Coupled Human and Natural Systems in Fire-Prone Landscapes: Interconnections and Research Needs

A workshop held August 4-7, 2014 in Bend, Oregon

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Participant List

Name	Institution	Expertise
Alan Ager*,**	PNW Research Station, USFS	Fire modeling
John Bailey*,**	Oregon State University	Fire ecology and management
John Bolte*,**	Oregon State University	Agent based models
Patrick Bourgeron**	University of Colorado	Landscape ecology
David Bowman	University of Tasmania	Fire ecology, climate change
Susan Charnley*,**	PNW Research Station, USFS	Social science and anthropology
Brandon Collins	PSW Research Station, USFS	Fire ecology and restoration
Paige Fischer*,**	PNW Research Station, USFS	Social science and networks
Bart Johnson**	University of Oregon	Fire ecology and modeling
Jeff Kline*,**	PNW Research Station, USFS	Economics
Jessica Leahy	University of Maine	Social attitudes in forestry
Jeremy Littell	USGS Alaska	Climate change and forests
James Millington	King's College London	Agent based models, fire
Cassandra Moseley	University of Oregon	Environmental political science, federal land management
Max Nielsen-Pincus**	Portland State University	Fire ecology and community-based natural resource management
Christine Olsen*,**	Oregon State University	Fire social science
Travis Paveglio**	University of Idaho	Community adaptive capacity
Emily Platt*,**	Oregon State University	Forest conversation and policy
Christopher Roos**	Southern Methodist University	Environmental archaeology
Bruce Shindler*,**	Oregon State University	Natural resource social science
Thomas Spies*,**	PNW Research Station, USFS	Landscape ecology
Toddi Steelman	University of Saskatchewan	Natural resource governance, fire
Michelle Steen-Adams*,**	University of New England	Environmental history
Forrest Stevens**	University of Louisville	Forest communities, social and ecological change
Jelena Vukomanovic**	University of Colorado	Ecology and geography
Eric White*,**	Oregon State University	Economics

* Host research team
** Participant in official NSF CHANS study

Summary

This report is a deliverable to share the impact of travel funding awarded by the Joint Fire Science Program (JFSP) in support of a workshop focused on fire-prone coupled human and natural systems (CHANS). From August 4th – 7th 2014, twenty-six scientists convened in Bend, Oregon to share successes, challenges, and ideas related to researching fire-prone CHANS. This workshop, titled *Coupled Human and Natural Systems in Fire-Prone Landscapes: Interconnections and Research Needs*, was hosted by the *Forests, People, Fire* research team from Oregon State University and the Pacific Northwest Research Station of the USDA Forest Service, which was an official CHANS project funded by the National Science Foundation (NSF). Other participants came from a variety of fire-related research programs and other NSF CHANS projects.

Funds from this JFSP award helped support travel for a number of the workshop participants. International scientists traveled from London in the United Kingdom, Saskatoon in Saskatchewan, and Hobart in Tasmania, Australia. From within the United States, scientists traveled from Anchorage in Alaska, Orono in Maine, Louisville in Kentucky, Dallas in Texas, Boulder in Colorado, Moscow in Idaho, Davis in California, and Portland, Eugene, and Corvallis in Oregon. The workshop program consisted of presentations by each research team or independent scientist, full group discussions, small-group work, and a field trip to fire-prone areas of central Oregon. As a result of this workshop, alliances were made among fire-prone CHANS researchers, new ideas and prominent research gaps were identified, and plans for two scientific papers were developed.

Workshop Agenda

Coupled Human and Natural Systems in Fire-Prone Landscapes:
Interconnections and Research Needs
Mt. Bachelor Village Resort—Bend, Oregon
August 4-7, 2014

Monday, August 4: Participants arrive—Evening reception at 6:00 p.m.

Tuesday, August 5: Introductions and presentations of research

8:00 a.m.

- Meeting structure, general goals, and intended outcomes—Bruce Shindler, Tom Spies
- Participant introductions
- CHANS research overview—Eric White
- Discussion of potential manuscript product —Paige Fischer
- Research themes and method for small group discussions

9:30 a.m. Break

9:40 a.m. CHANS Project presentations (12 minute presentations; 8 minutes for Q &A).

1. Tom Spies
2. Patrick Bourgeron & JelenaVukomanovic
3. Bart Johnson & Max Nielson-Pincus

BREAK (5 minutes)

4. Chris Roos
5. Travil Paveglio
6. Forrest Stevens

Brief follow-up discussion as time permits

12:00-1:00 p.m. Lunch

1:00 p.m. Presentations of related individual research (10 min. presentations; 5 min. Q&A)

1. David Bowman
2. Brandon Collins
3. Toddi Steelman
4. Jessica Leahy

BREAK (5 minutes)

5. Jeremy Littell
6. James Millington
7. Cass Moseley
8. Paige Fischer
9. Alan Ager

3:00 p.m. 5-minute video presentation (John Bailey) followed by break for field trip prep.

3:30 p.m. Field trip to past wildfire sites, Tumalo Falls, and evening dinner (catered BBQ).

Wednesday, August 6: Assembling ideas, refining themes and questions, healthy discussion of key ideas.

8:00 a.m

Reflections on what we heard yesterday

- Questions to help clarify presentation points
- Similarities/useful connections between CHANS and other presented research
- Free discussion, Q & A

9:00 a.m. Four small group discussions (breakout #1) based on participant priorities and preferences. Groups may decide to take a short break as needed.

10:30 a.m.

Reconvene and report back to full group on breakout discussions (15 minutes each). Further questions/ideas by full group

12:00 noon Lunch and opportunity for a river walk

1:30 p.m. Four small group discussions (breakout #2) with different participants based on priorities and preferences.

3:15 p.m. Break

3:30 p.m. Reconvene and report back to full group on breakout discussions (15 minutes each).

Further questions/discussion by full group.

5:00 p.m. Conclude

5:30-6:00 p.m. Walk to Mill District for (no host) happy hour and 7:00 p.m. dinner at Greg's Grill.

Thursday, August 7: New connections, policy roles, integration and synthesis across themes/questions, manuscript options, consider next steps

8:00 a.m.

Reflect on previous day's activity—new reactions/thoughts, unresolved issues?

- Reactions to workshop thus far?
- New perspectives? New nuggets? Connections that you had not seen before?
- What has changed in your thinking?
- Research gaps

9:00 a.m.

Revisit CHANS projects: open forum among six CHANS project groups—compare notes and ideas, ask questions.
Others will listen in and participate as appropriate.

10:15 a.m. Break

10:30 a.m. Group to decide how to address items from Big Questions list

12:00 noon Lunch

1:00 p.m.

Roles in the policy process

- What role(s) can/should scientists play in policy debates?
- Can scientists effectively engage policy makers about CHANS research?
- What are the options for us to engage stakeholders (agencies, practitioners, citizens) to communicate research and solicit feedback?
- What roles should our natural resource agencies and NGO's play in creating policy changes and providing leadership?
- Most useful/most realistic forums?

2:20 p.m. Break

2:30 p.m. to adjournment (by 4:00 p.m.)

What should a single research paper coming out of this meeting look like? (Paige)

- Reflect on paper focus, content, outline
- Determine interested contributors
- Outline of summary table characterizing existing CHANS projects

Discussion of potential follow-up activities. For example:

- What additional existing studies and/or papers would inform or support our work?
- What types of studies and/or publications seem most appropriate?
- Other potential collaborations?
- New proposals?

Abstracts of Presentations

Eric M. White – CHANS Research Overview

College of Forestry, Oregon State University

The literature on coupled natural and human systems defines the characteristics of these systems, describes why they are important to study, identifies challenges to completing interdisciplinary study of these systems, and describes the role of models in understanding these systems. Coupled natural and human systems are identified as linked natural and human systems that interact at multiple spatial and temporal scales and are influenced by within system non-linear dynamics, thresholds, feedback loops, time lags, and surprises along with external factors outside the system. The understanding of CNHS has become more imperative as the global landscape is increasingly connected and there is greater need to improve resilience and adaptation in social ecological systems being affected by natural disturbances and altered by climate change. Integrated social and ecological research is seen as offering the greatest promise to understanding these systems and improving resource management, adaptive capacity and resilience of social and ecological components. However, to be successful, such research must overcome the challenges of disciplinary language, differences in conceptualization and theoretical approaches, and the intrinsic complexity of integrated research. Models have become a central tool in studying CNHS and arriving at policy- and management-relevant research results. Models useful in CNHS research include conceptual models that identify system components and their interactions, numerical models that represent the behavior of the system and components, and computer simulation models, including agent-based models that attempt to represent individual players, or groups of players, on the landscape.

CHANS Project Presentation Abstracts

Tom Spies – Coupled Natural and Human Systems in Fire-Prone Landscapes: Interactions, Dynamics, and Adaptation

Thomas Spies[1], John Bolte[2], Alan Ager[1], Jo Albers[2], John Bailey[2], Susan Charnley[1], Paige Fischer[1], Jeffery Kline[1], Christine Olsen[2], Rob Pabst[2], Emily Platt[2], Bruce Shindler[2], Brent Steel[2], Michelle Steen-Adams[3], Cynthia Schwartz[2], James Sulzman[2], and Eric White[2].

[1]PNW Research Station, USDA Forest Service, [2]Oregon State University, [3]University of New England

We are exploring how heterogeneity, feedbacks, and external drivers in fire-prone landscapes of the eastern Cascades of Oregon can lead to complexity and limit the development of more adaptive approaches to policy and management. We are also looking at how institutions and social networks can counter these limitations and promote adaptation. We have developed a conceptual model that includes a robust characterization of social subsystems and have built an spatially explicit agent-based model. Our agent based model, Envision, which incorporates existing ecological models of vegetation and fire

and is based on empirical studies of land owner decision making, is being used to explore alternative management and fire scenarios with land managers and various publics. Social-ecological linkages in the model include, landowners altering forest vegetation and fuel beds through mechanical treatments, and prescribed fire, and exposure to fire events altering how private landowners manage their forests and engage in fire-wise behavior.

Key findings so far include evidence that private landowner risk perceptions and actions are sensitive to wildfire probability and probability of damage. We also have found that scenarios with increased fuel treatments reduce the amount of stand-replacement fire compared to with no management or current levels of management. These scenarios have different effects on habitat trends for wildlife species. We have characterized the social networks of the study area and found that fire protection and forest restoration networks interact less than expected by chance and that membership in social organizations has an effect on engagement forest management activities related to fire. Lessons learned include the observation that these large interdisciplinary efforts require long periods of time to attain their goals and that field trips and engagement with stakeholders are important parts of the process. We have also learned that science gaps for social science are larger in many ways than for biophysical science.

Patrick Bourgeron & Jelena Vukomanovic – CNH – Dynamics of Coupled Natural & Human Systems in the Colorado Front Range Wildland/Urban Interface: Causes and Consequences

Abstract currently unavailable.

