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Forest Ecology and Management 215 (2005) 103–112

Forest Ecology and Management

www.elsevier.com/locate/foreco

Conversion of uniform broadleaved stands to an uneven-aged structure

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Received 14 May 2004; received in revised form 3 May 2005; accepted 4 May 2005

Abstract

The conversion of an even-aged (single tiered canopy) stand to a multi-tiered (uneven-aged) structure can be accomplished by vertically partitioning growing space among canopy layers. A successful example of this methodology was accomplished in an upland oak stand in the Ozark Highlands of Missouri, USA. The conversion process on the study area was initiated in 1961 and completed with the establishment of a third cohort resulting from a harvest in 2000. The prescription calls for allocating growing space among three canopy tiers (overstory, midstory, and understory) at a ratio of 3:2:1 based on regional stocking charts. This distribution ensures full site utilization and maintains approximately 60% of stand basal area in the sawtimber size classes while reserving sufficient growing space for the recruitment of new cohorts as needed. Further, the conversion prescription facilitates transition of the stand into a maintenance phase of management following completion of stand conversion; the 3:2:1 ratio equates to a negative-exponential diameter distribution defined by a q-value of 1.7 (for 5 cm diameter classes). During conversion, however, a q-value based target diameter distribution should never be used to determine the cut. Rather, each cohort is treated as a separate even-aged entity where proper spacing, species, and stem form are the factors determining removal.

Keywords: Uneven-aged silviculture; Continuous-cover forestry; *Quercus* sp.; Oak management; Uneven-aged conversion; Transformation; Plentering

1. Introduction

The oak-dominated forests in the Ozark Highlands of Missouri, USA have traditionally been managed with even-aged silvicultural systems and natural regeneration. Although well suited to this type of management, some landowners prefer, or some objectives require, the application of a continuous cover system. Given the movement away from even-aged systems and the desire to convert existing even-aged stands to a more irregular structure, foresters are in need of proven conversion prescriptions. Although there are a number of well documented examples for managing existing uneven-aged stands that include such information as: marking procedures, length of cutting cycle, target diameter structure, and residual stand density (Arbogast, 1957; Leak et al., 1987; Murphy et al., 1991), in some forest

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doi:10.1016/j.foreco.2005.05.007

types, particularly those dominated by shade intolerant tree species, examples of sustainably practiced selection silviculture may not exist. Even where selection has been practiced successfully, the conversion process is not well understood. The tools used to maintain an uneven-aged structure have often been shown to be ineffective for stand conversion (Della-Bianca and Beck, 1985).

On the Salem Plateau in the Ozark Highlands of Missouri, USA there are successful examples of selection silviculture applied in stands dominated by white oak (*Quercus alba* L.), black oak (*Q. velutina* Lam.), scarlet oak (*Q. coccinea* Muenchh.), and shortleaf pine (*Pinus echinata* Mill.), all of which are intolerant to moderately tolerant of shade. One such example is the Pioneer Forest, a 65,000 ha, privately owned tract, located approximately 37° 15′ N and 91° 15′ W. It has been managed using single-tree selection for over 50 years with no evidence of shift in species composition. The Pioneer system maintains a stable ingrowth of desirable trees into the merchantable size classes and upgrowth sufficient to maintain a stable negative-exponential diameter distribution (Loewenstein et al., 2000).

Thus, evidence exists that it is possible to manage these stands with single-tree selection. Further, a long-term continuous forest inventory documents stand development during the conversion process, culminating in a fully stocked uneven-aged forest. Unfortunately, this example originated from terribly degraded stands that were in a greatly understocked condition (6–7 $m^2\ ha^{-1}$) when brought under management (Loewenstein et al., 2000). As many of the stands that are now candidates for conversion are neither degraded nor understocked, a prescription is presented to convert fully stocked even-aged stands that was developed based on experience derived in xeric to dry-mesic oak-dominated forests in the central United States.

2. Conversion considerations

Some initial factors to consider when developing a conversion prescription include stand age and species composition. These variables determine whether the dominant overstory is capable of surviving the conversion period or of reproducing a new cohort of trees. Species longevity, in conjunction with stand age, gives an estimate of the time available to complete the conversion before the remaining residual overstory must be removed or until the likelihood of senescence and mortality increases dramatically. The ability to maintain this residual overstory is not, in and of itself, integral to the conversion process; what is important is managing the growing space allocated to this age class. Widespread natural mortality of trees in the main canopy is an unpredictable event that affects both the development of trees in subordinate canopy classes and the regeneration/recruitment process. By losing control of growing space allocation, the ability to manage stand structure is compromised.

