters: neighborhood size, minimum-elevation separation, and minimum area of the slope position units.
4. **The download site** for both versions 1 and 2: http://ice.ucdavis.edu/project/landscape_management_unit_lmu_tool/.

Foundations for the GIS Tool

Historically, frequent low-intensity fire was a strong influence on the structure, composition, and ecological functions of mid-elevation Sierra Nevada forests (Skinner and Chang 1996). Aspect, slope position, and slope steepness can influence fire frequency and severity, producing different forest structures and species compositions as changes in these topographic variables occur across a landscape (Hessburg et al. 2007, Taylor and Skinner 2004). These variables can also influence soil depth, microclimate conditions, and soil moisture availability (Ma et al. 2010, Meyer et al. 2007), affecting tree density, composition, forest productivity, and overall habitat characteristics (Parker 1982, Urban et al. 2000). Most reconstruction studies have suggested historical Sierra Nevada forests were highly heterogeneous, with forest conditions likely varying with fine- and landscape-scale changes in factors such as topography and soils.

Forest heterogeneity may be particularly important for providing a diverse array of wildlife habitats. While some species are associated with areas of high canopy cover and stem density (e.g., the Pacific fisher (*Martes pennanti*), northern goshawk

(*Accipiter gentilis*), and California spotted owl (*Strix occidentalis occidentalis*), preferred habitat for others (e.g., some songbirds and small mammals) may be more open, xeric forest conditions or shrub patches. Managing for the optimal spatial arrangement and connectivity of these different forest conditions is challenging because there are few species that have been studied in enough detail to provide guidance for management practices. In the absence of better information, a reasonable approach may be to mimic the pattern of forest conditions that might have been produced by topographic differences in fire regimes and forest productivity.

Forest managers are faced with developing project plans that must meet multiple objectives including fuels reduction, ecosystem restoration, increased forest resilience, and the provision of a variety of wildlife habitat, especially old-forest conditions, which may be at odds with, or are adversative to, fuels objectives. For landscape planning, this has sometimes resulted in different areas being managed for single objectives (e.g., fuels reduction near the wildland-urban interface, or no entry around known sensitive species use areas). There has not been a conceptual framework or spatially explicit method for integrating and balancing these different objectives across a landscape. The GIS tool described here is an initial attempt to analyze and spatially parse forest landscapes into topographic zones with different desired forest conditions. Managers may use the tool to develop plans for increasing forest heterogeneity while using the conceptual framework to communicate their intent to stakeholders and the public.

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Background and Description of the GIS Tool

The first version of the GIS tool, developed by the Information Center for the Environment at the University of California, Davis can be downloaded from http://ice.ucdavis.edu/project/landscape_management_unit_lmu_tool.

It contains a series of scripts that work in Environmental Systems Research Institute ArcMap **version 10** (the scripts will not run in earlier versions). The essential inputs for the tool are the study area boundary and a digital elevation model (DEM) (ideally at 10 m (33 ft) resolution but it will also work on 30-m (98-ft) DEMs). The LMU tool contains three toolsets. The first is a preprocessing toolset that prepares the data sets, for example, by buffering the study area boundary and clipping the DEM by this extent. The main toolset parses the landscape into three classes of slope (ridgetop, midslope, canyon/drainage bottoms) and three classes of aspect (northerly, southerly, and a neutral class to reflect the amount of solar insolation received), and then recombines these into a total of nine LMUs (see table 10-1). Finally, the postprocessing toolset generates summary statistics for either each of the nine LMU groups or, alternatively, by the multiple individual units within each

Table 10-1—Classification of landscape management units

Description	Code	Canyon/ drainage bottom (Position on slope)	Slope (Position on slope)	Ridge (Position on slope)
		1	2	3
Aspect class:				
Neutral (120° to 150° and 300° to 330°)	10	11 (neutral canyon)	12 (neutral slope)	13 (neutral ridge)
Northerly (centered at 45°)	20	21 (northerly canyon)	22 (northerly slope)	23 (northerly ridge)
Southerly (centered at 225°)	30	31 (southerly canyon)	32 (southerly slope)	33 (southerly ridge)

LMU type. The summary tables report elevation, slope (in degrees and percentage of rise), aspect, net mean aspect, aspect strength, and wetness index (i.e., the amount of water received from upslope in the watershed) (see Underwood et al. 2010 for details).