Bart Johnson & Max Nielsen-Pincus – Climate Change Adaptation Planning: An Alternative Futures Approach

Bart R. Johnson[1], Max Nielsen-Pincus[1,2], John P. Bolte[3], David W. Hulse[1], Alan A. Ager[4,], Robert G. Ribe[1], Scott D. Bridgham[1], Gabriel I. Yospin[1], Timothy Sheehan[1,5], Jane A. Kertis[4], Dominique Bachelet[5], Ronald P. Neilson[4], David Conklin[3,5], Constance A. Harrington[4] and Peter J. Gould[4]

[1]University of Oregon, [2]Portland State University, [3]Oregon State University,
[4]PNW Research Station, USDA Forest Service [5]Conservation Biology Institute

Landscape planners typically derive a single "best" solution for every problem. But rapid global change is forcing human societies to face conditions unlike those ever experienced before. Looking toward the 50-100 year future reveals key uncertainties about climate change impacts and people's responses that make it impossible to identify the best solution to many problems. We developed an interactive modeling system to simulate the interactions and feedbacks among climate change, wildfire, forest succession, urbanization, and land management within a GIS framework using an agent-based model of human decisions. The agent-based model Envision was used as the core of a coupled systems model that included an agent decision submodel, a mechanistic wildfire submodel, a

climate-sensitive vegetation succession submodel, a spatially explicit population growth submodel, and landscape production submodels that provided feedbacks from the landscape to agent decisions. We applied the model within an alternative futures analysis framework to explore whether restoring fire-adapted oak ecosystems might reliably reduce wildfire risk in the Willamette Valley under the uncertainties of climate change and population growth. We engaged stakeholders to specify alternative fuels and restoration treatments, parameterize fire behavior and effects under different fire weather conditions, and establish overall scenario contrasts and policy approaches. We performed 50 simulations for each of 12 contrasting scenarios (two climate x two land-use x three wildfire management scenarios) for 50 years (2007-2056) in an 80,000 ha area in Oregon's southern Willamette Valley, USA. Using large output data sets that track every landscape change over time, we partitioned wildfire risk in space and decomposed risk over time to identify when, where and under what circumstances wildfire may occur and homes may be threatened. Our approach allows planners and citizens to explore large numbers of potential future landscapes so as to identify robust policy approaches that appear likely to perform well despite the uncertainties of global change impacts. The results brought focus to linkages between actions, uncertainty, risks and tradeoffs. For example, the shifting tradeoffs among reducing wildfire risk and conserving oak grassland biodiversity under different fuels management approaches and different intensities of climate change and rural development. They also exposed key challenges, for example the tensions of waiting for clear climate trends to emerge versus acting proactively before crisis. In many ways, the system served as much as a problem generator as a problem solver. For example, encouraging grassland restoration to reduce fire intensity could increase landscape-scale risk should grassland fires spread rapidly into untreated forest, requiring further steps to intensify home protection in untreated areas of the landscape. Finally, the modeling approach we developed supports probabilistic thinking in the face of no analog futures through exploration of multiple dimensions of future surprise – the what, when, where, how and why of how wildfire events outside the scale and intensity of historical wildfire might be anticipated and proactively addressed.

Christopher Roos – Multi-Century Perspectives on the Fire-Climate-Society Nexus

Christopher Roos[1] and Tom Swetnam[2]

[1]Southern Methodist University, [2]University of Arizona

Forests and communities are now extremely vulnerable to large, severe fires during droughts as a consequence of fire exclusion and other land use practices. The extent to which this vulnerability is influenced by climate and land-use remains unclear. Multi-century case studies from dendrochronology reveal that certain types of fire are critical for maintaining the health of forests in the Western U.S. In semi-arid pine forests of the Southwestern U.S., frequent surface fires clean out understory plants, maintain an open stand structure, and improve the resilience of these forests to severe droughts. The removal of these frequent, cool, surface fires during the 20th century by fire suppression has changed the fire-forest dynamic. Now, in the context of global warming, severe and

extended droughts have turned Southwestern forests into tinderboxes that threaten homes, infrastructure, and the very forests that have attracted so many human communities to these landscapes. The expansion of the human built environment into these fire- and drought-prone forests has created a unique fire and forest management problem referred to as the Wildland Urban Interface or WUI.

Just as paleo-records have illuminated the dynamics of forest fire regimes and their relationship to climate, we look to the past through interdisciplinary socio-ecological research to understand the climate vulnerabilities of human and ecological communities at the WUI. The last century seems to indicate that human activities at the WUI make these contexts particularly vulnerable to climate-driven perturbations in fire size and severity. However, many of these landscapes were home to agricultural populations for centuries before Euroamerican colonization, seemingly without creating climate vulnerabilities that we are currently experiencing. In the southwestern Jemez Mountains in particular, more than 8,000 Ancestral Jemez villagers lived at population densities equivalent to the modern WUI for at least three centuries, through several severe droughts. We have brought together the insights of archaeology, dendrochronology, paleoecology, traditional ecological knowledge, and dynamic computer simulations to investigate the complex, long-term couplings of forest ecosystems, fire regimes, climate change, and human communities in the Ancestral Jemez landscape. This interdisciplinary research focuses on evaluating whether or not particular fire-forest-society relationships can enhance or erode the resilience of these fire-adapted forests. Our ongoing research addresses this question at multiple scales from the daily lived environment of the human communities, across their agricultural landscape, and beyond to encompass a mosaic of humanized, coupled human-natural, and natural landscape patches.

Travis Paveglio – Assessing and Adaptively Managing Wildfire Risk in the Wildland-Urban Interface for Future Climate and Land Use Changes

Travis Paveglio[1], Tony Prato[2], Tyron Venn[3], Bob Keane[4], Jane Kapler Smith[4], Dan Fagre[5], Keith Stockmann[4], Yan Barnett[2]

[1]University of Idaho, [2]University of Missouri, [3]University of Montana, [4]USDA Forest Service, [5]USGS

This presentation introduces the conceptual and methodological basis behind the FIRECLIM (wildfire and climate) project funded by the Dynamics of Coupled Natural and Human Systems program of the National Science Foundation. The FIRECLIM project focuses on the creation and implementation of an integrated model for simulating wildfire risk in the wildland-urban interface (WUI) for Flathead County, Montana. The FIRECLIM model: (1) modifies the FireBGC and FSim models to simulate future vegetative growth and the likelihood of wildfires for individual residential properties in the wildland-urban interface (WUI) under the A2 climate change scenario; (2) employs the IMPLAN and RECID2 models to simulate future residential development in the WUI under moderate economic growth and a variety of land use policies; and (3) simulates the wildfire-related,

adaptive decisions of three agents or stakeholder groups (i.e., land and wildland fire management agencies, land use planners, and homeowners) based on minimizing net wildfire risk faced by the three agents. One important output of the FIRECLIM model is expected residential losses from wildfire (ERLW), which is a probabilistic, monetary measure of damages calculated for each individual property in the study area. ERLW values can be aggregated to different scales, are calculated using property specific data, and incorporate market and non-market values at risk from wildfire.

The FIRECLIM model has been used to simulate the variables listed above for Flathead County, Montana, during a 50-year evaluation period (i.e., 2010-2059) consisting of five, consecutive 10-year subperiods. It has also been used to test the impact of different land use planning scenarios on wildfire risk. Ongoing work uses multi-criteria decision making processes to simulate the adaptive forest management practices of six land and wildfire management agencies (e.g. U.S. Forest Service, Plum Creek Timber Company, etc.).

Empirical results obtained using a simplified version of the FIRECLIM model show that: (1) nominal expected residential losses from wildfire (ERLW) increased from $1,836,816 in 2000-2009 to $33,872,543 in 2050-2059, or 1,744%; (2) real ERLW increased from $1,836,816 in 2000-2009 to $8,937,346 in 2050-2059, or 387%; (3) nominal and real ERLW for 10-year subperiods peaked in 2020-2029. Hypothesis testing showed that: (1) there is a statistically significant increase in ERLW for Flathead County's WUI during the period 2010-2059; and (2) for every 10-year subperiod, differences in ERLW across 21 smaller neighborhoods in Flathead County are statistically significant. Other results surrounding land use planning confirm that: (1) the area of residential parcels in the WUI, number of residential structures in the WUI, and size of the WUI decrease as the land use policy becomes more restrictive relative to the policy that existed in 2010; (2) the three WUI metrics are substantially lower for the moderately restrictive (MR) and highly restrictive (HR) polices than for the 2010 policy; (3) there is a greater percentage decrease in ERLW between the 2010 and MR policies than between MR and HR policies; and (4) ERLW decreases significantly between the 2010 and MR policies, but not between the 2010 and HR policies.

Forrest Stevens – Changing Communities and Forests of the Inland Northwest: Perceptions and Realities

Forrest R. Stevens[1], Joel Hartter (PI)[2], Lawrence Hamilton[3], Mark Ducey[3], Russell Congalton[3], Michael Palace[3]

[1]University of Louisville, [2]University of Colorado, Boulder, [3]University of New Hampshire

Our USDA-funded Communities and Forests in Oregon (CAFOR) project focuses on "hazard mitigation practices of rural communities" with three emphases for research: vulnerability at multiple scales; risk perceptions and behaviors; and land-use decisions. Forests in the Wallowa-Whitman Ecosystem (WWE) of northeastern Oregon are threatened by the risk of catastrophic insect outbreaks and wildfire. Forecasted growth in these natural hazards

implies dramatic socio-economic costs to communities that are dependent on forests and their ecosystems. Coupled with that risk is ongoing ecological deterioration concurrent with declining commodity timber-production and changing management goals on public lands, all of which has completely transformed the ways that forests are perceived, valued, and managed. We apply a multi-scalar, multi-disciplinary approach to examine risk perceptions and behavioral reactions to forest management with implications for land use and housing. Further, we focused on the dynamic feedbacks between landscape changes, land use conversion, parcelization, and the strategies people use to respond to risk in the WWE. The WWE is also an example of a much broader forest ecosystem decline problem affecting landscapes and communities across the United States.

Major findings include a detailed analysis of the 2011 CAFOR telephone survey (1,585 interviews), including integration with data from surveys in 11 other mostly rural regions (more than 10,000 additional interviews) that asked some of the same questions. Our analysis highlights how "environmental concern" has several different dimensions, not all of which correlate with worldview and demographic characteristics traditionally thought to predict environmental beliefs. Integrated analyses using mixed-effects modeling puts CAFOR results in broader context by showing patterns of both common and place-specific effects on individual levels of environmental concern. We also conducted a detailed analysis and interpretation of data from the mail survey of forest property owners. Among 455 forest owners surveyed forest management activities occurred more often among individuals who perceive high risks from public land management practices, and also those who have participated in forestry extension activities. A generalized structural equation modeling analysis considered risk perceptions and participation as intervening variables that are predicted by individual background characteristics; and that in turn affect decisions to actively reduce fire risks on an individual's land. We also have begun to merge a satellite-derived land cover change analysis from 1984-2011, as well as combining ground-based measurements of forest conditions across different land owner types as a way to look at associations between forest conditions and spatialized survey responses about forest condition perceptions. This work is ongoing and represents an interdisciplinary approach to uncovering disconnects between perceptions about forests and their actual conditions, as well as how that relates to management activities at multiple scales. We have disseminated this work not only through academic avenues but it is also being incorporated into extension and education materials for stakeholders throughout the study region.

