FUEL LOADS AND OVERSTORY CONDITIONS AT LOS ALAMOS NATIONAL LABORATORY, NEW MEXICO

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ABSTRACT

In the wake of the 1996 Dome Fire, Los Alamos National Laboratory (LANL) has been evaluating the fire hazards on its property and on adjacent lands in northern New Mexico. Modification of fire-return intervals through active fire suppression and passive forest management has allowed the creation of high-density forest stands above high surface fuel loads. Plots were established in pinyon-juniper woodlands, ponderosa pine forests, and mixed conifer forests to obtain fuel load data and determine whether correlation exists between fuel load and overstory condition. Fuel loads and fire hazards are low in the pinyon-juniper woodlands and in some of the ponderosa pine stands. In contrast, the mixed conifer forests support high fuel loads where stand density is high. These forests are prone to high-intensity, stand-replacing fires that easily move into adjacent forest communities, endangering the facilities and research programs at LANL. The results of this study are being used to guide prefire management activities in and around LANL.

keywords: crown density, fire management, fuel hazard, fuel load, New Mexico, pinyon-juniper, ponderosa pine, stand density.

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INTRODUCTION

As with most southwestern U.S. ecosystems, fire has historically been an integral part of the environment at Los Alamos National Laboratory and surrounding areas (Wright and Bailey 1980:195, 209). Although low-intensity wildland fires prior to 1890 were common, they did little damage to forest canopies. Since then, human activities such as logging, grazing, and fire suppression have changed the fire regime to such an extent that the natural fire cycle has been interrupted and the occurrence of high-intensity, canopy fires has increased (Allen 1989).

In 1890 the forest vegetation in the LANL region, like the rest of the Southwest (Cooper 1960, Covington and Moore 1994*a*), was characterized by a few large, widely scattered trees with few shrubs and small trees but abundant grasses and sedges. After 80 years of attempted fire exclusion, this landscape is now characterized by numerous closely spaced trees, ranging in size from small saplings to large individuals. The historic herbaceous ground cover has disappeared in many areas, shaded out by dense overstory.

The shift in fire regime from numerous, low-intensity fires to less frequent, high-intensity fires is exemplified by 3 large fires in recent decades. The Water Canyon Fire started in June 1954 from a trash fire (Lowell 1954). Driven by 72 kilometer-per-hour winds, a fire front nearly 1.6 kilometers wide burned out of control until the winds abated and fire intensities dropped to manageable levels >6.4 kilometers from the point of origin.

The La Mesa fire was first reported on 16 June 1977 (Foxx 1984). This human-ignited fire swept over 61,800 hectares of ponderosa pine forests before being subdued on 23 June.

The most recent fire, the Dome Fire, started from an abandoned campfire approximately 8 kilometers from the southwest boundary of LANL and was reported on 25 April 1996. Before being declared under control on 3 May, the fire burned 6,684 hectares of forest and threatened the southwestern portion of LANL.

Although none of these fires caused major damage on LANL property, facilities were threatened and LANL programs were interrupted (Balice et al. 1999). The threat of catastrophic fire still exists at LANL. We now recognize that the current vegetative mix is actually a threat to these facilities and reflects poor ecosystem health (Covington and Moore 1994*b*, Covington et al. 1997). An Interagency Wildfire Management Team was formed to coordinate the management and suppression of wildfires at LANL and surrounding areas, including the Santa Fe National Forest, Bandelier National Monument, and Los Alamos County. Initial activities, many of which have already begun, include the reestablishment of old fire breaks, construction of new fire breaks, a prescribed burn on one of the LANL sites, thinning of some forest stands (as suggested by Scott [1998]), and the upgrading of equipment (R.G. Balice, B.P. Oswald, and K.B. Kelly, Forest and Woodland Fuel Loads at Los Alamos National Laboratory, Annual Symposium of Biological Research in the Jemez Mountains, 1997).

The lack of quantitative data on fuel levels and vegetation structures in the forests and woodlands on, or adjacent to, LANL property has limited the development of effective strategies for reducing fuel hazards and protecting LANL property. We believe that the conditions of the forests and the woodlands could have a large effect on the wildfire hazards during the wildfire-prone season, which is from late April through June. The objective of this study was to inventory the vegetation and fuels at selected locations in and around LANL and to determine whether any correlations exist between fuel load and community condition.

