Silviculture: Lessons From Our Past, Thoughts About The Future

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Introduction

Silviculture has always been a keystone of American forestry, but to many, it seems, this discipline has lost its relevance during the past decade or so. In some regions, silviculture has become unfairly equated with production forestry, leaving a perceived void that forest ecologists or other specialists have attempted to fill, I would argue, somewhat unsuccessfully. In reality, most silviculturists see production forestry as but one of many applications of silviculture, and in the past decade, many have embraced paradigms involving conservation biology, natural disturbance patterns and processes, and management for structure rather than yield. Yet silvicultural research, on both traditional and contemporary issues, has waned as the USDA Forest Service and other organizations have refocused on other more topical issues.

This paper traces the evolution of silvicultural doctrine and practice over the 20th century, with emphasis on paradigm shifts that at their times were embraced with enthusiasm, but that now, in retrospect, often seem to be excessive oscillations of the pendulum. These paradigm shifts define the endpoints of four distinct periods in North American silviculture, each of which is characterized below. In this historical reflection, I will draw heavily from the wide-ranging interview of David M. Smith conducted by Harold Steen (1990) published during the year of Professor Smith's retirement. Professor Smith has been an eye-witness to more than half the 20th century, learned from and knew well those who defined the first half, and arguably has had more influence over American silviculture than any other individual. It was a great honor and privilege to be one of his students. Contemporary attempts by silvicultural scientists to maintain the vitality of our discipline are discussed. I conclude with some observations about how silvicultural research, a necessarily long-term endeavor, can respond to the needs of today's and tomorrow's foresters and society.

The Custodial Era (ca. 1900-25)

During this period, American foresters had essentially two concerns: keeping wildfires from causing further devastation, and ensuring regeneration after logging, the latter usually beyond their control. Tending operations and other hallmarks of intensive silviculture were almost nonexistent.

One early silviculture text was authored by Carl Schenck (1912), instructor of the short-lived forestry program on the Biltmore estate of George Vanderbilt (now the Pisgah National Forest) near Asheville, North Carolina. Schenck recognized that natural regeneration was critical and the only feasible way to ensure forest renewal; he attempted to adapt what he termed “fixed European methods (of regeneration)” to the more “primeval” forest of America. He observed that regeneration methods, or “types” as he called them, can be classified using six different criteria: relative position of the old and new growth; size of the regeneration units; degree of exposure of new seedlings; timing of seedling establishment relative to the timing of logging; presence of competing woody vegetation; and number and distribution of “standards” (reserve trees from the previous cohort).

Schenck went on to categorize all regeneration methods into one of three types based on whether natural regeneration develops after, simultaneously with, or before, timber harvesting. Today, we could describe these as clearcutting or seed-tree, shelterwood, or overstory removal (release of advance growth), respectively. Within each of these methods, he

distinguished four basic variants based on the size of the regeneration units: entire compartment (stand), strips, groups, or "selection" (small patches). Each of the 12 permutations was then described in some detail, but it is obvious that he preferred shelterwood and systems based on advance growth for American conditions and eschewed clearcutting for most applications. I find this structure eminently logical, because it does not associate stand age structures with the ecological process of seedling establishment; for example, there is no "selection" method of regeneration.

For better or worse, Schenck's approach to silviculture never caught on. The growing preeminence of the Yale Forestry School, with its close connection to Gifford Pinchot and the USDA Forest Service, ensured that whatever was taught there would become influential. The first edition of "The Practice of Silviculture" (Hawley 1921)—a text that survives today into the nineth edition (Smith *et al*. 1997)—is usually regarded as the seminal work on American silviculture. In this work, Hawley insisted on simplifying regeneration methods into only a few basic types, and it is here that the long-standing convention of naming entire (rotation-long) silvicultural systems after the regeneration method (i.e., the shelterwood *system*) became established (Hawley 1921, p. 11). According to Dave Smith, this was a conscious decision by Hawley, done to emphasize the major stewardship issue of the era, timely regeneration after logging.

