SUSTAINABLE BIOMASS SUPPLY FROM FOREST HEALTH AND FIRE HAZARD REDUCTION TREATMENTS

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Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

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DBH	diameter at breast height
FIA	Forest Inventory and Analysis
iFLAMES	integrated Fireshed-Level Adaptive Management Evaluation Sites
USDA	United States Department of Agriculture

EXECUTIVE SUMMARY

These tasks focused on the translation of potential silvicultural treatments implemented at various levels across the dry-forest landscapes of the interior West to meet feedstock needs for potential biomass processing locations and sizes. To that end, it was a modeling effort examining scenarios and resultant patterns and limitations to feedback supply and delivery. Modeling included the development of reasonable and current silvicultural alternatives, the modeling framework and initial outputs, establishing and re-measuring sites to confirm model assumptions, and re-tooling the model as needed to refine feedstock supply estimates. All stages involved regular meetings and conversations with silviculturists across the nation and public presentations about the work to collaborative groups.

Model assumption verification comes from the literature and remeasurement of fuel treatment sites, as well as the implementation of some new treatment areas in an adaptive management framework. Mechanical treatments at iFLAMES Site 1 (on the Confederated Tribes of the Warm Springs land) began following the 2015 fire season and is ongoing through 2017 – several thousand acres total. We have re-measured and photographed all completed plots (~70%), including a revisit to the controls to re-sample fuel loading – we did not observe any major changes to overstory/understory vegetation to justify remeasurement. Data analyses are ongoing from this effort with leveraged funds.

We also re-measured several sites from the Fire Surrogate study initiated in 2002. These efforts have verified our modeling assumptions about treatment intensity impacts on vegetation and fuels and we will use them for years to investigate trends in silvicultural treatment effectiveness, fuels recovery, and ecology effects across broad geographic areas. The Blue Mountains Fire and Fire Surrogate study site was successfully re-analyzed as part of a completed MS thesis. Publication of these efforts is continuing, and more thorough analysis of regrowth and ecologically significant trends in fuel treatment effectiveness and ecological recovery will take place throughout 2017.

We continue to work with USDA Forest Service offices for various versions and extensions of iFLAMES that can be folded into ongoing Collaborative Forest Landscape Restoration efforts, including a new treatment area outside Lakeview that will employ tethered feller-buncher and forwarder technology on steeper slopes. A change to our model assumptions about slope limitations has the potential for substantial impact on conclusions about transportation distances and the economics of biomass feedstock collection and transport.

Finally, we have leveraged these efforts against a long-term monitoring project in the Blue Mountains funded by the USDA Forest Service. Now in the second year of that agreement, we have fielded two crews to establish pre-treatment monitoring plots and remeasure treated areas. Despite the lack of replication and control available with iFLAMES, these plots can be viewed as auxiliary to our efforts.

INTRODUCTION

This project was charged with quantifying the effect of regional land management policy and market trends on the supply of available biomass across ownerships in the western region; analyzing the range of forest health and fuel reduction management options and obstacles that will limit feedstock supply over time from given landscapes; developing models and tools for policy makers, businesses and advocacy groups to use in order to consistently assess the potential for feedstock yield from landscapes, which integrate long-term forest productivity and health, land management directions and practices, harvesting technologies and transportation systems; and establishing large-scale adaptive management studies that demonstrate and refine the options conceptualized in these models and provide a baseline for evaluation of long-term socio-economic and ecological effects.

TASK 1: DEVELOP PRELIMINARY PRESCRIPTIONS FOR PUBLIC LANDSCAPES NEEDED FOR REGIONAL SUPPLY MODEL

Task Objective
Synthesize example prescriptions with collaboration from USDA Forest Service silviculturists and land managers.

Methodology
Review and synthesis of literature and silvicultural prescription for relevant forest types; consultation with silviculturist by phone and in person (n=50).

Results
In order to investigate the impact that silvicultural choices would have on both stand-level fire hazard and on biomass feedstock supply, a simplified set of four treatment options were considered. A heavy restoration thinning across diameter classes was modeled both with and without a 21 inch DBH limit. This resulted in four different silvicultural treatment scenarios that were modeled (Figure SBS-1.1):

1. No action. It forms the baseline for comparisons and reflects the management choice on most acres.
2. Light restoration treatment - thin from below with a 21-inch DBH limit. The most common fuel treatment available, particularly in the wildland-urban interface and other areas where harvests are viewed negatively.
3. Heavy restoration treatment – thin across diameter classes with a 21 inch DBH limit. A more meaningful "restoration" treatment that builds resistance and resilience into the system for an extended length of time, but limited by a politically assigned size limit.
4. Heavy restoration treatment – thin across diameter classes with a no DBH limit. Full implementation of an ecologically-based treatment to build resistance and resilience into the system.

