# AN ABSTRACT OF THE THESIS OF

John Hughes for the degree of Master of Public Policy presented on June 10th, 2015.

Title: Exploring Roles for Scientists and Simulation Models in Collaborative, Science-Based Ecosystem Restoration.

Abstract approved:

Brent Steel

The U.S. Forest Service's Collaborative Forest Landscape Restoration Program (CFLRP) seeks to encourage collaborative, science-based ecosystem restoration of forest landscapes. Many theorists note a tension between participatory approaches in governance and the certainty and control that science is said to offer. This research explores how collaboration and science are currently being integrated in natural resource management through a qualitative examination of two forest collaborative groups that have interacted with a team of scientists proposing participatory simulation modeling. In particular, this study asks the question: among participants engaged in collaborative ecosystem restoration, what are the expectations for and perceptions of, the role of simulation models and scientists? Although this study centered on the potential use of simulation models, it also concerns itself with the role of scientists in the collaborative groups in general. Participants from two collaborative groups engaged in the CFLRP in Central Oregon were selected using a purposive sampling strategy and interviewed using semi-structured interview techniques. Interviews were recorded, coded and then analyzed with themes from the post-normal science framework and the participatory GIS and science integration literature. The results of this study suggest that the participants in these two groups have different strategies for incorporating science into their process and different expectations for the role of simulation models and scientists. One group in particular conforms more closely to post-normal science concepts and favored using a

simulation model for the purpose of supporting open-ended discussion and having scientists enter into a shared learning process with them.

# Exploring Roles for Scientists and Simulation Models in Collaborative, Science-Based Ecosystem Restoration

by
John Hughes

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Public Policy

Presented June 10th, 2015
Commencement June 13th, 2015

Master of Public Policy thesis of John Hughes presented on June 10th, 2015

APPROVED:

Brent Steel

Sally Duncan

Emily Jane Davis

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

John Hughes, Author

# ACKNOWLEDGEMENTS

I would like to thank the people of the Lakeview Stewardship Group, Fremont-Winema National Forest, Deschutes Collaborative Forest Project, and the Deschutes National Forest who volunteered their time to share their thoughts and experiences with me. My committee, Brent Steel, Sally Duncan, and Emily Jane Davis should also be recognized for their guidance and encouragement. This research was funded by the grant "Climate Change Adaptation, Sustainable Energy Development and Comparative Agricultural and Rural Policy," National Institute of Food and Agriculture (NIFA) *Higher Education Challenge (HEC) Grants Program* (2013-2016).

# TABLE OF CONTENTS

## Introduction and Statement of the Problem

Natural resource collaborative groups have been expanding their presence and acceptance in the United States over the past three decades, and federal agencies have begun to encourage their use in public lands management processes, most notably surrounding the issue of wildfire (Steelman and Burke, 2007). The Collaborative Forest Landscape Restoration Program (CFLRP) is an example of one such effort that seeks "to encourage the collaborative, science-based ecosystem restoration of priority forest landscapes" (USFS, 2014). This program, inspired by the philosophy of ecosystem management, offers a possible approach for reducing the threat and cost of large wildfires, restoring ecosystems, protecting social values, and ensuring thriving local economies and communities. However, there seems to be an inherent tension between the mandate for more inclusive, participatory approaches in governance and the need to base those decisions on science, the two main components of the restoration approach in the CFLRP. The seeming benefits of collaboration, which blends a diversity of opinions, values and knowledge to learn and negotiate, conflict with popular conceptions of science as objective and value-free. As Bäckstrand (2004) wrote "there seems to be an incompatibility between the quest for open-ended deliberation in democracies and the aim of prediction and control in science" (p.33). So what does the science of collaborative ecosystem restoration look like?

Many scientists, stakeholders, and managers believe science should dictate decisions regarding our shared natural resources, arguing that it provides the best solutions that will be free from bias and based on the fundamental laws of nature. However, there are others who believe that this perception of science is wrong, and science does not uncover the "Truth." They maintain that we can still learn much from science and use it to inform our decisions, but the traditional practice of science is not adequate for the task of addressing modern environmental problems. Countering the traditional model where scientists contribute their expertise from a distance, the proponents of "post-normal" science (Funtowicz and Ravetz, 1994) argue for reframing scientist as providers of important, but not exclusive, evidence that must be considered and debated along with the values and knowledge of an “extended peer-community” when making decisions. Many technological tools, such as simulation models have been promoted and evaluated by scientists and researchers as a means of facilitating more integrated roles for science and scientists. Previous research has explored the preferred roles of science in environmental decision-making and found that those with more traditional beliefs about science also support integrated roles for scientists (Steel, List, Lach, and Schindler, 2004). Yet, little research has been done to uncover what participants engaged in current collaborative ecosystem restoration efforts expect from science, scientists, and simulation models.

In this context of changing roles for scientists, methods for integrating research into public deliberation, and new structures of collaborative governance, there are still wide-ranging beliefs about the nature of science and the role scientists should take. This leaves many questions to be answered. What are the expectations for the roles of science and scientists within these collaborative groups? Do more integrated roles for scientists mean more post-normal roles that require scientists to join stakeholders in a collaborative process? Should scientists adjust their practices and tools (like simulation models) to fit new expected roles? This research will address the question: Among participants engaged in collaborative ecosystem restoration, what are the expectations for and perceptions of, the role of 1) simulation models and 2) scientists?

## Background

### Role of Science in Natural Resource Management

**Early 20th Century - The Machine Model.** Science has long been an ally to natural resource management. However, the relationship has not remained constant or uncontested over time. As Rittel and Webber (1973) noted, during the early and mid-20th century the professional’s role was to address problems that “appeared to be definable, understandable, and consensual” (p. 156). Kennedy and Quigley (1998) explained that for the United States National Forest Service in its early days pre-1910, this meant protecting the country’s natural resources (mainly trees) from wildfire and short-sighted capitalists, and later (1910-1969) the focus turned to providing sustained yields to boost local economies and supply the post-war housing boom (p. 114-115). The Forest Service operated under a "machine-model" view of the world in which nature could be controlled, and organizational structure could function efficiently to produce targeted outcomes (Kennedy and Quigley, 1998). As Weber (2000) noted, the first Forest Service chief, Gifford Pinchot, believed resources were to be harvested "efficiently for the current benefit of the citizenry using scientific management methods" (p. 242). At this time the linear transfer of scientific information was possible in which, if the manager understood the science, the best action was evident (Pielke, 2004; Bengston, 1994). Given the broad support of the public, the goals of minimizing fire and maximizing timber output as dictated by science were largely unchallenged.

**Mid to Late 20th Century - Ecosystem Management**. Shifting societal values by the early 1960s, however, helped usher in an age of environmentalism. This was largely in response to the industrial expansion of the postwar economy in which the consumption of resources, largely for housing markets, was prioritized above most other values (Weber, 2000, p. 242). Forests, long managed primarily to yield timber were increasingly valued by the public for non-consumptive reasons (Bengston, 1994). Meanwhile scientists were beginning to demonstrate the negative ecological impacts of clearcutting on watersheds (Likens, Bormann, Pierce, and Reiners, 1978) and plant and animal species (Perry, 1998). The perceived need of nature to be free from overburdening human interference became enshrined in laws such as the Endangered Species Act, which prohibited the consideration of costs in determining species' qualification for protection (Weber, 2000, p. 242). Additionally, Congress passed laws like the National Environmental Policy Act (NEPA). This bill, meant to gauge management's impact on the environment, required integrating the input of numerous experts as well as public comments into decision-making processes for all federal resource agencies (Kennedy and Quigley, 1998, p. 115). The growing environmental movement believed that in order to correct the damage of the production mentality of the past, humankind's impact on nature must be restricted (or eliminated) despite the economic costs (in general or to specific populations) and now had a legal framework to promote this belief (Weber, 2000, p. 242).

Confronted with new social pressures and legal requirements, the Forest Service is still shifting away from the machine-model towards an "organic model" of ecosystem management and sustainability, which calls for more inclusive, complex, and interrelated view of the world. Legislation and wake up calls such as the Bitterroot and Monongahela clear-cutting controversies (Koontz et al., 2004) and the Washington/ Oregon eastside forest health/fire problem the Forest Service began to:

> a) consider functional budget and USFS specialist impacts in a more long-term, integrated, cumulative, organic-model context;
> b) recognize that ecosystems and associated socio–economic systems are composed of complex, integrated structures and processes that do not stop at public or private ownership boundaries;
> c) accept that many line and staff specialists might not initially have the expertise and vision to adequately plan, manage and monitor more demanding and sophisticated ecosystem management organic-models; and
> d) consider that advanced trained, 'certified ecosystem managers' might be needed to direct and monitor landscape-scale ecosystems, cumulative effects, or the establishment and progress toward more stable, healthy, desired future conditions. (Kennedy and Quigley, 1998, p. 119)

In the paradigm of ecosystem management, sustainable ecosystems and multiple social values gained prominence over maximizing yields and singular values. This prompted changes not just in natural resource policies, but the administration of those policies (Weber, 2000, p. 238). This is because the new environmental laws did not provide a way to reconcile widely opposing points of view. Legal gridlock halted implementation of agency decisions and kept them tied up in court (Weber, 1998, p. 8). This gridlock, including the timber wars of the 1980s and other hugely contentious and at times openly hostile debates about public lands management, paved the way for more open, inclusive forms of governance. The ecosystem management approach entered the policy and management realm in high profile ways in the 1990s through the Forest Ecosystem Management Assessment Team's work for the Northwest Forest Plan in the 90s (Thomas, Franklin, Gordon, and Johnson, 2006) and the Interior Columbian Basin Ecosystem Management Project (Haynes, Quigley, Clifford, and Gravenmier, 2001).

Managing forests for new goals that seek a balance between wildlife, recreation, economics, and forest restoration means that the linear model of incorporating scientific information has become difficult. "Getting the science right" now involves consulting multiple specialists, gauging how actions might affect numerous components of a complex system, and estimating future conditions over long periods of time. Even if the best science is known, the agency still must figure out how to weigh public values and opinions with scientific information. This led to the growing suspicion within and outside of managing agencies that the questions "how and for whom public lands ought to managed" could not be answered by science alone (Bengston, 1994, p. 519).

**Wildfire Policy.** As mentioned above, a major part of the Forests Service's *raison d'être* at its creation in the early part of century and one of its major motivating goals through the mid-1900s was the control and eradication of wildfire. Using a system of lookout towers, transportation infrastructure and communications, wildfires were put out quickly while they were still small (Pyne, 2001). However, this success in putting out fires caused a disruption in natural fire regimes, which led to increased acres burned every year and skyrocketing costs (over $1 billion each year) for fighting fires on public lands (Dombeck, Williams, and Wood, 2004). This suppression, along with other factors like past timber harvest practices and a changing climate (Steelman and Burke, 2007) have interrupted natural processes, resulting in more severe and frequent fires. The increasing threat of wildfires is not only economically burdensome, but threatens the health and safety of municipal watersheds, housing developments in the wildland-urban interface, public and private timber supplies, and endangered species (Dombeck, Williams, and Wood, 2004).

An ecosystem management philosophy can be seen in the evolving approaches to the issue of wildfire. The first bill aimed toward restoration of the forest was the

National Forest Plan (NFP) in 2000 which made recommendations "for responding to severe wildfire, reducing the impact of wildfires to communities and the environment, and ensuring sufficient firefighting resources in the future" (Steelman and Burke, 2007, p. 68). Guiding the NFP were goals developed by the Western Governors' Association that focused on restoration and suppression, but also an approach which involved all levels of government and the community (Steelman and Burke, 2007). In 2003, the Healthy Forests Restoration Act (HFRA) helped put a more focused emphasis on fuels reduction through streamlined administrative procedures for priority projects. Also included in the Act was the Community Wildfire Protection Planning component, which encouraged groups of stakeholders to collaborate with federal partners in planning hazardous fuels treatments in the Wildland Urban Interface. Steelman and Burke (2007) point out that millions of acres have been treated through these two programs (mostly HFRA) but success was mostly defined in terms of acres treated, and less attention was paid to broader ecosystem restoration goals, and wide-scale, inclusive collaborations with stakeholders was lacking (p. 70). Butler and Goldstein (2010) say that the agency is caught in a "rigidity trap" that keeps it focused on fire suppression through "incentive structures, agency budgets, and professional practices" (p. 2).

In 2001, the Fire Learning Network (FLN) was created by the US Forest Service, The Nature Conservancy, and the Department of the Interior. Initially, 25 collaborative groups were assisted through a two-year planning process in order to create regional ecological restoration plans by coordinators and support staff hired by The Nature Conservancy (Butler and Goldstein, 2010). Since then the FLN has expanded and formed regional networks where stakeholders and agencies interact, share, and learn through various means such as workshops, field trips, publications, and trainings. Through these activities, collaborative ecological restoration plans have been developed in 150 landscapes (Butler and Goldstein, 2010). Butler and Goldstein (2010) credit the FLN with integrating more ecological fire restoration perspectives into plans that influence managers (p. 8). Also, by sharing obstacles and success stories, FLN participants (alongside TNC staff and other important agency and organizational representatives) were able to affect policy change by promoting the Collaborative Forest Landscape Restoration Program (CFLRP) which served as a means for helping fund the kind of ecological restoration projects developed by participants in the FLN (p.10). Passed through the Omnibus Public Land Management Act in 2009, the CFLRP was meant to aid in the "collaborative, science -based restoration on priority forest landscapes".