STUDY AREA

LANL covers 11,200 hectares of land. It is located on the eastern slopes of the Jemez Mountains in north-central New Mexico, approximately 120 kilometers northwest of Albuquerque. LANL is bordered by the Santa Fe National Forest, Bandelier National Monument, San Ildefonso Reservation, and Los Alamos County lands. Two urban zones, Los Alamos and White Rock, are adjacent to LANL. This mosaic of land uses and management agencies creates a complex wildland-urban interface.

The overall study area covered an elevational gradient that began at the Rio Grande River at the eastern edge of LANL (1,631 meters) and rose to 3,199 meters at the western edge. The areas of interest for this study included the pinyon-juniper woodlands, ponderosa pine (*Pinus ponderosa*), and mixed conifer forests within LANL, ranging from 1,920 meters–2,743 meters in elevation.

The pinyon-juniper woodlands were the dominant community type between 1,768 meters and 2,134 meters (Foxx and Tierney 1980, Balice et al. 1997). These woodlands ranged from open-canopy to closed-canopy communities dominated by pinyon pine (*P. edulis*) and one-seed juniper (*Juniperus monosperma*). Within LANL, one-seed juniper was more abundant at lower elevations (adjacent to the juniper savannas), and pinyon pine dominated the higher elevations.

These woodlands were patchy communities with a variety of grasses and forbs dominating the understory. Mountain muhly (*Muhlenbergia montana*) and blue grama (*Bouteloua gracilis*) were typical understory dominants, with oaks (*Quercus gambelii* and *Q. undulata*) and mountain mahogany (*Cercocarpus montanus*) common shrub species.

The ponderosa pine forests in the LANL region extended from 1,890 meters to >2,377 meters in elevation on steep south-facing slopes. Although ponderosa pine was the dominant overstory species, pinyon-juniper encroached from below. Douglas-fir (*Pseudotsuga menziesii*) and Rocky Mountain juniper (*J. scopularum*) were found in areas where fire had not occurred for prolonged periods (Balice et al. 1997).

The understory in this zone was typically shrubby, with Gambel oak (*Q. gambelii*) and Colorado barberry (*Berberis fendleri*) common associates. Graminoid species included a variety of sedges (*Carex* spp.), blue grama, mountain muhly, little bluestem (*Scizachyrium scoparium*), and pine dropseed (*Blepharoneuron tricholepis*).

Mixed conifer forests began as intergrades within the ponderosa pine communities and continued to above 2,743 meters on eastern exposures (Foxx and Tierney 1980:25). Douglas-fir and white fir (*Abies concolor*) were typical overstory dominants, with ponderosa pine often present. Limber pine (*P. flexilis*) may be found on rocky sites.

These forests had an extremely variable understory. Shrubs, including ninebark (*Physocarpus monogynous*), kinnikinnik (*Arctostaphylos uva-ursi*), Gambel oak, wild rose (*Rosa woodsii*), mountain maple (*Acer glabrum*), and dwarf juniper (*J. communis*) were found with numerous herbs and graminoids. Sedges, nodding brome (*Bromus inermis*), and muttongrass (*Poa fendleriana*) were commonly found grasses and grass-like species (Balice et al. 1997).

FIELD METHODOLOGY

Plot Layout

In the first year of the 2-year project, 49 sample sites were subjectively chosen. The location of these sites was designed to span the pinyon-juniper woodlands, ponderosa pine forests, and mixed conifer forests within LANL. Each sample site was determined to be relatively homogenous with respect to vegetation structure, soils, and topography within a 61-meter-diameter area. The center of each site was marked and the Universal Transverse Mercator coordinates of this center were recorded with a global positioning system. The slope and aspect of each plot were also recorded.

From the center of each sample site, a series of 15.2-meter radiating lines was established. Using a compass to determine true north, the initial line location was determined. Fifteen subsequent lines were placed at 22.5-degree intervals in a clockwise direction radiating outward from the center point. To avoid excessive sampling at the center location, the odd-numbered lines were started at 3 meters and even-numbered lines at 10 meters from the center point.

