Interagency Fuels Treatment Decision Support System Conceptual Design

Sponsored By

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PROTECTING COMMUNITIES & ENVIRONMENTS
National Interagency Fuels Coordination Group

National Interagency Fuels Management

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REVISION HISTORY

Version	Date	Changes
0.1	06/04/08	First rough draft submitted for comment from IFT-DSS working Team.
0.2	06/16/08	Comments from IFT-DSS Working Team incorporated.
0.3	06/17/08	Final changes to initial draft document incorporated.
0.4	07/01/08	Renamed FT-CSA to IFT-DSS. Added Section 6 details for system and model concepts and comparisons. Glossary remains incomplete as well as the System Tables.
0.5	07/15/08	Added sponsorship logos and made changes to clarify model and software system terms.
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0.7	07/21/08	Added new description for IFP-NIFTT-LANDFIRE, revised section 4
0.8	08/13/08	Added executive summary, revised language to conform to landscape vs treatment unit definitions, revised glossary, 3.4 Caveats, added the 6.1.5 Vegetation Data Considerations section
0.9	08/18/08	Redefined aspatial and spatial analyses and incorporated some updates from reviews by the developers of the systems mentioned.
1.0	01/20/08	Updated the document to respond to the critical review comments. Final Version.

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1 Glossary of Terms & Acronyms

TERM	DESCRIPTION
Architecture Framework	Architecture Framework (short for Enterprise Architecture Framework) defines how to organize the structure and views associated with an Enterprise Architecture. Because the discipline of Enterprise Architecture is so broad, and because the enterprises it describes tend to be large and complex, the models associated with the discipline also tend to be large and complex. To manage this scale and complexity, an Architecture Framework defines complementary projections of the enterprise model called *Views*, where each View is meaningful to different system stakeholders. See also: Collaborative System Architecture.
Aspatial Fuels Treatment Analysis	A fuels treatment analysis that is based on a single treatment unit with the focus of learning the fire behavior within that treatment unit or the biological effects of changing vegetation caused by the treatment implementation.
CD Document	Conceptual Design Document
Collaborative System Architecture (CSA)	A framework whose purpose is to integrate two or software systems so that the set of software systems performs some useful task efficiently. The platform is responsible for data fusion issues, managing input/output capabilities to solve the problem at hand, and for defining "handshaking" methods so new or other preexisting systems can be integrated as desired. The CSA can best be thought of as software whose role is to manage other software components. See also Architecture Framework.
FARSITE	FARSITE is a fire growth simulation model. It uses spatial information on topography and fuels along with weather and wind files.
FlamMap	FlamMap is a fire behavior mapping and analysis program that computes potential fire behavior characteristics (spread rate, flame length, fireline intensity, etc.) over an entire FARSITE landscape for constant weather and fuel moisture conditions.
FSPro	Fire Spread Probability
FVS	Forest Vegetation Simulator
GIS	Geographic Information System
ID Team	Interdisciplinary Team
IFP-NIFTT-LANDFIRE	Integrated Fuels Planning using LANDFIRE-data
IFT-DSS	Interagency Fuels Treatment Decision Support System
INFORMS	Integrated Forest Resource Management System
IT	Information Technology
Landscape	A landscape is a spatial area composed of many individually more homogeneous vegetation units that influence the movement and behavior of fire (for the purposes of the IFT-DSS). One or more of these more homogenous vegetation units may then be group together into treatment units for the purpose of analysis and management.
Model	From a scientific sense, a model is a quantitative or conceptual specification of relations among entities.
NEPA	National Environmental Policy Act
NIFCG	National Interagency Fuels Coordinating Group
NIFTT	National Interagency Fuels Technology Transfer team

TERM	DESCRIPTION
PHYGROW	Phygrow is a hydrologic based plant growth simulation model.
Project Area	Typically used to define a boundary for NEPA analysis and the area potentially affected by proposed treatments. A project area may be used to define the landscape being analyzed.
RERAP	Rare Event Risk Assessment Process
SEI	Carnegie Mellon Software Engineering Institute
SOA	Service Oriented Architecture
Software System	A type of IT application that provides an interface and fusion tools for one or more embedded models that address a specific set of user needs.
Spatial Fuels Treatment Analysis	We define two types of spatial fuels treatment analyses: (1) multiple vegetation units are examined across a landscape but with no explicit interaction between any of the units during the analysis; and (2) multiple vegetation units are examined across a landscape but with explicit consideration of the topology of fire spread and its effects on all vegetation units in the landscape of concern, ie. A particular vegetation unit may affect the spread and severity of fire on adjacent vegetation units to change the outcome of the analysis.
TA	Technical Architecture
TELSA	Tool for Exploratory Landscape Scenario Analyses (ESSA, Vancouver, BC)
Treatment Unit	The area within a defined spatial boundary that is to receive a single or a set of management treatments. A treatment unit is composed of either one or more vegetation units.
UI	User Interface
VDDT	Vegetation Dynamics Development Tool (ESSA, Vancouver, BC)
Vegetation Unit	A parcel of land where timber, shrubland, and/or grassland plant species predominate. Stand is the term commonly used in silviculture textbooks and within the Forest Service. Patch is the common term in landscape ecology. The vegetation unit term was chosen for the IFT-DSS to be as generically neutral as possible.
WFDSS	Wildland Fire Decision Support System
WUI	Wildland Urban Interface; defined as the area where structures and other human development meet or intermingle with undeveloped wildland.

2 INTRODUCTION

The Joint Fire Science Program (JFSP) Fuels Working Group crafted this conceptual design document for the Interagency Fuels Treatment - Decision Support System (IFT-DSS). The members of the JFSP Fuels Working group are: Erik Christiansen (FWS), John Cissel (JFSP), Dennis Dupuis (BIA), Dave Peterson (FS), Randi Jandt (BLM), Glenn Gibson (FWS), Mark Finney (FS), Michael Beasley (NPS), Brad Reed (NPS), Mark Clere (FS), Tessa Nicolet (FS), Dusty Pence (FS), Michele Tae (Contractor), Tami Funk (Contractor), Sean Raffuse (Contractor), Mike Rauscher (Contractor).

2.1 Purpose

This conceptual design (CD) presents the functional and structural “vision” for the IFT-DSS and defines the information technology (IT) and business concepts that will collaborate within the system to meet the defined requirements. No single depiction can fully describe a complex system, so the conceptual design includes multiple views:

- System Context: IFT-DSS’s role, boundaries, and dependencies at the enterprise level.
- System Vision: The entities collaborating within the system itself to meet the requirements. This view will focus on high-level subsystems and process flows.
- Software Systems: The abstract representations used to fulfill the system vision.
- Architecture: The underlying software systems, processing concepts and data that support the Framework Architecture.

This collection of diagrams and text represents the WHAT of the IFT-DSS system – what does it do, what are the processes, what are the entities, what are the subsystems? This is known as the “problem space”.

2.1.1 What This Document is Not

The conceptual design avoids answering the HOW of the IFT-DSS system. It avoids issues of how we build the system. In general, it will not identify specific solution technologies, products, or components. A future document, the Technical Architecture (TA) will move this vision from IT concepts to the actual solution components. The TA will define the “solution space”, that is, how we are to develop the system. The TA (not the CD) will address patterns, mechanisms, physical deployment, Web interface, administration, browsers, databases, protocols, and other solution specifics like those found in the Federal Enterprise Architecture documents. The audience for this document is: (1) the Sonoma Tech contractors that are responsible for writing the Technical Architecture specifications; (2) the community of Fuels Specialists working for any agency who are the primary user-clients of the IFT-DSS; and (3) the broader fire and fuels management, science and administrative community that may have an interest in learning about the JFSP IFT-DSS proof-of-concept project.

EXECUTIVE SUMMARY

The interagency Joint Fire Science Program (JFSP), through both formal and informal interactions with its partners and clients, became convinced that one of the more pressing problems facing fire and fuels managers is the confusion and inefficiency associated with the many existing software systems intended to help fire and fuels managers. These systems have proliferated in the last decade in response to various funding initiatives without any central control or vision. Managers are left with an assortment of unconnected systems in various stages of development with little guidance concerning the strengths and weaknesses of the various systems, and no framework for integration and fusion of data and outputs from these systems.

One of the principal voices articulating this problem has been the National Interagency Fuels Coordination Group (NIFCG). Acting in concert with NIFCG, the JFSP initiated the Software Tools and Systems Study in 2007. JFSP funded the Carnegie Mellon Software Engineering Institute (SEI) to perform a strategic analysis of this problem. This analysis was completed in March 2008, and SEI submitted a written report to the JFSP (Palmquist, 2008). One of the key findings of the SEI study was that "[T]he wildland fire and fuels management community needs a platform and approach that supports distributed collaboration."

The JFSP came to understand through its interactions with SEI that a platform that supports distributed collaboration includes certain key components:

- A software framework architecture that facilitates use and integration of data and scientific models, including a common user interface and shared data structures
- The flexibility for users to select and compose their own data and chain of models to help solve their own specific problems
- A clearly articulated set of standards so that software developers can develop models and modules that will function within the software framework architecture
- A lifecycle management system with processes to set priorities for software system development, training, and retirement

The SEI study identified the BlueSky framework architecture as a leading example of how scientific models can be modularized and connected to create a web-based, collaborative architecture system. The BlueSky framework was developed through the leadership of the U.S. Forest Service AirFire Team for the smoke management community. It is unique in that it offers operational customization to allow smoke managers to select and execute commonly used tools and modeling systems to fit specific user-defined scenarios.

JFSP and NIFCG have now initiated the second phase of the Software Tools and Systems Study to further investigate the feasibility of developing a framework architecture to support distributed collaboration to help solve fuels management problems. This work includes the following activities:

- Investment in BlueSky to further develop its potential as a web-based, user-friendly framework architecture
- Evaluate the Bluesky, the Wildland Fire Decision Support System (WFDSS), and other software integration systems for potential use as a framework architecture for the fuels analysis and planning domain
- Develop a conceptual design and technical architecture specification for a software framework architecture for the fuels analysis and planning domain

- Evaluate and categorize existing software systems used for the fuels analysis and planning domain for their potential inclusion in a framework architecture
- Test the new Wildland Fire IT Investment process as a software lifecycle management process

The remainder of this document describes the conceptual architecture for the fuels analysis and planning domain. Work is also progressing on the other activities listed above. If this approach to supporting distributed collaboration proves successful, future work will need to address how framework architectures developed for other domains, most prominently BlueSky and WFDSS, can work together with this architecture to improve software system use and integration in the wildland fire community. Our vision is that existing framework architectures such as BlueSky and WFDSS provide seamless (to the user) service support with each other and with newly developed architectures such as the Interagency Fuels Treatment DSS described in this document.

3 Background

3.1 The Initial Software Tools and System Study

The Joint Fire Science Program (JFSP) Governing Board became convinced that one of the most pressing problems existing in the field of fire and fuels management from an interagency perspective is the confusion and uncertainty around the many existing software systems. This conclusion was reached in 2006, as a result of numerous “user sensing” activities led. In 2007, JFSP organized a project entitled “The Software Tools and Systems Study” and contracted with the Carnegie Mellon Software Engineering Institute (SEI) to perform a strategic analysis of this problem. The strategic analysis was completed in March 2008 and the SEI submitted a written report to the JFSP (Palmquist, 2008). One of the key SEI findings that addressed the plethora of software tools and systems was, “The wildland fire and fuels management community needs a platform and approach that supports distributed collaboration.”

> “Because of the variety of operational contexts, it is impossible to centrally predict or resource the exact sets of models, tools, or data sets needed for each situation. This requires collaborative tools supporting net-enabled methods of analysis. This flexible and extendable integration framework (what we call framework architectures) will allow tool developers or sophisticated users to rapidly configure, calibrate, or extend Web-enabled capabilities to meet needs of a specific operational situation” (Palmquist, 2008 14).

The SEI team identified three types of Framework Architectures (Palmquist, 2008 17-26):

- Type I: typified by service-oriented architecture (SOA) infrastructure providing services (i.e. functions) with well-defined behaviors such as on-line banking systems. Users have no say in the type of services offered or in the way solution processes are configured.
- Type II: typified by allowing users to customize services in a finite number of commonly understood ways based on shared, community-wide assumptions about what is needed.
- Type III: typified by supporting the customization of services by users for specific, unique operational situations that may or may not be shared, community-wide ways of solving a particular problem.

Type III architectures were identified by the SEI strategic assessment as the key tools to adequately address the fuels software systems management problem.

3.2 The BlueSky Project

The SEI identified the BlueSky architectural framework as a leading example of modularizing and connecting scientific models and a likely candidate for creation of a web-based, Type III collaborative architecture system (Palmquist, 2008).

Based on this result, the JFSP funded a proposal submitted by the BlueSky lead scientist, Dr. Sim Larkin entitled “Conversion of BlueSky Framework into collaborative web service architecture and creation of smoke modeling application” (Larkin, 2008 on file with the JFSP, Boise, ID). The starting date for this project was June 2008 and the projected end date is May 2009. Larkin enumerated specific advantages of collaborative architecture systems (CSA):

- The development of scientific models is separated from user interfaces (UI’s).

- UI's are integrated and capable of driving multiple models.
- Faster development of models and UI's is possible.
- Direct comparison between similar models is supported.
- Faster transition between developed models and operational applications is possible.

3.3 The Fuels Treatment Collaborative System Architecture

The question still remains whether the BlueSky approach to collaborative system architecture (CSA) is sufficiently generic to support the development of software solutions outside the smoke management domain. The JFSP Board decided to focus the ongoing effort in the Software Tools and Systems Study on resolving this question. The NWCG National Interagency Fuels Coordinating Group (NIFCG), in cooperation with JFSP authorized a one-year software engineering design project, April 2008 – March 2009. The objective of this project is to produce a detailed software design specification of a Fuels Treatment Collaborative System Architecture. The Fuels Treatment domain was chosen to be "proof of concept" because it is relatively well-defined and there is a pressing need to clarify the many software tools and applications available to Fuels Specialists. A JFSP Fuels Working Group was assembled to provide the expertise in fire and fuels management and a contractor, Sonoma Technology Inc. of Petaluma, CA was engaged to:

- Task One: Perform an assessment to understand the IFT-DSS needs of the fire and fuels community. This involves understanding the models and systems commonly used by the fire and fuels community and their information inputs, outputs, and interdependencies. This will also include an identification of any overlap with BlueSky.
- Task Two: Provide a summary of the state of the science in CSA systems integration technology and strategy. Evaluate the BlueSky framework's systems and approaches and document BlueSky's advantages and disadvantages relative to other CSA options. Decide wether or not the BlueSky framework is an appropriate design analog for fuel treatment planning.
- Task Three: Recommend a CSA approach that best serves the needs of the fire and fuels community. Provide recommendations on possible modifications to the BlueSky framework that would enhance its use in the fire and fuels domain. Deliver a software architecture design specification document for the IFT-DSS.

3.4 Caveats

It is critical to understand that the IFT-DSS is NOT attempting to provide a single fuels treatment analysis process with hard-wired data and systems preselected by developers. Rather, the project will work toward the design of an "open", collaborative system architecture that allows the user at each major solution step to select from an appropriate set of software system services and thereby create a custom solution path, i.e. Type III software architecture as described in Section 3.1.