Schultz, Jedd, and Beam (2012) state the major objectives of the CFLRP are

> to promote ecological, economic, and social sustainability; leverage local resources to accomplish these goals; reduce fire management costs through the reestablishment of natural fire regimes and reduction of the risk of uncharacteristically severe fires; demonstrate the degree to which restoration activities achieve ecological/watershed objectives and affect fire activity and its associated costs; and show how capturing the value of forest restoration byproducts can reduce treatment costs and support local economies. ( p. 381)

Schultz et al. (2012) note that although ecosystem management as a term has fallen out of favor over the years, its principles are represented in the CFLRP in the following ways: a) It focuses on planning on larger landscapes (50,000 ac and larger) with the goal of making impacts on larger ecosystems rather than only stands; b) plans must be made in conjunction with neighboring landowners and managers so that integrated approaches can be developed; c) it concerns itself with the outcomes of restoration, rather than the commodities extracted d) resource management goals and the definition of a healthy ecosystem is socially defined.

In CFLRP, restoration is not explicitly defined, however projects must protect and encourage old-growth stands, fuel treatments must focus on small diameter trees, and prescribed fire and unplanned ignitions should be used to return a more natural[1] or historic low-severity fire regime. Other ecological goals include improvement of fish/wildlife habitat, improvement of watersheds, water quality and invasive species control (p. 380). However, how those priorities are balanced is left to the program participants. Another important criterion for evaluation of CFLRP proposals is that

---

[1] Awareness of historic range of variability (HRV) is considered useful in setting restoration goals, but many people note it is not possible or necessarily desirable to return to historic conditions (Brown, Agee, and Franklin, 2004).

they build on successful collaborative efforts (Charnley, Long, and Lake, 2014) although again, collaboration is left undefined.

The following sections will begin unpacking these ideas and uncovering relationships between them. First I will establish an ideal type of "normal" science and then outline the theory of "post-normal" science in order to further explore the different roles science, scientists, and their tools can occupy. The framework of post-normal science also serves as a means to explore integrated roles for scientists that diverge from those within "normal" science. Next, this review will define collaborative governance and outline Grass-Roots Ecosystems Management. Finally, the literature on the role of science in natural resource collaboration will be reviewed before closing on a discussion of simulation models and their participatory uses.

## Literature Review

### Normal Science and Positivism

Before describing new models for science it is important to define the traditional or "normal" type of science. The concept of post-normal science is so named to differentiate itself from "normal science" as first defined by Thomas Kuhn in his 1962 book "The Structure of Scientific Revolutions" wherein experts conduct research in order to provide answers to solvable puzzles within accepted "paradigms". To Kuhn, paradigms are the accepted frameworks that characterize the observable world in a particular scientific discipline. In the normal model of science, paradigms change because science has rejected false explanations for how the world works and adopted a new paradigm that is closer to the "truth", a notion which Kuhn denies, claiming instead that scientific inquiry is an ever-changing process in which current theories are not true, but only accepted as such within the reigning paradigm of normal science (Steel, List, Lach, and Schindler 2004).

Normal science has been linked to positivist thinking, springing from the scientific revolution and the Enlightenment in the 16th and 17th, and developed by Auguste Comte and others later in the 19th century (Steel et al., 2004). Positivism according to Fischer (2000) "relies on empirical measurement, analytical precision, and a concept of 'system' which provides the foundational worldview" (p.16). Steel et al., drawing from Scruton (1982) summarize key elements of positivism:

> (1) science can provide accurate information about the world; (2) the knowledge produced by science can be unbiased and value neutral; (3) the growth in scientific knowledge leads to general societal progress; (4) scientists must be free to follow the laws of reason in an open system or society; and (5) since science is a matter of truth that is independent of human thought, it is accessible to all peoples regardless of status, culture, belief, and background. (p. 3)

In the normal model, science uncovers "facts" by limiting biases, prejudice, and irrationality (Funtowicz and Ravetz, 1993). The knowledge that science uncovers is taken to be value-free and objective, and therefore could provide information to the policy realm from a disinterested, neutral position, uncorrupted by political influence or opinions (Nowotny, 1993, p. 72). This knowledge could be used to redesign social systems and institutions to solve social problems (Fischer, 2000). Therefore, strict positivist thinking has implications for not only the nature of science, but the role of scientists and nonscientists in decision-making. In this case, scientists stay removed from management (lest they risk their credibility) and provide information as experts and consultants only when called upon by managers, policy makers, or the public (Steel et al. 2004, p. 4). Although the tenets of positivism have been called into question by sociology of science academics, and many scientists themselves freely admit social influences shape research, the positivist conception of science is still very much alive in some scientific circles and the popular culture in general (Steel et al., 2004).

For normal science to work in decision-making, the policy realm must also be "normal" in that puzzle solving by experts provides adequate knowledge for decision-making (Funtowicz and Ravetz, 2003). However, Funtowicz and Ravetz (1993) add that normal research is conducted "in ignorance of the wider methodological, societal, and ethical issues raised by the activity and its results" (p.86). They argue that current environmental problems characterized by high decision stakes, a high degree of uncertainty, and conflicting values require a new type of science (Funtowicz and Ravetz, 1994).

## Post-Normal Science

There are many arguments for how and why the practice of science needs to change. Bäckstrand (2003) explains that movements that aim to change the relationship between "science, expert knowledge, and citizens in democratic society" (p. 24) broadly seek to address problems of representation, participation, and democracy in science. The three main arguments for increased public participation in the scientific domain she identifies are to restore public trust in science, respond to the demands of complex environmental systems, and democratize science (p. 33).

Many scientists have taken it upon themselves to regain public trust through science education and improved communication. Ultimately this type of outreach constitutes the least revolutionary change for science, as one of its core assumptions is that the public misunderstands science (or is scared or irrational) and therefore distrusts it, meaning education would allow the public to trust experts again (p. 31). Democratization of science finds its supporters in those who believe technocracy and the privileged role afforded to science challenges the rule of the people (p.33). Proponents argue for representation by minority groups in science, the right for people to deliberate upon issues that affect them directly, and for other types of indigenous and local knowledge to be considered equally along with scientific information (Bäckstrand, 2003, p. 34).

Finally, some argue that science needs to adjust due to the complexity of environmental problems, which often have high decision-stakes, system uncertainties, and intense value disputes (Funtowicz and Ravetz, 2003). Although post-normal science (PNS) describes many of the same changes underpinning efforts for the democratization of science, it does not do so to spread democracy, but to make science more effective (Bäckstrand, 2003). However, the theory and practice of post-normal science has been developed in response to the same kind of problems that may also require new administrative structures and models of public participation. This connection will be developed in the section on collaborative governance.

There are competing theories for the change in the practice of science that are used in the environmental policy realm such as Mode 2 science (Nowotny, Scott, and Gibbons, 2003) and post-academic science (Ziman, 2000). Yet as the academic debates continue, new ways of integrating science are being operationalized by funding agencies and practitioners (van Kerkhoff, 2005). For the purposes of this study the post-normal framework will be adopted since a substantial amount of literature in the field of natural resource management, environmental policy, and participatory modeling employ it, making it possible to draw from and contribute to a larger body of work.

Uncertainty plays a major factor in the argument for post-normal science. The classic problem of scientific uncertainty in environmental problems as described by Lemons (1996) is that when scientists try to find evidence of an environmental harm they use a standard criteria, such as a 95% significance level, which helps them minimize Type I error (rejecting a true null hypothesis) thus avoiding speculation. However, if scientists are not explicit about their treatment of uncertainty, the public often accepts scientific results as more factual than they are which hinders them from adopting a more precautionary approach (p. 1). For example, scientist may find that introducing a chemical to the environment might cause damage to human health at a lower confidence level than is considered statistically significant for a scientific finding. However, this confidence level may still be high enough for the people who might be affected to decide the risk of introducing the chemical is not worth it. Likewise, some argue that instead of attempting to minimize Type 1 errors as scientists often do, Type 2 errors (accepting a false null hypothesis) should be minimized since laypeople should have the right to protect themselves from decisions that affect their health and safety and not everyone bears risks and costs equally; therefore potential hazards should be considered guilty until innocent, instead of innocent until proven guilty (Shrader-Freshette, 1996).

Furthermore, sometimes risk cannot be calculated at any significance level, such in the case of siting of nuclear waste repositories, since such materials pose a risk over a timeline so long that all possible causes of leakage cannot be predicted and quantified. In this case science can provide no real assessment of the suitability of one site over another (Shrader-Freshette, 1996). Similar ideas of the incalculable risks have been raised in Ulrich Beck's (1992) descriptions of the risk society.

In basic science, one form of normal science, uncertainty is very low since there is the expectation that the problem can be solved (Funtowicz and Ravetz, 1994, p. 1882). Also, since the research is motivated by the interest or curiosity of the scientists the decision stakes, that is, the "costs, benefits, and value commitments that are involved in the issue through various stakeholders" (p.1882), is also very low. Funcowicz and Ravetz (1993) describe three problem solving strategies each facing larger levels of uncertainty and decision stakes: applied science, professional consultancy, and post-normal science.

In applied science, uncertainty and decision-stakes are low, but higher than in basic science. Uncertainty in applied science (the second normal science) is managed at the technical level by keeping instruments operating reliably and using software and statistical tools to process data. The decision-stakes are a little higher as well since some party, not necessarily the researcher, has use for the answers the research will supply. At higher levels of uncertainty, professional consultancy or "client-serving problem solving" (p. 1883), like medicine or engineering, uses applied science and technical methods for reducing uncertainty, but also employs personal judgment to make up for higher levels of uncertainty when theories or information are unreliable. Finally, when uncertainty is epistemological (meaning it borders on ignorance and is irreducible) or ethical (there is no clear way to adjudicate between competing rights), neither normal science, nor professional consultancy can completely solve post-normal problems (p.1884).

Since uncertainty cannot be reduced using normal science alone, quality becomes a much more important concept. Funtowicz and Ravetz (1993) clarify the relationship between uncertainty and quality in decision-making, since it may be acceptable for the former may be low if the latter is high. The authors define quality as "the totality of characteristics of a product that bear on its ability to satisfy an established use" (p.90). In this instance quality is determined in part by extended peer communities (EPC) of stakeholders and academics from various disciplines who contribute their own expertise and knowledge of local systems (Haag and Kaupenjohann, 2001). They bring to bear "extended facts" in the form of local knowledge, values, beliefs and perspectives that are considered alongside the products of traditional research which are now introduced as "evidence" instead of facts (Funtowicz and Ravetz, 1997). Therefore the EPC, by introducing these important elements, becomes a vehicle for the quality assurance of the results through "completeness of information assessed by a range of epistemological and ontological positions" (Turnpenny, Jones, and Lorenzoni, 2011, p. 6). The underlying reason that quality takes a central role is that learning "truth" is a distraction from the real goals of crafting policy (Funtowicz and Ravetz, 2003, p. 2).

Dialogue takes a central role in combining scientific evidence with stakeholders' own knowledge of their system and situation and assessing policy proposals (Funtowicz and Ravetz, 2003). Through an inclusion of "a multiplicity of legitimate perspectives" complexity is acknowledged (Funtowicz and Ravetz, 1997). Furthermore, in post-normal science, since uncertainty is so high and the impacts to people and systems (say in climate change mitigation) have the potential to be so disastrous, basing decisions on normal or applied science is unlikely to be politically tenable, therefore public values become crucial for assessing issues, setting policies, and distributing costs (Funtowicz and Ravetz, 1994, p. 1884). In this way, politics and values are acknowledged and legitimized. The fact/value dichotomy also has been eliminated since various actors can marshal different facts to support their values. Deliberation serves to clarify positions and ensure that values are made explicit, so that new avenues of research can be opened up (p. 1885). The focus then becomes about mutual learning between experts and stakeholders, instead of making blueprints (Ravetz, 2006). Post-normal science still uses the methods, data, disciplines, and theoretical lenses of normal science, however, it is fully acknowledge that these can provide stakeholders with their own relative facts which help form and inform interests and opinions (Sarewitz, 2004). However, research can continue when the EPC develops a consensus on a scientific framework for the problem (Funtowicz and Ravetz, 1994, p. 1885).

Post-normal science's treatment in the literature is not uniform. Turnpenny, Jones, and Lorenzoni (2011) note that it has been most commonly used as a response to Kuhn, an argument for extending traditional science, a method for scientists to approach research, and as a means for social and environmental change. The context for post-normal science has also changed recently, now embraced sustainability (and therefore ecosystem management) in the form of human physical, social, and cultural survival, instead of managing the uncertainty of technological risk (Ravetz, 2006).

It has, at times, been criticized for being prescriptive and normative (Turnpenny, Jones, and Lorenzoni, 2011). However, as Farrell (2011) states, the empirical observation that the need for new methods for approaching complex problems is linked to the character of the problems; therefore the sciences needed to address those problems are different from those that created it (p. 4). Farrell continues that post-normal science "offers a conceptual frame within which the character and dynamic of these situations can be placed and through which the complexity of their dynamics can be better understood and constructively managed" (p. 6). I accept Farrell's perspective, but also asks the question: Even though theorists and practitioners have widely embraced it, do participants engaged in collaborative ecosystem restoration embrace post-normal science and the roles it implies for scientists and simulation models?

