Fuel Treatment Science Plan

knowledge, guidance, tools, technology and process needs to advance program capability and accomplishments

Joint Fire Science Program

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Boise, ID 83705

September 2014

Acknowledgements

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Executive Summary

Significant changes occurring in the wildland fire environment of the United States are generating uncharacteristic shifts in the complexity, behavior, extent, and effects of wildfires. Increases in wildfire numbers, temporal and spatial scales, and ecological, social, and economic impacts are happening across all land uses and jurisdictions.

Treatment of wildland fuels to mitigate the risk of severe wildland fire impacts to human communities and valuable natural and cultural resources, and maintain and improve the health and resiliency of forest and rangeland ecosystems is emerging as a keystone land management process. With fuel treatment activities receiving greater attention and scrutiny, it is imperative to find ways to improve planning and implementation effectiveness. Science is increasingly important in advancing knowledge levels and facilitating opportunities to heighten management capabilities. Science can help identify and address critical research questions, encourage investigations to address those questions, and present and deliver new knowledge that informs decisions of natural resource policy makers and land managers.

The Joint Fire Science Program (JFSP) was established to identify and address information and technological support needs for wildland fuels management programs. Since its beginning, JFSP has solicited, peer-reviewed, and funded proposals to address fuel treatment effects and effectiveness. As part of continuing efforts to support research and management, JFSP commissioned development of Science Plans that aid in planning and implementing its research vision for the immediate future. Fuel treatment and effectiveness was formalized as a long-term line of work in 2009 and an initial science plan presenting initial themes was adopted (https://www.firescience.gov/documents/fuels/fuels_treatment_science_plan_110110.pdf). The current Fuel Treatment Science Plan (FTSP) presented in this report was initiated in 2013 and completed in 2014. This FTSP supports the JFSP Governing Board and Program Manager in directing a national program of wildland fuel treatment research.

The 2014 Fuel Treatment Science Plan has been constructed to address the full scope of the fuel treatment program. It includes assessments of important program elements and those central considerations and issues that influence and drive the program. It has strategic and operational implications across local, regional, national, and interagency planning scales; across the range of short-, intermediate, and long-term temporal scales; across unit, landscape, regional, and national level spatial scales, and is applicable to both public and private situations.

The FTSP was developed in multiple phases that included: information acquisition, information analysis, synthesis of FTSP framework, and plan preparation. Information gathering processes that were utilized included a web-based questionnaire, which was implemented as two distinct options: one for federal employees and organizations and one for non-federal employees and organizations. The response to both options was outstanding with a total of over 1300 responses received. Personal interviews, published literature reviews, attendance at professional conferences and meetings, and review of other relevant JFSP source information provided additional sources of information for the plan.

Information analysis during development of the FTSP was based on examination of the overall fuel treatment program. This approach supported responsiveness to topics across the entire fuel treatment program spectrum rather than only on current high interest topics.

The synthesis of the FTSP framework led to categorization of the program into four principal program elements: inventory, planning, implementation, and monitoring and evaluation. Seven program drivers that influence these four program elements were then identified. These seven drivers were ecology, climate interactions, humans/values at risk, collaboration and communication, policy and law, efficiency/effectiveness, and prioritization. The combination of program elements and program drivers

yielded 28 research focus areas. However, the large number of focus areas necessitated further analysis to develop a smaller, more practical set of research areas. For the purposes of this report, four research themes were developed that represent the foundation for the FTSP. The four themes are:

- Fuel treatment effectiveness
- Ecological science
- Fuel treatment and society
- Program implementation

Each theme has a clearly defined objective(s) to be achieved within a five-year program of research. The FTSP follows the principle that research is directly interconnected with investments, investigations, and in ultimately delivering improved service and outcomes. This FTSP places high importance on the identification of areas of uncertainty having high relevance to management performance and a high likelihood of enhancing high functioning outcomes. Developing the FTSP using program elements and drivers as the groundwork for themes allowed full consideration of factors affecting science, knowledge, management performance, and services. This facilitated the identification and recommendation of research investments.

A recommended five-year program of research (recommended research topics by year for the five-year period of 2015 – 2019) based on foundational needs, logical sequential flows, linkages with other sub-topics, and specific spatial needs (i.e., geographic, and national needs) was prepared and presented. Research recommendations are described within each research theme and point toward specific objectives rather than science needs in general terms. They are presented as annual undertakings to guide progress toward achievement of the plan and JFSP objectives.

The seriousness of changing conditions, increasing needs for action, and limitations facing fuel treatment planning and implementation all signified that the most comprehensive approach providing the widest possible perspective would be the most effective way to address this task. The broad approach taken during this project assured that the scope, magnitude, and impacts of the fuel treatment program on land management and society were adequately addressed. It was based on full consideration of all program elements, internal and external program drivers and other influences, and allowed selection of the most important areas in need of research. The establishment of the Knowledge Exchange Network of consortia by JFSP is strengthening the entire program. Inclusion of these consortia to support research direction and geographic area needs can greatly benefit this effort and ensure that local and regional, as well as national conditions are being considered.

The FTSP is built to be dynamic and able to respond to changing situations, requirements, and needs by shifting priorities and/or moving new sub-topics into the five-year plan as needed. Annual monitoring of progress, evaluation of accomplishments, and appraisal of current and emerging needs from a variety of sources, including the JFSP Knowledge Exchange Network consortia will be carried out to keep the plan current, consistent with national and regional conditions, and on track with objectives. As a result, the JFSP will be able to conduct annual research that is responsive to the most up-to-date situations.

Introduction

The fire environment of the United States is undergoing profound changes that are triggering substantial shifts in the complexity, behavior, extent, and effects of wildfires. Increases in numbers, temporal and spatial scales, and ecological, social, and economic impacts of significant fires are occurring across all wildlands.

Treatment of natural fuels (live and dead vegetation; downed and dead materials; and duff, litter, and humus layers, etc.) has been conducted throughout much of the history of natural resource management, although most often at smaller implementation schedules and spatial scales. This practice is now emerging as a keystone land management process with multiple values. Fuels are the only element in the fire-vegetation-weather-topographic dynamic that managers are able to modify through management activities. Fuel treatment activities can mitigate the risk of severe wildland fire impacts to human communities and valuable natural and cultural resources, can improve protection capacity by reducing potential fire behavior, can increase the potential success of suppression efforts, and can maintain and improve the health and resiliency of ecosystems. Available fuel treatment processes include a variety of fire and non-fire treatments at scales ranging from site-specific to landscape orientations. Treatment implementation can range from a single treatment to combinations of treatment types, single to multiple applications, or mixed treatment types of multiple applications.

With fuel treatment activities garnering greater attention and importance, there is a critical need to find ways to improve planning and implementation effectiveness integrating ecological, social, political, management, and economic perspectives. Science is critically important in advancing knowledge levels and facilitating opportunities to heighten management capabilities is a critical need. The role of science spans the range from defining areas of uncertainty to applying improved information in management applications. It includes the definition of critical science questions, research to address those questions, discovery of new knowledge, and delivery of that information through a variety of processes to inform decisions of natural resource policy makers and land management decision makers across all land ownerships and jurisdictions (Figure 1).
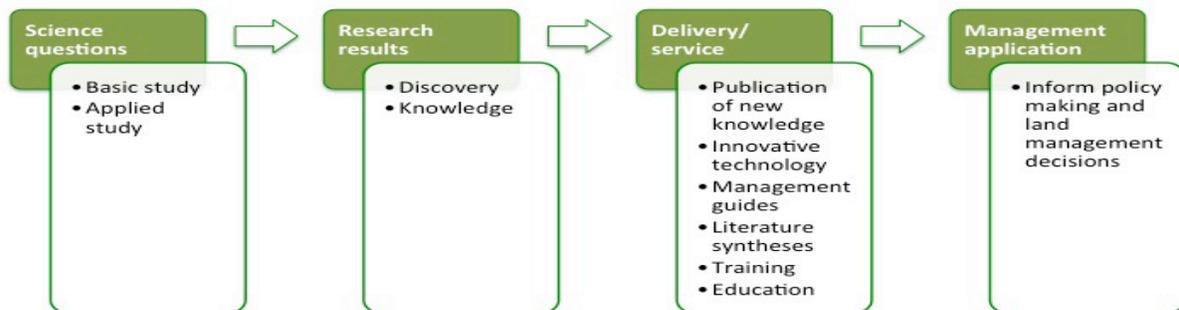
Figure 1. Generalized role of science in advancing management capability.

Although much work has been done pertaining to the fuel treatment program, there is a need to provide better guidance to research and development to help address high priority knowledge and technology needs for improving efficiency of operational implementation. Many questions remain at the center of both management and policy. In addition, current and future organizational fiscal projections necessitate greater efficiency in operation and return on investments.

In the Federal Fiscal Year 1998 Appropriation for Interior and Related Agencies, Congress provided funding and direction to initiate the Joint Fire Science Program (JFSP) to provide scientific support and tools for addressing wildland fuels issues. Federal wildland fire management agencies developed a plan, the Joint Fire

Science Plan, to address direction identified in a Congressional report, H.R. 105-163. This Joint Fire Science Plan is available on the JFSP website at https://www.firescience.gov/JFSP_plan.cfm.

The JFSP mission is to identify and address information and technological support needs for wildland fuels management programs across partner agencies and other federally administered lands. To the extent possible, the program will ensure that information and tools developed will benefit all wildlands including those under State and local jurisdiction and private ownership. The direction in H.R. 105-163 recognized four principal purposes as a focus for JFSP efforts. These are to:

- provide a scientific basis for planning, prioritizing, and evaluating effects of the implementation of fuels management treatments and programs, with a focus on activities that lead to development and application of tools for managers,
- evaluate the effects of fuels treatments including the no treatment alternative,
- increase access to available information, and
- provide a knowledge base for managers.

Since the beginning of the program in 1998, the JFSP has invested in many aspects of fuel treatment research. Much of this work is summarized in the final report and related publications for a JFSP project "Effectiveness of Fuel Treatments for Mitigating Wildfire Severity: A Manager Focused Review and Synthesis (Omi and Martinson 2009), and in the later Fuel Treatment - Line of Work, a science plan for meeting research needs (Omi and others 2010). In addition, JFSP has commissioned a series of fuel treatment guides for fuels managers specific to major fuel types where fuels treatments are common (loblolly pine, Front Range and southwestern ponderosa pine, Lake States mixed pine, northwestern mixed conifer, and southwestern mixed conifer) and has provided funding to support numerous individual research efforts.

As part of its continuing efforts to support research and management program function, JFSP has commissioned development of specific Science Plans that aid in planning and implementing its research vision for the immediate future. A Smoke Science Plan (SSP) was completed in 2010 and represents an initial template for science plan development. This Fuel Treatment Science Plan (FTSP) development project was initiated in 2013. The purpose of this project is to provide a five-year fuel treatment science plan to inform the JFSP Governing Board and Program Manager in directing a national program of wildland fuel treatment research. The FTSP produced from this project is presented in this document.

Fuel Treatment Program History and Development

Wildland fire management has historically been comprised of suppression of unwanted wildfires, management of naturally ignited wildfires, and application of planned prescribed fires. Program development over time has taken place in a situation bounded by expanding objectives, an evolving purpose, growing strategies and tactics, developing policy, expanding scientific and technological information, and often, increasingly inflexible accomplishment expectations. It has steadily grown from its earliest stages, focused solely on fire control, into today's comprehensive blend of suppression, the application of prescribed fire, and management of naturally ignited wildland fires as a balanced program that allows protection and resource objectives to be accomplished concurrently (Figure 2). Fuel treatment, including both fire and non-fire treatment types, is now a vital component of the fire management program.
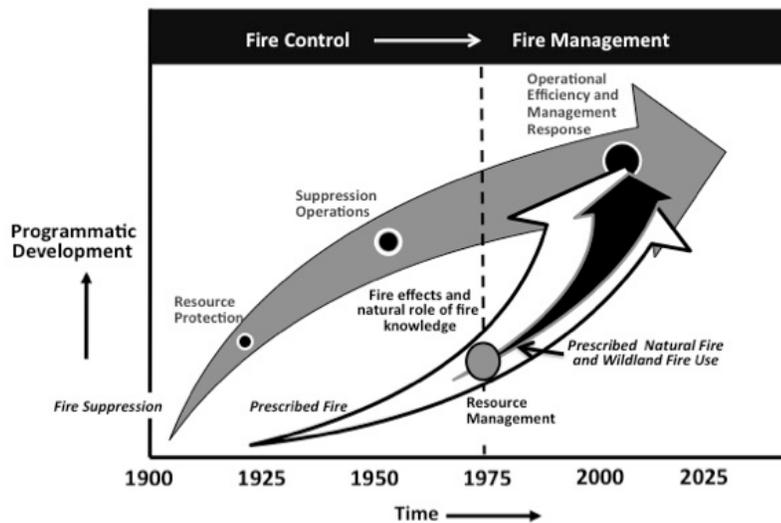

**Figure 2**. Wildland fire management program development (modified from Zimmerman 2011).

It is generally held that land management practices and indiscriminate wildfire suppression over the last 100 years have resulted in accelerated accumulations of forest and rangeland fuels, though not to the same degree everywhere. Fuel accumulation issues are extensive, commonly reaching scales of watersheds and landscapes and even entire vegetation zones. This situation has increased the potential for more and larger wildfires that is now being exacerbated by climatic trends and increasing development of the wildland urban interface. Federal and state efforts to protect people and manage natural resources in fire prone landscapes of the United States have become more challenging. Many scientists and natural resource agencies suggest that treatment of wildland fuels should be expanded as a means to mitigate potential wildfire effects (USDOI-USDA 2014, NWCG 2009; Reinhardt, et al. 2008).

Federal wildland fire management policy has responded. The extensive fires and the loss of 14 firefighters in Colorado in 1994 and increased concerns that fuel loadings were contributing to widespread catastrophic fires prompted a review of federal wildland fire policy. The "Federal Wildland Fire Management Policy Review and Report" led to the 1995 revision of federal wildland fire policy (USDOI-USDA 1995) directing federal agencies to achieve a balance between suppression capability and the use of fire to regulate fuels and sustain healthy ecosystems. This policy was reviewed and operationally clarified in 2009 (USDA-USDOI 2009) but retained the same direction. Following the severe fire season of 2000 the USDA Forest Service and the Department of the Interior began an intensive effort to mitigate the impact of these conditions by co-authoring the National Fire Plan, recommending measures to reduce hazardous fuels on agency lands and protect private citizens living in the vicinity of federal lands. Subsequent Congressional passage of the Healthy Forest Restoration Act of 2003 (summarized at:

) and the
Federal Land Assistance, Management and Enhancement Act of 2009 (FLAME Act)
()
provided the opportunity to increase federal emphasis on wildland fire and implement measures mitigating
the potential effects of wildfire.

As a result of the congressional action, and agency efforts, 52 million acres of federally funded wildland fuels
mitigation treatments have been implemented since 2001 (Figure 3).

Figure 3. Wildland area, in acres, treated to mitigate wildfire hazard from 2001 – 2013[1].
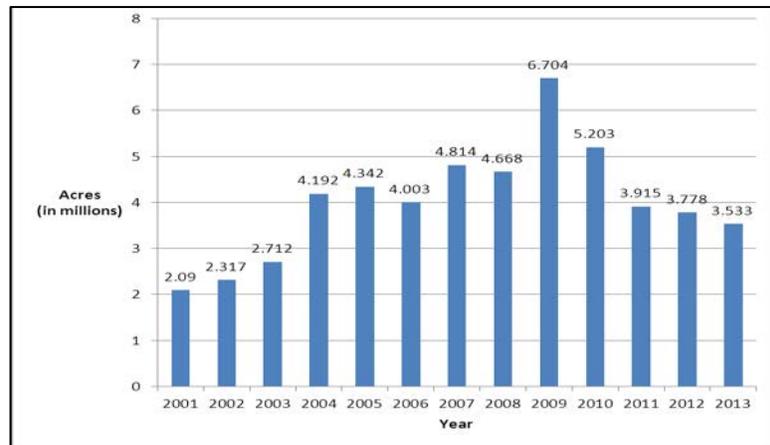
Strategic assessments evaluating current mission strategies and capabilities against best estimates of the future
environment for fire management were completed in 2005 and 2009. The 2005 Quadrennial Fire and Fuels
Review (QFFR) (NWCG 2005) and the 2009 Quadrennial Fire Review (QFR) (NWCG 2009) identify
opportunities in modeling, risk assessment, and ecological assessment, where further development and
integration would provide better information for decision-makers in fuel planning efforts. Completed through
the joint effort of the five federal natural resource management agencies and their state, local, and tribal
partners, these reviews present integrated strategic visions that recommend land management agencies focus
on meeting their land stewardship role, and continue to build expertise in environmental leadership for fire
management.

The National Cohesive Wildland Fire Management Strategy is the culmination of a collaborative effort by
Federal State, local, and tribal governments, non-governmental partners, and public stakeholders, to address
ecologic, social, economic, and political perspectives and concerns in managing wildland fire. Phase I of the
National Strategy (USDOI-USDA 2011) established a three-pronged vision for wildfire mitigation; 1) restore
and maintain fire resilient landscapes; 2) create fire adapted communities; and 3) use an appropriate
management response to wildfires. The final phase in the development of the National Cohesive Strategy
(USDOI-USDA 2014) places the emphasis for broad-scale fuels management in the West and Southeast, in
areas with the highest levels of wildfire, fire-adapted native vegetation, and communities within broad
wildland landscapes. Recommended strategic management actions include the full range of fuels
management techniques, including prescribed fire, vegetation management through forest and rangeland
management practices, non-fire treatments, and fuel treatments in conjunction with managing wildfire to
meet resource objectives. It also sets the stage for continued and expanded fuel treatment activity to support
its defined vision for the next century – to safely and effectively extinguish fire when needed, to use fire
where allowable, to manage natural resources, and to live with wildland fire.

