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FIREMON: Fire Effects Monitoring and Inventory System

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1. INTRODUCTION

Monitoring the effects of wildland fire is critical for (1) documenting fire effects, (2) assessing ecosystem damage and benefit, (3) evaluating the success or failure of a treatment, and (4) appraising the potential for future treatments. Objectives for monitoring depend on the type of treatment. Monitoring the effects of wildfire is necessary to evaluate the possible need for rehabilitation, while monitoring after prescribed fires is required to assess the effectiveness of the treatment. Monitoring data can have far-reaching applications in fire management because it provides the scientific basis for planning and implementing future burn treatments. Measuring post-fire ecosystem response also allows us to understand the consequences of fire on important ecosystem components and share this knowledge in a scientifically based language. Monitoring is the critical feedback loop that allows fire management to constantly improve prescriptions and fire plans based on the new knowledge gained from field measurements.

Monitoring has been one task that many fire managers have been reluctant or remiss to complete. Often, fire managers find themselves too busy with other essential duties to design and implement monitoring projects. Additionally, the complexity of monitoring sampling designs to obtain useful fire effects data often overwhelms or intimidates fire managers. This is especially true when the fires to be monitored are large (>1000

acres), on diverse landscapes, and of varying severity. It is difficult to design a cost-efficient sampling strategy that will scientifically quantify stand-level fire effects across an entire landscape. But perhaps the main reason fire monitoring projects are rarely implemented is the lack of standardized and comprehensive sampling methods and tools. Most fire management agencies do not have scientifically based sampling protocols for inventorying pre- and post-fire conditions to satisfy monitoring objectives. The major exception is the National Park Service, USDI, which has extensive guidelines and protocols for sampling ecosystem characteristics that are important to monitoring fire effects in its Fire Monitoring Handbook. (USDI NPS, 2001).

To fill the need for an agency independent fire monitoring system we developed FIREMON: fire effects monitoring and inventory system. FIREMON has been designed to satisfy the monitoring requirements of most fire managers. It is a plot level sampling system designed to characterize changes in ecosystem components over time, before and after treatment. FIREMON includes a set of sampling manuals, database, field forms and analysis programs that allow the manager to design a fire effects monitoring project, collect and store the sampled data, statistically analyze and summarize the data, link the data with satellite imagery, and map the sampled data across the landscape using image processing.

2. THE FIREMON COMPONENTS

FIREMON consists of four main components. First, the *Integrated Sampling Strategy* leads the fire manager through text,

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guides and keys to suggest the appropriate sampling approach (relevé or statistical), sampling intensity (detailed, alternative or simple) and sampling methods based on project resources and sampling objectives. Second, the FIREMON manual brings together a number of *sampling methods*, developed from existing recognized procedures to assist the fire manager in assessing the effectiveness of treatments. The sampling methods provide the following information about a plot: biophysical description, trees, down woody debris, fire severity, fire behavior and vegetation - cover, frequency and density. Also included in the manual are user guides for the database and analysis tools, a how-to section, glossary and appendix. The third component, the Microsoft Access®-based *FIREMON database*, is provided for data storage. Data entry forms look like field forms and dropdown lists limit data entry errors. Plot data can be summarized using built-in Access queries. Lastly, the *FIREMON Analysis Tools* package allows users to summarize data across a number of plots by any stratification and, assuming the data was collected appropriately, allows statistical comparison of plot data.

2.1 Integrated Sampling Design

The Integrated Sampling Strategy (ISS) is used to design fire monitoring sampling projects by selecting the most appropriate sampling approach and the most efficient sampling strategy, then choosing the appropriate methods. The first section of the ISS introduces the FIREMON user to the terminology and inherent properties of sampling design in the FIREMON monitoring approach. The second section presents the preliminary information that must be collected or compiled for designing a monitoring project. The third section documents how a monitoring project is implemented and the last section provides users with guides and keys to assist in developing the monitoring project.

The major difference between the FIREMON ISS and the traditional method of developing a sampling approach is that the sampling intensity is keyed to available resources, such as people, time, expertise and funding and not some statistical parameter, such as variance. Most fire managers are constrained by the project resources so it is important for them to have a sampling strategy guide that takes resources into account.

The ISS has been reviewed by U.S. Forest Service, Rocky Mountain Research Station Statisticians and clearly describes the costs and

benefits of a statistical versus non-statistical sampling scheme.

Once the ISS process has been completed the fire manager is able distribute plots across the sampling area in a design that is most efficient given the project objectives.