## Collaborative Governance

As the logic behind ecosystem management and sustainability push science to adapt, similar arguments also require more citizens, interest groups, industries, and government agencies at different levels to work together to make decisions (Paassen, Opdam, Steingrover, and van den Berg, 2011). Collaborative governance (CG) is an important concept for this study, since such arrangements often work with scientists and incorporate science into their discussions and decisions. One of the commonly identified motivations for collaborative arrangements are "wicked" problems or problems that are ill-defined, complex, highly disputed, and interminable (Rittel and Webber, 1973). Weber and Khademian (2008) note the cross-cutting nature of wicked problems wherein traditional boundaries of management, policy domains, and group interests are no longer valid. The similarity between "wicked" and "post-normal" problems is fairly evident; both are marked by high levels of complexity, dispute, and uncertainty. Other responses to such problems are outlined in the literature, such as the remaking of administrative institutions (Kettl, 2006) or developing new methods of problem solving (Roberts, 2000) to address wicked problems. Collaborative governance often includes both of the above. As others have observed, at times it is difficult to know whether the remaking of science requires changes in governance or changes in governance require new ways of doing science (Wesselink and Hoppe, 2011). Instead of engaging in this "chicken or the egg" question, this study approaches it from the science side, while acknowledging this may not tell the whole story.

Collaborative governance, as defined by Ansell and Gash (2008) is a "governing arrangement where one or more public agencies directly engage non-state stakeholders in a collective decision-making process that is formal, consensus-oriented, and deliberative and that aims to make or implement public policy or manage public assets or resources" (p. 544). This section will not provide a comprehensive overview of collaboration literature; since as Ansell and Gash (2008) note it often concerns itself with the species instead of the genus of collaboration. Instead, this section will identify the particular type of collaborative governance arrangement that the two groups included in this study represent.

In the American West, CG arrangements can often be characterized as what Weber (2000) calls Grass-Roots Ecosystem Management (GREM). GREM takes the view that the environment, economy, and society can be simultaneously addressed in public lands and natural resource management. It focuses on a balanced, long term perspective, and provides mechanisms for public deliberation (Weber, 2000). GREM is a particular method of enacting ecosystem management that reorients management from the bottom up and gives stakeholders more direct participation in the management process employing deliberation, negotiation, and consensus with the underlying assumption that the government cannot effectively manage complex systems alone (Weber, 2000, p. 250). Participants in GREM have a distinct connection to place, and engage in deliberation and shared learning that helps them transcend individual preferences (p. 251). They often do so through the formation of collaborative groups with a unique name and mission. Collaborative groups are the form of collaboration examined through the remainder of this study.

The literature has many models for how CG arrangements incorporate information and ideas from different perspectives, although many lack specific considerations relating to the integration of science and scientists into the process. Daniels and Walker's (2001) collaborative learning process hinges on systems thinking which is meant to bring participants a greater awareness of how complex systems work by bringing a multitude of perspectives to bear in order to ensure that problems, rather than only symptoms, are being treated (p. 20). Likewise, Emerson, Nabatchi, and Balogh (2012) agree that including "multiple perspectives and different interests" is not just a normative organizing principle but also offers better decisions that take all who are affected into account (p. 11). Weber and Khademian (2008) focus on the need for broad knowledge bases from many different domains when addressing wicked problems and the challenges of transfer, receipt, and integration of knowledge, particularly since each stakeholder will bring different expertise and expectations for expertise to the collaborative setting. Van Buuren (2009) writes about different "ways of knowing" (i.e. looking, thinking, dealing with a problem) that must be combined in a way to build a unified body of knowledge that will allow collaborative groups to gain a shared understandings of the problem, agree on a solution, and measure outcomes (p. 209).

## Integrated Roles for Science

Given the acknowledgement for a diversity of perspectives and ways of knowing to be brought to bear in order to address post-normal or wicked problems and strengthen collaborative governance arrangements, it would seem that this would drive more integrated roles for scientists in natural resource management, but studies have found a little more complicated picture. For example, positivist beliefs might be behind some people's preference for more integrated roles for scientists: Steel, List, Lach, and Schindler (2004) found that respondents in the Pacific Northwest belonging to the attentive public and interest group representatives have more positivist inclinations and are more likely than managers and scientists themselves to believe that science can provide objective facts. However, instead of supporting the minimalist, detached, normal science role, they favored scientists interpreting the results and even integrated them into management practices. Scientists on the other hand, had less positivist inclinations, yet still preferred more integrated roles. This study suggests that the wider belief in positivism in the public motivates them to bring scientists closer to management since they bring with them privileged knowledge. However, scientists are less certain about the objective truth they can provide, and may therefore engage in the process due to more "post-normal" beliefs (p. 9). This highlights the confusing nature of motivations for integrated research. Beliefs that scientists can access objective facts to guide management motivate some people's desire for scientists to occupy more integrated positions. Whereas scientists, perhaps acknowledging the limitations of science, see the need for closer linkages to management, possibly to make up for what science cannot provide. Given this research and other calls for more integrated research, it is important to unpack the term “integrated”.

Part of the issue when talking about integration is that the term is used to mean many different meanings as it is employed by funding agencies, researchers, theorists, and practitioners. Practitioners and proponents of integrated science draw on “different epistemologies, assumptions about governance and change and the role of science in society” (Paassen, Opdam, Steingrover, and van den Berg, 2011, p. 24). Van Kerkhoff (2005) says integration is “emerging as a formal concept—or suite of concepts—that is being used to prescribe research activity and the form and function of relationships between researchers and environmental policy-makers and managers” (p.452). In her paper “Integrated Research: Concepts of Connection in Environmental Science and Policy” she developed a typology of integration based on a review of studies of integration in policy contexts. She identified 12 thematic categories of integration which she positioned into a framework of four types: integration within science, integration across structures, integration beyond science, and integration across activities. This tool can be used to investigate how different kinds of integration affect the relationships between science and policy as some types of integration in many schemes imply new roles for scientists, and for science itself.

Science is a unique form of knowledge and integrating it into the decision-making process comes with its own challenges. Much of the literature on integration in the natural resource field focuses on the challenges for scientists as they integrate, two of which are advocacy and credibility. Advocacy refers to the practice of scientists speaking out in favor of policies. There is disagreement as to whether scientists should advocate for specific policies since their knowledge and perspective is unique and valuable, or if they should not advocate for any specific decisions since the information they provide must be viewed as credible and unbiased by all sides (Scott et al, 2007). Lackey (2007) argues that scientists should not only publish, but should be “involved in providing and explaining the underlying science to help resolve important policy questions” (p.12). He warns not only against the obvious forms of advocacy but what he calls “stealth advocacy” in the form of value-laden language included by scientists in published papers. For example, describing an ecosystem as “unhealthy” implies that there is some agreed upon preferred state of a healthy ecosystem that exists outside of people’s preferences. Put in another way: “One person’s damaged ecosystem is another person’s improved ecosystem” (p. 15). The dangers of advocacy have led some to recommend that researchers should maintain distance, perhaps by keeping separate institutional affiliation when conducting integrated research so that they remain independent from the final management decision (Mills and Clark, 2001, p. 193).

Trust is also a major determining factor of scientists’ credibility when working with the general public. Mostert and Raadgever (2008) say that trust includes the “track record of the researchers, their consideration of the information and the views of the public, their openness to criticism, their institutional affiliation” and the concepts and values reflected in their research (p. 1093). Roux, Rogers, Biggs, Ashton, and Sergent (2006) write that in order for a scientist to function well they need to be recognized as competent and safe by those with whom they work. Competency refers to the typical hallmarks of expertise (accomplishments, technical ability, experience, communication skills). Yet, the authors warn, scientists often neglect their safety credibility, which means that people in the group do not feel “intimidated by perceptions of his or her ‘superior knowledge’” (p. 4). The authors note that it is often hard to simultaneously increase both.

Hinkey, Ellenberg, and Kesler in their paper “Strategies for Engaging Scientists in Collaborative Processes” outline the large differences in the collaborative and scientific process and suggest that participants in integrated processes benefit from understanding both. Mills and Clark (2001) focus on the different work environment scientists are exposed to and how many have to adjust to “working on new types of problems; intense public scrutiny; criticism and attacks; cross-disciplinary science that often bring conflicting scientific ideologies, theories, and methodologies together, short time frames; different types of processes and products; and often changing questions and direction at the process unfolds" (p.192). Furthermore Mostert and Raadgever (2008) note that not all scientists will enjoy working in integrated roles since it requires more of them personally including "good social skills, flexibility, and the ability to cope with complexity and ambiguity" (p. 1093).

Other important concepts relating to integration relate to the literature on "boundary work" which studies how the integration of science and politics can lead to more productive policy making (Guston, 2001). Boundary organizations "involve the participation of actors from both sides of the boundary...and they exist at the frontier of the two relatively different social worlds of politics and science, but they have distinct lines of accountability to each" (p. 400-401). Also they contain professionals who serve in a mediating role. Often known as knowledge brokers, they are people who connect the science and policy worlds. They take on dual roles as "users in communication with knowledge producers, and producers in communication with knowledge users" (Raadgever and Mostert, 2007). They can also play a role in synthesis of knowledge (Jassanoff, 1990). Likewise "boundary objects" in the form such things as maps, websites, or participatory models "sit between two different worlds, such as science and nonscience, and can be used by individuals within each for specific purposes without losing their own identity" (Guston, 2001).

The ideas of boundary work help move the discussion past the pitfalls, into possibilities for integration. In their book, Knowledge in Action, Paassen et al. (2011) highlight the importance of system thinking and differentiate between four types; hard, soft, critical, and innovation systems thinking. The authors explain that embracing different types of systems thinking implies different roles for researchers (p. 43). Hard systems thinking directs the researchers to focus on knowledge integration and concrete goals. In its early forms it embraced a positivist epistemology that assumed ecological systems had optimum states, used a functionalist approach, and integrated geographic, ecological, and economic knowledge in order to understand how to achieve ecologically sustainable and economically productive outcomes (p. 25). Paasen et al. note that hard systems thinking has since recognized non-linear dynamics and the importance of localized knowledge to systems, but still maintains "command and control" roots. The main focus here are well defined goals with the additional challenge of integrating various types of knowledge.

The three remaining types of systems thinking; soft, critical, and innovations bring on new roles and concerns for researchers. Soft systems thinking builds on a constructivist epistemology which takes the stance that all knowledge including science is socially constructed and shaped by history and culture (p. 26). Soft systems thinking uses other types of knowledge and values to compensate for ignorance and scientific uncertainty and ensure that research is ethically sound. Soft systems thinking here begins to resemble post-normal science wherein researchers must adopt the attitude that their knowledge is not superior, and can be at times very relevant and other types ignored. The role of the scientists in soft systems thinking is to aid in social learning and capacity building.

Critical systems theory focuses on the power imbalances among stakeholders and attempts to encourage constant critical awareness, equitable distribution of power, and the use of complementary systems approaches (p. 28). The role of the researcher is to see to the equitable and inclusive exchanges and governance structures. Finally, innovation systems thinking recognizes that the institutions (defined as "cultural-cognitive beliefs, norms and values, rules and routines that provide stability and meaning to social life in groups") of the past are not necessarily suited for the goal of sustainability and they must be assessed, adjusted, and generally made adaptive (p.29). This puts researchers more in the role of knowledge brokers who "consult, inform and match knowledge of stakeholders at various system levels to enhance knowledge exchange for action, or opt for capacity building, and enable stakeholders to reflect upon and tackle intuitional bottlenecks for learning, communication and change" (p.43). These approaches and roles have spawned different tools for use within participatory research and the following section covers the tools examined in this study, simulation models, which are positioned within the larger field of Participatory GIS.

## Participatory Geographic Information Systems

Researchers have long been creating and adapting tools for interacting with stakeholders and interested publics. Participatory GIS (PGIS) is one of the tools that has been used for decades. Defined by Dueker and Kjern in 1989, GIS is "a combination of hardware, software, data, people, procedures, and institutional arrangements that are used in a process for collecting, storing, manipulating, analyzing, and displaying information about spatially distributed phenomena for the purpose of inventory, decision-making and/or problem solving within operations, management and strategic contexts" (Nyerges, Goodchild, Parks and Steyaert, 1993, p. 75). In its early days GIS was developed and used primarily within agencies (Nyerges, Janowski, Tuthill and Ramsey, 2006), but by the 1990s it was widely discussed as a tool for promoting increased public involvement in decision-making (Sheppard, 1995). GIS soon became a preferred tool for "analysing spatial data and the preferred medium for conveying scientific findings and policy alternatives to a wide range of audience" (Duncan and Lach, 2006, p. 202).

Participatory GIS, or PGIS, at its most basic level, as explained by Dunn (2006), "involves local communities in the creation of information to be fed into the GIS and subsequently used in the spatial decision-making which affects them" (p. 619). GIS' efficient data handling, ability to aid in visualization of landscapes, and communicative power of spatial information were initial motivating factors for bringing GIS to broader publics (Budic, 1994). Participatory GIS has been seen as a means of letting people affected by issues have a say (Jankowski and Nyerges, 2001), incorporating lay or traditional knowledge with scientific knowledge (Dunn, Atkins, and Blakemore, 1999; Kyem, 2004), and a tool that allows for more meaningful public participation in decision-making (Sieber, 2006; Craig, Harris, and Weiner, 2002). Jankowski (2009) wrote that PGIS helps "citizens understand spatial consequences of proposed projects, evaluate alternatives, and create new, original solutions." (p. 1965). They have been credited with the ability to aid in dispute resolution and open up the dialogue to include multiple perspectives and storytelling opportunities (Corbett and Keller, 2005).

