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What is close-to-nature silviculture in a changing world?

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Silviculture is a means to meet objectives ranging from timber production to wildlife habitat to naturalness. A common global trend in forestry is development of new silvicultural approaches as alternatives to plantation forestry that bear names that include the words 'nature', 'ecological' or some other positive expression regarding their intent or effects. Some approaches are attempting to emulate natural processes and others to minimize disturbance effects in an attempt to be more natural. In any case, the effects of climate changes, non-native plants, insects, pathogens and animals, and other anthropogenic effects are creating novel forest ecosystems where the silviculture of the past may not be appropriate. It should be recognized that forestry has always attempted to manage stands to meet objectives in ways that would not be similarly met without management. Rather than acquiescing to pressures to follow a nature-based model based on the past, we need to recognize that our forest ecosystems are changing and the rate of change may accelerate in the future. Natural processes and stand structures are important information about natural systems, but not necessarily for the management of these changing systems. Management of these novel ecosystems to meet societal needs will have to be novel. Rather than striving to be close to a nature that is under constant change, silviculture should strive to be better than nature. 'Close-to-nature' is flawed in both its intent to emulate nature and as a means to meet shifting ecological conditions and societal needs.

Introduction

A basic premise of forestry is that management produces a broader array of forest ecosystem benefits and services than can be achieved without management. Management may vary from simply salvaging trees before they die, to intensive management for single use objectives. It can alter the timing and abundance of these services. It can direct stand development from one structure to another or shift production from one service to another. These services may include timber production, water production or ecological benefits such as resistance to disturbance or ecosystem diversity. Forest management can guide the recovery of ecosystems damaged by previous human use, natural disaster or direct the development of non-forest lands to forested conditions. Without forest management, the amount and combination of services provided by forests would, in most cases, be less than with forest management.

In its origins around the world, forestry was an entity focused on producing wood products such as fuelwood or timber. Silvicultural practices were developed to manage the forest in ways that were sustainable, although primarily focused on sustainability of wood production. In the 1980s, new forestry paradigms emerged that, in contrast to previous approaches, emphasized the potential to manage for ecosystem values in addition to more traditional forest commodities (Franklin, 1989; Gillis, 1990). These ecosystem management approaches extended the context of the traditional emphasis on sustainability to include sustaining a variety of values and services, such as biodiversity over larger scales. In many ways, these new paradigms were a shift that removed wood production from being the primary objective of forestry on many lands to being a bi-product of ecosystem-based management (O'Hara *et al.*, 1994).

Subsequently, many stand-level silvicultural approaches have been proposed with names such as holistic forestry, ecoforestry, common sense forestry, continuous cover forestry, ecosystem management and others (O'Hara, 2014). Many of these approaches have borne the word 'nature' in various forms, such as nature-based, near-natural, back-to-nature or close-to-nature. Other names have included sustainable forestry, ecological silviculture and retention forestry. Indeed, a common theme of these approaches is a movement away from previous mindsets where nature was controlled to approaches that attempt to integrate natural processes into management or to use natural processes to guide management.

The names of these alternative approaches serve the purpose of describing their intent or philosophies. Many of the names convey a sense of naturalness that is intended to distinguish them from previous approaches that were more focused on wood production and, in some cases, abusive. Like all labels, they serve an important function inside and outside the forestry community: they advertise or signal new forestry approaches to a society that, in many locations, has become sceptical of forestry. Treatments in these alternative approaches are forms of multi-aged silviculture ranging from variable retention to selection treatments. A common feature is the avoidance of even-aged systems and particularly clearcut systems. In one sense, the philosophical intent of these alternative approaches is simply to avoid clearcut systems and the public sentiment against even-aged systems.

Although forestry in North America, Europe and other regions has reached a similar acceptance of alternative silvicultural in recent decades, these trends have not developed in parallel. In central Europe, alternative management approaches to the industrial forestry model existed well before those that emerged in the 1980s. 'Close-to-nature' forestry may be the original 'natural silviculture' movement dating to the late nineteenth century in central Europe (Gayer, 1880;1886; Möller, 1922; Schütz, 1999; Diaci, 2006; Puettmann *et al*., 2009; Bauhus *et al*., 2013; Brang *et al*., 2014). It emphasized species mixtures and irregular age structures as a response to even-aged plantations, which had become prevalent in some parts of central Europe. These even-aged, uniform, monoculture plantations were viewed as more susceptible to disturbances, and 'far-to-nature' (Johann, 2006).