Downed Woody Fuels and Duff Measurements

Fuel sampling followed the procedure described by Brown et al. (1982). To facilitate subsequent analysis, collected materials were subdivided into 1-hour (<0.6 centimeter), 10-hour (0.6–2.5 centimeter), 100-

Table 1. Mean fuel loads (kilograms per hectare) in forest communities. P-J = pinyon-juniper; Pipo = ponderosa pine; MC = mixed conifer communities. Downed woody = downed woody fuels; Total = total surface fuels (downed woody fuels, litter, and vegetation).

Community type	Downed woody (kilograms per hectare)	Total (kilograms per hectare)
P-J	20,033B[a]	25,342B
Pipo	31,257B	40,325B
MC	79,418A	90,936A

[a] Means with same letter within a column are not significantly different at the $P \leq 0.05$ level.

hour (2.6–7.6 centimeter) and 1,000-hour (>7.6 centimeter) fuels. Duff depths were measured at distances of 0.3 and 1.8 meters from the origin of each line. A ruler was used to measure the duff thickness to the nearest centimeter.

Tree Measurements

Trees were sampled in 0.1-hectare square plots. The diameters of trees <2.54 centimeters in diameter at 1.4 meters in height (DBH) were measured at ground level; all others were measured at DBH. Total heights were measured to the nearest meter and diameters to the nearest centimeter, and recorded to species.

Canopy cover of each plot was measured using a densiometer at the center of each 0.1-hectare plot. Four readings (facing the 4 cardinal directions) were made, and an average canopy cover was determined and recorded.

Litter and Vegetation Samples

Litter samples were evaluated within 4 0.3 × 0.6-meter rectangular plots along each sample line following Brown et al. (1982). One plot was located at 5 meters and another at 7 meters along each line. The remaining plots were placed at the same distance along the line, but at a perpendicular distance of 1.2 meters off the lines.

Once placement was completed, the litter and herbaceous non-woody vegetation (primarily grasses and forbs) were independently rated within each rectangular plot. The rectangle with the greatest amount of vegetation coverage was exhaustively sampled and the material placed in a labeled bag for drying and weighing. The plant biomass of the remaining rectangles was estimated as a percentage of the sampled rectangle.

To obtain litter samples, the above process was repeated in the same rectangles for litter. All estimated litter and vegetation percentages were recorded on data sheets.

LABORATORY AND STATISTICAL METHODOLOGY

The litter and vegetation samples were dried for 24 hours at 65°C and weighed. All data were entered into spreadsheet files. Fuel loads and numbers of trees were transformed to a per-hectare basis. These data were summarized for each of the 3 communities of interest (pinyon-juniper, ponderosa pine, mixed conifer).

Table 2. Mean fuel loads (kilograms per hectare [kg. per ha.]), trees (number per hectare [no. per ha.]), and canopy cover (%) by forest community type and topographic location. P-J = pinyon-juniper; Pipo = ponderosa pine; MC = mixed conifer communities.

Community type	Downed woody fuels (kg. per ha.)	Total (kg. per ha.)	Trees (no. per ha.)	Canopy (%)
PJ Canyons	16,092C[a]	19,331C	200B	12.4C
P-J Mesas	22,848C	29,635C	350B	21.8BC
Pipo Canyons	23,296BC	32,726C	196B	37.8B
Pipo Mesas	33,152BC	42,134C	289B	60.8A
MC Canyons	63,840B	77,302B	946A	73.0A
MC Mountains	98,112A	107,296A	934A	71.2A

[a] Means with same letter within a column are not significantly different at the $P \leq 0.05$ level.

The statistical analyses were conducted on an exploratory basis to determine general trends prior to additional sampling. The results were analyzed using PROC ANOVA and PROC CORR procedures in SAS Version 6 (SAS Institute Inc. 1990). PROC ANOVA (significance was set at $P \leq 0.05$) was used to determine whether significant differences existed in downed woody fuel loads (1-hour, 10-hour, 100-hour, 1,000-hour fuels) and total fuel loads (downed woody fuels, litter, and understory vegetation) among the 3 community types. ANOVA was also used to determine significant differences among overstory components of the 3 communities. Duncan's multiple-range test was used to identify where the significant differences occurred. During subsequent analyses, the ANOVA's will be replaced with MANOVA.

