USDA United States
Department
of Agriculture

Forest Service

**Rocky Mountain
Research Station**

General Technical
Report RMRS-87

April 2002

Development of Coarse-Scale Spatial Data for Wildland Fire and Fuel Management

Kirsten M. Schmidt
James P. Menakis
Colin C. Hardy
Wendel J. Hann
David L. Bunnell

Abstract

Schmidt, Kirsten M.; Menakis, James P.; Hardy, Colin C.; Hann, Wendel J.; Bunnell, David L. 2002. **Development of coarse-scale spatial data for wildland fire and fuel management.** Gen. Tech. Rep. RMRS-GTR-87. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 41 p. + CD.

We produced seven coarse-scale, 1-km^2 resolution, spatial data layers for the conterminous United States to support national-level fire planning and risk assessments. Four of these layers were developed to evaluate ecological conditions and risk to ecosystem components: **Potential Natural Vegetation Groups**, a layer of climax vegetation types representing site characteristics such as soils, climate, and topography; **Current Cover Type**, a layer of current vegetation types; **Historical Natural Fire Regimes**, a layer of fire frequency and severity; and **Fire Regime Current Condition Class**, a layer depicting the degree of departure from historical fire regimes, possibly resulting in alterations of key ecosystem components.

The remaining three layers were developed to support assessments of potential hazards and risks to public health and safety: **National Fire Occurrence, 1986 to 1996**, a layer and database of Federal and non-Federal fire occurrences; **Potential Fire Characteristics**, a layer of the number of days of high or extreme fire danger calculated from 8 years of historical National Fire Danger Rating System (NFDRS) data; and **Wildland Fire Risk to Flammable Structures**, a layer of the potential risk of wildland fire burning flammable structures based on an integration of population density, fuel, and weather spatial data.

This paper documents the methodology we used to develop these spatial data layers. In a Geographic Information System (GIS), we integrated biophysical and remote sensing data with disturbance and succession information by assigning characteristics to combinations of biophysical, current vegetation, and historical fire regime spatial datasets. Regional ecologists and fire managers reviewed and refined the data layers, developed succession diagrams, and assigned fire regime current condition classes. “Fire Regime Current Conditions” are qualitative measures describing the degree of departure from historical fire regimes, possibly resulting in alterations of key ecosystem components such as species composition, structural stage, stand age, canopy closure, and fuel loadings. For all Federal and non-Federal lands, excluding agricultural, barren, and urban/developed lands, 48 percent (2.4 million km^2) of the land area of the conterminous United States is within the historical range (Condition Class 1) in terms of vegetation composition, structure, and fuel loadings; 38 percent (1.9 million km^2) is moderately altered from the historical range (Condition Class 2); and 15 percent (736,000 km^2) is significantly altered from the historical range (Condition Class 3). Managers can use these spatial data to describe regional trends in current conditions and to support fire and fuel management program development and resource allocation.

Keywords: current conditions, fire regimes, fuel management, fire occurrence, potential natural vegetation, cover type, GIS, wildland-urban interface

You may order additional copies of this publication by sending your mailing information in label form through one of the following media. Please specify the publication title and series number.

Fort Collins Service Center

Telephone (970) 498-1392
FAX (970) 498-1396
E-mail rschneider@fs.fed.us
Web site http://www.fs.fed.us/rm
Mailing Address Publications Distribution
Rocky Mountain Research Station
240 West Prospect Road
Fort Collins, CO 80526

Rocky Mountain Research Station
240 West Prospect Road
Fort Collins, CO 80526

Authors

Kirsten M. Schmidt is a Resource Information Specialist with the USDA Forest Service at the Rocky Mountain Research Station, Fire Sciences Laboratory, P.O. Box 8089, Missoula, MT 59807; Phone 406-329-4957; FAX 406-329-4877; e-mail: kschmidt@fs.fed.us. She has worked on several research projects for the Fire Effects Research Unit involving GIS analysis and field sampling for ecosystem management, gradient modeling, and fire behavior and effects modeling. She received her B.A. degree in biology from the University of Montana, Missoula, and is pursuing her Ph.D. degree in remote sensing from the University of Montana.

James P. Menakis is a GIS Specialist with the USDA Forest Service at the Rocky Mountain Research Station, Fire Sciences Laboratory, P.O. Box 8089, Missoula, MT 59807; Phone 406-329-4958; FAX 406-329-4877; e-mail: jmenakis@fs.fed.us. Since 1990, he has worked on various research projects relating to fire ecology at a community and landscape level for the Fire Effects Research Unit. He was the GIS Coordinator for the Landscape Ecology Team for the Interior Columbia River Basin Scientific Assessment Project, and was involved with mapping FARSITE layers for the Gila Wilderness and the Selway-Bitterroot Wilderness. He received his B.S. degree in forestry and his M.S. degree in environmental studies from the University of Montana, Missoula.

Colin C. Hardy is a Supervisory Research Forester in the Fire Effects Research Work Unit, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT 59807. He is Team Leader for Landscape Analysis and Assessment, with emphasis on remote sensing applications. His earlier work involved the characterization of smoke from wildland fires. He holds a B.S. degree in resource conservation from the University of Montana, School of Forestry, and an M.S. degree in forest management from the University of Washington, College of Forest Resources. He is currently pursuing a Ph.D. degree in remote sensing at the University of Montana, School of Forestry.

Wendel J. Hann is a Fire/Landscape Ecologist for the USDA Forest Service, Washington Office, Fire and Aviation Management, Pike-San Isabel National Forests, Leadville, CO 80461; Phone 719-486-3214; FAX 719-486-0928; e-mail: hann@amigo.net. Since 1998, his primary responsibilities have been in national ecosystem and fire risk assessment, technology development and transfer, and land management planning and implementation. He was a member of the Interior Columbia Basin Science Team and Lead for Landscape Assessment at the Pacific Northwest Research Station. He worked for the Northern Region of the Forest Service in the Ecosystem Management Group, developing and implementing ecological and fire management applications. He taught ecology at the University of Idaho and served in the U.S. Navy for 4 years. He received a B.S. degree in range and wildlife management, and an M.S. degree in forest and watershed science from Washington State University, Pullman, and a Ph.D. degree in forest, wildlife, and range ecology from the University of Idaho, Moscow.

David L. Bunnell is the National Fire Use Program Manager with the USDA Forest Service at the National Interagency Fire Center (NIFC), 3833 S. Development Ave., Boise, ID 83705; Phone 208-387-5218; FAX 208-387-5398; e-mail: dbunnell@fs.fed.us. He started his career in the Forest Service as a seasonal Fire Guard, Biological Technician, Forestry Technician, and Research Technician in Alaska and Montana. From 1972 to 1978, he worked in wilderness fire planning, fire effects, and physical fuel properties. He was a Forest Fuel Specialist at the Lolo National Forest where he assisted in the early development of aerial ignition devices, prescribed fire planning, and economic risk considerations of prescribed fire applications. He was Fire Staff, Wildlife and Fisheries Staff, and Fire and Ecology Staff Officer on the Flathead National Forest, working in interagency centralized dispatch and on implementation of prescribed natural fire policy in wilderness areas. As National Fuel Specialist at NIFC, his responsibilities included prescribed fire applications and fire policy implementation. In 1999, he became the National Fire Use Program Manager with responsibilities in prescribed fire applications and wildland fire use. He received a B.S. degree in forestry from the University of Montana.

Development of Coarse-Scale Spatial Data for Wildland Fire and Fuel Management

Kirsten M. Schmidt
James P. Menakis
Colin C. Hardy
Wendel J. Hann
David L. Bunnell

Rocky Mountain Research Station
USDA Forest Service
Fire Sciences Laboratory
P.O. Box 8089
Missoula, MT 59807
Phone: (406) 329-4957, FAX: (406) 329-4877

USDA Forest Service
General Technical Report RMRS-GTR-87.
April 2002

Contents

Development of Coarse-Scale Spatial Data for Wildland Fire and Fuel Management

Kirsten M. Schmidt
James P. Menakis
Colin C. Hardy
Wendel J. Hann
David L. Bunnell

INTRODUCTION

Over 90 years of fire exclusion, grazing by domestic livestock, logging, and widespread establishment of exotic species have altered fire regimes, fuel loadings, and vegetation composition and structure (Barrett and others 1991; Brown and others 1994; Ford and McPherson 1999; West 1994; Whisenant 1990). As a result, the number, size, and intensity of wildfires have been altered (U.S. GAO 1999; Vail 1994). Fire managers recognize the need to reduce excessive fuel accumulations to decrease the threat of catastrophic wildfires (USDA Forest Service 2000), but lack national-level spatial data to support management plans to reduce fuels as well as to conserve and restore ecosystems. To accomplish fire and fuel management goals, managers need answers to the following questions:

- How do current vegetation and fuels differ from those that existed historically?
- Where on the landscape do vegetation and fuels differ from historical levels? In particular, where are high fuel accumulations?
- When considered at a coarse scale, which areas estimated to have high fuel accumulations represent the highest priorities for treatment?

The objective of this study was to provide managers with national-level data on current conditions of vegetation and fuels developed from ecologically based methods to address these questions.

This mapping effort was initiated as two associated projects under the auspices of the Fire Modeling Institute at the Fire Sciences Laboratory, Rocky Mountain Research Station, Missoula, MT. The first project, *Fire Regimes for Fuels Management and Fire Use*, began in 1997 through an agreement with the U.S. Department of Agriculture, Forest Service (USFS), State and Private Forestry, and USFS Fire and Aviation Management. The second project, *Ecosystems at Risk*, was undertaken to add a fire-related component to the USFS's Forests at Risk project. The Joint Fire Sciences Program subsequently funded these two projects to develop several additional spatial data layers (in other words, coverages, a set of thematic data, usually representing a single subject matter). In the context of these projects, risk was defined as "the relative risk of losing key components that define an ecosystem."

We mapped fire regime current condition classes and historical fire regimes using the methodology of assigning ecosystem characteristics to combinations of biophysical and vegetation spatial data layers. "Biophysical data" describes physiographic and ecological characteristics of the landscape. "Fire Regime Current Conditions" are qualitative measures describing the degree of departure from historical fire regimes, possibly resulting in alterations of key ecosystem components such as species composition, structural stage, stand age, canopy closure, and fuel loadings. One or more activities may have caused this departure: fire exclusion, timber harvesting, livestock grazing, introduction and establishment of exotic plant species, introduced insects and disease, or other management activities. The advantages of the methodology of assigning ecosystem characteristics to combinations of biophysical and vegetation spatial data layers include the familiarity that many land managers have with biophysical and vegetation classifications, the large body of research that utilizes this methodology, and the applicability of this methodology to multiple spatial scales. Quigley and others (1996) used a biophysical layer, potential vegetation, and two vegetation layers, cover type and structural stage, to describe ecosystem characteristics such as fuel characteristics, wildlife habitat, fire potential, and hydrology. Keane and others (1998, 2000) used a similar suite of biophysical and vegetation layers to assign fuel characteristics to the Selway-Bitterroot Wilderness, Montana, and the Gila Wilderness, New Mexico.

To assess fire regime current conditions, we needed a baseline of conditions from which to compare. A critical data layer developed to assess current conditions and departure from historical conditions was the "Historical Natural Fire Regimes" layer. Fire regimes describe historical fire conditions under which vegetation communities have evolved and have been maintained (Hardy and others 1998). Historical natural fire regime data are not exact reconstructions of historical conditions, defined here as conditions existing before extensive pre-Euro-American settlement (pre-1900), but rather reflect typical fire frequencies and effects that evolved in the absence of fire suppression (Hardy and others 1998). We used fire frequency and severity measures to determine departure from historical conditions, a context necessary to construct succession diagrams and assign fire regime current condition classes. Regional ecologists and fire managers assigned current condition classes to succession diagrams for combinations of potential vegetation type, current cover type, forest density, and historical fire regime spatial data. Managers will use the spatial data from this project to allocate resources to maintain or restore areas to historical conditions.

Scale and Use of Data

The objectives of this mapping project were to provide national-level data on the current condition of fuel and vegetation. Therefore, the data are most useful at that scale. The end products were not intended to be used at scales other than a coarse scale. While aggregating spatial data from fine scales to coarse scales is a well-documented practice, converting coarse scale data to finer scales is not recommended (Bian 1997; Bian and Butler 1999; Turner and others 1989; Weins 1989). The large cell size (1-km^2) combined with the coarse map scale (approximately 1:2,000,000) of these data products provide appropriate detail when viewed in their entirety or at a regional scale, but details expected at finer scales will be lacking. Zhu and Evans (1992) explicitly stated that the “end products are not intended to be absolute or precise in terms of accuracy in minute detail. It is the regional perspective and analysis that are most important in using the maps.” This statement addresses the appropriate use of the Resource Planning Act’s Forest Type Groups and Forest Density layers, two of the primary data layers used to develop our products. Our data products carry the same qualification.

METHODS

Data Layer Development

This section describes the methods used to develop the seven fuel management spatial data layers. Five of these seven layers were the result of integrating and modifying several pre-existing vegetation and biophysical spatial data layers:

- **Potential Natural Vegetation Groups,** a spatial layer of climax vegetation types representing site characteristics such as soils, climate, and topography.
- **Current Cover Type,** a spatial layer of current vegetation types.
- **Historical Natural Fire Regimes,** a spatial layer of fire frequency and severity.
- **Fire Regime Current Condition Class,** a spatial layer depicting the degree of departure from historical fire regimes, possibly resulting in alterations of key ecosystem components.
- **Wildland Fire Risk to Flammable Structures,** a spatial layer of the potential risk of wildland fire burning flammable structures based on an integration of population density, fuel, and weather spatial data.

In addition to the five vegetation and biophysical layers, two additional layers were developed to support assessments of potential hazards and risks to public health and safety:

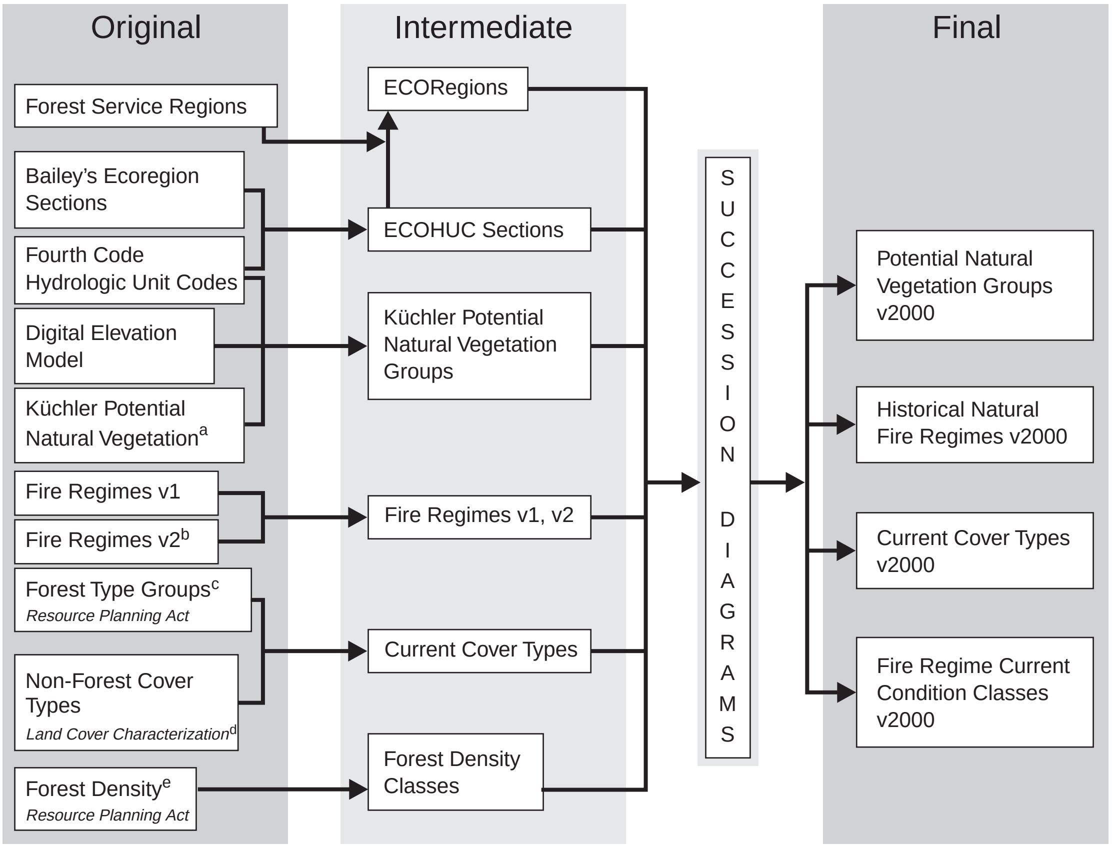
- **National Fire Occurrence,** 1986 to 1996, a spatial layer and database of Federal and non-Federal fire occurrences.
- **Potential Fire Characteristics,** a spatial layer of the number of days of high or extreme fire danger calculated from 8 years of historical National Fire Danger Rating System (NFDRS) data.

Four steps were used to develop the five vegetation and biophysical layers (Potential Natural Vegetation Groups, Current Cover Types, Historical Natural Fire Regimes, and Fire Regime Current Condition Classes):

1. Integrate multiple spatial data layers.
2. Regional experts develop succession diagrams.
    Transfer spatial data to succession diagrams.
    Assign relative departure index.
    Assign current condition classes.
3. Map spatial data layers from succession diagrams.
4. Review and refine final maps.

Vegetation and Biophysical Data Layer Development

1. Integrate multiple data layers—We integrated and modified several pre-existing spatial data layers, Bailey’s Ecoregion Sections (Bailey and others 1994), Fourth Code Hydrologic Units (HUC) (Seaber and others 1987), USFS regional boundaries, a Digital Elevation Model (DEM) (USGS 1994), Küchler’s Potential Natural Vegetation map (1975), earlier versions of fire regime maps, Forest and Range Resource Planning Act’s (RPA) layer of U.S. Forest Types Groups (Zhu and Evans 1992,1994; Powell and others 1992) for forest cover types, the Land Cover Characteristics Database (Loveland and others 1991) layer for nonforest cover types, and the RPA Forest Density layer, to derive final vegetation and biophysical layers (fig. 1). We developed six intermediate layers, two (ECOHUC and ECORegion) of which were not final products but were used to partition the landscape into coarse biophysical units (fig. 1). Three of the intermediate layers (Potential Natural Vegetation Groups, Current Cover Types, and Historical Natural Fire Regimes) were modified in the succession diagram process detailed below to become the final layers (fig. 1). The last intermediate layer (Forest Density Classes) was used in the succession diagram process, but was not a final layer (fig. 1). All working and final spatial data layers were converted to 1-km^2 pixel raster layers and projected to the Lambert



[a] Küchler 1975.
[b] Hardy and others 1998.
[c] Zhu and Evans 1992, 1994.
[d] Loveland and Ohlen 1993.
[e] Zhu 1994.

Figure 1—Flow diagram of spatial data layer development. ECOHUC Sections are Bailey's Ecoregion Sections (Bailey and others 1994) adjusted to Fourth Code Hydrologic Unit Codes (Seaber and others 1987). ECORegions are Forest Service regions merged with ECOHUC Sections.

Azimuthal Equal Area projection. Selection of pre-existing spatial data layers was based on immediate availability and continuity of data for the lower 48 States.

ECOHUC Sections—The first intermediate spatial data layer (fig. 1), ECOHUC Sections, partitioned the conterminous United States data layer into 165 relatively homogenous physiographic units of climate, vegetation, landform, and soils, following watershed, or Fourth Code HUC, boundaries. Because original Bailey's **Eco**region Sections (Bailey and others 1994) did not conform to any mapable features on the landscape such as watershed boundaries, we modified the Bailey's **Eco**region Section vector layer with the Fourth Code **HUC** vector layer (Seaber and others 1987), replacing Section lines with HUC lines (fig. 2). Bailey's Sections are the fourth level in Bailey's Ecoregion system, a hierarchical biophysical system based on climate, vegetation, landform, and soils. Ecoregions are widely used to describe ecological units in geographic analysis and planning (McNab and Avers 1994). Hydrologic units are a hierarchical system developed by the U.S. Geological Survey that divides the United States into multiple levels: regions, subregions, accounting units, and cataloging units (Seaber and others 1987). Cataloging units, also called watersheds, are equivalent to HUCs and delineate river basins with drainage areas usually greater than 1,800 km^2.

ECORegions—The next intermediate spatial data layer (fig. 1), **Eco**logical **Region**al Boundaries (ECORegions), divided the national-scale data into partitions containing each of the eight USFS regions for the development workshops that were structured around each region. Original USFS regional boundaries primarily followed State borders. To register the regional boundary layer with our first stratification layer, ECOHUC Sections, we delineated ECORegions by merging adjacent ECOHUC Sections within each USFS region to roughly the same area as the original region (fig. 3).