Often, conversion must be initiated in a subsequent rotation. Typical average longevity for white oak is 250–300 years; for scarlet oak, 80–100 years; black oak, 100–120; and shortleaf pine about 200 years. Attempting to convert a stand of relatively short-lived, mature to over-mature trees (60+ year-old black and scarlet oak) will ensure substantial mortality prior to completion of the conversion process. Conversely, initiating conversion in a stand with a large component of long-lived species such as white oak or shortleaf pine allows more flexibility. These concerns are not unique to conversion of oak-dominated forests. Schütz (2001) presents a decision making process for stand transformation that focuses on longevity of residual canopy dominant trees. He suggests not attempting transformation if a stand does not contain 40–60 trees per hectare that are capable of surviving 60–80 years.

Reproductive viability is another issue to consider prior to conversion. Many oak species do not begin producing substantial acorn crops until they reach 40 or more years of age (Rogers, 1990; Johnson, 1990; Sander, 1990). Stands that have not yet reached reproductive maturity cannot be expected to recruit seedlings. In that case, reproduction must be developed from sprouts. Conversely, sprouting viability decreases with increasing age and stump diameter (Johnson, 1977); as stands mature, seedling origin reproduction assumes increasingly greater importance.

3. Growing space allocation

In an even-aged stand, the forest canopy is typically a single layer. In a forest composed of even-aged stands, growing space is allocated among age classes horizontally across the landscape. When a new age class is desired, a stand is regenerated. When multiple age classes are required in close proximity, it can only be accomplished among adjacent stands. A similar pattern occurs with group selection, but at a smaller spatial scale. The age classes are again distributed horizontally, but in groups across the stand rather than stands across the forest. Conversely, an uneven-aged stand managed with single-tree selection theoretically consists of multiple canopy layers that are not horizontally separated. New cohorts are recruited beneath the shade of an existing forest canopy and multiple age classes are distributed relatively uniformly within the same stand. The difficulty in developing and maintaining this theoretical vertical stratification lies in determining the amount of growing space necessary to sustain each of the age classes. Tools that have been used to allocate growing space vertically within a stand include the MASAM model (O'Hara and Valappil, 1999) and stand density index (Long, 1996). The approach presented in this paper relies on a common tool used by foresters in the eastern deciduous forest of the United States, the Gingrich stocking chart (Gingrich, 1967).

A Gingrich stocking chart, reports stocking on a percentage basis and is a function of the number of trees in a stand and their diameter. It is a measure of the available or used growing space in a stand. At 100% stocking, the stand is at average maximum density or 'normal density'; on average each tree has the minimum growing space necessary for survival. Any additional growth is balanced by density dependent mortality. On the stocking chart, 100% stocking is referred to as the A-line. At approximately 60% stocking is the B-line. At B-level stocking (canopy closure), on average each tree has all of the space it can occupy; each tree is at full crown spread and there are just enough trees present that all of the growing space is being used. There are no gaps in the canopy. At any point between the A- and B-lines, the stand is considered fully stocked, which is to say that all of the available growing space is utilized.

Consider the dynamics implied by this stocking relationship. As has been mentioned, an even-aged stand is basically composed of a single canopy tier. Given that the crown dimensions of a tree are plastic within biological limits, if growing space is available adjacent to a tree, the crown will expand into that space. Although it is possible to squeeze A-level stocking into a single canopy tier, if stand density is reduced within the range of full stocking the residual trees will expand to fill all of the empty space. Thus, in order to recruit a new age class, stocking must be reduced below 60% stocking in the main canopy. Likewise, for a third age class to establish, the two superior canopy tiers (the midstory and the overstory) must not combine to equal full stocking. Further, as growth occurs between cutting cycles, if the dominant canopy tiers reach or exceed full stocking, density dependent mortality begins in the understory. If the cutting cycle is extended and the dominant canopy approaches full stocking, suppression and mortality begins in the midstory as well. At this point the stand loses its uneven-aged character, reverting to a more regular, even-aged structure. Thus, only if the stand is reduced below B-level is there sufficient growing space available to establish a new age class and only if all superior canopy tiers are maintained below full site occupancy will the new cohort grow and recruit into succeedingly larger size classes. This dynamic assumes uniform distribution of trees across the stand and that tree crowns are able to fully capture growing space immediately following harvest (both assumptions are fallacious, but the spatial variation and time lag associated with each are fairly small if silvicultural treatments are prescribed in a careful and timely manner; if not, stocking levels are somewhat overestimated giving an additional margin of safety before mortality occurs).

