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Large-scale interdisciplinary experiments inform current and future forestry management options in the U.S. Pacific Northwest

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ABSTRACT

Over the last 20 years, changing public values and increased ecological understanding have led to a paradigm shift in forestry from timber management to sustainable ecosystem management on U.S. federal lands. Forest managers are now seeking alternative management approaches that simultaneously meet socio-cultural, ecological and economic goals. Consequently, many field experiments have become increasingly interdisciplinary and larger in scale or scope. Individually and collectively, these studies in western Washington and Oregon represent major investments by research and land management organizations to enhance the science and understanding for sustainable forest management under increasing public scrutiny and demands for safeguarding healthy environments, conserving biological diversity and providing some level of economic prosperity. They also help to facilitate the transfer of scientific results into practical applications and to realize a more effective interface between science and policy. Questions addressed in this paper include (i) what do we mean by large-scale experiments, (ii) who is investing in these kinds of experiments and why, (iii) where is this information being put to use, and (iv) what does the future hold for these studies?

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1. Background

1.1. Science and the adaptive management process

The role of science in the decision-making process, particularly decisions that balance the interactions among social values, institutions, management and outcomes, has been emphasized by a number of authors with particular reference to federal forest lands in the U.S. Pacific Northwest region (Mills et al., 2002; Szaro and Peterson, 2004; Szaro et al., 2004). When making decisions, managers strive to balance the array of goods and services flowing to society from the managed lands. Such management decisions almost always include trade-offs and compromises for one or more resources. Furthermore, managers know fully well that the outcomes of their implementations will again be scrutinized and judged by the public (Szaro and Peterson, 2004; Szaro et al., 2006), making an adaptive management approach (e.g., see Walters, 1986; Borman et al., 1999) essential for addressing uncertainty by structuring management operations as science-based experiments in which results are used to continually correct course.

1.2. Interdisciplinary designs for integrative questions

Changing societal values now demand expanded approaches to forest management on U.S. federal and state lands that also integrate social, ecological and economic goals. U.S. federal (U.S. Forest Service, U.S. Bureau of Land Management) and state land management agencies (e.g., Washington State Department of Natural Resources) are being asked to provide for these public values with management practices that consider the best science available.

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Box 1

- *With the help of science*, we began basing much of our management on watershed health. Today, the Forest Service no longer focuses on the most efficient, cost-effective way to remove timber. Instead, *we focus on long-term ecosystem health, measured in terms of healthy watersheds* (Dale Bosworth Chief, USDA Forest Service, September 18, 2002). http://www.fs.fed.us/news/2002/09/McClurerev3.3.rtf.
- Twenty years ago, we focused primarily on outputs, measured in terms of board feet of timber; today we focus primarily on outcomes, measured in terms of healthy ecosystems. *We've learned that what we leave on the land is more important than what we take away* (Dale Bosworth, Chief, USDA Forest Service, March 27, 2003). http://www.fs.fed.us/news/2003/speeches/wildlife.pdf.

Early on, many scientists recognized that the science of silviculture in altering trajectories of stand structure and composition is vital to providing many of the public values (e.g., see DeBell and Curtis, 1993; O'Hara et al., 1994). One common element of many recent approaches to silviculture is the focus on what structural elements of existing stands are retained after harvest for the long-term to attain specific objectives (e.g. structural diversity), a term often referred to as "retention silviculture" (Franklin et al., 1997). More recently, a recent special session of the 2005 IUFRO congress strove to highlight examples and challenges (including statistical inference) of operational-scale experiments from North America, Europe, and Asia (Ganio, 2006; Hickey et al., 2006; Maguire et al., 2006; Seymour et al., 2006).

2. Operational-scale evaluation and demonstration of silvicultural options

2.1. Large-scale silviculture experiments

In the past 10–15 years, the Pacific Northwest Research Station has established numerous large-scale operational silviculture experiments on U.S. federal and state lands, using interdisciplinary approaches addressing a broad range of ecological objectives (see e.g., Szaro et al., 2004, 2006; Peterson and Maguire, 2005). These studies represent major investments by research and land management organizations to meet increasing public demands for forests that provide important ecosystem services for people (clean air and water), enhance biological diversity (e.g., habitat), and sustain economic productivity (wood or other forest products and jobs). These experiments commonly include restorative objectives and novel and untested silviculture treatments applied at operational scales (Peterson and Szaro, 2006; Szaro et al., 2006). The diversity of approaches and designs and interdisciplinary nature of these experiments (see e.g., Chan et al., 2004; Maguire et al., 2005) create value for the forestry community (Gadow and Kleinn, 2005).