Küchler Potential Natural Vegetation Groups—The third intermediate layer (fig. 1) was the Küchler Potential Natural Vegetation Groups biophysical layer. We used Küchler's (1975) Potential Natural Vegetation (PNV) map of climax vegetation types that represent site characteristics such as soils, climate, and topography. Küchler (1964) defined

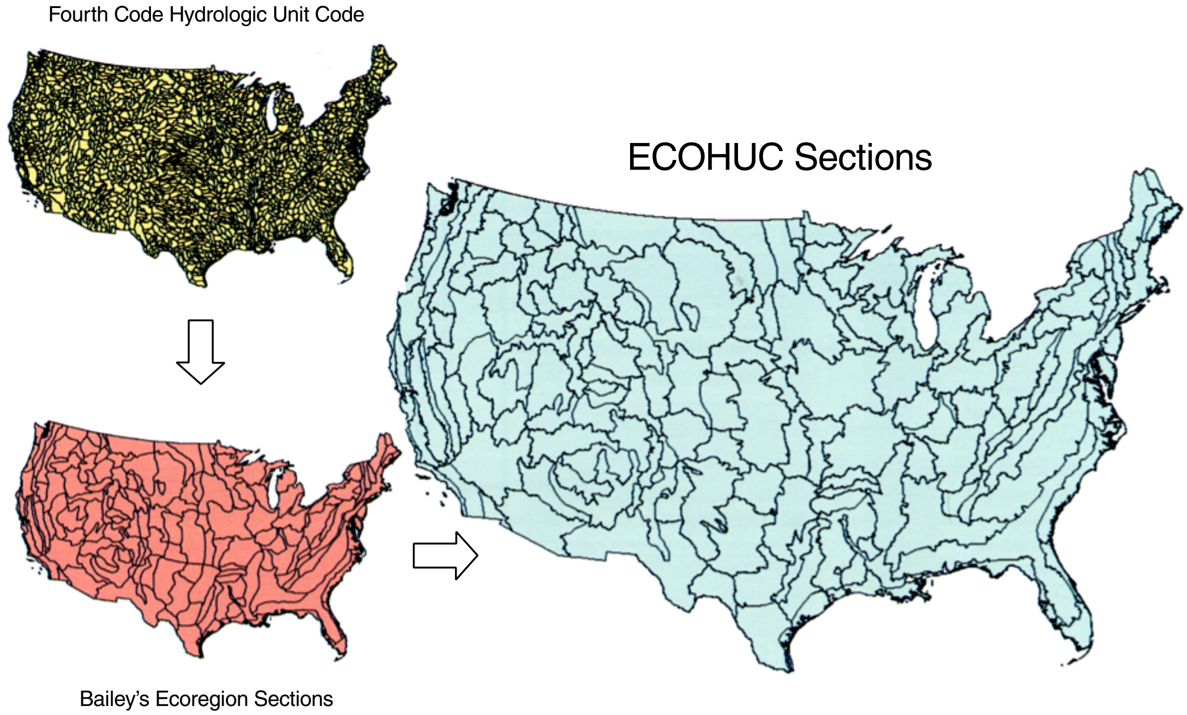


Figure 2 – ECOHUC Sections were developed by modifying Bailey's **Eco**region sections (Bailey and others 1994) with Fourth Code **H**ydrologic **U**nit **C**odes (Seaber and others 1987).

potential natural vegetation as (1) vegetation that would exist without human interference and (2) vegetation that would exist if the resulting plant succession were projected to its climax condition while allowing for natural disturbance processes such as fire.

We digitized the 1:3,168,000 scale, Küchler PNV map (1975), for the conterminous United States and then converted it to a 1-km^2 raster map. To make the Küchler PNV map useful in a spatial and modeling context, we adjusted the coarse Küchler PNV polygons to match topographic features and watershed delineations. We made these adjustments by using DEM and Fourth Code HUC spatial data.

We first created topographic classes of elevation and slope based on a 500-m DEM (USGS 1994). The continuous DEM data were reclassified into 50-m-elevation classes for the Western States (USFS Regions 1 through 6) and 10-m-elevation classes for eastern USFS Regions 8 and 9. Various elevation class breaks were tested for the Eastern and Western United States to best fit the original continuous elevation data. Fifty-meter-elevation classes best represented the high-relief topographic gradients of the Western United Staes. Ten-meter classes best represented the low-relief topographic gradients of the East. We increased the pixel size of the DEM data from 500 m^2 to 1 km^2 to match the pixel size of the other layers.

Slope classes were divided into two classes: (1) less than or equal to 5 percent slope to differentiate flat areas and (2) greater than 5 percent slope. These two slope classes were used to differentiate grassland and agricultural areas from forested or wooded areas. The elevation and slope class layers were then combined with the Fourth Code HUC watershed delineation layer to create a "HUC Terrain" grid. To build the terrain-matched Küchler PNV layer, we assigned the modal PNV to each of these HUC Terrain combinations.

Next, we aggregated the original 118 Küchler PNVs into 63 Küchler PNV Groups classes based on similar vegetation types to reduce the number of combinations in the succession diagram mapping process (appendix A). We reclassified grass and shrub lifeforms into the Forest-Range Environmental Study ecosystem classification (Garrison and others 1977) by using assignments in the Fire Effects Information System (Fischer and others 1996). For example, we grouped several of the forested PNVs based on similar forest types, grouping Küchler PNVs Western ponderosa pine forest, Eastern ponderosa forest, and Black Hills pine forest into one PNV, Pine Forest (see appendix A for a complete list of groupings by USFS region).

<u>Historical Natural Fire Regimes</u> —The fourth intermediate layer (fig. 1) was a combination of two earlier versions of fire regime spatial data. Fire regime data provided reference conditions against which current conditions can be compared. We modified Heinselman's (1981) seven fire regimes, which are defined by return interval and fire intensity, into five fire regimes defined by fire frequency and severity.

Fire frequency is the average number of years between fires. Severity is the effect of the fire on the dominant overstory vegetation, which can be forest, shrub, or herbaceous vegetation. Low-severity fires are fires in which more than 70 percent of the basal area and more than 90 percent of the canopy cover of the overstory vegetation survives (Morgan and others 1996).

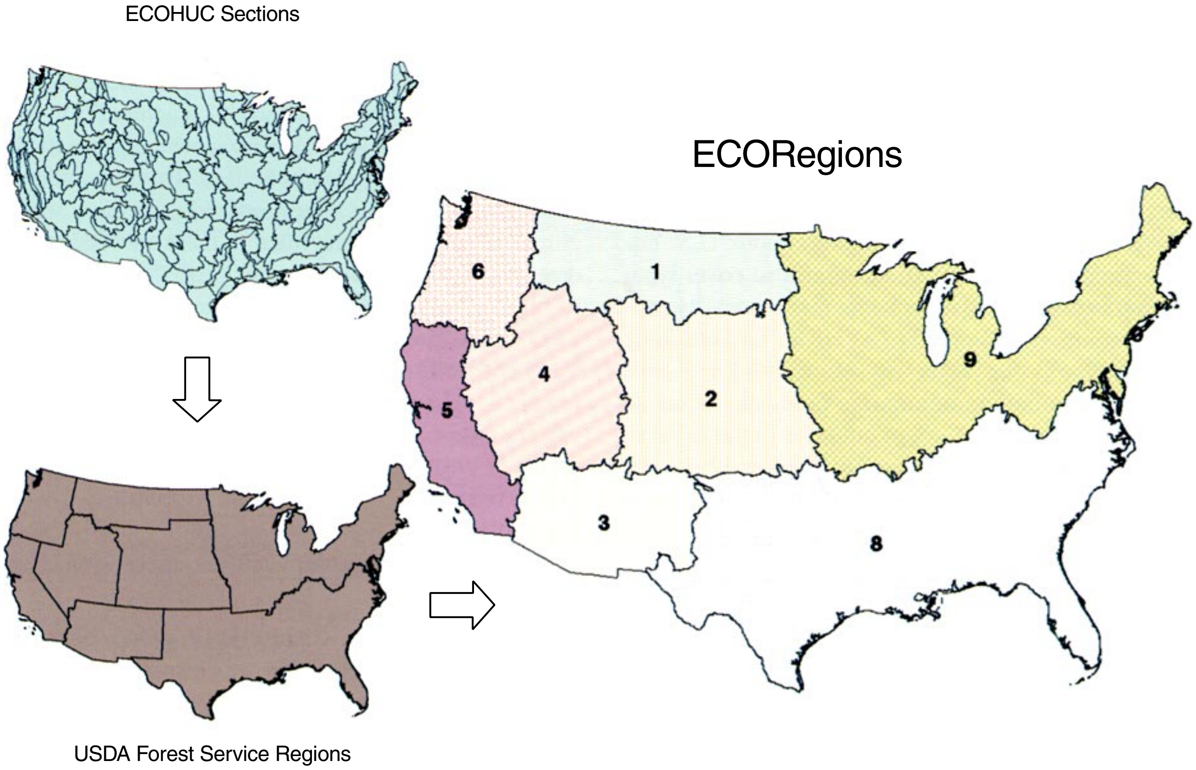


Figure 3—Ecological **Region**al Boundaries (ECORegions) were developes by modifying U.S. Forest Service regional boundaries with ECOHUC Sections (Bailey's **Eco**region sections and Fourth Code **H**ydrologic **U**nit **C**odes).

Mixed-severity fires are fires that result in moderate effects on the overstory, cause mixed mortality, and produce irregular spatial mosaics resulting from different fire severities (Smith and Fischer 1997). Stand-replacement fires consume or kill more than 80 percent of the basal area or more than 90 percent of the overstory canopy cover (Morgan and others 1996).

Our classification system includes five historical fire regimes (table 1). Fire Regime I (0- to 35-year frequency, low severity) is found primarily in forests that experience frequent, low-severity, nonlethal surface fires. Fire Regime II (0- to 35-year frequency, stand-replacement severity) is found primarily in grass and shrublands. Because fire consumes the dominant aboveground vegetation in the form of grasses or shrubs, fire severity is considered to be stand replacing regardless of the plants' response to fire (Brown 1994). Fire Regimes III (35- to 100+ year frequency, mixed-severity), IV (35- to 100+ year frequency, stand-replacement severity), and V (200+ year frequency, stand-replacement severity) can occur in any vegetation type.

Table 1—Historical natural fire regimes.

Code	Description
I	0–35-year frequency[a], low severity[b]
II	0–35-year frequency, stand-replacement severity
III	35–100+ year frequency, mixed severity
IV	35–100+ year frequency, stand-replacement severity
V	200+ year frequency, stand-replacement severity

[a] Fire frequency is the average number of years between fires.
[b] Severity is the effect of the fire on the dominant overstory vegetation.

The first version of the Historical Natural Fire Regimes data layer was a prototype developed for the conterminous United States, using expert knowledge to assign fire regimes to General Land Cover Classes (Loveland and Ohlen 1993). For the second version, we integrated expert knowledge, remote sensing, and biophysical data to map fire regimes (Hardy and others 1998) for the 11 conterminous Western States, from Washington south to California, east to New Mexico, and north to Montana. For the first two versions, we used a methodology similar to that used by Brown and others (1994), who integrated site characteristics, habitat types, topographic attributes, and vegetation to map fire regimes for the Selway-Bitterroot Wilderness of Montana.

A database of historical fire regimes by Küchler PNV groups was developed to assist expert panels in mapping Historical Natural Fire Regimes and to resolve mapping conflicts that occurred among adjacent USFS regions. The database was built by querying the Fire Effects Information System (Fischer and others 1996). All literature citations used to assign historical fire regimes were included in the database.

Current Cover Types—The fifth intermediate layer (fig. 1) was the Current Cover Type layer (appendix B). We used two existing remote sensing vegetation data layers to develop an integrated Current Cover Type layer: (1) the Forest and Range Resource Planning Act's layer of U.S. Forest Type Groups (Powell and others 1992; Zhu and Evans 1992, 1994) for forest cover types and (2) the Land Cover Characteristics Database (Loveland and others 1991; conterminous U.S. land cover characteristics dataset 1990) for nonforest cover types. Both data layers were derived from 1-km^2 resolution Advanced Very High Resolution Radiometry (AVHRR) satellite imagery. The Forest Type Groups layer was selected for forest cover types because it was based on intensive field data. Also, descriptions of the Forest Type Groups could be found in *Forest Resources of the United States* (Powell and others 1992). Forest types were also cross-referenced with the Society of American Foresters' *Forest Cover Types of the United States and Canada* (Eyre 1980).

In 1992, the USFS Southern Forest Experiment Station, Forest Inventory and Analysis Unit, developed a layer of forest types of the United States under the Forest and Rangeland Renewable Resources Planning Act (RPA) (Powell and others 1992; Zhu and Evans 1992, 1994). Because the Forest Type Groups layer represented only forested areas, we used the nonforest cover types of the Land Cover Characterization Database (Loveland and others 1991), to fill in the remaining nonforested areas.

In the development of the Western States fire regime layer described above, Hardy and others (1998) used the 26 General Land Cover Types (GLCTs) (Loveland and Ohlen 1993) aggregated from the 159 Land Cover Characterization Classes, expanding one of the classes, Western Coniferous Forest, into three subclasses: short-needle conifer, long needle conifer, and mixed short- and long-needle conifer. We combined the Hardy and others (1998) GLCT layer with the Forest Type Groups layer to produce an intermediate cover type layer. All nonforest areas of the Forest Type Groups layer were replaced with forest GLCTs.

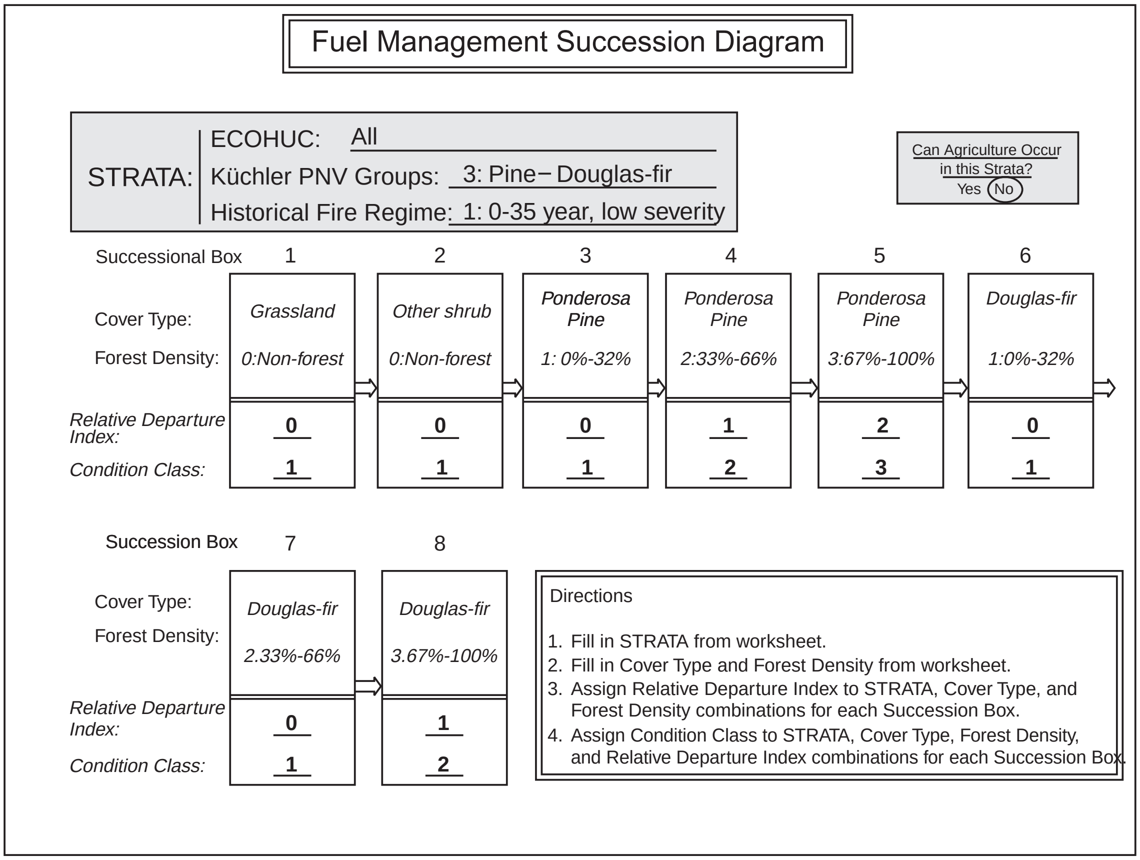
Forest Density Classes—The last intermediate layer (fig. 1) was a classification of forest density developed for the 1992 RPA assessment. We used this forest density data as a surrogate for forest structure because no spatial layer of forest structure for the conterminous United States existed and it was beyond the scope of this project to develop such a product. The layer was developed from several regression analyses between coregistered 1991 AVHRR data and classified LANDSAT Thematic Mapper data (Zhu 1994). Forest density was defined as the proportion of 28.5-m^2 LANDSAT Thematic Mapper cells per 1-km^2 AVHRR cell that was forested (Zhu 1994). We classified the continuous forest density values, which ranged from 0 to 100 percent, into four density classes: 0 = nonforest, 1 = 0 to 32 percent, 2 = 33 to 66 percent, and 3 = 67 to 100 percent. All nonforest cover types were assigned the nonforest density class.

2. Develop succession diagrams—Succession diagrams (fig. 4) were used to map fire regime current conditions as well as to refine all the input spatial data layers. Regional experts, during workshops held in 1999 and 2000 at the Fire Laboratory in Missoula, MT, developed succession diagrams for each combination of ECOHUC, Küchler PNV groups, and Historical Natural Fire Regimes, which we call STRATA, within their ECORegion boundary. The succession diagram consists of a series of boxes ordered from early seral through climax. Regional experts filled in these succession boxes with data provided in summary reports generated in a Geographic Information System (GIS) by combining the following layers: ECOHUCs, Fire Regime, Küchler PNV groups, Current Cover Type, and Forest Density within an ECORegion boundary (appendix C). The succession diagram is a very simplified version of the successional pathway diagrams described by Keane and others (1996); they differ in that they lack the multiple pathways, real-time intervals, and probability links among vegetation types.

Regional experts completed the succession diagrams in three steps:

1. The ECOHUC, Küchler PNV group, cover type, and forest density information was transferred from the summary report generated by combining all input layers in the GIS to the STRATA section of the succession diagram. The experts assigned historical fire regimes at this time. If they wanted to map combinations that did not occur in the report or remap a specific area, they filled in the succession diagrams with classes other than those provided by the reports. For example, all Pine PNV groups within a given ECOHUC could be combined into a single Pine-Douglas-fir PNV group.

2. The experts assigned a relative departure index (RDI) to each succession box in the succession diagram based on the STRATA, cover type, and forest density data. The relative departure index reflects either vegetation composition (cover type and density) and fuel loadings within historical ranges or it reflects changes in these attributes due to the cumulative effects of fire exclusion, livestock grazing, logging, establishment of exotic plant species, introduced insects or diseases, or combinations of these disturbances. Relative departure index values range from 0 to 3, with a value of 0 indicating that the cover type and density class combination for that specific succession diagram's STRATA are within the historical range. A value of 3 indicates that the cover type and density class combination for that specific succession diagram's STRATA is cumulatively three fire return interval increments from its historical conditions. For example, in figure 4, the first three succession boxes were assigned an RDI of 0, indicating that the current cover types and forest density classes assigned in each succession box could occur in a Pine-Douglas-fir PNV group and a Fire Regime I (0- to 35-year frequency, low severity). Succession box 4 was assigned an RDI of 1 because the cover types and forest density combination was one increment removed from the vegetation composition of the third succession box. The combination of a ponderosa pine current cover type and a forest density class 2 (33 to 66 percent)



Fuel Management Succession Diagram

STRATA:
ECOHUC: All
Küchler PNV Groups: 3: Pine–Douglas-fir
Historical Fire Regime: 1: 0-35 year, low severity

Can Agriculture Occur in this Strata? Yes [✓ No]

Successional Box	1	2	3	4	5	6
Cover Type:	*Grassland*	*Other shrub*	*Ponderosa Pine*	*Ponderosa Pine*	*Ponderosa Pine*	*Douglas-fir*
Forest Density:	*0:Non-forest*	*0:Non-forest*	*1: 0%-32%*	*2:33%-66%*	*3:67%-100%*	*1:0%-32%*
Relative Departure Index:	**0**	**0**	**0**	**1**	**2**	**0**
Condition Class:	**1**	**1**	**1**	**2**	**3**	**1**

Succession Box	7	8
Cover Type:	*Douglas-fir*	*Douglas-fir*
Forest Density:	*2.33%-66%*	*3.67%-100%*
Relative Departure Index:	**0**	**1**
Condition Class:	**1**	**2**

Directions

1. Fill in STRATA from worksheet.
2. Fill in Cover Type and Forest Density from worksheet.
3. Assign Relative Departure Index to STRATA, Cover Type, and Forest Density combinations for each Succession Box.
4. Assign Condition Class to STRATA, Cover Type, Forest Density, and Relative Departure Index combinations for each Succession Box.

Figure 4—Succession diagram example. Fields filled out in *italics* indicate information provided by summary reports (appendix C). Fields filled out in **bold** indicate information filled in by regional experts.

could not have occurred unless at least one fire return interval was missed. Succession box 5 was assigned an RDI of 2 because the combination of a ponderosa pine current cover type and a forest density class 3 (67 to 100 percent) was one increment from succession box 4, which was assigned an RDI of 1.