3.1. Conversion prescription

The conversion of an even-aged stand to an uneven-aged structure, and following conversion the maintenance of this structure, is accomplished by vertically partitioning growing space among age classes or canopy tiers (overstory, midstory, and sapling/reproduction) at a ratio of 3:2:1. This ratio has several attributes recommending its use. First is the ease of application; one-half of the growing space in the stand is allocated to the dominant canopy tier, one-third is allocated to the midstory, and the reproduction layer receives the remainder. Second, the 3:2:1 ratio closely approximates a negative-exponential distribution defined by a *q*-value of 1.7 (for 5 cm diameter classes). This trait

Table 1
Conversion prescription timeline and target stocking levels[a] by age class

Stand age (years)	Overstory (percent stocking)	Second age class (percent stocking)	Third age class
30	40	Cohort initiation	
45[b]	40	Untreated	
60[b]	30	20	Cohort initiation

[a] Stocking follows equations developed by Gingrich (1967) for the Central Hardwood Forest, USA.
[b] Age at reentry is approximate, stand treatment occurs before the dominant canopy tier reaches full site occupancy.

allows for an easy transition to a target diameter structure based marking guide when the conversion process is completed (see Larsen et al., 1999). Finally, and most importantly, this allocation of growing space has been shown to be sustainable in the oak-dominated Ozark Highlands of Missouri. The *q*-value on the Pioneer Forest (located in the Ozark Highlands) is 1.66 and has varied by less than 0.05 over 40 years (Loewenstein, 1996).

The prescription should not be initiated until the stand is at least 30 years old to allow roughly equal temporal spacing among three age classes at the conclusion of the conversion period (Table 1). This timing assumes that the fastest growing trees reach the largest target diameter class at approximately 90 years of age. Where this age varies, the initial entry should be changed accordingly (e.g. if the target size class is reached in 120 years, the initial entry should be at 40 years; if at 60 years, enter at 20 years, etc...). Additionally, conversion should not be attempted unless a stand inventory has determined that the age and species composition is suitable for conversion (Schütz, 2001).

At the initial entry, the stand is thinned to 40% stocking, leaving only the largest, most vigorous trees with the best form and at a uniform spacing. In particular, select against trees that show a propensity for epicormic branching because these trees will be open grown, similar to the leave trees in an irregular shelterwood (Miller, 1996). Thinning the stand to 40% allocates one-third of the growing space to the new cohort (full site occupancy occurs at approximately 60% stocking). In reality, slightly more growing space is available immediately following the harvest because the overstory trees require some time to reach full crown expansion. The new cohort is recruited almost exclusively from stump sprouts during the first cutting cycle. By age 30, most oak stands are not yet producing large quantities of acorns and the stand is sufficiently dense that accumulation of advance reproduction has not begun.

The stand is entered a second time after approximately 15 years and the dominant canopy is again thinned to 40% stocking. However, the actual timing of the second entry is dependent on when the dominant canopy approaches full site occupancy. The 15-year cutting cycle is based on an estimate that fully stocked upland oak stands grow at a rate of approximately 1.5% stocking per year (derived from Gingrich, 1971); because the dominant canopy is cut back to 40% stocking (two-thirds of full site occupancy), the annual growth rate should be proportionately less, about 1% per year. During the second entry, the developing midstory is left untreated because recruiting a new age class is not yet desired. Therefore, total stand stocking is not reduced below 60%. Reducing overstory density by one-third transmits sufficient light to the developing midstory to keep it alive yet retains the majority of the growing space in the most valuable stems. Not thinning the midstory at this time also results in cost savings. There is rarely a market for this small diameter material and density dependent mortality will begin to thin this cohort at no cost. Further, the greatest mortality occurs where the overstory is most dense and the fastest growth where gaps exist in the main canopy. Thus, proper management of density in dominant canopy tiers allows for control of pre-commercial operations in subordinate cohorts as well as affecting an increase in vertical stratification within these cohorts.

The third entry occurs when the dominant canopy again approaches full stocking (approximately 15 years). At this time, the overstory is cut to 30% stocking and the midstory to 20% stocking. This allows for the recruitment of a third age class. As has been emphasized, at 60% stocking, all available growing space is being utilized by the standing trees—assuming uniform spacing and full crown expansion.

Thus, in order to recruit a new cohort of trees into the stand, the total stocking level must be reduced below 60% (the lower limit of full site occupancy). Technically, this entry marks the end of the conversion period because the stand is now uneven-aged.

As has been mentioned, this conversion prescription was developed based on research and experience in the xeric to dry mesic oak-dominated forests of the Ozark Highlands in Missouri. In this region, shade-tolerant species tend to be at a competitive disadvantage relative to the drought tolerant oaks. Further, this system tends to accumulate advance reproduction of oak in the understory. In situations where advance reproduction is not present or vegetative competition is an issue, some sort of mechanical or chemical site preparation may be necessary to establish a new cohort.

