Eastern Innovation Landscape Network (EILN) White Paper

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INTRODUCTION

Land managers are facing a rapidly changing and increasingly complex social and ecological environment due to urbanization, the spread of invasive species, climate change, and other novel ecosystem transformations. Despite significant investment in science-based solutions, management-relevant tools, models, and technologies and the transfer of refined science and technology are not keeping pace with this accelerated change.

The end users of science and technology recognize the need to adapt to ecosystem change but are often left out of the innovation process and lack pathways to communicate effectively with the research community, slowing the development of innovation that responds to management and operational needs. There is recognition in the field of translational ecology that actionable science requires end users and decision makers be engaged collaboratively throughout the research process, and in developing new technologies, to foster trust and ensure management-relevant solutions (Enquist et al 2017). In the past, there are too many examples of science and technology that either never reach end users, or the end users have not found value or utility in the final product, so the innovation is never used.

> **KEY TERMS**
> ***Science and Technology***: data, analyses, innovations, new ecological understanding, and research results, as well as more specific models and tools, that can support land and fire management decisions.
> ***End Users***: primarily fire managers, fire planners, fuels specialists, fire ecologists, fire practitioners, fire training staff, and outreach specialists working at regional down to management unit scales. May include land and natural resource managers working within broader management contexts as well.
> ***Co-production***: "the process of producing usable, or actionable, science through collaboration between scientists and those who use science to make policy and management decisions (Meadow et al 2015).

Similar to the generalized field of land and natural resource management, this has too often been the case in the field of wildland fire management. The Eastern Innovation Landscape Network (EILN) is a novel approach that ensures "next generation" wildland fire fuel characterization tools and fire behavior models meet both the present and evolving needs of end users. By employing an interagency framework in which scientists and end users are engaged throughout the innovation, evaluation, and technology transfer process, the EILN strives to improve the utility and accelerate application of the science and technology being evaluated.

The Innovation Landscape concept, as originally conceived by the US Geological Survey (USGS) in Southeastern Arizona, has expanded to multiple landscapes across the U.S. through the National Innovation Landscape Network (NILN) (Figure 1). It is an interagency, user-centered effort to develop and transfer innovative science and technology through deliberate co-production between researchers and end users. The NILN was established by the Department of Defense (DoD) Office of the Deputy Assistant Secretary of Defense (ODASD) Environment and Energy Resilience (E&ER) offices, in partnership with the Department of Interior agencies (USGS, USFWS, NPS, BIA), USDA Forest Service, and several research labs representing USFS and Department of Energy (DOE), to increase the relevance and pace of innovation, reduce duplicative efforts, and develop and transfer new technologies across representative federally-managed landscapes. This approach aligns existing landscape-scale partnerships (e.g., Sentinel Landscapes) with new projects to meet federal priorities and interagency goals to confront threats (e.g., habitat loss and degradation, invasive species, wildfire, and climate extremes) to sustainable land management. The Innovation Landscapes within the NILN will serve as opportunities to evaluate *processes* and *strategies* that work in expediting technology transfer in management practices, while evaluating the technology itself.

The EILN will initially be focused specifically on wildland fuels and fire behavior research innovations, but there may be future opportunities to expand the concept to innovations within other fields and topic areas addressing ecological threats in the Eastern U.S. as needs arise. More information on the purpose, role, and Innovation Landscapes in development can be found in the NILN white paper and website (www.serdp-estcp.org/NILN).

WILDLAND FIRE SCIENCE INNOVATION

Figure 1. National Innovation Landscape Network (NILN)

According to the 2021 National Prescribed Fire Use Survey Report (Melvin 2021) produced by the Coalition of Prescribed Fire Councils and the National Association of State Foresters, the eastern U.S. accounted for 66% of prescribed fire acres nationally in 2020 across federal, state, and private ownership and 76% of prescribed fire acres when only federal agency lands are considered. In the 2023 update to the National Cohesive Wildland Fire Management Strategy, the Wildland Fire Leadership Council (WFLC) re-emphasized the need for an increase in use of prescribed fire and recognized that, “Science, data, and technology has not kept pace with the extent of wildland fire and postfire impacts, or been fully integrated into decision-making for fire, land and community managers.” WFLC specifically noted in their assessment that fire behavior modeling and other tools are not being effectively used and communicated to decision-makers and practitioners.