Much of the PGIS literature focuses on the potential drawbacks of the practice. GIS is described as costly and time consuming which can stress non-profit (and even government) organizations that have little spare time and resources (Pickles, 1995; Sheppard, 1995). It has also been blamed for privileging experts and putting up barriers for stakeholders' participation in the process (Duncan, 2006; Pickles, 2004).

## Simulation Models

Nested within the larger PGIS literature is participatory simulation modeling. While often the PGIS literature refers to the "map-making" aspect of GIS, simulation models add extra layers of complexity and potential. Currently, spatial models based in GIS coupled with landscape simulation models are a popular means of examining the complexity and uncertainty of contemporary land use problems (Oxley, McIntosh, Winder, Mulligan, and Engelen, 2004). Models at their most basic are a "simplified representation of a system (or process or theory) intended to enhance our ability to understand, predict, and possibly control the behaviour of the system" (Neelamkavil, 1988). The rise of computers coupled along with systems theory allowed ecosystems to be coded and captured within models (Haag and Kaupenjohann, 2001). Current computer-based simulation models, although still simplified versions of reality focusing only on key components of a system that account for the greatest variability in system behavior (Mitchell, 2005), are becoming more complex as they seek to address the interactions between "human influences, ecological processes, and landscape dynamics" (Bolte, Hulse, Gregory and Smith, 2007). Such models simulate bio-physical processes over time across a landscape incorporating feedbacks between interrelated systems (Allen, Kruger, Leung, et. al, 2013).

Development begins with adding mechanistic system parts (vegetation succession, fire behavior, etc) and integrating them, before adding human dimensions, such as actors who make policy decisions (Allen, Kruger, Leung, et. al, 2013). Often the physical models within the system have been in use in land management agencies like the Forest Service. Representing human management decisions is a newer development and includes such practices as agent-based modeling (Bolte, Hulse, Gregory, and Smith, 2007). Additionally, the need to focus on different scales as resource management concerns itself with both site-specific and landscape-scale processes (Letcher, Jakeman, and Croke, 2004), means the models must strike a "balance between model simplicity and complexity through, for example, using nested and linked models of varying degree of complexity applied to the same region or problem" (Liu, Gupta, Springer, Wagener, 2008, p. 852).

Building a model is a subjective process that involves judgment, experience, and many choices, and when using them in decision-making it opens all those choices to critique from scientists and laypeople (Haag and Kaupenjohann, 2001). Benefits of human -ecological integrated modeling efforts include their ability to represent information from different domains and disciplines in a single format that is easily understood by diverse decision-makers (Parson, 1995). It has been seen as a way to deliver the "best available" science to decision-makers (Liu et al., 2008). Although, participatory modeling suffers from many of the same criticisms as PGIS in general, namely that they can operate as black boxes that impose a technical rationale, thereby limiting participatory processes (Haag and Kaupenjohann, 2001).

Participatory simulation modeling is being pushed towards stakeholders, as well as requested by them. Funding agencies have been encouraging their grantees to engage stakeholders in research that could be useful to them (Oxley et al., 2004). However, this does not always guarantee that researchers believe incorporating stakeholders in their process as important. Allen et al. (2013) found that nearly one quarter of the principal investigators working on a large Earth systems modeling project designed to let stakeholders influence research questions believed the projects' main purpose was to answer academic questions and build technical capacity and considered academics their primary stakeholders (p. 354). Just as funding agencies are pushing GIS toward stakeholders, stakeholders have incentives to adopt it as well. GIS is often considered the lingua franca in the discussion of spatial issues, and can lend legitimacy to organizations that use it, allowing them to appear more professional and scientific (Sieber, 2000).

There are many ways for stakeholders to participate in the creation of models. Allen, Kruger, Leung, et. al, (2013) noted that "identifying research questions; sharing values, preferences, expectations and perceptions of risk; providing quantitative data or local expertise; commenting on research concepts, drafts and results; learning from the research process; and/or integrating research findings into decision-making processes (p. 346). Parker et. al (2003) described several levels of public involvement in model development: participation in all stages; participation in model running, but not building; and using models to present scenarios to stakeholders in order to solicit their input. Some argue that jointly developing a set of scientific questions is the crucial first step since it will allow participants to choose what variables will be included or excluded, the model's boundaries, and the model's objectives, and therefore create a research framework which will allow for data gathering and development of modeling systems as well as increase understanding and coordination between researchers and stakeholders and ensure the information produced is salient (Liu et al., 2008). Likewise development of a conceptual model, essentially a description of what will the simulation model will be, bridges the gap between the science questions and the model being built. Often a repetitive and adaptive process, it allows stakeholders and researchers to engage in discussions and build the model interactively (Liu et al., 2008). The choices that have to be made in participatory modeling mirror those of integrated research in general. Given that these tools can be used in ways that reflect both normal science and post-normal science, this study asks what uses do stakeholders prefer? What role do they expect scientists to take in using them?

# Method

The purpose of this study was to investigate the expectations for the role of scientists and simulation models among participants engaged in collaborative ecosystem restoration. Two collaborative groups, the Deschutes Collaborative Forest Project (DCFP) and the Lakeview Stewardship Group (LSG), located in Oregon and currently engaged in the CFLRP were selected for this study. In 2012 they were approached by a multidisciplinary research team called Forests, People, Fire (FPF) for the purpose of exploring the possibility of participating in the use of a simulation model. FPF's goal was to "use systems models, integrated research, and collaborative learning to improve our understanding of how humans adapt (or not) to living in fire-prone forests and to learn how policies could be made more effective" (FPF, 2011). At the time this study was beginning, Forests, People, Fire was conducting workshops with each of the collaborative groups in order to give an initial demonstration of the model's capabilities, gather feedback on the model itself, and discuss potential uses within the collaborative groups. This provided an opportunity to study two critical cases "having strategic importance in relation to the general problem" (Flyvbjerg, 2006, p. 229). In this instance, this meant speaking to participants about their expectations for such a model within their restoration efforts. Speaking about simulation models during the interviews allowed for the conversation to be widened to participant's expectations for scientists' role in the process and also the role of scientists in their collaborative work in general. I used the resulting data to examine the population of people exposed to FPF's simulation model, Envision, as well as conduct a comparative analysis of the collaborative group level of experience. The next sections will give a brief description of both collaborative groups' contexts.

## Context

**Deschutes Collaborative Forest Project.** Deschutes County in central Oregon had a population of 157,733 in 2010 and a median household income of $50,209 for the years between 2009 and 2013 (USCB, 2015a). Although the area around Bend and

Sisters experienced a decline in the natural resource extraction industries, outdoor recreation, tourism, and amenity-based in-migration contributed to the area's population doubling over the past three decades (Judson, Reynolds-Scanlon, and Popoff, 1999).

The DCFP focuses primarily on land in the Deschutes National Forest. The original 2010 CFLRP proposal covered 145,000 acres, the majority of them being Forest Service lands, and 33,000 acres of private lands owned by Whitefish Cascade Timber Resources that may become the Skyline Community Forest. In 2013, the restoration area was increased to 257,000 acres including areas to the west and south of the towns of Bend, Sisters and Sunriver and includes the source of Bend's municipal water (DCFP, 2013). According to the DCFP, 76% of the landscape is ponderosa pine or dry mixed conifer forest (65% of just federal land) of which 50% is classified as being in need of restoration (DCFP, 2013). Historically, the landscape would have been characterized as low fire hazard (visited by frequent, low severity fires), and the proposal suggests that within the 10 year period of the work the amount of landscapes characterized thusly will be increased from 32% to 50-65% (DCFP, 2010).

The DCFP's treatment objectives are to "restore resiliency in the Deschutes Skyline landscape and use the historic range of variability in forest structure and fire return intervals to identify the areas on the landscape that are highly departed, or different, from their historic conditions" (DCFP, 2010, p.1). Other goals the group has include providing for a diversity of wildlife habitats (e.g. northern spotted owl, white-headed woodpecker, steelhead) reducing the risk of high-severity fire in the wildland-urban interface and in watersheds that feed into municipal drinking water, preserving the quality of high-use recreation areas, supporting the reintroduction of anadromous fish, and providing restoration jobs.

The DCFP is a collaborative built on several other collaborative efforts (some originating in the early 90s); Central Oregon Partnerships for Wildfire Risk Reduction (COPWRR), Deschutes Fire Learning Network (DFLN), Project Wildfire, Deschutes Provincial Advisory Committee, and the Upper Deschutes Watershed Council, and thus functions as a "super-collaborative" pulling all of these groups together. Many parts of the proposed CFLRP plan build on work of these previous groups; for example, many areas have been selected for restoration work by the DFLN prior to starting the DCFP.

The group is guided by a steering committee consisting of approximately 20 people and is the formal channel for giving consensus recommendations for CFLRP fund allocation and restoration approaches to the Deschutes National Forest. Other subcommittees focus on restoration planning, implementation, communications and outreach, monitoring, and appropriations.

### Lakeview Stewardship Group

The 2010 census recorded 7,895 residents in Lake County. There was a median household income of $33,611 between the years of 2009-2013 (USCB, 2015b). The county has had slower growth than Deschutes County, about 23% since 1970, partly due to the in-migration of retirees. Its economy still largely remains focused on extractive industries.

The CFLRP proposal for LSG covers 682,289 acres consisting of the Lakeview Sustained Yield Unit. The landscape is a dry one consisting of juniper and ponderosa pine. About 88% of the landscape is forested with the remainder being sagebrush/steppe ecosystems (LSG, 2011). The group reports that past management and other human activities have caused loss of habitat, soil compaction, and increased fire risk. The group seeks to "sustain and restore a healthy, diverse, and resilient forest ecosystem that can accommodate human and natural disturbances" (p.5) including approximating historical species composition, stand ages, and fire regimes (p.8). The two other broad goals identified by the group focus on water quality and safeguarding people's material, recreational, and spiritual values (p. 5).

The Lakeview Stewardship Group was formed in 1998 in order to improve management of the Lakeview Federal Sustained Yield Unit. This unit was originally established in 1950 under the authority of the Sustained Yield Forest Management Act of 1944 for the purpose of maintaining the economic stability of nearby Lakeview and Paisley, Oregon mainly by supplying timber to local mills (LSG, 2011). The unit was reauthorized in 2001 with a focus on restoration and is the only remaining sustained yield unit in the nation.  In 2005, it completed a long-range strategy for the unit, which it updated in 2011 as it was applying to the CFLRP.  The group is composed of approximately 30 people.  They meet face to face approximately four times a year and communicate through phone calls and email throughout the year.

In 2002, the LSG created the Chewaucan Biophysical Monitoring Team to determine the current condition of the Chewaucan watershed, an ecologically and socially important watershed in the Sustained Yield Unit, and observe the effects of management (Thomas, 2012).  It conducts biophysical monitoring on permanent transects and collects data pertaining to soil type, canopy, vegetation, and streams characteristics.  The effort includes a place-based education component that allows local school students the opportunity to gather data and engage in the monitoring process.

## Sample population

This study took advantage of an event: a multidisciplinary research team comprised of research scientist exploring integrated work with a simulation model to collaborative groups. The goal was to document collaborative group participants' expectations for the role of scientists and simulation models in collaborative ecosystem landscape restoration.  A list of active collaborative members in the Deschutes Collaborative Forest Project and the Lakeview Stewardship Group was compiled using publicly available documents and websites, including the original CFLRP applications.  Additionally, Forest Service staff members who engage with the groups were also included. Forest Service employees often take an “arm’s length” approach towards CFLRP groups in order to retain ultimate management authority, avoid violating the Federal Advisory Committee Act, and comply with the National Environmental Policy Act (Butler, 2013). However, even if they are not officially listed as members of the group, they are often present at meetings in order to engage in deliberation and provide relevant information and perspectives and are therefore important participants in the collaborative processes.

## Participants

Interviewees were chosen using a purposive or “judgemental” (Babbie, 2010) sampling strategy. Purposive sampling, according to Ritchie and Lewis (2003) is a kind of non-probability sampling in which “units are deliberately selected to reflect particular features of or groups within the sampled population” (p. 78). Initially two main criteria were used to select participants in the study:

1. Activeness with the collaborative. Collaboration draws a lot of interest from the broader public and policy makers, but is a time consuming process. Therefore not everyone participates to the same degree. This study focused on the people in the collaboration who were most active, whether due to their role on a committee (as often the case with the DCFP), or longevity and frequency of time committed to the collaborative group’s activities. All interview participants for except one[2] were active members of the collaborative or were Forest Service employees who were actively working with the group.
2. Interest or perspective represented. Collaborative groups often have members who represent different interests (recreation, organizations, or government agencies). Interviewees were selected in order to represent this diversity. Additionally, in the DCFP, participation in various committees was also an important criterion for which diversity was maximized in the sample.

---

[2] One participant had recently left the DCFP, but was still included in the study since this individual had a sustained and instrumental role in the group, familiarity with the FPF project, and the organization was still in the process of filling the vacancy.

In early interviews I found participants reluctant to talk about simulation models if they had felt they did not have experience with them. Therefore, participants who had been invited to the Forests, People, Fire 2014 summer workshops were actively sought out since they since they a) had been exposed to a landscape scale simulation model b) had witnessed or participated in a discussion on how the model might be used and what role the scientists might play in it. However, several people were included who had not attended those meetings. These people were included in the sample mostly because prior experience gave them some exposure with simulation models. Ultimately I interviewed 10 people from the DCFP and 8 from LSG. It should be noted that participants will be referred to using the either DCFP or LSG in order to signify the collaborative group they are associated with and a randomly assigned number to help distinguish between individuals.