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[1] United States Department of the Interior, National Fire Plan Operation Reporting System (accessed 14 June 2014).

Development of the 2014 Fuel Treatment Science Plan

Purpose and Use of Science Plans

Science plans provide an organized approach to assess available knowledge and identify problems, information, and technology needs in a particular subject area, in order to design a program of scientific research. In their simplest form, science plans are the completion of a research planning and implementation process with a focus on a specific need for knowledge.

The Joint Fire Science Program has, for nearly two decades, been part of ongoing research activities. Much has been learned, and aggressive efforts are being made to assure that research findings are reaching the hands of policy makers and land managers. Since human and economic resources for research are limited, there is a critical need for careful planning of scientific efforts addressing important land management needs for the decades ahead. JFSP's Science Plans will be used to provide multiple benefits for land management programs, including, but not limited to:

- supporting planning focus for scientific efforts
- supporting JFSP program objectives
- supporting agencies charged with managing research and applying findings on the ground
- providing a basis for communication and increased collaboration with external research and management entities and the public, political, and governmental stakeholders and partners.

The 2014 Fuel Treatment Science Plan

The scope of the fuel treatment program is wide-ranging and encompasses a broad range of components. It is built on a foundation of the current and future ecological, social, economic, and political considerations that affect program management.

The 2014 Fuel Treatment Science Plan has been constructed to address the full scope of mitigating wildfire hazard and achieving resource benefits from the application of fuel treatments. It includes assessments of important program elements and those central considerations and issues that influence and drive the program. It has strategic and project–level implications across local, regional, national, and interagency planning scales; across the range of short-, intermediate, and long-term temporal scales; across unit, landscape, regional, and national level spatial scales, and is applicable to both public and private situations.

Objectives for the FTSP include:

- Assess the current status of scientific support for fuel treatment program planning, implementation, and monitoring and evaluation at all appropriate spatial and temporal scales.
- Review availability and use of management guides and tools to assist fuel treatment practitioners.
- Identify program research and technology needs most critical for enhanced fuel treatment efficiency and application.
- Provide research and technology indicators that will assist JFSP in soliciting requests for proposals, developing research program management guidelines, transferring research to practitioners, and monitoring progress of the fuel treatment science effort.

The Fuel Treatment Science Plan was developed in multiple phases that include: information acquisition, information analysis, evolution of the FTSP framework, and plan preparation.

Information Acquisition

The information acquisition phase included all activities to identify, organize, coordinate, and complete information gathering. During this phase, key contacts, stakeholders, and resources to inform project development were identified and venues to expedite information gathering were followed. Activities during this phase included:

- **Web-based questionnaires**. A web-based questionnaire was developed as a primary method to obtain feedback and input. The questionnaire was distributed in two versions - a federal employee-only and a non-federal individual adaptation. The full questionnaire was developed and managed through the Survey Monkey commercial software program (www.surveymonkey.com). A link to the federal version was distributed electronically to email contact lists and by manual delivery. Distribution and management of the non-federal version was facilitated and supported through the Northern Rockies Fire Science Network and the University of Montana.

  Questions in the two versions of the survey differed only in administrative information. Information requested through the questionnaire is shown in Table 1.

Table 1. Survey questions by information type, use, and benefits to FTSP development.

Type of Information	Use	Benefits to FTSP
Administrative	- Background on survey respondents.	Allow sorting capability to delineate range of respondent backgrounds, program involvement, etc.
Fuel treatment importance	- Background on importance of location, objectives, and scale in projects and programs.	Allow sorting of perspectives of importance of fuel treatment program.
Barriers and impediments to fuel treatment	- Background on perceived impediments to fuel treatment projects and the program.	Allow sorting on impediments to fuel treatment program and could identify additional categories.
Planning, analysis, and implementation tools and guidance	- Provide an answer if tools, guidance, etc., are adequate. - Provide an inventory of all tools, guidance, etc., utilized. - Provide information pertaining to accessibility of tools.	Assist in development of tools and guidance inventory.
Future research needs	- Provide information on needs for future research, technology transfer, and training	Provide information pertaining to future research needs and priorities.

The two questionnaires yielded 1316 total responses from users across the United States and from a wide range of positions and involvement in the fuel treatment program (711 from the federal version and 605 from the non-federal version). A more detailed description of respondents is provided in Appendix A.

- **Personal interviews**. Personal interviews with fire management professionals, policy specialists, governmental officials, scientists and practitioners and stakeholders were completed. Individuals from the following groups, organizations, agencies, committees, etc. were interviewed:

- National Wildfire Coordinating Group committees
- Joint Fire Science Program Knowledge Exchange Consortia
- State and Federal land management agency fuel and fire management staff
- University forestry and natural management programs
- Federal research labs
- Forest Service threat centers
- Ecological Restoration Institutes
- Governmental institutions
- Non-governmental organizations

- **Fuel Treatment literature examination.** Determining the appropriateness and efficacy of fuels management and fire ecology research in addressing both management issues and science needs is a subjective process compounded by an ever-increasing quantity of research. For the purpose of this FTSP, a focused approach that scrutinized research results from three perspectives helped refine searches and facilitate discovery and review of research for critical elements pertaining to fuel treatment effectiveness. These perspectives and their proportional representation in the FTSP corpus are:

  - fuel treatment effects on ecosystem components (44%)
  - effectiveness of fuel treatments in achieving social, fire behavior, and ecological objectives (33%)
  - methodologies for assessing fuel treatment project and program planning and implementation effectiveness (23%)

Research was further examined by filtering through four program elements (inventory, planning, implementation, and monitoring and evaluation) and seven fuel treatment program drivers (see the Synthesis of the FTSP Framework section later in this document). Research was placed in a spatial context by filtering through the boundaries of the 15 Knowledge Exchange Consortia. Figure 4 shows the breakdown of geographic representation in the FTSP corpus.
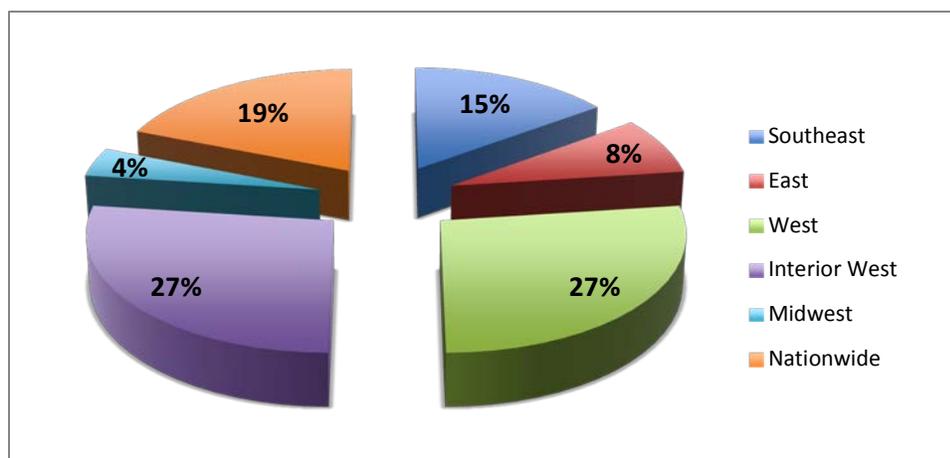
Figure 4. Geographic representation in the fuel treatment corpus: Southeast – South Consortium; East - Appalachian and North Atlantic Consortia; Midwest – Lake States, Great Plains, Oak Woodlands, and Tallgrass Consortia; Interior West - Great Basin, Northern Rockies, and Southern Rockies, and Southwest Consortia; West - Alaska, Pacific, Northwest, and California Consortia.

An assortment of sources and processes was used to find and acquire relevant literature. These included: Joint Fire Sciences Program sponsored research, Joint Fire Sciences Consortia websites, Google Scholar, Library of Congress, JSTOR, United States Department of Agriculture's National Agricultural Library, and U.S. Forest Service's Treesearch and GeoTreesearch. Examination of 57 syntheses and published

literature reviews, provided direction to additional relevant information. The review of literature for this FTSP principally focused on literature since 2010, because both the FT-LOW report (Omi and others 2010) and the Smoke Science Plan provide a summary of pertinent literature prior to that date.

A notable insight yielded from this review of literature is that no single source or process is capable of providing a complete set of relevant research reports and findings. The multitude of terms, variation in use, and subsequent lack of a standardized lexicon associated with fuel treatment confound the location of relevant research. Figure 5, a word cloud, visualizes terms and the frequency of their occurrence encountered during the FTSP literature survey.

Figure 5. Word cloud showing frequently encountered terms in FTSP literature survey.

▪ **Attendance at meetings and conferences.** Relevant regional, national, and international conferences and other meetings were attended as an additional means for gathering information. The following webinars, conferences, and meetings were used for this purpose:
  o Fire Management, Fuels, and Climate Change Tipping Points Webinar
  o International Smoke Symposium
  o Wildland Fire in the Appalachians
  o Fire Ecology of the Northeast: Restoring Native and Cultural Ecosystems
  o JFSP All Consortia Meeting
  o Large Wildland Fires: Social, Political, and Ecological Effects
  o USFS National Fuels Meeting
  o Status of knowledge workshop - Gambel oak fire, ecology, and management

▪ **Other JFSP Guiding Information**. Several other recently completed efforts provided guidance and insight information useful in development of the FTSP. A Smoke Science Plan (SSP) (Riebau and Fox 2010) was completed that compiled an extensive set of information on smoke science. Subject themes covering specific areas of interest were developed from information collected and objectives were established for each of the themes. A series of research projects within each theme was identified and planned to facilitate annual JFSP research investments and move incrementally toward achieving the objectives. The SSP provided a strong template and example that aided in development of the FTSP. It also provides a necessary link between fuel treatment and smoke science needs.

An additional JFSP generated effort produced a Fuel Treatment - Line of Work (FT-LOW), A Science Plan for Meeting Research Needs (Omi and others 2010). This report identified research needs in 13 topical themes across three focus areas. These themes were developed through reviews of extant literature, scoping with managers, workshops with experts, and finding from previous JFSP and non-JFSP research. A thorough review of literature was provided that, along with the themes and identified research topics, has been markedly beneficial to this effort.

The focus areas and themes from the FT-LOW are shown in Table 2.

Table 2. Research focus areas and themes in the FT-LOW report (Omi and others 2010).

Focus Area	Theme
Fuel Treatments	• Improved metrics for evaluating fuel treatment effectiveness • Effectiveness of various fuel treatments (i.e. for hazard reduction) over time • Understanding the relationship of fuel bed characteristics and dynamics to fire behavior and effects (primarily hazard reduction) • Effectiveness of pile burning • Fuels within intensively managed areas
Effects	• Reintroducing fire into long-unburned areas • Responses of shrubs, forbs, and grasses to fuel treatments in forested and non-forested environments • Influence of fuel treatments on nonnative species invasions and persistence in forested and non-forested vegetation types • Landscape resilience
Fuel Treatment and Effects Related Models	• Modeling fuel and duff consumption and soil heating • Improved high resolution prediction of local winds in complex terrain • Wildland urban interface • Analyze the strengths and weaknesses of current models used for prescribing and assessing fuel treatments

- **JFSP Knowledge Exchange Network Research Needs.** JFSP established a national collaborative science delivery network to accelerate the awareness, understanding, and adoption of wildland fire science information by federal, tribal, state, local, and private stakeholders within ecologically similar regions. Fifteen regional components or consortia currently exist within the national network to promote information dissemination. The network has the following six objectives:

  o Dissemination of information and building relationships
  o Listing and describing existing research and synthesis information
  o Methods to assess the quality and applicability of research
  o Demonstrating research on the ground
  o Adaptive management
  o New research, synthesis, or validation needs

These consortia are proving to be highly successful. In 2013, they prepared a set of research needs for their respective geographic areas. These identified research needs represented an additional source of information and were reviewed and considered during development of this FTSP.

Information Evaluation

Evaluation of the collected information enabled a review of the state of current fuel treatment science and the use of this science by managers. Questionnaires contained both closed and open-ended questions. All questions were viewed in terms of answer summaries, response trends in both data and chart formats, and were filtered and compared as needed. This information was used to define fuel treatment barriers; rank importance of scale, objectives, and land use; and compile identified research needs. Personal interview information was used to validate survey trends and to obtain additional fuel treatment research need input. Available literature was reviewed to ascertain areas where abundant research has been conducted and areas of uncertainty where research attention has been limited. Meeting and conference attendance served as an opportunity to gain emerging information during presentations, gather additional specific information from individuals, and solicit feedback on the plan development process.

All acquired information was compiled into a master dataset and then segregated into specific information sets pertaining to program elements and drivers (see the next section for more information).

Evolution of the FTSP Framework

The comprehensive nature of the fuel treatment program does not easily lend itself to a rapid or overview evaluation of high priority needs. Previous science plan efforts could be viewed as synoptic or top-down in nature in that they did not base results on a review of all aspects of the program area, but on only those identified high interest areas.

After evaluation of the potential scope and importance of this project, it was determined that this FTSP project would follow a different approach. It started with an evaluation of the complete fuel treatment program and categorization of it into four principal program elements (Table 3). Then, the program was evaluated in terms of what drivers, considerations or issues, both external and internal, influence these four program elements. The benefit of this bottom-up approach is that focus is not limited to only current high interest topics, but allows acquired information to be assigned into element/driver areas covering the entire fuel treatment program spectrum. This approach enabled evaluation of the entire program, principal elements and program drivers, in terms of research needs. It also provides a logical and linear flow that makes sequential direction over time easier to address.
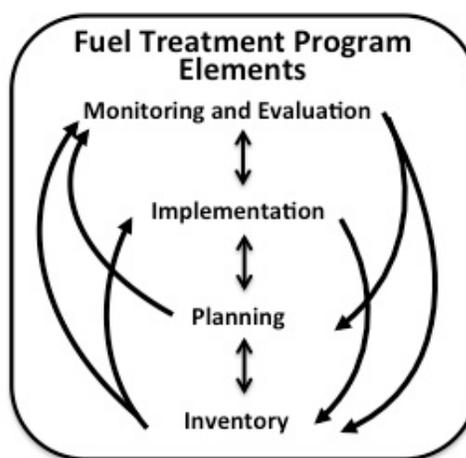
Program Elements

Program elements represent those activities that comprise the operative actions to utilize fuel treatment in support of land and resource management. Program elements are complementary and strongly linked (Figure 6). Each program element can support or affect each of the others. Inventory information sets the foundation for the fuel treatment program. Planning is carried out with, and only limited by, the applicability and quality inventory information. Implementation is completed in full compliance with the plan. Monitoring and evaluation is conducted on each of the elements. Each element provides feedback to each other.

Table 3. Fuel treatment program elements used in the FTSP analysis.

Program Element	Description
Inventory	The current level of knowledge available about the past and present social, political, and ecological considerations affecting and affected by fuel treatments. Provides situational information that is prerequisite to initiating a fuel treatment program.
Planning	The process of analyzing situational information, identifying the state of the land and resources, identifying treatment needs, setting desired objectives, reviewing treatment capability, projecting effects of various treatment options, and developing a course of action to accomplish objectives. Planning effectiveness is dependent upon the availability and quality of inventory information, analysis and predictive capabilities, and skill in defining objectives and needs.
Implementation	The process of implementing the fuel treatment plan to achieve fuel treatment objectives at appropriate temporal and spatial scales. Implementation proficiency is driven by inclusiveness of the plan, skill in executing operational activities, and situational observation.
Monitoring and Evaluation	The process of short-term examination of the completeness of the planning process, short-term examination of how well the implementation activities accomplished the objectives, and long-term evaluation of effects and longevity of treatments.

Figure 6. Fuel treatment program element linkages.