It is tempting for projects such as ours to want to dramatically improve the operating environment of the target user community. As laudable as this goal is, it must be tempered with what is realistic in terms of time and money and influence. Consequently, there are several issues related to the Fuels Treatment Planning and Analysis problem area that were specifically placed outside the scope of the IFT-DSS project. First, is the inherent complexity and cascading uncertainties that are propagated over space and time when multiple models are linked over large landscapes and long time periods. The IFT-DSS team decided, as a matter of practicality, to work within the confines of the present situation in the fire/fuels arena. Such errors are either passively or actively accepted at the present time. Our team decided to identify this as an important issue for further scientific research and refinement of existing modeling tools. However, we feel that it is essentially outside the scope of developing the first version of the IFT-DSS to try and solve this issue. Second, the IFT-DSS team has had vigorous debates about what solution process the fuels treatment specialist SHOULD follow based upon preferred scientific points of view or administrative points of view. The development team ultimately decided that it should not be the IFT-DSS that decides or enforces such things. If there are clearly preferred scientific solution paths, then the software tools within the IFT-DSS should make those paths available to users. If there are preferred administrative solution paths, then it should be the local administrative units that provide guidance to the fuels treatment specialist.

It is recognized that many fine software development efforts currently exist that address the fire and fuels management problem area. In particular, members of the JFSP Fuels Working Group have used ArcFuels, INFORMS, the LANDFIRE Interagency Fuels Planning Process for all or parts of their Interdisciplinary Team (ID Team) work in fuels management planning. This project will perform an in-depth examination of all candidate systems and assess how best to proceed toward our ultimate goal of developing a Framework Architecture, i.e. an Interagency Fuels Treatment Planning System and process containing a rich assortment of fully operational and fully supported services operating primarily in a web-based manner from a single user interface. The options for local, offline operations will also be investigated. **We are striving toward collaboration -- combining good ideas from existing systems across the country with the full cooperation and support of developers and users in the fire and fuels community.**

4 System Overview

The IFT-DSS is intended to support **interagency fuels treatment planning** and will provide a rich assortment of fully-operational and fully-supported services that operate in a web-based environment with a single-user interface. As the target user, the Fuels Specialist will employ IFT-DSS to assist with fire and fuels-related planning. The results from IFT-DSS should support and explain recommendations made by the IDTeam to the decision maker, whoever that may be, with full consideration and evaluation of those treatment units within the area of interest. Specific issues involving treatment implementation, i.e. how to plan and execute a prescribed fire, and monitoring, i.e. measuring what actually happened as a result of treatment implementation, are considered outside the scope of this project.

4.1 Major Features

The IFT-DSS will contain the following major features:

4.1.1 Providing a Web Based Approach to Access Software

All fuels specialists regardless of agency employer, as well as the public stakeholders interested in fuels treatment planning, should have access to the tools and data needed to perform competent fuels treatment planning analysis. The IFT-DSS intends to provide fuels specialists with the ability to perform fuels treatment planning analysis without having to wait for a Fuels Treatment Analyst to become available to perform some analysis for them. The IFT-DSS will also eliminate the need for each fuels specialists to obtain case-by-case permission from the Information Technology specialists of their particular agency. The IFT-DSS project, operating on the Internet, intends to cooperate with the Interagency Information Technology working group to create a uniform and practical way to ensure that all security and other business needs are met and that the IFT-DSS is certified for use by people in all agencies participating in NIFC.

Although web-based collaborative system architecture is our primary focus, we realize that web-independent operations are also required. Our design will therefore incorporate system operating strategies that will accommodate those occasions when local, non-web-based use is needed. We are aware that at the present time, most if not all NEPA fuels treatment planning analyses are being performed offline and there may be clear advantages for maintaining that capability even after a web-based IFT-DSS becomes a reality. This issue will be part of our design investigation.

4.1.2 Support for Landscape Scale Analysis

The IFT-DSS will provide the capability to probabilistically analyze fuels treatment alternatives using a landscape (spatial) quantitative risk assessment process that will evaluate changes in future fire behavior. The JFSP Fuels Working Group felt strongly that risk assessment cannot be meaningfully accomplished at the treatment unit scale and must be done at the landscape scale to properly evaluate vegetation unit interactions. The IFT-DSS is designed to be used at the level where treatment unit decisions are made. However, because the probability of fuels treatments affecting future fire behavior cannot be calculated at the treatment unit scale, the IFT-DSS requires a landscape risk analysis and assessment capability.

4.1.3 Multiple Systems

Currently, a plethora of software is available to analyze various individual aspects of fire, vegetation response, and risk (Peterson et al. 2007). This project will design a software architecture that allows users to efficiently assemble and integrate data and systems to plan alternative fuels treatments. The key is that the Fuels Specialist will have the freedom to mix-and-match different systems for different tasks within the overall analysis process. The system will ensure data compatibility and the selection of only appropriate choices to the user at any given step of the process.

4.1.4 Support for Fuels Specialist

The IFT-DSS will provide the Fuels Specialist with easy access to existing software tools and integrated data sets to provide a complete, one-stop-shopping solution to the fuels treatment assessment problem. In addition, the IFT-DSS will:

- Assess expected changes in the landscape as a result of implementing treatment alternatives. “How have we changed the landscape through the implementation of treatment alternatives on the problem acres?”
- Provide an estimate of how much area within a landscape needs to receive treatment in order to achieve a desired mitigating effect on future fire behavior. This leads to the ability to clearly describe the impacts of different levels of funding for fuels treatment within the landscape of interest.
- Provide estimates of the tradeoffs between the impacts of first-entry fuels treatments (typically expensive) versus maintenance of already treated areas (normally less expensive). Develop a time schedule of suggested maintenance treatments by treatment type.
- Allow for expansion in supported services, available data and new software systems.

4.1.5 Process Improvement

The IFT-DSS will improve the interagency fuels treatment planning process through the following features.

- The IFT-DSS will provide a smooth solution process reducing the data-manipulation work for the Fuels Specialist.

- The IFT-DSS will expand the current capabilities of the Fuels Specialist by linking existing analysis, report, and display capabilities, in user determined problem specific ways, into an effective problem solving process.
- The IFT-DSS will have enough internal software execution logic so that it provides the user context-appropriate choices of data and systems.
- The IFT-DSS will allow the Fuels Specialist on a typical ID Team to do project planning and develop National Environmental Policy Act (NEPA) documentation. This includes an analysis of treatment effects on future fire behavior and the development of recommendations for the decision maker on alternatives to address identified fuels issues.

4.2 System Context

The system context and vision are high-level views of the system and indicate the boundaries, intended users and system objectives. The functional requirements list the expected functionality of the system.

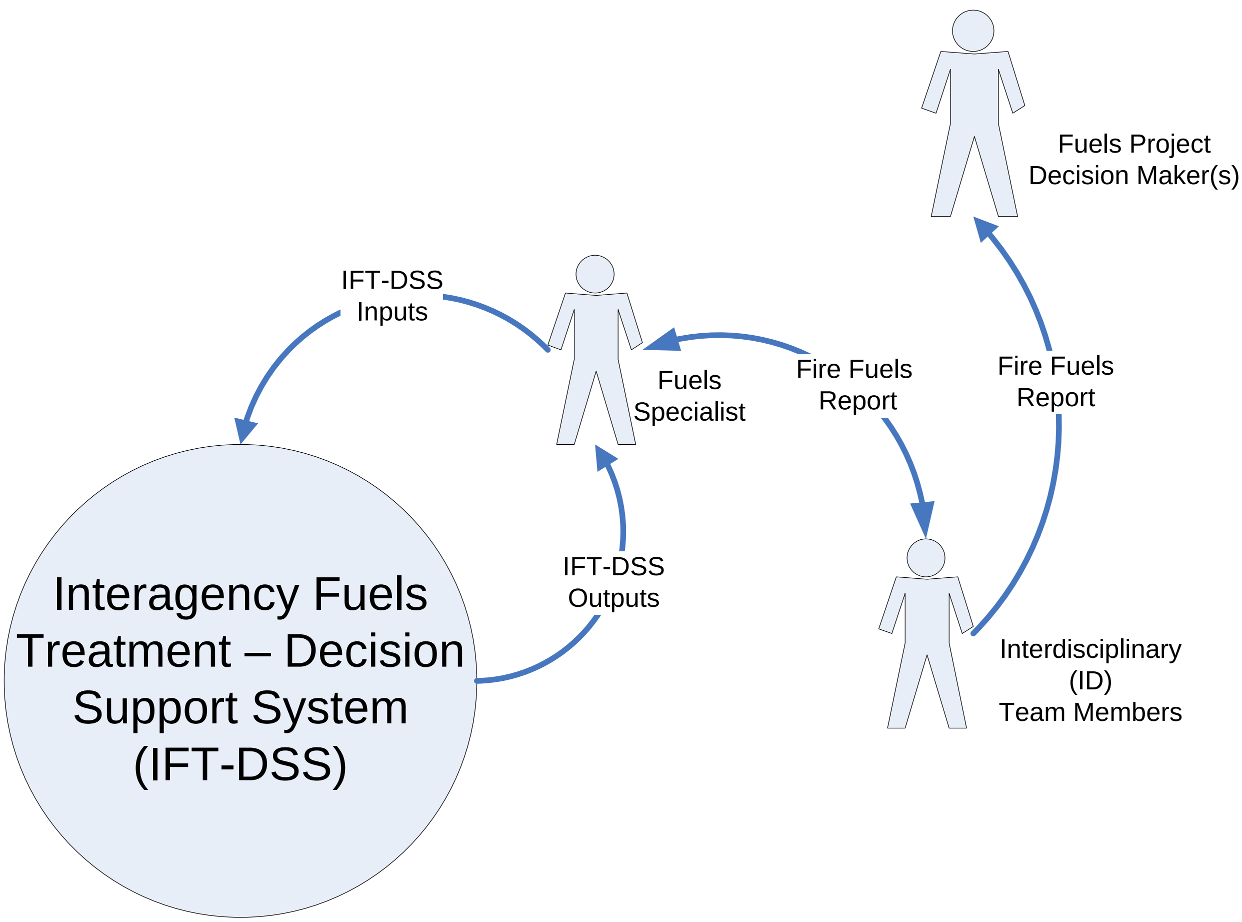

Figure 1- IFT-DSS System Context

The IFT-DSS is designed to help the Fuels Specialist on a typical ID Team to develop explainable and supportable project planning alternatives for the treatment of fuels from the fire risk and effects perspectives. The Fuels Specialist, working in close cooperation with other specialists on the ID Team, is expected to use the information and understanding gained through the application of the IFT-DSS to make recommendations for the decision process and to assist with National Environmental Policy Act (NEPA) analysis for the project area, if one is required.

4.3 System Vision

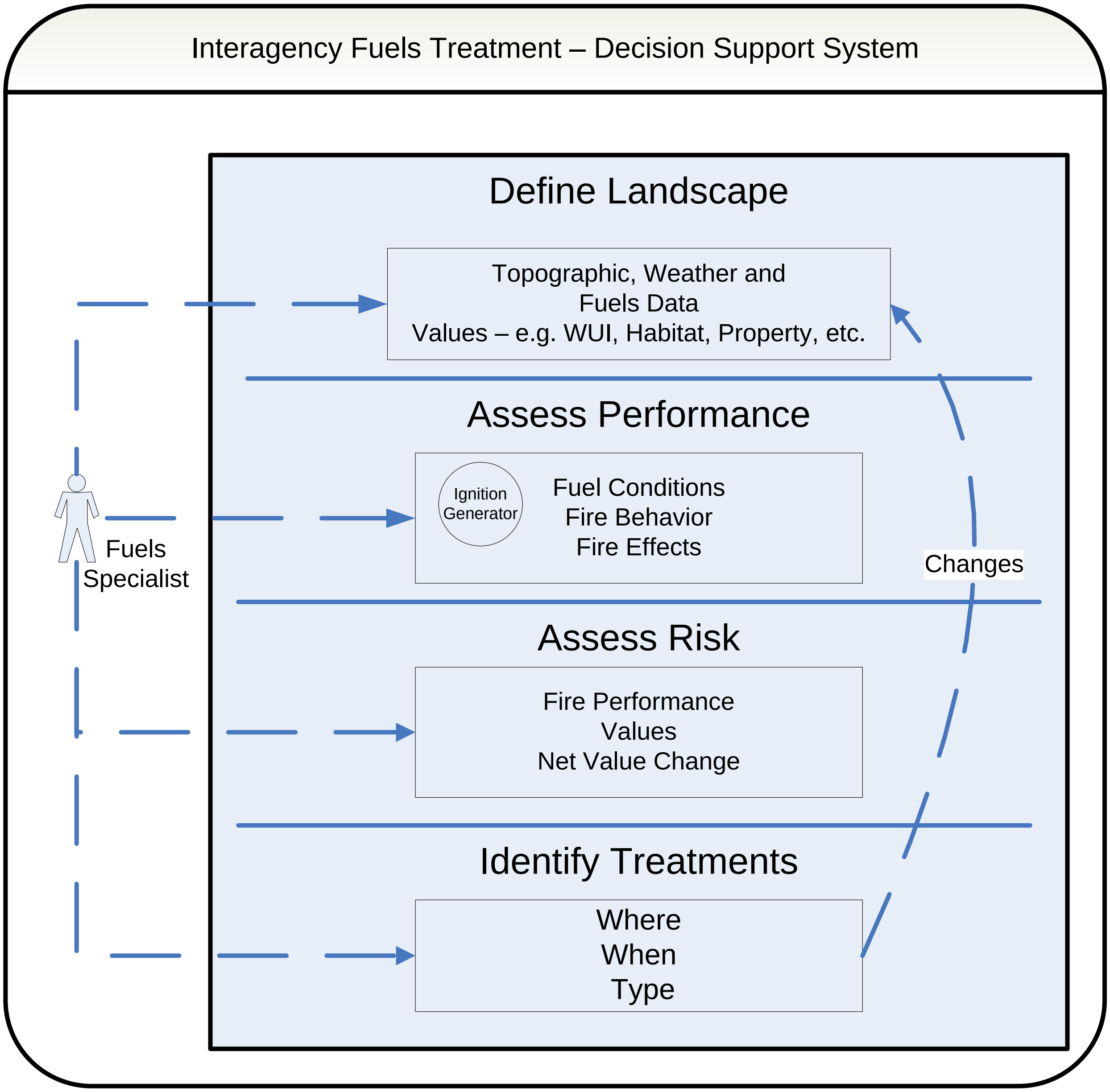

Figure 2 – IFT-DSS System Vision

At the highest, most aggregated level of organization, there are four steps to the fuels treatment problem area that the IFT-DSS will address. They are described in the following sections.

4.3.1 Define Landscape

Defining the landscape area of interest allows the user to select either spatial (map-based landscape) or aspatial (landscape described by tabular fuels and vegetation data) modes. We view the spatial and aspatial as two loops that touch each other every cycle, because they are linked and results feed information to each other. For some purposes, the single vegetation unit aspatial analysis may be of interest by itself or, more typically, it may be used as a precursor to doing a landscape analysis. As our design gets sharper, the relationship between the aspatial and spatial loops will become more clear. For aspatial analysis, vegetation unit data is provided or loaded by the user and a fire regime to simulate is selected. In the case of a spatial analysis, all topographic, weather, and fuels data is typically found preloaded and thus immediately available. In addition to landscape and scale, the user can identify fire-affected values. Displays and editing tools are provided to the user if customization of existing data is desired. Users may also want to create their own weather conditions.