There are a number of options within the tool that can be selected by the user. For example, a spatial layer depicting streams or water bodies can be specified if the user wants to ensure these are all captured as canyons/drainage bottoms. Also, there is an option to simplify the size of the output units within each LMU to remove any that are less than 10 ac (4 ha) (see Underwood et al. 2010 for details). This size simplification may be useful when the GIS tool is used for planning, but users should communicate that prescriptions and marking in the field will differ on smaller scales (chapters 9 and 11 through 13).

Examples: Kings River and Sagehen

Terrain conditions differ widely across the Sierra Nevada with slope steepness tending to increase in the southern portion of the range. In the first version of the tool, thresholds used to determine slope position can be set for either moderate or steep slope conditions. We used different thresholds because slope classes are relative. A location's slope position is determined by comparing each cell in a DEM to its neighborhood. A slight difference in elevation of the target cell to its neighbors in a moderate-terrain landscape may distinguish it as a ridge, whereas the same difference in elevation in a steep-terrain landscape may not. In the steep terrain version, the minimum elevation difference between adjacent cells is 25 m (82 ft) for ridges and -20 m (-66 ft) for canyons/drainage bottoms. In the moderate terrain version, the minimum elevation difference between adjacent cells is 15 m (49 ft) for ridges and -14 m (46 ft) for canyons/drainage bottoms (table 10-2). These values were

Table 10-2—Thresholds used to determine slope position in "steep" and "moderate" terrain types

			Terrain type	
Slope position	**Variable**	**Units**	**Steep**	**Moderate**
Ridge	Neighborhood	Meters	500	500
	Minimum separation	Meters	25	15
	Minimum area	Square meters	20,000	20,000
Canyon/drainage bottom	Neighborhood	Meters	500	500
	Minimum separation	Meters	-20	-14
	Minimum area	Square meters	40,000	40,000
Slope	Any cells not identified as ridge or canyon/drainage bottom			

developed iteratively with feedback from field personnel familiar with the two study areas presented here. The preprocessing tool will produce a table that gives summary statistics, most importantly mean and standard deviation, for the slope across the study area. The user can then use this to help determine whether the moderate or steep terrain version should be used in the main toolset analysis. For example, a region of steep terrain is the Kings River area in the Sierra National Forest with an average slope of 32.1 percent and a standard deviation of 19.6 percent (fig. 10-1). In contrast, an area of moderate terrain is the Sagehen Experimental Forest of the Tahoe National Forest with an average slope of 19.7 percent and a standard deviation of 14.3 percent (fig. 10-2).

User Input Version

The second version of the LMU tool has three adjustments to the basic tool that managers may find useful. These adjustments result in six final LMU classes rather than nine. This second version can also be downloaded from http://ice.ucdavis.edu/project/landscape_management_unit_lmu_tool/.

The first adjustment is removal of the aspect categories for the ridge and canyon/drainage bottom slope position classes. The tool identifies canyons/drainage bottoms and ridges as locations where there is little elevation change between adjacent pixels. Forest managers suggested that, in general, aspect has less influence on forest conditions in these two slope position categories because slope steepness is minimal.

A second adjustment is modification of the midslope categories. First we removed the neutral category (120 to 150° and 300 to 330°) and adjusted the aspect classifications to either southwest (136 to 315°) or northeast (316 to 135°). Managers suggested that as a planning tool, the neutral classification was ambiguous and did