3. Once the relative departure index was assigned, the regional experts completed the succession diagram by assigning a fire regime current condition class (table 2), which was based on the STRATA, species composition, forest density, and RDI found in each succession box. For example, succession box 4 (fig. 4) was assigned Current Condition class 2, indicating that the ecosystem components have been moderately altered from historical conditions due to the disturbances mentioned above.

3. Map spatial data layers from succession diagrams—All succession diagram assignments and changes were loaded into a database containing all STRATA, current cover types, and forest density combinations within the ECORegion boundaries and linked to a master spatial layer. This database also contained changes made to the cover type, potential natural vegetation groups, and fire regime layers completed during the succession diagram development. We generated new spatial data layers of historical natural fire regime, Küchler PNV groups, current cover types, and current condition classes for each ECORegion from the master spatial layer and database, then merged all ECORegions to create the conterminous United States layers of Potential Natural Vegetation Groups, Current Cover Types, Historical Natural Fire Regimes, and Current Condition Classes (appendix G).

4. Review and refine final maps—The final steps in the development of the vegetation-based data layers involved sending the maps produced from the workshops to the regional experts for review and refinement. Maps included their ECORegion boundary and the surrounding regions, allowing the experts to review how their assignments compared to other regions.

The final step in the editing process was to resolve edge effects among ECORegion boundaries. Edge effects resulted from different groups of experts making layer assignments, causing disagreement between adjacent region boundaries. Edge effects were resolved by one or more of the following steps: (1) literature review of the Fire Effects Information System, (2) expert knowledge of a specific area, or (3) majority opinion of regional experts from two or more ECORegions.

Table 2—Fire Regime Current Condition Class[a] descriptions.

Condition class	Fire regime	Example management options
Condition Class 1	Fire regimes are within an historical range, and the risk of losing key ecosystem components is low. Vegetation attributes (species composition and structure) are intact and functioning within an historical range.	Where appropriate, these areas can be maintained within the historical fire regime by treatments such as fire use.
Condition Class 2	Fire regimes have been moderately altered from their historical range. The risk of losing key ecosystem components is moderate. Fire frequencies have departed from historical frequencies by one or more return intervals (either increased or decreased). This results in moderate changes to one or more of the following: fire size, intensity and severity, and landscape patterns. Vegetation attributes have been moderately altered from their historical range.	Where appropriate, these areas may need moderate levels of restoration treatments, such as fire use and hand or mechanical treatments, to be restored to the historical fire regime.
Condition Class 3	Fire regimes have been significantly altered from their historical range. The risk of losing key ecosystem components is high. Fire frequencies have departed from historical frequencies by multiple return intervals. This results in dramatic changes to one or more of the following: fire size, intensity, severity, and landscape patterns. Vegetation attributes have been significantly altered from their historical range.	Where appropriate, these areas may need high levels of restoration treatments, such as hand or mechanical treatments, before fire can be used to restore the historical fire regime.

[a] Fire Regime Current Condition Classes are a qualitative measure describing the degree of departure from historical fire regimes, possibly resulting in alterations of key ecosystem components such as species composition, structural stage, stand age, canopy closure, and fuel loadings. One or more of the following activities may have caused this departure: fire suppression, timber harvesting, livestock grazing, introduction and establishment of exotic plant species, introduced insects or disease, or other management activities.

Version 2000—After the release of all the data products in November 1999, some inconsistencies were found across ECORegional boundaries because the data were compiled separately for each ECORegion. To eliminate these inconsistencies, we conducted another series of workshops in the summer of 2000 with participants from adjacent ECORegions who repeated the steps described above. For Version 2000 products, succession diagram assignments were made to ECOHUC sections (average size 2,400 km^2) instead of to ECORegions (average size 970,000 km^2) as was done for the first versions. Once all refinements were incorporated into the master database and GIS, final Version 2000 spatial data layers (appendix G) were completed.

Supplementary Data Layer Development

Three additional spatial data layers were developed that were not directly associated with the biophysical and vegetation-based layers. Development of these supplementary layers was in response to risk assessment needs identified both in the Joint Fire Sciences Program funding agreement and in the USFS's Forests at Risk project charter. In contrast to the focus on ecological conditions and risks to ecosystem components inherent in the biophysical and vegetation-based layers, the three supplementary layers were developed specifically to support assessments of potential hazards and risks to public health and safety. These include an 11-year National Fire Occurrence database, a Potential Fire Characteristics layer, and a layer expressing Wildland Fire Risk to Flammable Structures. The layers are based on syntheses of historical fire and weather data and their associated fire-related indices. These layers provide the probability component of a formal risk assessment, and can be used as such by agencies or administrative units.

National fire occurrence, 1986 to 1996—The National Fire Occurrence database and GIS coverage (appendix G) is a GIS database of natural and human-caused fire occurrences for the years 1986 to 1996. It includes Federal data from the USDA Forest Service and four Department of the Interior (DOI) agencies: Bureau of Land Management (BLM), Bureau of Indian Affairs (BIA), National Park Service (NPS), and U.S. Fish and Wildlife Service (FWS). It also includes non-Federal data from all conterminous States except Nevada (appendix D).

Federal Fire Occurrence Database—The USDA Forest Service administrative units submitted fire occurrence data to the national database, which is called the National Interagency Fire Management Integrated Database (NIFMID) (USDA

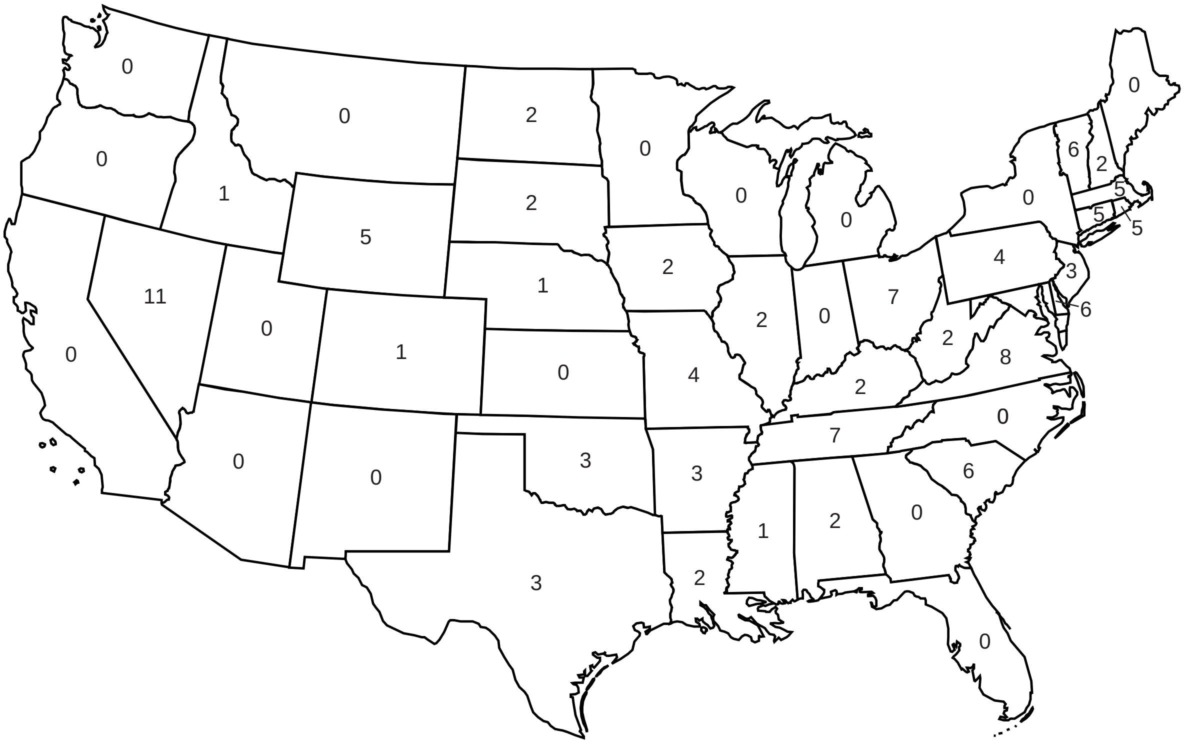


Figure 5—Number of years missing from non-Federal fire data for the 11-year period, 1986 to 1966.

Forest Service 1993), located at the USDA National Information Technology Center in Kansas City, MO. USDA Forest Service data were extracted from NIFMID for USFS Regions covering the conterminous United States (USFS Regions 1 through 6, 8 and 9) for the years 1986 to 1996. A GIS coverage was generated from the latitude-longitude coordinates, and database attributes were adjusted to conform to database items chosen for this project (appendix E).

Department of the Interior Agencies submitted fire occurrence data to the common Shared Applications Computer System, located at the National Interagency Fire Center in Boise, ID. We obtained new data directly from the DOI central database in October 1999 and worked closely with the FWS to summarize appropriate fire types and acreages. These new data were used in the final product. A GIS coverage was generated from the database's latitude-longitude coordinates, recorded in the database to the nearest second.

We performed several processing steps on both the USFS and DOI layers. We removed incorrectly recorded latitude or longitude coordinates from the USFS and DOI databases. Records from these databases were removed that contained data not needed for this analysis, such as pre-1986 data and records of false alarms. In addition, a GIS layer of State boundaries was overlaid with the point layers to identify those points that did not occur within the recorded State. If the point occurred further than 10 km from the nearest State boundary to which it was assigned, or if the point occurred within 10 km of the State boundary but was not recorded as being in the adjacent State, it was removed from the GIS database.

Non-Federal Fire Database—Non-Federal fire records were received from all lower 48 States except Nevada, which was composed primarily of Federal land. The quality and completeness of the data received varied by State (appendix F). Many States did not have complete fire records for each of the 11 years from 1986 through 1996 (fig. 5). In this case, we used only the years with complete data. For nine States that lacked digital fire data, data were obtained from the National Fire Incident Reporting System (NFIRS) database.

We received non-Federal fire locations in a variety of formats. Fire records that were provided in a GIS format or with latitude-longitude or Universal Transverse Mercator (UTM) coordinates were imported directly into the GIS. Fire locations recorded as legal descriptions (township, range, section) were converted to section centers. State records that had county as the most precise fire location were assigned the center of the county as the fire location.

Data for two States, Colorado and Missouri, were processed differently than the other States. We received fire records from Colorado in a GIS format, which contained both State and Federal fires. Because it was not possible to trace the records to their original agency source, the layer was overlaid with an ownership layer and only those records falling on non-Federal lands were kept as the non-Federal GIS coverage. Missouri provided fire records with both legal descriptions and county as the best location. Those records with legal descriptions were converted to the center of the section and appended to the State point coverage. Those with county as the best location were included in the county GIS database.

Table 3—National Fire Incident Reporting System (NFIRS) fire data and State Foresters' review data, 1987 to 1996 summaries.

State	NFIRS		State reviews	
	Total number of fires	Total km^2 (acres)	Total number of fires	Total km^2 (acres)
Alabama	168	Not reported	51,973	2,372 (586,208)
Kentucky	1,191	Not reported	16,903	2,707 (668,813)
Louisiana	3,206	Not reported	43,362	2,168 (535,631)
West Virginia	6,294	Not reported	12,720	3,932 (971,664)

Records from the NFIRS database were used for States from which we were unable to obtain data directly. Because participation in NFIRS is voluntary, the database does not represent all wildland fires within the State within a given time period. After attempting to contact State Foresters from each of the nine States for which only NFIRS data were available, State Foresters from Kentucky, Louisiana, Alabama, and West Virginia responded with reviews. The NFIRS data were determined to be an inadequate representation of State fire occurrence (table 3). All States with NFIRS data were given a status of unsatisfactory, but were included in the database as the only available data (appendix F).

Potential fire characteristics—The Potential Fire Characteristics layer, Version 1999 (appendix G), is a spatial representation of the number of days of high or extreme fire danger calculated from 8 years of historical National Fire Danger Rating System (NFDRS) data. The basis for the Potential Fire Characteristics layer is the Burning Index (BI), which was developed to assess containment problems at a fire's flaming front. Burning Index describes the magnitude of the fire containment problem in the context of coarse-scale, nonspecific fire potential (Andrews and Rothermel 1981). The fire potential interpretations shown in table 4 can be applied to corresponding BI values. These flame length classes and interpretations are familiar to fire managers and are widely accepted as an intuitive communications tool. Fires with flame lengths exceeding 8 feet present serious control problems such as torching, crowning, and spotting. Control efforts at the head of such fires are mostly ineffective, and major runs can occur in more extreme cases. Therefore, the 8-foot flame length threshold was selected for this project to indicate high or extreme fire potential.

National Fire Danger Rating System data characterize the near worst-case scenario of fire danger or potential for fires that could occur during a specific time period, and are intended for mid- to large-scale applications. Deeming and others (1977) note that "fire-danger rating areas are typically greater than 100,000 acres. Weather is observed and predicted for one specific time during the day at one specific location." The 1978 NFDRS indices are used throughout the lower 48 States to guide fire management planning activities (Deeming and others 1977). The primary NFDRS indices include Spread Component, Energy Release Component, and Burning Index (Bradshaw and others 1983).

The flame length inputs to the Potential Fire Characteristics map layer were derived from 180 days of interpolated BI data (April to September) for each of 8 years (1989 to 1996). Each daily map layer was individually processed in two steps:

1. Area-weighted mean BI values were calculated and summarized to Fourth Code HUC polygons (fig. 6).

2. Area-weighted mean BI values for each Fourth Code HUC were categorized into three potential flame length categories: less than or equal to 4.0 ft, 4.1 to 8.0 ft, and greater than 8.0 ft. Figure 7a shows the weighted-average data layer and the three flame length categories (fig. 7b) for April 1, 1991.

Table 4—Fire potential interpretations for four flame length classes. Potential flame length is calculated as BI/10.

Burning index	Flame length feet	Fire potential interpretation
≤40	≤4.0	Fires can generally be attacked at the head or flank by persons using handtools. Handline should hold the fire.
41–80	4.1–8.0	Fires are too intense for direct attack on the head by persons using handtools. Handline cannot be relied on to hold fire. Equipment such as plows, dozers, pumps, and retardant aircraft can be effective.
81–110	8.1–11.0	Fire behavior may present serious control problems such as torching out, crowning, and spotting. Control efforts at the head of the fire will probably be ineffective.
>110	>11.0	Crowning, spotting, and major runs are probable. Control efforts at the head of the fire are ineffective.

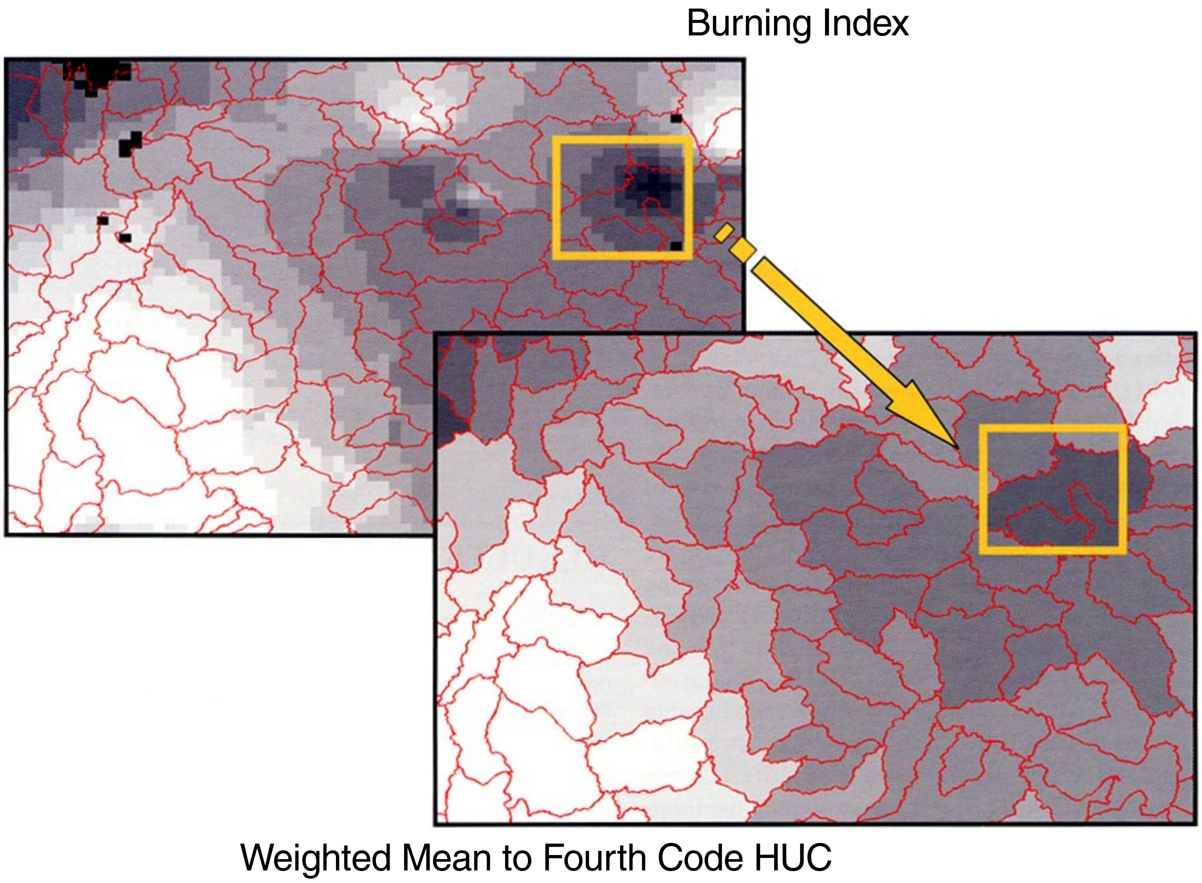
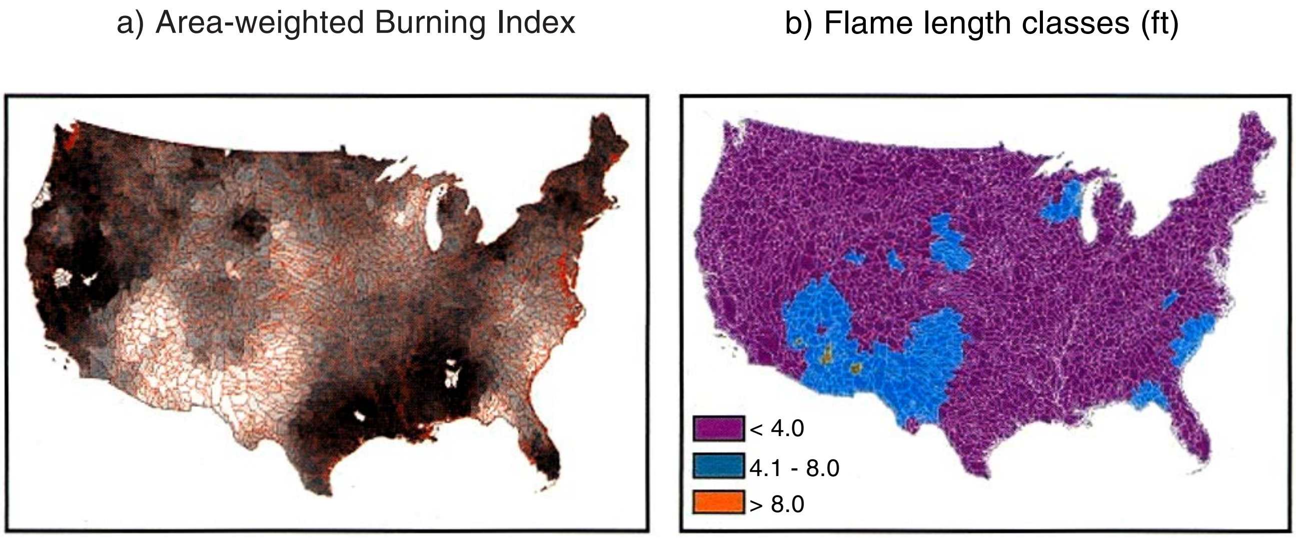


Figure 6—Area-weighted mean Burning Index values were calculated for each Fourth Code HUC, as shown in this example for April 1, 1991. In this procedure, each daily raster layer is converted to weighted-average polygon data.


a) Area-weighted Burning Index

b) Flame length classes (ft)

Figure 7—Area-weighted mean Burning Index data layer (a) and the three flame length classes (b) for April 1, 1991.

After each daily map layer was processed for a given year, the annual number of days that potential flame length exceeded 8 feet was counted for each sub-basin. Finally, the maximum annual number of days when 8-foot flame lengths were exceeded was determined for each sub-basin from the 8 years of data. The resulting map is Potential Fire Characteristics, Version 1999 (appendix G).

