SHORT COMMUNICATION

Multiaged silviculture in North America

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ABSTRACT: Multiaged silviculture is highly variable across North America but a commonality is the ties to the negative exponential diameter distribution to guide stocking control. These methods have evolved in several regions to include alternative stand structures and new stocking control tools are being developed. A trend in these new developments is integrating disturbance regimes and their effects on stand structure. The result, in some cases, is a movement towards longer cutting cycles and more flexible guidelines for stand structure.

Keywords: multiaged silviculture; North America; diameter distribution; stocking control

Multiaged silviculture in North America is as varied as the forest types where this form of silviculture is practiced. In eastern North America, these forest types include the northern hardwood forests with many shade tolerant broadleaved species and where wind is the dominant disturbance regime. In the southeast, mixtures or pure stands of southern pines (*Pinus taeda, P. echinata, P. palustris*) can be managed in multiaged stands, as can the upland hardwood forests that are found throughout eastern North America. Both of these forest types were influenced by a pre-European settlement disturbance regime of fire that varied in intensity and effects. There are also highly productive bottomland sites where multiaged stands can be promoted to grow high quality stems of various broadleaf species.

In western North America, fire is the dominant disturbance regime in most forest types. These include very frequent fire regimes in ponderosa pine (*Pinus ponderosa*) forests or mixed western larch (*Larix occidentalis*) forests that may include fires that occur on less than five-year intervals and kill very few trees. Other forest types experience fires on less frequent intervals and these fires often have severe to mixed-severity results where fires range from complete to partial stand replacement events. Coastal Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) or lodgepole pine (*Pinus contorta*) are examples of species that are the primary species in these forest types. In the coastal rainforests, fire ranges from being of mixed-severity in coastal redwood (*Sequoia sempervirens*), to non-existant in the western hemlock (*Tsuga heterophylla*)/Sitka spruce (*Picea sitchensis*) forests of southeastern Alaska and British Columbia. Most western forests are also affected by wind and many experience insects and pathogens that kill trees and affect stand structure.

An expanding trend in forest management is for silvicultural practices to emulate natural disturbances (Mitchell et al. 2002; Perera et al. 2004). In the past, as forestry moved towards more of an agrarian model for silviculture, practices became increasingly dissimilar to natural processes. The movement back to a more ecologically-based forestry – as evident in names such as "new forestry", "close-to-nature forestry", "continuous cover forestry", "near-natural silviculture", and others (O'Hara 1998) – is representative of the trend towards more natural practices and is a world-wide phenomena. Emulating natural disturbances is central to this trend as disturbances are the major factor determining stand structure in unmanaged forests. For multiaged forests, disturbance regimes that include frequent, low severity disturbances are required because these are the types of regimes that form these types of forests.

This history of multiaged or uneven-aged silviculture in North America varies widely with geographic area and forest type (O'Hara 2002). One of the key events was the work of H. A. Meyer, a Swiss emigrant, who brought ideas from Central Europe to North America (Meyer 1943, 1952). The central theme to Meyer's work was using the negative exponential or reverse-J diameter distribution to represent stand structure in uneven-aged forests. This procedure has subsequently dominated the management procedures for multiaged stands in North America. However, much of this domination was due to the general lack of alternative procedures.

Regional trends

The mixed broadleaved forests of the northeastern USA and eastern Canada are highly suitable for multiaged silviculture. A form of the negative exponential distribution has been used to guide structure. These methods have evolved into what is described as a BDq approach where "B" represents the basal area, "D" the maximum diameter in the distribution, and "q" a measure of the slope of the relationship. This "q" is a simple ratio of the number of trees in one diameter class to the number of trees in the next larger diameter class. The "q" is therefore sensitive to the slope of the distribution and also the range of the size classes. Prior to the development of the BDq approach, and even in current uses today, this method is also referred to as the q-factor approach. Over time, the management of this northern hardwood forest type has evolved to deviate from the traditional negative exponential diameter distribution to one that includes a greater allocation of growing space for larger trees and longer cutting cycles. The primary sources of information for this type are Eyre and Zillgitt (1953) and Leak and Gottsacker (1965).