It is also important to note that this study did not try to measure expectations for the specific simulation model being developed by Forests, People, Fire, and care was taken to ask participants what they expected from simulation models in general based on their understanding of them, which often included, but was not limited to the particular simulation model being developed by Forests, People, Fire. This study will examine the population of active participants exposed to FPF's simulation model, Envision, as well as conduct a comparative analysis of the two collaborative groups.

## Interviews

A total of 18 semi-structured interviews were performed for this study. Since the purpose of was to learn about expectations for the role of science and simulation models in collaborative ecosystem restoration, and since there is no agreed upon scale or typology for the roles of science especially when discussing the various meanings of integration, a more open-ended method is justified. An interview guide consisting of eleven questions was used. Each question had possible follow up questions listed but the interview was allowed to proceed in a manner in which it naturally unfolded. For example, for participants who described their role in the collaborative as delivering science to the group, it was more natural to begin by talking about the role of science in the collaborative in general first before talking more specifically about the role a simulation model and scientists could play.

## Analysis

First, I recorded and transcribed the interviews. I then coded and analyzed them following the grounded theory procedure laid out by Auerbach and Silverstein (2003). The procedure begins by choosing relevant text to the research concerns. In the initial coding process, the text is organized into repeating ideas. Repeating ideas are compared and grouped, forming more general themes. These themes are then connected to more abstract concepts from the theoretical frameworks. Finally, these constructs are used to tell participants' stories through a theoretical lens. This bridges the gap "between the researcher's concerns and the participants' subjective experience" (p. 40). Auerbach and Silverstein (2003) note that this is not a linear process, and the analyst will often go back and forth between steps, change themes, etc. The analysis I conducted was no exception, but I will present it in a mostly linear fashion in the interest of clarity.

I started the analysis by grouping the text based on answers to questions from my interview protocol. This helped me determine relevant text. Although specific questions steered participants toward speaking about the role of simulation models and scientists in collaborative ecosystem restoration, text relevant to those questions often came out at unpredictable times in the interviews. From this relevant text, I began grouping repeating ideas. From these repeating ideas, I developed themes, the strongest being simulation models as discussion tools or decision tools. I looked back at the literature I had been reading to see what could explain this difference. I decided to use the post-normal framework since these two divergent uses for a simulation model suggest a post-normal and normal use respectively.

I then extracted concepts from the post-normal framework to see if I could find consistent evidence for a post-normal/normal divide in the two groups' approaches. Using the post-normal literature, I categorized normal/post-normal ideal types for 1) Use for a simulation model 2) Context for incorporating science 3) Role of scientist in using simulation models 4) Role of scientist in general. These concepts helped me restructure the themes I had been developing, and the ideal types allowed me to compare the participants' experiences to theory.

To examine the first concept (Use for a simulation model), I used the initial themes of discussion and decision and added uncertainty as another indicator of normal/post normal use. I returned to the relevant text and found repeating ideas related to these themes. Since I was interested in learning if the groups saw themselves in a larger post-normal/normal context outside of using models, I choose the "facts and value" theme to indicate this, and grouped repeating ideas underneath this. For the third concept, role of scientists in using model, I grouped together all ideas surrounding "participatory modeling". Finally, to understand the role of scientists in general in collaborative ecosystem restoration, I grouped ideas surrounding "science in collaboration". Analyzing from these four perspectives allowed me to see if these concepts of post-normal/normal science were represented, and converging within each of the two groups.

## Results and Discussion

The theme of simulation models as discussion tools appeared within text from interviews of participants in the DCFP, and the theme of simulation models as decision tools appeared within text from interviews of participants in the LSG. Therefore it may be reasonable to expect the DCFP to more closely conform to concepts of post-normal science and the LSG to conform to concepts of normal science. However, the narrative that emerged is more complicated. In terms of model use, the DCFP seemed to favor a post-normal use and the LSG favored a normal one. For the context of integrating science, the DCFP shows strong evidence for conceiving of itself in a post-normal context. There is some evidence of a positivist thinking in the LSG, however more data would have to be gathered to state with confidence that they see themselves operating within a normal science context. In terms of the role of scientists in using the model, the results were not as might be expected. Both group's preferences were essentially identical when it came to the role of the scientists in using the model. Finally, there is evidence to suggest that the DCFP wants scientists to take more integrated, post-normal roles in their group. However, the LSG also wanted more integrated roles (albeit different ones) suggesting that even when participants hold positivist views and believe themselves to be operating in a normal science context, they can still favor integration. The final section on boundary work contains important themes that I hadn't prepared for in my analysis, but still helped tell the story of how science is incorporated.

## Role of a Simulation Model

Through semi-structured interviews I engaged participants in conversations in order to learn how they thought simulation models could be used within their groups in the process of ecosystem restoration. There was a range of answers among participants, but strong themes emerged within each group, and contrasting between the two groups sheds some light on how they see the role of a simulation model in their process. These two distinct roles cast a simulation model as either a tool of discussion or a tool of decision.

**Simulation Model as a Discussion Tool.** Through thematic coding, I found that participants in the DCFP were likely to say they wanted to use a simulation model in order to run different “scenarios”. Seventy percent of DCFP participants discussed using a simulation model in this way. Scenario building is often situated within futuring research which is defined as “the study of the present reality from the point of view of a special interest of knowledge of the future; knowledge of the future considered characteristically as knowledge of contingent events” (Manermaa, 1986, p.658). Futuring studies has been described as a “very fuzzy multi-field” Mannermma, 1986, p.658) which encompasses many different terms and approaches

(Frame and Brown, 2008). A “scenario” is defined by Borjeson, Hojer, and Dreborg, Ekvall, and Finnveden (2006) as something that describes both “possible future states and descriptions of developments” (p. 723). The authors propose a typology, developed from examining nine other prominent typologies. They organize their typology based on how the scenarios can be used, namely to answer the questions: What will happen? What can happen? or How can a specific target be reached?

I found that DCFP participants conceived of simulation modeling akin to the scenario typology described by Borjeson et al. that seeks to answer “What will happen?” More specifically scenarios seek to answer the question “What if?” since the goal is not to predict future states with scenarios or even assign likelihood that any of them will happen, but rather each scenario aims to show what could happen in the case that one or more variables change (p. 726). Alternatively, use might fall into more explorative scenarios that are somewhat similar, to “what-if” scenarios, where changes usually take a longer time horizon to allow for more profound changes to occur (p. 727). As one DCFP participant described it:

> To me the value in that is, from a discussion support tool perspective, is you can collaborate without having a time machine and can basically adjust the sort of assumption and the parameters that inform each of those individual modules within the bigger envision model, run various scenarios and then compare the results over time. (DCFP #4)

Frame and Brown (2008) in their paper “Developing post-normal technologies for sustainability” provide criteria for post-normal science tools (PNST). Tools to be used in post-normal science must allow for “deliberation on issues to take place in inclusive ways that permit multiple and potentially conflicting views to be aired, understood and considered outside of existing institutions” (p. 229). They should allow users to ask “what about/what if” questions (Ravetz, 2006, p. 277). For many (50%) of the DCFP participants a simulation model could act as a focal point for open-ended discussion, which is a post-normal use:

> So it helps understand risks and tradeoffs but it’s in a very general way. However, I think that’s important since it helps everyone in the collaborative get their head around these different scenarios in order to talk about them. It adds some structure and some organization. (DCFP #7)

Participants hoped this discussion based on the model would help them to integrate social and ecological issues. In this way, a simulation model could function to help blend scientific information in the form of the physical models with the knowledge and interests of the groups, thereby acting as a "soft systems" tool of social learning as discussed in the collaborative governance and post-normal science literature:

> What it does is helps provide structure to the dialogue and I think it's kind of a catalyst for creating the proper dialogue, because you do have to integrate the social, economic, and environmental issues, if you ignore one over the other eventually it's not going to turn out well.. (DCFP #9)

Not all participants in the DCFP saw a use for simulation models in this way, however. Two participants saw no real benefit from the group using simulations models to generate scenarios for use within the collaborative group. One participant said that a simulation model would not provide a good focal point for discussion since people would just argue the "science behind it" and you would not "have an absolute starting place" (DCFP # 8). The other participant thought that the scenarios generated by a simulation model would not add anything to the DCFP's discussions:

> Everybody wants the same thing so there's not the need to say, "It's going to look like this versus look like this." As long as the interests have been accommodated in our deliberations and are factored in our recommendations we're doing our job. (DCFP #7)

However, this participant did believe that they could be used to communicate the goals of restoration and provide a platform to give visuals of a potential future to the wider public, which would allow the DCFP to gauge their reactions. Likewise, 50%[3] of the participants also saw the potential to use simulation model to communicate to a broader audience. For many in the DCFP this was an extended conversation or "third tier" activity as participant DCFP #7 put it; the first tier being gathering and understanding science and the second being deliberation within the collaborative.

---

[3] Uses were often not mutually exclusive; some participants thought that a simulation model could be used within the group for discussion and to communicate to the public.

**Simulation Model as a Decision Tool.** Participants in LSG were likely to talk about using the model to make a decision (50%), often in terms of "strategic optimization" or identifying areas that would be most beneficial to receive restoration treatment:

> So that would probably be the main thing for the out years of our CFLRP program to see if the modeling is helpful identifying next areas to be treated and what kind of treatments would be most beneficial for the ecosystem and the community. (LSG #2)

The use of the simulation model here more closely fits the question "How can a specific target be reached?" Specifically, "the study has explicit normative starting points, and the focus of interest is on certain future situations or objectives and how these could be realized" (Borjeson, 2006, p. 728). In this sense it focuses more on the efficiency of how to reach a goal that has already been decided upon:

> Everybody's maxed out as it is. We need more resources, and the other thing is to help be smarter about using the resources you do have to get that strategic prioritization on the landscape. So I'm hopeful it can help with that. (LSG #4)

The model in this use becomes an example of hard systems thinking. Simulation models as a communication tool was a secondary use also mentioned by participants in the LSG (50%), although opinions varied on whether it would serve to educate the public about restoration work or serve as a means to convince others that restoration work was necessary and beneficial. Contrasted with the DCFP, many LSG participants believed that a simulation models was not the right tool to help integrate human and ecological concerns (50%). A smaller number (25%) thought that simulation models could, since they were able to generate information about possible economic outputs.

**Uncertainty**. The above section describes two different main uses for a simulation models in collaborative ecosystem restoration. Exploring the theme of uncertainty will help further explain why the two groups imagine different uses for a simulation model and relate those uses to theoretical concepts from the post-normal science framework.

Uncertainty in normal science and hard systems thinking can be reduced by technical means and falls within the conventions of normal science (Haag and Kaupenjohann, 2001). The use of a simulation model to reach certain targets puts more emphasis of the reduction of uncertainty in the model. Part of the reason that that LSG participants might have confidence in using simulation models to support decisions is that they have been using them in their monitoring activities. This had helped build confidence in their ability to reflect the landscape. One LSG participant speaking of using models in this way said:

> I think it models it pretty well for making decisions like that as long as somebody has taken the time and not gone and grabbed some data and take it to the computer but has gone forth to ground truth it and said, so, what percent is kind of like this? If 70 percent of the area fits the model that's really what it looks like and then I think it would be safe to make a decision to run fire through it or something like that. (LSG #8)

LSG conducts its monitoring activities to support its work in the CFLRP[4] and also as part of its larger adaptive management approach. LSG participants (60%) suggested that “ground truthing” a model would be an important factor for people to trust a model and a necessary requirement for its usability. LSG interviewees (25%) saw potential to use the monitoring data to improve the quality of any newly adopted simulation model:

> Well one thing that's important to the group is our local monitoring project which has been going on for 10-12 years and is producing a great deal of monitoring data about the forest, streams, soils, etc, so if there's a way to use this local monitoring information and make the model more based upon the actual reality of the ecological conditions within the area that would be, I'm not sure if that's feasible to do but theoretically that would be you know make for a very robust model I think and one that would make good use for the monitoring information and make the model much more credible locally. (LSG #2)

When I talked to LSG participants about the collaborative process and science, they frequently talked about monitoring and adaptive management. Although there are many adaptive management models, Mcfadden, Hiller, and Tyre (2011) note that

---

[4] All CFLRP groups are required to monitor ecological, social, and economic conditions for 15 years after implementation (p. 387). The idea being that generating knowledge about the successes and failures of activities will help facilitate learning for people inside and outside the program.

most stress that “active learning with continuous monitoring…. allow for more informed decision-making as the number of iterations increase” (p. 1356). The two main schools of thought related to adaptive management are the Resilience-Experimentalist and the Decision – Theoretic School. According to Mcfadden et al. the former leads to complex ecological models that include many details of the ecosystem, whereas the latter tends to create less complex models centered on the decision problem (p. 1355). When talking about the use of simulation models, participants often talked about their past and ongoing modeling efforts that used more specific models of the kind made in the Decision-Theoretic school of thought. In this way the simulation model was not being put to a post-normal use and uncertainty could be addressed at the technical level.

