General

1/1/97

Development of a Land Cover Map for Los Alamos National Laboratory and Vicinity

Steven W. Koch, Thomas K. Budge, Randy Balice

LA-UR-97-4628

12939

Development of a Land Cover Map for Los Alamos National Laboratory and Vicinity

Steven W. Koch, Thomas K. Budge**, Randy Balice**

*Ecology Group, Los Alamos National Laboratory
**Earth Data Analysis Center, University of New Mexico, Albuquerque, NM

Abstract

The Los Alamos National Laboratory's (LANL) Threatened and Endangered Species (TES) Habitat Management Plan calls for identifying areas on LANL property that are suitable or potentially suitable habitat for TES. The production of a land cover map was the first step toward meeting this goal. A 1992 Landsat thematic mapper image was classified into 30 classes using the Iterative Self-Organizing Data Analysis Technique. These 30 classes were aggregated into 10 land cover types through field surveys, aerial photo interpretation, and the incorporation of topographic information. The resulting cover types include major vegetational zones and physiognomic types that are important to the distribution and abundances of several TES. The final land cover map has been integrated into an ARC/INFO geographic information system, along with habitat criteria and other environmental and biological data.

1.0 Introduction

The Los Alamos National Laboratory's (LANL) Threatened and Endangered Species (TES) Habitat Management Plan (HMP) calls for identifying areas on LANL property that are suitable or potentially suitable habitat for TES. A basic land cover map identifying areas by the dominant overstory vegetation was developed in order to begin locating this habitat. Additional data specific to each species are then incorporated to identify species habitat.

In early 1996, a decision was made to use Landsat thematic mapper (TM) satellite imagery as the basis data for the land cover map. Of the various types of remotely-sensed data available for mapping the earth's vegetation, TM data is particularly suitable as it (1) is digital data; (2) has a high signal-to-noise ratio; (3) has high cartographic accuracy; and (4) has a high precision of radiometric data (Scott et al. 1993). TM sensors detect reflected radiation from the earth's surface in the visible and infrared (IR) wavelengths. The TM sensor has a spatial resolution of 28.5 m (94 ft) for the visible, near-IR, and mid-IR wavelengths and a spatial resolution of 120 m (396 ft) for the thermal-IR band. TM satellite data is widely used for producing land cover maps.

1.1 Geographic Setting

LANL and the associated residential areas of Los Alamos and White Rock are located in Los Alamos County, in north-central New Mexico, approximately 100 km (60 mi) north-northeast of Albuquerque and 40 km (25 mi) northwest of Santa Fe. The 111-km^2 (43-mi^2) Laboratory site is situated on the Pajarito Plateau. This plateau consists of a series of finger-like mesas separated by deep east-to-west-oriented canyons cut by intermittent streams. Mesa tops range in elevation from approximately 2400 m (7800 ft) on the flanks of the Jemez Mountains to about 1900 m (6200 ft) at their eastern termination above the Rio Grande. Most Laboratory and community

developments are confined to mesa tops. The surrounding land is largely undeveloped, and large tracts of land north, west, and south of the Laboratory site are held by the Santa Fe National Forest, Bureau of Land Management, Bandelier National Monument, General Services Administration, and Los Alamos County. The Pueblo of San Ildefonso borders the Laboratory to the east.

The area selected for this map extends beyond the Laboratory boundaries 12.5 km (8 mi) to the west, 12 km (7.4 mi) to the north, 6.4 km (4 mi) to the east, and 6.6 km (4.1 mi) to the south (Figure 1). These boundaries correspond to the following United States Geological Survey (USGS) 7.5-minute quadrangles: Valle Toledo, Guaje Mountain, Puye, Bland, Frijoles, and White Rock, and the northern halves of quadrangles Cañada, Cochiti Dam, and Montoso Peak. The highest peaks in this area reach up to 3350 m (11,000 ft) and the lowest elevations at the Rio Grande are 1600 m (5250 ft).

2.0 Methods

Preliminary data analysis was conducted at the Earth Data Analysis Center (EDAC) of the University of New Mexico. The raw TM images were processed using the software ERDAS IMAGINE, ver. 8.2, on a Sun SparcStation 20. Further analysis was conducted at the Ecology Group (ESH-20) of LANL on an HP 9000 series 735 workstation using ESRI ARC/INFO, ver. 7.0.4.