A range of silvicultural prescription forms (e.g. TFB, TAD) have been used in other previously completed biomass assessments as well as wide range residual basal areas. We performed a model sensitivity analysis in order to investigate how sensitive FVS modeled biomass and fire hazard outputs are to prescription form and residual basal area.

Conclusions/Discussion
Silvicultural prescription forms are straightforward and acceptable to land managers – these options are not the limiting factor to the modeling or the treatment of landscapes in reality. Our choices were widely acknowledged as the basic choices (Lehmkuhl et al, 2015). Managers uniformly desired to be able to do more full restoration treatments across their ownerships.

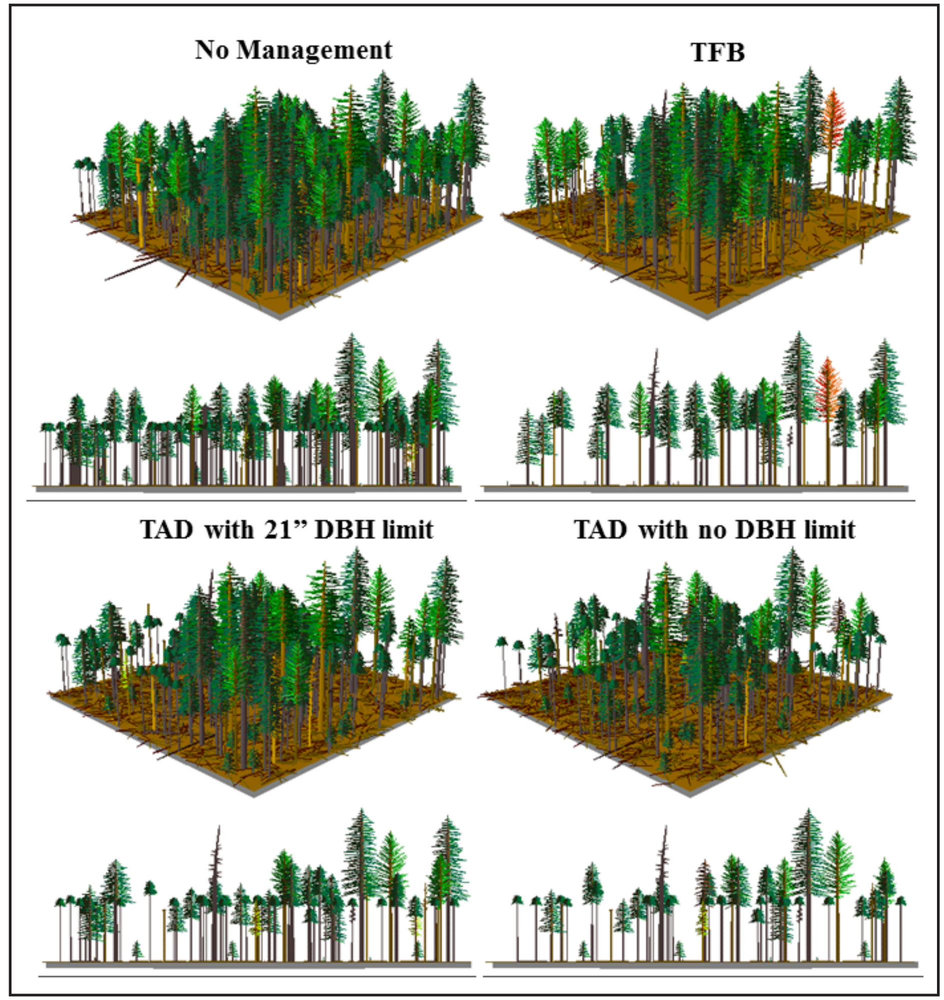

Figure SBS-1.1. Range of stand structures created by different silviculture prescription forms using stand visualizations of a mixed-conifer stand located in the Malheur National Forest with 579 TPA and 171 ft^2 BA prior to treatment (Vogler, 2014).

TASK 2: DEVELOP MODELS AND TOOLS FOR PUBLIC DECISION MAKERS TO CONSISTENTLY ASSESS POTENTIAL FOR FEEDSTOCK YIELDS

Task Objective

Assemble, test and validate the model with silviculturists and land managers; compile results into regional estimates of feedstock availability.