Wildland fire managers use fire behavior modeling tools to manage wildfires safely and effectively and to plan and implement prescribed fires for ecological restoration and wildfire mitigation. Current tools (e.g., BehavePlus, FlamMap, FARSITE, etc.) are computationally efficient but are coarse in resolution and do not accurately represent fire's physical processes. These modeling tools, which have primarily been used for fire suppression planning, are also becoming less reliable in response to changes in climate, weather, and wildland fuels. Prescribed fire practitioners use complex ignition patterns to manipulate fire intensity to meet management objectives and maintain control of a fire within a given management unit.

> **Gap**: Fire behavior modeling and other tools are not being effectively used and communicated to decision-makers and practitioners.

Available fire behavior models based on the Rothermel spread equation (Rothermel 1972) are inadequate for prescribed fire planning due to assumptions including, 1) a single point of ignition that becomes a free-burning fire, 2) averaged fuel characteristic values, 3) steady-state weather values, and 4) lack of explicit coupled fire-atmospheric interactions. Prescribed fire practitioners require new innovations in fuels characterization and fire behavior modeling to better predict outcomes from realistic management scenarios and to prepare and adapt to a dynamic and increasingly unpredictable environment. This is particularly true in the Eastern U.S., where prescribed fire is the cheapest, most effective, and most widely used tool for both managing wildland fuels and for restoring fire-dependent ecosystems.

Gap: Current tools are efficient but are coarse in resolution and do not accurately represent fire's physical processes.

In contrast, more recently developed physics-based computational fluid dynamics (CFD) fire behavior models, such as FIRETEC (Linn et al 2002) and the Wildland-Urban Fire Dynamics Simulator (WFDS, Mell et al 2009), and less computationally demanding coupled fire-atmospheric models, such as QUIC-Fire (Linn et al 2020) , are able to predict and account for changes in fire behavior resulting from discontinuous ignition patterns and multiple interacting fire lines more representative of prescribed fires (Furman 2018).

These so-called "next generation" fire models incorporate three-dimensional representations of wildland fuels and complex forest structure, as well as feedbacks between the atmosphere and the fire environment, for improved modeling of the effects of vegetation structure, convectional heating and cooling, firing patterns, and the influence of various fuel treatments (thinning, midstory removal, multiple prescribed burns, etc.) on fire behavior. In turn, these new models show promise for improving the performance of new and existing smoke dispersion models as well as for more accurate prediction of the effects of fire on ecosystems at multiple scales within the context of a rapidly changing environment.

Solution: "Next generation" fire behavior models account for fire-atmospheric feedbacks, vegetation structure, and complex ignition patterns.

Concurrently, the ability to accurately characterize and represent ecosystem structure and complex wildland fuels at multiple scales has recently improved with the development of three-dimensional representations of wildland fuels such as FastFuels and various light detection and ranging (LiDAR) technologies (Parsons et al 2023). FastFuels is a fuel modeling platform that generates 3D fuels across the conterminous U.S. at a 1 m^3 resolution based on Forest Inventory Analysis (FIA) and other spatial fuels data sources ([FastFuels: 3D Fuels for Next Generation Fire Models | Missoula Fire Sciences Laboratory (firelab.org)]). Research and application of LiDAR for aerial laser scanning (ALS) at the landscape scale and terrestrial laser scanning (TLS) at the forest stand scale are rapidly expanding in the fields of forestry and wildland fire management.

LiDAR point clouds can be used as three-dimensional inputs within the aforementioned coupled fire-atmosphere fire behavior models or analyzed to collect traditional forest biometrics data for silvicultural applications, monitor status and trends in ecological condition (Pokswinski et al 2021), estimate fuels biomass and consumption (Loudermilk 2023), estimate burn severity (Gallagher 2021), and to measure effectiveness of forest management and fuels treatments over time. Analyzed separately or integrated into coarser three-dimensional national fuels framework datasets such as FastFuels, ALS and TLS offer a leap forward in terms of high-resolution wildland fuels characterization and as rich data inputs for improved accuracy of "next generation" fire behavior models.

Solution: FastFuels, ALS, and TLS represent 3D fuel and forest structure for input into "next generation" fire behavior models and for fire effects monitoring.