Related Individual Project Abstracts

David Bowman – Pyrogeography and the nexus with coupled human and natural systems (CHANS) in flammable landscapes

School of Biological Sciences, University of Tasmania

'Pyrogeography' is an emerging field that that strives to develop a holistic way of understanding variation of landscape fire activity in space and time. A key objective of

pyrogeography is understanding to what degree landscape fire set by humans has overwritten natural fire activity, and whether these changes have had substantial ecological knock-on effects globally: therefore pyrogeography and CHANS in flammable landscapes are closely related. I illustrate pyrogeographic research (and implicitly nexus with CHANS) using two Australian examples (a) Ecological effects of Aboriginal landscape burning and (b) Human health impacts of biomass smoke. Features of both case studies are the integration of a diverse range of field, lab and computational methodologies analysed using advanced statistical and geospatial analyses. Both studies are more concerned with diagnosis and description than prognosis and prediction. The Aboriginal landscape burning study is organised around 'natural experiment' that contrasts of areas under active Aboriginal management with areas that are no longer managed by Aborigines. Biological data were acquiring by field survey, molecular and geochemical analyses, remote sensing analyses were conducted to map fire season and extent, and ethnography and observation was used to document traditional ecological knowledge systems. The prime motivation for this research is to better frame fire management philosophies, and help resolving debates about human impacts on biodiversity. The biomass smoke research was also transdisciplinary between human health and the environment (therefore within the remit of the emerging Ecohealth paradigm) involving on environmental epidemiological analyses of hospital records using smoke exposure estimates derived from urban air shed monitoring arrays, remote sensing analyses of smoke plumes and smoke events in urban airshed reported in the media. Predictive models of smoke exposure were developed to provide public health warning using pollution thresholds identified by the epidemiological analyses as being dangerous to the health of some sectors of the community. In summary, these studies can be considered as either examples of CHANS in flammable landscapes, or fitting within the broader field of pyrogeography.

Brandon Collins – Reconciling discrepancies between historical and contemporary fire-forest interactions to inform restoration efforts

PSW Research Station, USDA Forest Service

Many forests adapted to frequent, low- to moderate-severity fire regimes in the western US are experiencing uncharacteristically high proportions of stand-replacing fire. A recent assessment of land cover change in California demonstrated that fire now accounts for a greater proportion of forest "loss" than any other activity (e.g., timber harvesting, development). Given the observed and predicted future trends toward increasing temperatures and longer fire seasons it appears that fire-driven forest change will only continue to increase. Recent fire activity in the northern Sierra Nevada has been particularly high, relative to the rest of the range. Since 2000 there have been three large wildfires (>10,000 ha) that have burned in primarily mixed-conifer forests, burning a total of 73,000 ha. Cumulatively, 34% of the area burned in these three fires was stand-replacing (> 95% dominant tree mortality). Perhaps more important than the total proportion is the distribution of stand-replacing area, which tended to be aggregated in large patches (defined here as >1000 ha). In these three fires large patches accounted for a disproportionate amount of the total stand-replacing area, which will likely have adverse

impacts on forest regeneration and California spotted owls. The observed effects of these large fires point to a pressing need to implement landscape-scale fire-mitigation efforts (e.g., fuel reduction/restoration projects). However, such efforts are difficult where there is a complex arrangement of land ownerships, federal land designations, and human communities, as is the case in the northern Sierra Nevada.

Toddi Steelman – U.S. Wildfire Policy as Socio-Ecological Problem

School of Environment and Sustainability, University of Saskatchewan

Wildfire policy in the United States faces significant challenges. Evidence suggests that we could be doing a better job to reach the stated goals associated with wildfire policy. One hypothesis about why wildfire policy does not function as well as it could may be because the biophysical changes in fuels, wildfire behavior and climate have created a new set of conditions for which our existing policies, are poorly suited to address—problems not unique to the realm of wildfire. When we see historically stable ecological processes tipping toward a shift, governance systems are often unprepared to deal with such rapid and large scale change. Wildfire regimes globally may be tipping toward such change. The inability to match ecological changes with appropriate policies can be attributed to limited knowledge about how these institutions fit their ecological systems, the sheer complexities of socio-ecological systems that result in entrenched uncertainties, and ingrained interests resisting change or the basic challenge of institutional reform.

The findings from this analysis suggest that there is disconnect between the specific institutions that have been crafted to address exogenous controls and slower socio-ecological dynamics, especially when compared with those that address faster socio-ecological dynamics. Climate change is driving exogenous and slow ecological variables and the growth of the wildland urban interface (WUI) and funding priorities on suppression are driving fast social variables. Policy attention is focused primarily on fast, social variables. This disconnect suggests a mismatch in the fit of socio- ecological drivers in wildfire governance regime with the policies aimed at addressing the key problems.

Out of this analysis emerge three policy implications. First, the long term global policy for mitigating greenhouse gases (GHGs) will ultimately address the drivers behind changing in wildfire behavior. Second, the absence of effective global action on climate change, shifting federal budgetary resources to state and localities to deal more proactively with prevention and preparedness and away from suppression will create the best opportunity for context appropriate fire adaptive communities and resilient landscapes in the short and medium term. Third, the growth of the wildland urban interface (WUI) is a key driver in expenditures on suppression and until incentives are more appropriately aligned to reduce WUI growth and create greater homeowner/landowner responsibility, funding imbalances that favor suppression over prevention and preparedness is likely to continue.

Jessica Leahy – Forest-based CHANS in Maine

Jessica Leahy, Emily Silver, and Erin Simons-Legaard

University of Maine

In this presentation, we presented several CHANS projects completed or underway at the University of Maine. Maine's private individual landowners own 32% of the forest acreage in Maine (5.6 million acres) and account for 25% of the timber harvest volume. Agents were typically private forest landowners and applications were related to better understanding landowner decision-making processes and related social and biophysical impacts. Rules and decision making was guided by social psychology, communication, and environmental attitude and behavior theories. All projects involved agent-based modeling although the models were built using 1) self-designed using python and databases, 2) Netlogo, and 3) LANDIS-II. Given the expertise of the research team, the coupled human and natural systems models had a heavy focus on the social systems. The portfolio of projects at the University of Maine relates to CHANS concepts and theories such as human-forest interactions; flows, feedback loops and surprises. Benefits have included an integration of knowledge, the opportunity to work on interdisciplinary teams, the involvement of stakeholders in model design for increased knowledge-to-action, and the training of a new generation of graduate students.

Jeremy Littell – Climate and Fire in Landscapes of Western North America

United States Geological Survey, Alaska Climate Science Center

The relationship between climate and wildfire in landscapes of western North America has received considerable scientific attention in recent decades. While the role of extreme weather events in the ignition and spread of fires had long been clear, the role of longer-term climate in the seasons and years preceding fire events received less attention. It is now clear that the occurrence of fires and the area burned by those fires is affected both by climate and by weather, and weather interacts with local conditions (such as topography and vegetation) to affect other properties of fire regimes including fire intensity, severity, and ecological responses to fires. However, the climatic influences on fire vary with vegetation type, so considerations of sub-regional fire-climate relationships are required to understand the role of climate in the fire regimes we currently manage as well as the ways those fire regimes will change with climate change and future management efforts. Climate fire relationships are therefore important in understanding the ways that coupled human-natural systems evolve in the wildland-urban interface. In particular, the physical and ecological feedbacks between climate, fire, and vegetation both influence and are influenced by human activities, including fuels management, fire suppression, and socio-economic context. Regional manifestation of climate change impacts will likely unfold differently in different ecosystems due both to their different fire-climate relationships and to their differential history of human management of fuels, and this heterogeneity is a feature of the future coupled human-natural systems in wildland-urban interfaces.

Physical-ecological relationships alone are therefore not sufficient to produce transformational knowledge about living with fire in modern and future landscapes.

James Millington – Fire and Agents in Mediterranean Basin Landscapes

Department of Geography, King's College London

In the Mediterranean Basin, humans have been living with fire for thousands of years, often using it as a tool for landscape management. For example, fires have been used to clear land and improve pasture and in recent years it has been estimated that 95% of fires in this region are initiated by humans. However, recent economic, political and technological changes mean that many 'traditional' landscape management practices are being lost. Recent state-led fire management policies have emphasised fire exclusion, shifting landscape management from characteristic traditional pre-industrial management (in which fire is actively used) to the contemporary post-industrial state. In many landscapes, the decline of traditional management after prolonged history has resulted in substantial transformations in both their structure and function as natural succession processes resume unaltered. In some areas, such as EU Special Protection Area number 56 (SPA 56) 'Encinares del río Alberche y Cofio' in central Spain, large shifts in land area from arable and pasture to shrubland have been observed because farms have been abandoned as younger inhabitants have migrated from rural to urban areas.

To study such landscape dynamics we have taken a variety of empirical and modelling approaches. To provide empirical evidence of changes in relationships between forests, fire and people in central Spain we have examined the chestnut forest ecosystems of Casillas and Rozas de Puerto Real. Although these municipalities are situated in close vicinity to one another in the mountains of Gredos, they exhibit markedly different fire managements as a result of their disparate jurisdictional location under two different, unevenly developed, autonomous communities within the Spanish state (Madrid and Castilla y Leon). We have found that while in Casillas many traditional fire practices have continued, in Rozas they have mostly been abandoned. Differences seem to be influenced by cascading, interrelated and locally mediated transformations in land use, land tenure and cultural fire use driven by the state-led industrialization and post-industrialization processes taking place in Spain since the 1950s.

To explore future possible dynamics in SPA 56, we developed a socio-ecological landscape-simulation model that integrates an agent-based model with a grid-based representation of ecological succession and disturbance. We have used the model to investigate how the spatial configuration of land-tenure influences trajectories of land-use change and consequent effects on wildfire risk. Enabled by the spatially-explicit and disaggregated characteristics of the simulation modelling used, we found that changes in wildfire risk were not spatially uniform in the scenarios examined and that they varied according to land-use composition and spatial configuration. This highlights the importance of considering these changes in a spatially explicit manner and as the result of individual agents' actions. Humans have acted as agents of change in fire-prone landscape of the

Mediterranean Basin for millennia. By harnessing empirical and modelling approaches such as these, and comparing results with other fire-prone landscape around the world, we can better identify how fire and human agency can interact to ensure appropriate landscape management in the future.

Cassandra Moseley – Political Economy of Forests and Fire in the American West

Ecosystem Workforce Program, University of Oregon

This presentation examined how governance of fire and public forests is changing in the American West. This research suggests that fire and forest governance is highly networked, and includes entities such as community-based organizations that have emerged over the last two decades. In some cases, these community-based organizations are playing roles that the public and private sector played in the past. For example, they have been conducting analyses and other activities that federal land management agencies historically performed. Similarly, some community-based organizations have being doing business development work in areas of hazardous fuels reduction and wood products utilization. In doing this work, they do so in ways that both cultivate institutional change and replicate old institutional dynamics, thereby fostering a slow process of innovation.