The southern pine forests in Arkansas have also been a focal point for multiaged silvicultural procedures in the North America. The procedure in these loblolly pine/shortleaf pine forests began as a system where a diameter limit cut was flexible to the growth, and intentionally removed less desirable trees to encourage improvement in the growing stock (Reynolds 1954). Eventually a form of the BDq procedure was adopted for these stands (Baker et al. 1996). This work was highly important in the development of North American forestry because it has demonstrated the success of multiaged silviculture in a forest type assumed to be suitable only for even-aged forestry. It was also an effective treatment for rehabilitating degraded stand structures (O'Hara 2002).

Ponderosa pine of western North America occupies dry sites and is a shade intolerant species. Nevertheless, it is an excellent species for multiaged silviculture and is often found in multiaged stands of natural origin because of frequent, low-severity fires. A variety of methods were used for controlling stocking (see O'Hara 2002) including initially removing a percentage of the volume, a "maturity selection" system that considered the financial maturity of individual trees (Munger 1941), and the "improvement selection" system that focused on improving the amount and quality of the growing stock (Pearson 1942). These methods were largely supplanted with versions of the BDq approach for no better reason that because this was becoming the accepted method in other parts of North America. The most recent approach uses leaf area index to represent growing space occupancy and which is then allocated to age classes or canopy strata (O'Hara 1996; O'Hara et al. 2003).

Multiaged forestry in the Douglas-fir forests remains one of the most controversial episodes in North American silvicultural history. Kirkland and Brandstrom (1936) published a report advocating selection systems in old-growth forests. These practices were later found to be unsuccessful since they shifted species composition away from Douglas-fir and appeared to be high-grading (Isaac 1956; O'Hara 2002). The result was a shift away from uneven-aged silviculture that apparently affected forestry not only in the Douglas-fir region but also throughout North America. In hindsight, the method was unsuccessful because it was applied in old-growth stands and openings were not of sufficient size to favor regeneration of Douglas-fir.

Current trends and approaches

The move to emulate natural disturbances with forest management practices is part of a worldwide trend resulting from a complex set of socio-economic drivers. The most pronounced is a rejection of the even-aged plantation forest model by much of the public, particularly in more developed regions. This is increasing the interest in multiaged silviculture in North America as in other regions of the world. An additional factor influencing current management is the attempts to integrate natural ecosystem proc-

Table 1. Multiaged stocking assessment model (MASAM) for *Pinus ponderosa* growing in Montana (from O'Hara et al. 2003). This example shows a stand with four age classes (cohorts) and an inverse relationship between number of trees in each age class and the amount of leaf area index (LAI) allocated to each age class. The Diagnostic information provides information on the stand structure over one cutting cycle. The shaded boxes in the spreadsheet are those values provided by the user (Total Leaf Area Index (LAI) = 6)

	Cohort 1	Cohort 2	Cohort 3	Cohort 4	Total
User – specified variables					
Number of trees/cohort/hectare	**35**	**65**	**95**	**125**	320
Percent of LAI/cohort	**40**	**30**	**20**	**10**	100
Diagnostic information					
Leaf Area Index/cohort ECC	2.4	1.8	1.2	0.6	6.0
Leaf Area Index/cohort BCC	1.0	0.8	0.5		2.2
Leaf area/tree (m^2) ECC	685.7	276.9	126.3	48.0	
BA/cohort (m^2/ha) ECC	12.1	8.3	5.1	2.5	28.1
BA/cohort (m^2/ac) BCC	4.5	3.5	1.9		9.9
Avg. vol. increment/tree (m^3/yr) ECC	0.07	0.02	0.01	0.00	
Avg. vol. increment/CC (m^3/ha/yr)	1.6	1.0	0.7	0.1	3.4
Quadratic mean dbh/cohort (cm) ECC	58.7	35.8	23.2	14.2	
Tree vigor (cm^3/m^2/yr)	85.246	80.312	70.912	46.638	
Stand density index ECC	137.3	115.7	84.5	50.5	388.0
Stand density index BCC	62.3	57.8	38.4		158.5