In an effort to integrate 3D fuels data and these new fire behavior models into a user-friendly interface, the University of California – San Diego Supercomputer Center has been developing BurnPro3D (https://burnpro3d.sdsc.edu/), powered by WIFIRE Commons, through a National Science Foundation grant. BurnPro3D is unique in that it allows users to define desired consumption values for canopy and surface fuels for a given prescribed burn and input a complex ignition pattern and then runs multiple simulations to provide a range of fuel moistures (live and dead) and wind speed combinations which will achieve the desired consumption objectives. Due to the recent rapid development of innovative applications associated with coupled fire-atmospheric fire behavior models, such as QUIC-Fire and BurnPro3d, and emerging 3D fuels characterization technologies including FastFuels, ALS, and TLS, the EILN has chosen to make innovations related to these tools and models the initial focus of the project. As the EILN matures over time, additional wildland fire behavior analysis and planning tools will be considered for testing, evaluation, and transfer to practitioners as well.

EASTERN INNOVATION LANDSCAPE NETWORK

The wildland fire science and technology community is poised to meet the needs of managers, planners, and practitioners in the eastern U.S. through innovative fuels and fire behavior tools and technologies but lacks a framework for ensuring their research is relevant, useful, and timely for use by these end users. The EILN proposes to develop this framework through an interagency collaborative approach that provides a pathway for user input and feedback throughout the innovation and technology transfer process.

The Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) are the Department of Defense's environmental, resilience, and installation energy and water research programs. The SERDP Wildland Fire Science Initiative (WFSI) is a working collaborative that creates advanced science and technology in coordination with DoD fire managers. WFSI has existing structures in place that lend itself to scaling technologies and a collaborative network across DoD and federally managed lands.

The EILN was established in March 2023 to implement and evaluate refined tools and technologies from the WFSI at DoD installations, USFWS refuges, and USFS national forest lands that rely on prescribed fire for conservation and wildfire risk reduction in the Eastern United States. EILN was initiated through a workshop held with regional prescribed fire managers, agency leads within the Eastern U.S., and wildland fire scientists. Research groups presented emerging wildland fire tools and models for demonstration and accelerated technology transfer. Managers selected tools of most interest, committed resources and staff, and began planning for evaluation of technology with SERDP and ESTCP funded research groups.

An EILN Landscape Leadership Team of regional agency leads, research leads, and partners was formed to guide the technology innovation, evaluation, and transfer process. EILN builds on the partnerships in place with WFSI, Southeast Regional Partnership for Planning and Sustainability (SERPPAS), and regional Cohesive Strategy partners, representing a joint effort between the USFS, USFWS, and DoD ODASD E&ER. Participating research labs include USFS Southern Research Station, Northern Research Station, Rocky Mountain Research Station, DOE's Los Alamos National Lab, and UC-San Diego Supercomputer Center's WIFIRE Commons. A USFS Region 8 Fire and Aviation Management Technology Transfer Specialist will serve as the initial Innovation Working Group (IWG) Coordinator.

SERDP and ESTCP has committed to help organize funding partners, support innovative research focused on the wildland fire tools chosen in the workshop, and identify additional research and technology needs. Extension of existing projects funded through SERDP and ESTCP are already aligned with the management-relevant technology needs identified in the March workshop. Early planning for outreach to the larger wildland fire community in the Southeast has already begun through discussions with the Southern Fire Exchange (SFE), a regional wildland fire science communication program funded by the Joint Fire Science Program (JFSP).

EILN Vision Statement

"*Networked interagency co-production fostering deliberate accelerated wildland fire innovation*"

EILN Goals

1. Accelerate fire science and technological innovation via wildland fire scientist/practitioner co-production in the Eastern U.S.
2. Utilizing a combination of field data collection and fire managers' experiential knowledge, collaboratively develop a process for testing, evaluating, and refining:
    - 3D fuels characterization/monitoring,
    - Next generation fire behavior and smoke models, and
    - Fire planning tools for managers
3. Using a user-centered approach, develop and implement a process to transfer advanced fire management technologies and tools to wildland fire practitioners, planners, and managers for training, education, and/or operational use.
4. Accelerate the process for identifying future wildland fire research and technology needs in the context of a rapidly changing and novel environment.
5. Formalize and document communication feedback loops amongst the Leadership Team, the Innovation Working Group and wildland fire practitioners.
6. Define and communicate management-relevant wildland fire science and technological innovation funding priorities.

Organizational Structure

The EILN organizational structure (Figure 2) will be loosely based on the Incident Command System (ICS) used to manage wildland fire incidents. Wildland fire personnel are accustomed to working within ICS, so the ICS framework is a useful paradigm for promoting co-production.