4.3.2 Assess Fire Performance

For the given landscape described by the data, fire behavior and altered fuel loads and changed spatial distribution of fuels are simulated generating the probability of fire occurrence and intensity at each cell of a map layer. This step applies only to spatial analysis.

4.3.3 Assess Benefit/Risk

The IFT-DSS will support a benefit/risk assessment. Benefit/Risk is defined as some function of the likelihood or fire occurrence and the change in values affected. If the change in values affected is negative, we are talking about a risk; if positive, we are talking about a benefit. For each cell of a map layer, the probability of occurrence and intensity is matched with the new, post-fire value and a risk assessment map layer is produced. A net value change map layer can then be computed. This process includes fire behavior simulation and analysis of fire behavior, fire effects and fire risk for resources of concern.

4.3.4 Identify Treatments

The Fuels Specialist will determine whether or not treatments to mitigate risk are warranted based on whether management objectives are met. If treatments are needed, the user provides the system with where, when, and what type of planned treatment. Estimated costs of the fuels treatment may also be a part of the system. The fuels database is changed to simulate treatment implementation and another iteration of analysis is performed. If treatments are NOT needed or cannot be implemented for various reasons, the system will support appropriate evaluation of landscape changes and risk levels. At some point the user stops the iterations and produces map-based, statistical, and written output with the help of the system tools.

5 System Functionality

The diagram below describes the functionality of the IFT-DSS system.

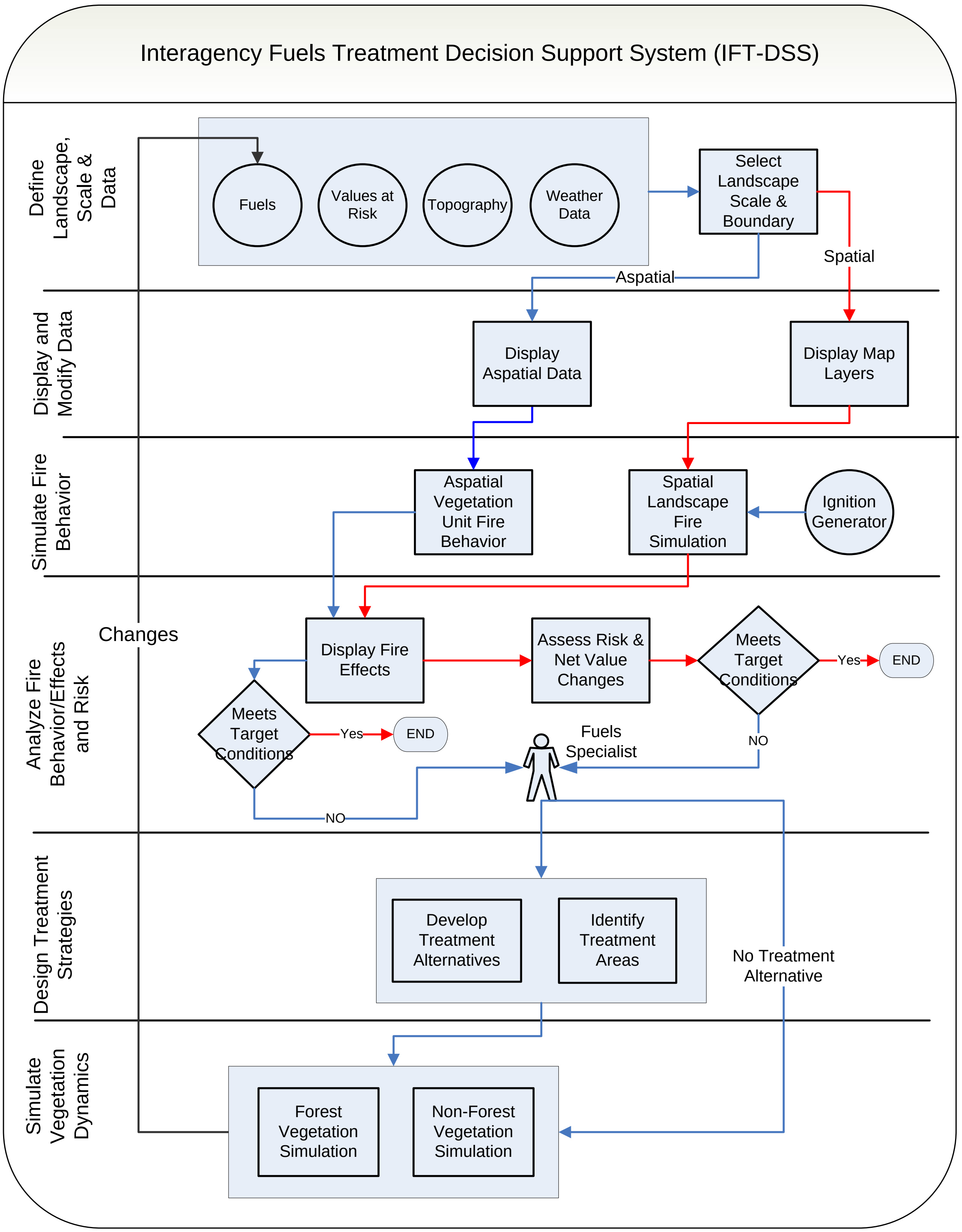

Figure 3 – IFT-DSS System Functionality

5.1 Diagram of System Functionality

The diagram shown in Figure 3 was developed by the JFSP Fuels Working Group after lengthy discussion of the workflow required by the Fuels Specialist. The following sections describe this workflow in more detail. The business case implied by each of the workflow steps supports the storyline of Fuels Specialist with regard to fire and fuels planning.

5.1.1 Define Landscape, Scale , & Data

The Fuels Specialist can perform analyses both aspatially and spatially and must select the pathway to follow (see Glossary for definitions). The data is dependent on the scale chosen. The IFT-DSS framework focuses on a standards-based, open access implementation design. The intention is that software tools of many types will be assimilated into the framework. These software tools will bring with them different data requirements. The IFT-DSS framework will provide standards and guidelines on how new software modules can be integrated or registered with the framework. A similar process will be designed for data, whether local data, regional, or national. Clear instructions will be made available on what it will take to integrate or register any particular data set so that it will be available for use by any of the other registers software tools that can accept that type of data and use it to perform some function.

For aspatial analysis, the Fuels Specialist will load vegetation unit data to describe fuels, topography, and weather. In addition, detailed vegetation data is usually needed for a vegetation unit analysis and later simulation over time. For spatial analysis, in addition to the fuels, topography, and weather data, the Fuels Specialist must identify the landscape boundaries. IFT-DSS will allow a Google-earth type of boundary selection process, which will automatically create pointers to the relevant data that is available for that area. The IFT-DSS must be able to upload local GIS layers, when available, that define the NEPA and fire analysis boundaries.

5.1.2 Identify Fire-affected Values

Only in the spatial pathway does the Fuels Specialist tell the system what fire related values each cell should contain. This is necessary input for the risk assessment step further down the chain of logic. This may include loading maps of infrastructure, property ownership and values, wildlife habitat, or other types of fire-affected values. Value data are notoriously difficult to obtain. Many natural resources have no economic value assigned to them, as they are often valued differently by different people. We anticipate that federal land management plans define many of the values that should be used. What may be more complex is identifying the fire effects – loss/gain relationships for these values at risk and linking these changes to projected costs.

5.1.3 Display and Modify Data

The user can display and review and/or analyze the data prior to initiating the simulation components of the IFT-DSS. The user may be interested in understanding the set of input data conditions and possibly changing some of the values to more directly analyze a particular problem situation. This function is available to both the aspatial and spatial pathways.

5.1.4 Simulate Fire Behavior

This may apply to either aspatial or spatial data. The most popular fire behavior model used in the field today for aspatial analysis is BEHAVE. For the spatial analysis case, FlamMap is frequently used.

5.1.4.1 Aspatial vegetation unit fire behavior

Aspatial vegetation unit fire behavior is simulated for the current condition of the vegetation unit as well as at selected times in the future. The vegetation unit might have one kind of fire response today but quite another in 5, 10, or 15 years. Knowledge of these different responses may affect the decision of whether, when, and how to treat this particular vegetation unit as well as similar vegetation units within the landscape.

5.1.4.2 Spatial landscape fire simulation

The entire selected landscape area is subjected to random ignition events under different weather regimes generating thousands of combinations each and resulting in the probability of fire occurrence and intensity for each cell in the landscape matrix. We recognize that there are useful landscape level tools which do not have random ignitions or run thousands of combinations of burning conditions. For example, a Fuels Specialist may want to do a run on a particular line across a landscape, connecting a potential fire edge to a point of concern using a system such as RERAP and FlamMap. We want to provide access to landscape level tools appropriate to the function and size of the project area/landscape to be analyzed.

5.1.5 Analyze Fire Behavior/Effects and Risk

Tools are provided to allow the user to analyze and display the effects of fire on values either on a vegetation unit for the aspatial pathway or on a landscape for the spatial pathway. The objective is to provide enough information to the Fuels Specialist so that they can determine whether target conditions are met and, if not, whether treatment is called for. If target conditions are met, then the user can exit the system and go to the report generation process. The IFT-DSS will be designed so any value of interest that can be defined in terms of some fire behavior variable, such as fire intensity, may be analyzed. Thus for example, the effect of fire occurrence and intensity on spotted owl habitat has been studied and defined. Other examples of values of interest that have been related to fire behavior characteristics include, but are not limited to, T&E communities, residential values, water quality, lynx foraging habitat, Ponderosa pine old growth habitat, etc. The IFT-DSS will not analyze the effects of non-fire disturbance events such as pine bark beetle epidemics, timber management activities, non-native invasive species impacts, etc.

5.1.6 Design Treatment Strategies

IFT-DSS supports the design of treatment strategies in either the aspatial or spatial modes. By this we mean that the fuels specialist “tells” the system what treatment to apply, when and where. The system will NOT be able to do this step independent of user input.

5.1.6.1 Aspatial

Vegetation unit treatment alternatives are selected by the user which results in changes to the vegetation unit data and another iteration of vegetation unit, aspatial analysis is initiated.

5.1.6.2 Spatial

The user defines treatment units within the landscape using a boundary selection process based on their interpretation of the fire behavior/effects analysis above. Once treatment units are identified, the user then specifies what treatments to simulate in what cell of the landscape matrix. This selection then causes changes in the vegetation/fuels data and another iteration of the spatial analysis is initiated.

5.2 Additional System Characteristics

The following sections describe required features for the IFT-DSS.

5.2.1 User Interface and Data Input

The IFT-DSS is intended to help the Fuels Specialist perform fire and fuels related planning by integrating existing data and software modules into a single accessible interface. The IFT-DSS will facilitate easy import of existing fuels, topography, and weather data using a web-based interface. The Fuels Specialist can use the IFT-DSS to simulate the probability of ignition and effects of fires on the present landscape or a “treated” landscape through the use of a Google-Earth type of visual interface.

5.2.2 Fire and Fuels Planning

The Fuels Specialist will be able to designate the particular system or combinations of systems they wish to use to perform the fire and fuels planning process.

5.2.3 Analysis

The IFT-DSS will provide the Fuels Specialist with the choice to perform a spatial landscape analysis of fuels and fire behavior or a vegetation unit aspatial analysis (see Glossary for definitions). The aspatial analysis is a fire behavior or effects run on a simulated treatment vegetation unit which generates measures such as rate of spread or crown fire potential. These measures are often used to compare fuel treatment impacts over time as a precursor to performing a spatial, landscape analysis. The landscape analysis will use approved GIS data layers and produce maps of fire potential, behavior, and effects.

The Fuels Specialist can identify one or more treatment units within the target landscape. The IFT-DSS will assist the Fuels Specialist in matching specific treatments to specific treatment units and simulating the change in the vegetation over time. The results of these simulations, captured in data sets, are then used as input to the landscape analysis to recalculate new expected losses/benefits and determine the effects of treatment on future fire behavior over time. Risk analysis, i.e. calculating benefit/loss expectations across a meaningfully large landscape unit can be performed to provide inputs for justifications and development of alternatives.

5.2.4 Changes

It is understood that the secondary iterations may modify the fuels data, making it variable across iterations, and that the topography and weather data may also change across iterations.

5.2.5 Generating Outputs

The Fuels Specialist can readily use the IFT-DSS to perform iterations of this process until a range of alternative treatment options is clearly identified for the decision maker to act upon. Fire effects are displayed so alternatives can be compared. The final result will be a preferred alternative, chosen by the decision maker, which is credible, justifiable and explainable to agency staff and public stakeholders.

6 Candidate Software Systems

This section examines the fuels treatments systems currently available to Fuels Specialists within the various agencies. Specifically this section contains:

- An overview of the known existing comprehensive fuels treatment systems. A comprehensive fuels treatment system is one that offers a solution process for the entire fuels treatment planning problem.
- A listing of the comprehensive fuels treatment systems with a brief description of their objectives, as well as a description of software systems that corresponds to the major functions identified in Section 5, figure 3 IFT-DSS System Functionality. A software system is a tool that performs one or more specific tasks within the fuels treatment problem area but does not span the entire solution process. A software system may include one or more models.
- A list of the other systems that were not used by any of the comprehensive fuels treatment systems.
- A Staircase Diagram that shows how known software systems may relate to IFT-DSS functional steps.

6.1 Overview of Fuels Treatment Modules

A recent survey of fuels treatment specialists employed by many different agencies, see Appendix of this document, revealed six different approaches to fuels treatment planning analysis:

1. The Fuels Specialist uses local data and unconnected software systems, such as FVS and BEHAVE and the Smoke Impact Spreadsheet, etc. and many other combinations but without an actual software system that manages the relationship between these systems.
2. ArcFuels based process
3. INFORMS based process
4. Integrated Fuels Planning using LANDFIRE Data (IFP-NIFTT-LANDFIRE)
5. Starfire based process
6. Southern Fire Risk Assessment System (SFRAS)

Results from our survey of Fuels Specialists, reported in the Appendix, confirms previously available anecdotal evidence that by far the majority of Fuels Specialists use various software systems with a variety of local and regional data sets to perform the fuels treatment planning process. A minority use one or the other of the comprehensive fuels treatment planning systems, ArcFuels, INFORMS, IFP-NIFTT-LANDFIRE, Starfire, SFRAS.

In order to bring some structure and understanding to this world of fuels treatment software tools, we can make a distinction between the comprehensive systems (ArcFuels, INFORMS, IFP-NIFTT-LANDFIRE, Starfire, SFRAS) on the basis of what type of data is available to the Fuels Specialists. This may seem like a trivial matter, however, Fuels Specialists assure us that it is not. One of the major reasons for selecting one software tool over another one for doing fuels treatment rests upon whether it can use the available data to perform the planning analysis. We therefore see two data-driven, fundamentally different approaches to fuels treatment planning and analysis within the agencies.

The first approach, exemplified by ArcFuels and INFORMS, bases the simulation of vegetation dynamics on the Forest Vegetation Simulator (FVS) family of software tools. The strength of the FVS-based systems is their ability to perform detailed within-forest vegetation unit simulations to analyze treatment impacts and responses in great depth. The extension of the aspatial nature of the FVS input data treelist to simulate all **forest** vegetation polygons in the landscape was the key development breakthrough for this approach to fuels treatment planning.

The second approach to fuel treatment planning, exemplified by IFP-NIFTT-LANDFIRE, Starfire and SFRAS, is based on the LANDFIRE data sets or locally developed data sets using the LANDFIRE data structure. SFRAS is a bit different in that it is based on a vegetation data set developed by the southern states independent of LANDFIRE. However, it is similar to LANDFIRE in approach and structure. A more detailed description of each comprehensive system is given below.

