

Fire Management Over Large Landscapes: A Hierarchical Approach¹

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Abstract:

Management planning for fires becomes increasingly difficult as scale increases. Stratification provides land managers with multiple scales in which to prepare plans. Using statistical techniques, Geographic Information Systems (GIS), and meetings with land managers, we divided a large landscape of over 2 million acres (White Sands Missile Range) into parcels useful in fire management. Within this hierarchy, 8 fire management areas (FMA), with major roads or drainages forming boundaries, were identified. Within these FMAs were 106 burn units (BU) defined by natural or human fire breaks. BUs can be used as prescribed burn areas or maximum allowable perimeters for fires. An intermediate level was needed between these two units. Using cluster analysis of vegetation data, 22 fire management zones were identified. Using this hierarchy, a large-scale vegetation map, and GIS, we were able to incorporate simplistic risk models based on fuel models, topography, and sites of concern for natural resource managers. The resulting maps provide a landscape view of the fire risk to natural and human resources and allow land managers to take a heads up approach in preventative fire management.

Introduction

Fire has been a major factor influencing the ecology, evolution, and biogeography of many vegetation community structures (Humphrey 1974, Bock and Bock 1988, Ford and McPherson 1996). The semi-desert grasslands and shrublands of the Southwest have evolved with fires caused by lightning strikes since the Pleistocene (Pyne 1982). Fires have played an important role in maintaining grasslands while reducing shrub invasion (Valentine 1971). Vegetation in New Mexico has developed under a fire influence over the past 10,000 years (Betancourt and others 1990, Anderson and Shafer 1991). Today, a proliferation of extreme fires is evident, because moderate fires can be controlled and only those burning in severe conditions and under dangerous circumstances impact the landscape, causing the most damage (Baisan and Swetnam 1997). The impact on the ecosystem depends on the current biological and physical environment and past land use patterns (Ford and McPherson 1996).

Little was known about the fire ecology on White Sands Missile Range (WSMR) and the deserts of the southwestern United States. This paper presents the results of an analysis that used existing data and incorporated Geographical Information Systems (GIS) to facilitate fire management planning on WSMR, providing fire personnel with a landscape view of fire risk.

¹ An earlier version of this paper was presented at the 2002 Fire Conference: Managing Fire and Fuels in the Remaining Wildlands and Open Spaces of the Southwestern United States, December 2–5, 2002, San Diego, California.

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Study Area

White Sands Missile Range covers over 828,800 ha (2,210,117 ac) in south central New Mexico. Terrain includes steep, rocky mountains, steep to moderate footslopes, level to rolling grasslands, dunes, lava flows, and salt flats. The maximum elevation is 2,783 m at Salinas Peak. Rainfall typically occurs during the summer (July, August and September) as short, intense, localized storm events that account for 55 percent to 64 percent of the total annual precipitation (Barlow and others 1983). The intensity of rains generally results in massive runoff and very little infiltration, especially in steep areas and areas with exposed bedrock. Average precipitation varies from 200 mm in the basin to 400 mm in the mountains.

Methods and Results

Fire Management Units

The first step was to create fire management units that could be used within fire planning and fire management activities. Meetings were held with WSMR fire and environmental personnel to discuss creating fire management units. Through an iterative process we derived 106 zones based on roads and topography. These 106 zones were identified within four large geographic areas of the Range determined by the White Sands Fire Department (WS-ES-F). The center point for these four areas was roughly the middle of the range and corresponded to logistical constraints regarding response time.

These zone delineations were brought into a GIS (ArcView) by intersecting the appropriate digital elevation model (DEMs) derived contour lines, road, and stream coverages. The initial four areas were then differentiated into eight Fire Management Areas (FMA) after discussing terrain and response time with WSMR personnel. The four FMA's included lowland and mountain sites, with increased response times assumed for mountainous regions. The division into eight FMAs created four FMAs predominantly of lowland grassland and shrubland and four FMAs comprised of desert montane vegetation.

These two levels of fire management unit are useful, but because of the generality of the eight FMAs and the difficulty in placing management decisions on 106 Burn Units (BUs), an additional step in the hierarchy was developed. This unit allows analysis and management to be applicable at a scale that was beneficial for fire management planning. These intermediate fire management units (Fire Management Zones) were derived by conducting a cluster analysis using New Mexico Natural Heritage Program (NMNHP) land cover map. The area of the Level 2 community types from the within each BU were derived and used for the cluster analysis. Thus Fire Management Zones (FMZs) were created by the grouping of BUs with similar vegetation.

Fire Modeling

Modeling potential fire risk is dependent on basic coverages that include vegetation, slope, aspect, and natural and human created firebreaks. The vegetation can then be associated with particular fire behavior models. A rating model was derived for all coverages. Ratings were placed on the variables to allow a final score to be placed on each grid cell (Caprio and others 1998). Areas with increased potential for rate of spread, fuel loading, human structures, and sensitive biological communities were given higher weights and values. Ratings are presented in the

following paragraphs for each of the coverages used within that model. Cell ratings were then compared to identify relative risk of fire based on all coverages derived for this project that were applicable to fire risk. Attribute ratings ranged from 0 to 10.