The Landscape Leadership Team will evaluate successful technology transfer, communicate refinements and emerging needs to research teams and funding agencies, develop scaling strategies that go beyond the landscape, and look for opportunities across the network for additional technology transfer, process development, and refinement. They will be responsible for evaluating metrics for successful adaptation, establishing partnerships that demonstrate sustainment, committing resources to build capacity and maintain use of the new science and technology approaches within their agencies, providing guidance on organizational changes, and promoting tool adoption.

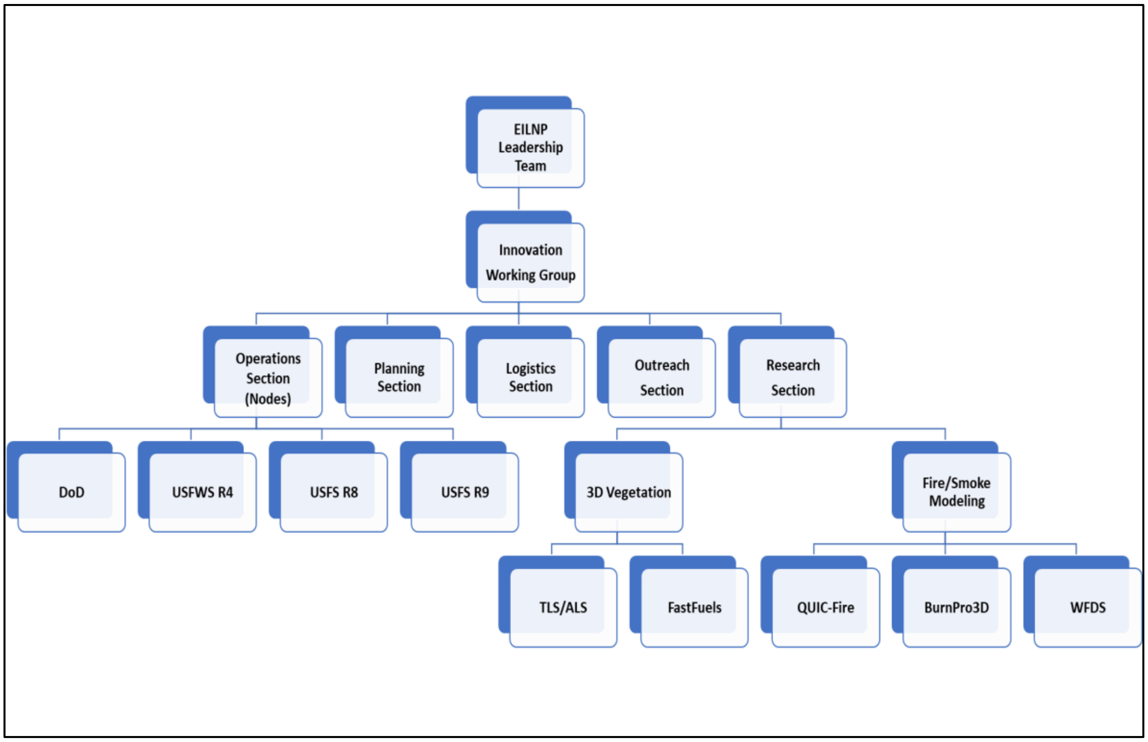

Figure 2. EILN Organizational Structure

The EILN Landscape Leadership Team will be composed of representatives from DoD ODASD, USFS Region 8, USFS Region 9, USFWS Region 4, USGS, SERPPAS, Southern Research Station, Northern Research Station, Rocky Mountain Research Station, and Los Alamos National Lab. The Coordinator of the Southeast Wildland Fire Management Cohesive Strategy has also been invited to sit on the Leadership Team to represent state, private, and tribal interests in prescribed fire science.

Landscape Leadership Team Roles

- Develop and clearly define vision, purpose, and goals for the EILN
- Provide guidance and leader's intent to the EILN Innovation Working Group (IWG)
- Communicate vision, purpose, and goals of EILN to intra-agency counterparts, leadership, and interagency partners to foster collaboration
- Provide resources based on feedback from the Innovation Working Group
- Composed of wildland fire leads from DoD, USFWS R4, USFS R8/R9, SE Cohesive Strategy, SERPPAS, and fire research community (SRS, NRS, RMRS, LANL, USGS, etc.)