2.2 Sampling Methods

The FIREMON sampling methods were developed from existing, recognized methods. They provide managers a suite of tools to collect information important to their monitoring program. The FIREMON manuals provide a recommended procedure for data collection, however, the database has been designed to be flexible and users can modify most of the sampling methods so that their data is collected in the most efficient manner. The manual for each field method provides a written description of the procedure, data forms (figure 1), cheat sheet, equipment list and data field descriptions.

Figure 1. Example Fuel Load field Form

Sampling methods are not provided for all ecosystem components. For example, we could not find a recognized water quality sampling procedure so we have not included one in FIREMON. Additional procedures could be added in the future. A brief description of the supplied sampling methods is provided below.

2.2.1 Plot Description

The Plot Description (PD) form is used to describe general biophysical characteristics of the FIREMON plot to provide ecological context for data analyses. The PD data characterize the topographical setting, geographic reference point, general plant composition and cover, ground cover, fuels, and soils information. This method provides the general ecological data that can be

used to stratify or aggregate fire monitoring results. The PD method also has comment fields that allow for documentation of plot conditions and location using photos and notes. The key for the FIREMON database, made up of the Registration Code, Project ID, Plot Number and Date, is part of the PD form. This key links all sampling data for a given plot.

2.2.2 Tree Data

The Tree Data (TD) methods are used to sample individual live and dead trees on a fixed-area plot to estimate tree density, size, and age class distributions before and after fire to assess tree survival and mortality rates. This method can also be used to sample individual shrubs if they are over 4.5 feet tall. When trees are larger than the user specified breakpoint diameter; diameter at breast height, height, age, growth rate, crown length, insect/disease/abiotic damage, crown scorch height and bole char height, are recorded. Trees less than breakpoint diameter and taller than 4.5 feet are tallied by species-diameter-status class. Trees less than 4.5 feet tall are tallied by species-height-status class and sampled on a subplot within the macroplot. Snag measurements are made on a snag plot that is usually larger than the macroplot. Snag characteristics include species, height, decay class and cause of mortality.

2.2.3 Fuels Data

The Fuel Load method (FL) is used to sample dead and down woody debris, depth of the duff/litter profile, estimate the proportion of litter in the profile, and estimate vegetative cover and height. Down woody debris (DWD) is sampled using the planar intercept technique based on the methodology developed by Brown (1974). Pieces of dead and down woody debris are tallied in the standard fire size classes: 1-hour (0 to 0.6 cm), 10-hour (0.6 to 2.5 cm), 100-hour (2.5 to 8 cm). Pieces greater than 8 cm in diameter are recorded by diameter and decay class. Duff and litter depth are sampled at two points along each 20-meter sampling plane. Litter depth is estimated as a proportion of total duff and litter depth. Cover of live and dead vegetation is estimated at two points along each 20-meter sampling plane. Biomass of DWD, duff, litter and vegetation is calculated using the Analysis Tools software and Access queries.

2.2.4 Species Composition

The FIREMON Species Composition (SC) method is used to provide ocular estimates of canopy cover and height measurements for plant species on a macroplot. The SC method provides plant species composition and canopy coverage estimates to floristically describe a stand or plant community and can be used to document changes over time. It is suited for a wide variety of vegetation types and is especially useful in plant communities with tall shrubs or trees. The method is relatively fast and efficient to conduct in the field and facilitates sampling many sites over large areas using few examiners. The SC method is an inventory method and does not quantify the variability within a plot. The SC data cannot be used to detect statistically significant changes over time.

2.2.5 Cover/Frequency

The FIREMON Cover/Frequency (CF) method is used to assess changes in plant species cover and frequency for a macroplot. This method uses quadrats to sample within-plot variation and quantify statistically valid changes in plant species cover, height, and frequency over time. Since it is difficult to estimate cover in quadrats for larger plants, this method is primarily suited for grasses, forbs, and shrubs less than 1 meter in height. Quadrats are placed systematically along randomly located transects. Canopy cover is assessed by visually estimating the percent of a quadrat occupied by the vertical projection of vegetation onto the ground. Plant species frequency is recorded as the number of times a species occurs within a given number of quadrats. Frequency is typically recorded for plant species that are rooted within the quadrat.

2.2.6 Point Intercept

The FIREMON Point Intercept (PO) method is used to assess changes in plant species cover or ground cover for a macroplot. This method uses a narrow diameter sampling pole or sampling pins, placed at systematic intervals along line transects to sample within plot variation and quantify statistically valid changes in plant species cover and height over time. Plant species or ground cover classes which touch the pin are recorded as "hits" along a transect. Canopy cover is calculated by dividing the number of hits for each plant species or ground cover class by the total number of points along a

transect. This method is primarily suited for vegetation types less than 1 meter in height and is particularly useful for recording ground cover.