Wildland fire risk to flammable structures—The threat of wildland fire to homes is a significant concern for Federal, State, and local land management agencies (Cohen 2000). Wildland fires have destroyed 8,925 homes from 1985 to 1994 (USDA 2000). The growing human population along with shifting demographics from urban to rural areas is increasing the concentration of houses adjacent to or embedded in wildlands, resulting in escalated risk of human life and private property loss from catastrophic wildfire (USDA 2000). To identify these problem areas, we created a map of the potential risk of wildland fire burning flammable structures based on an integration of population density, fuels, and weather spatial data for the conterminous United States (appendix G). For this product, we defined risk as the potential of wildland fire burning numerous houses in a single event. In physical terms, a wildland-urban interface fire occurs when a wildfire is close enough for its flames and/or firebrands to contact the flammable parts of a structure. Although recent research shows that the potential for residential ignition is usually determined by a home's exterior materials, design, and immediate surrounding conditions rather than by wildland fire behavior in surrounding lands (Cohen 2000), our analysis assumes that all homes are highly ignitable and flammable. Our national map portrays areas at risk of wildland fire burning flammable structures and will provide land managers with a tool for evaluating this increasing problem.

We integrated several spatial database layers in the GIS to map the potential risk of wildland fire burning flammable structures. The Potential Fire Exposure layer was created by first combining Potential Natural Vegetation Groups and Current Cover Types data layers and then assigning these combinations to severe fire behavior classes that produced similar fire or heat intensity. We created an Extreme Fire Weather Potential data layer by calculating the average number of days per year when historical weather conditions had exceeded thresholds and wildfires had burned structures. Weather conditions included temperature, relative humidity, and wind. To create the Housing Density layer, we reclassified the LandScan Global Population 1998 database, developed by Oak Ridge National Laboratory (Dobson and others 2000), into classes of housing density per hectare (assuming the average household contained three people per house) and assigned a risk rating to each class (table 5). By combining these data layers, we produced a matrix used to assign classes of potential risk of wildland fire burning flammable structures. A complete description of the methods used to develop Wildland Risk to Flammable Structures can be found in Menakis and others (in preparation).

Table 5—Risk rating of wildland fire burning flammable structures by houses per hectare and houses per acre.

Risk rating	Houses per hectare	Houses per acre
None	No houses	No houses
Very low	0.01–0.49	0.01–0.20
Low	0.50–2.48	0.21–1.0
Moderate	2.49–4.94	1.01–2.0
High	4.95–12.36	2.01–5.0
High/city	12.37–24.71	5.01–10.0
City	24.72+	10.01+

RESULTS

Vegetation and Biophysical Data Layers

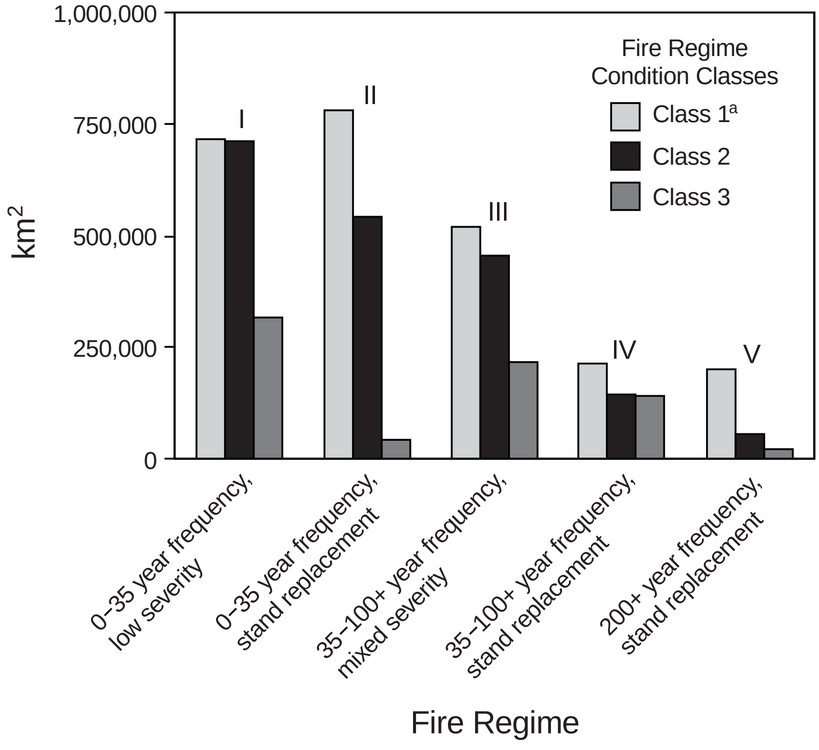
For all Federal and non-Federal lands, excluding agricultural, barren, and urban/developed lands, 48 percent of the land area of the conterminous United States is within the historical range (Condition Class 1) in terms of fuel loadings and vegetation composition and structure; 38 percent is moderately altered from the historical range (Condition Class 2); and 15 percent is significantly altered from the historical range (Condition Class 3) (table 6). Sixty-one percent of the conterminous United States historically experienced frequent fires (every 0 to 35 years) (table 6). Fire Regime I (0- to 35-year frequency, low severity) is primarily composed of forested lands, while Fire Regime II (0- to 35-year frequency, stand replacement) is primarily grass and shrublands. The moderately frequent Fire Regimes III and IV (35- to 100-year frequency) comprise 34 percent of the conterminous United States; these fire regimes are composed of both forest and shrublands. The highest proportion of area for all ownerships occurs in Fire Regimes I (34 percent) and II (27 percent) (fig. 8).

Fire Regimes I and II occupy nearly all the lower elevations across the United States and have been most affected by human intervention (Barbour and Billings 1988; Hann and Bunnell, in press; Wright and Bailey 1982). Forty-one percent of the area in Fire Regime I is within its historical range, while 59 percent is altered from the historical range. Fifty-seven percent of the area in Fire Regime II is within its historical range, while 43 percent is altered from the historical range (table 6). Typical types represented in these two fire regimes are pine, oak, and pinyon-juniper forests in Fire Regime I and grass and shrublands in Fire Regime II. Fire exclusion, housing and agricultural development, livestock grazing, logging, and invasion of exotic species are primary causes of departures. The areas in Condition Classes 2 and 3 within Fire Regimes I and II are often at the greatest cumulative risk to loss of native plant and animal habitats, reduction in air quality due to wildfire smoke,

Table 6—All ownership land summary of historical fire regimes by condition classes of all cover types except agriculture, barren, water, and urban/development/agriculture.

	Condition class							
	Class 1		Class 2		Class 3			
Historical fire regime	**km² (acres)**	**Row %**	**km² (acres)**	**Row %**	**km² (acres)**	**Row %**	**Total km² (Total acres)**	**Total %**
I. 0–35 years; low severity	712,901 (175,031,010)	41	708,325 (176,161,740)	41	313,60 (77,492,543)	18	1,734,828 (428,685,293)	34
II. 0–35 years; stand replacement	779,198 (192,544,136)	57	538,965 (133,181,268)	40	41,869 (10,346,175)	3	1,360,033 (336,071,579)	27
III. 35–100+ years; mixed severity	516,553 (127,642,957)	43	454,292 (112,258,095)	38	218,542 (54,002,982)	18	1,189,387 (293,904,034)	24
IV. 35–100+ years; stand replacement	214,737 (53,062,756)	43	142,990 (35,333,666)	29	141,755 (35,028,486)	28	499,483 (123,424,908)	10
V. 200+ years; stand replacement	196,509 (48,558,333)	72	55,469 (13,706,766)	20	19,853 (4,905,719)	7	271,831 (67,170,818)	5
Total	2,419,898 (597,969,922)	Col % 48	1,900,043 (469,510,805)	Col % 38	735,621 (181,775,905)	Col % 15	5,055,562 (1,249,256,632)	

degraded water quality and risk of wildfire degradation to watersheds, reduced commodity outputs, and risks to human health and safety as a result of the combination of ecosystem departure and risk of catastrophic wildland fire (Flather and others 1994; Frost 1998; Hann and Bunnell, in press; Hann and others 1997, 1998, 2001; Hunter 1993; Quigley and others 1996; Raphael and others 2000; Reiman and others 1999; Rockwell 1998; Wisdom and others 2000).



[a] See table 2 for condition class definition.

Figure 8—Area distribution of fire regime by condition class for all ownerships.

The highest percentage of Condition Class 3 (28 percent) is found in Fire Regime IV (35- to 100-year frequency, stand replacement), while 18 percent of Condition Class 3 is found in Fire Regime III (35- to 100-year frequency, mixed severity). Typical types represented in these two fire regimes are shrublands, lodgepole pine forests, mixed deciduous-conifer forests of the upper Midwest and Northeast, and Douglas-fir forests of the Pacific Northwest and Intermountain West. Fire Regimes III and IV have been less dramatically affected by human intervention as compared to Fire Regimes I and II, but the more subtle effects of homogenization and increased woody density have substantial risks to ecosystems (Barbour and Billings 1988; Hann and Bunnell, in press; Wright and Bailey 1982). Fire exclusion, establishment of exotic species, livestock grazing, and logging are primary causes of departure for Fire Regimes III and IV.

Lands in Fire Regime V (200-year frequency, stand replacement) are closest to historical conditions with 72 percent in Condition Class 1; 28 percent of the area is beyond its historical range. These areas typically occur in higher elevation and wetter forests of the United States. The high elevation types, where human population is scarce, have been least affected by human intervention, as compared to Fire Regimes I and II. High-elevation spruce/fir types, whitebark pine, and moist coastal spruce and Douglas fir-hemlock associations represent these types. Some high-elevation lodgepole pine and northeast conifer/hardwood forests are also included in this fire regime. In contrast, timber harvest and road effects have extensively affected the wet and productive forests of the coastal and Northern Rocky Mountain areas and have increased the risk of losing key ecosystem components.

Over two-thirds of USFS lands are beyond the historical range, with 26 percent significantly altered from the historical range (Condition Class 3) (table 7). Only the area in Fire Regime IV has a high proportion of USFS land (86 percent) within its historical range. Of particular concern is the high proportion of USFS lands altered from the historical range in Fire Regimes I, II, III, and IV; these fire-adapted ecosystems are perhaps the most adversely affected by fire exclusion, which causes excessive fuel loadings and ecosystem health problems. In addition, human populations tend to concentrate in the lower elevations of these fire regimes, putting people and structures at risk. With its cohesive strategy, the USDA Forest Service targets these areas to reduce fuel loadings, protect people, and sustain resources (USDA Forest Service 2000). On DOI lands, 56 percent of the land area is within its historical range, while 44 percent is altered from the historical range (table 8). Ten percent is in Condition Class 3 (significantly altered from the historical range), while 33 percent is in Condition Class 2 (moderately altered from the historical range). The highest proportion of area is in Fire Regime III (43 percent); this area is composed primarily of shrublands. The biggest threat to the loss of key ecosystem components in these shrublands, particularly the desert shrublands in Condition Classes 2 and 3, is the presence of exotic species such as cheatgrass (*Bromus tectormum*). In these shrublands, fire frequency has increased beyond the historical range, endangering native plant communities.

Table 7—USDA Forest Service land summary of historical fire regimes by condition classes of all cover types except agriculture, barren, water, and urban/development/agriculture.

	Condition class							
	Class 1		**Class 2**		**Class 3**			
Historical fire regime	**km^2 (acres)**	**Row %**	**km^2 (acres)**	**Row %**	**km^2 (acres)**	**Row %**	**Total km^2 (Total acres)**	**Total %**
I. 0–35 years; low severity	80,422 (19,872,707)	24	141,484 (34,961,526)	42	116,683 (28,832,900)	34	338,589 (83,667,133)	43
II. 0–35 years; stand replacement	18,044 (4,458,712)	33	35,033 (8,656,737)	64	1,45 (360,028)	3	54,533 (13,475,477)	7
III. 35–100+ years; mixed severity	64,937 (16,046,333)	30	108,110 (26,714,487)	50	45,186 (11,165,814)	21	218,233 (53,926,634)	27
IV. 35–100+ years; stand replacement	21,288 (5,260,312)	23	29,754 (7,352,286)	32	42,461 (10,492,461)	45	93,503 (23,105,059)	12
V. 200+ years; stand replacement	78,150 (19,311,301)	86	11,173 (2,760,876)	12	1,10 (273,542)	1	90,430 (22,345,719)	11
Total	262,841 (64,949,365)	Col % 33	325,553 (80,445,912)	Col % 41	206,894 (51,124,745)	Col % 26	795,288 (196,520,022)	

Table 8—U.S. Department of the Interior (BLM, DOI, FWS, and NPS) land summary of historical fire regimes by condition classes of all cover types except agriculture, barren, water, and urban/development/agriculture.

Historical fire regime	Condition class						Total km^2 (Total acres)	Total %
	Class 1		Class 2		Class 3			
	km^2 (acres)	Row %	km^2 (acres)	Row %	km^2 (acres)	Row %		
I. 0–35 years; low severity	75,679 (18,700,695)	38	96,448 (23,832,773)	49	26,151 (6,461,972)	13	198,277 (48,995,440)	22
II. 0–35 years; stand replacement	78,788 (19,468,939)	46	92,539 (22,866,849)	54	148 (365,960)	1	172,808 (42,701,748)	19
III. 35–100+ years; mixed severity	251,106 (62,049,637)	63	104,506 (25,823,917)	26	40,153 (9,922,142)	10	395,765 (97,795,696)	43
IV. 35–100+ years; stand replacement	97,030 (23,976,589)	72	11,838 (2,925,197)	9	26,734 (6,606,030)	20	135,601 (33,507,816)	15
V. 200+ years; stand replacement	17,106 (4,226,934)	89	153 (379,793)	8	475 (117,371)	2	19,118 (4,724,098)	2
Total	519,709 (128,422,794)	Col % 56	306,867 (75,828,529)	Col % 33	94,994 (23,473,475)	Col % 10	921,569 (227,724,798)	

Supplementary Data Layers

National Fire Occurrence, 1986 to 1996

A summary of Federal and non-Federal fire occurrence per year is shown in table 9, with over 900,000 fires and 100,000 burning km^2 from 1986 to 1996. Summaries of fires per State are shown in appendix D.

Potential Fire Characteristics

The final map of Wildland Fire Risk to Flammable Structures shows a concentration of Fourth Code HUCs of maximum annual days with potential flame length exceeding 8 feet from 1989 to 1996 in the Southwestern United States, particularly Arizona (appendix G).

Wildland Fire Risk to Flammable Structures

The final map of Wildland Fire Risk to Flammable Structures is shown in appendix G. Total area of the classes that have the highest risk of a wildland fire igniting flammable structures is shown in table 10. Ninety-two percent of the total area in the three risk classes falls in non-Federal ownerships (table 10). Of the 48 conterminous States, California had the largest area in the high risk class, with 3,222 km^2 (796,174 acres) or 42 percent of all area in the high risk class.

Table 9—Federal and non-Federal fire occurrence per year, 1986 to1996.

Year	Number of Federal fires	Federal km^2 burned	Number of non-Federal fires	Non-Federal km^2 burned	Total number of fires	Total km^2 burned
1986	16,376	5,226	36,728	2,108	53,104	7,334
1987	19,988	7,087	64,110	3,094	84,098	10,181
1988	20,294	14,996	79,717	6,126	100,011	21,122
1989	18,563	4,514	66,056	6,369	84,619	10,883
1990	18,755	3,790	68,479	5,181	87,234	8,971
1991	17,625	1,785	77,998	5,123	95,623	6,908
1992	20,484	5,059	69,598	5,469	90,082	10,528
1993	15,511	2,626	63,381	4,036	78,892	6,662
1994	25,437	10,497	74,402	7,306	99,839	17,803
1995	18,268	4,395	77,646	4,593	95,914	8,988
1996	21,599	13,885	75,634	8,146	97,233	22,031
Total	212,900	73,860	753,749	57,551	966,649	131,411

Table 10—Area and percent of Risk Class by Federal and non-Federal ownership.

	Federal lands		Non-Federal lands		
Risk class	**km² (acres)**	**Percent[a]**	**km² (acres)**	**Percent**	**Total km² (acres)**
Low	24,435 (6,038,021)	7	345,163 (85,291,641)	93	369,598 (91,329,662)
Moderate	4,656 (1,150,523)	23	15,716 (3,883,508)	77	20,372 (5,034,031)
High	1,717 (424,280)	23	5,904 (1,458,910)	77	7,621 (1,883,190)
Total	30,808 (7,612,824)	8	366,783 (90,634,059)	92	397,591 (98,246,883)

[a] Percent of total area for each risk class.

DISCUSSION

Vegetation and Biophysical Data Layers

While our methodology of using existing data layers and expert opinion provided a qualitative comparison of current vegetation and fuel conditions with estimated historical conditions, the methodology does have its limitations. Many of the assignments made in the expert opinion development process were subjective and potentially not repeatable. Some assignments made to adjacent regions were initially incompatible. These problems were specifically addressed and rectified in additional workshops, but revealed the potential for incongruities across regional boundaries given that different experts made assignments.

Because the vegetation-based data layers were based on pre-existing maps or spatial data, scale inconsistencies may cause error in the data layers. Many edits were made to the Küchler map because of scale differences between the coarse polygon delineations of the Küchler PNV and the finer scale, continuous data of the DEM used in terrain matching. We edited the PNV Groups and cover type layers by overlaying them with the fire regime layer to adjust conflicting combinations, but because neither the accuracy of the cover type layer or PNV layer was known, we were uncertain if this step actually improved the layers. We integrated two readily available, national-scale current cover type layers to create the Current Cover Type layer, but different methodologies used to develop these two layers caused spatial registration problems, such as large water bodies not overlaying, forcing us to shift the data up to two kilometers. Because the Historical Natural Fire Regimes layer was developed from these vegetation maps, any spatial inconsistencies were carried through to this layer.

Another weakness of our methodology was using forest density as a surrogate for structural stage. Because forest density data were mapped as the amount of forest per unit area, not as actual forest structure, the data were sometimes inadequate to reliably determine what condition class to assign to the combination of potential natural vegetation group, cover type, forest density, and fire regime. Mapping detailed and accurate forest structure over large areas is complex, data intensive, and usually requires high-resolution data (in other words, small cell size) (Cohen and Spies 1992). It was beyond the scope of this project to develop a National Forest structure map. Therefore, we used one of the few available spatial datasets covering the conterminous United States as a proxy for structure. Using true forest structure data, developed from newer sensor technologies such as lidar (Light Detection and Ranging), would likely improve classifications of condition class. In general, the quality of products could be improved by developing base layers in conjunction with one another and in developing layers required by the methodology, specifically forest structure.

One of the most noteworthy aspects of this project was the succession diagram. The methodology used to develop the succession diagrams could be used to assign other ecosystem components such as insect and disease infestation levels, smoke production, and hydrologic and soil processes. This pathway approach, as well as the integration of multiple data layers, can be applied to multiple scales from a national level, as was done for this project, down to a local level such as a National Forest or district.

Supplementary Data Layers

National Fire Occurrence, 1986 to 1996

Although we invested 2½ person-years to develop a complete, conterminous United States fire occurrence spatial database, not all data were in a usable spatial format or were not complete. While the Federal database has been verified by each Federal agency as being representative of the 11-year period, 1986 to1996, several States (non-Federal data) have years missing from this time period (appendix F). Fires in the spatial database are not represented as polygons but instead are represented as points. Therefore, summaries of area burned are limited to nonspatial summaries, but even these nonspatial summaries, if summarized for the entire conterminous United States, are limited because some States did not report acres burned (appendix F). Also missing from some non-Federal records are fields such as fire name, date of control, and cause (appendix F). Several States, such as Alabama, Oklahoma, Texas, and Ohio, did not send spatially complete databases, with some counties having few or no fire records.

Duplicate non-Federal and Federal records for the same fire may exist in the databases. Fires on Federal land may also be recorded by State (Bunton 1999). Because fire locations are generally imprecise (to the nearest section) and not all database fields that could aid in tracking duplicates are fully populated, we were unable to track fires duplicated between Federal and non-Federal databases.

While problems like different cause codes or absence of key data fields can be documented, it is not known to what extent wildland fires from States' urban and rural jurisdictions go unreported. Fires from volunteer rural firefighting organizations may not be reported to a centralized agency such as State Fire Marshals or State Foresters (Stuever and others 1995). For instance, the Forestry Division of Montana's Department of Natural Resources and Conservation in western Montana rarely receives fire reports from central or eastern Montana rural fire departments.

Despite the time invested in acquiring and synthesizing data, inconsistencies in the database still exist, primarily because most fire data are managed as databases, not as GIS spatial databases. While the fire occurrence data in its present state may illustrate trends, the usefulness of this type of product will be limited until fire reporting is standardized and consistently collected across all jurisdictions with spatial information such as fire perimeter as a requirement.

Potential Fire Characteristics

The Potential Fire Characteristics data have limited application at any level other than national planning. Although the concept and application of NFDRS indices has been widely accepted since the late 1970s, continuous spatial layers of these data clearly bring out "the worst" in the data. Perhaps the most limiting factor is the low spatial and temporal density of weather observations. Spatial density is defined by the number and distribution of acceptable NFDRS reporting stations; only about 2,000 are used for the entire conterminous United States. Values between stations are estimated with an inverse distance-squared technique on a 10-km grid. Burgan and others (1997) have noted that this works reasonably well in areas of relatively high station density, such as in the Western United States, but has obvious shortcomings in other areas, particularly for the Central and Eastern States. These shortcomings are also noted on the Web site for the Wildland Fire Assessment System: http://www.fs.fed.us/land/wfas (USDA Forest Service 1998). The NFDRS weather observation protocol is reported once a day at 2:00 p.m., the theoretical worst-case fire-weather period. This limits the temporal resolution of the dynamic fire-related weather observations.