Reliance on stump sprouting (coppice) for the initiation of the second cohort of trees in this conversion prescription as well as the fact that the dominant species in these stands are oak suggests similarity with the centuries old coppice-with-standards system (c-w-s) (Troup, 1952). However, the prescription presented is actually more similar to a system described by Gurnaud around 1870, 'light high forest' (see Schütz, 2002). The principle distinctions between c-w-s and light high forest is that there is little demand for small diameter material so the number of these stems need only be sufficient to sustain recruitment into the large diameter classes. In addition, the standards are recruited without stump sprouting in order to maintain stem quality. Reliance on sprouts to develop the second cohort in this conversion series is due to the lack of true seedlings in a young dense stand. Even so, quality is unaffected because the sprouts originate from young, small diameter trees that are likely to develop single stemmed sprouts free from rot. Subsequent cohorts are recruited from advance reproduction and new seedlings. Stem density is controlled at establishment and during development by managing the amount of growing space allocated to the dominant canopy tier, thus reducing the need to treat non-merchantable trees. Stem quality is further improved by maintaining a higher density in the overstory canopy than c-w-s causing better self pruning of low branches. Finally, the initial cohort develops as an even-aged stand for 30 years prior to the first treatment and each subsequent cohort remains untreated for 30 years prior to lateral release. This early intra-cohort competition serves to improve stem quality. It should be noted, however, that stand density in this system is continually maintained at the lower end of the range of full site occupancy so branch retention will be greater than that of even-aged stands.

The 15-year cutting cycle presented in this prescription may be modified by changing the residual stocking levels in each of the canopy tiers, but such modification should only be considered after examining the logical consequences of the action. A shorter cutting cycle would allow retention of proportionally higher residual basal area and may result in incrementally better stem quality. However, the volume produced at each harvest entry is reduced. Conversely, if for economic or operational reasons a 15-year reentry does not produce sufficient volume to justify the treatment, the cutting cycle could be extended to 25 or 30 years by thinning the overstory to 30% stocking during the first two entries and the overstory and midstory to 25 and 15% stocking respectively at the third entry. Opening the stand this severely will stimulate dense regeneration of the site. When it is time to recruit a third age class into the stand, this developing midstory will have to be thinned, probably at substantial cost. Additionally, the first entry during conversion may be precommercial or marginally profitable because the stand is young and the average diameter fairly small. Because of these significant consequences, if an extended cutting cycle is desired, a two-aged silvicultural system may better suit the management objectives (Long, 1996; Miller, 1996).

4. Prescription implementation—a case study

Testing the efficacy of this conversion prescription from initial entry through conclusion would take 30 or more years. Fortunately, a stand was available that allowed an opportunity to skip directly to the final treatment. This stand had been part of a thinning study and had been treated in a manner similar to what the conversion prescription recommended.

The study stand was part of an upland oak, growth and yield study that was installed in 1961 on the Sinkin Experimental Forest near Bunker, Missouri (37° 30′ N, 91° 15′ W) by the United States Forest Service, North Central Research Station. The site index was estimated at 20 m (base age 50 years) and the age of the stand when the study was initiated was 48. This stand was

Table 2
Stand characteristics for overstory trees (>11.25 cm DBH) before and after three silvicultural treatments designed to convert an even-aged stand to an uneven-aged structure[a]

	1961		1981		2000	
	Pre-treat	Post-treat	Pre-treat	Post-treat	Pre-treat	Post-treat
Average diameter (cm)	16.0	21.3	29.5	32.0	40.6	42.2
Basal area ($m^2 ha^{-1}$)	18.0	6.8	12.8	8.4	12.8	8.9
Trees (ha^{-1})	904	193	188	104	99	64
Stocking (percent)[b]	80.3	27.9	48.6	30.0	43.0	29.8

[a] Study area located on the USDA Forest Service Sinkin Experimental Forest, Missouri, USA (approx. 37° 30′ N, 91° 15′ W).
[b] Stocking follows equations developed by Gingrich (1967) for the Central Hardwood Forest, USA.

prescribed a 30% stocking treatment with mechanical understory removal. These treatments were applied in 1961 and again in 1981. The final cut in the conversion series was applied in 2000, at which time the overstory was cut back to 30% stocking and the midstory to 20% stocking. Thus leaving growing space equal to 10% stocking for a third age class to establish.