Program Drivers

Program drivers are those considerations, external influences, or issues that influence the program elements. Drivers comprise three broad areas: ecological; societal (social, economic, and political); and management. Fuel treatment program drivers are those areas that influence the program elements. Each driver has a potential influence on each of the program elements. Seven specific drivers were identified and are:

- Ecology
- Climate Interactions
- Humans/Values at Risk
- Collaboration and Communication
- Policy and Law
- Efficiency/Effectiveness
- Prioritization

Figure 7 presents an illustration of how the program elements and drivers are viewed in terms of linkages and interactions.
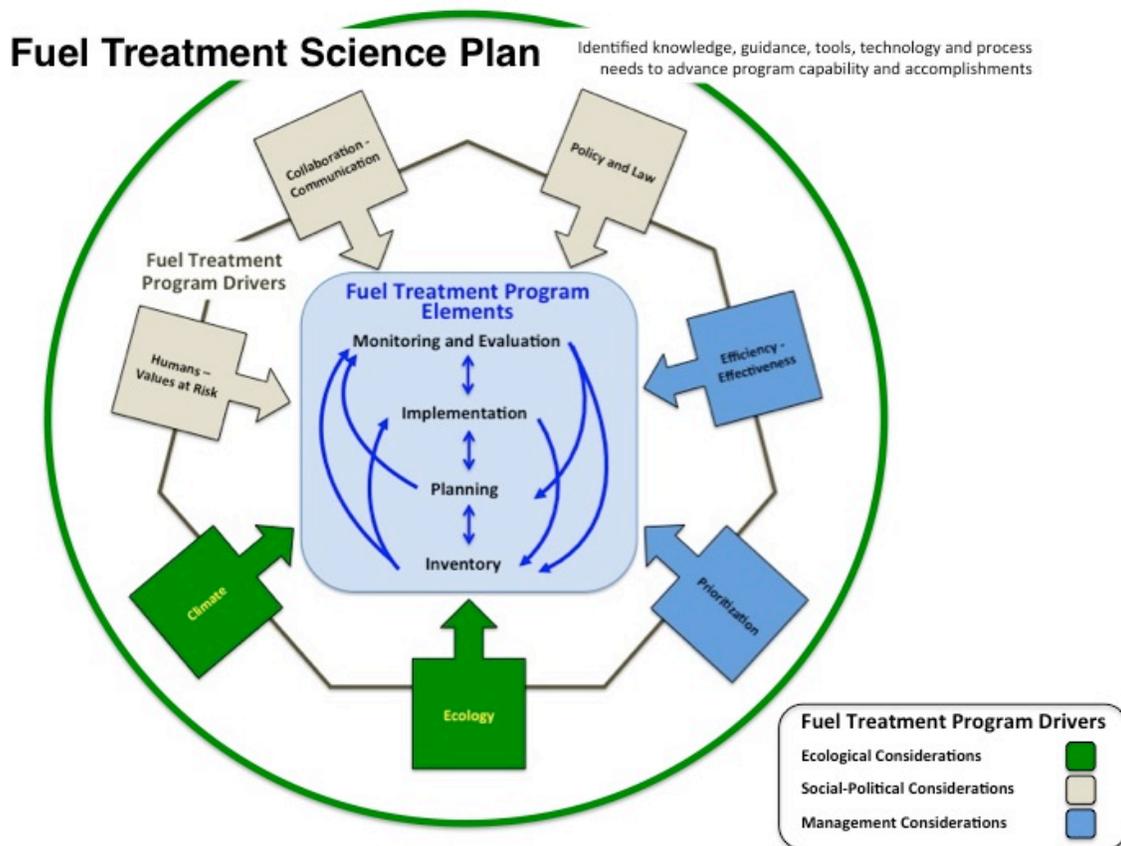

Figure 7. Fuel treatment program elements, drivers, and their interactions.

Potential Research Foci

The full set of four program elements and seven drivers combine to form a total of 28 possible program research foci that could be addressed by the FTSP and be used as compartments for research subtopic needs (Figure 8). Research foci formed by the combination of elements and drivers will support integration of science and management needs, expanded knowledge, and new tools for managers. Objectives were developed for each of the foci created by the combination of the four program elements and seven drivers. These objectives provide clarification of how these factors influence the program elements. Appendix B contains tables that define objectives for each of the research focus areas (element/driver combinations). Even though these objectives deal with a specific research focus area, they are still broad in nature.
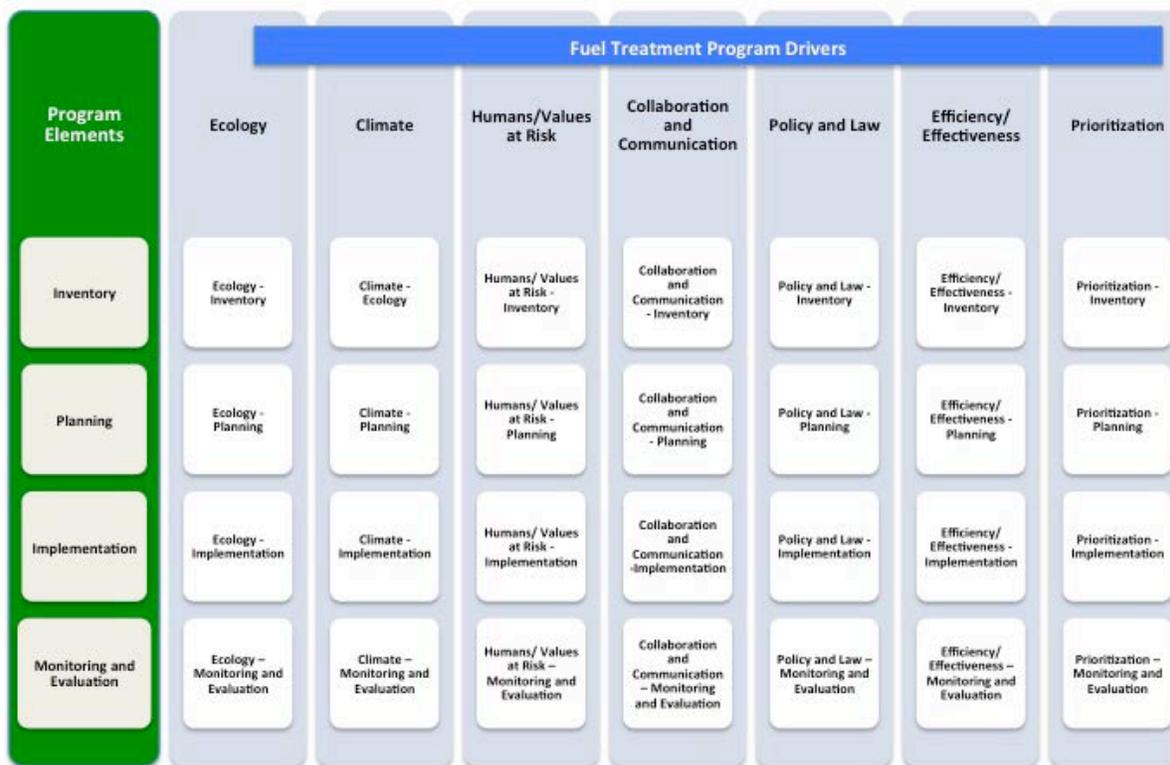
Figure 8. Fuel treatment program description showing 28 research foci based on the combination of program elements and drivers.

Analysis of the entire fuel treatment program through the use of the 28 research focus areas (element/driver areas) provided the total complement of research needs in each area and afforded a comprehensive and extensive perspective of the complete program set of research needs. Linkages and synergies of these areas provided context for needs in each area, improved understanding of various implications of specific activities, supported sequential investigations to build knowledge and procedures, provided a stream-lined means to evaluate progress in each of the focus areas, and provided a solid basis for increasing research investment value and benefits.

Analysis of the full set of information gathered during this project has produced some definitive trends that are shown in Appendix C, Tables C-1, C-2; Figures C-1, C-2, C-3, C-4, and C-5. These trends show that some program drivers have garnered more attention than others from a research needs standpoint. However, the comprehensive assessment approach taken during this project required that all areas be examined and all possible research sub-topics receive consideration.

A summation of obtained information on program driver, focus area, and research needs importance was developed. The identified relative importance ranking of each program driver in terms of future research efforts is provided based on responses from all data sources (Table 4). The drivers are listed in order of how frequently they were cited as having future research needs (i.e., # 1 cited most often, # 7 cited least often).

Table 4. Fuel treatment program drivers ranked by importance, based on information received during information acquisition phase of project.

Importance Rank	Program Driver
1	Efficiency/effectiveness
2	Ecology
3	Humans/values at risk
4	Prioritization
5	Climate interactions
6	Collaboration and communication
7	Policy and law

The proposed program of research, science communication, and future considerations are described in the following sections.

Proposed Program of Research

Research Themes

In order to establish a manageable set of research investments for JFSP, four themes were developed to consolidate much of the information created from the analysis of four program elements, seven program drivers, and 28 research focus areas. These themes were designed around the concept of investments, investigations, and service. Investments should be made to focus investigations in areas of uncertainty that have high relevance to and will boost management performance. Investments should also be made where there is a high probability that investigations would lead to development of new high performing services.

Use of these themes provides a means to integrate and organize the set of research that JFSP has already commissioned and the set of fuel treatment research that will be funded in the future. Some research that has already been funded represents stand-alone products that contribute to science and management while other projects are continuing efforts or precursors for additional research projects identified in this plan.

The use of themes follows the model defined in the Smoke Science Plan and allows for development of four parallel tracks of research effort. Discrete projects are defined for each theme or track and each project is planned to contribute progress toward achievement of the objective for that theme. The themes chosen here are compatible with the program drivers used in analysis during this effort and represent the consolidation of the research focus areas into a much smaller subset. The themes are designed to include the highest ranked program driver information and are designed to allow JFSP to use the plan with flexibility, including periodic review of the more detailed insights for the seven drivers and four program elements listed in the appendices. JFSP will be able to review recommendations, account for changing situations, and make decisions to proceed or modify the plan recommendations over time.

The four themes that have been developed are:

- Fuel treatment effectiveness
- Ecological science
- Fuel treatment and society
- Program implementation

Fuel Treatment Effectiveness. Currently, fuel treatment effectiveness is broadly defined in context of reducing fire behavior potential at project level scales and has been oriented towards western coniferous forested types. While this focus has developed the foundation for assessing fuel management activities, managers report difficulty in assessing fuel treatment effectiveness and communicating accomplishments to policy makers and stakeholders. Amorphous measures of effectiveness contribute to the continuing debate on the efficacy of fuel treatments in the nation's effort to protect or enhance resource values in fire prone landscapes. Given the national and broad ecological scope of fire management, greater precision in defining in defining fuel treatment effectiveness is needed to enable managers to plan, implement, and assess fuel treatment projects and programs from an eco-region perspective.

Developing eco-regional scale syntheses that define fuel treatment effectiveness would result in measures that are relevant to the fire regime and incorporate localized ecological, social, and resource management objectives identified in in the Cohesive Strategy. Considerations such as the effects of the spatial extent or arrangement of treatments, and longevity of treatment effectiveness are additional factors that are more appropriately analyzed in context of an eco-region's landscape characteristics. An eco-regional definition of fuel treatment effectiveness parameters and knowledge gained from their development would assist resource managers in planning, implementing, and assessing fuel treatment programs and projects. Subsequent national-level analysis and synthesis of the eco-regional variants would assist in developing national

programmatic assessment measures and support efforts to communicate fuel management program goals to stakeholders.

Ecological Science. The development of effective, ecologically sound guidelines for regionally-specific management of fuels and fire behavior depends upon a better understanding of ecological responses, including effects of natural disturbances and potential climate change on vegetation structure and distribution and fuel complexes. Fuel complexes – composition, amount, and distribution at multiple spatial scales – that have resulted from past management and natural disturbance effects are now being impacted by increasingly severe natural and human-influenced disturbance events, including insects, drought, and fire, and quite possibly enhanced by variation in climate. Fuel loading is often rapidly increased in response to disturbance events, whereas shifts in ecological trajectories unfold slowly, and emergent vegetation complexes reach resilient conditions only after much time has passed. Of greatest immediate concern are increases in extreme fire behavior associated with rapid and extensive buildup of fuels.

We need regionally-specific, forward-looking assessments of fuel conditions for current natural disturbance patterns and those anticipated under future climatic scenarios.   Such an assessment should include input from experts in vegetation modeling, natural disturbances, and potential climate change conditions, and lead to an identification and prioritization of landscapes and vegetation zones that are (a) most vulnerable to increased fuel accumulation, and/or (b) most suitable for preemptive treatments to mitigate fuel complex and fire behavior concerns.   Assessments also should consider potential vegetation shifts indicating where species or vegetation types are likely to remain stable, emergent into new areas, threatened, or lost because of shifts in environmental suitability. This should include assessment of soil and other suitability factors and biotic effects of seed dispersal and related life cycle processes associated with emergent vegetation in potential new areas of vegetation establishment.

Fuel Treatment and Society. There appears to be a sense within the fire management community, as evidenced by our questionnaire, available literature, and other sources, that a disparate understanding of the role of fuel treatments, ecological benefits, economic trade-offs, and precise messages being delivered exists. Data collected during this project indicate that this area is in need of additional research, information dissemination, and focused education. Understanding the full role and benefits of fuel treatments, including cost effectiveness, and capability to collaboratively plan and implement fuel treatments need to be improved. Messages being delivered to the public need to be clarified and targeted to address this understanding issue. We need to understand and educate the public on how they value restoring and maintaining landscapes, protecting and building fire-adapted communities, and determining and managing response to wildfires. We also need to improve strategic alignment and communications and collaboration by all affected parties, and programmatic alignment of all agencies and organizations involved. Work under this theme will be directly linked to and support tasks in each of the other three themes presented in this plan. We propose that JFSP provide research support for projects that address fuel treatment economics; and collaborative limitations, opportunities, and practices.

Program Implementation. Information gathered during this project strongly infers that while substantial research and attention has been given to fuel treatment activities, there is an inadequate information transfer process to management. The vast body of available literature combined with direct feedback that enough research has been completed but is not being used as well as feedback that much of the available information is not readily accessible and understandable strongly supports this perspective. Program implementation is a necessary commitment if the goals and vision for the future of wildland fire management are to be realized. Improved implementation efficiency is stalled and unable to advance without the best available information getting into the hands of managers and being applied. We propose that those areas of implementation that have the most urgent need for JFSP to provide research support for include the compilation of information into readily accessible and usable fuel treatment planning guidance, an examination of fuel treatment prioritization processes or development of a new process, and evaluation of additional treatment strategies.

Work under this theme will be directly linked to and support tasks in each of the other three themes presented in this plan.

Each theme has an objective that provides vision and direction for the work proposed. These objectives are shown in Table 5.

Table 5. Objectives for fuel treatment research themes.

Theme	Objective
Fuel treatment effectiveness	To develop new science and knowledge to establish viable fuel treatment effectiveness measures that 1) effectively evaluate fuel treatment programs and implementation activities in achieving both short- and long-term social, political, and ecological objectives at all spatial and temporal scales; and 2) provide eco-region guidance to managers in planning and implementing fuel treatment projects and programs.
Ecological science	To develop new science and knowledge that provides effective, ecologically sound guidelines for regionally-specific management of fuels and fire behavior based upon a better understanding of ecological responses and successional trajectories, including effects of natural disturbances and potential climate change on vegetation distribution and fuel complexes.
Fuel treatment and society	To develop new science and knowledge that characterizes the relationship of fuel treatments to human values; and promote improved communication and collaboration activities among governmental units, the public, and partner organizations.
Program implementation	To develop new science and knowledge that will improve planning, prioritizing, implementing, and evaluating effects of the implementation of fuels management treatments and programs, including attention to development and application of guidance and tools for managers.

The four themes encompass a wide range of needs associated with the fuel treatment program. Each theme has multiple research focuses that are intended for attention.

Fuel Treatment Effectiveness Research Focus: Given the national and broad ecological scope of fire management, greater precision in defining fuel treatment effectiveness is needed to enable managers to plan, implement, and assess fuel treatment projects and programs from an eco-region perspective. Developing eco-regional scale syntheses that define fuel treatment effectiveness will result in measures that are relevant to the fire regime and incorporate localized ecological, social, and resource management objectives identified in in the Cohesive Strategy. Subsequent national-level analysis and synthesis of the eco-regional variants will assist in developing national programmatic assessment measures and support efforts to communicate fuel management program goals to stakeholders. We propose that the JFSP engage with the Knowledge Exchange Network and provide research projects, assessments, and workshops to develop eco-region oriented syntheses defining fuel treatment effectiveness parameters by:

- Examining existing programmatic assessment metrics to determine if metrics are well defined, measurable, and adequately assess fuel treatment progress in meeting program goals.
- Examining and describe and eco-region level fire behavior characteristics to determine spatial and temporal scale for wildland fire, and identify thresholds for normal and extreme fire behavior conditions.
- Identifying the probability of fuel treatment measures successfully mitigating fire behavior at the expected thresholds across both forested and non-forested ecosystems.

- Researching the regionally-specific interrelationships of fuel treatments and wildfires. Expanded and continued studies are needed on how fuel treatment configuration can influence wildfire size, severity, and mitigate fire effects.
- Research how wildfires management can be used to meet fuel treatment objectives.
- Identifying key ecological values and examine the potential for fuel management activities to enhance or protect.
- Evaluating treatments to determine the appropriate spatial scale (landscape, project, or both) for placement to achieve protection and resource management objectives. Determining how the specification of spatial and temporal scales for treatment objectives to be met can be incorporated into performance metrics.
- Examining the longevity of effectiveness for fuel treatments and identify long-term maintenance needs from the perspectives of vegetation/fuel conditions progression.

Ecological Science Research Focus: The Knowledge Exchange Network should be used as a platform for regionally-specific, forward-looking assessments of fuel conditions for current natural disturbance patterns and those anticipated under future climatic scenarios. This will assure that advances are systematic and sufficient in scope yet responsive to regional differences. Existing and recently completed JFSP and other studies provide a useful foundation for expanding the analyses uniformly across all regions. Issues that we propose the JFSP consider providing research support to include:
- Enhancement of vegetation models to improve the identification of areas most prone to significant fuel complex changes, including a probabilistic assessment of the types, intensities, and distributions of potential natural disturbances most likely to have significant effects on fuels.
- Assessment of anticipated spatial shifts in environmental suitability and vegetation related to potential climate changes (e.g. where is vegetation likely to be stable, emergent, threatened, or lost as conditions change), and attending fuel complex conditions resulting from these shifts.
- Evaluation of fuel treatment options for enhancing spatial diversity in vegetation and fuel structure at meaningful (esp. landscape) scales, targeting a reduction in size and severity of large fires.
- Evaluation of resilience at landscape scales, and assessment of opportunities and limitations for achieving resilience for anticipated climatic conditions.