Experimental approaches encompass variable-retention (e.g., see papers in Peterson and Maguire, 2005; Maguire et al., 2005; McClellan and Hennon, 2005), alternative multi-aged systems (e.g., Anderson et al., 2007), and connections or corridors between similarly managed areas (Baughman and Guynn, 2005), and seek to gain public acceptance (Ribe, 2006).

All of these experiments address one or more thinning or harvesting treatments designed to create stand structures that may range from uniform to irregularly dispersed individual trees and aggregates (Fig. 1). Some of these experimental treatments include fine-scale structural features such as various-sized openings or gaps and patches of aggregated retention (or "leave islands") that accentuate within-stand heterogeneity. These within-stand features are intended to provide for recruitment of additional vegetation cohorts or taxa (gaps), or to serve as refugia (leave islands), thus enhancing potential habitat value for a broader array of organisms at the stand scale. Although there may be an initial focus on responses to the structural characteristics as implemented, the treatments are generally designed to create structures that can be managed to meet desired future conditions; therefore the effectiveness of the treatments may emerge only after a substantial period of stand development.

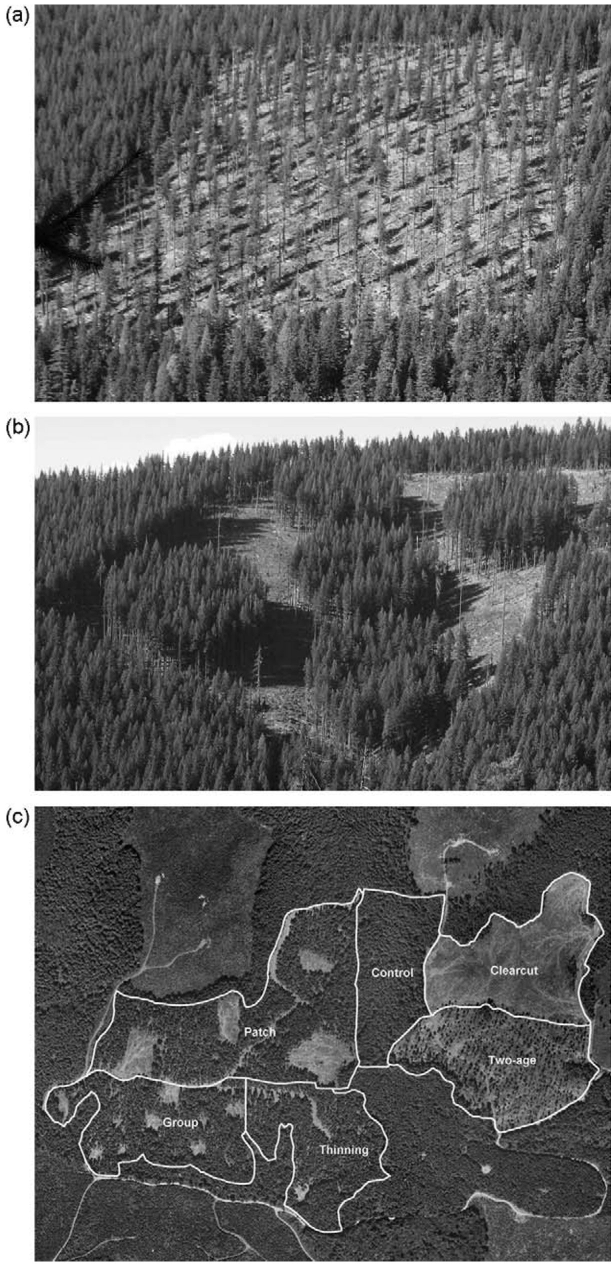

Fig. 1. Photographs of basal area retained in operational-scale experiments: 15% dispersed (a) and 40% aggregated (b) treatment units from a DEMO block on the Umpqua National Forest; an array (c) of treatment units from the Blue Ridge Study on Washington State Capitol Forest.

While these silviculture experiments are implemented at the stand-level as in the past, they are much more interdisciplinary (economic, social and ecological values). More significantly, the designs are often driven by ecological process and wildlife species that require larger areas to assess effects, such that treatments are applied to units of 5–20 ha (units in the past were 0.1–0.4 ha) that also represent an operational implementation. Therefore a replicate block might encompass 150–200 ha as compared to 5–10 ha in past silviculture trials.