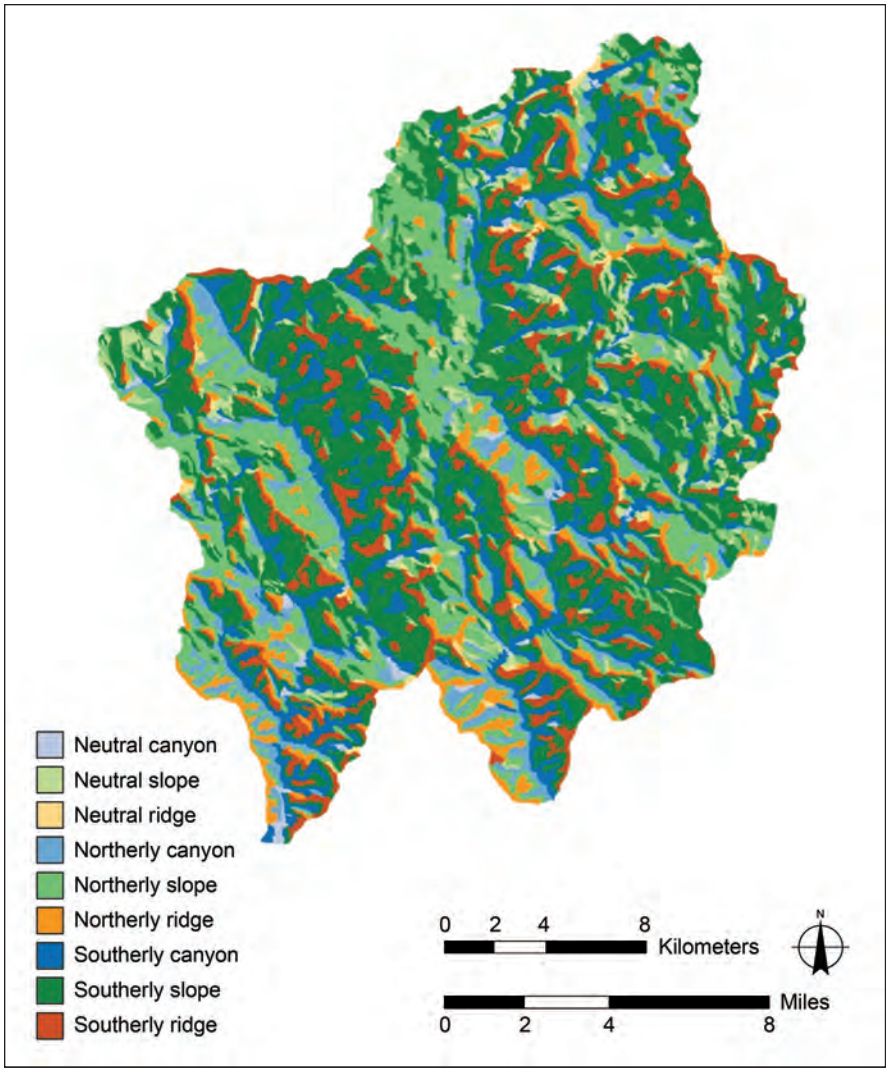

Figure 10-1—Landscape Management Units generated for the Kings River area in the Sierra National Forest, California.

not help identify management scenarios for those areas. In practice, on the ground assessments are often used to identify stand aspect and local conditions for these areas. We also split the midslope category into two classes, <30 percent and >30 percent steepness, for two reasons. Mechanical vehicles usually cannot be used on slopes steeper than 30 percent, necessitating hand thinning to reduce fuels. This limits the removal of cut material, leaving more activity fuel on site. In addition, steeper slopes can increase fire intensity particularly when high fuel loads are present, increasing potential tree mortality, and making suppression and containment more difficult (Safford et al. 2009). Planning treatments and managing these areas requires a different approach than more moderate slope conditions.