Pearson's correlation in PROC CORR was used to investigate the possible existence of correlation between overstory conditions (canopy cover, trees per hectare), topographic variables (slope, aspect), and fuel loads (downed woody, total).

RESULTS

A significant ($P \leq 0.05$) increase in downed woody fuels and total fuels was found between the 2 lower-elevation fuel types and mixed conifer forests (Table 1).

Separating the 3 communities by topographic condition (mesas and canyons for pinyon-juniper and ponderosa pine; canyons and mountains for the mixed conifer) showed the same significant trend for both downed woody and total fuel loads. Fuel loads in the mixed conifer community on the mountains were significantly greater than in any of the other communities (Table 2).

Both mixed conifer conditions supported significantly greater numbers of overstory trees than did the other communities. Canopy cover was also significantly greater on the mixed conifer and ponderosa

Table 3. Pearson correlation coefficients for significant ($P \leq 0.05$) relationships within forest community types. P-J = pinyon-juniper; Pipo = ponderosa pine; MC = mixed conifer communities; Downed Woody = downed woody fuels; Total = total surface fuels; Crown = canopy cover.

Community type	Variables	Coefficient
P-J	Downed Woody–Total	0.7245
Pipo	Downed Woody–Total	0.9587
MC	Downed Woody–Total	0.9962
P-J	Downed Woody–Crown	−0.1517
Pipo	Downed Woody–Crown	0.0915
MC	Downed Woody–Crown	0.0368
P-J	Total–Crown	0.0337
Pipo	Total–Crown	0.1234
MC	Total–Crown	0.0720

pine-mesa locations than in the other communities (Table 2).

Attempts to evaluate the effect of slope and aspect on fuel loads and overstory conditions produced significant differences, but we were unable to identify specific trends from these variables alone.

Evaluating the results from Pearson's correlation showed a very high correlation between the downed woody and total fuel loads (Table 3). The correlation between the fuel loads and canopy cover was very weak.

DISCUSSION

Fuel loads were found to increase from pinyon-juniper to ponderosa pine to mixed conifer. As in most pinyon-juniper communities in the Southwest, grazing by domesticated animals, coupled with fire exclusion practices, has resulted in reduced herbaceous vegetation and an increase in pinyon-juniper woody species densities (Wright and Bailey 1982:201). The low herbaceous growth in the pinyon-juniper community was reflected by the lack of a substantial difference between the downed woody and total fuel loads (on a percent basis) as compared to the ponderosa pine communities. The abundance of a variety of grasses and forbs in the more open ponderosa pine communities of the Southwest greatly contributes to the surface fuel base of these communities, allowing fire to move easily across the soil surface.

The high number of trees per hectare in the mixed conifer communities greatly reduced the amount of herbaceous growth. The tree density contributed to the proportionally (on a percentage basis) smaller increase in total fuel loads over the downed woody levels in these communities.

The mixed conifer communities in the canyons had significantly higher fuel loads than either the pinyon-juniper or ponderosa pine canyon communities (Table 2). The mixed conifers in the canyons were found on the cooler north and east aspects, which supported more tree growth and therefore greater downed woody fuel loads. The mountain mixed conifer communities are areas commonly hit by lightning strikes. With the dense stands and high fuel loads found in these communities, fires usually become crown fires and rapidly move into the lower mixed conifer and ponderosa pine communities.

Canopy cover (%) was not significantly different on the ponderosa pine communities found on mesas when compared to the mixed conifer communities but was significantly greater than on the ponderosa pine found in canyons or the pinyon-juniper communities. These mesa communities were found on loamier soils, which had greater water-holding capacity than the sandy canyon soils supporting ponderosa pine (Nyhan et al. 1978). While the Mesa ponderosa pine community did not have significantly different numbers of trees per hectare (289), compared to 196 in the canyons, these trees had larger crowns and the stands had fuller canopies.