Actually, the idea of simplification, and the distillation of systems themselves from their more elaborate European progenitors, was not original with Hawley; this basic classification first appeared in Graves' (1911) classic "Principles of Handling Woodlands." In the preface, Graves noted, somewhat apologetically, "I have laid special emphasis on some of the more primitive methods of forestry because these are often the only methods which can be applied under conditions of poor markets and difficult logging. Thus, a prominent place is given to the selection system in its first application to virgin forests; …"

The custodial period also witnessed the first systematic documentation of the ecology and silviculture of North American trees and associated communities. The USDA Forest Service assigned research foresters to each important region, and by the 1910s, they began to publish comprehensive monographs on tree species and important silvicultural issues. In my own region, the spruce-fir forest of northern New England, the research forester was Marinus Westveld. Even today, one cannot work in a region very long without recognizing the lasting legacy of these pioneers. For example, Westveld's (1931) synthesis on spruce-fir regeneration is as valuable today as 70 years ago. These early works included little, if any, formal research as we now know it, yet they are full of timeless information. These early foresters were skilled naturalists as well as professionals fully engaged in the issues of the time. Their writings not only provide an important window into the past, they remind us that honed powers of observation are as important as carefully designed studies.

The "Selective Cutting" Era (ca. 1925-60)

As the forestry profession grew, the National Forest System became well established, old-growth forests grew scarce in the East, and "experiment stations" were established in every region to address topical silvicultural issues. By this time, the profession had almost universally embraced selection cutting as a universal panacea. In part, this was a strong reaction against clearcutting, because this form of logging had become so closely associated with exploitation that any support of its legitimate applications would have threatened the profession's growing public support and mandate. Indeed, Bernhard Fernow at Cornell learned this lesson the hard way when he tried to create spruce plantations in the Adirondacks; the New York Legislature eliminated his forestry program, and Yale, not Cornell, is now recognized as the Nation's oldest forestry school. There is little doubt that

these early researchers were heavily influenced by the influential work of F.E. Clements (1916) on plant succession. The structure and function of the "climax forest" became a ruling doctrine, and silviculture that deviated from natural succession by interjecting disturbance was rarely considered.

Selection cutting also had a strong appeal beyond its putative ecological underpinnings. Practically, it seemed to be the only way to conserve some growing stock in the rapidly dwindling area of virgin forest where most of America's wood still stood. Logging systems for partial cutting and markets for anything but large, high-value trees were poorly developed or nonexistent. Thus, researchers eager to provide positive alternatives to clearcutting naturally began to install large trials of various partial cutting approaches on the growing body of experimental forests throughout the country. These trials were largely empirical studies of growth and yield as well as demonstrations of alternative logging methods. The fundamental dynamics of managed selection stands—most notably, the timely recruitment of desirable regeneration that would ensure stand sustainability—were rarely considered, and as we will see below, this oversight ultimately proved to be their undoing.

The attempts at selection cutting were not limited to the last remnants of eastern old growth; they were also enthusiastically embraced in the Pacific Northwest Douglas-fir region where forests remained largely unexploited. Unlike eastern North America, the Pacific Northwest was still dominated by high-volume old-growth timber, and if there was ever any place where stand sustainability was irrelevant and gap-phase regeneration inoperative, it was here. Yet this did not stop what we now see as a badly misplaced attempt at selection management that went on for decades (Munger 1950).

An important positive legacy of this era was the nationwide establishment of experimental forests that were devoted to large trials of various silvicultural systems (Ostrom and Heiberg 1954). Many of these survive and even thrive today, especially where the original trials included even-aged systems that were distinctly unpopular at the time. For example, Dave Smith once told me that the original plan for the Penobscot Experimental Forest did not include the shelterwood method. In response to Smith's comments, two shelterwood variants were added, and today, these are among the most useful and widely applied systems by landowners (Seymour 1995).