Fuel Treatment and Society Research Focus: We propose that the JFSP provide research support to projects that develop an improved science for assessing the interrelationships of fuel treatments and society. Research topics will include:
- Characterizations of human values, in terms of their impacts to, impacts from, and levels of public and agency tolerance of risk from fuel treatment activities.
- Evaluation of treatment implementation compliance with the public safety and protection of values of at risk parameters identified in the treatment plan.
- Assessment of progress and evaluation of the degree of success of fuel treatment effectiveness in mitigating suppression costs, resource loss, risk, hazards, health impacts, and firefighter and public and firefighter safety.
- Developing performance metrics to reflect the lifecycle costs of fuel treatments.
- Developing improved processes that promote communication and collaborative efforts in supporting fuel treatment planning and implementation activities and increased monitoring and comprehensive assessment of the effectiveness of these efforts.
- Use the Knowledge Exchange Network consortia to develop regionally-specific public education strategies and processes to disseminate the benefits, urgency, and needs for fuel treatment practices.

Program Implementation Research Focus: We propose that the JFSP provide research support to projects that improve science, knowledge, and processes for fuel treatment planning, prioritization, implementation, and monitoring and evaluation. Research topics will include:

- Establishing a stronger and more efficient link between research and management by rapidly and efficiently providing managers access and understanding to appropriate information. An effective means to accomplish this is to develop readily accessible syntheses of available tools, management guides, and reference materials that will expedite information transfer and application in the fuel treatment program.
- Research the link between specific and measurable treatment objectives and meaningful performance metrics (linked to fuel treatment effectiveness).
- Advancing planning guidance for fuel treatment activities.
- Improving prioritization processes and developing a standard process for universal use.
- Research into program implementation procedures and implications of objectives, spatial and temporal scales, and policy and law.

Recommended Five-Year Research Strategy

The analyses of information received from all sources culminated in the following recommended research topics by year for a five-year period, 2015 – 2019 (Table 6). This provides a solid foundation for future JFSP fuel treatment research activities.

Table 6. Recommended research topics by year for the five-year period of 2015 - 2019.

Year	Themes			
	Fuel treatment effectiveness	**Ecological science**	**Fuel treatment and society**	**Program implementation**
2015	A focused workshop to develop potential fuel treatment effectiveness analysis parameters and a template for use by consortia for the eco-region syntheses. Document this effort through publication.	Convene workshop to enhance vegetation modeling that addresses natural disturbances and climate model scenarios, focusing on the identification of vegetation types and areas having high probability of expanded fuel management concerns during the next several decades. Identify fuel treatment needs for uncharacteristically homogeneous vegetation zones, focusing on enhancing spatial diversity in vegetation structure and fuel conditions and targeting reductions in the size of large fires.	Identify elements that define cost effectiveness, economic benefits, of treatment type comparisons, and maintenance costs.	Develop project planning guidance for the development, clarification, and alignment of fuel treatment objectives (fire behavior, ecological, restoration, hazardous fuel reduction, maintenance, etc.).
2016	Consortia convene workshops and begin eco-regional assessment of existing fuel treatment effectiveness research, fire regime characteristics, and resource management objectives. Assess eco-region relevancy of the existing measures of fuel treatment effectiveness, and develop proposals for revised measures. Document this effort for presentation at national workshop in 2016.	Develop increased regional (consortium) specificity of vegetation and fuel modeling in response to natural disturbances and climate scenarios, building on previous workshop results.	Evaluate the effects of fuel treatments on reducing suppression costs.	Assess the long-term impacts of fuel treatment implementation for protecting communities and infrastructure on the spatial, temporal, and intensity elements of wildfire and other landscape processes.
2017	Combined national level consortia workshop to share eco-regional products. Assess and revise national fuel treatment effectiveness measures template. Document this effort through publication Consortia complete eco-region assessments and document through publication.	Continue regional vegetation and fuel modeling to identify spatially where fuel mitigation needs are likely to become most severe as a result of threatening or unsuitable environmental (climatic) conditions.	Identify and examine key regional social issues and "tipping points" impacting implementation of fuel treatment programs and projects.	Evaluate existing prioritization models for practicality, use, and outputs and identify the best process to prioritize treatments.
2018	National level assessment and synthesis of consortia developed eco-regional syntheses.	Incorporate probabilities of existing and anticipated future shifts in vegetation and fuel complexes into landscape-scale fuel treatment prioritization	Evaluate the effectiveness of current models and practices to explain short- and long-term wildfire risk and the benefit of fuel treatments in multi-	Identify and examine landscape scale multi-jurisdictional fuels management projects successfully integrating federal,

			jurisdictional settings.	state, and local planning requirements; provide recommendations for managers.
	Develop consolidated national synthesis.			
2019	Publish consolidated national fuel treatment effectiveness synthesis and deliver to field.	Evaluate ecological trajectories for vegetation in relation to climatic/environmental scenarios, and assess resiliency of existing vegetation.	Develop methodologies to evaluate the effectiveness of collaborative efforts in reducing barriers to fuels management project implementation.	Evaluate the role of post-wildfire fuel conditions, , alternative treatment methods, and the no-action alternative in terms of technology, frequency, advantages, disadvantages, and overall capability.

All recommended research topics could be expanded and clarified as needed. Other topics can also be expanded if the Governing Board moves them onto the annual research list. A master list of all potential research topic areas generated through this project is provided in Appendix D, Tables D-1 through D-7.

Science Communication

Throughout the process of information acquisition, a range of responses was received in regard to the need for additional fuel treatment research as well as the adequacy of what exists. A preponderance of needs were identified, analyzed, consolidated, and sharpened to provide the recommended program of future JFSP research focus that is identified in the previous section.

But, as well as identifying additional fuel treatment research needs, numerous information sources reported that much research has been completed. It was also stated that managers are either not using existing information, are unaware of its applicability, or are unable to obtain it; all of which indicates that some completed research is not easily accessible, understandable, or practical for use. Suggestions were made that priority should be given to improving and expanding technology transfer processes to get available research information into the hands of managers.

Figure 1 shows a generalized role of science in advancing management capability. Science communication is clearly present in this framework as shown in Figure 9.
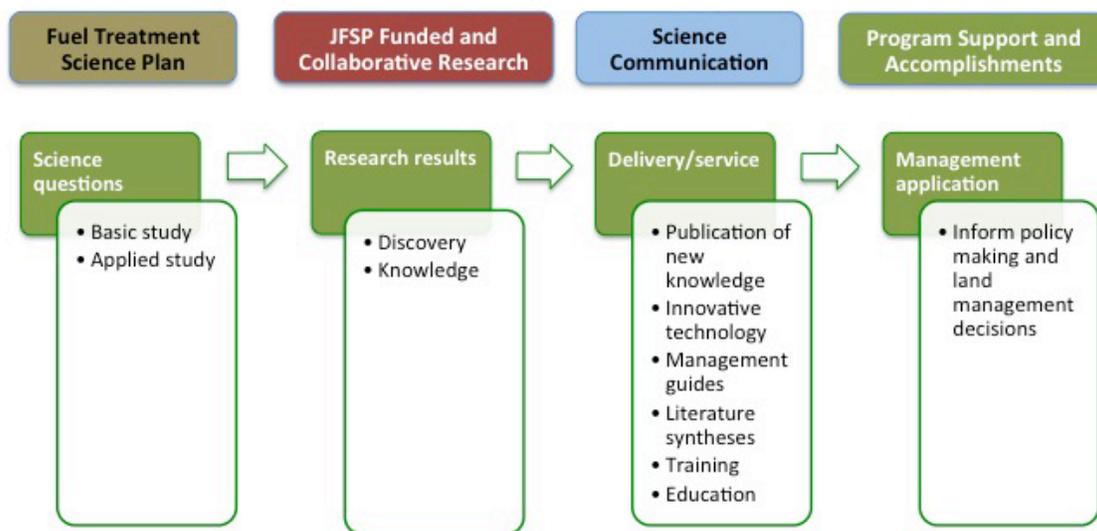

Figure 9. Generalized role of science in advancing management capability with clarification of the FTSP, funded research, science communication, and program implementation.

Communication and transfer of science products to current and future resource managers and others is essential and as equal in importance as obtaining new knowledge. The FTSP identifies areas of uncertainty and recommends research topics for consideration to improve management capability. Research projects are funded through JFSP or through collaborative projects as determined and research results are obtained. Science communication is a fundamental step in this process. Without science communication, people may not obtain, understand, or even be aware of increased knowledge and tools to support fuel treatment program planning and implementation.

Communicating new information to a multitude of users at a rate that keeps pace with its emergence is a daunting task. The geographic extent and volume of users coupled with the amount of information to be communicated, poses challenges to traditional training practices. No single method will meet communication needs, but effective communication and transfer of science can be accomplished through the integration of following approaches:

- **Technology Transfer Processes.** Development of new and expanded technology transfer processes in general was a frequent request during the information acquisition phase of this project indicating a significant need for greater action in this area. While there are numerous options for technology transfer, all methods that broaden the availability of science information should be considered.

  Existing technology transfer processes include, but are not limited to:
  - JFSP provided newsletters, digests, syntheses, other publications, and sponsors webinars on a frequent basis.
  - US Forest Service operation of a Wildland Fire Management Research, Development, and Application (RD&A) program for technology transfer.
  - USDOI implementation of technology transfer through multiple processes, professional societies produce publications and venues, and universities provide education, research, and outreach activities that accomplish technology transfer.

  These processes may appear to be a one-way process but a part of a larger multi-faceted network that still has room for improvement

- **JFSP Knowledge Exchange Network**. Regional knowledge exchange components of JFSP's national network can take on a more active role in science communication. These programs have only been in existence for a short time but are demonstrating their utility in science communication within targeted geographic areas. Their objectives span the full range of science communication and include areas of: information dissemination, existing research and syntheses listing and description, periodic assessment of research applicability, demonstrations of research and case studies, and furthering and validating new research and information syntheses. Regional knowledge exchanges are a valuable asset increasing both in importance and usefulness of fuel treatment science communication. Their value is associated with their ability to accelerate presentations of webinars, workshops, conference calls, local training, web-site hosted education and reference information, and informational field tours, as well as generating additional research needs at the geographic area level. They can also be highly instrumental in expediting the transfer of information to the public locally and regionally.

- **Education.** Education focuses on WHY -- why ecological concerns are higher in certain areas, why managing social, economic, and political concerns are important and even, at times, formidable challenges, and why management issues represent such an important issue for implementation. Key to preparing managers and others for future challenges, education supports critical thinking, finding, understanding and applying relevant science to practical problems, as well as providing the broader context. Ideally, education comes from an accredited University and classes that are documented on academic transcripts or through professional certificates. The Knowledge Exchange Network consortia also offer a significant opportunity to advance public education regarding the importance of fuel treatment as a social, economic, and natural resource management priority at local and regional levels.

- **Training.** Training is the customary method of transferring information and technology from research to managers. Local, regional, and national training, workshops, special sessions at conferences, and local field trips or tours are conducted to transfer specific information encompassing the full fuel treatment program spectrum and accomplish training objectives. Possible topics encompass the full fuel treatment program spectrum and appropriate information should be incorporated into coursework. Suggestions for possible topics of training or workshops that were derived from the information obtained during this project are shown in Table 7. In all of these, best practices for effective communication need to be used, and underlying science needs to be included so participants learn to access and apply science.

Table 7. Possible areas of education, training, workshops, and focused information presentations.

Title of Education, Training, Workshop, or Other	Purpose and Applicability	Associated Theme
Prescribed fire and effects on fauna	To improve understanding of the effectiveness of planning and implementation activities in achieving both short- and long-term ecological effects.	Ecological science, Program implementation
Educational techniques for fuel management on private lands	To improve awareness of communication and collaboration activities with the public and partner organizations for fuel management on private lands.	Fuel treatment and society
Policy and law requirements for fuel treatment planning and implementation.	To improve understanding of the necessary policy and law compliance during planning and implementation activities and to facilitate the long-term evaluation of policy and law impacts on achieving fuel treatment objectives.	Fuel treatment effectiveness, Fuel treatment and society, Program implementation
Knowledge of background and use of fuel treatment tools and guidelines.	To improve the understanding and capability to use the proper analysis and prediction tools for determining treatment parameters and predicting effects; and the use of planning guidelines and preparation tools.	Fuel treatment effectiveness, Program implementation
Workshops on prescribed fire in various ecological situations.	To improve understanding of treatment implementation effectiveness in specific ecological situations.	Fuel treatment effectiveness, Ecological science, Fuel treatment and society, Program implementation

- **Webinars, Self-Paced Study, On-line, and Other Alternative Information Delivery Processes.** In addition to face-to-face training, workshops, special session, field trips, etc., other alternative delivery methods can be highly successful. Webinars, web conferences, or web seminars, self-paced independent study, and on-line education and training courses offer valuable options to communicate information, engage wider audiences, and offer scheduling flexibility without the time and expense of traveling to central locations for a definite time period.

   Webinars allow a live presentation to be conducted for a group of individuals who are not in the same room, live interaction is possible, and the events can be recorded and archived. Recent information (Business.com, Inc. 2009. *2009 Business Social Media Benchmarking Study*) shows that webinars and podcasts clearly have the greatest value in reaching and providing trainees the ability to learn new skills and/or research information, products, and services.

   Additional alternative information delivery methods are available that can provide focused new knowledge and information on specific topics, rapid lesson sharing, presentation of case studies, presentation of examples, and conduct simulations. On-line courses, social media, and other internet uses can effectively increase opportunities for learning. Social media is another area where opportunities are expanding, although this method may be most effective for short communications of limited information.

- **Synthesis Papers:** Preparation of literature syntheses, reference guides, and process guidelines offers an effective and useful course for synthesizing information into a single or limited number of sources, reducing accessibility issues. Clearly stated goals and approaches used for these products and logical assembly and presentation will aid in improving management's understanding of the information. Preparation of literature syntheses, reference guides, and process guidelines can play an important role in the success of this FTSP, in support of the principal purposes of JFSP, and in strengthening the effectiveness of the fuel treatment program.

  Possible literature syntheses and other reference documents that could be developed in support of the FTSP based on information feedback are presented in Table 8. Numerous syntheses and guidelines have been prepared over recent years and provide significant information to the fuel treatment program. Efforts to increase awareness of existing syntheses will improve their use in planning and implementation. Periodic review and updating of these materials is also an item for consideration. Available syntheses and guidelines (although not limited to this list) are provided in Appendix E.

Table 8. Possible literature syntheses, reference guides, process guidelines, and other reference documents to support fuel treatment science communication.

Product Title	Purpose and Applicability	Associated Theme
Synthesis identifying eco-regional and national scale fuel treatment effectiveness definitions and parameters.	Identify and develop fuel treatment effectiveness measures that 1) effectively evaluate fuel treatment programs and implementation activities in achieving both short- and long-term social, political, and ecological objectives at all spatial and temporal scales; and 2) provide eco-region guidance to managers in planning and implementing fuel treatment projects and programs.	Fuel treatment effectiveness, Program implementation
Guidelines for fuel treatment planning and implementation under changing climatic conditions.	Consolidate information into more accessible products; improves accessibility.	Fuel treatment effectiveness, Ecological science, Program implementation
Synthesis of methodologies/ techniques to communicate spatial and temporal effects of fuels management strategies.	Consolidate information into more accessible products; improves accessibility.	Fuel treatment and society, Program implementation
Compendium of local/state/ federal regulations on fuels management planning and implementation.	Improve accessibility and understanding of regulations affecting fuel treatment planning and implementation.	Fuel treatment and society, Program implementation
Catalog of laws and zoning regulations regarding fuels treatments on non-federal lands.	Improve accessibility and understanding of laws and zoning requirements affecting fuel treatment activities on non-federal lands.	Program implementation
Guidelines for fuel treatment in watersheds and riparian areas that maintain desirable hydrologic and geomorphic processes.	Consolidate information into more accessible products; improves accessibility.	Fuel treatment effectiveness, Ecological science, Program implementation
Guidelines for livestock grazing after	Consolidate information into more	Fuel treatment effectiveness,

fire that account for variation in site productivity, pre-fire ecological conditions, and invasive species.	accessible products; improves accessibility.	Ecological science, Program implementation
Guidelines covering background and use of tools and reference guides.	To improve understanding that facilitates improved prioritization processes, including rapid evaluation of treatment methods, placement, and frequency and their contributions to achieving social, political, and ecological objectives.	Fuel treatment effectiveness, Program implementation

- **IFT-DSS.** The Interagency Fuels Treatment Decision Support System (IFT-DSS) has been under development under the guidance of the JFSP and the NWCG Interagency Fuels Committee.   It can e accessed at http://iftdss.sonomatech.com/. This project was initiated in response to a lack of an authoritative, cohesive development agenda and roadmap for fuels management software. Specific areas of concern included:
  - o The myriad of issues associated with a wide range of existing software packages
  - o Lack of understanding the best way to choose the appropriate software package
  - o Length of time required to learn how to operate software packages
  - o Amount of time required for data acquisition and preparation
  - o Lack of consistency across agency and locations

  IFT-DSS was designed to be a web-based application to provide users with a single user interface to multiple software tools supporting fuels management analysis and implementation. It incorporates new science, knowledge, and technology to advance the fuel treatment planning process. It helps define viable, measurable objectives; determine the best treatment type; assess appropriate spatial and temporal applications; select treatment methods that will safely and cost-effectively accomplish the objectives; evaluate economic tradeoffs; assess risk and identify appropriate risk management practices; facilitates the use of appropriate analysis and prediction tools for determining treatment parameters and predicting effects; and the provides quick access to planning guidelines and preparation tools.