Paige Fischer – Understanding Capacity to Adapt to Increasing Wildfire Risk through the Study of Organizational Network Structure in Central Oregon

PNW Research Station, USDA Forest Service

Wildfire size and frequency are expected to increase in future climate scenarios for the U.S. West. Because wildfire burns irrespective of property boundaries and land designations, organizations involved in governance of fire-prone landscapes could arguably benefit from communicating about and coordinating plans and actions. We investigated the patterns of interaction among organizations involved in fire-prone forest and wildfire management in Central Oregon for evidence of structural conditions that promote adaptive capacity, specifically the ability of diverse groups to learn, store knowledge and experience, and engage in creative, flexible decision-making and problem-solving. Through social network analysis of data gathered through interviews we explored the relationship between network structure and organizations' institutional beliefs, values and behaviors regarding fire and forest management. We used social capital and organizational learning theory to interpret the findings and identify implications for adaptive capacity. Preliminary findings indicate that organizations with fire protection and forest restoration goals do not frequently communicate or cooperate with each other, suggesting that opportunities for joint problem-solving, innovation and collective action may be limited.

Alan Ager – A CHANS approach to wildfire risk mitigation planning in the wildland urban interface

PNW Research Station, USDA Forest Service

We developed a conceptual framework that combines recent advances in wildfire simulation modeling with social science, including network analysis, to create a coupled biophysical and social systems approach to managing and mitigating wildfire risk in communities located in fire-prone landscapes. The framework relies on wildfire simulation to identify spatial patterns of wildfire risk and transmission within "firesheds" around communities, and social science to understand wildfire risk perceptions and behavior and collaboration among landowners, land management agencies and other organizations. The approach provides an improved method for defining the spatial extent of wildfire risk to communities compared to current planning processes, and creates an explicit role for social science to improve understanding of community-wide risk perceptions and to predict landowners' capacities and willingness to mitigate risk by treating hazardous fuels and conducting Firewise activities. This coupled systems approach can contribute to a more effective implementation of the new Federal Cohesive Strategy, and provides a more robust framework for prioritizing federal fuel management investments.

Summaries of Discussion Sessions

On the morning of the second day, the group participated in a facilitated one-hour reflection about key topics that emerged during the presentations and field trip the day prior. Major points from this discussion can be found in the Appendix.

Major Themes and Key Questions

Prior to the workshop, participants were asked to submit their "burning questions" relevant to CHANS research and fire research. The workshop organizers grouped the questions into eight major themes. Each theme is below with the "burning questions" in priority order as determined by workshop participants. Participants were assigned to work in small groups on these questions. Notes from these small group discussions can be found in the Appendix.

Theme 1: CHANS concepts

Burning questions:

1. What are the major feedbacks between ecological and human systems, and what is their relative importance in controlling CHANS behavior?
2. How can we improve documenting, describing, modeling, and otherwise accounting for feedback loops in CHANS models?
3. In what circumstances should CHANS in fire-prone landscapes be conceptualized from the bottom-up (smallest unit of organization) *vs.* top-down (largest unit of organization)?
4. What are differences and similarities of current approaches to the study of CHANS? Should CHANS research be primarily directed to prediction or description of landscape fire activity?
5. What aspects of historical CHANS in fire-prone landscapes might be useful for anticipating CHANS in future (no-climate analogue) fire-prone landscapes?
6. What is the relationship of the CHANS concept in fire-prone landscapes to the new field of pyrogeography and the concept of the Anthropocene?
7. Is a stable CHANS possible in fire-prone landscapes, and should managers/policy makers have that as a primary goal?

Theme 2: Modeling

Burning questions:

1. What are the options for modeling CHANS in fire-prone landscapes and how are these different models useful in developing theory or applications to current management problems?
2. In what circumstances are different types of modeling useful in CHANS research? (and how are they appropriately evaluated?)

3. How can CHANS simulation modeling be embedded into societal mechanisms of change so as to enhance adaptive capacity?
4. How can we model human behaviors more accurately when individual behavior cannot simply be aggregated up to the community level?
5. How do researchers design and agree upon consistent dependent variables for simulations of future wildfire risk or landscape processes?
6. How can illegal activities in fire-prone landscapes (e.g. arson) be incorporated into CHANS studies?

Theme 3: Role of science and applications to society

Burning questions:

1. How do we help people, from citizens to planners, learn to think probabilistically about wildfire risk? How do scientists (individually or *en masse*) best deliver this information? Who are the audiences?
2. How do stakeholders perceive CHANS models, and what steps can be taken to improve this situation? Is this necessary for decision-making?
3. Will land management solutions best be achieved by top-down or bottom-up approaches?
4. What role can/should scientists play in policy debates related to wildland fire management?
5. How can wildfire research bridge gaps in the often incongruent temporal and geographical scales characterizing social and biophysical systems?

Theme 4: Policy and institutions

Burning questions:

1. Can we better understand the multi-level spatial and temporal drivers in these CHANS such that they can be incorporated into policy relevant decision making? What are the barriers to doing so? What decision space do we really have?
2. What societal mechanisms are most needed to support coordination of fuels treatment patterns on mosaics of privately owned lands to reduce wildfire risk at landscape scales?
3. What are institutional and procedural issues preventing us from doing a better job of dealing with wildfire?
4. Under what conditions does land management and/or conservation policy backfire as multiple thresholds are breached?
5. Can air quality regulators recognize the natural role of fire in dry forests and exempt prescribed and managed wildland fire smoke from air quality observations?

Theme 5: Management and markets

Burning questions:

1. What are the interactions/tradeoffs between management for fire protection and management for forest restoration/resilience?
2. What is the capacity of fuels treatments and fire management to overwrite climate drivers of landscape fire activity?
3. What incentives can be put in place to create a relatively robust market for biomass to treat wildfire risk?
4. What is the role of the US Forest Service, and other public land management agencies that allow commercial timber harvesting, in providing timber-based jobs/business opportunities to local communities?
5. How can dry forest landscapes be integrated into an emerging carbon economy?
6. How do we reconcile the drastic change in contemporary forest conditions (e.g., stand density, species composition and fuels accumulation) with the habitat "needs" of sensitive wildlife species?

Theme 6: Fire effects, resilience, and adaptation

Burning questions:

1. How do we measure and capture the tradeoffs between and within different environmental, social, and economic benefits from reduced wildfire risk?
2. How will changing wildfire regimes influence the relationships people have with landscapes? What is a "fire-adapted community" when considering CHANS?
3. What are they key ingredients for creating "fire permeable" landscapes that allow fire to move through the WUI with low risk to people and property?
4. What are sustainable objectives/outcomes for human communities and ecosystems in fire-prone landscapes?
5. Given the need for fire in many dry forest types (both for restoration and for fuels reduction) can human communities living within and adjacent to forests tolerate the inconveniences associated with increased prescribed/managed fire and resultant smoke?
6. To what extent does the strategy of restoring native grasslands from successional forest to reduce fire severity pose a risk of rapidly spreading wildfire to untreated areas under extreme weather conditions?

Theme 7: Social organizations/networks/cultures

Burning questions:

1. What are the appropriate scales for research in fire-prone CHANS? Do large-scale, hierarchical social and ecological teleconnections undermine local efforts? Is local/landscape/place-based efforts a useful co-strategy?
2. How do social networks change over time and influence perceptions of wildfire risk, management and landscape outcomes?
3. How do we account for the social diversity of stakeholders exposed to or utilizing wildfire when managing landscapes? What are the most appropriate metrics of fire impacts on human systems?

4. What kind of cultural experiences or institutions are necessary to sustain healthy fire-prone communities in the face of demographic/economic/technological climate changes?
5. What is the role of local history in creating sustainable communities in fire-prone landscapes? Is there a role? Personal experiences? Shared or collective experience/social memory?

Theme 8: Climate interactions and scale

Burning questions:

1. Are there generalities in the mechanisms amplifying the impact of climate variability on disturbances, their connectivity among landscapes, and the interactions with land-use and land-cover change?
2. Are there generalities in the interactions and tradeoff among ES and thresholds? Have we identified the relevant metrics of risk, costs, and benefits?
3. What are the most critical known climate change wildfire risks… how serious? how soon? how certain are we?
4. What are the scale dependencies of ecosystem service (ES) correlations? Of the drivers of ES and their interactions? Of rates of land use change?
5. What are the most important specific actions/activities needed to slow climate change? What are the most important specific actions/activities needed to adapt to climate change?

<u>New Ideas, Observations, and Comments</u>

At the start of the final day, workshop participants were asked to each share new ideas, observations, or comments about CHANS and fire research. These comments were very diverse. They have been roughly grouped by topic area here:

The Uniqueness and Challenges of Fire-Prone CHANS

Fire-prone systems over the millennia were perfect CHANS. However, modern humans have decoupled that. There may be opportunity to recouple it now, but humans are more intensively influencing the system with suppression. Fire-prone CHANS may be different than other CHANS because of the effect one individual can have – one person can start a fire and change a system. Humans also have the ability to influence the behavior of fire as a hazard, which is different than some other CHANS. A challenge of studying fire-prone CHANS is understanding how they are nested within hazard CHANS, which is nested within overall CHANS. Which pieces are part of which systems? It is not always clear. Finally, fire-prone CHANS were viewed as powerful within the Anthropocene. One idea that was outside the box was the potential plausibility of substantial, large social change processes, such as the WUI changing from upper class to lower class residents as those with resources flee the high risk areas. To consider this scenario, we will need to better capture the interplay between rural poverty and landscape conditions because there are likely different impacts or behaviors that we don't currently consider.

Contributing to the System as Researchers

Questions were posed about how we as researchers can contribute to fire-prone CHANS in different ways, from ecological to social impacts. A question was also posed about how we present our work effectively to change the system. One idea that emerged is the pervasive need for vignettes and case studies to better understand these systems through information and cross-cutting characteristics. Such examples can offer insight into really hard problems and they are generally easily absorbed by target audiences. Some components of CHANS research may also be morphed into simple management frameworks, such as top-down versus bottom-up processes.

Methods, Models and Other Tools

The tensions in the way we think about these fire-prone systems were discussed. Simply, there are so many different ways to examine CHANS. We use different methods, use models in different ways, view the world through different lenses, and have a variety of approaches to choose from. From a review of CHANS fire projects, we appear to be inadvertently polarized on the applied research side. The basic research side also has merits, as does the space in between. Among the projects represented at the workshop, there is a diversity of approaches, spatial and temporal scales, and geographic scopes. It was also recognized that when we choose our own approaches we do so based on our personal characteristics and background, and our choice inherently makes it impossible to learn some things. The tension between the need to generalize and the need to be specific was also acknowledged. The role of case studies and vignettes surfaced in this conversation as well as one mechanism for sharing findings that may not be generalizable but could be useful across broad audiences.

Other topics under this theme include the role of assumptions in our models and how they affect results, the difference between a decision tool and a discussion tool, the importance of being very clear about unit of analysis, and the need to demonstrate cross-scale interactions in our work. Additionally, CHANS research was recognized for simultaneously attempting to address multiple contradictory concepts and viewpoints in one approach.

Issues of Gradient and Scale

The importance of context when it comes to landscape-level management was an important concept that was discussed. It is hard to generalize across these landscapes; it is true in ecology and even more so when considering the social system. The mismatches between ecological and social scales and coming to grips with that was also a key issue, as was the different scales at which people conceive the coupled system: ecoregion, county, community, place, or other. There was interest in exploring the transitional zone and gradient in fire-prone landscapes where the land shifts from primarily fire-driven to human process-driven. Finally, there was considerable reinforcement about thinking at the landscape scale, although it was acknowledged that this is juxtaposed against Forest Service processes where things happen at the ranger district scale. As researchers we need to help others to think about landscapes.