Near the end of this era, authorship of "The Practice of Silviculture" passed to David M. Smith. Smith was strongly influenced by his mentor and graduate advisor, Harold Lutz, who in turn had studied under Yale's pioneering forest ecologist, James Toumey. On the occasion of his retirement in 1990, Smith confided that he was driven by Lutz's concern that in order for silviculture to survive, it must become more scientific and less empirical. As junior author of the sixth edition (Hawley and Smith 1954), Smith began the process of revising Hawley's largely didactic approach to silviculture into one founded on its growing ecological underpinnings, a change that was not complete until the seventh edition (Smith 1962). Smith (pers. comm.) also indicated that he never lost sight of Hawley's admonition, *viz*. that if silviculture is ever to be relevant in America, it must become profitable. This is perhaps why Smith's texts have become so valuable: successful silviculture is all about balancing the ecological and economic, and one cannot read Smith's persuasive writing without embracing this philosophy. As this era drew to a close, the pioneers ended their careers, but not without publishing important monographs (e.g., Eyre and Zillgitt 1953, Westveld 1953) that have become classics and remain influential.

By the 1950s, the negative legacy of the selective cutting era was becoming increasingly apparent (Seymour *et al*. 1986). Poor markets and limited logging technology had too often led to high grading via diameter-limit cutting; smaller d.b.h. classes had not been tended, and regeneration had often been ignored. If one now doubts this history, one needs to look no further than the recommendations for white pine management in the Lake States contained

in R.H. Westveld's (1949, p. 315) regional silviculture text:

> *"Selection cutting is recommended for mature white pine stands, because it perpetuates the type most effectively and economically. Approximately 75 to 80 percent of the volume of the stand should be removed (Zon 1928). Included in the trees that are cut should be the largest trees of all species, except a few white pines over 15 inches dbh wherever seed-bearing trees are deficient, and most of the hardwoods unless they are well adapted to the site…."*

Such inattention to forest renewal and sustainability did not sit well with the stewardship ethic of the forestry profession. Entire landscapes dominated by mismanaged stands fueled an urgency to do something different.

The Multiple-Use, Production Forestry Era (ca. 1960-1990s)

I cannot trace from the literature exactly when and where the sea change occurred, but beginning ca. 1960, the Forest Service abandoned the doctrine of selection cutting and mandated that even-aged silviculture take its place, in virtually every forest type, everywhere, on the U.S. national forests (Boyce and Oliver 1999). Regime change, we would now call it, hit the forestry profession square in the forehead.

It was unmistakably during this era that silviculture became equated with production forestry. The post-World War II prosperity and housing boom, combined with continuing forecasts of timber scarcity, underscored the importance of the U.S. national forests as the Nation's wood basket. I cannot forget being repeatedly inculcated with the dogma *"What's good for timber is good for multiple use"* when I was a forestry student in the early 1970s. Much of forestry—extending through teaching, research, and practice—became dominated by an agricultural paradigm following successes in agronomy. This was a hopeful, upbeat era; rather than recognizing this paradigm for the millstone it would become, we embraced it with unbridled euphoria. Major scientific advances in genetics, weed control, stand tending, sampling, and growth prediction suggested that American silviculture had finally emerged from the dark ages. Growing trees in plantations or simplifying natural stands to homogeneous even-aged structures was seen as the highest form of practice; shelterwoods, however sophisticated, were regarded as lame holding actions until management intensified; and selection cuttings survived mainly as experimental trials on research forests.

In the Eastern U.S., silviculturists were called upon to produce silvicultural guides for many forest types. Included in each guide was an elaborate decision tree, in which the only outcomes were either (1) a balanced uneven-aged stand managed by a B-d-q structure or (2) a single-cohort stand regenerated by complete removal cuttings (e.g., Marquis 1994). Other feasible structures, especially two-aged ones that have strong natural precedents in many forests and that just plain make sense in many management situations, were not legitimized. Although there is much useful information in these guides about silvics, stocking, and regeneration, I believe this "cookbook" approach to silvicultural prescription effectively codified a stifling form of silviculture, and for this reason, I have never used them in my teaching. Interestingly, these guides are now being reassessed and revised, at least in some regions, to better reflect a wider range of possible stand structures and management objectives ranging from production forestry to restoration and conservation of ecological reserves (Gilmore and Palik, in press).