The high correlation between downed woody fuels and total fuel loads found in these communities is common in the arid West, where fire is often the major ecological force. We believe the low correlation between canopy cover and fuel loads is influenced by the impact of slope and aspect on the vegetative communities, and therefore the characteristics of the overstory. Basal area, rather than canopy cover, may provide a more consistent and stronger correlation between fuels and overstory conditions.

CONCLUSIONS

The forested environments of LANL and surrounding areas present a unique wildland-urban interface situation. The series of canyons and mesas between and around high-value research facilities contain forests and woodlands prone to stand-replacing fires. Surrounding LANL are these same vegetative communities with similar fuel loads. Decades of fire suppression have created fuel loads that increase the chance of stand-replacing fires that will have catastrophic consequences for these ecosystems, the facilities of LANL, and the populated Los Alamos townsite.

Efforts have begun to reduce fuel loads through prescribed burning, and silvicultural activities such as thinnings have been initiated to reduce the number of trees in the dense mixed conifer forests of the canyons and mountains around LANL. Although fire cannot be removed from these ecosystems, the potential impact of these fires can be reduced through appropriate management, as well as through increasing the awareness of the potential danger of wildfire to the Los Alamos Region.

Additional sampling of the various communities in and around LANL and further analyses to evaluate the interaction of topographic features such as slope and aspect with fuel loads will be performed. This information will become an important tool with local land management agencies in preparing for the recurrence of fire in the forests and woodlands of the LANL and the surrounding region.

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LITERATURE CITED

Allen, C.D. 1989. Changes in the landscape of the Jemez Mountains, New Mexico. Ph.D. Dissertation, University of California, Berkeley.

Balice, R.G., S.G. Ferran, and T.S. Foxx. 1997. Preliminary land cover classification for the Los Alamos region. LA-UR-97-4627. Los Alamos National Laboratory, Los Alamos, NM.

Balice, R.G., B.P. Oswald, and C. Martin. 1999. Fuels inventories in the Los Alamos National Laboratory region; 1997. LA-13572-MS. Los Alamos National Laboratory, Los Alamos, NM.

Brown, J.K., R.D. Oberheu, and C.M. Johnston. 1982. Handbook for inventorying surface fuels and biomass in the interior West. General Technical Report INT-129, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Cooper, C.F. 1960. Changes in vegetation, structure, and growth of southwestern pine forest since white settlement. Ecological Monographs 30:129–164.

Covington, W.W., and M.M. Moore. 1994*a*. Changes in multiresource conditions in ponderosa pine forests since Euroamerican settlement. Journal of Forestry 92:39–47.

Covington, W.W., and M.M. Moore. 1994*b*. Post-settlement changes in natural fire regimes and forest structure: ecological restoration of old-growth ponderosa pine forests. Journal of Sustainable Forestry 2:153–181.

Covington, W.W., P.Z. Fulé, M.M. Moore, S.C. Hart, T.E. Kolb, J.N. Nast, S.S. Sackett, and M.R. Wagner. 1997. Restoring ecosystem health in ponderosa pine forests of the Southwest. Journal of Forestry 95:23–29.

Foxx, T.S. 1984. Description of the La Mesa Fire. Pages 3–6 *in* T.S. Foxx (compiler). La Mesa Fire Symposium. LA-9236-NERP, Los Alamos National Laboratory, Los Alamos, NM.

Foxx, T.S., and G.D. Tierney. 1980. Status of the flora of the Los Alamos National Environmental Research Park. LA-8050-NERP, Vol I. Los Alamos Scientific Laboratory, Los Alamos, NM.

Lowell, S. 1954. Wind pushes flames away from A-City. The Santa Fe New Mexican, June 6.

Nyhan J.W., L.W. Hacker, T.E. Calhoun, and D.L. Young. 1978. Soil survey of Los Alamos County, New Mexico. Informal Report, LA-6779-MS. Los Alamos Scientific Laboratory, Los Alamos, NM.

SAS Institute Inc. 1990. SAS/STAT Guide. Version 6 Edition. SAS Institute Inc., Cary, NC.

Scott, J. 1998. Reduce fire hazards in ponderosa pine by thinning. Fire Management Notes 58:20–25.

Wright, H.A., and A.W. Bailey. 1980. Fire ecology: United States and southern Canada. John Wiley and Sons, New York.