The DCFP participants who were interested in using simulation models as a discussion tool (50%) talked about their goals in using a simulation model in a more open-ended way, acknowledging that they needed to reconcile values and accept tradeoffs. In this sense, the expectation is not that a simulation model will provide evidence that a particular management strategy will yield results, but rather it will open up discussion so that management actions can be linked to values. In this way, participants’ values can be acknowledged and validated by the group explicitly. In post-normal science, this is one way mutual learning is achieved. The DCFP participants did not talk about reducing uncertainty in the model, as it was not meant to reflect what was actually going to happen, but rather to look at numerous potential but highly unlikely states of the world, in order to open up discussion. One DCFP participant summarized it in this way:

> We often talk in terms of historic range of variability to better develop our understanding of what HRV is and then develop the best understanding of what the current condition is and what drivers led to that difference if one exists and in most of the frequent fire systems, there's significant difference between HRV and NRV especially where current restoration work is yet to take place. Then we kind of, we do a math problem, we take the difference between current and HRV and say: that's our opportunity to do restoration work. Of course, that gets messy in the collaborative because it may be in the WUI or mule deer range, or there is some other overlaying social value that would drive us to do something different from current or HRV and often there

> is. And so that's always where the collaborative process gets involved and you have to weigh it. The assumption is that if we can understand the science of HRV in terms of historic structure, composition, function, process like disturbance regime, we can understand the current conditions, and we know what that difference is. If we divert from that we can at least talk about the tradeoffs. Well, you know, because we're not going back to what our best guess of a resilience system was under a functioning system, if we don't do that, what are the consequences, and we try to be cognizant of what those tradeoffs would look like. (DCFP #4)

Thus far, this analysis has focused on how participants saw using simulation models in collaborative ecosystem restoration. It is important to note that just because LSG saw the use as decision support doesn’t mean that it neglects mechanisms for bringing people with diverse interests into their process, having discussions about values, and coming to agreements and compromises in their recommendations. Likewise, it should not be assumed that the DCFP bases its plans only on values. However, it is a significant finding that when talking about using simulation models, LSG participants see them as a useful tool for making decisions. DCFP participants, on the other hand, see simulation models operating in a way not to make decisions, but to open up discussion. This places the use of simulation models in a post-normal application in the DCFP, yet this does not tell the whole story. The next section will examine whether either group sees itself in a post-normal context that would require post-normal science.

## Context for incorporating science

**Facts and Values**. Positivist thinking suggests that science can provide objective facts, and that these facts are separate and distinct from values (Scruton, 1982). It is also amenable to the linear model of science in which if one gets the science right in the problem setting, one knows what the solution is (Pielke, 2004) . In post-normal science, on the other hand, the fact/value dichotomy breaks down. Given irreducible epistemological and ethical uncertainties, extended peer communities who engage in dialogue must use values to help guide action (Funtowicz & Ravetz, 1994). Scientific knowledge is also used, but it loses its status as a privileged form of knowledge that must take precedence over values. The theme of facts/values therefore helps explore perceptions of the role of science and its relationship to values in decision-making. There is some evidence of positivist thinking in the LSG, however more data would have to be gathered to state with confidence that they see themselves operating with a normal science context.

Some participants (25%) talked explicitly about science forming a basis for decisions in the collaborative. One member described it like this:

> No matter how scientifically minded an individual is sometimes emotions and beliefs overpower that so to have somebody there with the expertise and a paper that has certain findings helps reinforce the science of it. I think in too many decisions are made not on the science. (LSG #4)

This belief in science in providing a solid foundation in decision-making is connected to their strategic plans, which are informed and reviewed by other scientists, and adaptive management activities. Often this was the science participants were speaking about. One LSG participant said:

> [S]cience seems to me is very strongly informing the decisions that are being made on the ground. Definitely none of what's going on in the stewardship unit, none of that would be taking place without science, not just the unit, across the entire the Fremont Winema would not be taking place without the science. It would be being appealed, so science plays a pretty major role at least advising the group on what to do. ( LSG #8)

For some in the LSG, science functions as a basis for decision-making and also lends legitimacy to decisions so that they will be more acceptable to the larger public and more defensible if they were challenged in court. Some members expressed frustration about people's (not people in the collaborative group, but people in general) propensity to engage in scientific discussion while refusing to acknowledge that they were really using science to argue for their values. For example one LSG member, reflecting on a career in which he tried to introduce science into policy, said:

> I think you see that in the forest realm, in the sense that it struck me for a long time, that what causes tension and disagreement is less the specifics of science information, it's what people bring to the room in terms of how they respond to uncertainty, risk and the assessment of risk, and what kind of risk, risks to

> what. Values drive in a non-explicit way a lot of the conversation that is below the surface. (LSG #8)

Participants (50%) from the DCFP explicitly talked about the role of values as it relates to science in their process. In keeping with a post-normal framework, they saw the contribution of values and science as important, and also linked. One participant said:

> When people ask me what is collaborating about I say it's about values it's about science. And everybody thinks that forest management should always be about science. Everybody wants something from our forest and we need to explicitly acknowledge that and negotiate that. And then the science is the part that tells us how to get there. Tells us what the potential of the system is and tells us how to get the mix of things that we want out of it, but the science does not tell us what we want. Our values tell us what we want. (DCFP #5)

Another put it this way:

> We're the interpreters of the science; we're the interpreters or the mashers of the science and the social values. And that's not really science it's art (laughs). But it's necessary. (DCFP #8)

There was also a theme of frustration towards people who were not explicit about their values, and instead argued for their management preferences on the basis of science. The most common example given by participants related to people coming to collaborative meetings to argue against active management in favor of more passive management in which the forest was left to change without human interference. Although participants also spoke of diameter limits that prevented larger trees from being harvested, and the problems of defining “old growth”, as some claimed current standards were made strictly on values.

> For example the use of diameter limits and age limits, there's no basis in science for that. And yet every time you bring out “Well we need to get rid of this,” - well we can't do it. All of that is strictly a value system. There's no science behind that. The same thing with mistletoe, I mean, the best way to clean mistletoe out is to remove the overstory, but if you have a tree over 21 inches we can't cut. We can girdle it; we can kill that tree. But we cannot harvest it and utilize it? Now is that scientific? (DCFP #3)

Disguising values with science was seen as undesirable in the DCFP and participants reported adopting strategies to reduce the likelihood of people using science politically (Weible, 2008), including conducting literature reviews so that all scientific findings are put into context, having scientists in the collaborative so that they can “speak” for science, and conducting participatory research if the information they seek does not exists, or partially exists but is too contested. This helps keep the process of incorporating science one of shared learning, instead of a “science war”.

Analyzing the facts and values theme shows that some participants in the LSG see their approach as based on science, which gives their decisions authority and legitimacy. However, this theme was not consistently discussed by participants. It is interesting to note, however, that the interplay between science and values did not come up in the LSG, especially since it was a common theme in the DCFP. This is not to suggest that values do not have an influence in the LSG. Rather it may be that they don’t have a need to confront the political use of science often, or maybe there are simply fewer clashing values. Conversely, it may just be that they consider themselves more in the implementation stage of their process, since in their long range strategy they noted that in 2009 they compared a stakeholder designed priority map with a treatment optimization scenario so that they could develop a plan that helped balance tradeoffs (Anderson et al., 2005). The DCFP’s participants talked more explicitly about the interplay of facts and values, putting it within a post-normal context. One possible explanation may be that the DCFP, being a highly networked, super collaborative adjacent to a large, attentive population, is focusing on deliberative aspects in tangent with incorporating science and communicating with the public, whereas the LSG, being smaller in size and more homogenous in preferences can more easily discuss and agree on common values and then move on to implementation and monitoring as informed by scientific principles.

## Role of Scientists

**Role of Scientists in using simulation models.** Both groups imagined similar roles for scientists if they were to use a simulation model in their collaborative process. Interestingly, participants did not offer many opinions about how scientists should include them in model building. Most saw a need for scientists to help for technical reasons. They saw scientists as best equipped at explaining the data, inputs, and limitations. They also wanted scientists to help in crafting appropriate questions for a simulation model and interpreting the information:

> Make it useful for the collaborative by having some sort of resource that can help translate questions that would be fired at them from a variety of different folks and actually manage the model and run it, and be able to explain in simple terms what the outputs are telling us. (DCFP #2)

Ultimately there was no discernable difference between how participants in the LSG and the DCFP saw the role of scientists in using simulation models within the collaborative. They wanted them integrated into the process explaining how the model was built, its assumptions, and limitations. Then scientists would help translate questions, run the model and interpret the output. However, participants were skeptical about what any given scientists could do alone.

One DCFP participant thought that a model should be too difficult for the average layperson to use since that would require a scientist's involvement, which would reduce the risk of starting a "map war". A simulation model in this respect would potentially serve the function of a boundary object over which both sides could interact and learn about their individual perspectives.

> I think that that is important for someone who's the expert to be very transparent, the risk is if you create something that's super flashy and user friendly, you can just open a Google Earth type application and start running treatment across whatever piece of landscape you want and say look, this produced all this habitat. I feel like then you risk making, if you democratize the model so much that everyone comes in with their favorite tweak of the model, maybe that helps discussion or maybe it all just becomes noise because everyone thinks that suddenly oh I've figured out the perfect scenario. (DCFP #4)

Participants in both groups believed that not every scientist would be able to communicate the technical aspects of a simulation model in a clear way as well as understand the needs of the collaborative enough to translate their concerns into questions the model could address:

> It's that standard in-between kind of thing. You'd love to have the person with credentials, you love to have the person who has the reputation and experience to impress, and have the gravitas that would be necessary to have their results carry weight, but also be able to communicate well and be able to work with people and be part of a group and have them understand. (DCFP #10)

Many agreed that facilitators or translators are often necessary within collaborative groups:

> I guess what I'm saying; it's not entirely on the ecological scientists to have all the skills to do the work. They need some assistance from the collaborative; it's reciprocal and there may be additional kind of expertise and intermediaries to facilitate the conversation that could be brought into the picture as well and not ask every individual to be the true renaissance person who does it all and is responsible for everything. (LSG #3)

This uncertainty in the ability of scientists to build a bridge between the world of collaboration and science will be explored in the last section on knowledge brokers.

**Role of Scientist in General.** Although there was not much difference in participants' expectations for science when using a simulation model, there was difference in responses between groups about how scientists could support collaborative ecosystem restoration in general. In LSG, participants thought that scientists should help make the Forest Service policy and procedures more tailored and efficient[5] for restoration (25%) and educate the public (62.5%) on the benefits of restoration, prescribed burns, and harvesting. Some (37.5%) also expressed that they need more engagement from the social science and economics:

> One of the things we, it's kind of a narrow piece in social science and it's one of the shortcomings in these collaboratives is it's all about trees. Trees and mills and not necessarily about livestock effects or recreational opportunities or water supply or whatever, so broadening that. I think we've got a reasonable good handle on kind of the forest restoration producing board feet kind of stuff; everybody's bought into that. There may be ways to integrate that into and broaden the picture and discussion into what some of the socio-economic opportunities and pinch points or whatever to get us thinking more broadly ...I'm not convinced that we really explored full enough range of the

---

[5] One participant gave an example of how they need to "take GPS boundaries and do all these cruise plots" (LSG #5) and other intensive measures as if they were still taking off high value timber instead of removing low-value, small diameter logs.

> human dimension as expressed in socio-economic and kind of the core things communities are thinking about. (LSG #3)

When asked about future involvement, most participants said they would prefer scientists speak to the group face-to- face at a meeting or during a field tour if they had pertinent findings.

Participants in the DCFP also had a range of ways scientists could support restoration including more engagement from the field of economics, modeling efforts, and educating the public about restoration. But most of the participants (70%) said that they wanted scientists to become more integrated with their efforts, specifically participants wanted scientists to engage in a shared learning process together including participatory research:

> So I think that to the degree that researchers are willing to find opportunities to not step into the advocacy role but to step into, not into a policy or advocacy role within the collaborative, but to step in as a researcher and veer towards: What are the questions that they are asking right now and how can I be a part of that question seeking and or question development refinement, shared learning process? (DCFP #5)

Beyond simply participatory research, participants spoke of wanting scientists as collaborators and active participants of collaborative groups in several ways:

> I think for the most part scientists in the Northwest do a good job with understanding their role, but where I think they can be effective in the future is being more of collaborator and facilitator, instead of just a gatherer and presenter of information in science. And there's obviously some scientists who are better than that than others. Science as knowledge is wonderful but science is only limited to knowledge; if you don't apply it then its value is pretty limited. I think science should figure out a way to become a productive member of collaboratives around the country. ( DCFP #9)

Examining the role of scientist in general, not just within the use of simulation models, helped draw a difference between the two groups. In LSG, participants wanted greater engagement from a wider variety of scientists. It was thought that scientists could help the collaborative group by presenting relevant findings and consulting with the group. The DCFP however, wishes scientists to be integrated into collaboration so that they can participate in a shared learning process which puts value on multiple frames of reference and dialogue along with science. The scientist's role in this view is to then identify areas where his or her discipline can contribute and answer questions within a larger post-normal context. However, participants in both groups recognized that they had people with scientific backgrounds already working with them as will be explored in the next section.