As much as he disliked the abuses of the selective cutting era (see p. 143-191 in Hawley and Smith 1954) and welcomed the new openness to even-aged silviculture, Dave Smith (1972) also foresaw and warned us about the danger ahead for naively believing any single silvicultural system is appropriate for all conditions. At that point, citizens had already begun to resist very public manifestations of the agricultural paradigm that took the form of terracing on the Bitterroot National Forest in the late 1960s. And there was much more resistance to come: the Monongahela

controversy and the spotted owl, to name a couple of prominent examples.

Some time during the 1980s, leading silviculturists began to realize that just growing trees well, by whatever means necessary, was no longer enough. In the mid-1980s, Chad Oliver organized a series of papers published in the *Journal of Forestry* that challenged us to reflect on the past and look to the future. Critical introspection on these articles, my own included (Seymour *et al*. 1986), reveals that we were neither sufficiently prophetic nor honest with our colleagues and ourselves about the need for reinventing silviculture. Oliver (1989) was also responding proactively to another threat to silviculture: the increasing specialization of forestry faculties, and the devaluing of silviculture as an important, integrating, and academic discipline. He decried the trend of replacing retiring silviculturists with specialists focused only on scientific performance—"hyphenated silviculturists" as he called them—who were saddled with teaching the undergraduate silviculture course but did research in soils, ecology, or biometrics.

By the late 1980s, the profession's ignorance or disregard for noncommodity values of forest ecosystems on public forests increasingly had placed it at odds with society, whose increasing affluence began to value natural forests as much as cheap plywood and dimension lumber. By putting all of our silvicultural eggs in one basket, in many regions we were caught with egg on our faces: bereft of proven silvicultural systems that accommodate aesthetics, public uses, and natural ecosystems, and lapsing into tired rhetoric about "educating the public" in a futile attempt to change its value systems. Challenges to production silviculture were dismissed by its proponents as a nostalgic plea to return to the abuses of the selective cutting era, as if only two choices existed, rather than an opportunity to invent a new way.

Ever resilient, however, the progressives among us rallied to keep us relevant. In retrospect, a milestone was Jerry Franklin's (1989) plea for a "new forestry," which inspired the Type B foresters (sensu Aldo Leopold) who had heretofore been in the closet, while inciting the entrenched Type A's to dig in (Atkinson 1992). Chris Maser's (1990) book "The Redesigned Forest" unquestionably was influential in challenging the status quo in the Pacific Northwest, and in turn, the country. This debate, still very much ongoing, has caused the maturing forestry profession to reexamine its core values. It should come as no surprise that silviculture—where forestry meets the land—is at the heart of this introspection.

The Balanced Forestry Era (1990 - ?)

I write this section with some trepidation, because there is certain arrogance in trying to capture history as it unfolds, especially when one has attempted to influence its course while the outcome is still unclear. I was originally tempted to call this section "a return to our ecological roots," but this is not all that is happening. Rather, I like to believe we have learned and grown from the turmoil of the past decade and have come to view silviculture as a broadly inclusive, inherently diverse discipline that society will once again come to value for the ecological and commodity benefits it can produce (O'Hara *et al*. 1994).

The concept of a "balanced" forestry was first outlined in Seymour and Hunter (1999) as a chapter in a compendium about managing forests for biodiversity. Put simply, balanced forestry explicitly acknowledges that there is no single "right" way to manage all forests and make everybody happy. Further, and more controversially, it asserts that some forests should not be managed at all, but rather be retained humbly in their natural state as inspirational and scientific benchmarks against which to gauge our human interventions on the remaining landscape. Finally, with respect to the silvicultural schisms of the late 1980s, it attempts to validate both production forestry and ecological forestry and offers a way in which they may coexist in a win-win environment. Balanced forestry would be manifested on the landscape as a triad of ecological reserves and production forests, embedded in a matrix managed to conserve biodiversity.