2.2.7 Line Intercept

The FIREMON Line Intercept (LI) method is used to assess changes in plant species cover for a plot. This method uses line transects to sample within plot variation and quantify statistically valid changes in plant species cover and height over time. This method is suited for most forest and rangeland communities, but is especially useful for quantification of shrub cover greater than 1 meter tall, given that ocular estimation of cover for such species is difficult. The LI method can be used in conjunction with cover-frequency transects when vegetation over 1 meter exists. Line intercept can also be used to calibrate ocular estimates of shrub cover when the Species Composition (SC) method is used. Canopy cover is recorded as the number of meters intercepted along a transect. Percent canopy cover is calculated by dividing the number of meters intercepted by each item by the total length of the transect.

2.2.8 Density

The FIREMON Density (DE) method is used to assess changes in plant species density and height for a macroplot. This method uses quadrats and belt transects to sample within plot variation and quantify statistically valid changes in plant species density and height over time. Typically, herbaceous plant species are sampled with quadrats while shrubs and trees are sampled with belt transects. Quadrats for sampling herbaceous plants are placed systematically along randomly located transects. Belt transects for sampling shrub and tree density use the same randomly located transects. The number of individuals for each plant species in a quadrat or belt transect are calculated. Density is calculated as the number of individuals per unit area using the area of the sampling unit, quadrat or belt transect. This method is primarily suited for grasses, forbs, shrubs, and small trees in which individual plants or stems can be distinguished. However, we recommend using the FIREMON TD sampling methods for estimating tree density. The DE sampling can also be used to sample the density of other items such as pinecones and elk pellets.

2.2.9 Rare Species

The FIREMON Rare Species (RS) method is used to assess changes in uncommon, perennial plant species when other monitoring methods are not effective. This method monitors individual plants and statistically quantifies changes in plant survivorship, growth, and reproduction over time. Plants are spatially located using distance along and from a permanent baseline and individual plants are marked using a permanent tag. Data are collected for status (living or dead), stage (seedling, non-reproductive, or reproductive), size (height and diameter), and reproductive effort (number of flowers and fruits). This method is primarily used for Threatened and Endangered species and uncommon grass, forb, shrub, and tree species of special interest.

2.2.10 Composite Burn Index

The Composite Burn Index (CBI) method is used to derive index values that summarize general fire effects across multiple strata within the sample plot. The severity assessment is based on ocular estimation and judgment with each component ranked on a scale from 0 (no change) to 3 (maximum effect). The CBI is designed to calibrate moderate-resolution remote sensing applications, assuming a landscape perspective of entire burned regions. Plots are relatively large (707 m²) and widely spaced (>90 m apart). The primary task is to encompass the range of variation found within burns, covering as many fire effects and biophysical settings as possible.

CBI information is not solely limited to remote sensing, however. Field data can stand alone for general burn assessment, as a way to summarize conditions exceeding a few hectares. Methods work at stand or community levels to estimate the combined severity of individual factors. Data may be useful for reconnaissance, rapid assessment after burning, planning rehabilitation, documenting results of prescription burns, or any activity where burn information needs to be gathered relatively quickly over large areas. Other methods within FIREMON address smaller-scale sampling for detailed fire effects on individual components of a community. Those can complement the CBI when more site-specific information is needed.

2.2.11 Fire Behavior

The Fire Behavior (FB) method is used to describe the behavior of the fire and the ambient weather conditions that influence the fire behavior. Fire behavior methods are not plot based and are collected by fire event and time-date. In general, the fire behavior data are used to interpret the fire effects documented in the plot-level sampling. Unlike the other plot-level sampling methods, the Fire Behavior methods are documented observations taken for one fire event, not for the FIREMON macroplots. The FireID field in the PD method links this database to the plot level data. The Flame Length, Spread Rate and Fire Behavior Picture fields in the PD method allow you to enter plot specific fire behavior data.

2.3 Remote Sensing Method

The Normalized Burn Ratio (NBR) is an analysis method used to map fire severity across a landscape using remotely sensed imagery. The procedure applies a mathematical algorithm to the two bands of the TM/ETM+ sensors in Landsat data most correlated with fire effects at the surface. Pre-fire and post-fire scenes are processed and differenced pixel by pixel across the landscape. The final product displays fire severity, generally calibrated with data collected using the CBI sampling method, across the burned area. Uses include identifying areas that require rehabilitation (e.g. reduce erosion potential) or areas that may require post-fire treatment (e.g. remove stressed trees to reduce insect and disease potential), validate and improve fire spread models, update fuel model and vegetation layers for fire growth models and examining vegetation change effects for wildlife concerns.