Consistent with the operational scale of the experimental treatment installations, these studies have been conducted with a high degree of collaborative interaction among practitioners and researchers (Chan et al., 2004). In conceptualization, researchers have relied on practitioners to help frame the research objectives and the treatment alternatives. Researchers have translated those objectives and alternatives into experimental designs and monitoring protocols that provide for statistical rigor in findings. Managers have been instrumental in the operational aspects of implementation including timber sale preparation, contracting and administration. These studies have frequently provided opportunities for scientists to participate with interdisciplinary teams charged with conducting assessments to ensure that the study implementations fall within legal and administrative standards for environmental impacts. A few of these studies have reached a stage of development in which the research and management partnerships have developed plans for follow-up treatments to the original experimental implementation. In such cases it has been a continued dialogue between management and research partners, as well as other stakeholders, and the application of adaptive management principles to craft follow-up treatments for maintaining or altering trajectories of stand development.

2.2. Collective goals and objectives of the studies

In their broad review of large interdisciplinary studies in the Pacific Northwest Research Station, Peterson and Monserud (2002) provided overarching multi-scale research questions framed by two dozen scientists from the Pacific Northwest Research Station in 1997 for management issues:

- Can we as a society produce wood commodities and still maintain other desired attributes (functions and processes) of a forest ecosystem?
- On forested lands where wood commodities are not the primary value, will we need some manipulation of the forest in order to sustain the noncommodity high-priority values?

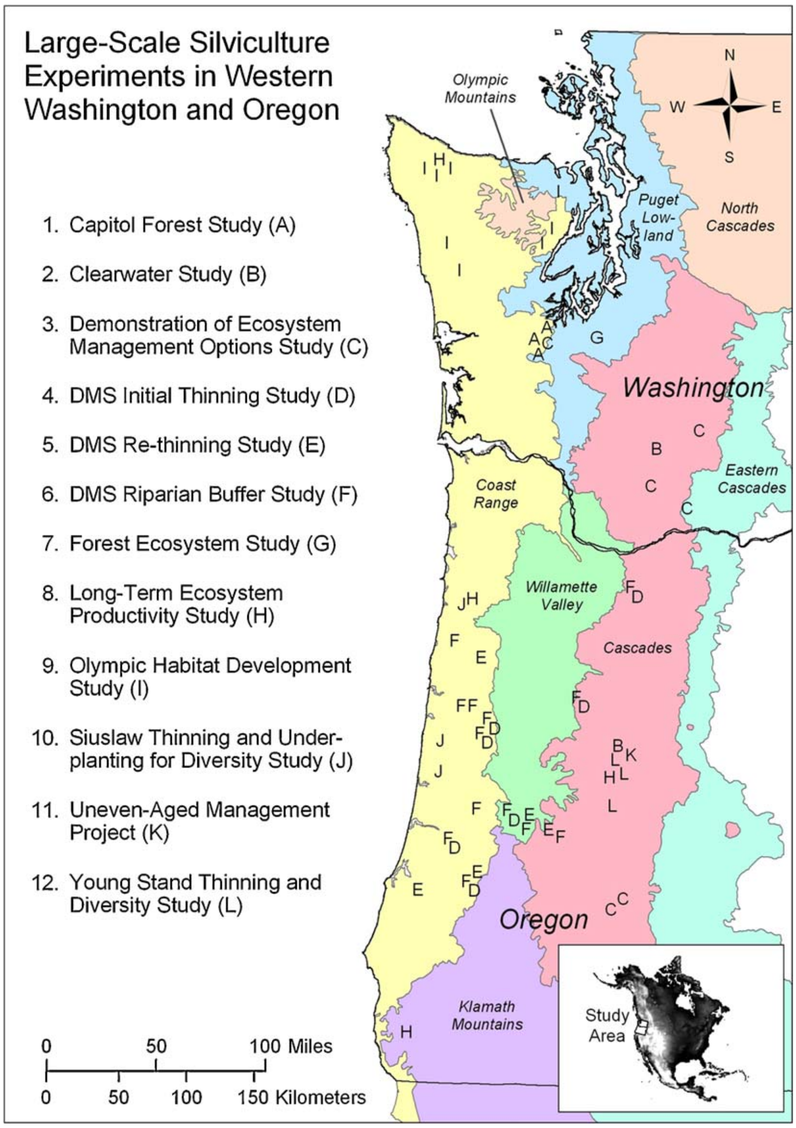

Fig. 2. Distribution of large-scale interdisciplinary silviculture experiments in western Washington and Oregon of the U.S. Pacific Northwest (from Poage and Anderson, 2007).