  IFT-DSS reduces training, re-familiarization, and data transformation time from previous processes. Its collaboration features allow data and project analyses sharing across units and agencies. It provides a single library of software modules that will make access easier, streamline version control, and allow for module updates in an easier and less expensive manner.

  Information gathered during the FTSP project indicated that IFT-DSS was receiving use at an increasing rate by field users. Numerous comments were received asking for expansion of IFT-DSS, asking if the Wildland Fire Decision Support System (WFDSS) and IFT-DSS could be merged, and if decision support tools could be streamlined in general. But, during this process, the Wildland Fire Information and Technology (WFIT) Executive Board formally approved IFT-DSS for further development. The WFM RD&A in collaboration with Interagency representatives will be project leaders for system development, improvements and enhancements over the next five years. IFT-DSS version 2.0 Beta is currently available for testing and evaluation and will be managed in beta test mode for the next two years, with full operational deployment planned for 2017. In its current form, there are four critically important workflow processes available to fire managers:
  - o Hazard Analysis
  - o First Approximation Risk Assessment
  - o Fuels Treatment Placement Analysis
  - o Prescribed Burn Planning

IFT-DSS represents a viable process for facilitating fuel treatment planning activities and should be maintained, expanded as possible, and communicated as another means of science communication as well as being a practical tool for managers. Current direction is strongly supportive of developing a system that supports effective risk-based fuels management planning, integrates with other applications (Fuels Treatment Effectiveness Monitoring (FTEM) Database, FACTS, NFPORS, WFDSS), facilitates data sharing and houses an official archive for federal fuels treatment planning.

- **Development of a Monitoring Repository.** No corporate database or repository for fuel treatment effects monitoring data currently exists. Scientifically based, standardized protocols for inventorying pre- and post-fire conditions that satisfy monitoring and management objectives are lacking (Lutes et al., 2006). Development of a corporate monitoring repository may be difficult to achieve from an interagency perspective but if accomplished, it would guide consistency in monitoring standards, type of data collected, allow use across project, unit, geographic levels, and support monitoring objectives. Informational responses during this project identified development of a monitoring repository as a need.

  Several systems exist that can fulfill some needs of a monitoring repository or could be expanded to do so. The Fire Effects Monitoring and Inventory System (FIREMON) (Lutes et al., 2006) is a comprehensive system designed to satisfy fire management agencies' monitoring and inventory requirements for most ecosystems, fuel types, and geographic areas in the United States. FIREMON is a standardized set of sampling manuals, databases, field forms, analysis programs, and image analysis tools that allow managers to design and implement fire effects monitoring projects (Lutes et al., 2006). FIREMON is not intended to be a corporate database, although it could support that objective. The National Park Service (NPS) and US Fish and Wildlife (USFWS) have agency standardized monitoring procedures available (FMH - National Park Service, Fuel and Fire Effects Monitoring Guide – US Fish and Wildlife Service). FIREMON is not intended to replace these or any agency monitoring systems and is not a repository for fire behavior documentation.

  FFI (FEAT/FIREMON Integrated) and FFI-Lite have been developed to assist managers with collection, storage and analysis of ecological information (Lutes and others 2009). This tool was developed through the complementary integration of two fire effects monitoring systems commonly used in the United States: FIREMON (Lutes 2006) and the Fire Ecology Assessment Tool (Sexton 2003). FFI provides software components for: data entry, data storage, geographic information system (GIS), summary reports, analysis tools and Personal Digital Assistant (PDA) use. FFI-Lite provides the features of FFI, with the exception of the GIS toolbar and PDA functionality. Standard FFI features allow FFI to be used for monitoring across a broad range of ecosystems and help managers fulfill monitoring mandates defined in land management plans and policy. Scalable (project to landscape scale) monitoring at field and research levels, cooperative, interagency data management, and ready information sharing are all facilitated by FFI.

  In addition, methods for archiving and sharing anecdotal information, past experiences, practical discussions, and other practitioner information have merit. The JFSP brief and digest information sources, IFT-DSS, and the Lessons Learned Center all offer resources that address this area in some measure. These measures promote rapid information sharing and expanded fuel treatment information communication in both scientific and management program areas.

Future Considerations

This plan represents a comprehensive approach to fuel treatment program analysis and identification of research needs developed through a careful and detailed process of gathering, reviewing, and summarizing information from many sources. The plan, however, cannot represent a complete picture of the fuels management program status and needs over time. At the time it was prepared, program elements, drivers, research focus areas, research sub-topics, and priorities presented embodied a compilation of the best information available. There are many sources of variation that exist. Some topics may ascend to a much more prominent position in the future, and some that are presently unknown could emerge as significant issues in the future. Regardless of whether these elements change slowly over time or develop rapidly in importance, they will require ongoing adjustment of FTSP direction and priorities.

As a result, a sound, effective program of research action for fuel treatment must have the ability to remain dynamic and adjust to changing conditions, issues, and influences. Ecologic conditions are in a state of continual change as a result of land use, management actions, and climatic interactions. Social, economic, and policy issues can present continuing, new, and challenging time-constrained requirements and demands that have a real potential to elevate the need for specific research focus and shifts in priorities. Variations in budgets can also be responsible for periodic reconsideration of research capabilities and priorities. Program adjustments will undoubtedly be necessary and the FTSP must remain flexible enough to accommodate and adapt to all potential sources of variation and influences while supporting the goal of identifying program research and technology needs to support fuel treatment efficiency and application.

As the FTSP is implemented, monitoring of progress and documentation of accomplishment milestones will be important. Annual milestones can be established to gauge progress. Annual reviews should be conducted to validate the FTSP and document accomplishments. Specific attention and scrutiny should be given to:

- identifying changing conditions
- monitoring program progression
- identifying accomplishments

Program adjustments will undoubtedly be necessary. Annual reviews, unless a more frequent interval is necessary, can clarify changing conditions that indicate need for changes in priorities. New needs can be added to the plan and direction adjusted accordingly. Annual monitoring and evaluating of research progress will help assure that the investment in research remains focused, and that change in research direction is done thoughtfully rather than randomly. As the FTSP progresses and accomplishments build, future direction can be evaluated, adjusted, or developed.

Monitoring the FTSP is an essential component of the complete process illustrated in Figure 9 and is typified in Figure 10. As critical questions are identified, research projects are initiated and conducted to address those questions, transfer of information to users occurs, and new information is applied in operations. Monitoring and evaluation occurs as an integral part of all steps. As shown in Figure 10, feedback occurs from all steps of the process to previous steps. As activities in each step are monitored and evaluated, feedback validates the accuracy, appropriateness, and completeness of what is taking place and if changing conditions warrant plan modifications. Provided monitoring and evaluation take place, the plan can be responsive and be modified and updated to reflect changes in priorities and incorporate additional and emerging needs as warranted.
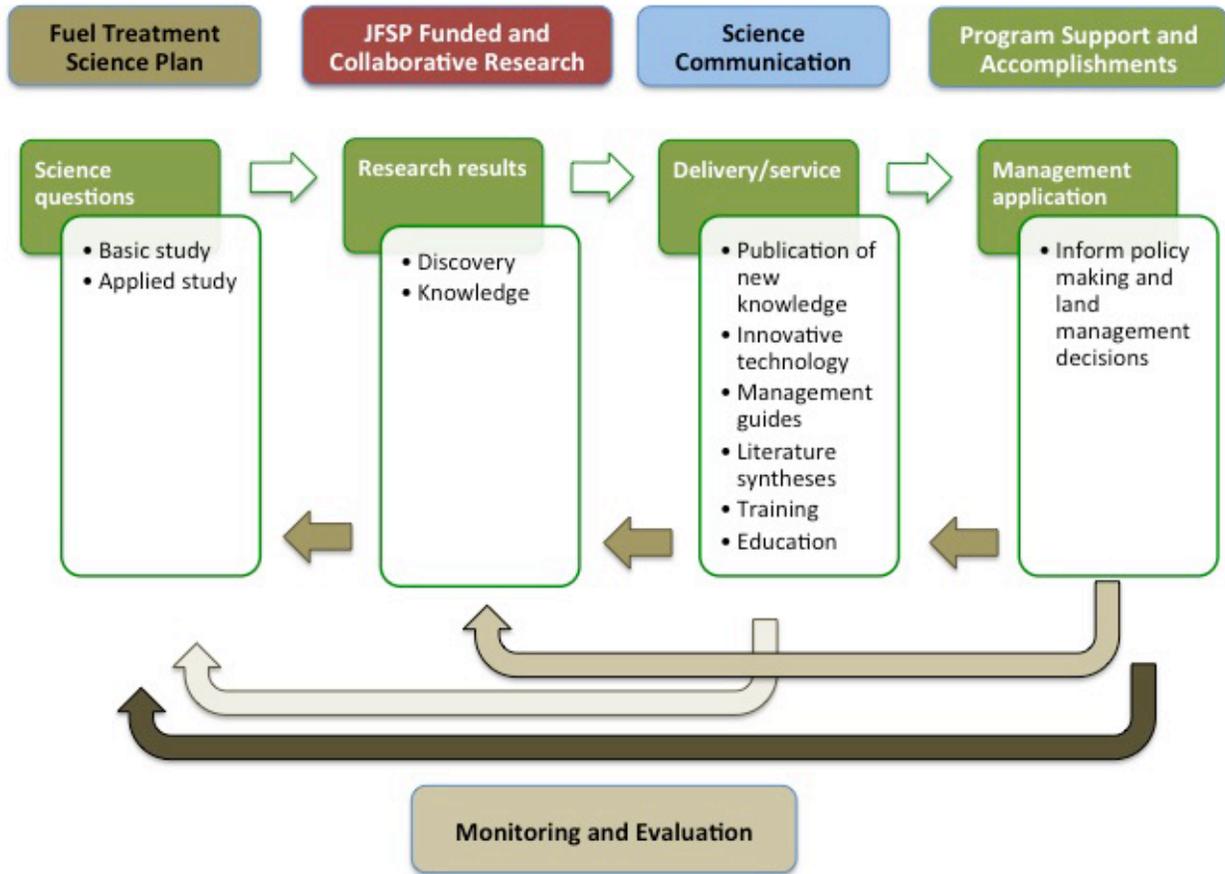
Figure 10. Monitoring and evaluation as part of the generalized role of science and in support of the FTSP.

As the FTSP is implemented over the next five years, the JFSP Governing Board will select research sub-topics from it to use in requesting proposals and funding projects. The topics listed in the plan are not constructed in sufficient detail to be proposal request-ready. As topics are selected for implementation during a funding cycle, a more detailed description of what the topic means will be developed, key questions for research projects to address will be identified, and information pertaining to the scope, scale, importance, application, and products will be defined.

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Appendix

Appendix A. Questionnaire response breakdown.

Table A-1. Combined survey response by agency/organization.

| Agency/Organization	Number of Responses	Percentage of Responses
USDA Forest Service	430	32.7
University (within USA)	193	14.7
USDOI Fish and Wildlife Service	95	7.2
USDOI National Park Service	85	6.5
State Land Management Agency	77	5.9
NGO	75	5.7
USDOI Bureau of Land Management	74	5.6
Local Government (city, county, etc.)	42	3.2
State Fire Management Agency	40	3.0
Consulting Company	37	2.8
USDOI Bureau of Indian Affairs	35	2.7
Private Landowner	25	1.9
Non-USA agency, organization, or university	23	1.8
Retired Resource Manager	18	1.4
USDA Other	15	1.1
USDOI Geological Survey	10	0.8
USDOD	8	0.6
Professional Organization	7	0.5
State Air Quality Organization	6	0.5
NASA	4	0.3
USDOI Other	4	0.3
USDOE	4	0.3
EPA	3	0.2
Agricultural Research Service	2	0.2
NOAA	1	0.1
Local Air Quality Agency	1	0.1
Total	1314	100.1
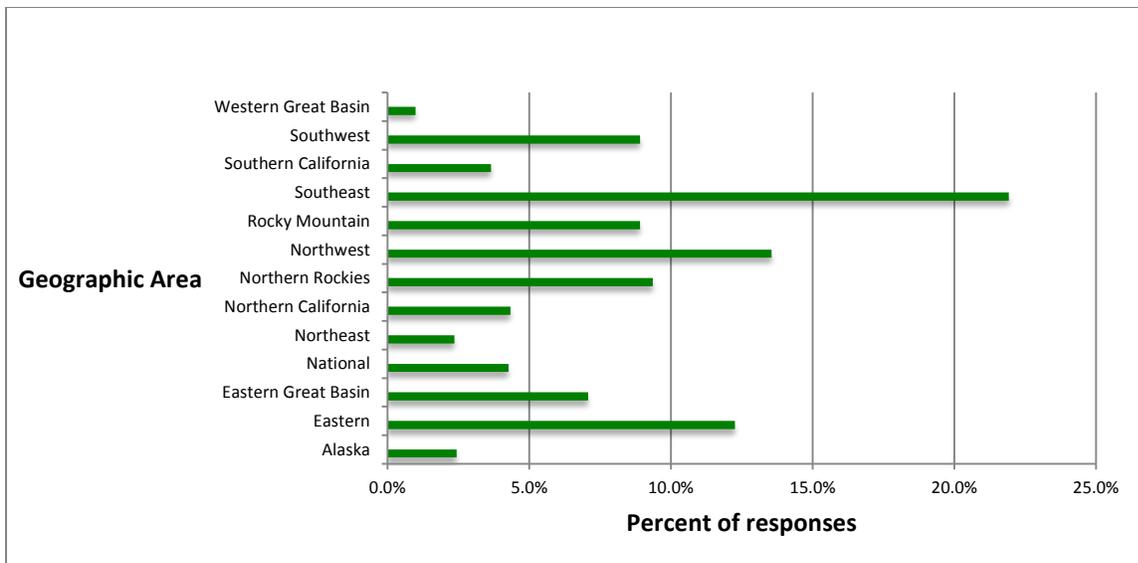
Figure A-1. Combined survey response by geographic area.
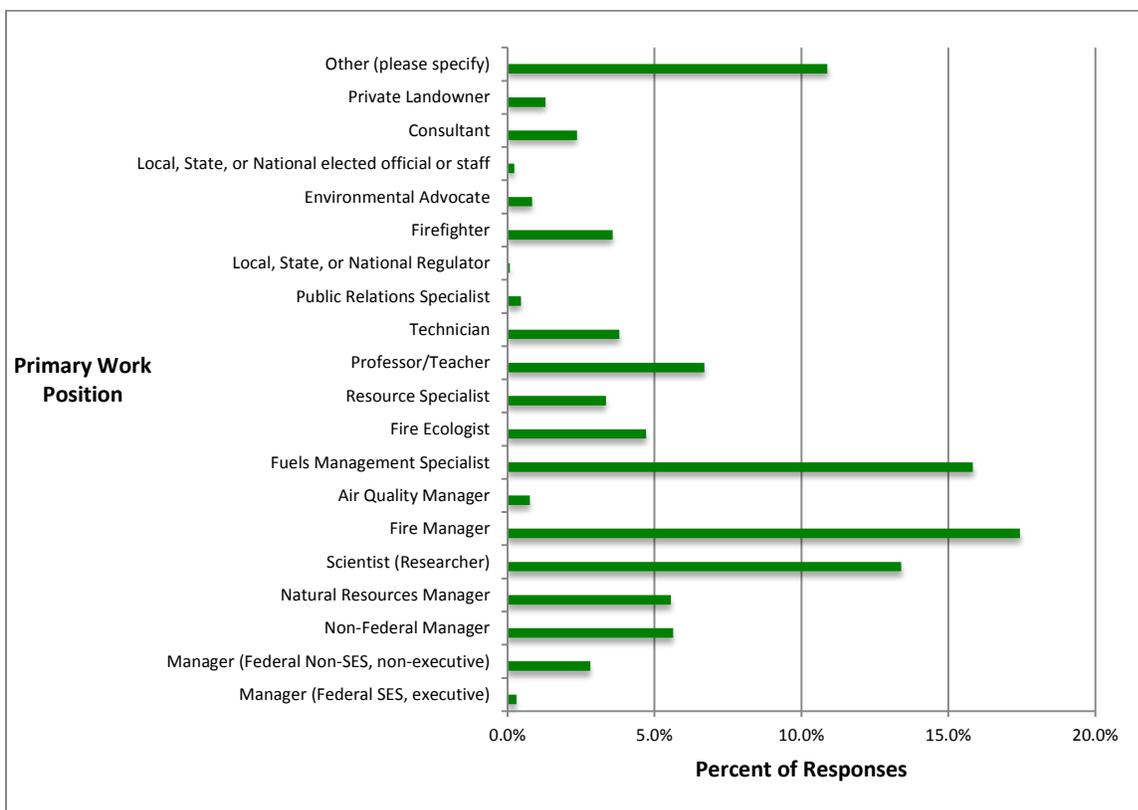

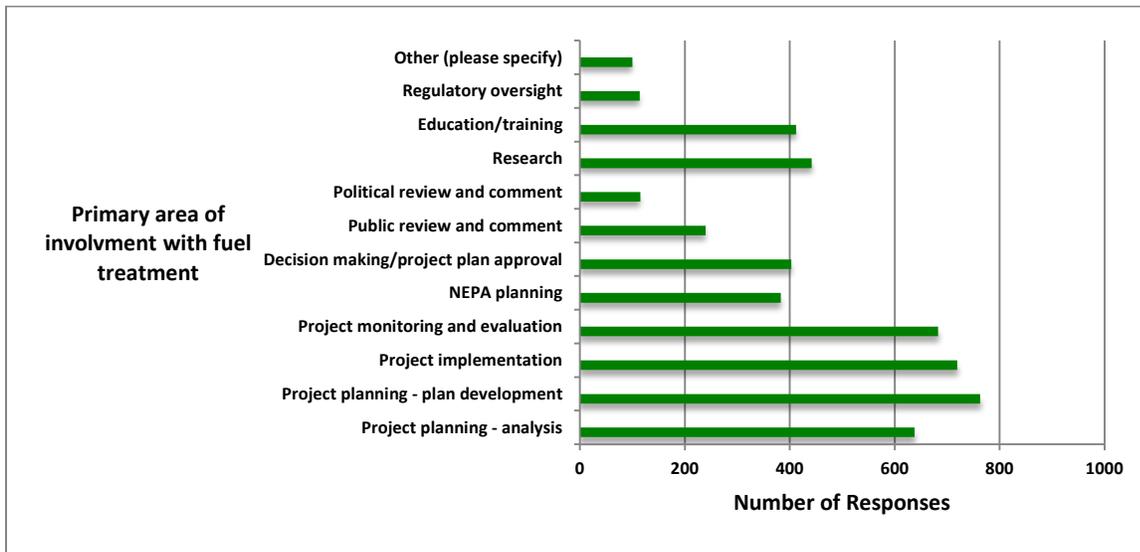**Figure A-2**. Combined survey response by primary work position.