Wildland Fire Risk to Flammable Structures

The classes used to assign risk to flammable structures from wildland fire were designed to target areas where a single fire event could destroy many homes. These single events are driven by a combination of extreme fire weather occurrence and high fire intensity. Areas with moderate to high populations but with low to very low hazard to flammable structures were missing one or both of these combinations. Though these areas were classified as low risk, it does not mean a single fire event could not occur and be a risk to structures. In 2000, wildland fires burned over 70 structures in western Montana. These areas were classified as low or very low risk because western Montana averages less than 10 days per year of extreme fire weather, compared to parts of New Mexico, which averages 27 to 90 days per year. The classification provides a relative comparison of areas from high to low risk across the conterminous United States.

Each of the input data layers used to develop the Wildland Fire Hazard to Flammable Structures layer has irregularities associated with them that may be compounded when combined (Menakis and others, in preparation). By classifying risk into general classes of low, moderate, and high, we smoothed some of these irregularities and presented information in a relative fashion (Menakis and others, in preparation). Our wildland fire risk analysis assumes that all homes are highly ignitable. This analysis does not consider home exterior materials, design, or ignition zone characteristics, but assesses the potential and degree of ignitable structure exposure to wildland fire (Menakis and others, in preparation).

Accuracy and Verification

No accuracy assessment or field verification of the spatial data layers developed for this project was conducted. Kloditz and others (1998) stated that classification accuracies for 1-km^2 resolution or coarser data are not feasible because obtaining ground truth data would not only be difficult and expensive but would represent only a very small portion of the image. Loveland and others (1991) stated that because developed classes are based on heterogeneous rather than homogeneous regions and because there is a lack of consistent ground-truth data, there are limitations to verifying coarse-resolution data. One potential method to verify coarse-scale data is to use high-resolution images in place of ground-truth data (Kloditz and others 1998), but it was beyond the scope of this project to acquire and classify high-resolution images as ground-truth data. Because condition classes are qualitative rather than quantitative attributes and because no similar fine-scale data exists, no such comparison could be made. Moreover, not all input data layers have quantitative accuracies associated with them. For one of the input data layers, the LCC nonforest cover types, Loveland and others (1991) verified the dataset by comparing it to other datasets such as Omernik's (1987) ecoregions, Major Land Resource Areas, and Land Use and Land Cover, but no quantitative assessment was attempted. Accuracy tests were performed on the Forest Type Groups and Forest Density data layers, but the tests were either performed in small areas relative to the entire study area or accuracies were reported for very broad classes (for example, forest and nonforest) (Zhu and Evans 1994).

MANAGEMENT IMPLICATIONS

Land management agencies need to initiate proactive measures to address combinations of natural resource, political, and social concerns. Obviously, not all lands can be treated during any given timeframe. Local criteria have been used in the past to select areas for treatment. This study provides the first national-level comparison of current vegetation and fuel conditions with estimated historical conditions. These data provide management with an ecological basis for identifying, then selecting, priority treatment areas based on both the opportunity and need to alter vegetation and fuel conditions.

The dynamic nature of vegetation and dead fuel conditions of forests and grasslands predisposes large areas of the country to increasing threats to loss of key components that define ecosystems, increased severity of wildland fires, and continued risk to human lives and property. Recently completed management plans, such as the Review and Update of the 1995 Federal Wildland Fire Management Policy (U.S. 2001) and Cohesive Strategy (USDA Forest Service 2000), highlight the need for proactive management to modify existing vegetation and fuel conditions to provide long-term relief from escalating risk to both societal and natural resource values (USDA Forest Service 2000).

Fire Regimes I and II and the Pacific coastal shrub communities included in Fire Regime III will be the focus of the majority of Federal land management actions. The greatest departure from historical conditions has occurred in these regimes. The areas in these fire regimes occur primarily in the highest population centers in the wildland urban interface, as well as in the most productive growing sites on forest and rangelands. Addressing social and political objectives of increased protection in wildland urban interface areas will be a continuing challenge in all fire regimes. The use of fire to alter vegetation and fuel conditions will be a secondary management option in most of these areas, due primarily to social sensitivity to smoke production and potential loss from escaped fires. Primary treatments of mechanical fuel manipulation should precede fire use applications to reduce the potential damage from fire restoration or maintenance management actions.

Where natural resource objectives are the primary management focus, aggressive use of fire can be highlighted as a priority to maintain existing Condition Class 1 areas in fire-adapted systems. Treatment with fire in these areas provides the greatest return for the investment, minimizes long-term risk to the environment, minimizes social impacts, and offers the greatest management flexibility for the future.

Depending on each situation, restorative management actions to reverse the vegetative trend in Condition Class 2 environments may require a combination of both fire use and mechanical treatments to effectively and safely restore conditions to the maintenance level. Multiple treatments for areas in Fire Regimes I and II in Condition Class 2 may be required over one or more historical fire intervals before a maintenance level, Condition Class 1, is achieved.

Area of fire regimes III, IV, and V in Condition Classes 2 and 3 will receive some focus from wildland management agencies. Risks in these systems also occur primarily in association with departure of vegetation and fuel composition, structure, and landscape patterns, but changes are often not as dramatic as in Fire Regimes I and II. However, fire regimes do not exist as unlinked entities to the other fire regimes in a wildfire risk, landscape, watershed, or airshed context. To avoid landscape scale fragmentation of ecosystem processes, hydrologic regimes, or native species habitats, it is important to prioritize and design restoration projects from an integrated ecological and human perspective and to restore whole landscapes using a watershed approach (Hann and Bunnell, in press; Hann and others 1997, 1998, 2001; Haynes and others 1996; Reiman and others 1999).

Future land management goals should include reducing the rate of change from lower risk levels of losing key ecosystem components (Condition Classes 1 and 2) to those with increased risk and loss of management flexibility (Condition Classes 2 and 3). This study and these data strongly suggest that continued protection from the natural disturbance element of periodic wildland fire provides only short-term societal benefits, and delays inevitable changes to vegetation and fuel conditions, producing more severe consequences to all values.

CONCLUSIONS

The coarse-scale mapping project described in this paper successfully provided land managers with national-level data on current conditions of vegetation and fuels developed from ecologically based methods to accomplish fire management goals and to maintain and restore ecosystems. Key to the project was the integration of biophysical and remote sensing data with disturbance and succession information. Data products produced from this project can also be used as input into risk assessments and other national-level analyses. The methodology used in this project could be applied to finer scales, using finer input data.

ACKNOWLEDGMENTS

This project was a success because of the assistance of many individuals. We thank all those who helped with the completion of this project, including Janice Garner, Dalice McIntyre, Roberta Bartlette, Don Long, Cameron Johnston, Denny Simmerman, Bob Burgan, Larry Bradshaw, Jane Kapler-Smith, Janet Howard, and Jack Cohen of the U.S. Department of Agriculture, Forest Service, Rocky Mountain Research

Station, Fire Sciences Laboratory; Jim Brown and Duncan Lutes, Systems for Environmental Management; Susan Goodman, Bureau of Land Management; and Delvin Bunton, John Skeels, and Lowell Lewis, USDA Forest Service. We also thank the condition class workshop participants: Rich Lasko, Barry Bollenbacher, Pat Green, Mark Grant, Glenda Scott, Byron Bonney, Jeff Jones, Henry Goehle, Clint Dawson, Ron Moody, Wayne Robbie, Reggie Fletcher, Steven Zachry, Dave Thomas, Tim Belton, Kathy Geier-Hayes, Joe Carvelho, Lynn Bennett, Sue Husari, Neil Sugihara, Bernie Bahro, Mark Borchert, Tim Rich, Peter Teensma, Dave Powell, John Stivers, Finis Harris, Andi Koonce, Sybill Amelon, Clint Williams, Jon Regelbrugge, Louisa Evers, Jeff Rose, Jane Kertis, Paul Tine, Dave Cleland, and Thomas Phillips with the USDA Forest Service; Joe Burns with the U.S. Fish and Wildlife Service; Karen Ogle with the Bureau of Land Management; and Dave Sapsis with the California Department of Forestry and Fire Protection.

We also wish to thank our technical reviewers: Emily Heyerdahl, Russ Parsons, and Bob Keane with the U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory; Cristina Milesi with the University of Montana; and Mike Hilbruner with the Forest Service Washington Office.

REFERENCES

Andrews, Patricia L.; Rothermel, Richard C. 1981. Charts for interpreting wildland fire behavior characteristics. Gen. Tech. Rep. INT-131. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 21 p.

Bailey, R. G.; Avers, P. E.; King, T.; McNab, W. H., eds. 1994. Ecoregions and subregions of the United States (map). Washington, DC: U.S. Department of Agriculture, Forest Service. 1:7,500,000. With supplementary table of map unit descriptions, compiled and edited by W. H. McNab and R. G. Bailey.

Barbour, Michael G.; Billings, William Dwight, eds. 1988. North American terrestrial vegetation. New York: Cambridge University Press. 434 p.

Barrett, Stephen W; Arno, Stephen F.; Key, Carl H. 1991. Fire regimes of western larch-lodgepole pine forests in Glacier National Park, Montana. Canadian Journal of Forest Research. 21: 1711–1720.

Bian, Ling. 1997. Multiscale nature of spatial data in scaling up environmental models. In: Quaattrochi, Dale A.; Goodchild, Michael F., eds. Scale in remote sensing and GIS. Boca Raton, FL: Lewis Publishers: 13–26.

Bian, Ling; Butler, Rachel. 1999. Comparing effects of aggregation methods on statistical and spatial properties of simulated spatial data. Photogrammetric Engineering and Remote Sensing. 65(1): 73–84.

Bradshaw, Larry S.; Deeming, John E.; Burgan, Robert E.; Cohen, Jack D., comps. 1983. The 1978 National Fire-Danger Rating System: technical documentation. Gen. Tech. Rep. INT-169. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 44 p.

Brown, James K. 1994. Fire regimes and their relevance to ecosystem management. In: Proceedings of the 1994 Society of American Foresters/Canadian Institute of Forestry Convention; 1994 September 18–22; Anchorage, AK. Bethesda, MD: Society of American Foresters: 171–178.

Brown, James K.; Arno, Stephen F.; Barrett, Stephen W.; Menakis, James P. 1994. Comparing the prescribed natural fire program with presettlement fires in the Selway-Bitterroot Wilderness. International Journal of Wildland Fire. 4(3): 157–168.

Bunton, Delvin R. 1999. Sharing information through fire reporting. Fire Management Notes. 59(2): 37–42.

Burgan, R. E.; Andrews, P. L.; Chase, C. H.; Hartford, R. A.; Latham, D. J. 1997. Current status of the Wildland Fire Assessment System (WFAS). Fire Management Notes. 57(2): 14–17.

Cohen, Jack D. 2000. Preventing disaster: home ignitability in the wildland-urban interface. Journal of Forestry. 98(3): 15–21.

Cohen, Warren B.; Spies, Thomas A. 1992. Estimating structural attributes of Douglas-fir/western hemlock forest stands from LANDSAT and SPOT imagery. Remote Sensing of the Environment. 41: 1–17.

Deeming, John E.; Burgan, Robert E.; Cohen, Jack D. 1977. The National Fire-Danger Rating System—1978. Gen. Tech. Rep. INT-39. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 63 p.

Dobson, Jerome E.; Bright, Edward A.; Coleman, Phillip R.; Durfee, Richard C.; Worley, Brian A. 2000. A global population database for estimating populations at risk. Photogrammetric Engineering and Remote Sensing. Vol. 66.

Eyre, F. H., ed. 1980. Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters. 147 p.

Fischer, W. C.; Miller, M.; Johnston, C. M.; Smith, J. K.; Simmerman, D. G.; Brown, J. K. 1996. Fire Effects Information System: user's guide. Gen. Tech. Rep. INT-GTR-327. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 131 p.

Flather C. H.; Joyce, L. A.; Bloomgarden, C. A. 1994. Species endangerment patterns in the United States. Gen. Tech. Rep. RM-GTR-241. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 42 p.

Ford, P. L.; McPherson, G. R. 1999. Ecology of fire in shortgrass communities of the Kiowa National Grassland. In: Warwick, C., ed. Fifteenth North American prairie conference proceedings; 1996 October; St. Charles, IL. Bend, OR: The Natural Areas Association: 71–76.

Frost, Cecil C. 1998. Presettlement fire frequency regimes of the United States: a first approximation. In: Pruden, Teresa L.; Brennan, Leonard A., eds. Fire in ecosystem management: shifting the paradigm from suppression to prescription. Tall Timbers Fire Ecology Conference Proceedings No. 20. Tallahassee, FL: Tall Timbers Research Station: 70–81.

Garrison, George A.; Bjugstad, Ardell J.; Duncan, Don A.; Lewis, Mont E.; Smith, Dixie. 1977. Vegetation and environmental features of forest and range ecosystems. Agric. Handb. 475. Washington, DC: U.S. Department of Agriculture, Forest)Service. 68 p.

Hann, W. J.; Bunnell, D. L. [In press]. Fire and land management planning and implementation across multiple scales. International Journal of Wildland Fire. 27 p.

Hann, W. J.; Hemstrom, M. A.; Haynes, R. W.; Clifford, J. L; Gravenmier, R. A. 2001. Cost and effectiveness of multi-scale integrated management. Forest Ecology and Management. 153: 127–145.

Hann, W. J.; Jones, J. L; Keane, R. I.; Hessburg, P. F.; Gravenmier, R. A. 1998. Landscape dynamics. Journal of Forestry. 96(10): 10–15.

Hann, Wendel J.; Jones, Jeffrey L.; Karl, Michael G.; [and others]. 1997. Landscape dynamics of the Basin. Chapter 3. In: Quigley, Thomas M.; Arbelbide, Sylvia J., tech. eds. An assessment of ecosystem components in the Interior Columbia Basin and portions of the Klamath and Great Basins: Vol. 2. Gen. Tech. Rep.

PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Hardy, C. C.; Menakis, J. P.; Long, D. G.; Brown, J. K.; Bunnell, D. L. 1998. Mapping historic fire regimes for the Western United States: integrating remote sensing and biophysical data. In: Proceedings of the seventh biennial Forest Service remote sensing applications conference; 1998 April 6–9; Nassau Bay, TX. Bethesda, MD: American Society for Photogrammetry and Remote Sensing: 288–300.

Haynes, R. W.; Graham, R. T.; Quigley, T. M., tech. eds. 1996. A framework for ecosystem management in the Interior Columbia Basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-374. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 66 p.

Heinselman, Miron L. 1981. Fire intensity and frequency as factors in the distribution and structure of Northern ecosystems. In: Fire regimes and ecosystem properties: proceedings of the conference; 1978 December 11–15; Honolulu, HI. Gen Tech. Rep. WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service: 7–57.

Hunter, M. L., Jr. 1993. Natural fire regimes as spatial models for managing boreal forests. Biological Conservation. 65: 115–120.

Keane, R. E.; Garner, Janice L.; Schmidt, Kirsten M.; Long, Donald G.; Menakis, James P.; Finney, Mark A. 1998. Development of the input data layers for the FARSITE fire growth model for the Selway-Bitterroot Wilderness Complex, USA. Gen. Tech. Rep. RMRS-GTR-3. Ogden, UT: U.S. Department of Agriculture, Forest Service. Rocky Mountain Research Station. 121 p.

Keane, R. E.; Long, D. G.; Menakis, J. P.; Hann, W. J.; Bevins, C. D. 1996. Simulating coarse-scale vegetation dynamics using the Columbia River Basin Succession Model—CRBSUM. Gen. Tech. Rep. INT-GTR-340. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 50 p.

Keane, Robert E.; Mincemoyer, Scott A.; Schmidt, Kirsten M.; Long, Donald G.; Garner, Janice L. 2000. Mapping vegetation and fuels for fire management on the Gila National Forest Complex, New Mexico, [CD-ROM]. Gen. Tech. Rep. RMRS-GTR-46-CD. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 131 p.

Kloditz, Christiane; Boxtel, Angelien; Carfagna, Elisabetta; van Deursen, William. 1998. Estimating the accuracy of coarse scale classification using high scale information. Photogrammetric Engineering and Remote Sensing. 64(2): 127–133.

Küchler, A. W. 1964. Potential natural vegetation of the conterminous United States (manual and map.) Special Publ. 36, 1965 rev. New York: American Geographical Society. 116 p.

Küchler, A. W. 1975. Potential natural vegetation of the conterminous United States. 2d ed. Map 1:3,168,000. American Geographical Society.

Loveland, T. R.; Merchant, J. M.; Ohlen, D. O.; Brown, J. F. 1991. Development of a landcover characteristics database for the conterminous U.S. Photogrammetric Engineering and Remote Sensing. 57(11): 1453–1463.

Loveland, T. R.; Ohlen, D. O. 1993. Experimental AVHRR land data sets for environmental monitoring and modeling. In: Goodchild, M. F.; Parks, B. O.; Steyaert, L. T., comps., eds. Environmental modeling with GIS. New York: Oxford University Press: 379–385.

McNab, W. Henry; Avers, Peter E., comps. 1994. Ecological subregions of the United States: section descriptions. WO-WSA-5. Washington, DC: U.S. Department of Agriculture, Forest Service, Ecosytem Management. 52 p.

Menakis, J. P.; Cohen, J. D.; Bradshaw, L. S. [In preparation]. Mapping wildland fire risk to flammable structures for the conterminous United States. In: Brennan, L. A.; [and others], eds. National Congress on Fire Ecology, Prevention, and Management Proceedings No. 1. Tallahassee, FL: Tall Timbers Research Station.

Morgan, P.; Bunting, S. C.; Black, A. E.; Merrill, T.; Barrett, S. 1996. Fire regimes in the Interior Columbia River Basin: past and present. Final Report for RJVA-INT-94913. On file at: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, MT. 31 p.

Omernik, J. M. 1987. Ecoregions of the conterminous United States: annals of the Association of American Geographers. 77(1): 188–125.

Powell, Douglas S.; Faulkner, Joanne; Darr, David R.; Zhu, Zhiliang; MacCleery, Douglas W. 1992. Forest resources of the United States, 1992. Gen. Tech. Rep. RM-234. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 132 p.

Quigley, Thomas M.; Graham, Russell T.; Haynes, Richard W. 1996. An integrated scientific assessment for ecosystem management in the Interior Columbia River Basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-382. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 303 p.

Raphael, Martin G.; Holthausen, Richard S.; Marcot, Bruce G.; [and others]. 2000. Effects of SDEIS alternatives on selected terrestrial vertebrates of conservation concern within the Interior Columbia River Basin Ecosystem Management Project. In: Quigley; [and others], tech. eds. Draft science advisory group effects analysis for the SDEIS alternatives. Internal Working Draft. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Bureau of Land Management, Interior Columbia Basin Ecosystem Management Project, Portland, OR.

Rieman, Bruce; Howell, Phil; Clayton, Jim; [and others]. 1999. Draft aquatic effects analysis of the SDEIS alternatives. In: Quigley; [and others], tech. eds. Draft science advisory group effects analysis for the SDEIS alternatives. Internal Working Draft. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Bureau of Land Management, Interior Columbia Basin Ecosystem Management Project, Portland, OR.

Rockwell, D. 1998. The nature of North America: rocks, plants, and animals. New York: The Berkley Publishing Group. 379 p.

Seaber, P. R; Kapinos, F. Paul; Knapp, G. L. 1987. Hydrologic unit maps. Water Supply Paper 2294. U.S. Geologic Survey. 63 p.

Smith, Jane Kapler; Fischer, William C. 1997. Fire ecology of the forest habitat types of northern Idaho. Gen. Tech. Rep. INT-363. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 142 p.

Stuever, Mary C.; Crawford, Clifford S.; Molles, Manuel C.; White, Carleton S.; Muldavin, Esteban. 1997. Initial assessment of the role of fire in the middle Rio Grande bosque. In: Greenlee, J. M., ed. Proceedings: first conference on fire effects on rare and endangered species and habitats; 1995 November 13–16; Coeur d' Alene, ID. Fairfield, WA: International Association of Wildland Fire: 275–283.

Turner, Monica G.; O'Neill, Robert V.; Gardner, Robert H.; Milne, Bruce T. 1989. Effects of changing spatial scale on the analysis of landscape pattern. Landscape Ecology. 3(3,4): 153-162.

U.S. Department of Agriculture. 2001. Review and update of the 1995 Federal wildland fire management policy report. On file at: National Interagency Fire Center, External Affairs Office, 3833 South Development Avenue, Boise, ID 83705. 78 p.

U.S. Department of Agriculture, Forest Service. 1993. National Interagency Fire Management Integrated Database (NIFMID) reference manual. Washington, DC: U.S. Department of Agriculture, Forest Service, Fire and Aviation Management. 58 p.

U.S. Department of Agriculture, Forest Service. 1998. Wildland Fire Assessment System. [Online] Fire Behavior Research Work Unit, Rocky Mountain Research Station (producer). Available: http://www.fs.fed.us/land/wfas [1999, December].