An Innovation Working Group (IWG), initially led by an Innovation Coordinator from USFS Region 8 Fire and Aviation Management, will report to the Landscape Leadership Team and will be composed of a core team of agency representatives, former and current wildland fire managers, subject matter experts, and technology transfer specialists who will plan and coordinate research co-production activities between agency fire managers and fire scientists. Members of the IWG will serve as liaisons to ensure manager input and feedback is communicated at all stages of innovation and technology development and will develop a technology transfer process as tools and models are validated and refined.

The IWG will oversee an Operations Section composed of demonstration sites, termed "Innovation Nodes", from each of the three primary federal agencies (DoD, USFWS, USFS), a Research Section that includes the various primary investigators for each innovative tool or model to be evaluated, a Planning Section tasked with scheduling meetings and events and maintaining documentation, and an Outreach Section for communicating EILN successes and lessons learned to interagency partners and the larger wildland fire community. SFE and other JFSP fire exchange programs in the Southeast will likely be key EILN fire science delivery partners within the Outreach Section as the network matures. Though the EILN will initially focus fire science innovation and tech transfer efforts within federal agencies, the EILN will seek opportunities to expand the concept to other federal, state, private, and tribal prescribed fire stakeholders and invite them to participate on the IWG as the network grows and matures.

Innovation Working Group (IWG) Roles

- Develop specific objectives to meet Leadership Team's defined goals
- Develop and implement a process for testing, evaluating, and accelerating next-generation fire technology innovation
- Promote co-production of science at Innovation Nodes
- Facilitate technology transfer of operational tools to field units, managers, and practitioners
- Based on co-production outcomes and management-relevant innovations, develop, prioritize, and submit fire research Statements of Need to the Leadership Team

The evaluation of innovative models and tools, and eventual technology transfer within the EILN, will occur throughout a hierarchical network of management units representative of the three primary federal agencies committed to the EILN (DoD, USFS, and USFWS) with feedback loops and communication pathways established within and between all levels (Figure 3).

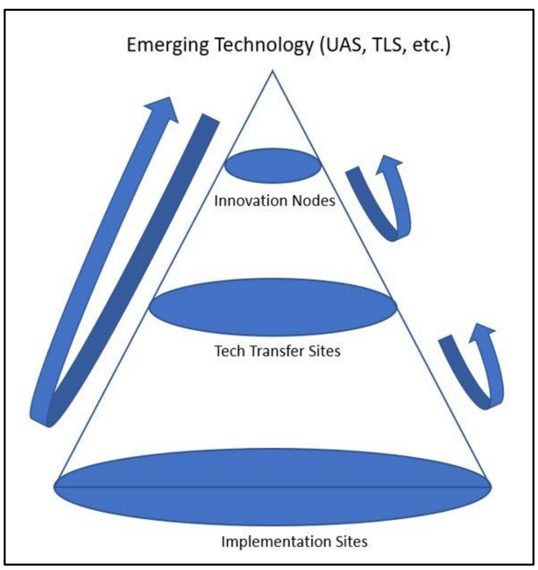

Figure 3. EILN hierarchy of tool/model evaluation and technology transfer

The primary demonstration sites within each of the three agencies for initial and more thorough evaluation of each wildland fire model or tool will be known as "Innovation Nodes" (Table 1). Fuel and fire behavior models such as FastFuels and QUIC-Fire will be tested and evaluated at these Innovation Nodes using data from field experiments for model refinement and calibration paired with end-user (fire manager and practitioner) feedback on model performance and practical ease of use.

Initial Innovation Nodes were chosen based on the success of their respective wildland fire programs and their willingness to engage in innovation with fire scientists. Nodes were given priority if they had a history of engagement with fire researchers and/or possessed fuels and fire behavior datasets that could be leveraged for the project. Management units were also selected geographically within the Gulf and Atlantic Coastal Plains and Piedmont to test and evaluate fuels characterization tools and fire behavior models on relatively flat and simple topography to refine the technology before testing in more complex, mountainous terrain.

Models and tools that meet the criteria defined for practical application and usability by the Innovation Nodes will then be transferred to "Tech Transfer Sites" over time to evaluate performance at a greater variety of locations, identify technological limitations, improve efficiency of learning, and to modify applications based on local conditions. For example, once a given "next generation" fire behavior model has been thoroughly evaluated on predicting fire spread and heat release over relatively flat topography within the coastal plain, a number of Tech Transfer Sites within the Southern Appalachians or Interior Highlands may be selected to further evaluate its performance and applicability in more mountainous terrain. As the network grows, there may be opportunities for other willing federal agencies, state, and tribal partners to join as additional innovation nodes and/or tech transfer sites.