## Boundary Work

**Knowledge Brokers.** Oftentimes, at the end of an interview, an interviewee would suggest that I talk to a certain individual who they believed would give me a good perspective on these issues. When I did speak with theses individuals, they would identify not scientists or researchers, however they had a scientific background and saw it as their role to help collaborative groups incorporate science into their process. They, along with individuals from university extension and other organizations like Sustainable Northwest or the Fire Learning Networks, form a support network that offers opportunities and resources. For instance, participants referenced ongoing efforts by Oregon State University Extension Service agents and others that helped them learn about the social and institutional aspects of their efforts (see Paasen et al., 2011, p. 48). These individuals who work within the group and see it as their roles to help incorporate science into the collaborative process can be thought of as knowledge brokers (Raadgever and Mostert, 2007; Jassanoff, 1990). Some just saw it as their role to bring a scientific perspective to the table:

> I don't refer to myself as a scientists, but I do have a lot of background in forest ecology, and a lot of what I do in collaboratives is bring both a conservation perspective and I hope to think some credibility on the science as well, but also we rely on literature, we rely on agency sciences, university scientists. But on the day-to-day people accepted that I was familiar with the science and presented it in a straightforward manner as I could. (LSG #4)

Others took on more specialized roles. One such participant in the LSG, who described part of his role as "helping the group understand science application in forest management restoration" said that he spent much of his time helping the collaborative be explicit about how the projects they propose will meet their management objectives and determine ways to measure the effects:

> It's social license, gained through collaboration, can pave the way to forest management and restoration and is it restoration or is it management or what is it? And so you know the social license that's gained through collaboration, where is that taking us? And so this science side of that would say well what are we saying we are doing, and are we doing it, and can we measure it? (LSG #1)

In this way, the LSG's adaptive management program mirrors the scientific process and therefore, collaborative members need assistance in formulating hypotheses about how their actions will affect the land and then determine a strategy for gathering data in order to test those assumptions.

In the DCFP one individual described a complicated, multifaceted role:

> My role is a little messy and challenging sometimes. And by that I mean I wear a lot of different hats in the collaborative realm. I end up doing a whole bunch of things that make the collaborative move, but that also makes it challenging to provide my other role, outside of staffing, which is the science support piece. So providing science support, you know, requires me to take positions, and I try to present science and the extent of research as objectively as possible and make sure the full suite of science is getting out to the group, but again because I have to wear this other hat too, focusing on the process of collaboration, funding the collaboration, hiring outside contractors, it makes it hard because sometimes I'm walking a tightrope between the two sides. (DCFP #4)

This interviewee also spoke of many other instances where they helped conduct scientific literature reviews, bringing scientists on field trips to talk with collaborative members, and organizing participatory research. They explained further how they saw their role:

> I'm not a researcher, I don't do primary research much anymore, although this last summer, this has been my opportunity to get back to that a little bit, but my, I look at my job as a forest ecologist for this region and these two forests as I'm not going to answer research questions anymore. I'm a connector, that's what I do. I'm a synthesizer and a connector. I rarely look at the collaborative process and say: What am I gonna do? It's more like: Who do I need to bring together? (DCFP #4)

The roles of these knowledge brokers again shed light on the different strategies of the two groups. The LSG needs scientists to help in its adaptive management, whereas in the DCFP, science is brought in at different times during the non-linear, mutli-layered process, involving different stakeholders and researchers. The discovery of these knowledge brokers was unexpected but important. These individuals proved to be key participants in this study since they were mentioned by others in their respective groups as important in the effort of bringing science into collaboration. They helped articulate, sometime in a very comprehensive way, many of the themes and connections I discovered through coding.

## Conclusion

The participants selected and interviewed for this study gave their own perspective but when compared within the same group dominant answers emerged through thematic coding. Comparing those dominant answers between those in LSG and DCFP and viewing them through a post-normal framework allowed a larger story to present itself in which the two groups favored different ways of using a simulation model and integrating scientists into their process. It also highlighted a potential difference in the way the groups incorporate science, with one adopting a more post-normal model. However, it must be emphasized that the purpose of this study is not to make a judgment on the appropriateness of any approach over the other. In all actuality it is likely that, as one LSG participant and knowledge broker, observed,

> collaborations kind of work independently and have their own way of working …and so science will play a different role in each one of those collaborative groups because of the different problems they are confronting, or the mysteries if you want to think about it that way. (LSG #1)

This study shows that two groups engaged in the same program have different methods of integrating science with their collaborative process. Following van Kerkhoff’s typology of integration, we can see that both groups support “integration beyond science”, “integration across structures”, and “integration across activities”, yet in different ways. Either strategy of integration could prove legitimate. More research would uncover why collaborative groups decide on their strategy of integration. One possible explanation may be that the DCFP, being itself a highly networked, super collaborative adjacent to a large population, simply must focus more on deliberative aspects prior to incorporating science, whereas the LSG, being smaller in size and more homogenous in preferences can more easily reconcile opposing values and more on to implementation and adaptive management. In that sense, perhaps the LSG is not in a post-normal context, and PNS is not needed. Even though they do not want to bring scientists into a highly deliberative post-normal science process, they do want to consult and work with scientists from different disciplines in order to make sure that they are balancing social, economic, and ecological concerns.

## Policy Recommendations

This research suggests that programs like the CFLRP that seek to bring a collaborative, science-based approach to restoration are, in fact, doing just that. Programs like it that specify the need for science-based restoration but still allow local collaborative groups to seek their own definitions and methods for doing so could be expanded if further research demonstrates their success. Although it is encouraging to see that collaborative groups are finding their own unique ways to integrate science into their process, they may need more help in doing this. The following recommendations may help collaborative groups accomplish collaborative, science-based ecosystem restoration.

### *Expand funding beyond implementation to include capacity-building*

Currently, CFLRP funding goes exclusively towards implementation and monitoring. But scientific learning does not only take place after monitoring results are gathered. This study confirms that collaborative groups are incorporating science during earlier stages of their process by defining measurable indicators for adaptive management, or seeking outside researchers to help fill information gaps for example. The collaborative governance literature tells us that the process of building trust, norms, institutions, and capacity are essential parts of the collaborative process, which allow for the blending of different types of knowledge (including science) and values. This is crucial for ensuring that target outcomes are balanced, socially acceptable, and scientifically informed. The importance of the early stages of collaboration should be recognized by policy-makers, especially as collaborative groups are encouraged to plan on larger scales and incorporate more stakeholders as part of an “all-lands approach”. This is beginning to happen in Oregon as the state is recognizing that restoration activities on federal lands have positive impacts on local communities and the economy (White, Bennett, and Ellison, 2015). Oregon’s Federal Forest Health Collaborative Capacity Assistance Grants, awarded through the Oregon Watershed Enhancement Board, aim to help groups come to agreement by providing funding for organizing meetings, field trips, and communications materials. If such strategies continue to show success, more state governments or other entities such as nonprofits may want to increase investment in collaborative capacity.

### *Improve connections between universities and stakeholders*

As this study illustrates, scientists are needed within collaborative groups for many reasons, whether in designing monitoring programs or engaging in highly deliberative and interactive exercises using GIS based simulation models that have the potential to build new knowledge communities (Duncan and Lach, 2006). Stronger linkages should be formed between the scientific community and collaborative groups. Government agencies currently bring useful scientific and technical resources to collaboratives (Koontz et al., 2004). But in order to broaden disciplinary representation, universities could do more to break down the barriers that exist between themselves and society that would allow for both scientific and stakeholders’ bodies of knowledge to be combined and the co-production of knowledge to occur (Healy, 1999; Frame and Brown, 2008; Turnpenny, Jones, and Lorenzoni; 2011). For example, Whitmer, Ogden, Lawton, Sturner, and Groffman (2013) recommend developing communication and leadership skills training for graduate students, restructuring faculty hiring and tenure criteria to include community engagement, creating topic-oriented research centers, and hiring faculty in “issue clusters”. Also, university extension services professionals are moving beyond their traditional roles as providers of direct service to individuals by providing leadership and capacity-building services for communities, initiatives, and organizations (Brown and Evans, 2004). This should be encouraged. Having scientists and other science professionals more connected to collaborative groups will allow them to use their professional expertise and proximity to the context and concerns of the broader collaborative group to craft appropriate strategies for integrating science.

### *Create knowledge broker networks*

Additionally, more can be done to assist existing university extension agents, scientists, and knowledge brokers already working with the collaborative groups. Creating "communities of practice" for knowledge brokers, similar to the Fire Learning Network (Goldstein and Butler, 2010), may also help foster learning and speed the diffusion of successful practices thereby ensuring that scientific knowledge is not only being incorporated within a single collaborative group, but also shared among them. Policy makers should look for natural leaders and conveners (such as The Nature Conservancy in the case of the FLN) that could help leverage funding and resources needed to build such networks.

## References

Allen, E., Kruger, C., Leung, F. Y., and Stephens, J. C. (2013). Diverse perceptions of stakeholder engagement within an environmental modeling research team. *Journal of Environmental Studies and Sciences*, *3*(3), 343-356.

Ansell, C., and Gash, A. (2008). Collaborative governance in theory and practice. *Journal of public administration research and theory*, *18*(4), 543-571.

Auerbach, C., & Silverstein, L. B. (2003). *Qualitative data: An introduction to coding and analysis*. NYU press.

Babbie, E. R. (2010) *The basics of social research.* Cengage Learning.

Bäckstrand, K. (2003). Civic science for sustainability: Reframing the role of experts, policy-makers and citizens in environmental governance. *Global Environmental Politics*, 3(*4)*, 24-41.

Bengston, D. N. (1994). Changing forest values and ecosystem management. *Society and Natural Resources*, *7*(6), 515–533. doi:10.1080/089419294093808 85

Bolte, J. P., Hulse, D. W., Gregory, S. V., and Smith, C. (2007). Modeling biocomplexity–actors, landscapes and alternative futures. *Environmental Modelling and Software*, *22*(5), 570-579.

Börjeson, L., Höjer, M., Dreborg, K. H., Ekvall, T., & Finnveden, G. (2006). Scenario types and techniques: Towards a user's guide. *Futures*, *38*(7), 723 –739. doi:10.1016/j.futures.2005.12.002

Brown, R., & Evans, W. (2004). The collaborative community change model: Understanding and evaluating university extension professionals' role in community change. *Journal of Extension*, *42* (2).

Budic, Z. D., (1994). Effectiveness of geographic information systems in local planning. *Journal of the American Planning Association*, 60, 244–263.

Butler, W. H. (2013). Collaboration at arm's length: Navigating agency engagement in landscape-scale ecological restoration collaboratives. *Journal of Forestry*, *111*(6), 395-403.

Butler, W. H., and Goldstein, B. E. (2010). The US fire learning network: Springing a rigidity trap through multiscalar collaborative networks. *Ecology and Society*, *15*(3). doi:10.1177/0002764207312000

Charnley, S., Long, J. W., & Lake, F. K. Collaboration in national forest management. *Science Synthesis to Support Socioecological Resilience in the Sierra Nevada and Southern Cascade Range*. 663–704.

Corbett, J. M., and Keller, C. P. (2005). An analytical framework to examine empowerment associated with participatory geographic information systems (PGIS). *Cartographica: The International Journal for Geographic Information and Geovisualization*, *40*(4), 91–102. doi:10.3138/J590-6354-P38V-4269

Craig, W., T. Harris, and D. Weiner. (2002). *Community participation and GIS.* London: Taylor & Francis.

Daniels, E., and Walker, G. (2001). Understanding Conflict Situations. In *Working through Environmental Conflicts. The collaborative approach* (p. 1–53).

Department of the Interior (2013) A national cohesive wildland fire management strategy. Retrieved from: http://www.doi.gov/pmb/owf/upload/1_ CohesiveStrategy03172011.pdf

Dombeck, M. P., Williams, J. E., and Wood, C. A. (2004). Wildfire policy and public lands: Integrating scientific understanding with social concerns across landscapes. *Conservation Biology*, *18*(4), 883–889. doi:10.1111/j.1523-1739.2004.00491.x

Dueker, K. J., and Kjerne, D. (1989). *Multipurpose cadastre: Terms and definitions*. Bethesda, MD: American Congress on Survey and Mapping.

Duncan, S. L. (2006). Mapping whose reality? Geographic information systems (GIS) and “wild science”. *Public understanding of science*, *15*(4), 411-434.

Duncan, S. L., and Lach, D. H. (2006). GIS technology in natural resource management: Process as a tool of change. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *41*(3), 201-215.

Dunn, C.E., Atkins, P.J., Blakemore, M.J. and Townsend, J.G. (1999). Teaching geographical information handling skills for lower-income countries. *Transactions in GIS.* 3(4): 319–33.

Dunn, C. E. (2007). Participatory GIS a people’s GIS? *Progress in Human Geography*, *31*(5), 616–637. doi:10.1177/0309132507081493

Emerson, K., Nabatchi, T., and Balogh, S. (2012). An integrative framework for collaborative governance. *Journal of Public Administration Research and Theory*, *22*(1), 1–29. doi:10.1093/jopart/mur011

Farrell, K. N. (2011). Snow white and the wicked problems of the west: A look at the lines between empirical description and normative prescription. *Science, Technology and Human Values*, *36*(3), 334–361. doi:10.1177/0162243910385796

Fischer, F. (2000). *Citizens, experts, and the environment: The politics of local knowledge*. Durham, NC: Duke University Press.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, *12*(2), 219–245. doi:10.1177/1077800405284363

Forests, People, Fire. (2011). *Coupled natural and human systems in fire-prone landscapes: Interactions, dynamics, and adaptation*. Retrieved from http://fpf.forestry.oregonstate.edu/system/files/CNH_III_project_description_final_111609.pdf

Funtowicz, S. O., and Ravetz, J. R. (1993). The emergence of post-normal science. In Rene von Schomberg (Ed.), *Science, politics and morality,* (pp. 85-123) Dordrecht , Netherlands: Springer Science+Business Media Dordrecht.