Figure A-3. Combined survey response by primary area of involvement with fuel treatment.

Appendix B. Objectives for research focus areas

Table B-1. Objectives for the ecology research focus areas.

Research Focus Area	Objectives
Ecology - Inventory	• To develop new science and knowledge that will improve the characterization and understanding of relevant existing ecological processes and ecosystem components at all spatial and temporal scales. • To develop new science, knowledge, and technology to help better predict and describe potential ecological impacts to ecosystem sustainability and resilience with and without fuel treatments.
Ecology - Planning	• To develop new science, knowledge, and procedures that strengthen planning processes so that consideration and inclusion of all relevant current ecological situational information; available analysis processes; full descriptions and predictions of both desirable and undesirable ecological conditions; treatment option descriptions, including advantages, disadvantages, limitations, and ecological effects; comprehensive, measurable desired ecological objectives; and processes to develop treatment plans are ensured.
Ecology - Implementation	• To develop new knowledge, technology, and processes that improve treatment implementation safety, capabilities, using the correct tools, technology, and resource capacity, in compliance with the treatment plan to accomplish ecological objectives.
Ecology - Monitoring and Evaluation	• To develop new science, knowledge, and technology to more easily and productively monitor for progress and evaluate the effectiveness of planning and implementation activities in achieving both short- and long-term ecological effects.

Table B-2. Objectives for the climate research focus areas.

Research Focus Area	Objectives
Climate Interactions - Inventory	• To develop new science and knowledge that describes relevant potential effects of global and regional climatic changes on fuel complexes and vegetation communities.
Climate Interactions - Planning	• To develop new science, knowledge, and techniques that facilitate the incorporation of relevant information and predictive capability of how global and regional climatic changes affect fuels and fuel complexes through the effects of uncharacteristic natural disturbance patterns on vegetation and through unsuitable environmental conditions.
Climate Interactions - Implementation	• To develop new knowledge and technology that improves treatment implementation activities using the most appropriate tools, technology, and resource capability at appropriate temporal and spatial scales for all objectives, commensurate with current and predicted climate interactions identified in treatment plans.
Climate Interactions - Monitoring and Evaluation	• To develop new science, knowledge, and technology that advance managers' ability to monitor progress and evaluate the degree of success of the inventory, planning process, effectiveness of implementation activities in accomplishing objectives, and on long-term effects and treatment longevity under climate change influences.

Table B-3. Objectives for the humans/values at risk research focus areas.

Research Focus Area	Objectives
Humans/Values at Risk -Inventory	• To develop new science, knowledge, and technology to characterize relevant human values, in terms of their impacts to, impacts from, and levels of public and agency tolerance of risk from fuel treatment activities.
Humans/Values at Risk -Planning	• To develop new science, knowledge, and technology to ensure the planning process includes relevant current and projected fuel treatment program and project goals that address human and values at risk needs and considerations.
Humans/Values at Risk -Implementation	• To develop new knowledge and technology that improves the ability of treatment implementation activities to be carried out in compliance with the treatment plan and accomplish public safety and protection of values of at risk.
Humans/Values at Risk -Monitoring and Evaluation	• To produce new science, knowledge, and technology that advance monitoring of progress and evaluation of the degree of success of fuel treatment effectiveness in mitigating suppression costs, resource loss, risk, hazards, health impacts, and firefighter and public and firefighter safety.

Table B-4. Objectives for the collaboration and communication research focus areas.

Research Focus Area	Objectives
Collaboration and Communication - Inventory	• To develop new science, knowledge, and technology to improve and document the understanding of the social environment and existing relationships between governmental units and the public.
Collaboration and Communication - Planning	• To develop new science, knowledge, and technology to ensure the planning process includes all relevant information regarding the social environment (understanding, acceptance, and tolerance) and existing relationships between governmental units and the public.
Collaboration and Communication - Implementation	• To develop new knowledge and technology to promote improved communication and collaboration activities with the public and partner organizations as part of implementation activities.
Collaboration and Communication - Monitoring and Evaluation	• To develop new science, knowledge, and technology to support improved monitoring and comprehensive assessment of effectiveness of communication and collaborative efforts in supporting fuel treatment planning and implementation activities.

Table B-5. Objectives for the policy and law research focus areas.

Research Focus Area	Objectives
Policy and Law - Inventory	• To develop new science, knowledge, and technology to improve the understanding and clarification of outcomes and parameters required by policy and law for all social, economic, and biophysical elements of the fuel treatment program or project.

Research Focus Area	Objectives
Policy and Law - Planning	• To develop new science, knowledge, and technology to ensure that the planning process addresses and incorporates all policy and law requirements.
Policy and Law - Implementation	• To develop new knowledge and technology to facilitate implementation activities commensurate with the plan and within the framework of policy and law.
Policy and Law - Monitoring and Evaluation	• To develop new science, knowledge, and technology to improve the capability to examine the compliance of planning and implementation activities with policy and law and to facilitate the long-term evaluation of policy and law impacts on achieving fuel treatment objectives.

Table B-6. Objectives for the efficiency/effectiveness research focus areas.

Research Focus Area	Objectives
Efficiency/Effectiveness - Inventory	• To develop new science, knowledge, and technology to improve and document current information describing how social, political, management, and ecological considerations influence fuel treatment effectiveness and how they are mitigated by fuel treatments and wildfires.
Efficiency/Effectiveness - Planning	• To develop new science, knowledge, and technology to promote more effective planning based on a thorough assessment and inclusion of the best available information and science. • To develop new science, knowledge, and technology that advance the planning process capability to define viable, measurable objectives; determine the best treatment type; assess appropriate spatial and temporal applications; select treatment methods that will safely and cost-effectively accomplish the objectives; evaluate economic tradeoffs; assess risk and developing appropriate risk management practices; use of the proper analysis and prediction tools for determining treatment parameters and predicting effects; and the use of planning guidelines and preparation tools.
Efficiency/Effectiveness - Implementation	• To develop new knowledge and technology to improve treatment implementation effectiveness, using the correct tools, technology, and resource capability, and carried out in compliance with the treatment plan.
Efficiency/Effectiveness - Monitoring and Evaluation	• To develop new science, knowledge, and technology to more effectively evaluate program and project planning and implementation activities in achieving both short- and long-term social, political, and ecological objectives and effects at all spatial and temporal scales.

Table B-7. Objectives for the prioritization research focus areas.

Research Focus Area	Objectives
Prioritization - Inventory	• To develop new science, knowledge, and technology to improve and document current information regarding the social, political, and ecological considerations affecting and affected by fuel treatments that support the identification and prioritization of fuel treatment activities of highest need.
Prioritization - Planning	• To develop new science, knowledge, and technology that facilitates improved prioritization processes, including rapid evaluation of treatment methods, placement,

	and frequency and their contributions to achieving social, political, and ecological objectives, as part of the program and project planning process.
Prioritization - Implementation	• To develop new science, knowledge, and technology to facilitate implementation of prioritization activities based on a review of objectives, scale, treatment method, costs, logistical requirements, resource requirements, treatment duration, treatment timing, and capability to implement.
Prioritization - Monitoring and Evaluation	• To develop new science, knowledge, and technology to improve monitoring and evaluation of the prioritization process based on both individual treatment project and program effectiveness.

Appendix C. Information Trends (from Survey, Previous Research Identification, Efforts, and Literature Review)

The sum of information gathered through all methods from all sources was assembled into a master set of potential future research statements.

The fuel treatment questionnaire, accessed and completed by a diverse audience of federal and non-federal managers, researchers, educators, practitioners, and specialists provided rankings of importance of specific research sub-topic areas (Table 4). While the questionnaire limited the specific research area choices, respondents were able to provide written comments pertaining to other important and needed areas of research.

Research sub-topic areas shown in Table C-1 are representative of choices offered in the questionnaire. After review of these topics, they were assigned to the appropriate program driver. The most notable trend in these data is that prescribed fire treatment effectiveness was easily ranked as the most important research sub-topic. This topic corresponds to the efficiency/effectiveness program driver. The additional sub-topics and their assigned research focus area are shown in Table C-1.

Table C-1. Ranked importance of sub-topics and their associated research focus areas (element/driver areas) based on questionnaire response.

Rank	Research Sub-topic (from questionnaires)	Associated Program Driver
1	Prescribed fire treatment effectiveness	• Efficiency/effectiveness
2	Effects of treatments on achieving resilient landscapes	• Ecology • Efficiency/effectiveness
3	Public awareness, acceptance, and interrelationships	• Collaboration and Communication
4	Effects of treatments on vegetation communities, wildlife, soils, water, etc.	• Ecology
5	Effects of treatments on achieving desired fire behavior	• Efficiency/effectiveness
6	Monitoring and evaluation	• Efficiency/effectiveness
7	Effects of treatments on improving firefighter safety	• Humans/Values at risk
8	Effects of treatments on reducing wildfire suppression costs	• Humans/Values at risk • Efficiency/effectiveness
9	Air quality/smoke management and fuel treatment interrelationships	• Humans/Values at Rick
10	Non-fire treatment effectiveness	• Efficiency/effectiveness
11	Fuel treatment planning and implementation procedures	• Ecology • Climate • Humans/Values at Rick • Collaboration and Communication • Policy and law • Efficiency/ • Prioritization
12	Decision support models, data, and tools to support fuel	• Efficiency/effectiveness

13	Climate change interactions with fuel treatments	• Climate

treatment planning and implementation

Further aggregation of these data into the corresponding fuel treatment program driver only shows that efficiency/effectiveness is the highest ranked in terms of future research needs (Figure C-1). Review of the data generated from the survey question asking for additional areas of research shows that efficiency/effectiveness is also ranked as the greatest need but that prioritization occupies a markedly higher ranking (Figure C-1). Looking at the combination of the future and additional research needs indicates that the efficiency/effectiveness program driver stands out as the highest ranked research area (Figure C-1).
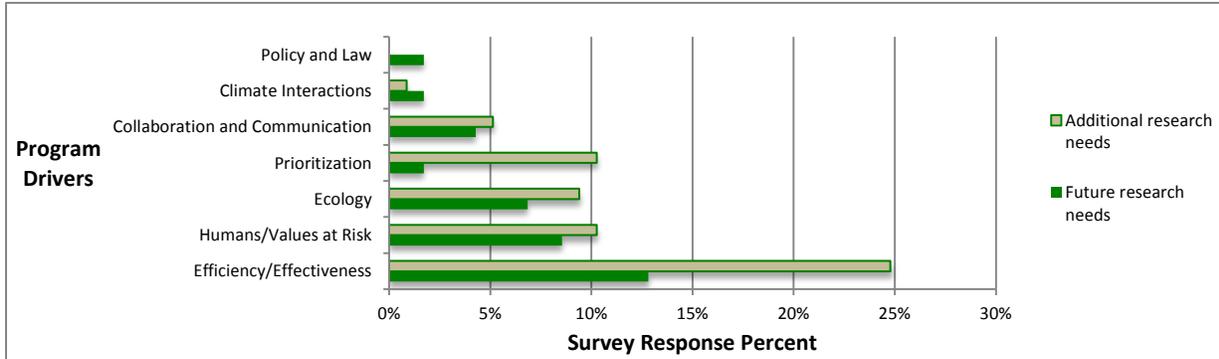

Figure C-1. Future research needs and additional research by program drivers ranked by importance as derived from the combined survey data.

The JFSP Knowledge Exchange Network consortia have developed research needs for their respective geographic areas. Consolidating these needs into the corresponding fuel treatment program driver shows that the greatest proportion of consortia identified topics having the highest need for future research needs in the efficiency/effectiveness program driver (Figure C-2). This was followed by ecology, humans/values at risk, prioritization, climate interactions, collaboration and communication, and policy and law, in that order (Figure C-2).
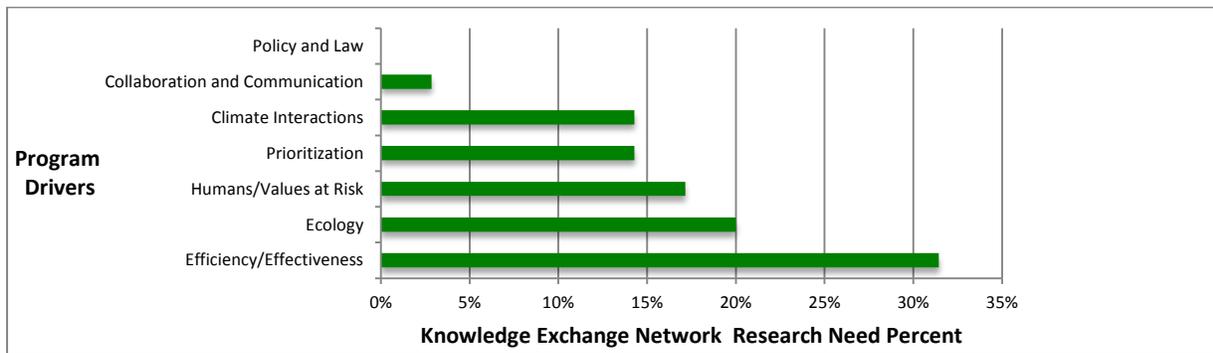

Figure C-2. Research needs by program drivers ranked by importance as identified from JFSP Knowledge Exchange Network consortia research needs.

The Fuel Treatment – Line of Work (Omi and others 2010) identified specific focus areas and themes that were shown in Table 2. These themes have been correlated to the research focus areas and program drivers used in this FTSP (Table C-2).

Table C-2. Focus areas and themes presented in the FT-LOW report (Omi and others 2010) and their relationship to program drivers in this FTSP.

Focus Area	Theme	Relationship to FTSP Program Drivers
Fuel Treatments	• Improved metrics for evaluating fuel treatment effectiveness	• Efficiency/effectiveness
	• Effectiveness of various fuel treatments (i.e., for hazard reduction) over time	• Efficiency/effectiveness
	• Understanding the relationship of fuel bed characteristics and dynamics to fire behavior and effects (primarily hazard reduction)	• Ecology
	• Effectiveness of pile burning	• Efficiency/effectiveness
	• Fuels within intensively managed areas	• Ecology
Effects	• Reintroducing fire into long-unburned areas	• Ecology • Efficiency/effectiveness • Prioritization
	• Responses of shrubs, forbs, and grasses to fuel treatments in forested and non-forested environments	• Ecology
	• Influence of fuel treatments on nonnative species invasions and persistence in forested and non-forested vegetation types	• Ecology • Efficiency/effectiveness
	• Landscape resilience	• Ecology
Fuel Treatment and Effects Related Models	• Modeling fuel and duff consumption and soil heating	• Ecology • Efficiency/effectiveness
	• Improved high resolution prediction of local winds in complex terrain	• Efficiency/effectiveness
	• Wildland urban interface	• Humans/values at risk • Efficiency/effectiveness • Prioritization
	• Analyze the strengths and weaknesses of current models used for prescribing and assessing fuel treatments	• Efficiency/effectiveness

While these data assignments are not completely comparable because the FT-LOW did not utilize the same comprehensive approach of program drivers used in this project, they still reinforce, to some degree, what has been shown in Table C-1 and Figures C-1 and C-2 above (Figure C-3).
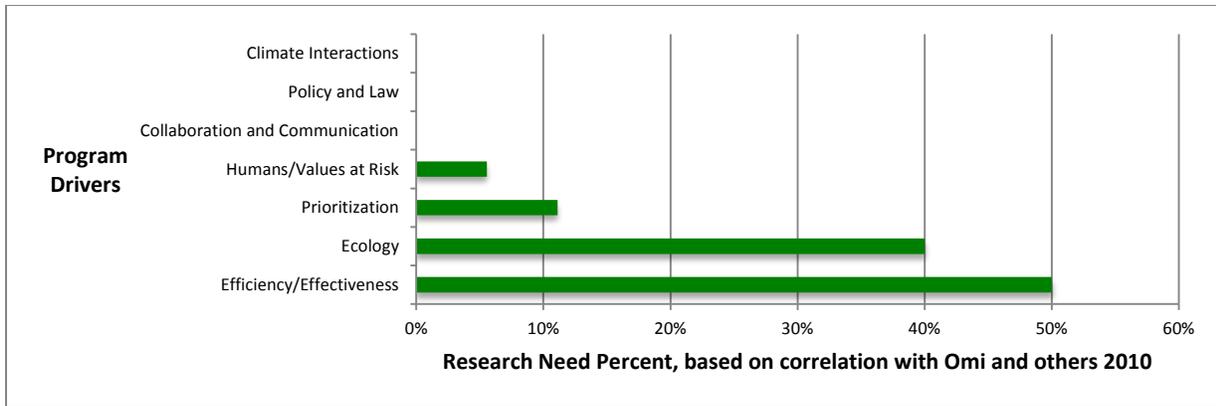
Figure C-3. FT-LOW research themes correlated into research needs by FTSP program drivers and ranked by importance.