Networks and Connectivity
The importance of networks in transmitting fire or behaviors through the landscape was discussed from the ecological and social standpoints, as well as the coupling of those networks. The role of social networks in fire prone systems and multi-scalar and temporal interactions emerged as a key interest; we need to understand the role of social networks in mediating these fire and other networks.

Surprise and Other Big Processes
There was considerable discussion around how we deal with surprise in CHANS. Surprises happen in the natural and social worlds, and we cannot predict them. However, it was generally agreed that modeling proxy surprises was useful. We may not get the surprise exactly right, but we would learn from how the system reacts, particularly the range of responses for different subsystems in fire-prone CHANS. Examples of surprises that came up included the 2008 global financial crisis and the rapid industrial growth in China with the resulting increase in log exports from the United States. Other external drivers were also discussed, and the importance of considering them. This included climate change, which was a focal topic. Specifically, we need to understand how climate change affects both biophysical and social systems and can result in uncertainties: people change their behaviors as a result of climate change—this can introduce non-linear responses and surprises. To examine this we could use approaches beyond just quantitative models to explain how systems work.

One thought expressed by several participants was how the workshop itself and sharing information about our projects made it more clear how many more things we could include in our analyses. Many of the examples discussed were global processes, and in general it left the group feeling like we are really just scratching the surface in studying fire-prone CHANS. Finally, the distinction between fast versus slow variables was an intriguing topic for many. Discussion on how we put those pieces together and how they intersect and tie to cross-scale interactions was important. It was also mentioned that slow variables may easily be overlooked because they can be beyond our normal temporal scale.

<u>Research Gaps and Needs</u>
Workshop participants were then asked to identify research gaps and needs. These comments were also very diverse. They have been roughly grouped by topic area here:

Climate and Resilience
Three research gaps were identified in this category. First, there is interest in understanding the biophysical and social buffers that can be adjusted that lead to resilience. Second, increasing our knowledge of how people have responded to landscape change/climate variability over long timeframes; there might be a source of information there that helps us understand future or current behavior. Finally, examining the interactions between patterns of fuel and landscapes, and how climate presses down on them; the relationship is likely nonlinear. There is a real need for work on the intersection of meso-scale and climate drivers, and a need for regional climate models.

Networks, Engagement and Culture

Networks were identified as a large research gap. There is interest in exploring how networks organize themselves and how they interaction with landscape patterns, as well as linkages across scales of space and time. We just do not know how ecological and social networks interact. It was also generally discussed that we do not know much about networks yet and may not know how to ask the right questions. A number of gaps were identified around engagement as well, from a variety of perspectives. It was noted that stakeholder engagement is central to CHANS and that we need to further develop this component and look for effective ways of accomplishing it. On the other end, how we justify our existence and share our knowledge with policy makers and decision-makers was identified as a large gap. Specifically, we need to be able to distill the complexity and uncertainty that is inherent in CHANS for use in management, as well as be more explicit about the scales we are studying and how our results are applicable. How to best do this is still a large gap. Finally, there are knowledge gaps around how to incorporate or use historical or ongoing culture to temper our modeling aspects. What is the importance of capturing culture in our study of CHANS, and what is the scale?

Models and Methods

There were a number of questions related to models and methods of studying CHANS that surfaced. How do we better or appropriately evaluate the model learning process? How do we do discussion support? How do you model mixed landscapes with large landowners? We need to figure out how to more accurately situate our models in time and history. We could further represent periods in the Anthropocene with world views and the response to drivers. There is also a gap about how to couple ecological networks with social networks methodologically, as well as how to capture the complexity of these systems more fully. Finally, there is a need for reflecting on the toolbox of models currently used, as well as the way in which we use them.

Surprises and Learning

Two topics were identified as research needs in this area. First, the ability to identify, define, and predict surprises. We need to think more creatively about surprises and how that may affect model output and system behavior. We also need to examine what happens when the surprises are from exogenous factors and think about how we bring them into CHANS models. Second, we need to consider how human systems learn and how we can take learning into account. Learning and change can take place quickly (e.g., new inventions) and may be a major influence on the system.

Research and Generalizability

Several gaps were identified related to the process of doing this type of research, and how it is generalized. It was acknowledged that simulation models such as those used in CHANS research are in their infancy and it will be a while before these models will be better 'predictors.' We are influenced by the systems in which we work and it is hard to compare across systems because of the unique characteristics of those systems. There is a need for more landscapes to be studied so more generalizable knowledge can be developed for local application, yet the importance of the particulars of place cannot be forgotten; we must maintain both to develop generalized principles that can be adapted for application in a

particular place. We also need to get better at representing the behavior of actors and processes on the landscape. Along with this, it was identified that managing tremendously large output files and the development of tools to comb through that output is a significant gap. And finally, one person advocated that there are no gaps, but that we need more confidence in conducting our work. We have methodological needs, but we can proceed with what we currently have.

CHANS Panel and Paper Discussions

A panel discussion of researchers involved in official CHANS projects took place on the final day. Notes from this discussion can be found in the Appendix. Detailed discussions about the two scientific papers that are being planned as products of this workshop also took place on the final day. Rough outlines of these papers can also be found in the Appendix.

Appendix

Group Reflections after Day One

On the morning of the second day, the group participated in a facilitated one-hour discussion about key topics that emerged during the presentations and field trip the day prior. Following are the major points that surfaced.

- The organization of the first day of presentations and field tour was applauded.
- A significant objective of this workshop overall was to learn about each other as fire and CHANS researchers, providing us all as scientists with resources and allies to draw on. It was also acknowledged that discussing our failures was just as important as discussing our successes because they things that we try that do not work are not published but we could learn a great deal from them.
- The question was posed – how is CHANS different from other research methods? It is anticipatory on a broad scale, which is different from most other methods. However, this leads to the question – how realistic is it that we can truly anticipate future trends or changes? Anticipating what may happen in a non-stationary system is a challenge.
- Just because we don't anticipate exactly what happens doesn't mean what we learn from our studies isn't useful. An example of an unanticipated event was the 2008 financial crash around the world. Such externalities are generally not considered in CHANS work. Another example of an externality that likely influences fire through fuel reduction and timber harvests is China's growth rate. We do not fully understand what is driving these systems and we do not attempt to include such global processes in our models.
- CHANS work is different from other types of research because of its applied nature and its approach of addressing management questions and challenges. CHANS research requires an interdisciplinary perspective. The findings are more relevant when they come from an integrated team such as in a CHANS approach. Such approaches also have more understanding in how management decisions are made because of all the research perspectives and disciplines that are considered.
- CHANS work is really in its infancy. Models can be the docking station between ecological and social things, but it is not the only way to do this kind of interdisciplinary work. Is CHANS really the right method? We do not know.
- A useful way to think about this work is looking for the meta-questions that need to be unpacked. Can many models be integrated into a single framework? Yes, many of our projects do this. But everything is not thrown into those models. Our modelling efforts are still maturing. All the components do not have to be used at the same time and people can have different objectives but we can still work with and learn from each other through our contributions to the larger project. Having a formal, rigorous approach that is still flexible is key.
- A key aspect of our research is dealing with uncertainty. Managers generally cannot respond with certainty and need to be okay in saying "I don't know" or "I'm not sure" though the agencies do not reward risk-taking, which is an outcome of uncertainty. The days of linear programming and optimizing to get the exact

answers are falling away, but agencies do not yet fully embrace the uncertainty and broad dynamics across multiple systems that are inherent in CHANS studies. Because of the uncertainties that are central to natural disturbances, it makes agency management of these systems and environments very challenging.

- The most important things that we learn through this research comes from developing and parameterizing the model, not from what the model says. The model does allow us to fit the pieces together and begin to understand the dynamics across multiple, disparate disciplines. We learn about the linkages between systems and how people are viewing the systems in order to understand the system and address challenges.
- One of the more interesting pieces from the presentations came from the network analysis work because it demonstrated that the agencies are not necessarily the major players, but that the NGOs and others are filling key gaps. Outside groups are sometimes doing the work of agencies when there is a strong need. Some of the challenges are simply too big for agencies to deal with alone. People are beginning to understand that wildfire is everyone's responsibility.
- In writing a paper that will come out of this workshop, we want to address both basic and applied dimensions. Looking at slow versus fast variables is important. Slow variables are key – they can drive a system yet people may not be aware of them. Identifying thresholds and tipping points is also important, as well as trying to predict surprises. We do not want the paper to be about agent-based models but about the nature of the connections and interconnections of the complex systems. What are the limiting features of CHANS systems? What features in these systems are key, and why are they key? When and why are local factors more important than something like climate? We need to drill down the basic relationships and interconnections. What are the general characteristics of CHANS that we currently do and don't understand well and what can be do about it.

<u>Small Group Discussions of Major Themes and Key Questions</u>

Prior to the workshop, participants were asked to submit their "burning questions" relevant to CHANS research and fire research. The workshop organizers grouped the questions into eight major themes. Workshop participants were then assigned to work in groups on the theme areas. Four themes were simultaneously addressed in the morning, and the other four themes were simultaneously addressed in the afternoon, so each participant attended two group sessions. Groups reported out to the entire workshop after each small group session. For each theme listed below, the "burning questions" that were identified are listed in priority order as determined by the workshop participants, and notes from the small group report out follow. Groups addressed the questions however they saw fit. Some groups did not address all questions.

Theme 1: CHANS concepts

Burning questions:

8. What are the major feedbacks between ecological and human systems, and what is their relative importance in controlling CHANS behavior?
9. How can we improve documenting, describing, modeling, and otherwise accounting for feedback loops in CHANS models?
10. In what circumstances should CHANS in fire-prone landscapes be conceptualized from the bottom-up (smallest unit of organization) *vs.* top-down (largest unit of organization)?
11. What are differences and similarities of current approaches to the study of CHANS? Should CHANS research be primarily directed to prediction or description of landscape fire activity?
12. What aspects of historical CHANS in fire-prone landscapes might be useful for anticipating CHANS in future (no-climate analogue) fire-prone landscapes?
13. What is the relationship of the CHANS concept in fire-prone landscapes to the new field of pyrogeography and the concept of the Anthropocene?
14. Is a stable CHANS possible in fire-prone landscapes, and should managers/policy makers have that as a primary goal?

Notes from small group report-out:

- In the US, Australia, and Europe, feedbacks include fire risk which drives fire suppression which drives fuel accumulation, institutions manage, and there is the external risk of WUI growth which increases hazard and probability of loss. Feedbacks discussion was further refined later in the workshop and is shown below in Figure 1.
- There is a major disjuncture between federal policies, nonlocal actors and local actors.
- Where is the tipping point between state and local policies, management and decisions? This relates to bottom-up versus top-down conceptualization.
- There is tension between fire as a natural hazard and fire as an important ecological process.
- Considering cross-scale interactions, it is more of a question of who has decision-making capacity and power.
- A regime shift to consider would be if WUI residents flee back to the cities or take fire protection and fire management into their own hands (no longer flocking to the forested landscape and relying on government to protect them). Suppression machine and perceptions people have of it subsidizes WUI growth.
- Differences and similarities of the current approaches to studying CHANS – they were plotted on axes depicting generalizability and amount of computational data. See Figure 2 below.