Differentiating the various fuels treatment systems along the spatial dimension is also an extremely useful way to understand these systems. The distinction here would be support for vegetation unit versus landscape analyses. Only the landscape approach examines the landscape effects of the fuel treatments and requires a landscape analysis tool like FlamMap (Alan Ager, Pers. Comm.). The vegetation unit approaches are able to examine only local effects albeit in great detail and perhaps, with more biological reality. Anecdotal evidence points to (1) a continuing need for detailed biologically accurate assessment of fuels treatments at the vegetation unit level and (2) the simultaneous ability to examine the benefits of Fuels treatments at a landscape, outside the specific treatment units. We may conclude that a comprehensive fuels planning Decision Support System (DSS) would serve the fuels Specialists best by offering both vegetation unit and landscape analysis capabilities. At the present time, both ArcFuels and the INFORMS process allows both vegetation unit and landscape scale analyses. The IFT-LANDFIRE and Starfire processes only support landscape scale analyses, although intensive landscapes analyses may occur on areas as small as 100 acres (W. Hann, Pers. Comm.). The real distinction between a vegetation unit versus a landscape analysis hinges on whether vegetation units have explicit spatial associations and interactions among them (see Glossary).

6.1.1 The ArcFuels Process

The ArcFuels process provides software flow control in the form of a library of ArcGIS macros within ArcMap 9.2 and offers users a single, comprehensive process for fuels treatment planning analysis including fire risk assessment, treatment unit identification and simulation, and treatment effectiveness assessment. ArcFuels provides tight data linkages to FlamMap to facilitate spatial treatment optimization and leverage other FlamMap functionalities. ArcFuels also has an extensive interface to FVS to permit detailed vegetation modeling at the vegetation unit and landscape scales. Ingeniously, ArcFuels, contains a base-model that allows the impact of treatments to be obtained from a look-up table in a database instead of running FVS to simulate the treatment effects on inventory data. This makes it possible for ArcFuels users to use LANDFIRE (below) type grid data to simulate vegetation dynamics without having to use VDDT. It may not be widely recognized that ArcFuels contains a large set of grid-based fuels treatment planning tools (Alan Ager, Pers. Comm.).

6.1.2 The INFORMS Process

The INFORMS process, also uses the FVS family of software systems, for simulating FOREST vegetation dynamics. However, INFORMS also offers PHYGROW, a software system that simulates non-forest vegetation dynamics. Fire behavior on non-forested as well as forest vegetation units is possible in the INFORMS process by passing data from one software system to another. This capability is unique and extremely valuable to fuel treatment planners. The INFORMS system offers complete flow control across the fuels treatment problem space with the exception of the PHYGROW/BRASS-G non-forest vegetation dynamics simulation process.

One problem with the current version of INFORMS is that vegetation data must be in the Forest Service FSVeg database format. This limitation to Interagency applications is currently being addressed by the INFORMS development team. (Eric Twombly, Pers. Comm.)

6.1.3 The IFP-NIFTT-LANDFIRE Process

The Integrated Fuels Planning process using National Interagency Fuels Technology Team (NIFTT) tools and LANDFIRE Data (IFP-NIFTT-LANDFIRE) is transferred with a set of online courses that apply ArcGIS tools developed by the National Interagency Fuels Technology Team (NIFTT) and LANDFIRE data sets. A five step planning and integration process is applied. These steps are to: 1) identify issues; 2) analyze fire behavior, effects, and regimes; 3) prioritize treatment or strategic areas based on issues; 4) change conditions to achieve priorities; and 5) evaluate the outcomes. Issue identification analysis is conducted with ArcGIS. Analyses are conducted with the three ArcGIS tools: Fire Behavior Assessment Tool (FBAT), First Order Fire Effects Model map tool (FOFEMmt), and Fire Regime Condition Class map tool (FRCCmt). Prioritization is performed with the Multi-Resource Integration Tool (MRIT). Change is conducted with the Area Change Tool (ACT). Evaluations are conducted with the three analysis tools (FBAT, FOFEMmt, FRCCmt). For futuring the IFP-NIFTT-LANDFIRE process uses the state transition matrix base model, VDDT, as input to a spatial model to simulate vegetation dynamics under no-action vs. fuel treatment or fire planning scenarios compared to historical fire and vegetation regimes. The IFP-NIFTT-LANDFIRE process is used at the landscape scale (ie. 100 to millions of acres) to identify treatment units or fire management strategies. Areas treated or burned may range from as small as a 10 acre treatments to large areas where wildland fire use may affect thousands of acres. Fuel treatments and wildland fire strategies are identified that would address the integrated planning issues. As part of this process the analyst can investigate which treatments are "best" to apply to particular forest or non-forest vegetation units. The analyst could use , the spatial VDDT futuring tool, FVS, or FOFEMmt and tree-lists for forest stands of interest or the spatial VDDT futuring tool for non-forest stands of interest. Tools and a learning path are also provided for updating LANDFIRE data and increasing accuracy (W. Hann, Pers. Comm.). Anecdotal evidence suggests that it is commonly not understood that the IFP-NIFTT-LANDFIRE process can be used to support landscape level, project planning. A recent article explains:

> "The LANDFIRE fuels data layers can be used for applications at varying scales, including project level planning (for example, < 5000 acres), particularly when higher resolution data are lacking. These data are particularly well suited for comparative analyses within and between regions. Thus, it is the responsibility of the user to determine the appropriate scale and usefulness of LANDFIRE fuels data. These fuels layers span all ownerships, a trait not likely to be found in other fuels data sets. These layers are expected to form the baseline data for interagency planning, while local datasets, which cost more and take longer to produce, can be used in place of, or in addition to, LANDFIRE data. However, because of their objective and comprehensive nature, LANDFIRE data can be used efficiently for such activities as strategic fuels reduction plans, tactical fire behavior assessment and estimating fire effects. These fuels data are the first of their kind because they will seamlessly cover the nation. Any project with this scope will have tradeoffs between quantity and quality. As a result, there is a

need for further research for improving the quality of these layers and for assessing their true efficacy. To meet this need we recommend cohesive, scientific, interagency assessments of LANDFIRE fuels data" (Reeves et al. 2006. Fuels Products of the LANDFIRE Project in Andrews et al. Fuels Management – How to Measure Success. RMRS-P-41 239-252)."

6.1.4 The Starfire Process

The Starfire fuels treatment planning process was developed by the USDI National Park Service Fire Program Planning office at NIFC in cooperation with Dr. Douglas Rideout at Colorado State University. Starfire performs a landscape analysis to identify the areas most often selected by the analysis system for fuels treatment weighted by treatment values. It uses locally developed data which is formatted in the LANDFIRE-type data structure with the intention that those National Parks that cannot develop their own data would use the less precise but available LANDFIRE data as input. We have only recently (July 9, 2008) been made aware of Starfire, so our current understanding of this system is limited. We will be investigating it further to be able to better interpret its potential applicability to the IFT-DSS.

6.1.5 Southern Fire Risk Assessment System (SFRAS)

SWFRA is the Southern Wifldfire Risk Assessment (the background ArcGis database) that was completed circa 2005. This is the database backbone of the SFRAS software. SWFRA began life as a regional risk assessment system with the database being in the public domain. SFRAS is used for (1) fire program evaluation; (2) information and communication purposes; (3) planning tool for mitigation; (4) also has been used for fire incident management and planning.

The Southern fire Risk Assessment System is a Sanborn LLC ArcGis software toolkit that is a licensed product. It is available free of charge to member institutions. SFRAS has gained attention in the Southern United States as a powerful tool for identifying risks and setting priorities for mitigation analysis and funding. Recent work and planned work has resulted in a system that can be used for watershed and planning area analysis. This brings it into the project fuels treatment scale that the IFT-DSS is focusing on. The Southern SFRAS is oldest and most mature version. More recently a version was developed for Colorado and a private version for the California Insurance Company. The Western Group of State Foresters have committed approximately $1.2 Million for 2009 to construct a Western variant of SFRAS. Jim Wolf is the project coordinator for the Oregon Dept. of Forestry, the primary contractor for this work.

Sanborn is the consultant company with the contract for developing SFRAS. David Buckley is Project Manager for Sanborn Consultants (dbuckley@sanborn.com). Dave is the contact for the functionality and technical implementation of SFRAS. Don Carlton, Fire Program Solutions LLC, is the fire expert who came up with the design and features of SFRAS (dcarton1@aol.com). The current website is: www.southernwildfirerisk.com .

6.1.6 Vegetation Data Considerations

If there is one point on which all fuels specialists seem to agree it is that the single most critical factor common to all fuels treatment planning projects is the availability of good vegetation data. As of mid-2008, data related issues appear to be among the dominant impediments to the efficient and effective use of available software systems in fuels treatment planning. This statement appears to be true regardless of agency employer. As everyone knows, data related issues are complex, difficult and expensive to resolve. Nevertheless, improving the effectiveness of fuels treatment planning software support without simultaneously improving the quality and applicability of the supporting vegetation data is likely to lead to little, if any, real progress. A summary evaluation of data issues as they relate to the deployment of the IFT-DSS is included in the appendix of this document.

The important data related issues may be grouped as follows:

- **Data availability**: The recent creation of the LANDFIRE data layers which now span the entire western United States and Alaska has been a gigantic step forward. At the local fuels specialist level, we have encountered frequent statements concerning problems with the quality of LANDFIRE data and a nearly ubiquitous lack of understanding and confusion concerning appropriate applications for LANDFIRE data. Nevertheless, it is most commonly the only vegetation data set readily available to ID Team specialists and thus used – but rarely without considerable local evaluation and modification. The availability of FVS-compatible tree-list data is extremely spotty. No standardized United States-wide coverage is available as of mid-2008. Several pioneering research projects have, however, shown that wall-to-wall polygon or raster-based treelist data coverage can be produced given a LANDFIRE-scale effort to do so (Ohmann, pers. Comm.). At the present time, we commonly encounter fuels specialists interested in using fuels treatment software systems that depend upon treelist data but stymied by its unavailability. The Western Wildland Environmental Threat Assessment Center is sponsoring a pilot study to develop and refine nearest neighbor techniques that will allow the creation of a nation-wide, FVS-compatible treelist database using FIA data (see http://www.fs.fed.us/wwetac/ for further information). Oregon and Michigan were completed in 2008. In addition, the ArcFuels project has developed a method of using FVS to determine adjustment factors for the some of the LANDFIRE data values (Alan Aager, Pers. Comm.). For example, sample inventory plots are processed in FVS with and without treatments, and the change in canopy fuels are used to created adjustment factors for the LANDFIRE data.

- **Data resolution capability information**: Next to data availability, the most important missing element for fuels treatment specialists is a clear, understandable set of written guidelines which provide information on appropriate and inappropriate uses of available vegetation data. This issue involves question of scale, uses to which it is put, and how to understand the level of accuracy, even in the grossest terms, for a particular use of the data. Again, at the root of this problem lies a series of considerations that are complex and difficult to understand and communicate. Broadly, the choice of software prediction methodologies, the relationship of the available data variables to the vegetation dynamics of interest, and the match that exists between the scale at which the data variables were measured to the scale of the solution space essentially determine the quality of the analytical output (Cushman et al. 2007). A feel for the complexity and subtlety of these issues may be developed by reading the excellent paper from Cushman, McKenzie, Peterson, Littell, and Mckelvey. 2007. Research agenda for integrated landscape modeling. Rocky Mountain Research Station, GTR-194, 50 pp. We encounter this issue most frequently in relation to LANDFIRE data concerning appropriate ways to scale down. But FVS-treelist data is also vulnerable to such issues primarily dealing with appropriate ways to scale up. There is no question that the FVS-based systems can be used for landscape analyses and that support systems such as ArcFuels and INFORMS provide the technology to support this.

- **Data availability for non-forest vegetation units**. Not surprisingly, those fuels specialists working in landscapes with significant non-forest vegetation units find it difficult to use the FVS-based fuels treatment planning software systems. The INFORMS project is trying to remedy that situation by grafting the Phygrow/Brass systems developed by researchers at Texas A&M University into INFORMS. Those fuels specialists using the LANDFIRE DATA-based fuels treatment analysis processes have access to vegetation change coefficients for non-forest vegetation units that can be used with the VDDT/TELSA models. There appears to be significant confusion among fire/fuels specialists about the available software systems and data sources for resolving this issue.

- **Local data versus regionally standardized data**. The availability and form of locally developed data sets appears to vary tremendously. Local administrative units frequently have operating procedures in place that require all ID Team specialists to use a common data set to perform their analyses to ensure the results are comparable. The issue here is that the local data might not be as complete or as "good" as some other available data set that supports primarily the fuels specialist but not the wildlife specialist, for example. Local translations between data sets then become costly and time-consuming. The structure of the local data may not be compatible with some fuels treatment planning software systems. Local data sets may be developed for several scales (FVS-treelist for lowest scale, Interagency Mapping and Assessment Project (IMAP) in Forest Service Region 6 and the Vegetation Mapping Project (VMAP) in the Forest Service Region 1 for the intermediate scale (fifth-order watershed) and LANDFIRE for the largest scale. Such an approach poses obvious problems of how to relate the various data set to each other and how to provide cross-scale data fusion when needed. The misconception that FVS-treelist data cannot be used for large landscape analyses needs to be dealt with once and for all as long as appropriate care is taken when imputing treelists across a landscape (Alan Aager, Renate Bush, Pers. Comm.).

6.1.7 Opportunities for IFT-DSS

The IFT-DSS is intended to offer the Fuels Specialist, regardless of agency employer, the full range of choices of software systems and analytical approaches without the need for the human to personally "rework" the data. **It is critical to remember that the IFT-DSS is NOT attempting to provide a single fuels treatment analysis process with hard-wired data and software systems preselected by developers. We are working toward the design of an "open" framework architecture where at each major solution step the user is able to select from an appropriate set of services and therefore, will be able to create a customized solution path.** The Collaborative System Architecture will be fully open to any software developer or team to add new software systems or upgrade existing ones. With the consent and cooperation of the developers of ArcFuels, INFORMS, and IFP-LANDFIRE (as well as other software systems), we may be able to offer a canned flow-control choice for each that mimics the stand-alone programs.

The IFT-DSS will be primarily a web-based program but we are looking into options for downloading all or parts of the system to be run independent of the Internet. Details will be supplied by the Technical Architecture design document (under development). The bottom-line is that the IFT-DSS proposes to provide the web-based collaborative framework architecture, hardware infrastructure, data handshaking standards, and minimum operating control standards for use by any developer or team. Cooperating with the IFT-DSS project will in no way limit the same software system from being used by anyone on a stand-alone basis if they so choose. We want to make the job of the fuels treatment planner easier, more effective, and more efficient without sacrificing the freedom of developers and scientists to expand the power, scope, and quality of the software systems that make effective fuel treatment planning solutions possible. The leaders of the ArcFuels, INFORMS, Starfire, and IFP-NIFTT-LANDFIRE development teams have communicated their initial support for the IFT-DSS vision and have agreed to cooperate in our common effort to improve the software tools available to the community of interagency Fuels Specialists (Alan Ager, Eric Twombly, Jeff Manley, Kathy Schon, and Kevin Ryan, Pers. Comm.).