The fuel treatment literature search and exploration information depicts research emphasis since 2010, which, to some degree, reflects an historic view of research needs. The efficiency/effectiveness, and ecology program drivers have received the greatest emphasis in recent research (Figure C-4).
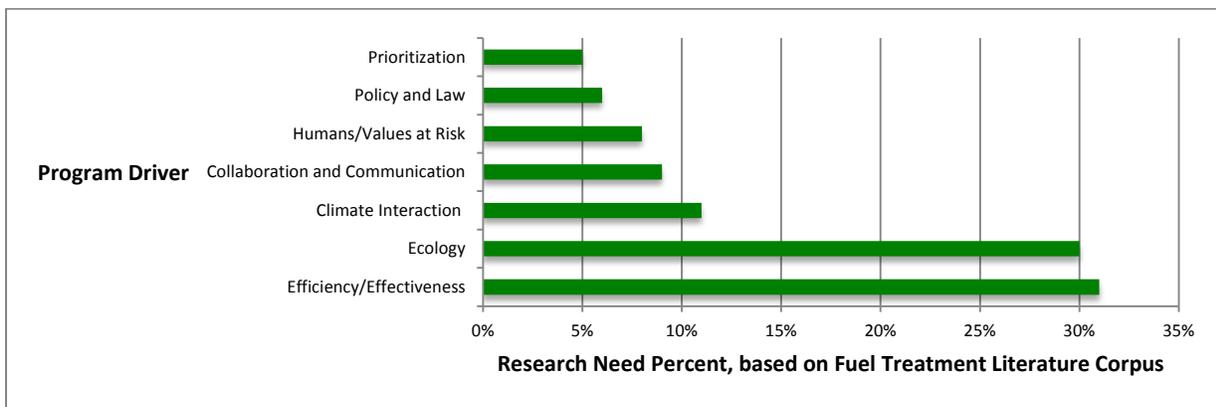

Figure C-4. Research needs emphasis from survey of fuel treatment literature corpus.

Examination of the set of reviewed research, research projects in progress, and syntheses during this project yielded insight into the spatial context (geographic areas corresponding to Knowledge Exchange Network consortia) of potential research topics. Geographic representation of reviewed research is shown in Figure C-5a, geographic representation of reviewed pending research is shown in Figure C-5b, and geographic representation of reviewed syntheses is shown in Figure C-5c.

These figures show that the research community has not placed equal past, current, and future research attention to all geographic areas. This should not be taken as a unilateral indication of areas of highest future needs, but instead an identification of potential geographical venues for future research. Prioritization of future effort must be weigh potential research impact with available funding and determine where projects can be focused. A science plan can assess and present highest needs but cannot account for budget limitations. The JFSP will need to evaluate, with Knowledge Exchange Network consortia input, where future efforts can be focused.

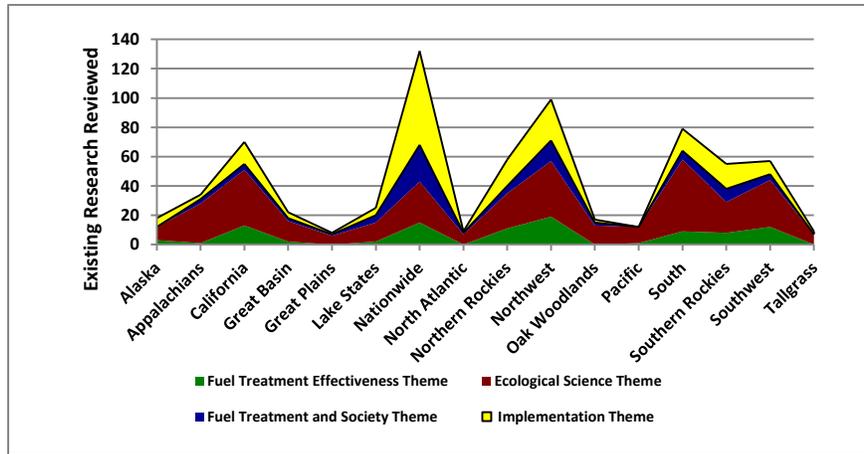Figure C-5a. Geographic representation of reviewed research projects.

Figure C-5b. Geographic representation of reviewed pending research projects.
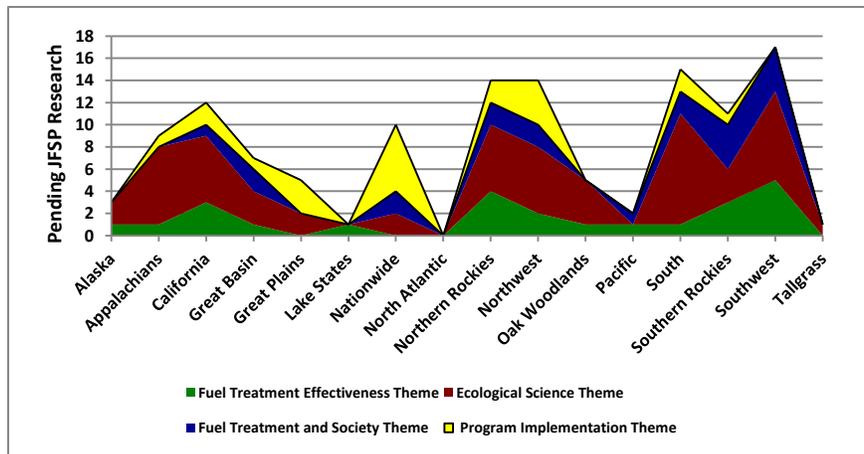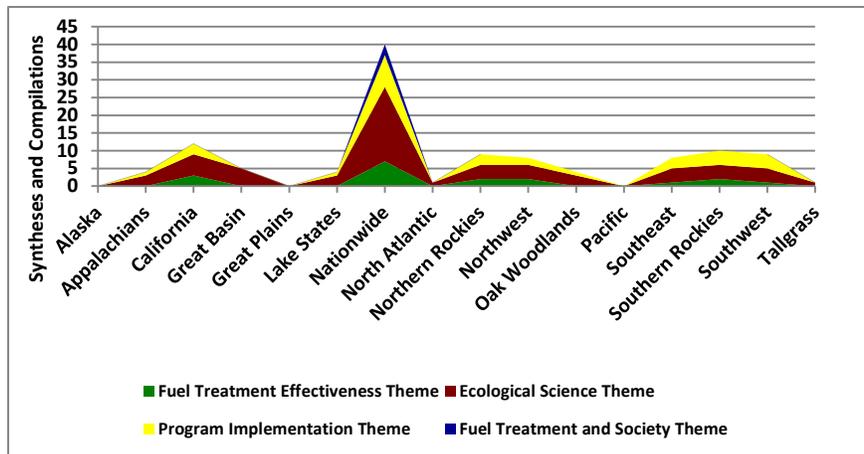

Figure C-5c. Geographic representation of reviewed syntheses.

Appendix D. Master list of FTSP project research needs responses.

Table D-1. Ecology research needs by program element.

Program Element	Research Need

Inventory	• Define parameters for characterizing resilience at multiple spatial and temporal scales
	• How to incorporate multiple natural disturbances in parameters for resilience
	• Define/develop objectives to achieve ecological resilience
	• Identify approaches to incorporate the effects of typography, land use, and climate in fire regime classification
	• Describe fire regimes in:
	    ○ complex topography and vegetation patterns
	    ○ riparian and wetland areas
	    ○ understudied ecosystems
	    ○ uncharacteristic (altered) systems
	• Characterize fuel complexes for:
	    ○ complex landscapes and land use patterns
	    ○ individual and multiple natural disturbances
	    ○ mixed land management histories
	• Characterize fuels in relation to ecological processes and conditions, e.g. fuel ecology
	• Characterize fuels and fire behavior for various treatment types and vegetation conditions:
	    ○ pre- and post-wildfire
	    ○ pre- and post-prescribed fire
	    ○ after thinning
	    ○ after mastication
	    ○ with invasive species and other uncharacteristic conditions
	• Relate fuel condition to:
	    ○ smoke management
	    ○ carbon sequestration

Planning	• Evaluate landscape treatment options and strategies that result (or fail to result) in sustainable and resilient ecosystems
	• Assess amount and type of treatments needed in landscapes to protect ecosystems and human values at risk
	• Identify and examine tradeoffs where ecosystem protection is a lower priority than protecting other values at risk
	• Examine effectiveness of fuel treatment for achieving acceptable fire behavior patterns at landscape scales
	• Acquire knowledge of fuel treatment effectiveness for achieving ecosystem resilience and sustainability, including:
	    ○ vegetation structure and successional trajectories at landscape scales
	    ○ appropriate levels of natural disturbances
	    ○ protection of biodiversity (incl. T&E species)
	    ○ adequate management of invasive species
	    ○ protection of watersheds and soils
	    ○ protection of wildlife habitat
	• Acquire knowledge of fuel treatment effectiveness for achieving ecosystem resilience and sustainability, including:

- vegetation structure and successional trajectories at landscape scales
- appropriate levels of natural disturbances
- protection of biodiversity (incl. T&E species)
- adequate management of invasive species
- protection of watersheds and soils
- protection of wildlife habitat

- Acquire knowledge of fuel treatment effectiveness considering:
  - incorporation of recent fire footprints in treatment design
  - treatment placement for acceptable future fire behavior
  - treatment placement for achieving landscape and ecosystem resilience
  - treatment timing that best benefits landscape ecology and wildlife management
  - grazing practices
  - fire use in comparison with other treatments such as mechanical or chemical control

- Develop models that predict potential future landscape outcomes incorporating effects of:
  - recent fires
  - previous fuel and other management treatments
  - recent and potential future insect, disease, and drought disturbances

- Develop models that describe fuel ecology as it relates to ecosystem characteristics and successional trajectories

- Examine methods to resolve conflicts between restoration and hazardous fuels reduction objectives, particularly in forest types that historically had mixed or high severity fires?

Implementation

- Assess how fuel treatment implementation practices meet expectations developed during planning processes
- Identify barriers that limit the success of implementation practices
- Examine effects of soil/veg/fuels on defining burn windows.
- Examine the life cycle (e.g., timing, velocity, load) of eroded sediment and pollutants from upland streams to municipal water intakes over a range of fire severity and fire sizes in relation to catchment size. This work should focus on fire effects on channel processes rather than hill-slope erosion.

Monitoring and Evaluation

- Identify effects of large fires on:
  - successional trajectories at landscape scales
  - protection of biodiversity, including T&E species and wildlife
  - management of invasive species
  - water quality and yield
  - air quality

- Identify and examine the opportunities created by large fires that may be used to:
  - establish increased landscape heterogeneity
  - assist in use of fuel treatments to manage the size and intensity of future fires
  - enhance the use of prescribed and wildland fire for achieving various objectives

- Examine how various fuel treatment practices contribute to restoration of landscape heterogeneity:
  - single vs. multiple treatment applications
  - combinations of treatment types
  - seasonal and long term timing of treatments

- Examine the effects of landscape heterogeneity (or lack of heterogeneity) on:
  - fire behavior patterns
  - spatial and temporal patterns of other natural disturbances

- Identify the ecological benefits and costs of fuel treatments, alone or in combination with other treatments:
  - for life cycle processes including germination and seedling establishment, growth, and mortality of key species
  - in relation to seasonality of treatment
  - for management of invasive species
- Increase knowledge of the effects of prescribed fire on fauna (wildlife habitat, T&E spp etc.).
- Need vegetation models for interpreting long term landscape trajectories including the consequences of fuel treatment on:
  - landscape heterogeneity
  - vulnerability to fire and other natural disturbances
- Identify, assess, and improve models that predict fuel complexes in relation to vegetation changes over time and space
- Examine capability of models that systematically assess landscape resilience and sustainability to assess:
  - structure and composition characteristics of vegetation in the landscape
  - role of natural disturbances
  - protection of biodiversity
  - watershed condition

Table D-2. Climate interactions research needs by program element.

Program Element	Research Need

Inventory	• Characterize climate change effects:
	  ○ by individual species
	  ○ by habitats
	  ○ by natural disturbance patterns
	• Classify species and communities/habitat type zones according to vulnerability to spatial displacement as a result of altered environmental conditions:
	  ○ likely to disappear
	  ○ threatened
	  ○ stable
	  ○ emerging
	• Assess vulnerability of vegetation with regard to:
	  ○ life cycle processes including regeneration and mortality
	  ○ growth processes affecting vigor and resistance mechanisms
	  ○ migration capabilities including dispersal of propagules and capacity to compete
	• Assess how vegetative communities will change in relation to climate change:
	  ○ conventional or novel successional pathways
	  ○ limited or uninhibited by abiotic factors such as soils
	  ○ affected by change agents such as natural disturbances or by loss of vigor affecting life cycle processes
	• Assess effects of climate change on fuel complexes:
	  ○ short term consequences of drought, heat, and natural disturbances on fuel composition and structure
	  ○ during transitions as vegetation adapts to new environments
	• Assess effects of climate change and changes in fuel complexes on:
	  ○ fire behavior, including frequency, intensity, seasonality, and size
	  ○ *fuel treatments and their effectiveness
	• Assess fuel and other vegetation treatment and management options for achieving optimal:
	  ○ protection of life and property
	  ○ long term resilience and sustainability
	  ○ protection of biodiversity
	  ○ protection of water and other resources
	• Assess feedback effects of fuel complexes and fuel treatments on climate change:
	  ○ emissions from fire or decomposition
	  ○ sequestration of carbon

Planning	• Evaluate landscape vulnerabilities under climate change scenarios:
	  ○ vegetation types and locations where climate change effects may be most severe as a result of drought, insect or disease epidemics, or general loss of vigor and capacity to compete
	  ○ anticipated areas of high fuel loading and risk of severe fire
	• Assess ecological characteristics of landscapes that will likely impart resilience under climate change scenarios:
	  ○ models predicting future vegetation incorporating anticipated environment conditions and natural disturbance processes
	  ○ description of potential fuel and vegetation treatments mitigating undesirable fire behavior patterns
	  ○ Identify and evaluate options (including fuel treatment) for reducing vulnerability to severe wildfire:
	  ○ pre-emptive vegetation treatments to reduce future fuel loading
	  ○ selection of treatment options limiting fuel loading while assisting landscape adjustment to new environmental conditions

	• Identify processes to allow public concerns over climate change and smoke to be discussed cogently by providing framework fire emissions scenarios that will result from projected fire ecology shifts under the IPCC scenarios.
Implementation	• Assess how implementation practices succeed at addressing planning expectations with climate change
Monitoring and Evaluation	• Assess effectiveness of fuel and other treatments for increasing landscape resilience under climate change conditions

Table D-3. Humans/values at risk research needs by program element.

Program Element	Research Need
Inventory	• Examine influence of public opinion on implementing risk mitigation (fuels management) programs, versus increasing suppression capability.
	• Catalog "environmental" issues and assess their impact on planning and implementing fuels management activities.
	• Examine the "wildfire risk tolerance" of communities and population adjacent to public lands to determine if there geographic variations that are relevant to land managers.
	• Examine air quality factors (duration, pollution level, etc.) contrasting public tolerance with regulatory standards.
	• Examine geographic or demographic variations in regards to public tolerance of air quality conditions.
	• Identify and examine fuel management implementation factors (i.e., project size, project type, visual impact, project duration, etc.) that are of the greatest concern to the public.
	• Assess public awareness (at consortia or similar scale) of the fire environment (ecology etc.) to identify knowledge gaps or misperceptions.
	• Assess demographic (age,) variances in tolerance to fuels project implementation and identify communication strategies for age groups.
	• Identify and examine socio-economic factors that contribute to wildfire risk and loss in context of potential fuel mitigation strategies.
	• Assess public opinion on the importance of firefighter safety.
	• Evaluate economics of treating WUI versus non-WUI.
	• Evaluate short and long term economics of full suppression events versus managing wildfires for resource benefit.
	• Assess the market and non-market costs and benefits associated with prescribed fire and other fuels treatments.
	• Assess the consideration of fire ecology and fuels management issues in land management and resource management plans.
	• Are plans assessing the longevity of effectiveness and long-term maintenance needs?
Planning	• Are plans assessing the longevity of effectiveness and long-term maintenance needs?
	• Analyze cost effectiveness of WUI wildfire mitigation alternatives and their effectiveness in protecting values at risk (i.e., fuels management versus "hardening structures").
	• Examine capabilities, applicability, and usefulness, of existing landscape-scale risk modeling tools for fuel management analysis.
	• Assess tools to evaluate wildfire risk factors and their effects on ecological, and human values.
	• Assess tools to analyze tradeoffs between ecological objectives, human values, and protection objectives.
	• Improved knowledge on methodologies to assess the effectiveness of fuel treatments in mitigation resource loss.
	• Identify and examine information requirements to plan and implement fuels management at landscape scales.
	• Evaluate methodologies to identify effective programmatic, landscape, or project goals that mitigate fire effects on the public, firefighters, and values at risk.
	• Compare and contrast long and short-term impacts on air quality from fuel treatments and wildfire.
	• What are the long-term impacts of fuels management and land use on the spatial, temporal, intensity elements of fire and other landscape processes.
	• Examine methods to assess the longevity of fuel treatment effectiveness and its

relationship to long-term maintenance needs?