2.1 Geocorrection

Two Landsat TM satellite images were acquired in order to cover the entire study area. The eastern image was collected by Landsat on August 15, 1992, and the western image was collected on September 7, 1992. EDAC geocorrected, or registered, both images to the USGS 1:100,000 base map to an accuracy of approximately one pixel (about 28.5 by 28.5 meters [94 by 94 ft]). The geocorrection process consisted of identifying well-mapped locations on the base map, such as road intersections, and digitizing their coordinates. The coordinate system used was universal transverse mercator (UTM) projection, zone 13, Clark 1866 spheroid, North American Datum of 1927 (NAD27). The line and column of the matching satellite image pixels were also obtained, and the sets of coordinate pairs were entered into the computer. The ERDAS software then evaluated the fit of the coordinate match and provided the results as a root-mean-square (RMS) fit in pixel units. Each coordinate pair was evaluated for their fit, the worst pair was deleted, and the RMS fit was calculated again. The process was repeated until each coordinate pair was fit to within two pixels.

EDAC reprojected the classified image from UTM, NAD27, to State Plane, NAD83, so that the cartographic data available at LANL could be used.

2.2 Contrast Matching

After the geocorrection was completed, the two images were contrast matched. Even though the acquisition dates were only three weeks apart, there were minor contrast differences due to subtle changes in vegetation greenness, in atmospheric conditions, and in satellite viewing angle. Since the western image occupied the majority of the study area, the eastern image was matched to it. When the two images were joined together into a single image, the seam between the two was virtually invisible.

2.3 Classification

The spectral information was first grouped into similar classes, and then these classes were assigned to appropriate land cover