Continuing that synthesis effort of experiments in the U.S. Pacific Northwest, the second author of this paper is focusing on 12 major experiments in western Washington and Oregon (Fig. 2). These operational-scale experiments have commonalities that lend to their consideration as a collective research resource: these studies were developed in response to societal concerns about harvesting of old-growth forests, the practice of clear-cut harvesting, and ecosystem management; they are all located within a geographic area associated with an overarching management plan (the Northwest Forest Plan); they are interdisciplinary with all evaluating multi-taxa responses to alternative silvicultural practices; treatment and monitoring units are of operational size (5–40 ha) with replicate blocks of 150 ha and larger; and all address critical elements of experimental design – randomization and replication of treatments (Poage and Anderson, 2007).

Because of these commonalities, this group of experiments may afford opportunities for integration across disciplines over place and time. The potential for quantitative synthesis may be relatively robust for forest structure and vegetation response variables as common metrics for these variables exist across studies (Poage and Anderson, 2007). The potential for formal synthesis of responses associated with fauna, ecological services, or social values may be more limited as a result of inconsistencies in monitoring across studies, particularly with respect to various species or guilds of fauna (Poage and Anderson, 2007; Monserud, 2002), and the general lack of well-defined metrics for various ecosystem services and social values (Kline, 2007). In spite of these potential difficulties, synthetic analyses of these types of studies have been undertaken. In a meta-analysis across nearly 200 studies, 81% of which occurred in North America, Rosenvald and Lõhmus (2008) found that green-tree-retention harvests had neutral or positive effects on species richness and abundance for a variety of taxa. Live trees retained within harvest units served as refugia for many taxa, particularly ectomycorrhizal fungi, epiphytic lichens, and small ground-dwelling animals. Additional synthetic analyses are underway for smaller subsets of studies in the Pacific Northwest using modeling approaches to quantitatively link responses of various wildlife taxa to understorey and overstorey vegetation dynamics following thinning, however, these have yet to be published.

2.3. Products and outcomes in the short term

Recognizing that the early results coming out of these studies are a measure of progress that needs a much longer period to verify, nonetheless much has been learned and implemented by land managers after just 5–10 years. To date all of the studies have resulted to one or more peer-reviewed publications detailing initial responses to experimental treatments. The number of publications per study generally reflects the degree of study maturation as well as the degree of interdisciplinary engagement; the BLM Density Management Studies and the Demonstration of Ecosystem Management Options study each has generated more than 20 publications based on 5-year response data. Field tours have been common for most of the studies both prior to and following implementation. Participation in tours has extended beyond scientists and managers to include elected government officials and their staffs, and representatives of a variety of stakeholder organizations and individuals. Technical transfer workshops have been conducted by individual study teams as well as in the form of larger, theme-based events such as the previously mentioned IUFRO workshops.

Managers are increasingly confident in implementing alternative silvicultural practices as evidenced by the widespread incorporation of various elements of experimental treatments in recent operational harvests throughout the region. For example, current thinning practices on U.S. federal lands typically include various elements of legacy retention and within-stand features such as openings or leave islands that contribute to structural heterogeneity. It can be surmised that the operational implementation of these practices has arisen due in considerable extent to the demonstration values and shared learning experiences associated with these experimental installations. As a result of site visits, technical transfer and publication of study findings practitioners have increasingly looked to these studies in planning and assessment processes as credible, scientific bases for implementing novel silvicultural practices. In addition, these various activities continue to inform the debate on social acceptability of forest management practices.

2.4. Examples of what we have learned

We need to emphasize that our results are derived from observations made during the initial 5–10 years since these studies were implemented. However, we have already benefited from new information and development of new tools that we would expect to be validated over a much longer period of response:

2.4.1. We can increase stand heterogeneity through silviculture operations

A wide range of treatments was implemented in 12 large-scale studies (Poage and Anderson, 2007). When characterized by the intensity of harvest (percent of pre-harvest basal area retained) and the degree of within-stand structural heterogeneity (percent of stand area in gaps or leave islands), the existing operational studies encompass a full spectrum of structural heterogeneity (Fig. 3). Abundance and composition of understorey vegetation have been demonstrated to respond, at least in the short term (up to 10 years), to harvest intensity (Halpern et al., 2005; Chan et al., 2006; Wilson and Puettmann, 2007) and to gap creation (Wilson and Puettmann, 2007). Underplanting thinned stands with conifer species of varying degrees of shade-tolerance suggests that subsequent overstorey thinning treatments will be needed to maintain some species as a component of a developing understorey cohort (Maas-Hebner et al., 2005; Chan et al., 2006).