The decade of the 1990s witnessed an explosion of influential literature, but now that the dust has begun to settle on this transition, two contributions stand out. The first was Mac Hunter's (1990) publication of "Wildlife, Forests, and Forestry," in which he introduces the concepts of biological diversity and conservation biology to foresters in a familiar, empowering fashion. One cannot read Mac's seminal book without having the reaction, "This stuff isn't so hard; I can do this. Thanks for giving me all the reasons I should." If others with less understanding and acceptance of foresters and forestry had written such a book first, then foresters might have come to view these subjects more as threats to be vanquished rather than as critical additions to our scientific roots.

The other major contribution I credit to Chad Oliver, who more than any other individual, brought disturbance ecology into the forefront of silvicultural thinking with his seminal 1981 paper. By documenting voluminously a myriad of examples of how the world's forests respond to and develop after disturbances, he reinforced the natural ecological basis of silviculture, which clearly had been fading into empiricism. His subsequent book, "Forest Stand Dynamics" (Oliver and Larson 1990, revised in 1996), further defined and described four major stages of natural stand development (initiation, stem exclusion, understory reinitiation, old growth) each with familiar silvicultural analogues. The emphasis on cohort initiation, as it responds to various types, intensities, and frequencies of disturbance, strongly reinforces the fact that silviculture based on natural disturbances is both ecologically grounded and inherently flexible. Because many possible silvicultural pathways exist for nearly all forests, all of which have natural precedents, locking onto any single pathway (e.g., single-cohort) needlessly hamstrings the practice of silviculture.

Other noteworthy additions to the contemporary silvicultural literature during the past decade include Ralph Nyland's (1996) silviculture text, which continually reminds us that silviculture has strong ethical underpinnings if we choose to find them. Barrett's (1995) "Regional Silviculture" also was revised for a third edition, making a strong attempt to discuss non-commodity issues in each region. "The Practice of Silviculture" entered its ninth edition, now coauthored by three of Dave Smith's most successful offspring. Kohm and Franklin's (1997) book captures well the sea change in the Pacific Northwest, and Chapter 7 (Franklin *et al*. 1997) details the important development of variable-retention harvesting. Most recently Lindenmayer and Franklin (2002) published the first book about landscape ecology that is accessible to foresters. This book relegates silviculture largely to a single chapter entitled "Matrix Management in the Harvested Stand," virtually all of which is about how to mitigate clearcuts. Issues with multi-aged forests, the most common natural structures in the humid temperate zone, including many of the Lakes States' forests, receive only five short paragraphs of attention.

Clearly, the forests of the Lake States and Northeastern U.S. demand not more ways of mitigating clearcuts, but diverse alternatives to them. As an example of how ecologically based silvicultural systems might be devised for our multi-aged forests driven by gap dynamics, I offer a recent publication of my own (Seymour *et al*. 2002) that allows silviculturists to judge the "naturalness" of any silvicultural system relative to gap size and disturbance return interval. This paper would not have been possible without the pioneering work of Craig Lorimer, silviculturist at the University of Wisconsin, who over a very productive career has systematically and creatively studied the region's natural forests in ways that are extremely valuable for silvicultural application in the new ecological era.

Thoughts on Silvicultural Research

It is not lost on contemporary silviculturists that our discipline is not exactly popular today, as evidenced by the lack of financial and political support from its potential sponsors. A quick perusal of the recently released review of the Nation's capacity for forestry research (National Academy Press 2002) reveals the dominant role of the Forest Service, which provides 82 percent of all

public sector funding. A quick scan of Forest Service Web sites for each research station reveals few "silviculture" projects, though many involve silvicultural treatments but eschew the word. Candid reflection suggests that our efforts of the last 15 years at controlling damage and reestablishing our identity have, at best, been a holding action.

I believe silviculturists must make greater efforts to become engaged in multi-disciplinary studies of important forest management issues. With this in mind, let me offer a few thoughts about how future silvicultural research might be directed toward this end. Some of these ideas are not original; they stem in part from the 1999 Yale Forest Forum on Silvicultural Research (Friedman and Guldin 2001, Wishnie *et al*. 2000) where the themes of sustainability, flexibility, and rigor were stressed.