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6.2 Comprehensive Fuels Treatments Systems

System Acronym or Short Name	System Description
ArcFuels	A library of ArcGIS macros developed to streamline fire behavior modeling and spatial analyses for fuel treatment planning. The system architecture currently manages all tools for offering a comprehensive fuels treatment planning process. It uses the client/server architecture.
INFORMS Process	Integrated Forest Resource Management System used to assist forest service users with resource project management to support decisions. INFORMS is at the core of a fuels planning process that involves other software systems outside of the INFORMS framework.
IFP-NIFTT-LANDFIRE Process	The LANDFIRE process links a starting set of vegetation, fuels, weather, and topography data with a sequence of software tools that provide geospatial representations of fire

System Acronym or Short Name	System Description
	effects fuel models to help prioritize fuel treatment areas, evaluate fire hazard and potential, and examine past, present, and future fuel loading characterizations (Ryan et al. in press). LANDFIRE provides input data to permit a fuels treatment planning process that chains a series of independent software systems by passing data between them.
Starfire	Developed jointly by the National Park Service and Colorado State University and applied to the Sequoia National Park as the first application site. Starfire uses LANDFIRE-type data and performs landscape level analyses to identify the most important areas on the landscape to receive fuels treatments. It uses an optimization process for making this determination.
WFDSS	While WFDSS is NOT a fuels treatment analysis system it is of direct interest because of its advanced collaborative architecture design. WFDSS is designed to provide decision support for ongoing wildfires with time frames measured in hours. It does give a good concept of how a thin client fuels planning system might work, with centralized data and computing horsepower. The system architecture is quite advanced because it hosts comprehensive LANDFIRE databases, access to all weather data (current and historical), maps & display capability, web-based and multi-user, relies on remote processing on high performance computers, and supports FSPro (for 1-fire burn probability and behavior analysis), FlamMap (for stand level fire behavior), and by 2009 will have a version of FARSITE in it. The framework could easily be extended to facilitate interaction through user-supplied databases and additional fire behavior simulation products for doing the risk assessment.

6.2.1 Software Systems & Base Data Sets: Describe Landscape, Values and Scale

System Acronym or Short Name	System Description
LandFire Existing Vegetative Data (EVT)	http://www.landfire.gov/index.php
LandFire Biophysical Settings Data (Bps)	http://www.landfire.gov/index.php
Surface Fuel Data	http://www.landfire.gov/index.php
Canopy Fuel Data	Canopy Height and Cover is used by crown fire models
FUELCALC	Computes canopy height and density (Reinhardt and Crookston 2003).
MSN	Most Similar Neighbor model populates an entire landscape with vegetation data and FVS tree lists based on matching a full data polygon with one that only has partial data.

System Acronym or Short Name	System Description
Slope, Aspect, Elevation Data	This data comes from USGS DEM's, FVS stand description files, or LANDFIRE map layers
Values at Risk (VAR)	All risk analysis processes require VAR data, for example, RAVAR defines VAR layers representing critical infrastructure, structure/building values, water supplies, critical environmental resources, and cultural artifacts.
Weather	Custom weather files, RAWS

6.2.2 Software Systems: Display and Modify Data

System Acronym or Short Name	System Description
SVS	Stand Visualization System takes input from FVS and displays it in 3-dimensional drawings of the forest stand.
Generate Difference Grid Maps	ArcFuels contains software to construct different grids that show changes for a variable between one alternative run and another.
FRCC Mapping Tool	Compares spatial data between treatment and no-treatment alternatives. www.fire.org
Landscape Visualization	Specific software system not yet identified.

6.2.3 Software Systems: Simulate Fire Behavior

System Acronym or Short Name	System Description
LANDSUM	Landscape Fire Succession Model
FRCC	Fire Regime Condition Class
13 Fire Behavior Models	Integrates characteristics necessary for fire propagation on the ground; output goes to other fire behavior models.
40 Fire Behavior Models	Integrates characteristics necessary for fire propagation on the ground; output goes to other fire behavior models.
Behave Plus	Andrews and members of the Missoula Fire Lab.
Farsite	A spatial-temporal fire growth simulator
NEXUS	Scott & Reinhardt, Missoula Fire Lab.
BRASS-G	Burning Risk Advisory Support System for Grazing lands (http://brass.tamu.edu) .
FlamMap	Creates raster maps of potential fire behavior characteristics and environmental conditions over an entire FARSITE landscape.
FSPro	A software system that produces a fire spread probability grid (map) and a fire spread shape file for displaying in ArcView.
FVS/FFE	Given vegetation data will provide fire behavior and fuels information.

6.2.4 Software Systems: Analyze Fire Behavior / Effects and Risk

System Acronym or Short Name	System Description
Fuel Loading Models (FLM's)	Lutes et al. (in prep)
FCCS	Fuel Characterization Classification System, Ottmar Seattle Fire Lab.
FOFEM	Risk analysis support, Reinhardt, Missoula Fire Lab.
CONSUME	Ottmar, Seattle Fire Lab.
RAVAR	An analysis process that geo-spatially identifies values at risk (VAR) associated with a wildland fire.
Fire Effects Planning Framework	Leopold.wilderness.net/research/fprojects/F001.htm Anne Black, Aldo Leopold Research Institute
Smoke Impact Spreadsheet (SIS)	SIS calculates 1- and 24-hour particulate matter (PM) emissions and concentrations downwind of fire (wildfires, broadcast burns, pile burns). The SIS model is a screening-level modeling system for calculating PM2.5 emissions and airborne concentrations downwind of natural or managed wildland fires (mschaaf@airsci.com). http://forest.moscowfsl.wsu.edu/fuels/tools.html
Fire Effects Tradeoff Model (FETM)	The Fire Effects Tradeoff Model (FETM) is an aspatial, mechanistic model (with probabilistic components) designed to analyze fuels treatment alternatives over a landscape by evaluating future fire behavior (mschaaf@airsci.com). http://www.fs.fed.us/r6/aq/fetm/index.htm
Southern Wildfire Risk Assessment (SWRA)	The SWRA consists of a series of computer-based Geographic Information System (GIS) layers that can be used separately or in combination to provide powerful graphic images of wildfire occurrence and wildfire risk in the South. http://www.southernforests.org/swra.htm

6.2.5 Software Systems: Design Treatment Strategies

System Acronym or Short Name	System Description
SPOTS	Strategic Placement of Treatments
Assign Treatment to Vegetation Unit Process	ArcFuels offers five methods for assigning treatments to vegetation units. The intelligent part of this process is done by people and NOT by the software system.
Fuel Treatment Spatial Optimization (TOM)	FlamMap offers an automated approach to the landscape design of treatments. It relies on Minimum Travel time calculations to identify major fire travel routes and to impede them with fuel treatments and is based on published work by Mark Finney. ArcFuels automates the use of TOM outputs to "put" the optimal treatment back on the landscape so it can be simulated and see if it meets project objectives.
NIFTT Multiscale Resource	MRIT was developed as an extension of ArcMap to facilitate

System Acronym or Short Name	System Description
Integration Tool (MRIT)	the integration of multiple treatment priorities leading toward fuels treatment implementation. http://www.fs.fed.us/r1/cohesive_strategy/mrit.htm

6.2.6 Software Systems: Simulate Vegetation Dynamics

System Acronym or Short Name	System Description
VDDT & TELSA	State-transition-matrix based vegetation dynamics simulators. VDDT is aspatial; TELSA is a pseudo-spatial version. A true spatial version is currently under development. http://www.essa.com/downloads/vddt/index.htm
FVS	Forest Vegetation Simulator is an individual tree, distance-independent forest growth and yield model management system. A landscape extension of FVS called the parallel processing extension recognizes stand contagion and other landscape properties and is basically a landscape version of FVS. http://www.fs.fed.us/fmsc/fvs/
PHYGROW	A daily time-step computation engine that models above ground herb and shrub growth, forage consumption, and hydrological processes. http://cnrit.tamu.edu/phygrow/Whatis
Simulating Treatments to LANDFIRE grid data	ArcFuels contains a software system that allows the impact of treatments to be obtained from a look-up table of treatment coefficients in a database instead of running FVS to simulate the treatment on inventory data. For example, a prescription that calls for thinning and underburning needs to be translated into changes in the LANDFIRE grid data for canopy closure, fuel model, crown bulk density, etc. The key point is that users can run FVS to find treatment coefficients that then can be used by the LANDFIRE grid system for simulating landscape dynamics under treatment or no treatment.
Understory Response Model	URM predicts qualitative changes in shrub, forb, and grass biomass at 1, 5, and 10 year intervals caused by fuels treatment activities, based on species-specific life history traits (life form, shade tolerance, etc.) and site-specific effects (soil heating, bare mineral soil, etc.). http://forest.moscowfsl.wsu.edu/fuels/urm/

6.3 Other Potential Software Systems

This collection of software systems have not been used as part of ArcFuels, INFORMS, or the IFT-LANDFIRE comprehensive fuels systems. They will be investigated by members of Sonoma Technology as part of the Technical Architecture design for the IFT-DSS for possible inclusion in the first version of the IFT-DSS. Some columns on these tables are intentionally blank and will be completed in the future.

System Acronym or Short Name	System Description
AlFresco	TBD

System Acronym or Short Name	System Description
BlueSky	TBD
Burnpro	TBD
CA-Fuels	TBD
CRAFT	TBD
Custom Fuel /Vegetation Succession Models	TBD
Custom Fuels Data	TBD
Custom Transportation Infrastructure Ownership	TBD
Digital Photo Series	TBD
FBP	TBD
FMA-Plus	TBD
FPA	The purpose of the Fire Program Analysis (FPA) System is to provide managers with a common interagency process for fire management planning and budgeting to evaluate the effectiveness of alternative fire management strategies through time, to meet land management goals and objectives. FPA will reflect fire objectives and performance measures for the full scope of fire management activities.
Google Earth	TBD
KCFast	An archive of 1300-hr weather data. The new FS Data Warehouse will replace KCFAST.
LANDIS	TBD
LMP, RMP, CWPP	TBD
Map Export	TBD
MyFTP	TBD
NFDRS	Can be a source of fuel models or fire potential outputs.
NFMAS	TBD
NVC Table	TBD
RERAP	TBD
SIMPPLE	TBD
WRCC	Western Regional Climate Center is the official archive for hourly point weather data.
WIMS	WIMS is the NFDRS processor for 1300-hr weather observations.

6.4 Staircase Diagram

The figure below represents **listing of potentially useful systems and tools** for the FT-CSA. This list will be modified as the conceptual design matures. It is clear that we will need to develop some method for prioritizing the systems and tools that we will review initially to find the most promising set of software systems.

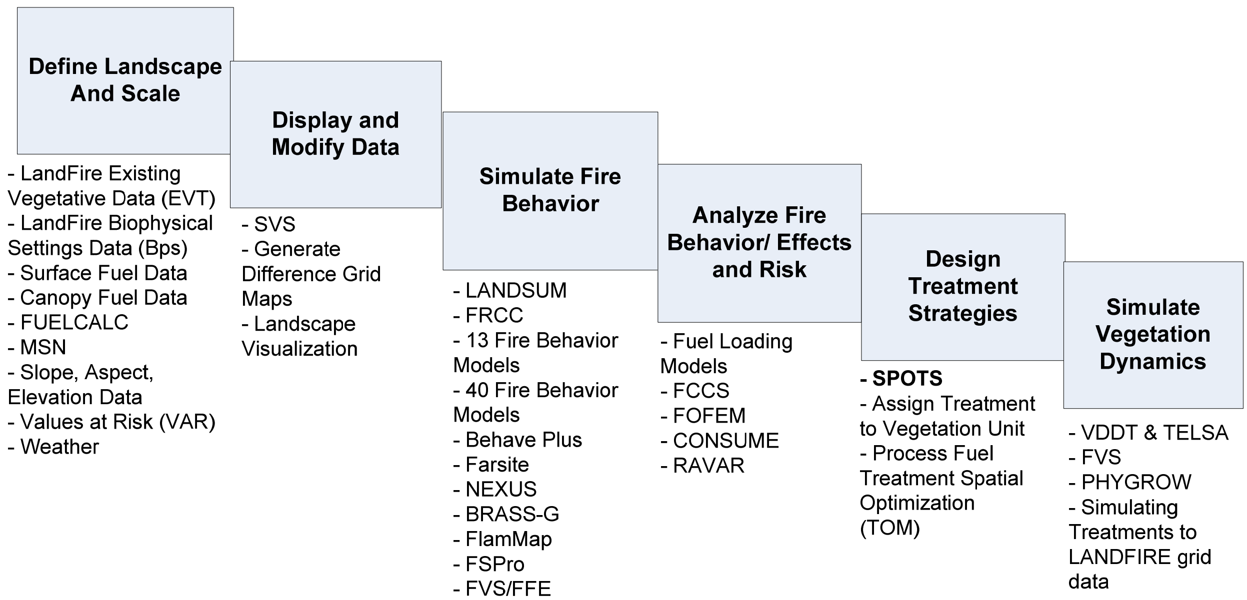

Figure 4 – Preliminary System and Tool Overview

Appendix (Survey & Data Summary Document)

Joint Fire Science Program and National Interagency Fuels Working Group
Summary of Fire and Fuels Specialists Software Tools Survey
December 3, 2008
H. Michael Rauscher (mrauscher@bellsouth.net)

As part of a comprehensive study of the issues related to software systems in the fire and fuels subject area, it was desirable to understand what software tools were actually in use nationwide for fuels treatment analysis and planning. The survey asked each respondent the following questions:

> What software program(s) are you using to perform fuels treatment planning work? Feel free to elaborate on how you are using these tools and if they are helpful.
> If you are not using any software to plan fuels treatments please still answer the question by responding "none" and feel free to elaborate.

It is estimated that the various federal agencies employ approximately 700 – 800 fuels treatment specialists. The 44 responses to this survey translates approximately into a 5% sample of the population of fuels treatment specialists. The sample was random in the sense that everyone had the same opportunity to respond. It was biased in the sense that the respondents were self selected and thus constitute a particular subset of the entire population with unknown characteristics. However, the point of the survey was not to produce a statistically valid result but rather to obtain an impression of what software tools fuels specialists used most frequently and conversely, which ones they did not use. Many respondents choose to provide additional comments concerning the issues and situations which provide the context in which they use these software tools.

Results

The results of the enumeration of software tools used by the respondents are given in Table 1, below. A couple of interesting points emerge from a study of this table:

- Behave, with all its variants, is one software tool that is almost universally used (89% of respondents) on a routine basis. It is by far the single most widely used software tool.

- Eight other software tools (programs and published data sets) make up the second round in terms of use, from 20% - 50% of respondents: FOFEM, FIREFAMILY+, all versions of ArcGis, FARSITE, FLAMMAP, LANDFIRE DATA, FMA+, and FVS/FFE.

- Finally, another eight software tools make up the third group of software that is used less widely but still used by at least 10% to 19% of the respondents: FFI/Firemon, RERAP, NEXUS, GOOGLE EARTH, WIMS DATA, CONSUME, FRCC, SIS.