One of the strongest proponents of the alternative or 'natural' approaches in central Europe is the 'close-to-nature' philosophy promoted by the organization Pro Silva (Pro Silva 2012). Pro Silva's guiding principles include: 'guaranteed continuity of naturalness', 'adopt a holistic approach involving continuous forest cover', 'adding value by selection felling and tending at all stages of development' (i.e. selection systems), 'working towards a balance on as small a scale as possible between increment and harvesting in each management unit', 'use of natural regeneration', 'restricting the use of exotics' and many others (Pro Silva, 2012). More generally, Pro Silva promotes strategies, which attempt to both conserve and utilize the forest.

Alternative silvicultural approaches, such as those that are part of ecosystem management or ecological forestry, have become more mainstream in forestry in recent decades and have evolved to integrate greater ecological understanding. A bigger question regards whether these approaches are adaptable to the changes in our environment and to rapidly evolving demands from society. This paper discusses the relationship of silviculture to naturalness and the capability of these alternative approaches – particularly the 'close-to-nature' approach advocated by Pro Silva – to respond to our ecologically changing world. It concludes that 'close-to-nature' is flawed in both its intent to emulate nature and as a means to meet shifting ecological conditions and societal needs.

Nature and naturalness

A common feature of many of the alternative approaches to forestry is the objective of being more natural. 'Natural' is poorly defined in any sense, and no less so for forests. Forests move through a vast array of structural changes or states as they follow different development trajectories: all of which may be natural. Similarly, the term 'naturalness' may mean many different things depending on context; the naturalness of a stand may be based on the conditioning of the viewers, its location or its relation to other stands. A stand's naturalness may be perceived as the degree to which it has been modified by humans, where human modification or management is generally viewed as undesirable. Maintaining naturalness is an objective of some park systems, but active management of these protected areas is increasingly seen as a necessity (Cole and Yung, 2010).The ideal of managing for naturalness in even these most natural of forests has to be compromised to meet societal objectives.

Wilderness has been described as a state-of-mind (Nash, 2001). Naturalness, a concept on which wilderness is defined is also based on perceptions. Managing to be close to nature also varies with context, much like naturalness. There is also a 'sense of place' (Williams and Stewart, 1998) that provides many of the intrinsic values associated with forests. Forests vary widely in their naturalness from heavily disturbed to those that have had relatively little apparent interaction with humans. Where one society may see natural, another may not, and the role of humans may be integrated into what is natural, or may not. Hence, the central European preoccupation for being close to nature may be rooted in the perception that a low level of human intervention typical of selection systems is close to nature even though it may not be natural. In other regions, close to nature may represent a lack of human influence. Hence, there is great difficulty in defining the naturalness of the 'close-to-nature' approach (Schmidt, 1997; Çolak *et al*., 2003).

Concepts related to a 'balance of nature' also affect how we interpret nature and naturalness. The balance of nature is a classical paradigm in ecology that assumed ecological systems were closed, self-regulating and operated at a stable equilibrium (Christensen, 1988; Pickett and Ostfeld, 1995; Oliver and Larson, 1996; Hobbs *et al*., 2010). For forests, stable equilibria implied these systems achieved a steady-state with disturbance being only an unusual event. Perceptions about a balance of nature are consistent with the use of single tree selection or plenter systems as part of 'close-to-nature' approaches. These approaches imply a disturbance regime of light perturbations where single trees are removed and only small gaps are formed. Maintaining 'natural' systems is therefore achieved with these light, unobtrusive treatments that presumably emulate nature within an ecological equilibrium.

Making silviculture 'Natural'