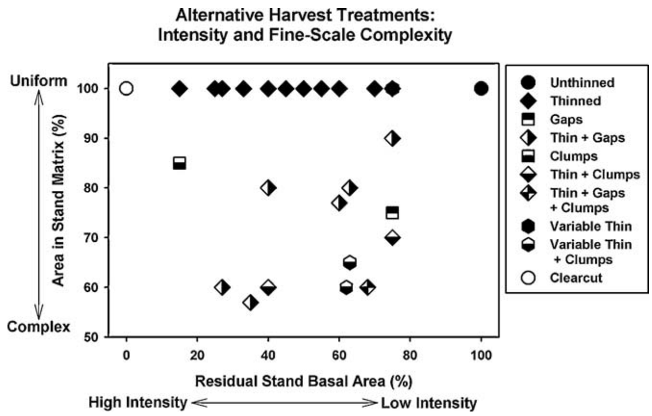

Fig. 3. Range of alternative silvicultural treatments represented by 12 operational-scale experiments in western Oregon and Washington of the U.S. Pacific Northwest. Treatments are arrayed along axes representing intensity of harvest (percent of stand basal area retained) and degree of within-stand uniformity (percent area in stand matrix). Higher intensity of harvest decreases stand basal area relative to unharvested stands. Decreased percent area in matrix implies an increased proportion of the stand area defined by within-stand features such as gaps or patch openings, clumps of aggregated retention (leave islands), or variable density thinning (adapted from Poage and Anderson, 2007).

2.4.2. Initial 5–10 years observations indicate that green-tree-retention levels greater than 15% may be needed to protect residual trees, retain sensitive species, and gain public acceptance

Harvests leaving low levels of green-tree retention can initially result in substantial stress to advanced regeneration of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and other species having persistent shade-adapted foliage, thus delaying increases in growth rate up to several years (Maguire et al., 2006). Although species of all seral stages have demonstrated various responses to decreased overstorey cover, late-seral species are particularly sensitive, with species extirpation being more common in areas of aggregated or intensive harvest (patch openings or 15% dispersed retention, respectively) than areas with moderate (40%) dispersed retention (Halpern et al., 2005). These declines in late-seral species may be associated with substantial differences in microclimates among varying levels of retention (Heithecker and Halpern, 2006). Furthermore, residents of western Oregon surveyed at random clearly favored moderate levels of retention and often objected to low levels of retention when considering not only aesthetics, but also the wildlife, social and economic values being met through management (Ribe, 2006).

2.4.3. Legacy retention and recruitment of down wood in managed stands benefit ground-dwelling organisms

Terrestrial salamander abundance may be strongly associated with the abundance of downed wood in managed stands (Olson et al., 2007; Rundio and Olson, 2007). However, retention of legacy downed wood alone may not meet desired habitat conditions in young stands, as demonstrated by Wilson and Carey (2000); they observed that the abundance of forest-floor small-mammals in variable-thinned stands was about 1.5 times that found in unthinned stands managed for legacy downed wood retention.

2.4.4. Buffers on headwater streams provide amphibian habitat, mitigate upslope harvest effects on microclimate, and provide connectivity across the landscape

Headwaters riparian areas are "hot spots" of diversity (Chan et al., 2004; Olson et al., 2007). A driver of this diversity is likely the juxtaposition of aquatic and terrestrial habitat features which are reflected in the spatial structuring of faunal assemblages (Olson and Weaver, 2007). Retention of unharvested buffers of various widths has been shown to mitigate impacts of upslope thinning on channel and riparian microclimates (Anderson et al., 2007) and to also provide suitable habitat for the common amphibian species and assemblages (Olson and Rugger, 2007). However, some salamander species demonstrated interannual variation in abundance that may be associated with variability in stream hydrologic and downed wood characteristics (Olson and Rugger, 2007).

2.4.5. New technology for characterizing and mapping forest structure and the underlying terrain has been validated

Finally, an unintended but very beneficial outcome from one of the experiments was establishing the utility of airborne laser scanning (LIDAR) technology for generating spatially explicit data for forest measurement and monitoring (Reutebuch et al., 2006), including digital terrain models of unprecedented accuracy in areas with heavy forest canopy (Reutebuch et al., 2003) and mapping forest canopy fuels (Andersen et al., 2005).