ECC – end of cutting cycle; BCC – beginning of cutting cycle; BA – basal area; dbh – diameter at breast height

esses through emulation of disturbance effects. In areas where disturbances can be characterized as low to mixed severity, they result in multiaged stands and can serve as models for multiaged silviculture. These stands experience disturbance on variable cycles and severity is also not constant over time. New approaches to multiaged silviculture are therefore attempting to integrate flexibility in frequency and severity of treatment, and for adapting to more variable stand structures that may not follow traditions related to negative exponential diameter distributions.

O'Hara and Gersonde (2004) provide an international summary of the current state of stocking control in multiaged stands. With the exception of the Plenter system, these methods are all in use in North America. The leaf area allocation approach (O'Hara, Valappil 1999) is an attempt to provide a flexible system to emulate a variety of stand structures. For example, the diameter distributions of stands resulting from natural disturbances rarely follow the smooth negative exponential diameter distribution characterized by the BDq approach. Instead, these stand structures are highly variable, do not follow smooth diameter distributions, and occasionally have greater numbers of large than small trees (O'Hara 1998). The flexibility of the leaf area allocation approach provides for the capability to meet a variety of stand structure objectives while using a variable that is ecologically meaningful in terms of its relation to energy transfer, water usage and stocking. A silviculturist can therefore accommodate unique stand structural features such as additional large, old trees, or gaps in the diameter distribution.

Because of the relation of LAI to stand growth, the effect of selection treatments on multiaged stand volume increment can be predicted. A series of spreadsheet-based models called Multiaged Stocking Control Models (MASAM) have been developed for LAI allocation in ponderosa pine (Table 1; O'Hara et al. 2003), lodgepole pine (O'Hara, Kollenberg 2003), redwood (Berrill, O'Hara 2007), and mixed Norway spruce (*Picea abies*)/Scots pine (*Pinus sylvestris*) in Finland (O'Hara et al. 2001). These models provide a flexible user interface and can predict volume increment, density effects, and tree vigor. These models are available at http://www.cnr.berkeley.edu/~ohara/downloads.

CONCLUSIONS

Multiaged silviculture in North America has a relatively short history compared to Europe. European practices have had a large effect on North American practices particularly with MEYER's (1942, 1953) influence and recognition of the long history of European forestry. This developed into a somewhat rigid procedure for controlling stocking in multiaged stands called the BDq approach. More recently there has been a recognition that more flexibility is needed, particularly in western forests in North America where disturbance regimes are better understood, and result in a variety of stand structures. There is also a need to provide a stronger ecological foundation for multiaged silviculture and linkages to other resources such as wildlife, hydrologic functions, as well as timber production. The development of the MASAM tools represents this need.

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Pěstování různověkých porostů v Severní Americe

ABSTRAKT: Pěstování různověkých porostů má v Severní Americe mnoho variant, společná je pro ně vazba na rozdělení četnosti tlouštěk stromů podle negativní exponenciály, které slouží pro dosažení a kontrolu optimálního zakmenění a struktury porostu. Tyto metody, které byly rozvíjeny v některých regionech, zahrnují alternativní porostní struktury, pro které byly vyvinuty nové nástroje pro kontrolu zakmenění a struktury porostů. Trendem v těchto nových postupech je interakce režimů disturbance a jejich efektů na porostní strukturu. Výsledkem je v některých případech posun směrem k dalším těžebním cyklům a flexibilnějším směrnicím, týkajícím se porostní struktury.

Klíčová slova: pěstování různověkých porostů; Severní Amerika; tloušťková struktura; kontrola zakmenění

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