A theme of contemporary silviculture is using natural disturbance regimes to guide silvicultural treatments (Attiwill, 1994; Angelstam, 1998; Franklin *et al*., 2002; Perera *et al*., 2004; Drever *et al*., 2006; Geldenhuys, 2010; Kuuluvainen and Grenfell, 2012; O'Hara and Ramage, 2013; Patry *et al*., 2013; O'Hara, 2014). This is a major change from earlier paradigms where the importance of disturbances as an ecological factor was minimized (Pickett and White, 1985; Pickett and Ostfeld, 1995; Oliver and Larson, 1996; Hobbs *et al*., 2010). Disturbance emulation involves developing silvicultural regimes that resemble the types, extents and frequencies of disturbances or directing ecosystems to more resilient states (e.g. Drever *et al*. 2006): for example, using prescribed fire to simulate fire effects on fire-dependent species, or using disturbance effects to guide gap sizes and amounts of live tree retention. Disturbance emulation is viewed as contributing to naturalness – or minimal human interference (Reif and Walentowski, 2008) – because it replaces natural processes, particularly disturbance effects, with similar, but artificial, processes. Disturbance emulation requires knowledge about disturbance regimes and disturbance effects on trees, stands and forested landscapes. Although disturbance emulation is viewed as a common justification for contemporary silviculture, species' responses to disturbances have traditionally been used as a guide for silvicultural treatment (Hawley, 1921; Toumey, 1928). Hence, the theme of disturbance emulation is new, but the foundation of silviculture has traditionally been based on species life history or adaptations to changes in environmental factors or growing space availability.

Historical ranges of variability define reference conditions for management based on known ranges of past disturbance regimes (Keane *et al*., 2009). Maintaining ecosystems within these ranges, in theory, sustains natural levels of diversity. The concepts of disturbance emulation and historical ranges of variability are therefore closely related. Disturbance emulation is an excellent model for maintaining historic ranges of variability; however, the emphasis is on historical regimes, not necessarily those of the present or future. Concepts related to future ranges of variability have been used to describe ranges of conditions appropriate for anticipated environmental conditions and expected social demands (Thompson *et al*., 2009). Management treatments in the future may involve emulating parts of historical disturbance regimes that meet current societal or ecological objectives. Environmental change is likely to exceed our capability to use history as an analogue of present and future patterns. This is much like the interpretations of history in ecological restoration where historical reference conditions are of limited value in a changing world (Higgs, 2012; Higgs *et al*., 2014).

Disturbance emulation may be as varied as natural disturbance regimes and their effects on forests, and there is considerable uncertainty regarding future disturbance regimes. The scale of natural disturbance regimes ranges widely, and it may be impractical to emulate extremely large or small disturbances. Short-term fluctuations in landscape patterns of stand structures may vary tremendously due to disturbance events. If society values steady production of ecosystems services from these landscapes, management becomes a compromise between using silviculture to emulate disturbances and produce ecosystem services.

Natural disturbance regimes are highly variable from region to region. Within a single region, a variety of different types of disturbances could affect a single stand resulting in multiple potential pathways of post-disturbance stand development. Some parts of the world have a more limited history of human interactions with forests, and disturbance patterns and processes can be more easily reconstructed. In parts of North America, Australia and many boreal forests, reconstructions indicate stand-replacement disturbances were common. In other regions, mixed-severity disturbance regimes may occur that involve multiple disturbances occurring at different frequencies, severities and scales. Although there may be greater precedence for small-scale disturbance emulation in some tropical forests, larger-scale and more severe disturbances seem to predominate in temperate and boreal forests (Oliver and Larson, 1996). Our capability to emulate disturbances based on historical reference conditions is limited in some regions by a lack of information that is unlikely to be overcome. Hence, silviculture may be developing in different ways in North America where this historical information is more available than in central Europe.

The single tree selection systems that are central to the Pro Silva version of 'close-to-nature' forestry apparently have limited resemblance to natural processes. Schütz (1999) described the Plenter system as man-made and also stated 'as a general rule, plentering is a man-made system, which needs either man's intervention in the form of structure intervention, or spontaneous occurrences to maintain it in the long run.' (Schütz 2001). Instead of being truly close to nature, the Pro Silva approach is a philosophy of light treatments to create small openings and perpetuate an all-aged forest. It resembles the balance of nature philosophy where disturbance regimes consist of small-scale disturbances that damage or remove individual trees and create small gaps: a process that may be emulated with single tree selection. In reality, disturbance regimes are much more complex, involving multiple disturbance agents, variable timing and severity, and across a range of spatial scales (Oliver and Larson, 1996; O'Hara, 2014).

Emulating nature involves highly varied and complex silviculture. Multiple strategies may be necessary to achieve both the diversity of stand structures over forest landscapes, and the potential variation in structures over time within a single stand (O'Hara and Nagel, 2013). Moreover, silviculture is not static and evolves over time due to advances in silvicultural research and changes in societal values regarding natural resource management. A truly nature-based silviculture should therefore be highly varied across time and space. It should be grounded in emerging knowledge regarding disturbance ecology, and it should meet societal objectives.