3. Future of large-scale interdisciplinary experiments in the Pacific Northwest

Clearly, these large-scale operational studies are important to the Pacific Northwest research station and public land management organizations for enhancing the science and understanding of sustainable forest management, conserving biological diversity and providing some level of economic prosperity. However, all long-term experiments face common problems such as continuity of financial support, longevity and persistence of researchers, and continued relevance to shifting societal goals and values (Franklin, 2005; Innes, 2005). It is important to ask how well these experiments might individually or collectively address emerging issues such as climate change or issues that are not as yet apparent.

Hedging against the future uncertainty or impacts of those issues, our goals for the collection of studies would be to retain a suite of study components that

(i) provide a range of densities or spatial heterogeneity, site occupancies, and geographic coverage,
(ii) are characterized by a common suite of fundamental measures or metrics, and
(iii) continue to facilitate dialogue among land owners, scientists and other stakeholders.

Possible near-term actions could include dropping components (location, variables, replications, etc.) of individual studies, mothballing elements of some studies, and even initiating something new on another scale to help in linking the studies and enhance their collective value beyond the sum of the parts. An ongoing synthesis effort (see Poage and Anderson, 2007) involving principal investigators of these studies is already yielding significant benefits such as the development of a relational database describing study objectives, experimental treatments and design, response variables, geographic locations, and principal contacts. This synthesis has increased awareness among researchers and management partners of the breadth of studies being conducted and opportunities for collaboration or cooperation. A principal objective is to ensure that administrative decisions regarding the allocation of limited resources among various research studies are made with greater awareness of the role any particular study plays in addressing regional research needs.

Finally, as Blackburn (1994) reminds us, "The public does not understand a great deal of science and what cannot be understood is generally distrusted." It is critical that scientists become more engaged in a continual dialogue with the public. That is to say, while scientists search for alternatives to inform the public, it is also important for scientists to learn from the public in order to really gain clarity on the societal issues. Considered collectively, the ongoing research studies are addressing socially important values and with careful consideration there is an opportunity to use these studies efficiently to address important current and emerging issues in resource management.

References

Andersen, H.E., McGaughey, R.J., Reutebuch, S.E., 2005. Estimating forest canopy fuel parameters using LIDAR data. Remote Sens. Environ. 94, 441–449.

Anderson, P.D., Larson, D.J., Chan, S.S., 2007. Riparian buffer and density management influences on microclimate of young headwater forests of western Oregon. For. Sci. 53, 254–269.

Baughman, W.M., Guynn, D.C., Jr., 2005. The effect of forested corridors within harvested pine plantations on herpetofauna assemblages. In: Peterson, C.E., Maguire, D.A. (Eds.), Balancing Ecosystem Values: Innovative Experiments for Sustainable Forestry. USDA Forest Service, General Technical Report PNW-GTR-635, Portland, OR, pp. 235–242.

Blackburn, C. (Ed.), 1994. Improving government decision-making in science and technology.Proceedings of the Conference on the Role of Nongovernmental Organizations. Sigma Xi, Research Triangle Park, North Carolina, p. 13.

Borman, B.T., Tarrant, R.F., Martin, J.R., Gordon, J., Wagner, F.H., McIver, J., Wood, G., Reeves, G., Alegria, J., McIlwain, J., Cunningham, P.G., Verner, J., Brooks, M.H., Christensen, N., Friesema, P., Klein, K., Berg, J., Furnish, J., Henshaw, J., 1999. Adaptive Management: Common Ground Where Managers, Scientists, and Citizens Can Accelerate Learning to Achieve Ecosystem Sustainability Ecological Stewardship: A Common Reference for Ecosystem Management. Elsevier Science Ltd., Oxford, UK, pp. 505–534.

Chan, S.S., Anderson, P.D., Cissel, J.H., Larsen, L., Thompson, C., 2004. Variable density management in Riparian Reserves: lessons learned from an operational study in managed forests of western Oregon USA. For. Snow Landsc. Res. 78 (1/2), 151–172.

Chan, S.S., Larson, D.J., Maas-Hebner, K.G., Emmingham, W.H., Johnston, S.R., Mikowski, D.A., 2006. Overstory and understory development in thinned and underplanted Oregon Coast Range Douglas-fir stands. Can. J. For. Res. 36, 2696–2711.