U.S. Department of Agriculture, Forest Service. 2000. Protecting people and sustaining resources in fire-adapted ecosystems: a cohesive strategy. The Forest Service management response to the General Accounting Office Report GAO/RCED-99-65, April 13, 2000. 89 p.

United States General Accounting Office. 1999. Western National Forests: a cohesive strategy is needed to address catastrophic wildfire threats. Report to the subcommittee on forests and forest health, committee on resources, House of Representatives. GAO/RCED-99-65. 60 p.

United States Geological Survey. 1994. A 500-meter resolution digital elevation model of the U.S. and Southern Canada. Oklahoma City, OK: U.S. Geological Survey.

Vail, Delmar. 1994. Symposium introduction: management of semiarid rangelands—impacts of annual weeds on resource values. In: Monsen, Stephen B.; Kitchen, Stanley G., eds. Proceedings—ecology and management of annual rangelands; 1992 May 18–22; Boise, ID: Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 3–4.

Weins, J. A. 1989. Spatial scaling in ecology. Functional Ecology. 3: 385–397.

West, Neil E. 1994. Effects of fire on salt-desert shrub rangelands. In: Monsen, Stephen B.; Kitchen, Stanley G., eds. Proceedings—ecology and management of annual rangelands; 1992 May 18–22; Boise, ID: Gen. Tech. Rep. INT-GTR-313. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 71–74.

Whisenant, S. G. 1990. Changing fire frequencies on Idaho’s Snake River plains: ecological and management implications. In: McArthur, E. Durant; Romney, Evan M.; Smith, Stanley D.; Tueller, Dave T., comps. Proceedings—symposium on cheatgrass invasion, shrub die-off and other aspects of shrub biology and management; 1989 April 5–7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 4–10.

Wisdom, Michael J.; Holthausen, Richard S.; Lee, Danny C.; [and others]. 2000. Source habitats for terrestrial vertebrates of focus in the Interior Columbia Basin: broad-scale trends and management implications. Working Draft. 4 Vol. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 112 E. Poplar, Walla Walla, WA 99362.

Wright, Henry A.; Bailey, Arthur W. 1982. Fire ecology: United States and Southern Canada. New York: John Wiley & Sons. 501 p.

Zhu, Zhiliang. 1994. Forest density mapping in the lower 48 States: a regression procedure. Res. Pap. SO-280. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 11 p.

Zhu, Zhiliang; Evans, David L. 1992. Mapping midsouth forest distributions. Journal of Forestry. 90(12): 27–30.

Zhu, Zhiliang; Evans, David L. 1994. U.S. forest types and predicted percent forest cover from AVHRR data. Photogrammetric Engineering and Remote Sensing. 60(5): 525–531.

Appendix A: Potential Natural Vegetation Groups (after Küchler 1975)

Potential natural vegetation group	Küchler PNV	
ECORegion 1		
1: Pine forest	K011	Western ponderosa forest
	K016	Eastern ponderosa forest
	K017	Black Hills pine forest
3: Pine-Douglas-fir	K018	Pine-Douglas-fir forest
4: Douglas-fir	K012	Douglas-fir forest
7: Grand fir-Douglas-fir	K014	Grand fir-Douglas-fir forest
13: Cedar-hemlock-Douglas-fir	K002	Cedar-hemlock-Douglas-fir forest
	K013	Cedar-hemlock-pine forest
16: Western spruce-fir	K015	Western spruce-fir forest
25: Sagebrush	K038	Great Basin sagebrush
	K055	Sagebrush steppe
	K056	Wheatgrass-needlegrass shrub steppe
28: Desert shrub	K040	Saltbrush-greasewood
31: Mountain grassland	K050	Fescue-wheatgrass
	K051	Wheatgrass-bluegrass
	K063	Foothills prairie
32: Plains grassland	K064	Grama-needlegrass-wheatgrass
	K065	Grama-buffalo grass
	K066	Wheatgrass-needlegrass
	K067	Wheatgrass-bluestem-needlegrass
	K068	Wheatgrass-grama-buffalo grass
33: Prairie	K074	Bluestem prairie
	K075	Nebraska Sandhills prairie
37: Alpine meadows-barren	K052	Alpine meadows and barren
38: Oak savanna (ND)	K081	Oak savanna
60: Northern floodplain	K098	Northern floodplain forest
ECORegion 2		
1: Pine forest	K016	Eastern ponderosa forest
	K017	Black Hills pine forest
3: Pine-Douglas-fir	K018	Pine-Douglas-fir forest
4: Douglas-fir	K012	Douglas-fir forest
16: Western spruce-fir	K015	Western spruce-fir forest
	K021	Southwestern spruce-fir forest
22: Juniper-pinyon	K023	Juniper-pinyon woodland
25: Sagebrush	K038	Great Basin sagebrush
	K055	Sagebrush steppe
	K056	Wheatgrass-needlegrass shrub steppe

Potential natural vegetation group	Küchler PNV	
26: Chaparral	K037	Mountain mahogany-oak scrub
28: Desert shrub	K039	Blackbrush
	K040	Saltbrush-greasewood
32: Plains grassland	K063	Foothills prairie
	K064	Grama-needlegrass-wheatgrass
	K065	Grama-buffalo grass
	K066	Wheatgrass-needlegrass
	K067	Wheatgrass-bluestem-needlegrass
	K068	Wheatgrass-grama-buffalo grass
	K069	Bluestem-grama prairie
33: Prairie	K070	Sandsage-bluestem prairie
	K074	Bluestem prairie
	K075	Nebraska Sandhills prairie
37: Alpine meadows-barren	K052	Alpine meadows and barren
39: Mosaic bluestem/oak-hickory	K082	Mosaic of numbers 74 and 100
45: Oak-hickory	K084	Cross timbers
	K100	Oak-hickory forest
60: Northern floodplain	K098	Northern floodplain forest

ECORegion 3

Potential natural vegetation group	Küchler PNV	
1: Pine forest	K019	Arizona pine forest
3: Pine-Douglas-fir	K018	Pine-Douglas-fir forest
10: SW mixed conifer (AZ, NM)	K020	Spruce-fir-Douglas-fir forest
16: Western spruce-fir	K021	Southwestern spruce-fir forest
22: Juniper-pinyon	K023	Juniper-pinyon woodland
24: Mesquite bosques (NM)	K027	Mesquite bosques
25: Sagebrush	K038	Great Basin sagebrush
26: Chaparral	K031	Oak-juniper woodland
	K032	Transition between 31 and 37
	K037	Mountain mahogany-oak scrub
27: Southwest shrub steppe	K058	Grama-tobosa shrub steppe
	K059	Trans-Pecos shrub savanna
28: Desert shrub	K039	Blackbrush
	K040	Saltbrush-greasewood
	K041	Creosote bush
	K042	Creosote bush-bur sage
	K043	Palo verde-cactus shrub
	K044	Creosote bush-tarbush
	K046	Desert: vegetation largely absent
29: Shinnery	K071	Shinnery
32: Plains grassland	K065	Grama-buffalo grass
	K066	Wheatgrass-needlegrass
34: Desert grassland	K053	Grama-galleta steppe
	K054	Grama-tobosa prairie
37: Alpine meadows-barren	K052	Alpine meadows and barren

ECORegion 4

Potential natural vegetation group	Küchler PNV
2: Great Basin pine (NV, UT)	K022 Great Basin pine forest
3: Pine-Douglas-fir	K011 Western ponderosa forest
	K018 Pine-Douglas-fir forest
	K019 Arizona pine forest
4: Douglas-fir	K012 Douglas-fir forest
7: Grand Fir-Douglas-fir	K014 Grand fir-Douglas-fir forest
9: Spruce fir-Douglas-fir	K020 Spruce-fir-Douglas-fir forest
16: Western spruce-fir	K015 Western spruce-fir forest
	K021 Southwestern spruce-fir forest
17: Lodgepole pine-Subalpine (CA)	K008 Lodgepole pine-subalpine forest
22: Juniper-pinyon	K023 Juniper-pinyon woodland
23: Juniper steppe	K024 Juniper steppe woodland
25: Sagebrush	K038 Great Basin sagebrush
	K055 Sagebrush steppe
26: Chaparral	K037 Mountain mahogany-oak scrub
28: Desert shrub	K039 Blackbrush
	K040 Saltbrush-greasewood
	K041 Creosote bush
	K042 Creosote bush-bur sage
	K043 Palo verde-cactus shrub
	K046 Desert: vegetation largely absent
	K053 Grama-galleta steppe
	K057 Galleta-three awn shrub steppe
31: Mountain grassland	K051 Wheatgrass-bluegrass
	K063 Foothills prairie
36: Wet grassland	K049 Tule marshes
37: Alpine meadows-barren	K052 Alpine meadows and barren

ECORegion 5

Potential natural vegetation group	Küchler PNV
1: Pine forest	K010 Ponderosa shrub forest
	K019 Arizona pine forest
2: Great Basin pine (NV, UT)	K022 Great Basin pine forest
5: Mixed conifer	K005 Mixed conifer forest
8: Red fir (CA)	K007 Red fir forest
11: Redwood (CA)	K006 Redwood forest
13: Cedar-hemlock-Douglas-fir	K002 Cedar-hemlock-Douglas-fir forest
15: Fir-hemlock (WA, OR)	K004 Fir-hemlock forest
17: Lodgepole-subalpine	K008 Lodgepole pine-subalpine forest
18: California mixed evergreen	K029 California mixed evergreen forest
19: Oakwoods (CA)	K026 Oregon oakwoods
	K030 California oakwoods
	K028 Mosaic of 2 and 26

Potential natural vegetation group	Küchler PNV	
22: Juniper-pinyon	K023	Juniper-pinyon woodland
23: Juniper steppe	K024	Juniper steppe woodland
25: Sagebrush	K038	Great Basin sagebrush
	K055	Sagebrush steppe
26: Chaparral	K009	Pine-cypress forest
	K033	Chaparral
	K034	Montane chaparral
	K035	Coastal sagebrush
	K036	Mosaic of 30 and 35
28: Desert shrub	K040	Saltbrush-greasewood
	K041	Creosote bush
	K042	Creosote bush-bur sage
	K043	Palo verde-cactus shrub
	K046	Desert: vegetation largely absent
	K058	Grama-tobosa shrub steppe
30: Annual grassland	K048	California steppe
31: Mountain grassland	K047	Fescue-oatgrass
	K051	Wheatgrass-bluegrass
36: Wet grassland	K049	Tule marshes
37: Alpine meadows-barren	K052	Alpine meadows and barren

ECORegion 6

1: Pine forest	K010	Ponderosa shrub forest
	K011	Western ponderosa forest
4: Douglas-fir	K012	Douglas-fir forest
5: Mixed conifer	K005	Mixed conifer forest
6: Silver fir-Douglas-fir	K003	Silver fir-Douglas-fir forest
7: Grand fir-Douglas-fir	K014	Grand fir-Douglas-fir forest
12: Cedar-hemlock-pine (WA)	K013	Cedar-hemlock-pine forest
13: Cedar-hemlock-Douglas-fir	K002	Cedar-hemlock-Douglas-fir forest
14: Spruce-cedar-hemlock (WA, OR)	K001	Spruce-cedar hemlock forest
15: Fir-hemlock (WA, OR)	K004	Fir-hemlock forest
16: Western spruce-fir	K015	Western spruce-fir forest
18: California mixed evergreen	K029	California mixed evergreen forest
19: Oakwoods	K026	Oregon oakwoods
20: Mosaic cedar-hemlock-Douglas-fir and oak (OR)	K028	Mosaic numbers 2 and 26
21: Alder-ash (WA, OR)	K025	Alder-ash forest
23: Juniper steppe	K024	Juniper steppe woodland
25: Sagebrush	K038	Great Basin sagebrush
	K055	Sagebrush steppe
28: Desert shrub	K040	Saltbrush-greasewood
31: Mountain grassland	K050	Fescue-wheatgrass
	K051	Wheatgrass-bluegrass
37: Alpine meadows-barren	K052	Alpine meadows and barren

Potential natural vegetation group	Küchler PNV
ECORegion 8	
3: Pine-Douglas-fir	K018 Pine-Douglas-fir forest
16: Western spruce-fir	K021 Southwestern spruce-fir forest
22: Juniper-pinyon	K023 Juniper-pinyon woodland
26: Chaparral	K031 Oak-juniper woodland
27: Southwest shrub steppe	K058 Grama-tobosa shrub steppe
	K059 Trans-Pecos shrub savanna
28: Desert shrub	K040 Saltbrush-greasewood
29: Shinnery	K071 Shinnery
32: Plains grassland	K065 Grama-buffalo grass
	K069 Bluestem-grama prairie
	K085 Mesquite-buffalo grass
33: Prairie	K070 Sandsage-bluestem prairie
	K074 Bluestem prairie
	K076 Blackland prairie
	K077 Bluestem-sacahuista prairie
	K083 Cedar glades
	K088 Fayette prairie
34: Desert grassland	K054 Grama-tobosa prairie
35: Texas savanna	K045 Ceniza shrub
	K060 Mesquite savanna
	K061 Mesquite-acacia savanna
	K062 Mesquite-live oak savanna
	K086 Juniper-oak savanna
	K087 Mesquite-oak savanna
36: Wet grassland	K072 Sea oats prairie
	K073 Northern cordgrass prairie
	K078 Southern cordgrass prairie
	K079 Palmetto prairie
	K092 Everglades
39: Mosaic bluestem/oak-hickory	K082 Mosaic of numbers 74 and 100
40: Cross timbers	K084 Cross timbers
43: Eastern spruce-fir	K097 Southeastern spruce-fir forest
45: Oak-hickory	K100 Oak-hickory forest
48: Mixed mesophytic forest	K104 Appalachian oak forest
55: Oak-hickory-pine	K111 Oak-hickory-pine forest
56: Southern mixed forest	K112 Southern mixed forest
57: Loblolly-shortleaf pine	K114 Pocosin
	K115 Sand pine scrub
58: Blackbelt	K089 Blackbelt
59: Oak-gum-cypress	K090 Live oak-sea oats
	K091 Cypress savanna
	K105 Mangrove
61: Southern floodplain	K113 Southern floodplain forest

ECORegion 9

Potential natural vegetation group	Küchler PNV	
32: Plains grassland	K067	Wheatgrass-bluestem-needlegrass
33: Prairie	K074	Bluestem prairie
	K075	Nebraska Sandhills prairie
	K083	Cedar glades
36: Wet grassland	K073	Northern cordgrass prairie
39: Mosaic bluestem/oak-hickory	K082	Mosaic of numbers 74 and 100
41: Conifer bog (MN)	K094	Conifer bog
42: Great Lakes pine forest	K095	Great Lakes pine forest
43: Eastern spruce-fir	K093	Great Lakes spruce-fir forest
	K096	Northeastern spruce-fir forest
44: Maple-basswood	K081	Oak savanna
	K099	Maple-basswood forest
45: Oak-hickory	K100	Oak-hickory forest
46: Elm-ash forest	K101	Elm-ash forest
47: Maple-beech-birch	K102	Beech-maple forest
48: Mixed mesophytic forest	K103	Mixed mesophytic forest
49: Appalachian oak	K104	Appalachian oak forest
	K105	Mangrove
	K106	Northern hardwoods
50: Transition Appalachian oak-northern hardwoods	K104	Appalachian oak forest
	K106	Northern hardwoods
52: Northern hardwoods-fir	K107	Northern hardwoods-fir forest
53: Northern hardwoods-spruce	K108	Northern hardwoods-spruce forest
54: Northeastern oak-pine	K110	Northeastern oak-pine forest
55: Oak-hickory-pine	K111	Oak-hickory-pine forest
60: Northern floodplain	K098	Northern floodplain forest

Appendix B: Current Cover Types (from LCC database, 1990, and RPA Forest Cover Types, 1992)

Code:	Cover type name
1:	Agriculture
2:	Grassland
3:	Wetlands
4:	Desert shrub
5:	Other shrub
6:	Oak-pine
7:	Oak-hickory
8:	Oak-gum-cypress
9:	Elm-ash-cottonwood
10:	Maple-beech-birch
11:	Aspen-birch
12:	Western hardwoods
13:	White-red-jack pine
14:	Eastern spruce-fir
15:	Longleaf-slash pine
16:	Loblolly-shortleaf pine
17:	Ponderosa pine
18:	Douglas-fir
19:	Larch
20:	Western white pine
21:	Lodgepole pine
22:	Hemlock-Sitka spruce
23:	Western fir-spruce
24:	Redwood
25:	Pinyon-juniper
26:	Alpine tundra
27:	Barren
28:	Water
30:	Urban/development/agriculture

Appendix C: Example of a Succession Diagram Summary Report

ECOHUC Section: -212A

PNV Group: 43: Spruce - fir *Fire Regime:* 4 : 35-100+ yrs; Stand Replacement

	Cover Types	*Forest Density*	*Area -Km^2*
1	10: Maple - beech - birch	2: 33 - 66 %	1
2	10: Maple - beech - birch	3: 67 - 100 %	3
3	11: Aspen - birch	3: 67 - 100 %	2
4	30: Urban/Development/Ag	0: Non Forest	6

PNV Group: 45: Oak - hickory *Fire Regime:* 3 : 35-100+ yrs; Mixed Severity

	Cover Types	*Forest Density*	*Area -Km^2*
5	9: Elm - ash- cottonwood	2: 33 - 66 %	5

PNV Group: 48: Mixed mesophytic forest *Fire Regime:* 3 : 35-100+ yrs; Mixed Severity

	Cover Types	*Forest Density*	*Area -Km^2*
6	6: Oak - pine	2: 33 - 66 %	6
7	6: Oak - pine	3: 67 - 100 %	6
8	7: Oak - hickory	1: 0 - 32 %	6

PNV Group: 50: Transition Appalachian Oak - Northern Hardwood *Fire Regime:* 3 : 35-100+ yrs; Mixed Severity

	Cover Types	*Forest Density*	*Area -Km^2*
9	10: Maple - beech - birch	2: 33 - 66 %	1
10	10: Maple - beech - birch	3: 67 - 100 %	5

PNV Group: 53: Northern hardwoods - spruce *Fire Regime:* 5 : 200+ yrs; Stand Replacement

	Cover Types	*Forest Density*	*Area -Km^2*
32	13: White - red - jack pine	2: 33 - 66 %	4
33	13: White - red - jack pine	3: 67 - 100 %	50
34	14: Spruce - fir (East)	2: 33 - 66 %	124
35	14: Spruce - fir (East)	3: 67 - 100 %	1836
36	30: Urban/Development/Ag	0 : Non Forest	443

Appendix D: Federal[a] and Non-Federal Fire Occurrence Per State, 1986 to 1996

FIPS[b]	State	Number of Federal fires	Federal km^2 burned	Number of non-Federal fires	Non-Federal km^2 burned	Total number of fires	Total km^2 burned
1	Alabama	1,230	106	168		1,398	106
4	Arizona	31,548	4,326	9,201	2,571	40,749	6,897
5	Arkansas	1,853	116	23,626	1,116	25,479	1,232
6	California	36,751	10,337	101,144	6,467	137,895	16,804
8	Colorado	10,182	1,011	4,868	500	15,050	1,511
9	Connecticut	2	0	1,268	16	1,270	16
10	Delaware	19	13	401	not reported	420	13
11	District of Columbia	32	0	0	0	32	0
12	Florida	3,182	1,624	51,519	4,709	54,701	6,333
13	Georgia	1,229	131	91,935	1,492	93,164	1,623
16	Idaho	16,416	16,595	5,169	2,357	21,585	18,952
17	Illinois	362	20	1,201	not reported	1,563	20
18	Indiana	668	21	14,004	291	14,672	312
19	Iowa	102	10	378	not reported	480	10
20	Kansas	191	59	74,933	7,148	75,124	7,207
21	Kentucky	1,641	293	1,191	not reported	2,832	293
22	Louisiana	1,386	428	3,206	not reported	4,592	428
23	Maine	62	1	7,564	96	7,626	97
24	Maryland	123	13	5,850	157	5,973	170
25	Massachusetts	52	0	29,677	156	29,729	156
26	Michigan	839	51	6,166	229	7,005	280
27	Minnesota	3,556	964	18,482	2,206	22,038	3,170
28	Mississippi	2,882	358	39,427	2,213	42,309	2,571
29	Missouri	2,559	328	18,457	1,235	21,016	1,563
30	Montana	13,787	5,638	4,467	1,582	18,254	7,220
31	Nebraska	590	391	14,672	2,420	15,262	2,811
32	Nevada	7,128	4,883	not reported	not reported	7,128	4,883
33	New Hampshire	38	1	1,484	not reported	1,522	1
34	New Jersey	81	1	11,237	277	11,318	278
35	New Mexico	10,986	3,385	7,397	4,936	18,383	8,321
36	New York	404	6	4,412	172	4,816	178
37	North Carolina	1,494	271	51,017	4,352	52,511	4,623
38	North Dakota	4,355	368	3,087	447	7,442	815
39	Ohio	481	16	2,412	60	2,893	76
40	Oklahoma	2,617	356	16,781	2,071	19,398	2,427
41	Oregon	20,851	7,556	13,083	1,064	33,934	8,620
42	Pennsylvania	174	5	9,124	239	9,298	244
44	Rhode Island	3	0	335	not reported	338	0
45	South Carolina	1,098	66	28,616	620	29,714	686
46	South Dakota	6,583	862	382	187	6,965	1,049
47	Tennessee	1,161	111	9,528	365	10,689	476
48	Texas	2,089	899	14,262	1,065	16,351	1,964
49	Utah	8,335	4,236	4,891	2,837	13,226	7,073
50	Vermont	10	1	942	8	952	9
51	Virginia	809	102	4,167	76	4,976	178
53	Washington	7,514	1,965	12,892	852	20,406	2,817
54	West Virginia	240	10	6,294	not reported	6,534	10
55	Wisconsin	1,333	29	19,197	189	20,530	218
56	Wyoming	3,872	5,898	3,235	772	7,107	6,670
	Total	212,900	73,861	753,749	57,550	966,649	131,411

[a] Federal fires include USDA Forest Service, USDI Bureau of Land Management, USDI Bureau of Indian Affairs, USDI Park Service, and USDI Fish and Wildlife Service.