- It is clear that very few of the respondents use any of the four available comprehensive fuels treatment analysis and planning systems, ie. ArcFuels, IFP-LANDFIRE, INFORMS, SFRAS. It was often difficult to differentiate between those respondents who said they used LANDFIRE DATA versus those that used the suite of LANDFIRE Interagency Fuels Planning tools. Only two of the respondents specifically mentioned the IFP-LANDFIRE tools. Given this fuzziness, it reasonable to conclude that of the four comprehensive systems, the IFP-LANDFIRE fuels treatment process has the most field use in 2008. SFRAS is a special case because it is system funded and sponsored by the Southern Group of State Foresters and aimed and marketed to state fuels specialists. For some inexplicable reason, state fuels specialists were left out of the target audience of this survey. However, a significant number of the respondents were fuels specialists in federal agencies stationed in the southern United States and none of them reported using SFRAS. Information obtained from the SFRAS development team indicates that it is being used primarily by state fuels specialists in Florida and Texas. INFORMS had one respondent using it and ArcFuels had none. ArcFuels was mentioned several times in the free form comments as being a tool that people want to learn how to use at some point in the future.

- Most fuels treatment specialists create their own, what may be call ad-hoc processes, chaining together available fuels planning tools to satisfy their project needs. They are thus custom designing a flow control process that converts their locally available data of various kinds into the type of output they need to support their work. This means that they prepare their own data for initial input to a software tool and then reformat that data, if necessary, for input to the next program in the process chain until they get the results that they are looking for. This is a very labor intensive, expertise intensive, and time intensive process. It is not yet clear whether the creation of these custom flow controls are the result of preferences to have the freedom to do this, or that the comprehensive systems present obstacles of one type or another and thus are not used.

An examination of the free form responses is also extremely revealing in describing the context of the working world in which federal fuels treatment specialists must function. These free form responses are summarized below:

- The proliferation of fuels and vegetation models available: each requires time to learn and maintain familiarity with. New software and updates of old software is happening faster than anyone in the field can possibly keep up with. Even sorting through the choices available to figure out the data input requirements and outputs available is a daunting task in the face of all the other operational demands that necessarily are given higher priority. There are certainly many fuels specialists that can use a variety of available software tools to produce great fuels treatment analyses and plans. These are a distinct minority. Most field fuels specialists don't have the time, training, or familiarity with these software tools to make them an efficient use of their time. The typical response is to simply stick to a few easy to use programs and essentially ignore the rest.

- Developing information and guidance on the correct resolution requirements and capability is an urgent need. Field fuels specialists need clear and easy ways to understand which software tools and which data sets are applicable to which scale: project level, mid-level, and high-level. There currently exists a very confused situation in which even the scale level definitions are not uniform and mean different things to different people.

- FFI needs to link to FSVeg seamlessly because it is the database of record for the Forest Service much like FFI is the database of record for the Interior Department agencies. Having to enter data twice is unrealistic. There are a lot of great features in FFI that could support Forest Service monitoring activities as well as USDI activities.

- Several respondents complain that ArcGis is updated frequently and each update requires you first to remove not only the old version, but also much of the associated software, before you can install the new version. This process takes on the order of hours up to a full day to perform and is hugely irritating to fuels specialists. The inability to upload software tools on their desktop due to security and administrative restrictions is also a major hurdle to using some potentially useful software tools.

- Fuels treatment analysis and planning tools for rangeland conditions are no where near as well developed as tools that apply to forest land conditions. This situation needs to be remedied urgently.

The questions asked of fuels treatment specialists in this survey focused on what was being used today and what the issues and problems are today. A second survey is currently being planned to ask: what functionality would you want to have if you were not software limited?

Table 1 : Final compiliation of the software tools and data sets reported most frequently used by 44 fuels specialists from the Fish and Wildlife Service, Bureau of Indian Affairs, National Park Service, Bureau of Land Management, and Forest Service.

Dec. 1, 2008

Times Mentioned in the Survey

Software System	Number Sample Size = 44
Behave (all variants)	39
FOFEM	19
FIREFAMILY+	16
ArcMap ArcGis	16
FARSITE	15
FlamMap	13
LANDFIRE DATA	10
FMA +	10
FVS-FFE	10
FFI/Firemon	7
RERAP	6
Nexus	6
Google Earth	6
WIMS DATA	5
CONSUME	5
FRCC	5
SIS	4
SASEM	2
PROBACRE	2
Vsmoke GIS	2
LANDFIRE TOOLS	2
BLUESKY	1
INFORMS	1
FCCS	1
FSPRO	1
KCFAST	1
Map Tech Terrain Navigator Pro	1
Microsoft Digital Image Suite	1
NFPORS	1
Parcel Quest	1
Rainbow Series	1
RAMS	1
Simple Graphical Smoke Screening System	1

Compare 4 Fuel Model Spreadsheet	1
Starfire	1
NFDS Calculator	1
NRIS Reporting System	1
FACTS Reporting System	1
SVS	1
VDDT	1
MTT/TOM	1
Wind Ninja/Wind Wizard	1
Topo 4.0	1

Summary of Data Related Issues as they Affect
The JFSP IFT-DSS Development and Deployment

H. Michael Rauscher
30 October 2008

The JFSP Software Tools and Systems (STS) study has identified the fuels treatment analysis and planning process as the most important application area to test the design and implementation of the Interagency Fuels Treatment Decision Support System (IFT-DSS), an innovative collaborative system architecture approach to DSS. During the development of the conceptual design document, it became apparent that there exist 4 more-or-less comprehensive systems that address the fuels treatment analysis and planning process. They are ArcFuels, INFORMS, NIFTT fuels treatment, and Starfire. In addition, a direct survey of field fuels treatment specialists resulted in the recognition that the majority of respondents used their own ad-hoc process rather than one of the 4 comprehensive systems.

Almost every direct contact with field fuels treatment specialists as well as discussions with developers of fuels treatment systems brought up the fact that data issues presented enormous challenges to the deployment of software support systems. It became obvious that the JFSP Fuels Working group had to find out what was going on in the data arena if the proposed IFT-DSS was to be successful.

Note: this summary of data related issues as they affect the JFSP IFT-DSS development and deployment project is intended ONLY a BEGINNING scoping of the situation and should by no means be regarded as a fully comprehensive analysis. This summary was produced with limited resources in people and time on a volunteer basis. In the opinion of its authors, the main use of this summary should be to motivate discussion and perhaps a more formal analysis of the situation leading to well reasoned and supported suggestions on how to proceed in the future.

The NIFTT fuels treatment planning process and Starfire use the LANDFIRE database layers
(www.landfire.gov). These database layers are available to anyone for use and they provide wall-to-wall coverage in the lower 48 United States, forest and non-forest. The LANDFIRE project has mapped FLM and FCCS fuelbeds for the Western US and is in the process of mapping the Eastern US . Additional FLM and FCCS fuelbeds may be developed through research and may be mapped by LANDFIRE during Operations and Maintenance (LFOM). Tree-lists in FVS, FUELCALC, and FOFEM format have been developed by NIFTT in parallel with LANDFIRE National and LFOM. In 2009, LANDFIRE coverage is expected to be completed for Alaska and Hawaii. The data issues of interest concerning LANDFIRE data are (1) how to assess suitability for a particular project level analysis and match the correct questions to those that the data accuracy is able to address; data is intended for broad- and mid-scale analyses for fire and fuel related issues; with local evaluataion and editing data can be used for fine-

scale analyses on fire incidents and for project fuels planning.   Accuracy is expected to be less than optimum for local-scale analyses without this local evaluation and editing (Ohmann et al. below) (2) LANDFIRE National data currently available for download represent circa 2000. LFOM was kicked off with the Rapid Refresh in the Western US, for which data is now available for download that includes enhancements for vegetation and fuel layers with updates for wildland fires through 2007. The full LANDFIRE Refresh component of LFOM has been started, which will enhance and update all vegetation and fuel layers for treatments and disturbances to circa 2008. Data for the Southeast and Northwest will become available in spring and summer of 2009 followed by staged completion across the rest of the US by September of 2010. In addition to the updated layers the state and transition models for predicting future changes across forests and non-forest will be released. The biennial and decadal components of LFOM will start in 2011 with a focus on updates of post-2008 change areas every 2 years using new techniques in change detection combined with Refresh tools and decadal updates based on new remote sensing. Release of update and editing tools and guidelines for local evaluation and editing will parallel these various components of LFOM.   This may or may not be sufficient for current year analyses or for analyses of small project areas; (3) For local planning LANDFIRE data should be revised and calibrated based on available local data (NIFTT offers processes for doing such updating or editing). LANDFIRE data offers easy access and the tools developed to perform a fuels treatment analysis, along with training to learn how to use them, are available.

ArcFuels has been updated to be able to use LANDFIRE grid data to conduct a fuels treatment analysis and planning process with largely the same functionality as the NIFTT fuels treatment planning process (Ager, Pers. Comm..)

ArcFuels and INFORMS use treelist data to provide vegetation data input to a fuels treatment analysis. They offer a lot of analysis power for project level planning as well as support the landscape level analysis to place treatments into the appropriate context for their effects to be evaluated. The trouble is that wall-to-wall FVS treelist data rarely exist for a particular project area. Various data imputation methods, reviewed by Ohmann et al. below, have been developed and tested that support the generation of wall-to-wall FVS treelist data. These imputation methods work across ownership boundaries as long as representative data is available for the entire range of vegetation units encountered and as long as the vegetation units in the analysis area are forests. FVS cannot simulate dynamics for non-forested vegetation units. The only vegetation dynamics simulator that works on non-forested lands is PHYGROW, a part of the INFORMS toolkit. The use of PHYGROW as of 2008 is still in the experimentation and testing stage. Australia, New Zealand, and other locations have developed indices to track grassland conditions with regards to fire that might be explored for use in the US.

To do imputation, requires high quality, field plot based data that is available to resource specialists regardless of employing agency. Rauscher et al (see below) conducted a review and summary of the data source availability issues. As of 2008, most existing data sources restrict access to only those fuels treatment specialists working for the agency owner. The only exceptions are the LANDFIRE data and the GNN FVS treelist data in the Pacific Northwest. A national-level imputation pilot study (NaFIS) could provide the technical basis for developing nationwide data of this kind, but it may not be sufficiently reliable for local-scale analyses. Despite plans for making data sources widely available, none of the agencies have so far accomplished this. This means that USDA FS employees are able to access FSVeg data but nothing else. NPS employees can access DataStore databases in FFI format but nothing else. BLM employees can access their data in FIREMON/FFI formats but not the NPS data in FFI format. You get the idea. The bottom line is that fuels treatment specialists in many cases cannot use the best available, ground-based data for their project analyses.

Let me recap the situation by highlighting an excerpt from the Ohmann et al. paper:

> **Sources of tree list data currently available to various users**
>
> Data for all ownerships, nationwide (mid- to national-scale): LANDFIRE data, available to all. Useful for many analytical purposes but intended for large geographic extents (regional to national) if not evaluated and edited, and for fire- and fuel-related issues. Accuracy is expected to be less than optimum for local-scale analyses unless data is locally evaluated and edited. Presumably these data will continue to be supported under the ongoing LANDFIRE program.
>
> Data for all ownerships in the Pacific Northwest (mid-scale): GNN data, available to all. Maps contain more forest attributes than LANDFIRE but accuracy varies among attributes. GNN mapping of fuels-related variables has been explored (Pierce et al., in review), but is not part of the current implementation. Developed primarily for mid-scale analysis; accuracy at the local scale may be insufficient for local management decisions. New analytical technologies are being developed to take advantage of these data where available. The GNN project is a research effort with no long-term home or support. Ongoing updating and maintenance of GNN datasets is not within the research mission. A long-term plan to maintain and support this kind of data on existing vegetation is needed for the region and possibly beyond. The NaFIS project may provide direction for national implementation of nearest neighbors methods, but the expanded scope may result in less reliable data at the regional (mid-) scale.
>
> Data for Forest Service lands, in FSVeg (local- to mid-scale): Tree list data available for polygons on Forest Service lands where stand exam data have been stored in the National Field Sampled Vegetation Database (FSVeg), and where data have been extracted for use with FVS. Available to Forest Service employees only. INFORMS with stand exams in FSVeg allows the user to do their own imputation, where the user also provides the necessary GIS (polygon) layer and other related datasets in addition to stand exam data of sufficient quality. The current version of INFORMS includes imputation technology that can be run locally for a project or Forest-wide with sub-projects. This application is intended for local-scale data and analyses, but there are no accuracy assessment tools in the current version. Users are trained to field-verify results and use internal statistics to evaluate the overall quality of each analysis. Accuracy assessment methods are under development.

The FSVeg database has long term support, but currently is available only to users within the Forest Service.

Data for other Agency lands and other ownerships in FFI (FEAT/FIREMON Integrated): The FFI monitoring tool assists managers with collection, storage, and analysis of ecological information, and includes tree list data similar to that in the above FSVeg databases for Forest Service lands. (In some cases Forest Service sites are included in FIREMON.) There currently are no imputation tools linked directly to these data (although GNN [and LANDFIRE???] is using some FIREMON plots). Employees of other agencies in general have no imputed landscape data available to them other than GNN and LANDFIRE as described above. Efforts are underway by INFORMS and other groups to include these data.

Please refer to the two summary papers below for a good bit more in depth analysis and understanding of the data related issues.

So what needs to happen?

The JFSP IFT-DSS project will use the collaborative system architecture design approach to make the 4 existing comprehensive fuels treatment planning systems and the most common ad-hoc approaches (along with all their supporting subsystems) available to fuels specialists in an organized, understandable, and useful way. For the IFT-DSS to be truly useful, the fuels specialists of all agencies must have easy access to all available data for a project area regardless of who "owns" the data. They must have the necessary support tools that can gather the available data based on a simple landscape identification method to define project and analysis boundaries, data mining software needs to automatically reformat data from various sources into the needed analysis standard, tools that help the users understand the different degrees of accuracy need to be available, and finally, powerful data visualization and analysis tools need to be assembled so that the user can convince themselves as well as stakeholders of the appropriateness of the input data layers that form the foundation of any effective fuels treatment analysis.

This brief summary of the state of data imputation and data sources is not adequate to answer HOW we need to proceed to achieve the data related vision stated above. It must be regarded as only a beginning evaluation and discovery of what currently exists. It appears that momentum is building from many directions, not just fire and fuels, for the development of a national tree-list dataset based on one or another of the many variants of nearest neighbor analysis. We are not talking about a huge investment in gathering new field data. The FIA plots records as well as other existing datasets are sufficient to impute mid-scale, national data treelist data sets. The richness and complexity of nearest neighbor maps comes with the added burden of user education. In fact, users of all kinds of fire and fuels related data badly need training in the appropriate use and interpretation of the various available data sets. It is noteworthy that the NIFTT fuels treatment planning and analysis process does an admirable job of training fuels specialists in the application of that type of data. Data availability and quality for non-forest lands is far below that of forested lands. It is noteworthy that other countries in Europe and Australia seem further advanced in grassland fire analysis and planning than we are here in the US. We are not convinced that it will take a huge amount of investment to improve the data situation. It is likely to be more a matter of making current data available to everyone. Investment in software improvements needs to go hand-in-hand with investments in data management.

In a late breaking development, we have recently been made aware that Dr. Karen Short of the LANDFIRE project (kshort@landfire.org) has specialized in accessing available field inventory records for the purpose of imputing wall-to-wall vegetation, treelists, and other variables for use by Interagency Resource Specialists. We did not have time to tap into her expertise and suggest Dr. Short be a key player in any further summary efforts on this topic area.

We recommend that the JFSP and the NWCG National Interagency Fuels Treatment Coordinating Group (NIFCG) combine forces to organize and fund a special project over the next year that will examine these data issues in more depth and develop a credible and practical improvement pathway for the future. Ideally, a centralized storage process that includes FSVeg, FFI, FMA and other vegetation unit scale data sources needs to be crafted with open access to everyone, including the public, with a user friendly web interface.