DeBell, D.S., Curtis, R.O., 1993. Silviculture and new forestry in the Pacific Northwest. J. For. 91, 25–30.

Franklin, J.F., 2005. Long-term studies: the basis for science-based resource management. In: Peterson, C.E., Maguire, D.A. (Eds.), Balancing Ecosystem Values: Innovative Experiments for Sustainable Forestry. USDA Forest Service, General Technical Report PNW-GTR-635, Portland, OR, pp. 13–14.

Franklin, J.F., Berg, D.R., Thornburgh, D.A., Tappeiner, J.C., 1997. Alternative silvicultural approaches to timber harvesting: variable retention harvest systems. In: Kohn, K.A., Franklin, J.F. (Eds.), Creating a Forestry for the 21st Century: The Science of Ecosystem Management. Island Press, Washington, DC, pp. 111–139.

Gadow, K., Kleinn, C., 2005. Forest management science-based and transparent. In: Peterson, C.E., Maguire, D.A. (Eds.), Balancing Ecosystem Values: Innovative Experiments for Sustainable Forestry. USDA Forest Service, General Technical Report PNW-GTR-635, Portland, OR, pp. 15–24.

Ganio, L.S., 2006. Challenges in statistical inference for large operational experiments. Special issue of the German forestry journal Allg. Forst- u. J.-Ztg. (Allgemeine Forst und Jagdzeitung), 177. Jg., 6/7, 131–136. ISSN 0002-5852.

Halpern, C.B., McKenzie, D., Evans, S.A., Maguire, D.A., 2005. Initial responses of forest understory to varying levels of green-tree retention. Ecol. Appl. 15, 175–195.

Heithecker, T.D., Halpern, C.B., 2006. Variation in microclimate associated with dispersed-retention harvests in coniferous forests of western Washington. For. Ecol. Manage. 226, 60–71.

Hickey, J.E., Neyland, M.G., Grove, S.J., Edwards, L.G., 2006. From little things big things grow: the Warra Silvicultural Systems Trial in Tasmanian wet *Eucalyptus obliqua* forest. Special issue of the German forestry journal Allg. Forst- u. J.-Ztg. (Allgemeine Forst und Jagdzeitung), 177. Jg., 6/7, 113–119. ISSN 0002-5852.

Innes, J.L., 2005. Long-term forest experiments: the need to convert data into knowledge. In: Peterson, C.E., Maguire, D.A. (Eds.), Balancing Ecosystem Values: Innovative Experiments for Sustainable Forestry. USDA Forest Service, General Technical Report PNW-GTR-635, Portland, OR, pp. 25–31.

Kline, J.D., 2007. Defining an economics research program to describe and evaluate ecosystem services. USDA Forest Service, General Technical Report PNW-GTR-700, Portland, OR, 46 p.

Maas-Hebner, K.G., Emmingham, W.H., Larson, D.J., Chan, S.S., 2005. Establishment and growth of native hardwood and conifer seedlings underplanted in thinned Douglas-fir stands. For. Ecol. Manage. 208, 331–345.

Maguire, D., Canavan, S., Halpern, C., Aubry, K., 2005. Fate of taxa after variable retention harvesting in Douglas-fir forests of western North America. In: Peterson, C.E., Maguire, D.A. (Eds.), Balancing Ecosystem Values: Innovative Experiments for Sustainable Forestry. USDA Forest Service, General Technical Report PNW-GTR-635, Portland, OR, pp. 271–279.

Maguire, D.B., Mainwaring, D., Halpern, C.B., 2006. Stand dynamics after variable-retention harvesting in mature Douglas-Fir forests of Western North America. Special issue of the German forestry journal Allg. Forst- u. J.-Ztg. (Allgemeine Forst und Jagdzeitung), 177. Jg., 6/7, 120–131. ISSN 0002-5852.

McClellan, M.H., Hennon, P.E., 2005. Maintaining old-growth features in forests used for wood production in southeast Alaska. In: Peterson, C.E., Maguire, D.A. (Eds.), Balancing Ecosystem Values: Innovative Experiments for Sustainable Forestry. USDA Forest Service, General Technical Report PNW-GTR-635, Portland, OR, pp. 127–133.

Mills, T.J., Smythe, R.V., Diaz-Soltero, H., 2002. Achieving Science-Based National Forest Management Decisions while Maintaining the Capability of The Research and Development Program. USDA Forest Service, Washington, DC.

Monserud, R.A., 2002. Large-scale management experiments in the moist maritime forests of the Pacific Northwest. Landsc. Urban Plan. 59, 159–180.