2.4 Other Documentation

The next sections give guidance on applying FIREMON and provide general information.

2.4.1 Analysis Tools and Database Guides

Separate guides are provided for the database and analysis software. The FIREMON Analysis Tools Guide provides directions and examples for the analysis program. The FIREMON Database Tools Guide provides directions and examples on using and managing the Microsoft Access database.

2.4.2 How-to Guide

The How-to guide explains procedures that are common to more than one method. For instance, compass use is common to a number of different methods so a description of its use is referenced in the methods but described in the How-to section.

2.4.3 Glossary

Recognizing that many FIREMON users may not have the extensive background needed to be familiar with all the sampling methods and the associated terminology we compiled a common glossary. Definitions are provided along with references so that the context is clear. For instance, the term fire severity may have multiple meanings however in the FIREMON glossary it is only defined as it is used in the Composite Burn Index and Normalized Burn Ratio sections of FIREMON.

2.4.4 Reference list

A comprehensive list of references is provided to the user.

2.5 The FIREMON Database

The FIREMON database actually consists of two linked Microsoft Access databases; the *Application* database and the *Data* database. The application database provides the user interface for the data (figure 2).

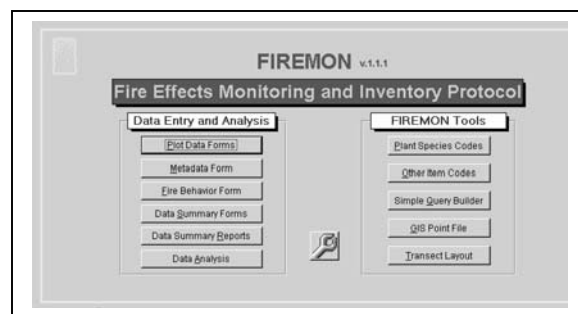


Figure 2. FIREMON database main screen.

The *Data* database contains the tables, which store the actual FIREMON data and the standard lookup codes used in various FIREMON fields. Using two different databases allows changes to be made to the data summaries, reports and forms through *Application* database without affecting data that users have stored the *Data* database.

The FIREMON database and the associated software allow users to enter data (figure 3), view summary tables and generate summary reports. Additionally, users can build local species lists for individual projects, add new item codes, build simple queries, create GIS point files and run the Transect Layout program which assists in randomly determining sample locations for the vegetation sampling methods.

Figure 3. Fuel Load data entry form.

2.6 Analysis Tools

The FIREMON Analysis Tools program is designed to let users perform grouped or ungrouped summary calculations of single measurement plot data, or statistical comparisons of grouped or ungrouped plot data taken at different sampling periods. Plots can be summarized by any field on the PD form or manually. Statistical comparison is made using F-tests to identify significant difference among all means and, if the F-test shows significant differences, Dunnett's t-test is used to identify which means are different. A minimum of three plots per group is required for statistical analysis. The program allows the user to create reports and graphs, which can be saved to a file, printed, or cut-and-paste into other documents (figure 4).

Tree and fuels data can be exported to files necessary to run the Forest Vegetation Simulator and Fire and Fuels Extension.

3. FIELD REVIEW

FIREMON was substantially reviewed by managers and field crews. In March of 2002 a meeting was hosted in Missoula, MT that included fire managers, fire ecologists and, other fire and monitoring experts from the U.S. Forest Service, National Park Service and private contractors. Comments from that meeting proved critical in making FIREMON an effective tool that fills the

needs of most managers. Over the course of the following year we received numerous useful comments from field crews, scientists and potential FIREMON users as they tested the draft version of FIREMON. In May of 2003 we held a 4-day user's workshop in Missoula. Forty-seven participants including fire management officers, fire ecologists and fuels technicians from the U.S.

Figure 4. Analysis report showing data summarized across all plots over three sampling events.

Forest Service, Bureau of Land Management, National Park Service and U.S. Fish and Wildlife Service had the opportunity to learn and use FIREMON. Again, we received valuable input from the participants that was incorporated into the FIREMON system.

4. AVAILABILITY

FIREMON is currently in press. It will be released as a U.S. Forest Service, General Technical Report on CD sometime in early 2004. Currently all documentation (in final draft form) and software is available for download from the FIREMON website: www.firelab.org/firemon.

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Courtney Couch worked diligently to take the authors' stick-figure diagrams and create the illustrations that add significantly to FIREMON. She also created the Pat Firemon character present in many of the figures. Virginia Arensberg searched numerous publications to build a thorough glossary of terms. RMRS statisticians Rudy King and Dave Turner provided critical input regarding the ISS and the analysis tools software.

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