[b] FIPS: Federal Information Processing Standards.

Appendix E: National Fire Occurrence GIS Database Fields

Field Name	Length	Type[a]	Comments
UNIQUENUM	9	B	Unique number for each record State records: State FIPS + FIRENUMBER Federal records: Agency code + 2-digit year + FIRENUMBER
AGENCY	1	I	Federal agency codes: 0 = Non-Federal 1 = BLM, Bureau of Land Management 2 = BIA, Bureau of Indian Affairs 3 = NPS, National Park Service 4 = FWS, Fish and Wildlife Service 5 = U.S. Forest Service
FIRENUMBER	7	B	Numeric identifier within each State or agency
FIRENAME	30	C	Not always provided
YEAR	4	B	Year of fire (4 digit: 1986, 1987, and so forth)
MONTH_DISC	2	I	Month discovered (or comparable)
DAY_DISC	2	I	Day discovered (or comparable)
TIME_DISC	4	B	Time discovered (2400 clock)
MONTH_CONT	2	I	Month controlled (or comparable)
DAY_CONT	2	I	Day controlled (or comparable)
TIME_CONT	4	B	Time controlled (2400 clock)
ACRES_TOTAL	12	F	Allow for 2 decimals
CAUSE_STD	2	B	Standardized cause code with the following categories: 1 = Lightning 6 = Equipment use 2 = Campfire 7 = Railroad 3 = Smoking 8 = Children 4 = Debris burning 9 = Miscellaneous 5 = Incendiary 0 = Unknown
CAUSE2	2	I	Cause of fire reclassified as: 1 = Lightning/natural cause 2 = Human cause 0 = Unknown or not reported
STATE	20	C	State name
COUNTY	32	C	County name
STATE_FIPS	3	I	State Federal Information Processing Standards (FIPS) code
DATA_SOURCE	5	C	Source of data recorded as state or agency abbreviation REG (1-6, 8, 9) = U.S. Forest Service Region BLM = Bureau of Land Management BIA = Bureau of Indian Affairs NPS = National Park Service FWS = Fish and Wildlife Service
YEARSINDB	25	C	Years for which data are present, for example, 1986–1996
LOC_SOURCE	14	C	Best location provided by state or agency, for example, County, Legal-TRS (Township, Range, Section), Legal-TRSQQ (Township, Range, Section, Quarter, Quarter), UTM, GIS, Lat/Long
NUM_YEARS	3	B	Number of years provided in database, for example, 11 if 1986–1996
STATUS	1	I	Item specifying status of data based on review by agency or State fire directors 1 = Satisfactory 2 = Unsatisfactory 0 = Not reviewed
LONG_DD	8,18	F	Longitude in decimal degrees, 5 decimals
LAT_DD	8,18	F	Latitude in decimal degrees, 5 decimals

[a] Type: **B**inary, **I**nteger, **C**haracter, **F**loating.

Appendix F: Non-Federal Fire Data Completeness (* indicates field was included in database obtained from State)

					Discovered			Contained				
State	**Location source**	**Years in database**	**Status[a]**	**Fire name**	**Month**	**Day**	**Time**	**Month**	**Day**	**Time**	**Area burned**	**Cause of fire**
Arizona	UTM	1986–1996	0		*	*	*	*	*	*	*	*
California	GIS	1986–1996	1,2[b]		*	*	*	*	*	*	*	*
Colorado	GIS	1986–1995	0		*	*					*	*
Connecticut	County	1991–1997	0		*	*	*				*	*
Delaware	NFIRS	1987–1988, 1990, 1995–1996	2		*	*						*
Florida	Legal–TRS[c]	1986–1996	0		*	*	*	*	*	*	*	*
Georgia	County	1986–1996	0		*	*	*	*			*	*
Iowa	NFIRS	1987–1988, 1990–1996	2		*	*						*
Idaho	Legal–TRS	1986–1989, 1991–1996	0	*	*	*	*	*	*	*	*	*
Illinois	NFIRS	1987–1988, 1990–1996	2		*	*						*
Indiana	County	1986–1996	0		*	*					*	*
Kansas	County	1986–1996	0		*	*	*				*	*
Kentucky	NFIRS	1987–1988, 1990–1996	2		*	*						*
Louisiana	NFIRS	1987–1988, 1990–1996	2		*	*						*
Massachusetts	County	1991–1997	2		*	*	*				*	*
Maryland	County	1987–1992, 1994–1996	0		*	*					*	*
Maine	Lat/Long	1986–1996	0	*	*	*	*	*	*	*	*	*
Michigan	Legal–TRS	1986–1996	1		*	*	*	*	*	*	*	*
Minnesota	Legal–TRS	1986–1996	1		*	*	*	*	*	*	*	*
Missouri	Legal–TRS, County	1990–1997	0		*	*	*	*	*	*	*	*
Mississippi	GIS	1988–1997	0		*	*	*			*	*	*
Montana	Legal–TRS	1986–1996	0	*	*	*	*	*	*	*	*	*
North Carolina	County	1986–1996	0	*	*	*	*	*	*		*	*
North Dakota	County	1988–1996	0		*	*					*	*
Nebraska	County	1987–1996	0		*	*					*	*
Nevada	Non–Federal fires not reported											
New Hampshire	NFIRS	1987–1988, 1990–1996	2		*	*						*
New Jersey	Lat/Long	1986, 1989–1995	0		*	*					*	*
New Mexico	Legal–TRS	1986–1996	0	*	*	*	*	*	*	*	*	*
New York	County	1986–1997	0	*	*	*		*	*		*	*
Ohio	County	1993–1996	0		*	*					*	*

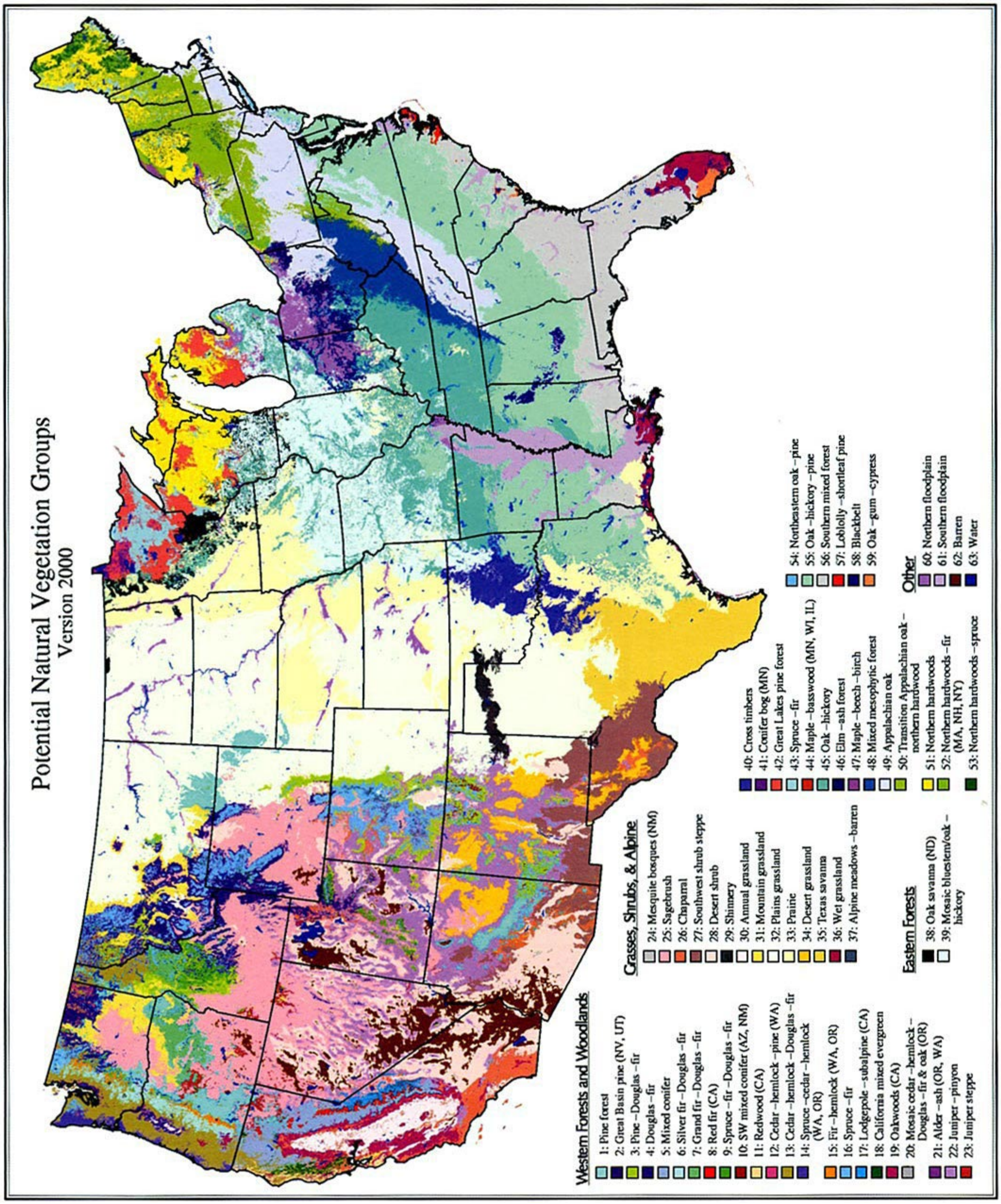
Oklahoma	Legal–TRS	1989–1996	0		*	*	*	*	*	*	*	
Oregon	Legal–TRS	1986–1996	0		*	*	*	*	*	*	*	*
Pennsylvania	County	1986–1992	0		*	*					*	*
Rhode Island	NFIRS	1987–1988, 1990–1995	2		*	*						*
South Carolina	Lat/Long	1988–1992	0		*	*					*	*
South Dakota	Legal–TRS	1988–1996	0	*	*				*	*	*	*
Tennessee	County	1993–1996	0	*	*	*	*	*	*	*	*	*
Texas	County	1988–1993, 1995–1996	0		*	*	*			*	*	*
Utah	Legal–TRS	1986–1996	0		*	*					*	*
Virginia	County	1990–1992	0		*	*					*	*
Vermont	County	1992–1996	0		*	*	*				*	*
Washington	Legal–TRS	1986–1996	0		*	*	*	*	*	*	*	*
Wisconsin	Legal–TRSQQ	1986–1996	1		*	*	*	*	*	*	*	*
West Virginia	NFIRS	1987–1988, 1990–1996	2		*	*						*
Wyoming	Legal–TRS	1991–1996	0		*	*					*	*

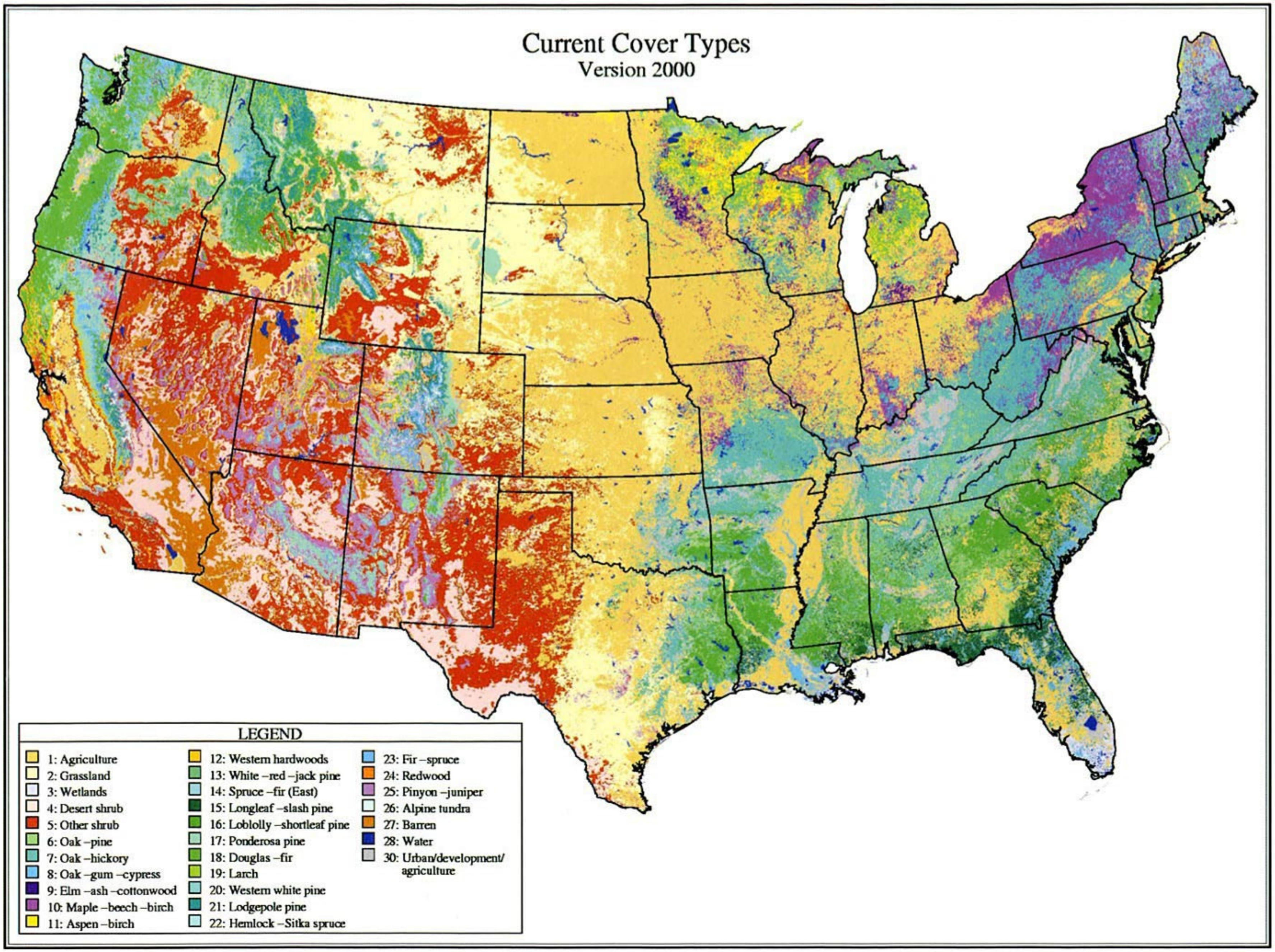
[a] Status codes: 1 = Satisfactory, 2 = Unsatisfactory, 0 = Not reviewed.

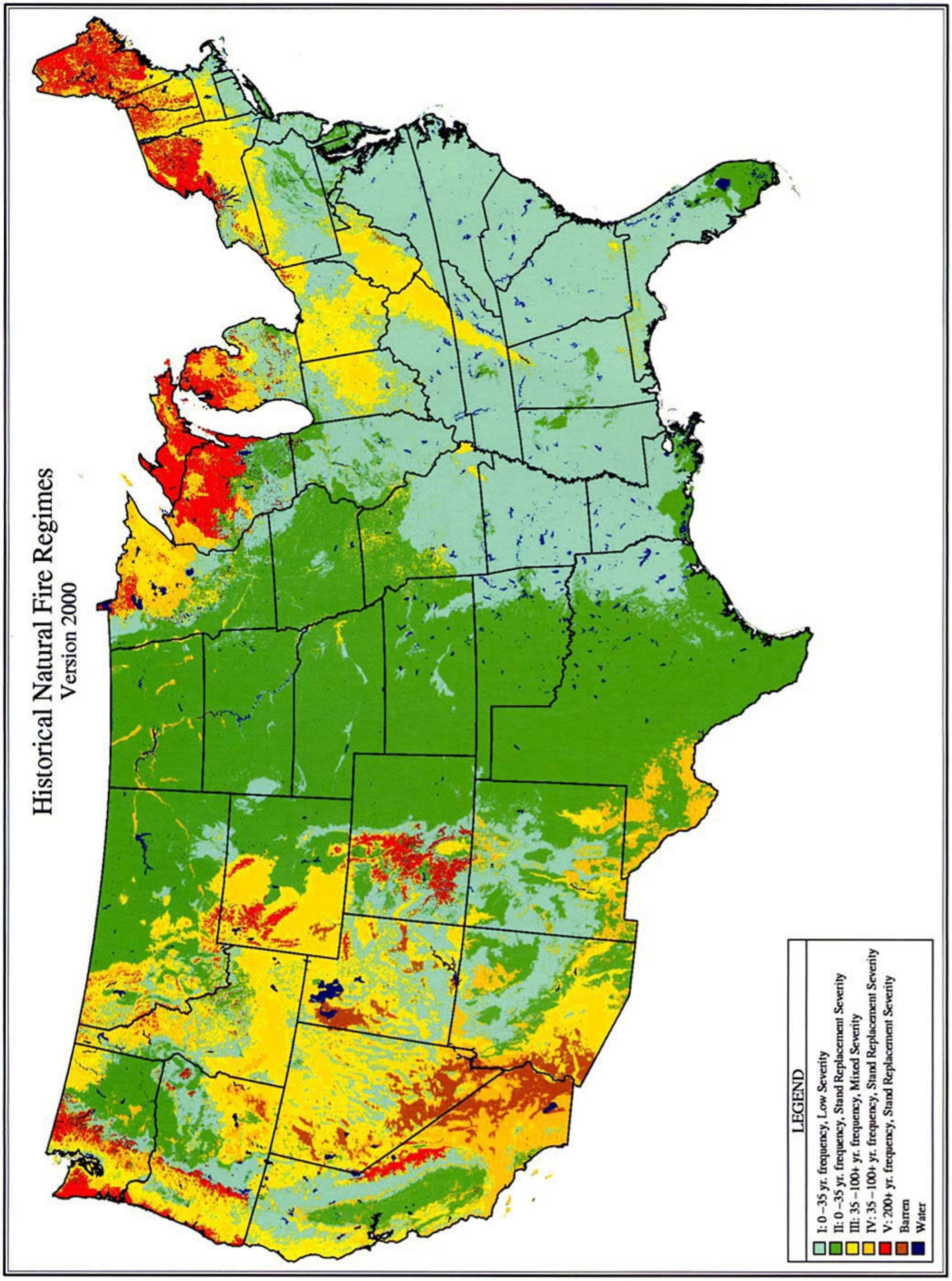
[b] Data for years 1987, 1991, 1993, and 1996 were given an “unsatisfactory” in review by State Foresters.