O'Hara, K.L., Seymour, R.S., Tesch, S.D., Guldin, J.M., 1994. Silviculture and our changing profession: leadership for shifting paradigms. J. For. 92, 8–13.

Olson, D.H., Rugger, C., 2007. Preliminary study of the effects of headwater riparian reserves with upslope thinning on stream habitats and amphibians in western Oregon. For. Sci. 53, 331–342.

Olson, D.H., Weaver, G., 2007. Vertebrate assemblages associated with headwater hydrology in western Oregon managed forests. For. Sci. 53, 343–356.

Olson, D.H., Anderson, P.D., Frissell, C.A., Welsh Jr., H.H., Bradford, D.F., 2007. Biodiversity management approaches for stream–riparian areas: perspectives for Pacific Northwest headwater forests, microclimates, and amphibians. For. Ecol. Manage. 246, 81–107.

Peterson, C.E., Maguire, D.A. (Eds.), 2005. Balancing ecosystem values: innovative experiments for sustainable forestry: Proceedings of a conference. USDA Forest Service, General Technical Report PNW-GTR-635, Portland, OR, 389 pp.

Peterson, C.E., Monserud, R.A., 2002. Compatibility between wood production and other values and uses on forested lands: a problem analysis. Gen USDA Forest Service, General Technical Report PNW-GTR-564, Portland, OR, 51 pp.

Peterson, C.E., Szaro, R.C. (Eds.), 2006. Building a foundation for sustainable science-based forest management: long-term multi-purpose experiments in the forest sector. Special issue of the German forestry journal Allg. Forst- u. J.-Ztg. (Allgemeine Forst und Jagdzeitung), 177. Jg., 6/7, 97–98. ISSN 0002-5852.

Poage, N.J., Anderson, P.D., 2007. Large-scale silviculture experiments of western Oregon and Washington. USDA Forest Service, General Technical Report PNW-GTR-713, Portland, OR, 44 pp.

Reutebuch, S.E., Andersen, H.-E., McGaughey, R.J., 2006. Light detection and ranging (LIDAR): an emerging tool for multiple resource inventory. J. For. 103, 286–292.

Reutebuch, S.E., McGaughey, R.J., Andersen, H.E., Carson, W.W., 2003. Accuracy of a high-resolution lidar terrain model under a conifer forest canopy. Can. J. Remote Sens. 29, 527–535.

Ribe, R.G., 2006. Perceptions of forestry alternatives in the U S. Pacific Northwest: information effects and acceptability distribution analysis. J. Environ. Psychol. 26 (2), 100–115.

Rosenvald, R., Lõhmus, A., 2008. For what, when, and where is green-tree retention better than clearcutting? A review of the biodiversity aspects. For. Ecol. Manage. 255, 1–15.

Rundio, D.E., Olson, D.H., 2007. Influence of headwater site conditions and riparian buffers on terrestrial salamander response to forest thinning. For. Sci. 53, 320–330.

Seymour, R.S., Guldin, J., Marshall, D., Palik, B. 2006. Large-scale, long-term silvicultural experiments in the United States: historical overview and contemporary examples. Special issue of the German forestry journal Allg. Forst- u. J.-Ztg. (Allgemeine Forst und Jagdzeitung), 177. Jg., 6/7, 104–112.

Szaro, R.C., Peterson, C.E., 2004. Evolving approaches toward science-based forest management. For. Snow Landsc. Res. 78, 9–20.

Szaro, R.C., Peterson, C.E., Gadow, K., Kräuchi, N. (Eds.), 2004. Creating a legacy for sustainable science-based forest management: lessons learned from field experiments. For. Snow Landsc. Res. 78, 1–208.

Szaro, R.C., Peterson, C.E., Gadow, K., 2006. Operational experiments for sustainably managing forests. Special ssue of the German forestry journal Allg. Forst- u. J.-Ztg. (Allgemeine Forst und Jagdzeitung), 177. Jg., 6/7, 98–104. ISSN 0002-585252.

Walters, C., 1986. Adaptive Management of Renewable Resources. Macmillan, New York, pp. 374.

Wilson, D.S., Puettmann, K.J., 2007. Density management and biodiversity in young Douglas-fir forests: challenges of managing across scales. For. Ecol. Manage. 246, 123–134.

Wilson, S.M., Carey, A.B., 2000. Legacy retention versus thinning: influences on small mammals. Northwest Sci. 74, 131–145.