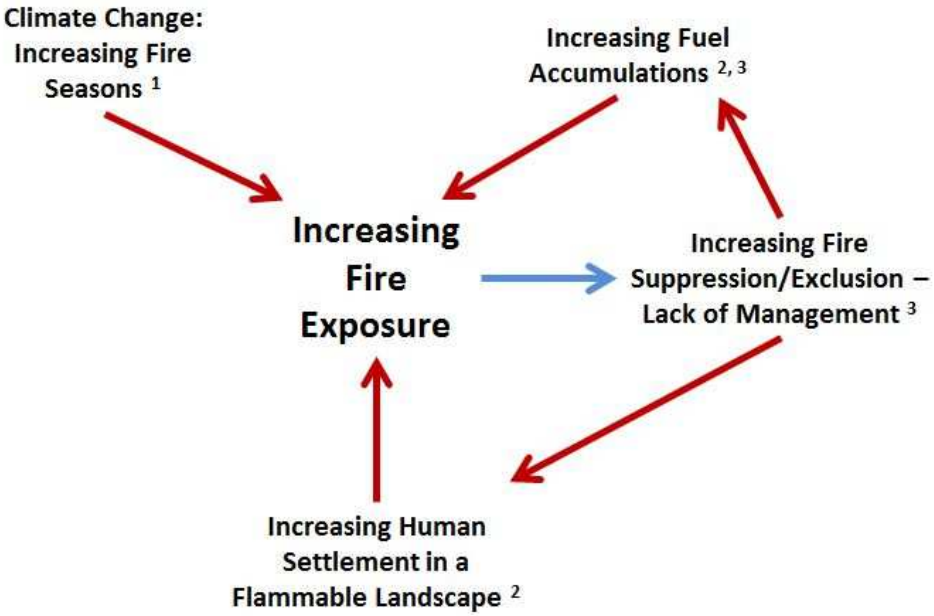

Figure 1. Three major contributors to fire exposure. We currently only "drain" the fire exposure box with increased suppression and exclusion efforts, but together with lack of active land management that feeds back around into the very issues to drive increased future exposure. Scale differences for breaking this cycle: [1] global action, [2] regional/state/local planning actions, and [3] agency and individual action.

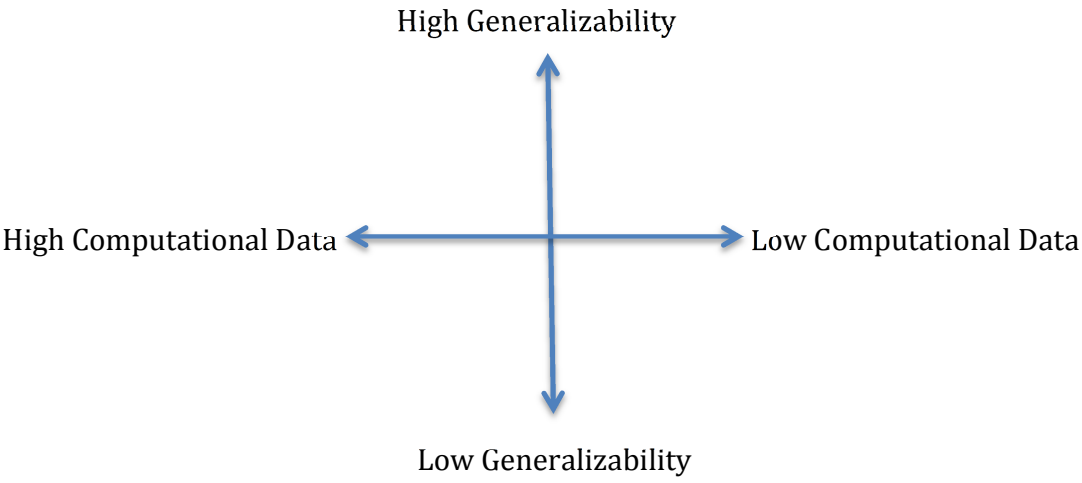

Figure 2. CHANS and CHANS-related fire projects fall in different quadrants. Most of the projects represented at this workshop fell on the high end of the computational data spectrum.

Theme 2: Modeling

Burning questions:

7. What are the options for modeling CHANS in fire-prone landscapes and how are these different models useful in developing theory or applications to current management problems?
8. In what circumstances are different types of modeling useful in CHANS research? (and how are they appropriately evaluated?)
9. How can CHANS simulation modeling be embedded into societal mechanisms of change so as to enhance adaptive capacity?
10. How can we model human behaviors more accurately when individual behavior cannot simply be aggregated up to the community level?
11. How do researchers design and agree upon consistent dependent variables for simulations of future wildfire risk or landscape processes?
12. How can illegal activities in fire-prone landscapes (e.g. arson) be incorporated into CHANS studies?

Notes from small group report-out:

- Models can be empirical, statistical, and/or simulation. They can be nested and hierarchical or linear. There are numerous types to consider.
- How do you decide what process of modeling to use? Consider qualities of models: Spatial, dynamic, extent and grain, degree of coupling, feedbacks between processes, decision making types (top-down, bottom-up)
- Need to consider modeling processes/decision-making processes:
    - Questions/objectives- driven by who, what, system that is being studied
    - Guiding theory (ies) – need to work these out as a group as a whole before you can talk about the model, need to revisit guiding theory over and over
    - Credibility with users
    - Feedbacks
    - Loops within loops – adjust process part way through realizing that (Carl Stein's decision-making process), how to revisit guiding theory without looping back over and over and over again
    - How well are students trained for the modeling process? Often a big time sink
- Steps in Modeling: Modeling process (ID key question, ID system, select model, evaluate model), determine tactics (stakeholder engagement?)
- Define features of fire prone systems relevant to modeling process
    - Social memory
    - Feedbacks
    - Characteristic scales: Large spatial and temporal scales of fire-prone systems; small scale of some effects (soils)
    - Good fire, bad fire
    - Transmission of risk

    - Hierarchy of decision-makers
    - Residence times (tenure)
    - Biophysical (pattern dominated) interactions with social systems (network dominated) - one individual can affect large scale impacts (arson) unlike other hazards (e.g., flooding, earthquakes, tsunamis)
    - Driven by episodic events
    - Fundamentally stochastic, long-tailed distributions
    - Spatial stratification of exposure to risk
    - Multi-scalar
- Fire shares characteristics with technological hazards: hybrid hazards, there can be an attribution (the arsonist)

Theme 3: Role of science and applications to society

Burning questions:

6. How do we help people, from citizens to planners, learn to think probabilistically about wildfire risk? How do scientists (individually or *en masse*) best deliver this information? Who are the audiences?
7. How do stakeholders perceive CHANS models, and what steps can be taken to improve this situation? Is this necessary for decision-making?
8. Will land management solutions best be achieved by top-down or bottom-up approaches?
9. What role can/should scientists play in policy debates related to wildland fire management?
10. How can wildfire research bridge gaps in the often incongruent temporal and geographical scales characterizing social and biophysical systems?

Notes from small group report-out:

- There needs to be an interactive dialog between science and the public including communication about probabilistic risk.
- Role of science needs to be both top-down and bottom-up
- A bottom-up idea: insert CHANS into existing agency planning frameworks (e.g., CWPP, Scorecard, Accelerated restoration)
- A top-down idea: insert changes into high level policy/decision-making/management discussions (e.g., AAAS Fellow)
- Case study idea: most compelling ways to change policy and behavior in agencies is to use case studies of CHANS
- Most management approaches are biased towards one side: biophysical or social. It would be beneficial to add the other side, integrate them, and manage. CHANS can help with that.

- How do people perceive models? Not an important question. More important is how people perceive the information that comes out and all of its foibles, insights, shortcomings; what makes it acceptable? Because people they trust deliver it.
- How do help people think about risk and hazard? Don't make it probabilistic because people will ignore what you say. Just make it binary; is there risk – yes or no. Make laws to incentivize behavior. Work towards a better understanding of cognitive and social processes of risk perception and protective action. The best way to inform people is more case studies; risks just aren't that high in terms of homes.
- What role should scientists play in policy? They shouldn't dictate, but should engage in policy process. The degree and character of that engagement depends on the context.

Theme 4: Policy and institutions

Burning questions:

6. Can we better understand the multi-level spatial and temporal drivers in these CHANS such that they can be incorporated into policy relevant decision making? What are the barriers to doing so? What decision space do we really have?
7. What societal mechanisms are most needed to support coordination of fuels treatment patterns on mosaics of privately owned lands to reduce wildfire risk at landscape scales?
8. What are institutional and procedural issues preventing us from doing a better job of dealing with wildfire?
9. Under what conditions does land management and/or conservation policy backfire as multiple thresholds are breached?
10. Can air quality regulators recognize the natural role of fire in dry forests and exempt prescribed and managed wildland fire smoke from air quality observations?

Notes from small group report-out:

- How can we better understand effects of multilevel spatial and temporal drivers across individuals and institutions in CHANS? Which are the most important drivers in different places? Which are politically feasible….no answers?
    - There are multiple levels or scales to consider - Household to community to local institutions to county/state government levels
- What societal mechanisms are most needed to support coordination of fuels treatment patterns on mosaics of privately owned lands to reduce risk at landscape scales?...no answers?
- What institutional and procedural issues are preventing us from doing a better job of dealing with wildfire?
    - Bureaucracies/risk aversion/incentives and disincentives (e.g., money)/disconnect between land management and fire protection
    - Externalities and common goods issues/grants and incentives/assumption of agencies protection (acceptance of risk)
    - Command and control vs. incentivizing fuel reduction/landscape restoration: big policy implication for hazards like wildland fire

- Under what conditions does land management or conservation policy backfire? More fire is spread and more smoke for more of the year; escaped Rx burn
    - Landscapes that people find themselves in determine strategies (i.e., ownership distribution, existence of watershed groups…..)
    - Tension between developing applied questions with strong normative bases vs. questions that generate the study of those desires
- CHANS researchers trapped in the now? Need to think about plausible future scenarios. Regime shifts. What role can scenario planning play in CHANS research and vice versa?

Theme 5: Management and markets

Burning questions:

7. What are the interactions/tradeoffs between management for fire protection and management for forest restoration/resilience?
8. What is the capacity of fuels treatments and fire management to overwrite climate drivers of landscape fire activity?
9. What incentives can be put in place to create a relatively robust market for biomass to treat wildfire risk?
10. What is the role of the US Forest Service, and other public land management agencies that allow commercial timber harvesting, in providing timber-based jobs/business opportunities to local communities?
11. How can dry forest landscapes be integrated into an emerging carbon economy?
12. How do we reconcile the drastic change in contemporary forest conditions (e.g., stand density, species composition and fuels accumulation) with the habitat "needs" of sensitive wildlife species?

Notes from small group report-out:

- Question 1: What are the differences/tradeoffs between managing for forest restoration vs fire protection?
    - In the age of the Anthropocene, we should be thinking about managing for sustainable ecosystems and future resilience rather than the fire protection/forest restoration dichotomy.
    - Is managing for forest resilience vs fire protection a matter of spatial distribution? Are the forests we want to restore in the same place as the forests we would treat for fire protection? When they are not spatially co-located, there are tradeoffs, we are trading off resilience for protection because we will always choose protection.
    - People may also be driven by threat to water security from fire. People care about protecting water resources and fireproofing those catchments.
    - Resilient landscapes in the future will be managed for in ways that maintain water quality and security, generate electricity from biomass, set aside grazing areas, etc. – for multiple values and biodiversity conservation won't be a driving value.
    - Our best opportunities for restoration projects are in rural, dry forest areas in the middle of nowhere where there are no people and you can treat at

large scales and use fire. Restoration of fire adapted ecosystems is pointless in small patches, at small scales like in WUI.