Methodology

A plot selection prioritization framework was developed (Table SBS-2.1) to allow for the ability to simulate different policy options within model framework and test different possible future scenarios.

Table SBS-2.1. A plot selection prioritization framework

1.) Input Data	2.) Silvicultural Prescription Scenarios	3.)Setting Harvest Intensity Level
• FIA Plot level data used • Stratified into: • BM – Ochoco, Malheur, Umatilla, Willowa-Whitman • SO – Deschutes, Fremont-Winema • DF and PP labeled forest types reclassified into mixed conifer based on percentage of total BA	Four prescription scenarios were modeled: 1) Grow Only 2) Rx 1 – Thin from below (TFB) to BA target 3) Rx 2 – Thin across diameter classes with a 21" DBH limit (TAD21) to BA target 4) Rx 3 – Thin across diameter classes with no diameter limit (TADNL) to BA target	Three management intensity levels were modeled: 1) Current harvest levels 2) ½ full restoration in 25 Years ≈ 2x increase in harvest levels 3) Full restoration in 25 Years ≈ 4x increase in harvest levels
4.) Plot Prioritization	**5.) Growth and Yield**	**6.) Data Products**
The Landscape Treatment Designer (LTD) was used to prioritize treatment areas based on equal weighting of: 1. Treatment effectiveness in reducing mortality of trees > 10" diameter 2. Distance to the WUI (Radeloff et al., 2005)	• The Treatment Analysis Tool within the ArcFuels Toolbar was used to iterate FVS in order to model harvest on every plot at each time step • All runs were compiled and queried to select plot management year based on LTD prioritization and management intensity level.	• Total of 10 model scenarios • Physically available biomass (bone dry tons) and fire hazard (flame length) data was compiled for each time of the 10 modeled scenarios

Results

Projections indicated that restoration need consistently dwarfs both the amount of treatment and the amount of wildland fire across National Forests in the region (Figure SBS-2.1). These results and similar efforts have repeatedly established this pattern and driven recent moves to accelerate the pace and scale of restoration treatments. However, if with a modest implementation of a range of silvicultural prescriptions, the available biomass is not sufficient to supply a NARA centralized processing facility as currently envisioned (Figure SBS-2.2). Distributed smaller facilities would be possible, and would reduce hauling distances/expenses, but with uncertain implications for fuel production.

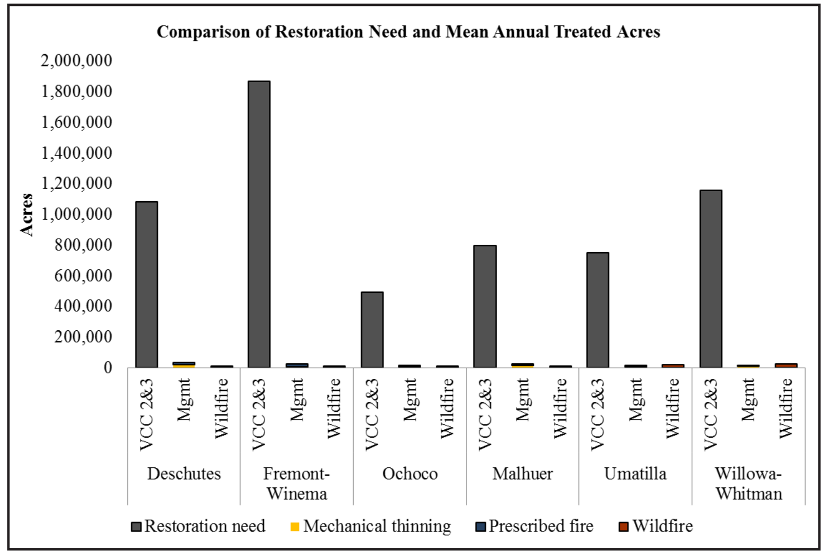

Figure SBS-2.1. Comparison of restoration need relative to current levels of treatment (mechanical thinning and prescribed fire) and average acres burned by wildfire for each national forest in eastern Oregon (Vogler, 2014).