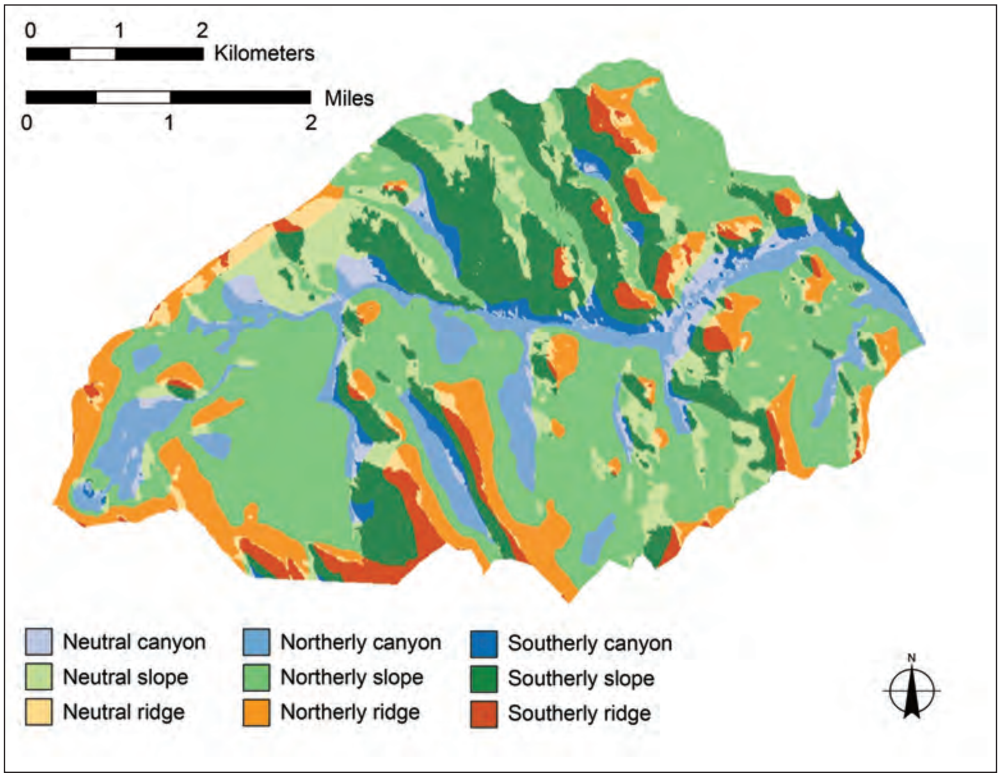

Figure 10-2—Landscape Management Units generated for the Sagehen area in the Tahoe National Forest, California.

Version 2 also has a third adjustment that lets the user modify three parameters: neighborhood size, minimum elevation separation, and the minimum area of the slope position units created. These adjustments only affect ridge and canyon/drainage bottoms classification because slope areas are identified as any cells not classified as ridge or canyon/drainage bottoms. Neighborhood size determines the circular radius around each cell that is used to calculate average elevation and is compared to the target cell's elevation. This will allow users to adjust the grain size at which elevation is averaged. Adjusting the minimum elevation separation between the cell's elevation and that of its neighborhood will allow users to alter the slope position classifications for the area they are analyzing. Changing minimum area will allow users to reduce or increase canyon/drainage bottoms and ridge unit size for the scale of analysis that is practical for their planning applications. This flexibility may allow managers to adjust the classifications such that final output more closely agrees with expert knowledge from field personnel.

Chapter Summary

The GIS tool is designed to accommodate a range of forest types in the Western United States and can be applied to project areas of any size. It is also simple to implement requiring easily accessible, basic data inputs such as DEMs.

The GIS tool is designed to accommodate a range of forest types in the Western United States and can be applied to project areas of any size. It is also simple to implement requiring easily accessible, basic data inputs such as DEMs and consequently, the units generated are readily interpretable. These units can then provide a basis for storing data about each unit within a GIS framework. This foundation can be used for further spatial analyses such as calculating the solar radiation associated with each unit. It also may be a useful tool for communicating different management scenarios to stakeholders and the public.

All such tools progress through iterative stages of trial, learning, and adjustment. We expect that users of this tool will be able to offer important suggestions for improvement once they have had opportunities to test it with real world applications. Technical GIS experts within the agency are well positioned to work with managers, making adjustments as experience accumulates and needed improvements become apparent.

Forest Service managers have enormous challenges when contemplating a management strategy for any given landscape. They depend on sound science to form a foundation from which to build a management strategy. Part of this body of defensible scientific knowledge is a set of technical tools that can be used to evaluate ecological conditions and alternative strategies to manage a forested landscape toward a desired future condition. We hope the LMU tool is a helpful addition to their toolbox, adding analytical power for planning and evaluation of management alternatives.

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