- Question 2: What is the capacity of fuels treatments and fire management to override climate drivers of landscape fire activity?
    - It can be done but the problem is, depending on climate scenarios, what a silviculturalist would do to regulate fire behavior might be socially unacceptable, and you could still get climate surprises.
- Question 3: What incentives can be put in place to create a relatively robust market for biomass to treat wildfire risk?
    - Carbon tax
    - Insurance market – for homes or using community ratings
    - Regulatory socialism/pyrofascism
    - Subsidize chip markets
    - Homeowner risk tax
    - Address air quality regulations
        - The air quality issue: ironically we constrain activities that would reduce the amount of smoke in the air (prescribed fire, biomass electricity facilities) through regulations, and default to unregulated sources of smoke in the air – wildfires – which are much worse for air quality than the other two options.
- Question 4: What is the role/responsibility of the USFS and other agencies to provide jobs to communities?
    - Many Acts and Directives pertaining to the USFS identify this as a management objective - to provide economic sustainability to communities and to consider rural job creation. We should and do think about this as an agency in decision-making, though we shouldn't totally tradeoff ecological values for the sake of job creation.
    - Should the USFS be helping to create jobs? It depends…can vary depending on where you are. It's hard to capture this variation in models.
- Question 5: Can air quality regulators recognize the natural role of fire in forests and exempt prescribed and managed fire smoke?
    - Group decided this was too specific and didn't discuss it.
- Question 6: How do we reconcile the drastic change in contemporary forest conditions with the habitat needs of sensitive wildlife species?
    - We need to be thinking about creating future resilient landscapes. Treatments in areas that are supporting species that have moved in to live in over-dense forests will affect those species and tend not to favor them; but sensitive species may be threatened by over-dense forests. What are the treatment tradeoffs? Think about resilience frameworks for the future.
    - To what degree do we know the answers as researchers to questions like, how does managing for wildlife affect the carbon balance? Landscape scale studies about the role of treating forests to reduce fire risk in order to increase C storage in trees are missing. There are still debates about the role of fuels reduction in affecting the C balance/C sequestration in forests.

- The USFS is so variable, that the "right" science answer varies depending on where you are. What is the social nature of science acceptance; and, the ability to absorb/use science across different USFS management units?

Theme 6: Fire effects, resilience, and adaptation

Burning questions:

7. How do we measure and capture the tradeoffs between and within different environmental, social, and economic benefits from reduced wildfire risk?
8. How will changing wildfire regimes influence the relationships people have with landscapes? What is a "fire-adapted community" when considering CHANS?
9. What are they key ingredients for creating "fire permeable" landscapes that allow fire to move through the WUI with low risk to people and property?
10. What are sustainable objectives/outcomes for human communities and ecosystems in fire-prone landscapes?
11. Given the need for fire in many dry forest types (both for restoration and for fuels reduction) can human communities living within and adjacent to forests tolerate the inconveniences associated with increased prescribed/managed fire and resultant smoke?
12. To what extent does the strategy of restoring native grasslands from successional forest to reduce fire severity pose a risk of rapidly spreading wildfire to untreated areas under extreme weather conditions?

Notes from small group report-out:

- This group focused on the "adaptation" piece of the theme. They covered all six questions in a non-linear way so the questions are not listed here.
- In agencies and the policy world, there are uniform definitions of adaptation, and what a fire-adapted community is. But in reality, adaptation looks really different in different types of communities. There are many different types of communities where different types of adaptations can occur; can we develop a typology of WUI communities that take different approaches to reducing wildfire risk? What would be the definitions of these different types of communities? (i.e., fire permeable WUIs vs. hunker down in a community house until the fire is over WUI vs. building resilient hobbit houses in the shire) Can we identify emerging typologies of/pathways to adaptation?
- Is fireshed the same as WUI, and how do they align? Can turnover in local populations make it possible to sustain a fire adapted community?
- What are the tradeoffs associated with different adaptation strategies? What are some metrics associated with different types of fire adapted communities?
- As communities develop strategies for adaptation, they could look at a suite of values and assess them and identify tradeoffs associated with them, and priorities for their own community – then risk reduction and suppression activities could be consistent with these priorities. Researchers could help give communities a way to identify and assess tradeoffs associated with different metrics of adaptation.

- What tools could help communities do this? CHANS models, what else? What's realistic? What have scientists learned from using CHANS models that they could communicate to communities to help them in assessing tradeoffs?
- Several of our participants have been working together to identify typologies of WUI communities and to develop them that could be relevant for this discussion. Elements of the typology that Travis et al. have been working on: it has 22 characteristics in 4 arenas. Ex. High resource/high amenity communities, working landscape communities. Different types of WUI communities relate to risk reduction and fire suppression in different ways.
- How to prioritize new investments in the communities at highest risk? The fire community says they have the answer based on exposure; but there are many other factors that could influence whether the investments are worthwhile or not. The USFS deputy chief is looking for CHANS case studies to help demonstrate how to prioritize these communities

Theme 7: Social organizations/networks/cultures

Burning questions:

6. What are the appropriate scales for research in fire-prone CHANS? Do large-scale, hierarchical social and ecological teleconnections undermine local efforts? Is local/landscape/place-based efforts a useful co-strategy?
7. How do social networks change over time and influence perceptions of wildfire risk, management and landscape outcomes?
8. How do we account for the social diversity of stakeholders exposed to or utilizing wildfire when managing landscapes? What are the most appropriate metrics of fire impacts on human systems?
9. What kind of cultural experiences or institutions are necessary to sustain healthy fire-prone communities in the face of demographic/economic/technological climate changes?
10. What is the role of local history in creating sustainable communities in fire-prone landscapes? Is there a role? Personal experiences? Shared or collective experience/social memory?

Notes from small group report-out:

- Question 1: What are the appropriate scales for research in fire-prone CHANS?
    - It's important to use a landscape scale, like an ecoregion. This is the largest scale that is logical, but it is also important to look at smaller scales such as ownership and "decision units" to understand what is driving the system socially.
    - How to treat cross-scale interactions in models, or as external features that are not modelled? We've done cross-scale analysis more in the ecological realm than in the social realm.
    - "Telecoupling" – can it undermine local-level initiatives? Yes. For example, energy markets – global energy markets can undermine bioenergy markets locally that would make restoration treatments financially viable.

- Question 2: How to represent social network change and response over time in our research?
    - There is a need for research in this area, because people who have worked on social networks have found that change within these networks can occur, such as when an important leader is no longer in the network. Movement of key individuals affects the network. How to treat these dynamics in CHANS research?
    - We might think about modelling this social component in the way the ecological component has been modelled.
- Question 4: What cultural experiences/institutions are needed to sustain healthy fire-prone communities in the face of change?
    - Paveglio and colleagues have published on this …. some of the elements they discussed include: longevity of individuals in communities over time; experience of people with fire in the past; recency/intensity of fire experience; school programs for education and outreach to provide information through curriculum development, then talk to parents; mechanisms for creating and transmitting shared experiences; time and motivation; incorporation of newcomers; finding ways of extending out from the individual to create a community learning experience.
    - Institutions were discussed, from more of an Elinor Ostrom perspective of rules of use of a commons resource. There is a need to be explicit and transparent about norms for managing a fire prone landscape.
- Question 5: What is the role of local history in sustaining local communities in fire-prone landscapes?
    - There is much value in connection to place for sustaining local communities. How to create this connection? It can be hard in places with rapid growth, many newcomers. Mechanisms for creating connections for newcomers could be integrating them into existing networks; outreach and education through national parks; interpretive signs in special places to provide landscape context; documenting local history. Making people aware of their local history can build a stronger sense of local stewardship.
    - How to build social memory into CHANS? Get at Traditional Ecological Knowledge and Local Ecological Knowledge as a way of characterizing values people have in fire-prone landscapes. Where does culture fit into any of this? Culture has been treated as a constant, though it has been treated in various ways in various projects. It's an element of diversity however that needs to be dealt with in projects and across projects. Outcomes could be different if the agents had a worldview or cultural norms derived from one place vs another. It would help us see what a more diverse future of cultural attitudes/values would be in influencing the system if we included them in our models. Different cultural perspectives lead to different desired forest conditions.
    - Culture: With CHANS in general, it would be useful to clarify whether this type of research is about localism or developing generalities. This needs to be clear in order to understand the relevance of the outputs. How place-based

are our models/findings? If localism is the issue, you need to deal with the social/cultural variability in that place in your model.
    - Thinking at a landscape/all lands scale first has to be something that there is social agreement around. Then you can scale down to the community level. But we aren't capturing the convergences that exist across cultural contexts in our work. Cross-system comparison ecologically and culturally is an opportunity for us in comparing CHANS work from different places.
    - Looking at ecological history can help communities see a range of different restoration options.

Theme 8: Climate interactions and scale

Burning questions:

6. Are there generalities in the mechanisms amplifying the impact of climate variability on disturbances, their connectivity among landscapes, and the interactions with land-use and land-cover change?
7. Are there generalities in the interactions and tradeoff among ES and thresholds? Have we identified the relevant metrics of risk, costs, and benefits?
8. What are the most critical known climate change wildfire risks… how serious? how soon? how certain are we?
9. What are the scale dependencies of ecosystem service (ES) correlations? Of the drivers of ES and their interactions? Of rates of land use change?
10. What are the most important specific actions/activities needed to slow climate change? What are the most important specific actions/activities needed to adapt to climate change?

Notes from small group report-out:

- There were 5 questions under this theme; Question 5 was determined to be too big to address. This group focused on Questions 1 and 3.
- Question 1: Are there generalities in mechanisms that amplify the impact of climate variability on disturbances?
    - They thought about spatial and temporal scales. Temporal: fast vs. slow processes. Amplifying mechanisms often get more attention than moderating mechanisms. But moderating mechanisms must be thought about as well. They thought about this with regard to connectivity and top down vs. local drivers. They got to the idea that the meso-scale (in between top down and bottom up) is key. What is the scale at which top down, large-scale processes don't overwhelm the local dynamics? At what scales can management influence the landscape mosaic in order to work with local patterns but respond to broader top-down processes and forces?
    - Top-down processes may trump the local level, small scale processes we want to manage for. As you get extreme climates the patterns of fuels treatments on landscapes are less important; fire and weather patterns will override those patterns. Landscape scale heterogeneity vs top down climate extremes.