- Studies should create wide, but experimentally controlled, gradients in (1) annual disturbance rates (i.e., cohort initiation); (2) spatial patterns (gaps vs. dispersed regeneration); and (3) permanent retention of biological legacies.
- We should not just cut, stand back, and measure; rather, we can hypothesize distinct silvicultural pathways (*sensu* Oliver and O'Hara *in review*) and test them in an adaptive management setting.
- We should include two kinds of reference benchmarks as controls: (1) comparable untreated stands (as usual), and (2) intensively managed monocultures of common species. The former allows us to see how well we can emulate nature; the latter tells us how much we sacrifice for noncommodity values. The latter also gives us an opportunity to continue to refine production silvicultural practices in ways that may correct their perceived ecological shortcomings.
- We must not monitor only growth and regeneration; studies of tree senescence, death, and afterwards, are also critical. Here, the work of Seydack (1995) and Seydack *et al*. (1995) is well worth studying.
- Wherever possible, paleoecological studies to characterize vegetation and disturbance rates over the past several millennia should be included. Such studies are valuable not only as presettlement benchmarks, but more importantly, as signs of how vegetation responded to past changes in climate.
- Thinking ahead to application by practicing foresters, such studies should develop and apply area-based (not size- or d.b.h.-based) targets for stand structure. The resulting silvicultural systems should be based on planned cohort structures and their spatial pattern; it is past time to shed Graves' and Hawley's early insistence on emphasizing regeneration methods over other factors.
- We must not be constrained by the conventional economic wisdom of the time. Such studies should generate fundamental understanding of vegetation dynamics and not apologize for including treatments that may be "uneconomic." On the other hand, growing trees on long rotations may produce specialty products of such high value (e.g., spruce for instrument sound boards; tall white pines for ship masts and spars) that silvicultural systems thought not to be profitable could prove otherwise.
- Research should anticipate changes in forest age structure, species composition, and ownership, using visual, predictive models that capture the complex spatial and vertical structure within stands and across landscapes (e.g., McCarter *et al*. 1998). Such capability will help us look forward and guard against focusing on silvicultural issues that have only historical relevance. Dave Smith frequently emphasized that "once we understand the forest of the present, it is gone, and we're faced with a new, more perplexing one."
- Finally, silvicultural researchers should not lose sight of the fact that application of any silvicultural system requires a thoughtful and rigorous prescription process. Compare, for example, how

> Magnetic Resonant Imaging systems have revolutionized the diagnosis of human ailments, against our present-day foresters who still go to the woods with their 10 BAF prism, a Biltmore stick, and maybe a 30-year-old stocking chart. Imagine if a forester could go to the field with a device like a "smart" digital camera that required only quick horizontal and canopy images to measure stand composition, density, and structure. One could take hundreds of such "plots" in the routine course of a stand exam, allowing the forester to concentrate on thoughtful observation instead of making measurements. Such a device could incorporate remote sensing data and use GPS to give data a spatial context. The resulting information could be linked seamlessly with expert systems that incorporate information about biodiversity as well as traditional growth and yield models.

The need for improving the efficiency of the prescription process is especially compelling in regions dominated by complex natural forests, where overly simple prescriptions driven by cookbooks with even-aged underpinnings do not conserve biodiversity as they could. We researchers must work with practitioners to develop simple and efficient ways to make prescriptions that do not simplify the forest itself. If we ignore this, or fail at it, northern forests will either be managed poorly—for example, by expedient diameter-limit cuts—or not be managed at all because "it's too expensive" to do right. The sought-after triad would thus degenerate to a biad like New Zealand, where the only active silviculture occurs in exotic plantations.

Conclusions

We must remember that silviculture is fundamentally an active discipline, and that, in the words of Chad Oliver (Wishnie *et al*. 2000), "No matter how issues develop in the coming years, we need to keep in mind that the role of silviculture is to inform and improve forest management." We learn most by tweaking the system, not merely by observing it. We have known things for centuries that ecologists are just discovering. James Toumey recognized this in 1928 when he wrote in the preface of his seminal silvics book,

> *"When biologists took their investigations of the relation of plants to the environment from the laboratory to the field, they found the silviculturist already there with the accumulated facts of a century of field work."*

But ultimately, it is not enough just to do good silvicultural science, publish it, and see that it gets applied. We must remember that it is not enough that the Ponderosa pines on the Bitterroot terraces have grown into thrifty 30-year-old stands. Silviculture will regain its deserved prominence only if we engage in solving problems important to society. We will struggle with this, but we must succeed, for the alternative of being characterized as a self-serving, arrogant bunch, allied only with commodity interests, serves the interests of no one.