Funtowicz, S. O., and Ravetz, J. R. (1994). Uncertainty, complexity and post-normal science. *Environmental toxicology and chemistry*, *13*(12), 1881-1885.

Funtowicz, S.O., Ravetz, J.R., (1997). The poetry of thermodynamics. *Futures* 29, 791–810.

Funtowicz, S., and Ravetz, J. (2003). Post-normal science. *International Society for Ecological Economics,* Retrieved from http://www.ecoeco.org/publica/encyc.htm.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., and Trow, M., (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. London: Sage.

Goldstein, B. E., and Butler, W. H. (2010). Expanding the scope and impact of collaborative planning. *Journal of the American Planning Association*, *76*(2), 238–249. doi:10.1080/01944361003646463

Guston, D. (2001). Boundary organizations in environmental policy and science: An introduction. *Science, Technology, and Human Values*, *26*(4), 399–408. doi:10.1177/016224390102600401

Haag, D., and Kaupenjohann, M. (2001). Parameters, prediction, post-normal science and the precautionary principle—a roadmap for modelling for decision-making. *Ecological modelling*, *144* (1), 45-60.

Haynes, R. W., Quigley, T. M., Clifford, J. L., and Gravenmier, R. A. (2001). Science and ecosystem management in the interior Columbia basin. *Forest ecology and management*, *153*(1), 3-14.

Healy, S. (1999). Extended peer communities and the ascendance of post-normal politics. *Futures*, *31*(7), 655–669. doi:10.1016/S0016-3287(99)00025-7

Hinkey, L. M., Ellenberg, K. T., and Kessler, B. (2005). Strategies for engaging scientists in collaborative processes. *Journal of Extension*, Retrieved from http://www.joe.org

Jankowski, P., and Nyerges, T. (2001). GIS-Supported collaborative decisions making : Results of an experiment. *Annals of the Association of American Geographers*, *91*(1), 48–70. Retrieved from http://onlinelibrary.wiley.com /doi/10.1111/0004-5608.00233/abstract

Jankowski, P. (2009). Towards participatory geographic information systems for community-based environmental decision making. *Journal of Environmental Management*, *90*(6), 1966–71. doi:10.1016/j.jenvman.2007.08.028

Jasanoff, Sheila. (1990). The fifth branch: Science advisers as policy-makers. Cambridge, MA: Harvard University Press.

Judson, D.H., Reynolds-Scanlon, S., Popoff, C.L., 1999. Migrants to Oregon in the 1990's: working age, near-retirees, and retirees make different destination choices. *Rural Development Perspectives*, 14, 24–31.

Kennedy, J. J., and Quigley, T. M. (1998). Evolution of USDA forest service organizational culture and adaptation issues in embracing an ecosystem management paradigm. *Landscape and Urban Planning*, *40* (1), 113-122.

Kettl, D. F. (2006). Managing boundaries in American administration: The collaboration imperative. *Public Administration Review*, *66*, 10–19. doi:10.1111/j.1540-6210.2006.00662.x

Koontz, T. M., Steelman, T.A., Carmin, J., Korfmacher, K.S., Moseley, C., and Thomas, C. (2004). *Collaborative environmental management: What roles for government?* New York: Routledge.

Kuhn, T. S. (1996). *The structure of scientific revolutions*. Chicago, IL: University of Chicago press.

Kyem, P.A. Kwaku (2004) Power, participation, and inflexible institutions: An examination of the challenges to community empowerment in participatory GIS applications. Cartographica 38 (3and4): 5–17.

Lackey, R. T. (2007). Science, scientists, and policy advocacy. *Conservation*

*Biology : The Journal of the Society for Conservation Biology*, *21*(1), 12–7. doi:10.1111/j.1523-1739.2006.00639.x

Lemons, J. (1996). *Scientific uncertainty and its implications for environmental problem solving*. Hoboken, New Jersey: Wiley-Blackwell.

Letcher, R. A., Jakeman, A. J., and Croke, B. F. W. (2004). Model development for integrated assessment of water allocation options. *Water Resources Research*, *40*(5), 491-501.

Likens, G. E., Bormann, F. H., Pierce, R. S., and Reiners, W. A. (1978). Recovery of a deforested ecosystem. *Science (New York, N.Y.)*. doi:10.1126/science.199. 4328.492

Liu, Y., Gupta, H., Springer, E., and Wagener, T. (2008). Linking science with environmental decision making: Experiences from an integrated modeling approach to supporting sustainable water resources management. *Environmental Modelling and Software*, *23*(7), 846–858. doi:10.1016/j.envsoft.2007.10.007.

Mannermaa, M., (1986). Futures research and social decisionmaking: alternative futures as a case study. *Futures*, 18, 658–670.

McFadden, J. E., Hiller, T. L., & Tyre, A. J. (2011). Evaluating the efficacy of adaptive management approaches: Is there a formula for success? *Journal of Environmental Management*, *92*(5), 1354–1359. doi:10.1016/j.jenvman.2010.10.038

Mills, T. J., and Clark, R. N. (2001). Roles of research scientists in natural resource decision-making. *Forest Ecology and Management*, *153*(1), 189-198.

Mitchell, B. 2005. Participatory partnerships: Engaging and empowering to enhance environmental management and quality of life? *Social Indicators Research,* 71:123–44.

Mostert, E., and Raadgever, G. T. (2008). Seven rules for researchers to increase their impact on the policy process. *Hydrology and Earth System Sciences*,*12*(4), 1087-1096.

Neelamkavil, F. (1987). *Computer simulation and modelling*. New York, NY:John Wiley and Sons, Inc.

Nowotny, H. (1993). A new branch of science, Inc. In R. von Schomberg (Ed.), *Science, politics and morality,* (pp. 85-123) Dordrecht ,Netherlands: Springer Science+Business Media Dordrecht.

Nowotny, H., Scott, P., & Gibbons, M. (2003). “Mode 2” Revisited: The New Production of Knowledge, 179–194.

Nyerges, T. L., Goodchild, M. F., Parks, B. O., and Steyaert, L. T. (1993). *Understanding the scope of GIS: Its relationship to environmental modeling*. Oxford, UK: Oxford University Press.

Nyerges, T., Jankowski, P., Tuthill, D., and Ramsey, K. (2006). Collaborative water resource decision support: Results of a field experiment. *Annals of the Association of American Geographers*, *96*(4), 699-725.

Oxley, T., McIntosh, B. S., Winder, N., Mulligan, M., and Engelen, G. (2004). Integrated modelling and decision-support tools: a Mediterranean example. *Environmental Modelling and Software*, *19*(11), 999-1010.

Paassen, A. Van, Opdam, P., Steingröver, E., and Berg, J. Van Den. (2011). *Knowledge in action* (Vol. 11). doi:10.3920/978-90-8686-724-0

Parker, D. C., Manson, S. M., Janssen, M. a., Hoffmann, M. J., and Deadman, P. (2003). Multi-Agent Systems for the simulation of land-use and land-cover change: A review. *Annals of the Association of American Geographers*, *93*(2), 314–337. doi:10.1111/1467-8306.9302004

Parson, E., (1995). Integrated assessment and environmental policy making. *Energy Policy,* 23 (4), 463-475.

Perry, David A. The scientific basis of forestry. *Annual Review of Ecology and Systematics* (1998): 435-466.

Pickles, J. (1995). Representations in an electronic age: Geography, GIS, and democracy. In Pickles, J. (Ed.) *Ground truth: The social implications of geographic information systems*, 1-30. New York: Guilford Press.

Pickles, J. (2004). *A history of spaces: Cartographic reason, mapping, and the geo-coded world*. East, Sussex, UK: Psychology Press.

Pielke Jr., R. A. (2004). When scientists politicize science: making sense of controversy over “The Skeptical Environmentalist”. *Environmental Science and Policy*, *7*(5), 405-417.

Pyne, S. J. (1982). *Fire in America. A cultural history of wildland and rural fire*. Princeton, NJ: Princeton University Press.

Ravetz, J. R. (2006). Post-normal science and the complexity of transitions towards sustainability. *Ecological complexity*, *3*(4), 275-284.

Rittel, H. W., and Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy sciences*, *4*(2), 155-169.

Roberts, N. (2000). Wicked problems and network approaches to resolution. *International Public Management Review, 1*(1), 1–19.

Roux, D. J., Rogers, K. H., Biggs, H. C., Ashton, P. J., and Sergeant, A. (2006). Bridging the science–management divide: Moving from unidirectional knowledge transfer to knowledge interfacing and sharing. *Ecology and Society*, Retrieved from *http://www.ecologyandsociety. org/vol11/iss1/art4/knowledge*

Sarewitz, D. (2004). How science makes environmental controversies worse. *Environmental Science and Policy,* 7(5), 385–403. doi:10.1016/j.envsci. 2004.06.001

Schultz, C. A., Jedd, T., and Beam, R. D. (2012). The collaborative forest landscape restoration program: A history and overview of the first projects. *Journal of Forestry,* 110(7), 381–391. doi:10.5849/jof.11-082

Scott, J.M., Rachlow, J.L., Lackey, R.T., Pidgnorna, A.B., Aycrigg, J.L., Feldman, G.R., Svancara, L.K., Rupp, D.A., Stanish, D.I., Steinhorst, R.K. (2007). Policy, advocacy and science: Prevalence in the research literature and perspectives of conservation biologists. *Conservation Biology* 21: 29–35.

Sheppard, E. (1995): GIS and society: towards a research agenda. *Cartography and Geographic Information Systems,* 22, 5–16.

Shrader-Frechette, K. (1996). Methodological rules for four classes of scientific uncertainty. In J. Lemons (Ed.), *Scientific uncertainty and environmental problem solving*, (12-39). Cambridge: Blackwell Sciences.

Sieber, R. E. (2000). Conforming (to) the opposition: the social construction of geographical information systems in social movements. *International Journal of Geographical Information Science*, *14*(8), 775-793.

Sieber, R. (2006). Public participation geographic information systems: A literature review and framework. *Annals of the Association of American Geographers*, *96*(3), 491-507.

Scruton, R. (1982.) A Dictionary of Political Thought. New York, NY: Hill and Wang.

Sheppard, E. (1995). GIS and society: towards a research agenda. *Cartography and Geographic Information Systems*, *22*(1), 5-16.

Steel, B., List, P., Lach, D., and Shindler, B. (2004). The role of scientists in the environmental policy process: a case study from the American west. *Environmental Science and Policy*, *7*(1), 1–13. doi:10.1016/j.envsci.2003.10.004

Steelman, T. A., and Burke, C. A. (2007). Is wildfire policy in the United States sustainable? *Journal of Forestry*, *105*(2), 67-72.

Thomas, J. W., Franklin, J. F., Gordon, J., and Johnson, K. N. (2006). The northwest forest plan: Origins, components, implementation experience, and suggestions for change. *Conservation Biology*, *20*(2), 277–287. doi:10.1111/j.1523-1739.2006.00385.x

Turnpenny, J., Jones, M., and Lorenzoni, I. (2011). Where now for post-normal science?: A critical review of its development, definitions, and uses. *Science, Technology and Human Values*, *36*(3), 287–306. doi:10.1177/0162243910385789

United States Census Bureau. (2015a). State and county quickfacts: Dechutes County, Oregon. Retrieved from: http://quickfacts.census.gov/qfd/states /41/41017.html.

United States Census Bureau. (2015b). State and county quickfacts: Lake County, Oregon. Retrieved from: http://quickfacts.census.gov/qfd/states/41/41037 .html.

United States Forest Service. (2014). Collaborative forest landscape restoration program overview. Retrieved from http://www.fs.fed.us/restoration/CFLRP /overview.shtml

Van Buuren, A. (2009). Knowledge for Governance, Governance of Knowledge: Inclusive Knowledge Management in Collaborative Governance Processes. *International Public Management Journal*, *12*(2), 208–235. doi:10.1080/10967490902868523

Van Kerkhoff, L. (2005). Integrated research: Concepts of connection in environmental science and policy. *Environmental Science and Policy*, *8*(5), 452–463. doi:10.1016/j.envsci.2005.06.002

Weber, E. P. (1998). *Pluralism by the rules: Conflict and cooperation in environmental regulation*. Georgetown University Press.

Weber, E. P. (2000). A new vanguard for the environment: Grass-Roots ecosystem management as a new environmental movement. *Society and Natural Resources*, *13*(3), 237–259. doi:10.1080/089419200279081

Weber, E., and Khademian, A. (2008). Wicked problems, knowledge challenges, and collaborative capacity builders in network settings. *Public Administration Review*, (April). Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1540-6210.2007.00866.x/full

Weible, C. M. (2008). Expert-based information and policy subsystems: a review and synthesis. *Policy Studies Journal*, *36*(4), 615-635.

Weiner, D., Harris, T. M., and Craig, W. J. (2002). Community participation and geographic information systems. *Community participation and geographic information systems*, 3-16.

Wesselink, A., and Hoppe, R. (2011). If post-normal science is the solution, what is the problem?: The politics of activist environmental science. *Science, Technology and Human Values*, *36*(3), 389–412. doi:10.1177/0162243910385786

Whitmer, A., Ogden, L., Lawton, J., Sturner, P., Groffman. (2013). The engaged university: Providing a platform for engaged research that transforms platform society, *8*(6), 314–321. doi:10.1890/090241

Ziman, J.M., 2000. *Real science: What it is, and what it means*. Cambridge: Cambridge University Press.