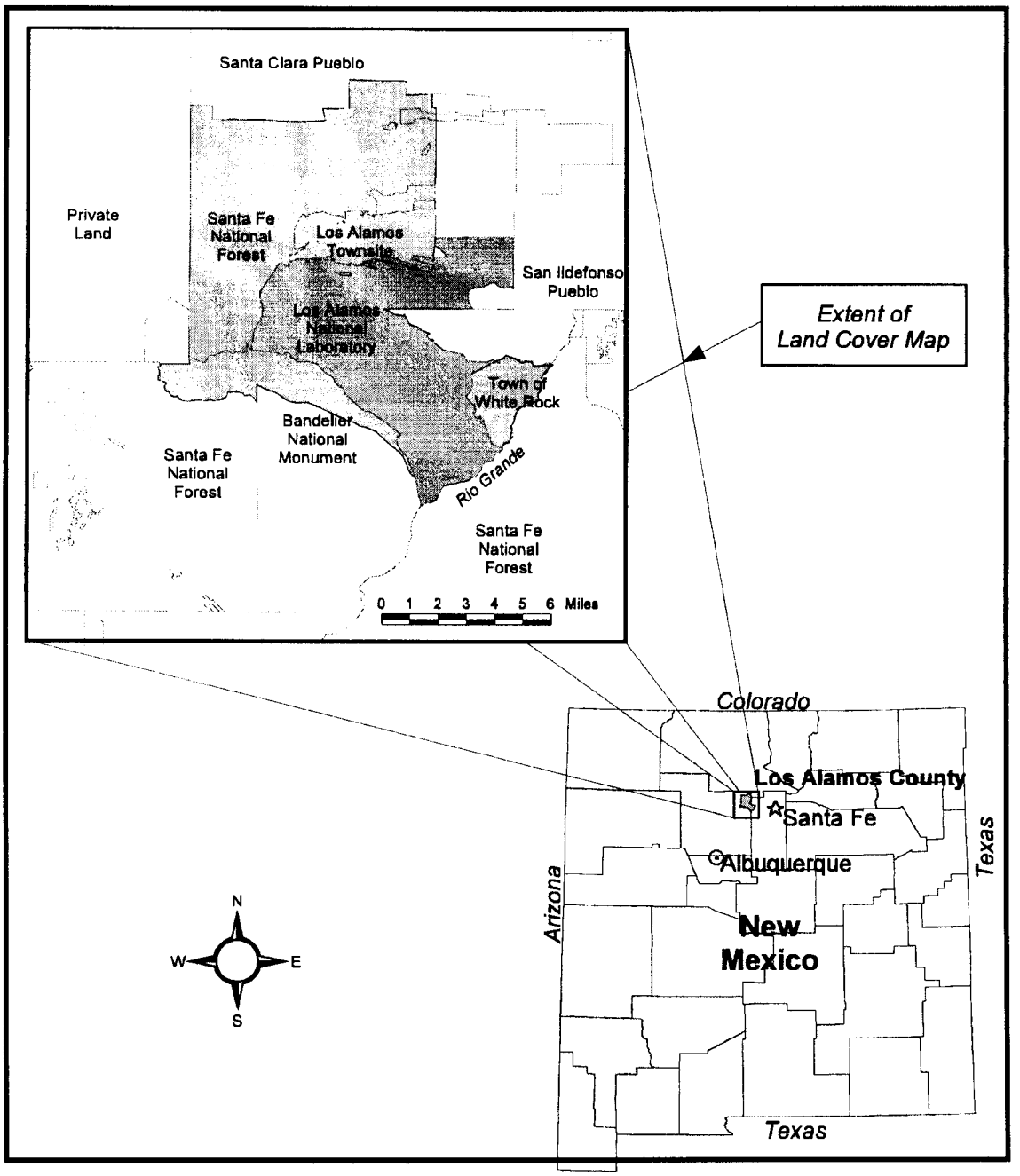

Figure 1. The area that is included on the land cover map.

categories based on data collected on the ground. This classification method is called unsupervised classification and the Iterative Self-Organizing Data Analysis Technique (ISODATA) (ERDAS 1994) was used to group the spectral information into 30 classes. Before this procedure was executed, developed areas in the towns of Los Alamos and White Rock and on the Laboratory were masked out of the image. These areas were identified from aerial orthophotographs by ESH-20. Eliminating the spectral information contributed to the TM image by developed areas improves the classification by the ISODATA procedure. Thirty color classes were chosen because it is large enough to provide a good breakdown of differing vegetation without being so large that field checking the classes is overwhelming. For this classification, six of the seven TM spectral channels were used. The coarse resolution thermal band was excluded. However, a normalized vegetation difference image (NVDI) was used in its place. The NVDI is essentially a ratio of TM band 4 divided by TM band 3.

After the spectral information was grouped into the 30 classes, homogenous polygons from each class were selected as ground-truthing plots. Field crews were sent to those sites which were large enough to be easily located in the field and were fairly accessible. The crews collected such floristic information as overstory, understory, shrub, grass, and forb species types and percent covers. Most sites were also located using a geographic positioning system (GPS) receiver. Based on this data, each site was assigned to one of ten land cover types. Problems with GPS and other data collected reduced the number of useable sites to 128. Fortunately, a similar dataset containing 350 points was available for Frijoles Canyon in Bandelier National Monument. Craig Allen, currently of the USGS-Biological Resources Division, kindly contributed his dataset. Table 1 shows the cross-tabulation between spectral color classes and ten land cover types. Half of these 478 points were used as the training dataset, with the other half held back for accuracy assessment. Aerial orthophotographs were examined in order to clarify ambiguous color classes.

3.0 Results

Table 2 shows the correspondence between the 30 color classes and eight of the ten land cover types. The Shrub and Spruce categories were dropped from the land cover because the data and processing failed to clearly distinguish these cover types from the others. Shrublands in this region tend to be small and patchily distributed. They generally occur as a result of a disturbance, such as fire or mechanical clearing, hence their patchy nature. Most of the pixels classified as color class 1 were shadows and a minority were actually water. EDAC re-ran the ISODATA procedure on class 1 and broke out the Rio Grande from the surrounding shadows.

Table 3 lists the areal extent of each cover type on LANL property. LANL is dominated by piñon-juniper woodlands and ponderosa pine forest. The influence of microclimate on vegetation can be seen in the strings of mixed conifer forest running down canyons along their north-facing slopes.

3.1 Land Cover Types

In Balice et al. (1997) the land cover types are described in detail. They are summarized in this section. In general, the mapping classes can be subdivided into those that correspond to the major elevational and climatic gradient of the region and those that correspond to edaphic, topographic, or moisture criteria.

Table 1. Number of Plots in each Cover Type and the Corresponding Color Class.