Literature Cited

Atkinson, W.A. 1992.
Silvicultural correctness: the politicalization of forest science. Western Wildlands. 17: 8-12.

Barrett, J.W. 1995.
Regional Silviculture of the United States. 3d ed. New York, NY: Wiley and Sons. 643 p.

Boyce, S.G.; Oliver, C.D. 1999.
The history of research in forest ecology and silviculture. In: Steen, H.K., ed. Forest and wildlife science in America: a history. Durham, NC: Forest History Society: 414-453.

Clements, F.E. 1916.
Plant succession: an analysis of the development of vegetation. Publ. 242. Washington, DC: Carnegie Institute. 512 p.

Eyre, F.H.; Zillgitt, W.H. 1953.
Partial cuttings in northern hardwoods of the Lake States. Tech. Bull. 1076. Washington, DC: U.S. Department of Agriculture, Forest Service. 43 p.

Franklin, J.F. 1989.
Toward a new forestry. American Forests (Nov.-Dec.): 37-44.

Franklin, J.F.; Berg, D.R.; Thornburgh, D.A.; Tappeiner, J.C. 1997.
Alternative silvicultural approaches to timber harvesting: variable retention harvest systems. In: Kohm, K.A.; Franklin, J.F., eds. Creating a forestry for the 21st century. Washington, DC: Island Press: 111-139.

Friedman, S.T.; Guldin, J.M. 2001.
The future of silviculture research – thoughts from the Yale Forestry Forum. In: Beyond 2001: a silvicultural odyssey to sustaining terrestrial and aquatic ecosystems; proceedings of the 2001 National Silviculture Workshop; 2001 June 13-17; Hood River, OR. Gen. Tech. Rep. PNW-GTR-546. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 110-114.

Gilmore, D.; Palik, B. [In press].
A revised manager's guide for red pine in the North Central region. Gen. Tech. Rep. NC- . St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station.

Graves, H.S. 1911.
The principles of handling woodlands. New York, NY: Wiley and Sons. 325 p.

Hawley, R.C. 1921.
The practice of silviculture (with particular reference to its application in the United States). New York, NY: Wiley and Sons. 352 p.

Hawley, R.C.; Smith, D.M. 1954.
The practice of silviculture. 6th ed. New York, NY: Wiley and Sons. 352 p.

Hunter, M.L., Jr. 1990.
Wildlife, forests, and forestry. Englewad Cliffs, NJ: Prentice Hall. 370 p.

Kohm, K.A.; Franklin, J.F. 1997.
Creating a forestry for the 21st century. Washington, DC: Island Press. 475 p.

Lindenmayer, D.B.; Franklin, J.F. 2002.
Conserving forest biodiversity: a comprehensive multiscaled approach. Washington, DC: Island Press. 351 p.

McCarter, J.M.; Wilson, J.S.; Baker, P.J.; Moffett, J.L.; Oliver, C.D. 1998.
Landscape management through integration of existing tools and emerging technologies. Journal of Forestry. 96: 17-23.

Marquis, D.A., ed. 1994.
Quantitative silviculture for hardwood forests of the Alleghenies. Gen. Tech. Rep. NE-183. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 376 p.

Maser, C. 1990.
The redesigned forest. Toronto, CA: Stoddart Publishers. 224 p.

Munger, T.T. 1950.
A look at selective cutting in Douglas-fir. Journal of Forestry. 48: 97-99.

National Academy Press. 2002.
National capacity in forestry research. http://www.nap.edu/openbook/0309084563/html/R1.html

Nyland, R.D. 1996.
Silviculture: concepts and applications. New York, NY: McGraw-Hill. 633 p.