Submitted for consideration by:

H. Michael Rauscher
JFSP Project Manager for the STS Study

Nearest-neighbors mapping of vegetation and 'tree lists' at landscape scales in the US
by Janet L. Ohmann
with contributions from Eric Twombly, Bob Keane, Nick Crookston, and Alan Ager
30 September 2008

The need for multi-attribute vegetation and 'tree-list' maps for large landscapes

Maps of existing vegetation and land cover are needed at a range of spatial extents: from the local stand- or project-level, to support operational decisions; to the mid-scale, defined as large landscapes, watersheds, or regions that usually span multiple land ownerships, to support regional assessments, strategic planning, and policy analysis; to national, continental, or even global scales. The specific needs for spatial vegetation information, in terms of vegetation attributes, spatial resolution, reliability, and currency (how up-to-date) vary with geographic extent and objectives. This summary focuses on meeting information needs at the *mid-scale*, typically areas of 10,000 to 25,000 acres, and broader. We approach the problem with a philosophy of developing data at the most detailed level that is practical (basic vegetation attributes, finest spatial resolution), with the notion that data can be aggregated, generalized, or summarized to meet a variety of needs and possibly across a range of scales. This approach affords the greatest analytical flexibility and cost-effectiveness.

At landscape to regional scales, forest managers, policymakers, and researchers increasingly desire spatially explicit, wall-to-wall, digital maps for a large array of forest attributes. Such data are needed to support a variety of applications including assessments and scenario modeling (e.g., fire, insect, pathogens, wildlife habitat) to ecosystem modeling (e.g., carbon sources/sinks, climate change, and ecosystem services). Many applications require digital maps where each map unit is attributed with a 'tree list,' defined as the tally of individual-tree-level data typically recorded on a forest field plot (species, diameter, height, live crown, and density). Tree lists can be input directly to stand projection models such as the Forest Vegetation Simulator (FVS) (Crookston and Dixon 2005, Dixon 2002, Reinhardt and Crookston 2003), and can be used to derive many attributes of forest structure and composition relevant to fuels, wildlife habitat, timber, and other forest values.

Nearest neighbors is a relatively new family of methods that is gaining in popularity, due largely to capability to provide maps of multiple forest attributes with associated measures of reliability. Some applications of nearest neighbors methods can provide tree-list maps. This paper briefly describes nearest neighbor methods, and summarizes current projects at mid-scale and broader in the US. We emphasize forest lands, only because that is where most efforts have concentrated, primarily due to the lack of regionally consistent field data for nonforested areas.

A short primer on nearest neighbors mapping

Nearest neighbors methods are used to develop estimates for unsampled areas (*target* map units) by relying on the relationship between sampled areas (*reference* dataset) and spatially comprehensive, correlated data from auxiliary sources such as remotely sensed imagery, forest type maps, physiographic data, climate models, or other relevant GIS layers (*predictor* variables). Several variants of nearest neighbors mapping are currently being used, including *k* Nearest Neighbors (*k*NN) (Tomppo 1990), Most Similar Neighbor (MSN) (Moeur and Stage 1995), and Gradient Nearest Neighbor (GNN) (Ohmann and Gregory 2002). The methods differ in how search space and nearness (distance) between target and reference points is assessed, how many neighbors (k) are selected, and how they are weighted when $k > 1$.

Actual applications of the methods also can vary in terms of the reference, predictor, and target data used. The reference data, for which complete vegetation data are available, typically are either field plots or stand exams. The target set (map units) can be pixels in a raster (grid) of any spatial resolution, or polygons (e.g., forest stands) of any size. Lastly, nearest neighbors methods can use one or many nearest-neighbor plots or stands (values of k) in the imputation process. Applications where tree lists are imputed to pixels or stands typically have used a single plot or stand ($k = 1$) (Temesgen et al. 2003). In this case, the covariance structure of trees and derived attributes within the stand or plot is maintained in the target map unit, which can be advantageous for subsequent analyses. Several techniques are available for diagnosing whether a given application of nearest neighbors has yielded results that are satisfactory for a particular purpose (McRoberts et al. 2007, Stage and Crookston 2007).

Evaluating map quality

Map accuracy can be assessed at the local (plot or stand) or regional scale (across the map area as a whole). Local-scale accuracy traditionally is evaluated using cross-validation, by comparing paired predicted (map) and observed (plot or stand) values for a subsample of the reference plots or stands that were excluded from model development. Diagnostics may include measures of precision (e.g., root mean square error, kappa statistic) and bias. Two-way error matrices, or confusion matrices, often are constructed for vegetation classes or variables of interest.

At the regional scale, distributions of map area can be constructed by summing map pixels or stands for vegetation classes or for intervals of continuous variables. For validation, the map distributions are compared against independent estimates for the region, such as from design-based inventories by Forest Inventory and Analysis. Regional-scale accuracy assessments are less commonly conducted, yet provide information on whether the full range of variability of vegetation is represented in a map, which may be more important to a landscape-level application than local accuracy. Several other map diagnostics are possible, but are beyond the scope of this paper.

Evaluation of whether the reliability of a particular map is satisfactory or 'good enough' is highly dependent on the objectives and scale of the application. Map products may be unreliable at the local stand or pixel scale while providing excellent representation at the landscape or regional level. Conversely, map quality may be quite good for a local area where supporting data are abundant and up-to-date, but map coverage may be inconsistent or biased when viewed across a broader, multi-ownership landscape. Reliability also may vary greatly among vegetation attributes. Because accuracy assessment methods differ widely among map products, caution is needed when comparing maps and accuracy assessments.

Quirks and caveats for use of nearest neighbors maps and tree lists

Much of the attractiveness of nearest neighbors methods is that they are multivariate and non-parametric, allowing simultaneous prediction of more than one variable. They also are uniquely suited to providing maps attributed with 'tree lists.' However, nearest neighbors models can be 'tuned' to emphasize one or more variables over others, which can strongly influence neighbor selection and the relative accuracies of variables in the resulting maps. As a general rule, univariate methods that focus on a single vegetation attribute tend to provide better local-scale map accuracy for that attribute compared to multivariate methods, which by their nature arrive at a 'compromise solution' across many variables. However, high local accuracy often comes at the expense of regional-scale accuracy, in the form of loss of range-of-variability (loss of the highest and lowest values) across the map as a whole. Furthermore, layering several single-attribute maps together, even if each one individually is highly reliable, may result in unrealistic combinations for specific map locations. Although nearest neighbor imputation may result in lower prediction accuracy for any single variable when compared to other methods (although this is not always the case), the maps may better represent regional distributions. If a single nearest-neighbor plot is imputed to each map unit, the covariance of vegetation attributes is maintained.

It's important to note that the reliability of nearest neighbors maps may be more a function of data quality used in map development than of the particular mapping method used. Characteristics of both reference and predictor data influence the outcome of nearest neighbors analyses. Elements of reference data quality, whether stand exams or plots, include the sampling intensity (number of observations), representativeness of conditions within the mapping area, timeliness, temporal match to imagery or other predictors, within-plot or -stand sampling error, and completeness of the vegetation measurements (which vegetation components are tallied).

Most of the nearest neighbors maps currently available fall into two categories: polygon maps constructed from a stand map and stand exams, and raster (grid) maps constructed using plots and satellite imagery. Debates over the merits of these two approaches are best focused on the underlying data quality and on suitability of the map relative to the scale of the application (e.g., operational treatment decisions vs. regional strategic planning). These two map types also differ greatly in terms of their spatial patterning or ‘look-and-feel,’ determined by interactions among the spatial resolution and pattern of the target map units, and characteristics of the reference and predictor data. Although spatial configuration can be quantified using various metrics, there are no standard accepted measures of ‘accuracy,’ and map choice is more a matter of subjective preference and practical considerations regarding the map application. For example, land managers typically work with stand maps, whereas ecosystem modelers operate with grids.

Several caveats for use of nearest neighbors maps and tree lists apply equally to any of the methods or products discussed in this paper. As a general rule, these tree list maps are expected to be reliable for analysis at the landscape scale; local applications should be avoided or undertaken with extreme caution. As discussed above, relative accuracies of individual map attributes will vary, depending on particulars of the nearest neighbors analysis. For example, tree list maps constructed to emphasis fuels (or any other single use) may provide better accuracy for this purpose than alternative maps, but also may be less suited to other analyses. The tree-list data imputed to map units are dependent on the sample of trees included in the source plot data. For example, FIA plots do not provide an adequate sample of seedlings, so they are not included in imputed tree lists, which may impact derived canopy fuels variables.

Most inventory programs come from a traditional focus on timber resources and therefore forest lands and live trees. Over recent decades, inventories have expanded to more completely sample all vegetation, including snags, large down wood, understory vegetation, and in some cases surface fuels. However, the population characteristics and sampling properties for these vegetation components are not well understood, particularly in the context of nearest neighbors imputation of tree lists, and within-plot sampling error can be quite high.. Dead wood and understory vegetation are notoriously variable in time in space, with patterns strongly influenced by disturbance history and poorly correlated with overstory conditions. Although some nearest neighbors maps include attributes of these other vegetation components, accuracy assessment is problematic. Furthermore, many nearest neighbor models rely on affordable satellite imagery such as Landsat, which is not particularly sensitive to understory conditions.

Fuels mapping at regional scales is particularly challenging – see Keane et al. (2001) and Pierce et al. (in review) for detailed discussions. Characteristics of the tree canopy, including derived canopy fuels variables, may be mapped with acceptable accuracy for many applications. However, mapping of surface fuels based on the reference and predictor data that currently are widely available and affordable is much more difficult. Mapping of fuel models is particularly challenging. Tools available in FVS-

FFE for generating fuel models for use in fire simulations does not always work well in regional applications. Furthermore, most current applications of nearest neighbors methods are confined to forest land. Areas of nonforest are mapped using ancillary data sources such as the National Land Cover Data which contain their own errors and biases. For fuels and fire applications, reliable depiction of burnable nonforest (e.g., grasslands and shrublands) and non-burnable nonforest (non- or sparsely-vegetated) is a critical need.

Current broad-scale nearest neighbors mapping projects in the US

A number of groups in the US and internationally have developed and applied various nearest neighbor methods, and research in this area is active and ongoing. This paper briefly describes several projects underway in the US that are relevant to the goal of providing tree list data for large landscapes and broader. There are many local projects by researchers or land managers, but they are beyond the scope of this paper.

yaImpute. yaImpute is a tool that can be used for developing tree list maps for an area of interest, rather than a map product *per se*. yaImpute is a statistical package (Crookston and Finley 2008), written in R, that performs several popular nearest neighbor routines including kNN, MSN, GNN, and a novel nearest neighbor distance metric based on the random forest proximity matrix (Breiman 2001). The yaImpute user can define the search space, subsequent distance calculation, and imputation rules for a given number of nearest neighbors. The package offers a suite of diagnostics for comparing results and a set of functions for mapping results.

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Websites: *http://www.jstatsoft.org/v23/i10/*, *http://cran.r-project.org/web/packages/yaImpute/index.html*

INFORMS. INFORMS (Integrated Forest Resource Management System) is another tool that can be used for developing tree list maps. INFORMS is decision support software developed for the USDA Forest Service. The current version includes an MSN tool set and links to vegetation data (stand exam polygons) in the USDA FS corporate database (FSVeg) and to FVS. INFORMS is being updated to accommodate several alternative imputation methods by integrating the yaImpute software, to utilize raster (grid) vegetation data in addition to polygons, and to accommodate nonforest within a landscape. A key component of INFORMS will be a way to sample or otherwise scale-up pixel-level imputation data (e.g., from GNN grids, see below) to map polygons, to create tree lists for input to FVS. Other practical issues to be addressed are a mechanism for updating out-of-date plots or stand exams used in imputation, and issues related to access to corporate databases and proprietary plot locations by those outside the USDA FS.

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The Nationwide Forest Imputation Study (NaFIS). This study is evaluating alternative nearest neighbor techniques with the goal of recommending an approach for nationwide implementation. The vision for a national nearest neighbor application is to rely on FIA and plots as the primary reference data for forest land, and Landsat as the primary remotely sensed data. Other regional plot datasets may be considered as regional options (e.g., Current Vegetation Survey (CVS) in the Pacific Northwest, FIREMON plots). The study is investigating nearest neighbor methods through a pilot study focused on seven large mapping zones across the US that vary in terms of ecological conditions and availability of FIA data. The analyses are evaluating efficient nearest neighbor algorithms, variance estimators and other diagnostics, and data processing techniques for broad-scale mapping. Spatial data products will depict a national core set of forest variables at moderate spatial resolution (30-m pixels). Only a subset of the various nearest neighbors methods will result in tree-list maps. Lessons learned from the pilot study will provide operational guidance for efficient implementation nationwide. Implications of findings for various applications may be explored in a follow-on study. NaFIS partners are from the USDA Forest Service (Western and Eastern Wildlands Environmental Threats Assessment Centers, Forest Health Technology Enterprise Team, FIA, PNW and Northern Research Stations, Remote Sensing Applications Center), Michigan State University, and Oregon State University.

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Gradient Nearest Neighbor (GNN) mapping in the Pacific Coast States. The GNN variation of imputation mapping was developed to support analysis of forest policy effects on large, multi-ownership landscapes. Tree-list data are needed to support stand and landscape projection systems and response models for wildlife, timber, and other values. As currently implemented, GNN uses gradient modeling to impute a single plot (with tree list) to each pixel in a raster map. Reference data are from regional plot datasets (FIA, CVS, FIREMON, etc.). Predictors are derived from Landsat imagery, climate models, digital elevation models, soils, disturbance maps, and other spatial data. The GNN maps are rasters at 30-m resolution with multiple joined attributes describing live trees, snags and down wood, and understory vegetation. Several map diagnostics are provided for both local and regional scales, and for all individual vegetation variables. Prediction accuracy varies widely among vegetation attributes, and users are expected to evaluate the sufficiency of the map data for their applications.

GNN data are being developed for all of Washington and Oregon and much of California for use in many applications, including the Interagency Mapping and Assessment Project (IMAP), National Forest Planning in Region 6, BLM cumulative effects analysis, Effectiveness Monitoring for the Northwest Forest Plan, strategic planning by state agencies and non-governmental organizations, and many research studies. The GNN method has been evaluated specifically for mapping fuels (Pierce et al., in review; Wimberly et al. 2003). The GNN grids are being linked to ArcFuel's method of using a few ideotypic tree lists to run various fuels treatment scenarios and to develop "correction factors" for LANDFIRE data values. An interactive landscape visualization system based on computer gaming technology is available for GNN and other tree list maps.

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A spatially explicit tree-list for the US linked to LANDFIRE data products. The LANDFIRE group is developing methods to summarize FIA plot data to create a tree list for every combination of LANDFIRE's existing vegetation type, biophysical setting, successional class, and canopy bulk density (Herynk and Drury, in prep.). Although the tree lists can be input to FVS, they were developed primarily to input to FOFEM, FUELCALC, and other fire-related programs to aid in spatial analysis of fuel treatments and fire effects. Because of the emphasis on predicting fire-related tree mortality, selection of reference plots is based on bark thickness, and the tree lists were not found to predict basal area and tree density very well. This implies that other approaches to building tree lists might be needed for each management or analysis objective. This approach is viewed by LANDFIRE as a stop-gap measure to create a LANDFIRE tree list for the Rapid Refresh and Fire Severity mapping project. Other approaches for developing tree-list maps may be better in the long term, but may require more work to prepare wall-to-wall US layers needed by LANDFIRE. The same caveats and limitations described above for all nearest neighbors products apply to the LANDFIRE data.
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Sources of tree list data currently available to various users

Data for all ownerships, nationwide (mid- to national-scale): LANDFIRE data, available to all. Useful for many analytical purposes but intended for large geographic extents (regional to national), and for fire-related issues. Accuracy is expected to be less than optimum for local-scale analyses. Presumably these data will continue to be supported under the ongoing LANDFIRE program.