- Identify and examine planning methodologies assessing fuels management issues in federal and state land management and resource management plans.
- Improved knowledge of potential for incorporation of biomass energy into fuel management strategies.

Implementation

- Examine how risk thresholds are established and implemented.
- Identify key social factors (i.e. air quality, risk, etc.) affecting prescribed fire implementation.
- Identify the level of public concern that restricts project implementation.
- Examine the effects of management factors (i.e. organizational, command and control etc.) on fuels management implementation.
- Conduct a systematic survey of social factors (i.e. air quality, risk, etc.) affecting prescribed fire implementation.
- Examine burning regulations and their effectiveness in addressing public and firefighter safety issues.
- Identify factors that affect implementing fuels management on a landscape scale; and identify landscapes where landscape scale projects are most likely to be successful.

Monitoring and Evaluation

- Examine the longevity of effectiveness and long-term maintenance needs for significant fuel types.
- Assess methods to collect wildfire suppression and fuel management cost data.
- Assess methods to capture spatial and temporal data portraying wildfire and fuel management activities.
- Assess fire ecology knowledge (and identify knowledge gaps) of resource managers planning and implementing fuels management projects.
- Conduct studies to examine the risks to resource values with and without post wildfire fuel treatments.
- Identify and assess effectiveness of data collection for metrics describing effects (benefit and loss) of wildfire (i.e., structures lost, resource value gain or loss, etc.).
- Additional research (for significant fuel types) to document and quantifying the effects of fuels management programs on the impacts of wildfire in WUI.
- Examine methodologies to assess both the damages and benefits (long-term and short-term) associated with wildland fire.
- Assess status of landscape scale fuel treatment implementation versus project scale implementation.
- Assess effectiveness of grazing in wildfire mitigation.
- Assess effectiveness of fuels modification in chaparral types in mitigating impacts from extreme fire events.

Table D 4. Collaboration and communication research needs by program element.

Program Element	Research Need
Inventory	• Assess how culture, and perception of fire contribute to understanding of fuel management issues. • Identify key social issues and "tipping points" for implementation of fuel management programs and projects (regional perspectives). • Assess public expectations and understanding of the objectives of fuels management. (To assist program managers developing a communication strategy). • Assess the degree to which fire ecology and fuels management concepts are presented in K-12 education. • Identify the attributes of communities and population adjacent to public lands in terms of the social order, organization, and composition. Determine if there are geographic variations that are relevant to land managers. • Assess the impact of advocacy groups on planning and implementing fuels management activities.
Planning	• Compare methodologies/techniques to communicate spatial and temporal effects of fuels management strategies. • Examine the relationship of individual vs. organizational influences on the acquisition and use of research. • Evaluate effectiveness of formal and informal networks; literature systems, etc., in the communication of fire / fuels science concepts and knowledge to managers, and the public. • Identify, describe, and assess conflict resolution techniques for fuels management issues. • Identify and evaluate collaborative practices between communities and natural resource managers in addressing fuels management across private and public land boundaries • Explore approaches to tailor education for various demographics. • Assess methodologies to identify and evaluate public issues.
Implementation	• Identify, describe, and evaluate educational techniques for fuel management on private lands. • Identify, describe, and evaluate community-level communication strategies for fuel management implementation. • Identify, describe, and evaluate tools to provide field and public information on smoke impacts. • Assess effectiveness of models in explaining fuel management risk and benefit to the public.
Monitoring and Evaluation	• Assess status of programs incorporating "citizen science" into monitoring fuel treatments? Identify attributes of successful programs. • Identify methodologies for evaluating how well communication and collaborative efforts and activities increase awareness, involvement, and reduce barriers to implementation. • Conduct comparative analysis of collaboration effectiveness by monitoring project implementation (outcome based approach). • Identify factors associated with the community that drive successful outcomes. • Identify and assess collaborative models demonstrating cooperation between communities and natural resource managers addressing fuels management across private and public land boundaries. • Do wildfire prevention programs affect public attitudes towards fuels management?

Table D-5. Policy and law research needs by program element.

Program Element	Research Need
Inventory	• Develop a synopsis/compendium of local/state/ federal regulations on fuels management planning and implementation. • Compile and evaluate legal challenges to fuels treatment plans and implementation activities • Evaluate current policy and laws to determine consistency with national wildfire mitigation goals and objectives (i.e. Cohesive Strategy). • Contrast and evaluate federal state local (i.e. county) fuels management program goals and objectives. • Catalog, synthesize, and assess laws and zoning regulations regarding fuels treatments on non-federal lands.
Planning	• Examine and contrast federal and state planning requirements and approaches for fuels management. • Identify methodologies for meeting standard of "best available science" in fuel treatment planning. • Identify and examine planning practices successfully integrating fuel management across political boundaries. • Identify and examine examples of successful NEPA compliance and provide planning guidelines. • Compare state, federal, and local definitions of WUI to assess impacts definition has on implementation.
Implementation	• Examine regulatory, policy, or decision criteria currently being used to establish acceptable conditions for the use of fire to meet management objectives. • Compare how policy and regulatory burn windows vary nationally and affect the use of fire. • Compare optimal burning thresholds with existing federal and state prescribed burn guidelines. • Examine decision support systems, indexes, and criteria, used to gauge burning conditions to determine adequacy, applicability, and efficacy for prescribed fire activities. • Compare and assess impacts of "liability" law on project and program implementation.
Monitoring and Evaluation	• Assess level of compliance with policy and laws. • Assess wildfire policy impacts on fuels management implementation at relevant spatial and temporal scales (project, landscape; long-term and short-term) • Examine programmatic accomplishment metrics to determine validity and practicality. Are programmatic metrics well defined, measurable, and applicable to ecotypes. Are current reporting systems and associated metrics (i.e. condition class, area treated, etc.) adequately assessing fuel treatment progress in meeting program goals? • Examine and evaluate state and federal fuels management accomplishment reporting frameworks. • Examine and evaluate state and federal fuels management accomplishment reporting frameworks. • Assess effectiveness of regulatory criteria mitigating unwanted fire effects and risk from the use of fire. • Assess the effectiveness of regulatory requirements in the wildland-urban interface on mitigating loss from fire.

Table D-6. Efficiency/effectiveness research needs by program element.

Program Element	Research Need
Inventory	• Identify a process to define better objectives
	• Develop procedures to promote better clarification and alignment of objectives (fire behavior, ecological, restoration, hazardous fuel reduction, maintenance, etc.).
	• Examine fuel treatment alternatives and identify most appropriate use and application (advantages, disadvantages, costs, limitations).
	• Document detailed knowledge on treatment longevity (change, treatment types, scale, objectives, etc.)
	• Assemble knowledge of specific information on wildfire - fuel treatments interrelationships: under current climatic conditions, under changed climatic conditions, and interactions of fuels, treatments, and climate change.
	• Consolidate knowledge of fuel treatment effects on wildfire behavior - need to address treatment size and strategic placement.
	• Compile knowledge of effects of fuel treatments on fire behavior.
	• Compile knowledge of the use of wildfires as treatments.
	• Clarify elements that define cost effectiveness.
	• Define the economic benefits of prescribed fire (aesthetic values, hunting revenues, tourism, ecological services, etc.).
	• Define cost effectiveness of treatment type and scale alternatives.
	• Define costs of maintenance treatments (based on objectives, scale, treatment types, etc.).
	• Assess effects of fuel treatment on reducing wildfire suppression costs.
	• Develop improved information defining strategic placement of fuel treatments around WUI.
	• Develop improved knowledge of treatment types, individually and in conjunction with other treatment types.
	• Examine effects of mastication treatments on grass production, rearrangement of fuels, change in surface fuel structure and composition, and resultant effects on wildfire behavior.
	• Evaluate alternative treatment methods, technology, frequency, advantages, disadvantages, and overall capability.
	• Assemble information on the effects of fuel treatment on fire behavior.
	• Develop improved techniques for measuring or sampling fuels.
	• Develop improved techniques for measuring and characterizing the fuel load of grasslands encroached by woody plants.
	• Evaluate data capture and mapping methods to support improved risk characterization and management in WUI.
Planning	• Define the role of fuel treatment in risk management.
	• Effects on protection capability.
	• Evaluate the effects of fuel treatments on landscape patterns - how to pattern treatments on landscape.
	• Clarify information regarding wildfire - fuel treatments interrelationships: under current climatic conditions, under changed climatic conditions, and interactions of fuels, treatments, and climate change.
	• Define the thresholds for meteorological conditions for conducting prescribed burns safely and effectively, given specific fuels conditions and objectives?
	• Assess the net impacts of controlled grazing on wildfire management and ecosystem response- friend or foe? What are the differences in impact and contribution among different species of ungulates?
	• Evaluate alternative treatments for effectiveness in fuel break maintenance (e.g., domestic livestock for foraging on grass regeneration, planting/seeding of desirable

species).

- Determine what alternative treatments should be tested to maintain fuel breaks (e.g., domestic livestock for foraging on grass regeneration, planting/seeding of desirable species).
- Fire vs. Herbicide/Mechanical/Grazing & Other Non-Fire Vegetation Manipulation Practices.
- Compile detailed information on fuelbreak maintenance strategies
- Evaluate how burn windows should vary with different environmental conditions such as vegetation type, fuel level, etc.
- Assess how to locate treatments across landscapes,
- Assess differences in types and spatial arrangement of fuels treatments in and near the WUI.
- Define obstacles to Prescribed Burning.
- Assess knowledge of fuel treatment planning adjacent to and in WUI areas an in non-WUI areas.
- Assess knowledge of fuel treatment planning at landscape scales.
- Evaluate the effects of fuel treatments on wildfire protection capability and why it is important to avoid spending funds on protecting homes with low probability of success or high threat to safety.
- Determine what are the most cost-effective and successful strategies for establishing green fuelbreaks (species, structure, placement, native vs. non-native).
- Compile knowledge on tracking sun angle, moisture content, cloud cover, RH recovery to assist in planning and implementation
- Define training and skills for fuel treatment (simulation training, short courses, webinars - need training in a more useful format that get science and managers together).
- Develop information syntheses on a regional scale.
- Develop more effective information dissemination processes (can accelerate use of consortia).
- Develop streamlined decision support tools (can WFDSS and IFT-DSS be merged, can IFT-DSS be expanded).
- Develop a Decision Support Tool and simple methodology to document dynamic fire boundaries and describe when they do and don't function as a barriers to fire spread.
- Expand existing tools, such as FVS, for more effective support about future changes in forest economics due to fire.
- Improve knowledge of background and how to use tools and guidelines
- Improve literature accessibility.
- Develop guidelines to support for fuel treatment in watersheds and riparian areas that maintain desirable hydrologic and geomorphic processes.
- Develop guidelines for livestock grazing after fire that account for variation in site productivity, pre-fire ecological conditions, and invasive species.
- Evaluate scientific data supporting thresholds for prescription windows and burn bans. Look at retrospective fires and how burning under different conditions affected fire behavior and effects may help in finding effective criteria for establishing such thresholds.
- Define how silvicultural/prescription tools should be used to efficiently and effectively implement treatment designs.
- Define project planning processes or multiple benefits (especially needs of other species).

Implementation
- Define how existing spatial and non-spatial fire effects, behavior, regime, vegetation, disturbance, and fuels information/tools help inform best practices when evaluating pre- and post- wildland and prescribed fire management decisions/planning.

- Define thresholds for meteorological conditions for conducting prescribed burns safely and effectively, given specific fuels conditions and objectives.
- Determine how the role of wetlands as barrier or carrier to fire spread be anticipated and incorporated into management decisions.
- Clarify the net impacts of controlled grazing on wildfire management and ecosystem response- friend or foe? What are the differences in impact and contribution among different ungulate species.
- Evaluate and document the full array of implementation tools that will permit accomplishment of desired objectives.
- Clarify how to use technological support to facilitate efficient and safe implementation of the treatment plan.
- Develop updated go-no-go guides for rx fire.
- Determine what makes up effective syntheses - manager input, must be transparent about what is included as source material, communicate uncertainties.
- Expand technology transfer processes.
- Review existing guides tools etc., for currency and relevance.
- Conduct workshops on prescribed fire in various ecological conditions (wetlands, uplands, etc.).

Monitoring and Evaluation	- Determine the short-term effectiveness of the planning and implementation activities in accomplishing objectives, and long-term effectiveness of treatments. - Develop specific information on wildfire - fuel treatments interrelationships: under current climatic conditions, under changed climatic conditions, and interactions of fuels, treatments, and climate change. - Assess fuel treatment effects on wildfire behavior - need to address treatment area and strategic placement. - Assess fuel treatment effects on wildfire behavior - need to address treatment area and strategic placement - Evaluate the use of wildfires as treatments. - Develop ways to characterize fuel treatment effectiveness. - Recognize and capture that variability is part of system of effectiveness. - Assess the effectiveness of fuel treatment in Lodgepole pine. - Evaluate fuel break effectiveness. - Assess retreatment frequency necessary to maintain ongoing benefits. - Evaluate treatment longevity, what types of fuels regenerate, and what are the associated fire risks. - Assess the effectiveness of landscape fuel treatment strategies in protecting communities. - Assess the effectiveness of landscape fuels treatment strategies in protecting sensitive ecological resources. - Define necessary variables to monitor to assess management outcomes (fuels, fire behavior, fire intensity, flora, plant functional groups, invasive species, fauna). - Assess the effectiveness of monitoring programs in providing adequate feedback about management decisions when designed to address specific objectives in burn plans. - Define the relationship between suppression costs and fire behavior in order to assess the overall effectiveness of restoration and fuel treatments on suppression costs. - Expand knowledge and develop methods to monitor expected fire behavior during prescribed burns and in wildfires that ignite and spread in masticated fuels. - Evaluate the effectiveness of Rx fire in control of invasive species. - Evaluate the effectiveness of grazing as fuel treatment in grassland vegetation types. - Evaluate the effectiveness of grazing as fuel treatment in grassland vegetation types.

- Quantify fuel loading and moisture across a complex landscape to support estimates of fuel consumption and subsequent emissions.
- Develop detailed monitoring and evaluation procedures.
- Develop a monitoring repository - establish a monitoring database for reference, research, and application.
- Develop detailed standards for consistency and effectiveness in data capture.
- Design a framework for data archiving and required metadata specific to re-measurement studies so data from long-term studies can be pooled and used in decision support.
- Develop methods and information on the effects of high severity wildland fire use.
- Assess the relative marginal value of fire management i.e. R-CAT and STAR.

Table D-7. Prioritization research needs by program element.

Program Element	Research Need
Inventory	• Evaluate the effects of fuel treatments on landscape patterns • Assess how treatment placement across landscapes can be used to maximize effects on landscape pattern • Assess how treatment location can be used to best meet changing conditions and maximize effectiveness • Evaluate the contribution of specific fuel treatment actions in reducing potential for ignition and loss • Evaluate how fuel treatments can most effectively mitigate those factors that contribute to wildfire impacts - assess where to target fuel treatments
Planning	• Evaluate how fuel treatments can most effectively mitigate those factors that contribute to wildfire impacts - assess where to target fuel treatments • Evaluate the role of strategic placement of treatments in accomplishing objectives at all scales. • Evaluate the longevity of alternative treatment types. • Evaluate the appropriate scale to maximize fuel treatment effectiveness • Assess the effectiveness of specific treatment types for accomplishing human value objectives as opposed to ecological values and how this influences planning prioritization. • Develop guides covering background and use of tools and guidelines
Implementation	• Evaluate the importance and use of information on resilience to fire, management activities, and resistance to annual invasive grasses in order to prioritize management actions at landscape scales, and to determine the most appropriate treatments at site scales
Monitoring and Evaluation	• Develop methods to evaluate how well prioritization practices affect outcomes. • Identify how to shift fuel treatments techniques to enhance implementation during climate change. • Develop a risk-assessment framework for wildland fire that provides procedural guidelines and incorporates risk-analysis concepts. • Develop methods to quantify expected value change, especially for non-market resources. • Develop probability assessment techniques accounting for wildfire complexities. • Develop seamless, interactive decision-support systems with efficient data management • Develop ways to analyze tradeoffs - how to harden landscapes, appropriate treatment scale across landscapes, homes in WUI

Appendix E. Fuel Treatment Syntheses and Guidelines.

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