Vegetation maps created by the New Mexico Natural Heritage Program (NMNHP) (Muldavin and others 1997) and the New Mexico Gap Analysis Project (NM-GAP) (Thompson and others 1996) were cross-walked by fire behavior fuel models (Albini 1976, Anderson 1982). The NMNHP mapped two levels of community corresponding to the alliance (34 types) and association (95 types) levels of the National Vegetation Classification System (NVCS) created by NatureServe (2002). The NM-GAP coverage mapped 19 types of vegetation to the formation level of the NVCS on or adjacent to WSMR. Because of the differing resolutions, all three vegetation maps were used for different analyses and modeling. The NMNHP maps are more detailed with greater accuracy and provide for more thorough analyses, but are limited to the boundary of WSMR. The NM-GAP map allows the incorporation of the adjacent lands into any analysis to bring a contextual aspect of fire ecology.

The standard fire behavior models (Anderson 1982) that were applicable to WSMR were identified by the main fuel component such as grass, shrubs, forest/woodland, or slash. Models were identified based on the hazard potential given with regards to WSMR and rated based on potential fire intensity (*table 1*).

Table 1. Classification of fuel models for fire risk modeling on White Sands Missile Range, New Mexico.

Fuel Model	Typical Description	Level 1 Classification	Rating
1	Short grass (1 ft)	Grama grass grasslands	2
2	Timber (grass and understory)	Ponderosa pine and Juniper savannas	2
3	Tall grass (2.5 ft)	Alkali Sacaton	2
5	Brush (2 ft)	Shrublands	4
6	Dormant brush, hardwood slash	Montane scrub and Interior Chaparral	4
8	Closed timber litter	Ponderosa Pine, Piñon pine with grass understory	8
9	Hardwood litter	Can be used for Piñon-Juniper areas such as those on the Oscura Mountains	8
No Fuel Model			0

Slope was derived from DEMs and reclassified based on associated risks ($<10^\circ=0$; 10 to $20^\circ=2$; 20 to $30^\circ=4$; 30 to $40^\circ=7$; $>40^\circ=10$). The aspect coverage was derived and reclassified based on associated risks (flat=0; SW,S,SE=2; W,E=6; NE, N, NW=10). On WSMR, many of the northeast-facing drainages along the mountains have high quantities of oak and other more mesic plant species that add to the fuel loading.

WS-ES-ES personnel identified biological and human resources of concern. These ranged from specific species (threatened, endangered, and sensitive) to habitats that are either limited in the southwest (e.g., riparian) or limited on WSMR (piñon-juniper community in Oscura Mountains). Human resources included existing structures and historical structures.

Habitats of concern included species-specific habitat pertaining to threatened, endangered, sensitive, and rare species and other habitat types. These habitat types include alkali sacaton (*Sporobolus airoides*); interior chaparral; piñon (*Pinus edulis*)-juniper (*Juniperus monosperma*) woodland of Oscura Mountains; ponderosa pine (*Pinus ponderosa*) at Salinas Peak; black grama grasslands (*Bouteloua eriopoda*); eastern valley grasslands of blue (*Bouteloua gracilis*) and hairy grama (*B. hirsuta*); juniper (*Juniperus monosperma*) encroachment in all grasslands; San Andres cactus community; cryptogamic soils; raptors on escarpments of mountains; wolf reintroduction areas; previous burn areas; springs and seeps; wetland habitats; and wildlife water units. These vegetation communities of concern were identified where possible from the New Mexico Natural Heritage Program land cover map. Specific areas such as the San Andres cactus community and cryptogamic soils are not identified because of lack of spatial data. All 3 land cover coverages were modified and concern communities labeled accordingly.

Point coverages of other biologically significant components were obtained including springs, seeps, and wildlife water units. Springs and seeps are important because these sites provide refugia for many wildlife species. These areas were buffered by 500 meters in order to clearly identify a defensible area. These polygons of buffers were then rasterized and each site given a rating of 10 for their ecological importance.

Similar to the biological points, point coverages of human components such as facilities, archeological sites, historical sites, and telephone poles were obtained. These point coverages were also buffered at 500 m to provide a defensible area and the polygons rasterized for inclusion into the modeling process. These areas were given a rating of 10.

Using grid coverages of each model variable previously discussed, we combined the grid values in an arithmetic overlay. This provided a value for each pixel based on the risk assessment of each input. After the initial model run, the slope and aspect variables were modified by multiplying the rating for slope by 1.5 and the rating of aspect by 0.5. This was done to eliminate an undue bias of the aspect modeling factor on model and give more importance to the slope factor. The model was run once for each of the three land cover coverages available.