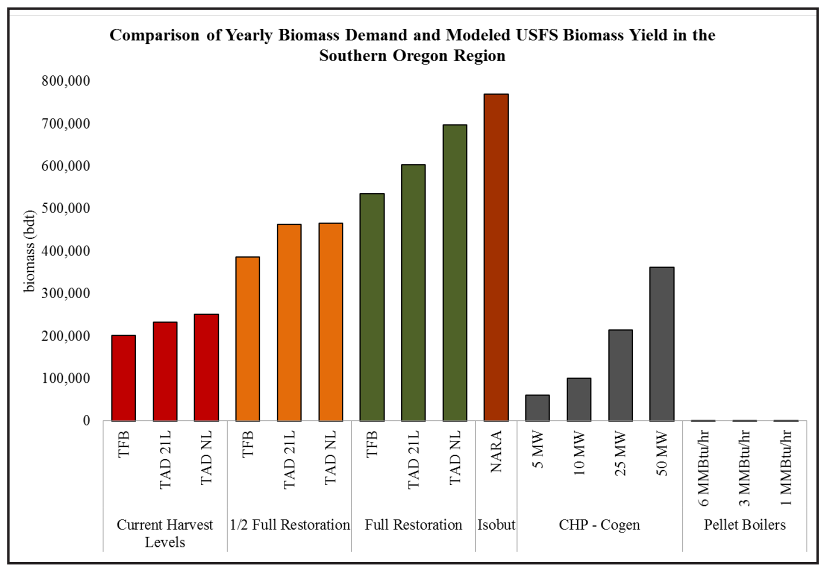

Figure SBS-2.2. Comparison of modeled feedstock supply over a range of silvicultural prescriptions and harvest intensity levels and biomass feedstock demand of different scales of biomass infrastructure within the southern Oregon subregion (Vogler, 2014).

Conclusions/Discussion

The observed linear increase in biomass availability over all forest types and prescription groups shows that the model is functional but not particularly sensitive to thinning intensity in regards to feedstock supply. As thinning intensity increases and prescription form removes larger trees, the relative amount of biomass proportionally increases. Modeled biomass feedstock estimates supply would respond proportionally to the change.

Overall, biomass yields were lower than expected, especially in model runs where *residual* basal area was modeled at 0 ft^2/ac (clear cut). This is likely due to the method in which the data were summarized (average yield per acre per forest type within each subregion). The presence of poorly-stocked stands that would produce low levels of biomass at each residual basal area target likely lowered the predicted total biomass availability. In addition, the targeted residual basal area was often not reached due to the maximum diameter cut limit resulting in lower than expected biomass yields.

The main point, however, is that even the most aggressive treatment approaches implemented at an accelerated pace will not fully supply the feedstock requirements of the projected size of facility envisioned by NARA (other parts of the project). This most aggressive mix approaches the right biomass level. Associated research examining the pace and scale of treatment in these forest types conclude that only a doubling is feasible given the amount of land area that is treatable within current policy constraints (Barros et al., 2017) and social issues that interfere with the ability to address a struggling wildfire management system (Fischer et al., 2016)

TASK 3: ESTABLISH LARGE SCALE ADAPTIVE MANAGEMENT STUDIES

Task Objective
Draft and implement new research/adaptive management installations in cooperation with land managers.

Methodology
Network with the tribes and USDA Forest Service to identify potential sites within planned areas of fuel treatment work.

Results
The framework for "iFLAMES" (integrated Fireshed-Level Adaptive Management Evaluation Sites) was completed and distributed to a subset of regional federal land management collaborative groups, as well as federal and tribal silviculturists, in the second year of the project. We attended multiple regional meetings and field tours to promote the iFLAMES effort over ensuing years, reviewed planning areas, and made many site visits. The contrast between light thinning-from-below treatments and heavier restoration treatments, which was conceptualized and modeled in early phases, was implemented in the marking guidelines at site 1. The first remeasurement will confirm implementation; subsequent prescribed fire treatments will fulfill the modelled silvicultural approach.

Mechanical treatments at Site 1 (on Confederated Tribes of the Warm Springs) began immediately following the fire season in 2015 and continued, weather permitting, into the next year. We re-measured and photographed all treated stands/plots in summer of 2016 (Figure SBS-3.1). Prescribed fire treatments are planned for 2017. All additional sites continue to languish in various planning (NEPA) and approval stages, though some hints still emerge that projects might move forward in 2017.

Figure SBS-3.1. Warm Springs treatments begin.

Conclusions/Discussion
A single site is insufficient to draw broad conclusions, but re-measurement of Fire and Fire Surrogate study sites augmented our understanding of fuel treatment effectiveness. These new sites will add to an emerging set of long-term research installations.