	COLOR CLASS																													
COVER TYPES	1	*3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	SUM
ASPEN						1	1	3																						5
UNVEG																2			2	1		3	1							9
GRASS							1	2		1		1		4			1			1				2	5	3	1	1		23
JUNIPER																			2		3	1	2						2	10
MIX CON		8	5	13	15	17	12	3	7	1	3																1			85
POND PIN				1	2	1	1	1	6		6	6	6	4			1			1					1	1	1			39
P-J												1	1	4	5		5	3	3	8	5		2	3	1					41
SHRUB									1					1			1		1						1	1	2			8
SPRUCE		1		2		1																								4
WETLAND	1			2	2		1	3	3			1	1		1	1														16
																														240

* No plots were recorded in color class 2.

Table 2. Cover Type Assignment to Each Color Class.

COLOR CLASS	ASSIGNED COVER TYPE
1	Water/Shadows
2-8	Mixed Conifer
9	Aspen
10-15	Ponderosa Pine
16, 18, 19	Piñon-Juniper
21, 22, 24, 25	Piñon-Juniper
17, 23, 30	Unvegetated
20	Juniper Savanna
26 - 29	Grassland

Table 3. Areal Extent of Land Cover Types at LANL.

COVER TYPE	AREA (sq mi)	AREA (acres)	AREA (hectares)	%
Mixed Conifer	1.34	859.79	347.95	3.11
Aspen	0.07	47.65	19.28	0.17
Ponderosa Pine	12.64	8091.75	3274.63	29.27
Piñon-Juniper	19.95	12770.03	5167.87	46.20
Juniper Savanna	1.62	1034.85	418.79	3.74
Grasslands	2.88	1842.85	745.78	6.67
Water	0.04	27.97	11.32	0.10
Unvegetated	2.85	1824.20	738.23	6.60
Developed	1.57	1002.74	405.80	3.63
Shadows	0.22	140.67	56.93	0.51
SUMS	43.19	27642.50	11186.57	100.00

The elevational gradient in the LANL region encompasses five vegetational cover types that reflect the associated changes in climatic conditions. These cover types are defined by their dominant tree species and by their structural characteristics as follows: juniper savannas, piñon-juniper woodlands, ponderosa pine forests, mixed conifer forests, and spruce-fir forests. In contrast, aspen forests, grasslands, shrublands, open water, and unvegetated lands are not primarily influenced by elevational and climatic gradients. Instead, they are controlled by topographic features, soils and geologic conditions, and moisture levels.

Juniper savannas. Landscapes along the Rio Grande from Frijoles Canyon (1634 m, 5360 ft) to Otowi Bridge (1681 m, 5513 ft) are primarily vegetated by the juniper savanna cover type. Juniper savanna communities also extend approximately to 1768 m (5800 ft) in the bottoms of adjacent canyons. One-seed juniper (*Juniperus monosperma*) is typically the only overstory species in the juniper savanna. Canopy coverage for this species typically ranges between 10 and 30 percent. Piñon (*Pinus edulis*) may also be present as scattered individuals.

Piñon-juniper woodlands. Although piñon-juniper woodlands can extend to as low as 1650 m (5500 ft) on protected topographic positions, they are the dominant, upland community type between 1740 and 2100 m (5800 and 7000 ft) in elevation (Balice et al. 1997). They also can be found as high as 2160 m (7200 ft) on south-facing exposures. The dominant tree species in piñon-juniper woodlands are one-seed juniper or piñon.

Ponderosa pine forests. Ponderosa pine forests extend to as low as 1860 m (6200 ft) in some of the protected canyons in the LANL region. At these lower extremities ponderosa pine forests intergrade with piñon-juniper woodlands. On the mesas and the lower slopes of the Sierra de los Valles, ponderosa pine forests extend to 2340 m (7800 ft) in elevation. They may also be found at higher elevations, up to 2610 m (8700 ft), on steep, south-facing slopes. Ponderosa pine (*Pinus ponderosa*) is the dominant tree species throughout the ponderosa pine cover type. One-seed juniper and piñon may also be present, particularly at lower elevations. At higher elevations, Douglas fir (*Pseudotsuga menziesii*) and Rocky Mountain juniper (*Juniperus scopulorum*) can be found in ponderosa pine forests.

Mixed conifer forests. Mixed conifer forests begin as intergrades with ponderosa pine communities and as stringers on north aspects of the canyons above 2070 m (6900 ft) in elevation. These communities continue to the highest elevations of the Sierras, 3149 m (10,496 ft). Douglas fir and white fir (*Abies concolor*) are the typical overstory dominants in mixed conifer forests. At elevations above 2700 m (9000 ft), Engelmann spruce (*Picea engelmannii*) becomes more important. Ponderosa pine and aspen (*Populus tremuloides*) are also typically present. Limber pine (*Pinus flexilis*) can also be found in mixed conifer forests, especially on rocky ridgeline positions.