Severe disturbances do occur and can be emulated with management. A nature-based silviculture may therefore include large clearcuts that emulate stand-replacement disturbances in some ecosystems/regions or the intentional development of single-species stands. Emulating disturbance 'is' nature emulation despite the ugliness and unpleasantries of many disturbances.

Future forests

The forests of today will likely be very different from those of the future. Climate change will alter species ranges and change forest communities to mixtures that may be both unfamiliar and unprecedented (Kirilenko and Sedjo, 2007; Kölling and Zimmermann, 2007; Lindner *et al*., 2010). There may also be strong regional variation (Bussotti *et al*., 2015). Natural disturbances may be of greater severity and more frequent (Seidl *et al*., 2011). A changing climate may have profound effects on the insects and pathogens that affect forests. Increasing temperatures and drier (or wetter) conditions can exacerbate forest health problems by providing conditions favourable for increased annual life cycles insect or decreased insect mortality rates (Fettig *et al*., 2013; Weed *et al*., 2013; Ayres *et al*., 2014). The increased activity of insects and pathogens may define the future limits of tree ranges (Garnas *et al*., 2011; Liebhold, 2012; Ayres *et al*., 2014).

Non-indigenous plants, insects and pathogens are also altering the structure and function of our forest ecosystems. The full extent of non-indigenous species invasions in North America is much greater than generally recognized and is increasing rapidly (Levine and D'Antonio, 2003; Aukema *et al*., 2010). Similar scenarios are occurring in other continents. They result in fundamental changes in forest structure and composition and alter many ecological processes. Silvicultural options for controlling these invasives are limited (Waring and O'Hara, 2005), and society is likely to find control too expensive (Higgs, 2012). The continuing presence of these non-native organisms may not fit either the model for close-to-nature silviculture or disturbance emulation.

Additionally, pollution affects both atmospheric and soil chemistry in ways that can be either positive or negative on forests. For example, nitrogen deposition may have positive effects (Eastaugh *et al*., 2011) and ozone may have detrimental effects (Ollinger *et al*., 1997). In any case, the effects of pollutants on forests will be the result of complex interactions between climate and soil factors. Most importantly, these perturbations are generally unprecedented.

These potential changes, in combination with disturbances that are endemic to a region, will result in novel disturbance regimes that will be fundamentally different than those of the past (Hobbs *et al*., 2006; Turner, 2010; Trumbore *et al*., 2015). These novel ecosystems will likely require novel management approaches (Seastedt *et al*., 2008). Production of ecosystem services, or the specific services produced, is likely to decrease in some regions or increase in others (Biber *et al*., 2015; Zubizarreta-Gerendiain *et al*. 2015). Societies are also placing greater demands on forests that range from placing forests in unmanaged reserves to expectations for increased production of ecosystem services including fuelwood or wood products.

The world in which we live is changing rapidly, and our forests must also adjust to these changes. Our future forest ecosystems will truly be novel (e.g. Hobbs *et al*. 2006). The assumption that there is a single stable state for a stand implies that a single developmental pathway or trajectory is normal (Hobbs *et al*., 2010), when there should be at least as many developmental pathways as there are different stand structures (O'Hara 2014). Brang *et al*. (2014) described 'close-to-nature' as 'particularly suitable for managing forests in a changing climate' when it encompassed a variety of forms of multiaged silviculture. However, Brang *et al*. also found that single tree selection did not meet all potential climate change adaptation strategies because it is essentially limited to creation of only small gaps. Silviculture needs to be varied to emulate the range of disturbance regimes in any one region. Any approach is looking backwards if the past is used to guide silviculture instead of the future. It is a non-existent reality that assumes a management model focused on past conditions can prepare forests for the novel ecological changes and social demands of the future.

Better than nature!

The objective of forestry is to meet societal objectives. These may involve producing wood, maintaining habitat for wildlife, providing recreational opportunities or many others. Emulating natural processes and managing in ways that are 'close-to-nature' are simply examples of alternative models for silviculture. They may provide some assurances that management will retain the structures, diversity and processes we consider natural or they may also provide additional ecosystem services. However, if forests are managed to provide the ecosystem services in amounts and at the times that society desires, then we have already moved beyond what nature provides and improved on natural processes. Although management may be outside known historical ranges of variation, our ecosystems are already outside these ranges of variation without direct human intervention through silviculture.