Data for all ownerships in the Pacific Northwest (mid-scale): GNN data, available to all. Maps contain more forest attributes than LANDFIRE but accuracy varies among attributes. GNN mapping of fuels-related variables has been explored (Pierce et al., in review), but is not part of the current implementation. Developed primarily for mid-scale analysis; accuracy at the local scale may be insufficient for local management decisions. New analytical technologies are being developed to take advantage of these data where available. The GNN project is a research effort with no long-term home or support. Ongoing updating and maintenance of GNN datasets is not within the research mission. A long-term plan to maintain and support this kind of data on existing vegetation is needed for the region and possibly beyond. The NaFIS project may provide direction for national implementation of nearest neighbors methods, but the expanded scope may result in less reliable data at the regional (mid-) scale.

Data for Forest Service lands, in FSVeg (local- to mid-scale): Tree list data available for polygons on Forest Service lands where stand exam data have been stored in the National Field Sampled Vegetation Database (FSVeg), and where data have been extracted for use with FVS. Available to Forest Service employees only. INFORMS with stand exams in FSVeg allows the user to do their own imputation, where the user also provides the necessary GIS (polygon) layer and other related datasets in addition to stand exam data of sufficient quality. The current version of INFORMS includes imputation technology that can be run locally for a project or Forest-wide with sub-projects. This application is intended for local-scale data and analyses, but there are no accuracy assessment tools in the current version. Users are trained to field-verify results and use internal statistics to evaluate the overall quality of each analysis. Accuracy assessment methods are under development. The FSVeg database has long term support, but currently is available only to users within the Forest Service.

Data for other Agency lands and other ownerships in FFI (FEAT/FIREMON Integrated): The FFI monitoring tool assists managers with collection, storage, and analysis of ecological information, and includes tree list data similar to that in the above FSVeg databases for Forest Service lands. (In some cases Forest Service sites are included in FIREMON.) There currently are no imputation tools linked directly to these data (although GNN [and LANDFIRE???] is using some FIREMON plots). Employees of other agencies in general have no imputed landscape data available to them other than GNN and LANDFIRE as described above. Efforts are underway by INFORMS and other groups to include these data.

Where to from here?

Many existing applications of nearest neighbors methods at broad spatial extents are *ad hoc* efforts that have coalesced around particular information needs and funding. These projects have been led by the research community, often with partners in land management. The widespread recognition of the value and flexibility of imputation-based maps for meeting a variety of research and management needs has led to discussions at many levels (e.g., IMAP in the Pacific Northwest, NaFIS at the national level) on how to ensure continued availability of this kind of data. Specifically, institutional structures (people and funding) are needed that will ensure the continued availability of up-to-date maps of existing vegetation and land cover based on the best available technology and data.

Such an endeavor will be most effective if it involves partners in both research and management, to keep current with evolving technology while assuring the relevance of products. There also are compelling advantages to an interagency approach, for cost efficiency and to minimize proliferation of contradicting vegetation datasets. Furthermore, it would be important to avoid allowing a single resource or issue to dominate the development of broad-scale imputation datasets, in order to maximize product utility for a variety of uses, to facilitate integrated analyses of multiple values, and to foster ‘ownership’ and investment in the process by many groups. Many jurisdictional and institutional challenges will need to be overcome to make this happen, but the payoff would be large.

Data needed to support local-scale analyses also are lacking in many -- if not most -- locations. Minimum data requirements need to be defined, particularly if data other than FIA plots are to be used, and in regards to developing information for nonforested landscapes. Improving technology in remote sensing, in particular LiDAR, may allow map accuracy based on extensive datasets like FIA to be improved to a level that is acceptable for local analyses.

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Accessing Available Field Inventory Records for the Purpose of Imputing

Wall-to-Wall Vegetation, Treelists and Other Variables for use by Interagency Resource Specialists

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Introduction

"At landscape to regional scales, forest managers, policymakers, and researchers increasingly desire spatially explicit, wall-to-wall, digital maps for a large array of forest attributes. Such data are needed to support a variety of applications including assessments and scenario modeling (e.g., fire, insect, pathogens, wildlife habitat) to ecosystem modeling (e.g., carbon sources/sinks, climate change, and ecosystem services). Many applications require digital maps where each map unit is attributed with the variables of interest. For example, a 'tree list,' defined as the tally of individual-tree-level data typically recorded on a forest field plot (species, diameter, height, live crown, and density) can be input directly to stand projection models such as the Forest Vegetation Simulator (FVS) (Dixon 2002, Reinhardt and Crookston 2003), and can be used to derive many attributes of forest structure and composition relevant to fuels, wildlife habitat, timber, and other forest values (Ohmann et al. 2008, in review)."

Ohmann et al. (2008, in review) have identified and summarized all of the ongoing FVS treelist imputation projects in the United States and provided a brief introduction to the various tools that have been developed to support imputation. As Ohmann noted above, FVS treelists are useful for many resource analyses and planning problems including fuels treatment analysis and planning. Within the fuels treatment analysis domain, two comprehensive fuels treatment planning software packages, INFORMS and ArcFuels, need FVS treelist data as a primary input.

Through the efforts of the LANDFIRE project, there currently exists wall-to-wall vegetation data in the lower 48 states. LANDFIRE data is projected to become available for Alaska and Hawaii in 2009. FCCS is also a source of fuels information. There is an existing 1-km grid map for the entire United States. NIFTT is also developing an online training package to teach people about FCCS. FCCS fuelbeds are being developed in parallel with LANDFIRE releases, with current coverage of the western U.S. at 30-m grids. At the end of 2009, FCCS fuels information will also be available for the eastern U.S., Alaska, and Hawaii. The scale and accuracy of LANDFIRE data is not always the best for project level fuels treatment analysis. For many fuels treatment project analyses, FVS-ready treelist data is preferred and few, if any, new fuels treatment planning analyses have a wall-to-wall treelist vegetation data layer available for the subject landscape and project area. More commonly, some subsample of the vegetation units within a landscape will have field plot records available, others will have none. In addition, the available field plot records will have been sampled over some time period before a project is initiated, so the attributes may not represent the current conditions at the beginning of the project analysis year.

The following summary of data source availability is focused on FVS-ready treelist vegetation data with some consideration given to other vegetation data for fuels treatment planning. To help make this situation more tractable for resource manager, there is a need to be able to "impute" missing treelist data from known sample records and then to use the FVS Vegetation Dynamics simulator to "grow" all plots to a common year. This then provides the wall-to-wall treelist vegetation data layer that can be the foundation of the ID Team analysis and planning project whether for fuels treatment or other resource objectives. **Data to support the imputation process exists and it can be aggregated if desired to make it more broadly accessible and useful.**

It is the **objective** of this summary paper to describe the database sources available to Interagency specialists that contain field records eligible for use in the data imputation process for predicting FVS-ready treelist data. Furthermore, this paper describes the desirability of improving access and availability to these various data sources so that an ID Team in any agency can be sure to assemble the best available data for the landscape under study. The ultimate goal is to use the data and imputation procedures to create data layers for the entire U.S. These data layers would include all the fuels information needed by managers for fuel treatment planning.

Tree List and Other Vegetation Data Sources

USDA Forest Service - FSVeg Database

The Forest Service - FSVeg (Field Sampled Vegetation) database is currently only available within the Forest Service firewall. This data is currently stored in an Oracle database at the USDA - data center at Kansas City. There is currently work underway to build a duplicate data warehouse. This data would then be available for use in imputation by any application. This is anticipated to be complete in the next calendar year. This was confirmed with the NRIS (National Resource Information System) staff.

USDI FFI (FEAT-FIREMON)

Recently FEAT and FIREMON (fire effects monitoring tools developed to assist managers with collection, storage, and analysis of ecological information) were integrated into FFI. However some FIREMON users have elected not to upgrade at this time. Thus, data is available in both the FIREMON and FFI databases. These databases reside on PC's or on servers depending upon the agency involved. The databases on servers are behind a firewall (either BLM, FWS, or NPS) and thus generally not available except to users who operate behind each particular agency firewall. The databases that reside on PC's are accessible only by the person operating that particular PC, no one else. The BLM has taken pains to seek out these dispersed databases and consolidated them into FIREMON and FFI. All of NPS fire effects monitoring data, with the exception of a few parks, are in FFI and could be easily consolidated into one database if desired. Indeed, effort is underway within the NPS to consolidate the meta-data for 91 locally maintained FFI databases on the NPS

DataStore site (science.nature.nps.gov/nrdata/). Access will be initially limited to NPS employees and it will be updated annually. The NPS DataStore application provides data producers and users with standardized, integrated metadata and data management and dissemination capabilities. Part of the DataStore design allows for distribution of metadata and data to other federal and non-federal clearinghouse sites. FWS uses FFI and FIREMON for fire effects monitoring as well. The BIA has fire effects monitoring data mostly in FIREMON with some in FFI. This tribal data may or may not be available for imputation purposes depending upon the level of restrictions a particular tribe places on the data access.

GNN Database and grid Layers

Another source of already imputed tree list data is the GNN (gradient nearest neighbor) product for all of Oregon and Washington States. This data is currently stored in export files and on the Oregon State University server, but this is not considered a long term solution. Storing this data at FRAMES (Fire Research and Management Exchange System) could be a solution for data storage and would make this data available to interagency users. (ArcFuels currently uses this data and INFORMS is developing the ability to use this data)

Forest Inventory and Analysis (FIA) Data

Many imputation technologies including LANDFIRE utilize FIA data as part of their source data. These tree lists are used above in GNN as well but the initial plot locations are not available. The tree lists are now available for use after imputation (GNN example) because it is impossible to tell where the actual plot is located. By law FIA can not divulge the plot locations. An on-going discussion with FIA has been the development of technology that would allow for an extensive data set to be available for needed imputation relationships without having to disclose plot locations. This would allow the imputation technologies to take advantage of FIA data to update data layers without going through agreements and storing these sensitive locations.

Other Potential Sources

Investigation should be made with other agencies regarding the availability of their “corporate” data. For example BLM has the FORVIS database, BIA has Continuous Forest Inventory data, and NPS has data from their Inventory and Monitoring program. Each of these sources likely has more data than is currently stored in FFI/FIREMON that has potential utility to the support the treelist data imputation process.

Issues Affecting the Availability and Use of Treelist Data Sources

Data Access: There are a lot of potentially useful data floating around out there that are not accessible or that nobody knows exists. Some of the issues that limit access are: (1) the data are behind a firewall that only a particular segment of the Interagency resource specialists have access to; (2) legal concerns, such as sensitive species, limit data access; (3) personal concerns on the part of the data "owner" about sharing the data; (4) propriety data (BIA); (5) lack of time and energy to place data into open use systems.

It appears from the information that we have collected that the USDA Forest Service has centralized their field data and is about one year away from placing a copy of the entire national database into an open access warehouse system at their Kansas City server farm. The USDI agencies appear also to be moving in this direction with the ongoing FFI project. One answer might be to consolidate USDI data at a single source such as FRAMES (Fire Research and Management Exchange System) which is an interagency cooperative project with the University of Idaho. Greg Gollberg, the FRAMES project leader, is very open to hosting a copy of the various source data from which treelists can be imputed. USGS/NBII hosts FRAMES at the present time. If only two database repositories could be created, FFI databases on FRAMES and FSVeg on the KC warehouse site, it would be much easier for data mining software tools to locate, capture, and process relevant data for particular projects.

Missing data mining software: The key issue is that the data can be extracted into FVS ready form and that proper expansion factors are stored to determine the proper use of the data in the model. Methods must be developed to determine if each tree list to be used contains adequate sampled attributes to support imputation needs. A proof-of-concept approach might first provide a tool to gather data for the imputation process and then a basic delivery system. The proof-of-concept may provide some useful insight into the feasibility of a full-blown approach, which would serve data for the multitude of models and reporting tools used by managers. It is important to understand that most projects could benefit from a larger base of field records to support the imputation effort, even if the project itself is wholly within one agency ownership.

Considerations of the type of data made generally available: Development of a data source that can make available more than just basic tree data is an important goal. What has been discussed to date are tree lists. A database of just trees limits our ability to use the data for fire behavior modeling or, just as importantly, fire effects. Information for tree lists are just a subset of the information available in FFI, FIREMON, FSVeg, and other data sources. Most monitoring databases store much more vegetation information such as Coarse Woody Debris, Duff, Litter and other attributes that are very important when analyzing vegetation. While imputation of non-treelist vegetation data is important and desirable, it is currently vulnerable with significant prediction accuracy problems (see the discussion on this topic by Ohmann et al.). This is especially a problem for fuels treatment analysis and planning because the existing fuels load could easily be a residual from some previous vegetation community rather than the current vegetation community and thus completely confounds the imputation process.

Vegetation data (tree lists) are not the only data needed to generate imputations. Global data and Vegetation Polygon data are generally needed to run imputation models and will also need long term availability and storage solutions. It should be clearly understood that project level fuels treatment analysis often is based not on

Grid-type GIS layers but rather on polygon-type GIS layers. Where LANDFIRE data can be used for project level fuels treatment analysis, the following points do not apply.

> **Global Data**: Global data includes Landsat Data and DEM data transposed into various forms such as slope, aspect, solar insolation, solar duration, slope catchment area etc. Will need to be stored and made available just as the tree list data. This may not be required initially. Further discussions will be needed to decide how to handle all these data which are mostly grid data but there are issues around joining tiles and how it will work. There are some solutions that could be developed but we need to negotiate standard solutions.
>
> **Vegetation Polygon Layers**: Vegetation polygons are common in many management areas. Many users want to interact with polygons and really cannot or will not deal with grid or pixel data. There will also need to be a minimum data attribute sets associated with these layers. This attributes can be very minimal. If these can be stripped down to the minimum a layer joining technology could be built (some already exist). This would allow vegetation layers convering multiple ownerships to be used. Many land management agency units don't currently have up to date vegetation polygon layers. There are new technologies on the horizon, which need more testing, that may allow inexpensive and efficient delineation of vegetation.

What's Needed Next

It is generally agreed that data exists which can be aggregated for imputation purposes. This data is often inaccessible because it is scattered, behind firewalls, difficult to locate, often on PC's, and so on. Particularly from an Interagency operations point of view, it is critical that these expansive and valuable data be found, organized, aggregated, and a copy placed in some public warehouse system that is accessible to everyone to use.

The initial steps for bringing the existing data together would be: a) determine the data variables important for imputation, fire behavior modeling and fire effects modeling (what the managers need), b) determine the amount of field data available (including permission to use the data), c) create a home for tree list data to be imputed and spatial references to these treelists to be made.

Steps for serving the data layers back to managers would be: d) determine the data layers that managers need, e) include agency representatives to assist technical approval to access the data, f) provide funded positions to assist with data management (FRAMES?), g) provide tools to access the data (be able to view and clip the desired scenes/data), h) provide documentation and training for the tool. The LANDFIRE project has had to deal with much of steps d – h and may be able to provide assistance based on their experience.

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