TASK 4: APPLY TOOLS AND MODELS OF FIRST-YEAR RESULTS TO LARGE-SCALE EXPERIMENTS TO IMPROVE PREDICTIVE ABILITY OF MODELS

Task Objective

Revise and update the modeling framework addressing key issues about stand structure, silvicultural treatment options, fire histories and fuel responses.

Methodology

Expand and revisit the network of silviculturists with modeling results and re-measurement data in hand for potential model updates and re-estimates of feedstock supply.

Results

The Blue Mountains Fire and Fire Surrogate study site was successfully re-measured during the summer of 2015. Designed as a replicated, adaptive management study, changes in trees, vegetation, and fuels can be tracked over the 15-17 years since original fuel reduction treatments. All data is entered, verified, and saved in multiple locations. More thorough analysis of regrowth and ecologically significant trends in fuel treatment effectiveness and ecological recovery was published in Kat Morici's thesis in February 2017 (Morici, 2017).

In addition, remeasurement data from the Southwestern Plateau Fire and Fire Surrogate study sites were acquired and used to investigate trends in silvicultural treatment effectiveness, fuels recovery, and ecology effects across broad geographic areas. The heavy-thin, restoration treatment was used in Fire and Fire Surrogate study design as implemented at Hungry Bob and the Southwest Plateau sites; hence, remeasurement and analysis of those installations provided insight into our modeling approach. Analysis is ongoing.

Outreach continued with the tribes and Forest Service for potential iFLAMES site establishment, including meetings and site visits in the region. A dozen other potential sites have been identified, but planning processes are lengthy. Therefore, we leveraged against the remeasurement of sites associated with other research and monitoring initiatives in order to verify the modeling assumptions from earlier in this project.

James Johnston, working with the Blue Mountains Forest Partners, collected data to evaluate trends in large, old tree structure on the Malheur National Forest using the FIA database and new data from a USFS-funded monitoring project (Johnston *et al*., 2016). Trends in tree growth and mortality in response to a range of treatments will provide the iterative data we need for verification as well as help the Malheur NF adapt for old and large tree conservation strategies in the context of ongoing Land and Resource Management Plan (LRMP) revision.

Conclusions/Discussion

There was little reason to re-model silvicultural alternatives again using Vogler's framework (Vogler et al., 2015). We leveraged much of the work and data from this project into expanded modeling efforts at the landscape scale (e.g. Barros *et al*., 2017; Spies *et al*., 2017; Ager *et al*., 2017).

NARA OUTPUTS

Publications

Spies, T. A., E. White, A. Ager, J. Kline, J. Bolte, E. Platt, K. Olsen, R. Pabst, A. Barros, J. Bailey, and others. 2017. Using an agent-based model to examine forest management outcomes in a fire-prone landscape in Oregon, USA. *Ecology and Society 22(1):25.*

Barros, A., A. Ager, M. Day, H. Preisler, T. Spies, E. White, R. Pabst, K. Olsen, E. Platt, J. Bailey, and J. Bolte. 2017. Spatiotemporal dynamics of simulated wildfire, forest management and forest succession in central Oregon, USA. *Ecology and Society 22(1):24.*

Johnston, J., J. Bailey, and C. Dunn. 2016. Influence of fire disturbance and bio physical heterogeneity of pre-settlement ponderosa pine and mixed-conifer forests. *Ecosphere 7(11): 1-19.* (Impact: 2.6)

Fischer, A.P., T.A. Spies, T.A. Steelman, C. Moseley, B.R. Johnson, J.D. Bailey, A. Ager and others. 2016. Wildfire risk as a socio-ecological pathology. *Frontiers in Ecology and the Environment 14(5):276-284.* (Impact: 8.5)

Vogler, K., A. Ager, M. Day, M. Jennings, and J. Bailey. 2015. Prioritization of forest restoration projects: tradeoffs between wildfire protection, ecological restoration and economic objectives. *Forests 6:4403-4420.* (Impact: 1.6; 7 citations)

Lehmkuhl, J.F., W. Gaines, D. W. Peterson, J.D. Bailey, and A. Youngblood. 2015. *Silviculture and monitoring guidelines for integrating restoration of dry mixed-conifer forest and spotted owl habitat management in the eastern Cascade Range*. **PNW-GTR-915.** USDA Forest Service General Technical Report, Pacific Northwest Forest and Rangeland Research Station, Portland OR. 160pp.