    - Coping with climate change: Coping = when people can't adapt, but things have that we aren't prepared for. Fire can be right next to communities that are oblivious to the problem. It would be interesting to look at spatial variability in preparedness among homeowners, communities.
- Question 3: What are the most critical known climate change wildfire risks and how serious are they?
    - Seriousness depends on whether your house is on fire and how soon it will be again. The answer to this part of the question is, It depends.
    - Smoke: the spatial connectivity of smoke, how does it influence transportation, which then has economic impacts? If it blocks a node in a transportation network the impacts will be felt much further away.
    - Ecosystem services: it's important to think about both biophysical and social cascading impacts. For example, a fire is burning and having an ecological effect, but there are also cascading impacts like smoke and effects on dams and other ecosystem services. Multi-scale analysis is important to do here.
    - When do we need to turn to complex science to solve a problem, like CHANS, in order to solve a problem? The need to couple human and natural systems to solve a problem is the definition of CHANS problems. Not all problems need to use this approach to be solved but some will, a small percentage. The social component is what makes a problem wicked, in other words, complex. Not all problems are complex and need a complexity approach. When people frame problems in many different ways because they have different perspectives and different expectations, you get a complex and wicked problem.
    - How do you know when you have fixed a problem? There is no end point here for a fire adapted community for example.
    - People seem to think they float above problems when they are totally embedded in them. You are the problem as much as you are solving it. It is dangerous to see yourself as being abstracted from a problem when you are embedded in it- like a management agency.
    - Our models will never be right because we can't model the power relations within our models.
    - Where do we stand in relation to these systems we are studying?
    - Are we problem diagnosing vs problem solving?
    - Two important aspects of the research that we do are: advancing theory, and being relevant in an applied way. Are these mutually exclusive goals, and what should we focus on in CHANS studies?
    - Scientist as facilitator vs advocate vs participant in a decision-making process... what are the roles we should play in the policy process?
    - CHANS is a new term but not a new thing necessarily. Vulnerability and community capacity – these aren't really different and when we use new terms for old things and don't include the people that have been doing it all along, we exclude people.

Big questions deemed too big to tackle

Of the questions submitted by participants before the workshop, these ten were deemed too large to tackle by this group or within the allotted time:

1. How do CHANS vary globally and what are the major dimensions of this variation?
2. How can different societies and cultures, and variations in economic, political, and historical circumstances within these cultures and societies, be handled by CHANS?
3. How do we create institutions land management procedures that account for social and natural dynamics in CHANS?
4. Why isn't policy doing a better job in dealing with wildfire?
5. How do we rethink resilience and what it means to adapt when we take into account these multi-level spatial and temporal drivers?
6. With the social system, how are different social groups, particularly, economic/social classes impacted by current and future fire-prone landscape conditions, management, and policy?
7. How can conflicts of interest be overcome in complex CHANS to achieve desirable and sustainable landscape outcomes?
8. To what extent do dynamics outside of the regional system induce regime shifts within a given region and therefore constrain land management?
9. Is the role of social-ecological thresholds universal for ES management? How can we account for social equity and the distribution of costs and benefits?
10. How have humans influenced fire regimes and what are the consequences for ecological and social systems?

Panel Discussion of Official CHANS Projects

Integrating Disciplines and Engaging Stakeholders

Participants were asked to speak about how they integrated disciplines in their work. This led to the topic of engaging stakeholders as well, as some groups accomplished integration using engagement. The following key points emerged from the various teams:

- There was a modeling structure for integrating social and ecological systems, but it wasn't the only way we would integrate. Some aspects of the project couldn't be integrated into the model but were used to support and provide context as well as assist with interpreting model results. Integration requires not only thinking outside the box, but creating a new box.
- As we got into the model, it evolved from a pure agent-based model project to more of an applications model. The first few years included field trips and model-free planning exercises with stakeholders. This helped us discuss the scenarios and figure out what would go into model. It also allowed us to keep groups up to speed about what was going on with the model so when we brought it out at the end of the project, they wouldn't be caught off-guard.
- Stakeholders are a key part of integration. Alternative futures work is inherently participatory. Stakeholders helped us build the model, define some of the scenarios, and understand what the data means to people who live in the WUI. They lead the

process and we just run the analysis. Then we bring it back to them and ask what it means and reflect. Working with stakeholders also means they call you on your assumptions and mistakes. Some were surprised at all the people using terms like resilience and vulnerability, so the conversation was framed with those terms that they understood.

- Integration was slow and individual actors in the project felt uncertain in their place and role because there wasn't a lot of face-to-face time for this multidisciplinary and multi-institution project. There were a lot of roadblocks. Getting to integration and asking questions across disciplines requires face-to-face time, which started in the second year.

Team Adaptability and Dynamics

The topic of research team dynamics and adaptability brought up many key points:

- Pragmatism is important. If having three study areas means it will be a ten-year project, consider dropping down to two study areas. If the model can't do something for us, we have to cope and adapt in order to address the issue we're considering. We can't throw everything away because the model wouldn't do the one thing we really wanted it to do. The model can also be changed. Some changes may be so significant it may look like a new model by the end of the project.
- It is helpful to have people in a variety of seniority roles. This helps with being able to adapt and reach across disciplines.
- The team may lose researchers who are not able to adapt to the team dynamic. The team may also gain new researchers, which brings challenges. New researchers may need to learn a new geographic area. It will take a while for them to get to know the team members, how they work and where everyone fits. Frequently returning to the original research proposal can be helpful for new team members.
- Non-research team members can be very helpful. One group brought in the local governor/tribal member who was very intellectually curious. For some of natural scientists on the team, his involvement really brought everything home about connections for people and relationships. He also kept them honest.
- It can be beneficial to engage all project members in some integrative piece such as a field trip. It helps them see everyone else's role and what they bring back to the table. If don't earlier in the process it can help everyone think about big synthesis at the end.

Publications

The following points emerged about how the teams are handling project publications:

- Some teams chose to have one or two concept papers written first. These generally have most team members as authors. Other publications are written by smaller sub-groups within the teams.
- Most teams do not use "CHANS" in the title of their papers. Rather, the titles tend to reflect the systems and the analysis.
- Great care is taken in selecting the journal, with some groups contacting multiple editors before making a decision. Teams mentioned publishing in *Ecology & Society*, *Anthropocene*, *Landscape & Urban Planning*, and *Ecological Planning.*

Next Time
Teams had a few comments about what they would do differently next time:

- Discuss narratives of the model and also do more trips into the landscape and out to the people in the study area. The fire model finally made the decision for timeframe. Those decisions both guided and constrained everything else we did in the model.
- Evaluate the tradeoffs of detail – drilling down means you are constrained by model capabilities. Ask whether you would rather do a ton of runs that may be generalizable or do fewer runs to get different ideas to discuss with stakeholders. Some feel it is a more tractable project by drilling in.
- Have confidence that you can make those kinds of big calls about model detail and generalization.

<u>Discussion and Planning for CHANS Paper 1</u>

Potential title: uncertain; about the uniqueness of fire-prone systems as CHANS

Target journals:
- *Science*
- *Proceedings of the National Academy of Sciences*

Lead author: Paige Fischer
Paper development: September – December 2014
Key elements of the paper developed during the workshop follow below.

I. <u>Justification</u>
   a. Abundant literature on empirical research on fire-prone systems and both empirical and conceptual work on human interactions with those systems, but no single paper synthesizes research on fire-prone systems using a CHANS or SES framework or charts a course for future CHANS research on fire-prone systems
   b. Fire-prone systems are especially deserving of attention because:

i. developed or evolved with human use of or manipulation of fire;
ii. pressing social, economic and natural resource policy issue
iii. The WUI (broadly defined) is a quintessential CHANS
iv. Fire-prone landscapes also are a type of natural hazard system in which concepts of risk and risk management apply but have received little attention in the CHANS literature

c. Fire-prone landscapes exhibit many of the fundamental characteristics of CHANS. Some things

II. Potential Goals

a. Document and synthesize our work and the work of others by characterizing fire-prone CHANS or SES in dry temperate forest landscapes in the global north;
    i. How are we different? How are we similar?
    ii. What are the distinguishing features of fire-prone CHANS?
b. Identify the contributions of this work on fire-prone systems to the CHANS, SES or other interdisciplinary fields more broadly; and
c. Lay out research priorities for ourselves and our colleagues; What are the major gaps?

III. Ideas about fire-prone systems as unique CHANS

a. WUI broadly defined is a problem (human ecotone in flammable temperate forest) that can only be understood with a CHANS approach
b. Tension between fire as natural hazard and fire as an important ecological process
c. Unlike so many other natural hazard systems, humans interact with fire-prone systems on many scales: individuals, social group (i.e., community) and institutions
d. Fire prone CHANS feedbacks and threshold crossings span spatial and temporal scales; both local (homes, timber assets) and global (smoke, alteration of globally important habitats)
e. Is there a unique distribution of slow and fast variables in fire-prone CHANS?
f. Interactions between plausible WUI regime shifts and other social processes going on in rural forested areas (multifunctional rural transition, amenity migration, urban drift)
g. Risk and cooperation; is this a unique evolutionary feature of fire-prone CHANS that people cooperate on other forest management related activities and fire suppression but not risk mitigation (thinning); relationship between adversity and scarcity and exposure and cooperative fire risk mitigation and fire adaptiveness

h. Difference between fire-prone forested landscapes and other landscapes (agricultural); fewer opportunities for social interaction to build conditions for cooperation
i. Importance of teleconnections: global, national energy markets and local solution to restoration and hazard protection challenges
j. Different definitions of and paths to adaptation; typology of fire-adapted communities; measures for assessing fire-adapted communities: unique to fire-prone CHANS?
k. Direct manifestation of climate change: strong endogenous and exogenous interactions; as climate changes become more extreme, the pattern of fuel treatments on the landscape become less important
l. Cascading impacts: fire, smoke, sedimentation….connection between different ecological systems; social cascading impacts, requires multi-scale analysis, levels of organization at different scales: Unique to fire-prone CHANS?
m. Command and control vs. incentivizing fuel reduction/landscape restoration: big policy implication for hazards like wildland fire
n. Under what conditions does land management or conservation policy backfire? More fire is spread and more smoke for more of the year; escaped Rx burn
o. Definite features of fire prone systems relevant to modeling process

<u>Discussion and Planning for CHANS Paper 2</u>

Potential title: The dynamics of fire-prone CHANS: coupling social and ecological systems

Target journals:
- *Ecology and Society*
- *Current Opinion and Sustainability*

Lead author: Patrick Bourgeron
Paper development: October – December 2014
Main elements of the draft outline developed during the workshop follow below.

I. <u>Introduction</u>
   a. Why did the approach develop?
      i. Some things we can learn? Applications?
      ii. Use of range of variability, based on case study in CO.
   b. Historically, ecological and social systems were assessed separately.
   c. Currently, due to the interconnected nature of fire, ecology, and social codependence, a CHANS approach can improve upon the historical approach

d. Notion of coupling: explain its relevance to addressing fire-prone system issues.

II. The approach
   a. Gradient of intensity of the coupling over spatial gradients in a given area
   b. One or several CHANS in a spatial-temporal context
   c. Decisions about fire-prone CHANS: how fire management decisions were made?
      i. Globally, all nations are dealing with changing climate, but they are responding to fire processes differently

III. Results from on-going projects
   a. Use of the CHANS approach by different projects
   b. CHANS dynamics and opportunities to manage for resilience or navigate transformations: are we learning from the stakeholders?
   c. Challenges and change: when and where do we need CHANS?

IV. Discussion and conclusions
   a. Recommendations
   b. The road ahead: how much we have to change the way we function