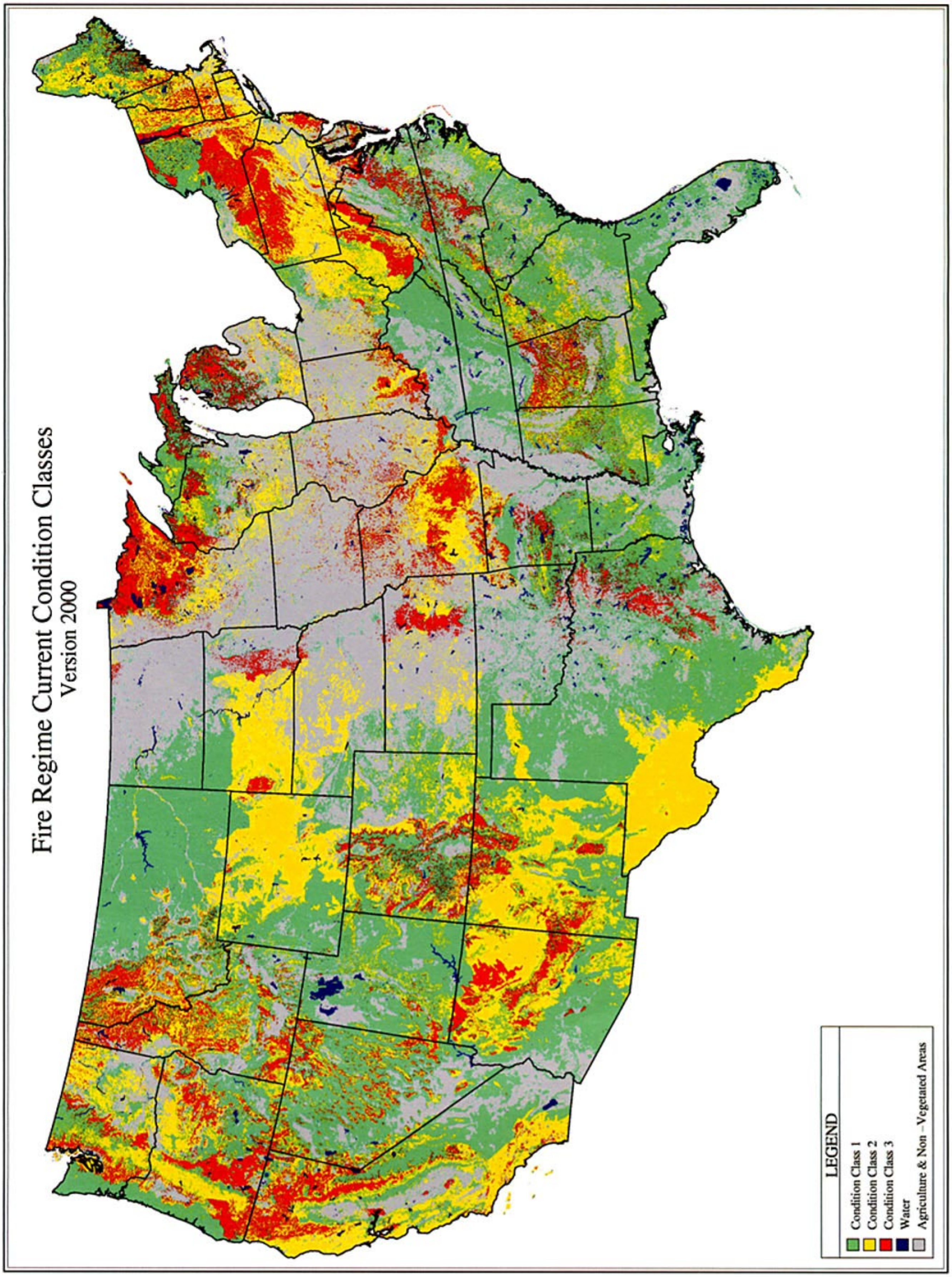
[c] TRS is Township, Range, Section; TRSQQ is Township, Range, Section, Quarter, Quarter.

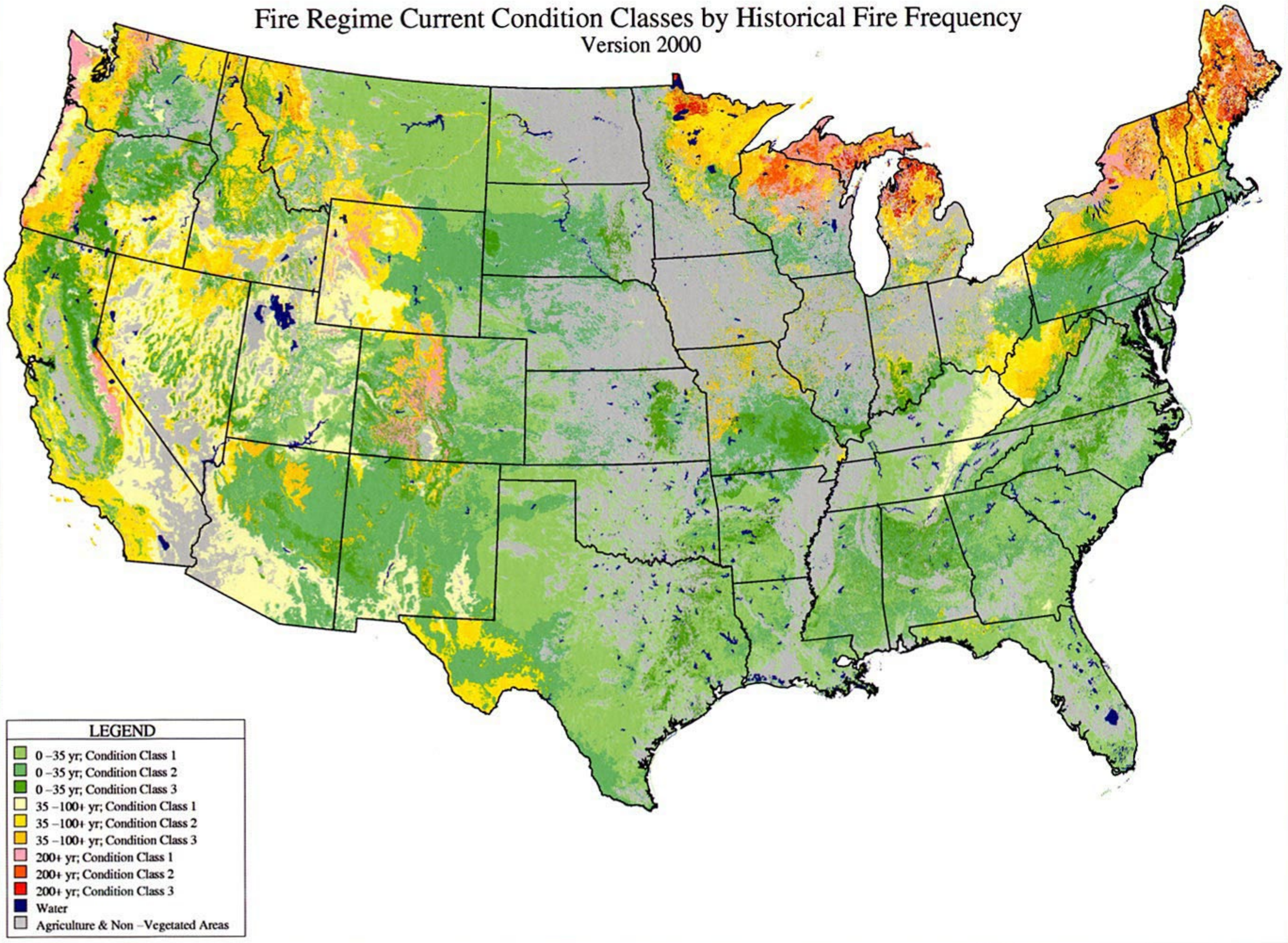
Appendix G: All Maps



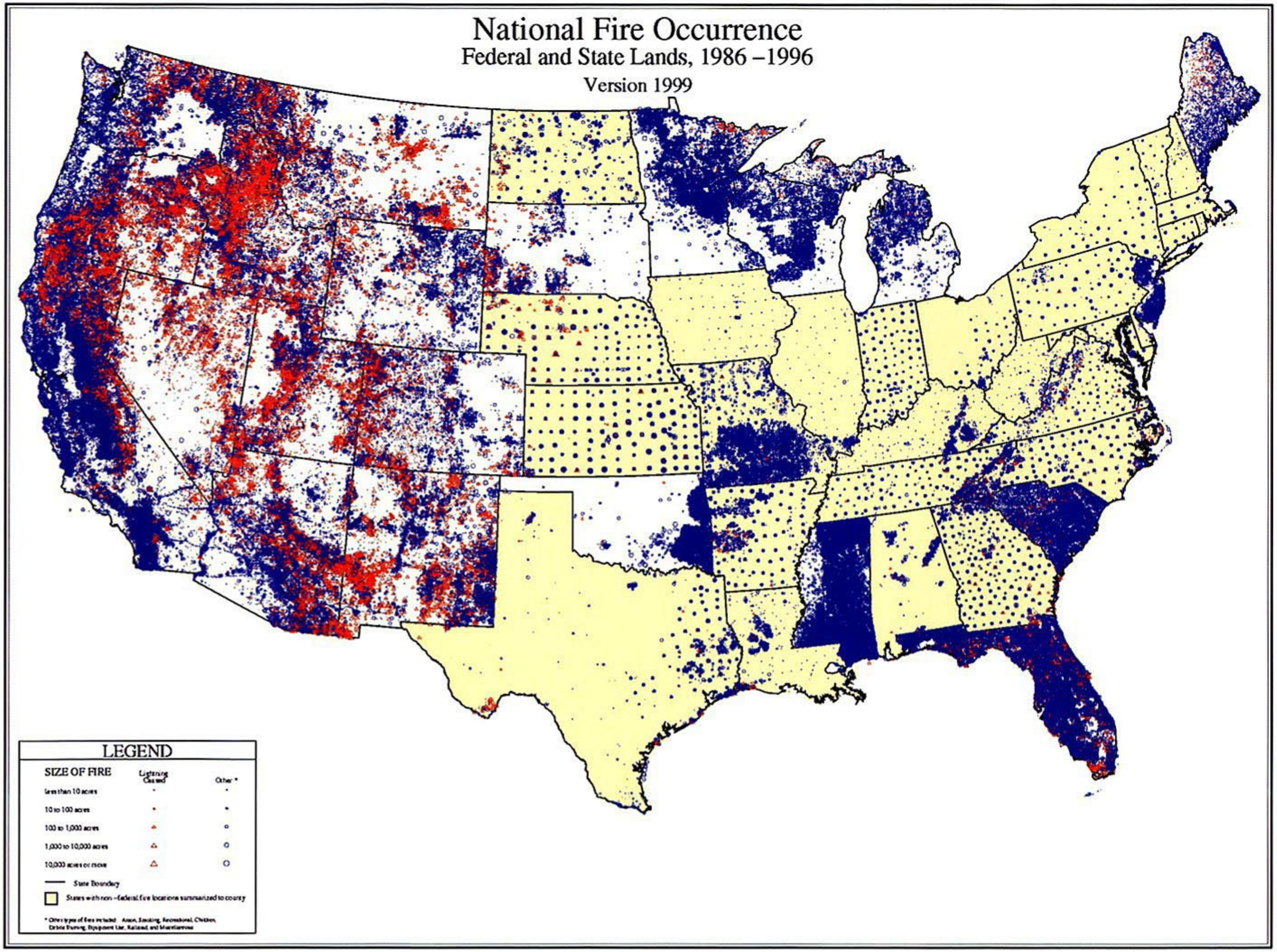

Current Cover Types
Version 2000
LEGEND
1: Agriculture
2: Grassland
3: Wetlands
4: Desert shrub
5: Other shrub
6: Oak –pine
7: Oak –hickory
8: Oak –gum –cypress
9: Elm –ash –cottonwood
10: Maple –beech –birch
11: Aspen –birch
12: Western hardwoods
13: White –red –jack pine
14: Spruce –fir (East)
15: Longleaf –slash pine
16: Loblolly –shortleaf pine
17: Ponderosa pine
18: Douglas –fir
19: Larch
20: Western white pine
21: Lodgepole pine
22: Hemlock –Sitka spruce
23: Fir –spruce
24: Redwood
25: Pinyon –juniper
26: Alpine tundra
27: Barren
28: Water
30: Urban/development/ agriculture

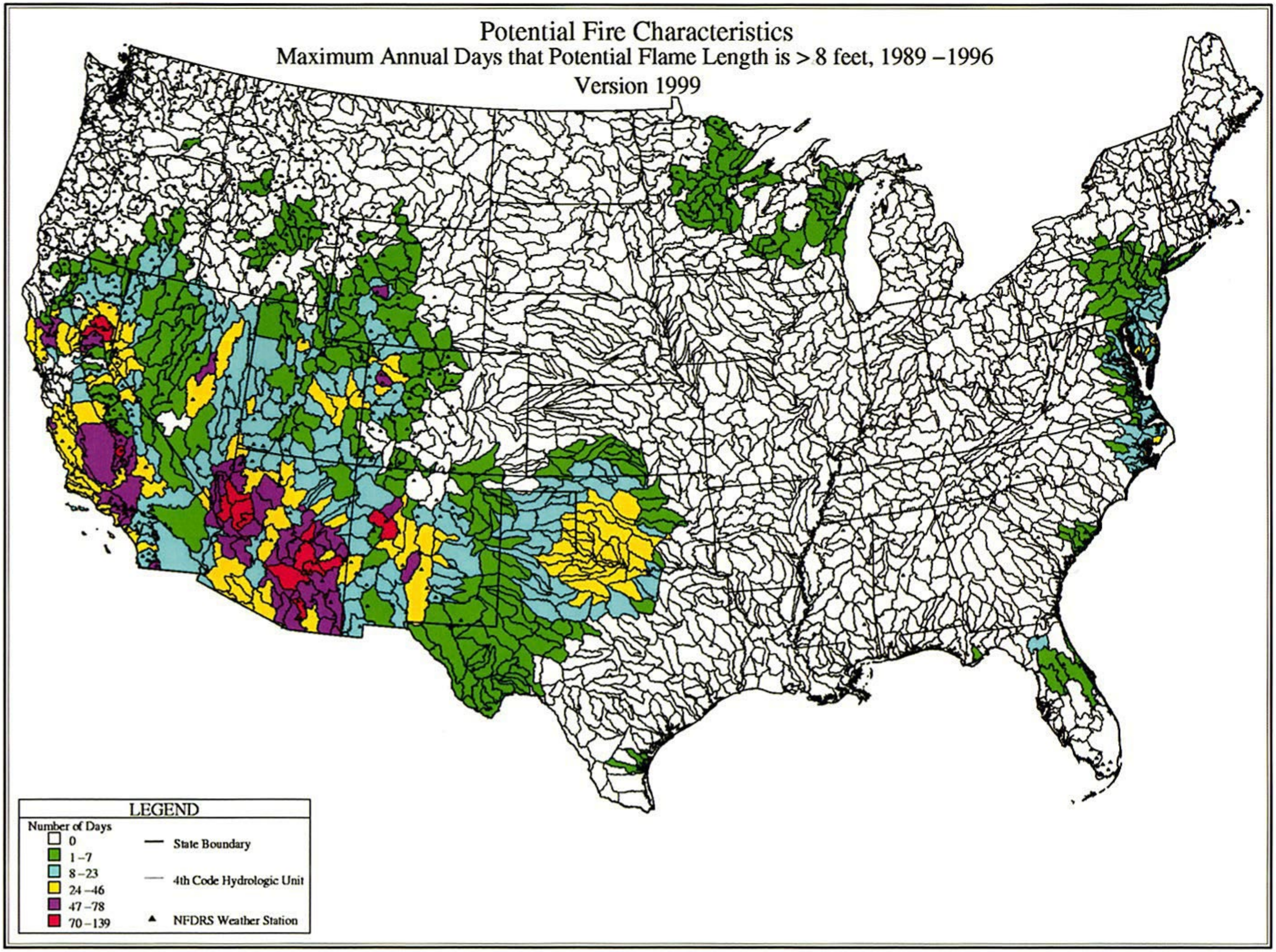

Historical Natural Fire Regimes
Version 2000
LEGEND
I: 0 – 35 yr. frequency, Low Severity
II: 0 – 35 yr. frequency, Stand Replacement Severity
III: 35 – 100+ yr. frequency, Mixed Severity
IV: 35 – 100+ yr. frequency, Stand Replacement Severity
V: 200+ yr. frequency, Stand Replacement Severity
Barren
Water


Fire Regime Current Condition Classes
Version 2000
LEGEND
🟩 Condition Class 1
🟨 Condition Class 2
🟥 Condition Class 3
■ Water
▨ Agriculture & Non –Vegetated Areas



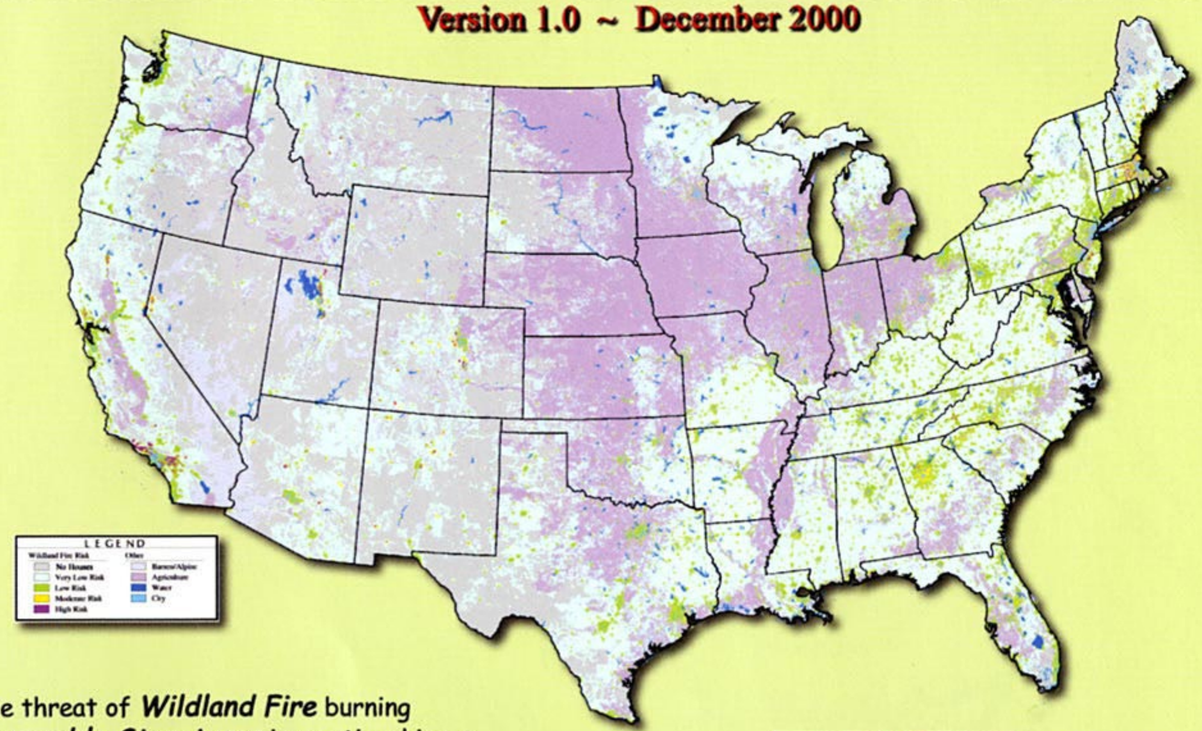
Fire Regime Current Condition Classes by Historical Fire Frequency
Version 2000


National Fire Occurrence
Federal and State Lands, 1986 –1996
Version 1999
LEGEND
SIZE OF FIRE
Lightning Caused
Other *
less than 10 acres
10 to 100 acres
100 to 1,000 acres
1,000 to 10,000 acres
10,000 acres or more
State Boundary
States with non –federal fire locations summarized to county
* Other types of fires included: Arson, Smoking, Recreational, Children, Debris Burning, Equipment Use, Railroad, and Miscellaneous


Potential Fire Characteristics
Maximum Annual Days that Potential Flame Length is > 8 feet, 1989 –1996
Version 1999
LEGEND
Number of Days
☐ 0
🟩 1 – 7
🟦 8 – 23
🟨 24 – 46
🟪 47 – 78
🟥 70 – 139
State Boundary
4th Code Hydrologic Unit
▲ NFDRS Weather Station

Wildland Fire Risk to Flammable Structures

Version 1.0 ~ December 2000



The threat of ***Wildland Fire*** burning ***Flammable Structures*** is a national issue. Each year the risk increases because fuels are constantly accumulating and flammable structures are being built adjacent to wildlands. We defined and mapped potential risk of wildland fire burning flammable structures for the conterminous United States. This map is an integration of the three GIS data layers you see to the right: ***Extreme Fire Weather Potential, Potential Fire Exposure, and Housing Density.***

Produced by
Jack Cohen, Jim Menakis, & Larry Bradshaw
for the Fire Modeling Institute at the Fire Sciences Laboratory,
USDA Forest Service, Rocky Mountain Research Station,
Missoula, Montana

http://www.fs.fed.us/fire/fuelman

http://firelab.org

Flammable Structures
are structures that have low resistance to ignition.

Wildland Fires
are vegetation fires that start and burn in unpopulated/undeveloped areas.

Extreme Fire Weather Potential
is a classification of the average number of days per year when weather conditions, (temperature, relative humidity, and wind speed) were similar to conditions under which wildland fire burned multiple structures in a single event. *(Source: Hourly observations for 16 years at 500+ weather stations throughout the conterminous United States, data compiled by USAF Combat Climatology Center)*

Potential Fire Exposure
is a classification of vegetation type into classes that exhibit similar fire behavior or heat intensity under extreme weather conditions. *(Source: Potential Natural Vegetation Groups Version 2.0 and Current Cover Types Version 1.0, USDA Forest Service Fire Effects Project, RMRS, Missoula, MT)*

Housing Density
is a classification of human habitation ranging from wildland to city in units of houses per hectare, derived from estimates of ambient populations. *(Source: Landscan Global Population 1998 database, Oakridge National Laboratory)*

RMRS
ROCKY MOUNTAIN RESEARCH STATION

The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals.

Studies accelerate solutions to problems involving ecosystems, range, forests, water, recreation, fire, resource inventory, land reclamation, community sustainability, forest engineering technology, multiple use economics, wildlife and fish habitat, and forest insects and diseases. Studies are conducted cooperatively, and applications may be found worldwide.

Research Locations

Flagstaff, Arizona
Fort Collins, Colorado*
Boise, Idaho
Moscow, Idaho
Bozeman, Montana
Missoula, Montana
Lincoln, Nebraska
Reno, Nevada
Albuquerque, New Mexico
Rapid City, South Dakota
Logan, Utah
Ogden, Utah
Provo, Utah
Laramie, Wyoming

*Station Headquarters, Natural Resources Research Center, 2150 Centre Avenue, Building A, Fort Collins, CO 80526