Models and tools that make it through a rigorous test and evaluation process at both Innovation Nodes and Tech Transfer Sites may eventually be considered for transfer to "Implementation Sites" through more formalized training. The transfer of refined technologies to Implementation Sites will require more widespread approval for use of these tools within each agency and will rely on creative methods to scale and implement at a regional scale. All levels within the hierarchy of test and evaluation from Innovation Nodes to Implementation Sites will be used to identify strengths, weaknesses, and needed improvements for each technology as well as for the innovation and tech transfer processes themselves.

Table 1. EILN Initial Innovation Nodes

Department of Defense	US Fish and Wildlife Service	USDA Forest Service
Fort Stewart	St. Marks NWR	Chattahoochee-Oconee NF
Fort Liberty	Piedmont NWR	Francis-Marion/Sumter NF
Joint Base McGuire-Dix-Lakehurst	Merritt Island NWR	Savannah River Site

For more information, contact **Brett Williams**, USFS Region 8 FAM Fire Management Specialist, brett.williams@usda.gov, or **James Furman**, USFS Fire Management Specialist, james.h.furman@usda.gov.

LITERATURE CITED

Enquist, C.A., Jackson, S.T., Garfin, G.M., Davis, F.W., Gerber, L.R., Littell, J.A., Tank, J.L., Terando, A.J., Wall, T.U., Halpern, B. and Hiers, J.K., 2017. Foundations of translational ecology. Frontiers in Ecology and the Environment, 15(10), pp.541-550.

Furman, J. 2018. Next Generation Fire Modeling for Advanced Wildland Fire Training. Fire Management Today 78: 48-53.

Gallagher, M.R., Maxwell, A.E., Guillén, L.A., Everland, A., Loudermilk, E.L. and Skowronski, N.S., 2021. Estimation of plot-level burn severity using terrestrial laser scanning. Remote Sensing, 13(20), p.4168.2021

Linn, R.; Reisner, J., Colman, J.J., Winterkamp, J. 2002. Studying wildfire behavior using FIRETEC. International Journal of Wildland Fire. 11(4): 233–246.

Linn, R.R., Goodrick, S.L., Brambilla, S., Brown, M.J., Middleton, R.S., O'Brien, J.J., and Hiers, J.K. 2020. QUIC-fire: A fast-running simulation tool for prescribed fire planning. Environmental Modelling & Software. 125: 104616. https://doi.org/10.1016/j.envsoft.2019.104616

Loudermilk, E.L., Pokswinski, S., Hawley, C.M., Maxwell, A., Gallagher, M.R., Skowronski, N.S., Hudak, A.T., Hoffman, C. and Hiers, J.K., 2023. Terrestrial laser scan metrics predict surface vegetation biomass and consumption in a frequently burned southeastern US ecosystem. Fire, 6(4), p.151.

Meadow AM, Ferguson DB, Guido Z, et al. 2015. Moving toward the deliberate co-production of climate science knowledge. Weather Clim Soc 7: 179–91.

Mell, W., Maranghides, A., McDermott, R., and Manzello, S.L. 2009. Numerical simulation and experiments of burning Douglas fir trees. Combustion and Flame. 156(10): 2023–2041.

Melvin, M.A. 2021. 2021 National Prescribed Fire Use Survey Report. Technical Report 01-22. National Association of State Foresters and Coalition of Prescribed Fire Councils, Inc.

Parsons, R., Wells, L., Marcozzi, A., Linn, R., Hiers, K., Pimont, F., Riley, K., Altintas, I., and Flanary, S. 2023. Going #D with fuel and fire modeling: FastFuels and QUIC-Fire. Fire Management Today. 81(1): 48-51.Pokswinski, S., Gallagher, M.R., Skowronski, N.S., Loudermilk, E.L., Hawley, C., Wallace, D., Everland, A., Wallace, J. and Hiers, J.K., 2021. A simplified and affordable approach to forest monitoring using single terrestrial laser scans and transect sampling. MethodsX, 8, p.101484.

Rothermel, R.C. 1972. A mathematical model for predicting fire spread in wildland fuels, US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. General Technical Report no. INT-115, 40.