The underlying philosophy behind 'close-to-nature' implies that, as an ideal, managing forests in ways that are nature based is the most appropriate model. However, it ignores the dynamism that governs natural systems and avoids the unpleasant reality that changes in climate, invasive species, and evolving disturbance regimes make the concept of nature-based management a moving target. Approaches that focus on being close to nature may result in forests that are poorly adapted to future conditions. A nature-based model also assumes that closely emulating nature is a better solution as a singular objective than attempting to modify stand structures to meet different combinations of other objectives or to develop landscape patterns that do not experience the extremes of natural disturbance cycles. Society more accurately demands forests that are 'better than nature': forests that sustain production of multiple ecosystem services beyond those that come from forests that might emulate nature. Silviculture has the potential to meet management objectives in ways that nature cannot. This is not a new form of management, but possibly a new perception. It may also be viewed as an antithesis. Nevertheless, forestry can, and should, be better than nature.

The silviculture of the future will be highly varied and highly flexible. It will embrace the forms of free silviculture that have been advocated (Graham and Jain, 2005; Bončina, 2011; O'Hara, 2014) because they accommodate the variation in site characteristics on which silviculture is based (Spiecker, 2003). It will recognize the importance of adaptive or 'artificial' treatments such as tree planting, planting non-native species, moving species beyond their native range or developing even-aged forests. These are treatments that will help forestry maintain productive forest landscapes in a period of changing climate, conversion of forest land to other uses and expanding problems with invasive plants, insects and pathogens. If the purpose of a close-to-nature forestry is to persuade a doubtful public that our intentions are good and our actions are sound, then why risk alienation by using terms that are misleading? Why promote a suite of treatments that are artificially limited by a selective interpretation of ecology and truly unnatural? The responsibility of forest management is to be better than nature, to meet societal needs in ways that are sustainable and build upon our unique understanding of forest dynamics.

Conclusions

The justifications for alternative approaches to forestry are based on broad demands for sustainable forest practices that do not degrade site resources while maintaining production of ecosystem services. The labelling of some of these approaches as 'natural' is an attempt to differentiate them from the heavy-handed approaches of plantation forestry. Describing any approach as 'natural' or 'close-to-nature' implies that it: (1) achieves a form of silviculture that emulates natural processes resulting in stand structures that are natural or (2) promotes natural processes such as maintaining soil productivity, nutrient cycling or biodiversity. In either case, these names imply these systems are more desirable and superior to approaches which do not bear these names. These approaches imply a strategy that embraces concepts of maintaining naturalness through emulation of historical disturbance regimes, maintaining historical ranges of variation or other means to provide for natural levels of diversity. However, forestry should not base itself on ecological patterns of the past, dated ecological knowledge or rigid silvicultural systems that cannot be sustained.

Managing with the intent of being nature based may be a sound objective if it recognizes and emulates the dynamism of ecological systems. If it fails to recognize the dynamics of disturbance, climate change, invasive species or the effects of pollution, then it exacerbates the risk that management will not meet objectives. It creates labels that may sound, or feel good, but which have no substance. A dichotomy has apparently developed in the interpretation of nature-based silviculture where it is interpreted as having either minor or light effects, or as emulating natural processes. These two interpretations can overlap, but neither may be natural if they do not accommodate the dynamism of our changing world. Whereas our understanding of natural processes and stand dynamics has advanced, rebranding forestry with new labels that use the words 'nature', or 'balance', or 'holistic' is really just advertising or a form of 'buzzword creep' (e.g. Park 2011). If existing scientific information is ignored to pursue management strategies based on tradition, beliefs or old science, the label of close-to-nature is simply misadvertising. Or misleading the public to think that close-to-nature is the best management direction.

Near-natural approaches may have the potential to develop complex and sustainable forests that are adapted to our changing world (Bauhus *et al*., 2013; Brang *et al*., 2014). If these near-natural approaches are not founded on a sound understanding of forest science, they may favour ecosystems that fail to meet either societal objects or provide natural ecosystems. They will also not be transferable to other forest types or regions (Hickey *et al*., 2015). The Pro Silva version of close-to-nature resembles what Kimmins (1993) described as 'green religion' where tree planting, monocultures and herbicides are bad, and single tree selection is good, but where science is not the foundation for these options. In this sense, close-to-nature has strayed from being based on the best available science to a set of values poorly grounded in science and poorly suited for the future. Instead, it is time to recognize the role of forestry is to be better than nature.

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