O'Hara, K.J.; Seymour, R.S.; Tesch, S.D.; Guldin, J.M. 1994.
Silviculture and our changing profession. Leadership for shifting paradigms. Journal of Forestry. 92: 8-13.

Oliver, C.D. 1981.
Forest development in North America following major disturbances. Forest Ecology and Management. 3: 153-168.

Oliver, C.D. 1989.
The 2030 forest: directions of silvicultural research. In: Proceedings of the fifth biennial southern silvicultural research conference; 1988 May 12-14; Memphis, TN. Gen. Tech. Rep. S0-74. New Oeleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station:15-22.

Oliver, C.D.; Larson, B.C. 1996.
Forest stand dynamics. New York, NY: Wiley and Sons. 520 p.

Oliver, C.D.; O'Hara, K.L. [In press].
Effects of restoration at the stand level. In: Stanturf, J.A.; Marsden, P., eds. Restoration of boreal and temperate forests. London, UK: CRC Press.

Ostrom, C.E.; Heiberg, S.O. 1954.
Large-scale tests in silviculture research. Journal of Forestry. 52: 563-567.

Schenck, C.A. 1912.
The art of the second growth or american sylviculture. 3rd ed. Albany, NY: Brandow Printing Co. 206 p.

Seydack, A.H.W. 1995.
An unconventional approach to timber yield regulation for multi-aged, multispecies forests. I. Fundamental considerations. Forest Ecology and Management. 77: 139-153.

Seydack, A.H.W.; Vermeulen, W.J.; Heyns, H.E.; *et al*. 1995.
An unconventional approach to timber yield regulation for multi-aged, multispecies forests. II. Application to a South African forest. Forest Ecology and Management. 77: 155-168.

Seymour, R.S.; White, A.S.; deMaynadier, P.G. 2002.
Natural disturbance regimes in northeastern North America – Evaluating silvicultural systems using natural scales and frequencies. Forest Ecology and Management. 155: 357-367.

Seymour, R.S.; Hunter, M.L., Jr. 1999.
Principles of ecological forestry. In: Hunter, M.L., Jr., ed. Managing biodiversity in forest ecosystems. Cambridge, UK: Cambridge University Press: 22-61.

Seymour, R.S.; Hannah, P.R.; Grace, J.R.; Marquis, D.A. 1986.
Silviculture: the next 30 years, the past 30 years. Part IV. The Northeast. Journal of Forestry. 84: 31-38.

Seymour, R.S. 1995.
The northeastern region. In: Barrett, J.W., ed. Regional silviculture of the United States. 3rd ed. New York, NY: Wiley and Sons: 31-79.

Smith, D.M. 1962.
The practice of silviculture. 7th ed. New York, NY: Wiley and Sons. 298 p.

Smith, D.M. 1972.
The continuing evolution of silvicultural practice. Journal of Forestry. 70: 89-92.

Smith, D.M.; Larson, B.C.; Kelty, M.J.; Ashton, P.M.S. 1997.
The practice of silviculture: applied forest ecology. 9th ed. New York, NY: Wiley and Sons. 537 p.

Steen, H.K. 1990.
David M. Smith and the history of silviculture. Durham, NC: Forest History Society. 126 p.

Toumey, J.W. 1928.
Foundations of silviculture upon an ecological basis. New York, NY: Wiley and Sons. 73 p.

Westveld, M. 1931.
Reproduction on the pulpwood lands in the Northeast. Tech. Bull. 223. Washington, DC: U.S. Department of Agriculture, Forest Service. 52 p.

Westveld, M. 1953.
Ecology and silviculture of the spruce-fir forests of eastern North America. Journal of Forestry. 51: 422-430.

Westveld, R.H. 1949.
Applied silviculture in the United States. 2d ed. New York, NY: Wiley and Sons. 590 p.

Wishnie, M.; Ashton, M.; Friedman, S.T.; Dunning, G. 2000.
The future of silviculture and applied ecology research – a summary of a forum exploring the evolving role of silviculture and silviculturists in the United States. New Haven, CT: Yale School of Forestry and Environmental Studies. Yale Forest Forum Series. 3(2): 40 p.