Aspen forests. Aspen communities are common at mid-elevations in the mountains. They range in elevation from approximately 2700 to 3030 m (8900 to 9950 ft). Below 2820 m (9250 ft), aspen stands occupy north and northeast aspects, whereas above this elevation they are mostly found on southeast- to southwest-facing positions. Aspen is the dominant tree species in these forests. At higher elevations and on southerly aspects, aspen typically exceeds 45 percent coverage

and may be the only species present in the overstory. At lower elevations and on northerly aspects, white fir, Engelmann spruce, and Douglas fir may collectively contribute up to 30 percent of the overstory coverage. Depending on the fire history of the specific stand, other tree species, such as ponderosa pine and limber pine, may be common or rare.

Grassland. The vegetation in this cover type is dominated by grasses, grasslike plants, or by species that dominate in disturbed areas. Forbs and other nonshrubby species may be dominant components of these communities. Shrubs and trees are absent or rare. The grassland cover type consists of a wide range of communities, including successional fields that are undergoing post-fire revegetation, abandoned homestead areas, montane meadows, and subalpine grasslands.

Open water. This cover type includes all land that is at least periodically flooded or is open water. In the wettest of these sites, the vegetation cover is limited to plant species that require or prefer wet soil conditions. In general, these cover types are marshes, lakes, rivers, and streams.

Unvegetated land. This land cover type consists of all undeveloped land that is covered by less than 7 percent vegetation. Land surfaces are dominated by cobbles, boulders, bedrock, or bare ground. This includes tuffaceous cliffs, basalt cliffs, felsenmeers, and basalt talus.

4.0 Conclusions

A land cover map is an essential component to managing TES at LANL. For example, areas containing mixed conifer are important to Mexican spotted owls (*Strix occidentalus lucida*). This map is one input to a model which attempts to predict the location of habitat suitable for Mexican spotted owls. Models for peregrine falcon (*Falco peregrinus*) and bald eagle (*Haliaeetus luecocephalus)* will also be developed. The map's utility is not restricted to TES management. Fire management planning is using the map to distinguish forested from non-forested areas and guiding decisions on how many man-hours and how many dollars will be required to meet fire management goals. Environmental restoration projects are using the map in models on contaminant transport and cleanup.

4.1 Future Plans

Within the next few months, the different versions of this map will be evaluated for accuracy using error matrices as describe by Congalton (1991). The outcome of this assessment will help us determine if filtering out the small habitat regions improved the map. We will also assess the inclusion of a shrubland category. A large portion of the study area burned in 1996, but this map does not reflect this change in cover since the satellite imagery was acquired in 1992. The burned area will need to be updated.

4.2 Availability

The most recent version of the land cover map can be acquired from the principal author. It is in ArcInfo export format, as either a grid or polygon coverage.

Acknowledgments

Thanks to Craig Allen of USGS-Biological Resources Division for his datasets, Kay Beeley of Bandelier National Monument for coordinating data exchanges, Tom Garrison and Mike Blandford of the Facility for Information Management, Analysis and Display at LANL for Arc Macro Language programming and geographic information system support, the field crews led by Terry Foxx, Tim

Haarmann, Kathy Bennett, James Biggs, Gil Gonzales, John Huchton, David Keller, Eric Pacheco, Mary Salisbury, Leonard Sandoval, and Scott Ferran, and Belinda Gutierrez for manuscript editing.

Literature Cited

Balice et al. 1997: R. G. Balice, S. G. Ferran, and T. S. Foxx, "Preliminary Land Cover Classification for Los Alamos National Laboratory," Los Alamos National Laboratory report LA-UR-97-4627.

Congalton 1991: R.G. Congalton, "A Review of Assessing the Accuracy of Classification of Remotely Sensed Data," Remote Sensing of the Environment. 37:35–46.

ERDAS, Inc. 1994: ERDAS Field Guide.

Scott et al. 1993: J. M. Scott, F. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D'Erchia, T. C. Edwards, Jr., J. Ulliman, and R. G. Wright, "Gap Analysis: A Geographic Approach to Protection of Biological Diversity," Wildlife Monographs, No. 123, The Journal of Wildlife Management 57(1) supplement.