Ager, A.A., K.C. Vogler, M.A. Day and J.D. Bailey. Economic opportunities and trade-offs in collaborative forest landscape restoration. **ACCEPTED**: *Ecological Economics*

Dissertation: *Successional accretion along a productivity gradient following fire exclusion in the southern Blue Mountains, Oregon, USA*. James Johnston, PhD. 2016

Thesis: *Sustainable Biomass Supply from Fuel Reduction Treatments: A Biomass Assessment of Federally Owned Land in Eastern Oregon*. Kevin Vogler, M.S. 2014

Thesis: *Fuel Treatment Longevity in the Blue Mountains*. Kat Morici, M.S. 2017

Presentations

Presented silvicultural prescriptions to fire and forest management professionals at the **5th International Fire Ecology and Management Congress** in Portland, OR, 2014 – Kevin Vogler and John Bailey (two)

James Johnston gave presentations to the **Blue Mountains Forest Partners** and the Malheur National Forest on August 21 and October 16, 2016 about historical successional and disturbance dynamics on forests targeted for restoration treatments under the CFLRP program.

Poster Presentation: Morici, K., Bailey, J. Longevity of Fuel Treatments in the Blue Mountains of Northeastern Oregon. **6th International Fire Ecology and Management Congress**, San Antonio, TX, November 2015

Bailey invited presentation: "Fire history and fire ecology in Central Oregon – implications for land management and living sustainably." **High Desert Museum**, March 5, 2016 in Bend, OR. (Speaker)

Bailey invited presentation: "Training the next generation of foresters for a changed world." **Portland Chapter of the Society of American Foresters**, February 22, 2016 in Portland, OR. (Speaker)

Bailey invited presentation: "Fire and Rain: the role of forestry in Oregon with a changing climate." **Environmental Action Council**, January 14, 2016 in Corvallis, OR. (Speaker)

"Living with Fire" **Pacific Northwest Science and Management Team Retreat,** *June 5-6, 2014 in* Skamania, WA. (Speaker)

"Ecological forestry and fire management – draining the biomass reservoir" **Central Oregon Fire Science Symposium**, April 8-9, 2014 in Bend, OR. (Speaker)

"Climate change and wildland fire: It is a good day to burn!" **Foresters Forum**, February 5-7, 2014 in Coeur d'Alene, ID. (Speaker)

"Mixed-conifer fire behavior and silviculture." **Restoring and Managing Mixed Conifer Forests in the Pacific Northwest**, April 15, 2013 in Hood River, OR. (Speaker and Panel Member)

"On ecological effects of wildfires: experiences in the western U.S." **Sveriges Lantbriksuniversitet**, **Mark och Miljo Lecture**, March 20, 2013 in Uppsala, Sweden. (Visiting Scientist)

"Forest restoration and biomass utilization as a partnership in the Pacific Northwest U.S." **Sveriges Lantbriksuniversitet, Focus on Soil and Water Graduate Seminar**, March 18, 2013 in Uppsala, Sweden. (Visiting Scientist)

"Balancing early- and late-seral successional stand conditions in fire-prone mixed-conifer forests of the western U.S." **Universidad de Valladolid**, February 27, 2013 in Palencia, Spain. (Visiting Lecturer)

"Balancing early- and late-seral successional stand conditions in fire-prone forest types." **4th International Association of Wildland Fire – Fire Behavior and Fuels Conference**, February 20, 2013 in Raleigh, NC. (Speaker)

"Fire regimes in dry mixed-conifer ecosystems of the West: balancing early- and late-seral stand conditions for the broadest services." **Joseph W. Jones Ecological Research Center, Visiting Scientist Seminar**, February 6, 2013 in Ichauway, GA. (Speaker)

"Stocked stands to standing stocks: sustainable forest management and bioenergy." **Pacific Northwest Biomass Symposium**, November 12, 2012 in Seattle, WA. (Speaker)

NARA OUTCOMES

My part of the project had no formal assessment of learning outcomes by silviculturists and land managers, either in the process of assembling the model, planning iFLAMES sites, or revisiting the modeling with re-measurement data. However, these folks were engaged at all those stages – including on-the-ground land managers who routinely visited us on site and/or leaned over our maps as we ponder alternatives and locations. Perhaps most exciting, I train 35 silviculturists each year as part of the National Advanced Silviculture Program. These students have been involved in the project each of the 5-6 yeas as part of their education experience.

FUTURE DEVELOPMENT

- Continued implement of iFLAMES sites, or similar testing grounds for implementation and effective monitoring of restoration treatments is imperative

- A revised regional biomass estimate with BIOSUM is in preparation

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