Risk values for each model ranged from 3 to 45 out of a possible high 50. For fire management purposes we classified these risk values based on natural breaks in the data as identified within the GIS software. This provided three levels of relative fire risk with low (3 to 13), moderate (14 to 22), and high (23 to 45).

Conclusions

Fire Management Units

WSMR was stratified into fire management units at three geographical scales to aid in the future development of a fire management plan. These units allow scale appropriate management strategies to be put into place. FMAs are large areas with major roads or drainages acting as the boundaries. FMZs are areas within these FMAs that were delineated based on ecological factors (e.g., vegetation, topography) as well as incorporation of some fire management and WSMR infrastructure logistical constraints such as roads and firebreaks. BUs are the smallest units and can be used for prescribed burns because either natural or human created firebreaks

generally surround them. These BUs can also be utilized as the maximum allowable perimeter for wildfires.

Stratification by FMA, FMZ and BU provides a level of detail for fire management. On WSMR, one can view the number of endangered, threatened, rare, and sensitive species that occur within the fire management units, thus providing a planning level tool for prescribed fires and other ecological needs. Through this process it was identified that the habitat for 41 species could occur within one FMA. Similar analysis can be done with springs and associated riparian areas. Two FMZs had the overwhelming number of springs with 110 and 73. The number of wildlife water units or other biologically significant sites can also be analyzed and that information brought into fire planning

Fire Modeling

The fire risk modeling provides a relative risk ranking for the entire landscape of WSMR using a scale from 3 to 45, with higher numbers having a higher risk for intensive burning and extreme fire behavior. The resulting grids can be used with a multiple number of classifications depending on the needs of the fire managers. I presented these based on three levels of classification based on natural breaks within the data. This classification was normalized over all three grids to present a comparison of the models in regards to the spatial scales.

Plant communities and fuels are based on the NMNHP land cover maps. Basing fuel behaviors and fuel loadings on these remotely sensed land cover maps can be problematic. Remotely sensed data generally do not distinguish between high and low fuels loads. The purpose of these maps is to present communities. Therefore determination of fuel loading, fire behavior, and risk assessment using these coverages must be viewed as the average of that variable associated with that community type. This study presents fire ecology at a landscape level, and even at the most refined scale (Burn Unit) fuel loadings are quite variable, as are plant communities. It is difficult to quantify fuels in these large areas because of variability and cannot be discussed adequately without going into more site-specific detail.

Risk models will change through time as natural and human fire breaks change and military missions change the landscape of WSMR. Also fires, natural or management ignited, will change the community types that were modeled. Using the standard model created for this project and modifying it through time will allow this model to remain dynamic.

The risk models validate many concerns expressed by WSMR personnel during meetings. The piñon-juniper communities in the Oscura Mountains were identified as concern areas because of the threat of a stand replacement fire. Risk models at each thematic scale indicate that this area is at a relatively higher risk than most of the range. Although WSMR personnel drove some aspects of the modeling, it should be viewed as independent because of the additional variables included within modeling.

Overall

Fire plays a major role in many of the vegetation communities that occur on White Sands Missile Range. These communities on WSMR are structurally different from similar communities in the Southwest because of the accumulation of fine fuels and high densities of closed canopy piñon woodlands. The impact of fire suppression on these fuel loads on WSMR cannot be determined because comprehensive historical fire suppression documentation is not available. Historical reports that do

exist indicate that many fires were actively attacked, but the degree and success in which those fires were observed, located, and controlled is unknown.

The information generated by this study and the fire management plan will enable WSMR to strengthen their fire management program. The products derived from this work can be used in conjunction with the LCTA monitoring program that provides baseline and postfire data to evaluate and understand the fire program and its ecological context within the Southwest.

The fire modeling and risk assessment conducted in this study provides basic spatial information for management decisions regarding fires. The fire management units (fire management areas, fire management zones, and burn units) provide a method for stratification of these management decisions.

Finally, any fire management of a large area such as WSMR must take into account the boundary of that parcel with private, state and federal landowners. Fires near these boundaries take on further complications as management and suppression response should be reviewed with those individuals or entities. A landscape approach such as presented here can identify the initial threats to such a fire and provide fire managers with tools for effective communication and management should that occasion arise.

Acknowledgments

Special thanks are extended to the White Sands Missile Range Environment and Safety Directorate (WS-ES), for development of the project, financial support, data and input, particularly to Dr. David Anderson (WS-ES-ES) and Chief Larry Burns (WS-ES-F). This work was part of the a larger project “The Ecology of Fire on White Sands Missile Range, New Mexico: Implications for Fire Management” completed by the New Mexico Cooperative Fish and Wildlife Research Unit submitted through U.S.G.S. Biological Resources Division. Research performed under U.S.G.S. Cooperative Agreement 14-34-HQ97-RU-01572, Research Work Order No. 18.

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