4.1. Overstory treatment and development

In 1961, prior to the first treatment, the stand averaged 904 trees ha^{-1}, 18 $m^2 ha^{-1}$, and 16.0 cm DBH (Table 2). The species mix was predominately black oak with lesser numbers of scarlet and white oak. For all stems >11.25 cm DBH, stocking was calculated at 80.3%. The best, most vigorous trees were left at the most uniform spacing possible, 711 trees ha^{-1} were removed, and stocking reduced to approximately 28%. The treatment increased average diameter by over 5 cm.

Over the next 20 years, the stand average diameter increased by just over 8 cm and the stand basal area nearly doubled to 12.8 $m^2 ha^{-1}$ (Table 2). Five trees ha^{-1} were lost to mortality. The residual stems were much more uniform in diameter than in 1961; removing 45% of the remaining trees had only a marginal effect on the average stand diameter, increasing it by 2.5 cm to 32 cm DBH. As in 1961, by selecting the most vigorous trees at the most uniform spacing possible, the residual stocking was again reduced to 30%.

By 2000, the residual trees had again added over 8 cm in diameter on average and an additional 5 trees ha^{-1} were lost to mortality. The stand was now 87 years old and the final cut in the conversion series was applied in the same manner as the previous two. Concentrating on spacing and vigor, the remaining overstory was thinned to 30% stocking by removing approximately one-third of the remaining trees (Table 2).

4.2. Stand characteristics—midstory

Examining the development of reproduction reveals that a reduction of stocking levels in the overstory to 30% is more than sufficient to stimulate the development of a new age class. By 1981, almost 1600 stems ha^{-1} had grown into the 4-cm size class; these trees averaged 4.6 cm DBH (Table 3). As has been mentioned, the original purpose of this study area

Table 3
Stand characteristics for midstory trees (4–11.25 cm DBH) before and after the second and third treatments from a silvicultural prescription designed to convert an even-aged stand to an uneven-aged structure[a]

	1981		2000	
	Pre-treat	Post-treat	Pre-treat	Post-treat
Average diameter (cm)	4.6	0	4.1	6.6
Basal area ($m^2 ha^{-1}$)	2.7	0	6.7	2.6
Trees (ha^{-1})	1569	0	5491	756
Stocking (percent)[b]	21.0	0	55.1	20

[a] Study area located on the USDA Forest Service Sinkin Experimental Forest, Missouri, USA (approx. 37° 30′ N, 91° 15′ W).
[b] Stocking follows equations developed by Gingrich (1967) for the Central Hardwood Forest, USA.

was to examine growth and yield, not stand conversion. So in 1981 when the overstory was thinned back to 30% stocking, the vigorously developing midstory was mechanically removed as well. By 2000, almost 5500 stems ha^{-1} had grown back into the 4 cm size class with a 4.1 cm average diameter and accounting for 2.6 $m^2\ ha^{-1}$ and over 55% stocking (Table 3). Had the midstory not been removed in 1981, growth models project that by 2000 this cohort would have attained an average DBH of 9.7 cm, self thinned to approximately 1365 trees ha^{-1}, and accounted for approximately 59% stocking.

Following the overstory treatment in 2000, the new midstory (the second age class) was treated as well. Many of the small diameter stems were damaged during the overstory harvest operation. However, given the density of this age class, the harvest damage had little effect other than to reduce the amount of precommercial thinning that was needed. Like the overstory treatment, stems were selected based on form, vigor, and spacing. Harvest damage and thinning in the second age class removed over 4700 stems ha^{-1}, increased average diameter to 6.6 cm DBH, and reduced stocking to 20% (Table 3). Of the trees remaining in this age class, 94% were oaks and 6% hickory (*Carya* sp.).

4.3. Stand characteristics—reproduction

While the stand was marked for harvest in 2000, plots were installed to monitor the development of reproduction. Of the midstory stems that were cut and the advance reproduction that had been present prior to harvest, in 2002, following two growing seasons, 91% of the stems had resprouted and were still alive, approximately 3400 trees ha^{-1}. Of these, 66% were oaks, 10% hickory, 4% ash (*Fraxinus* sp.), gum (*Nyssa sylvatica* Marsh.), and maple (*Acer* sp.), and 20% understory species, predominately dogwood (*Cornus florida* L.) and sassafras (*Sassafras albidum* Nutt.). Note that the species composition, even within the most subordinate canopy tier, does not appear to be adversely affected by this prescription.

4.4. Conversion versus maintenance

A common approach to stand conversion is to apply marking rules similar to that followed with a stand that has an existing uneven-aged structure (Della-Bianca and Beck, 1985). Often the target diameter structure is some sort of reverse J-shaped distribution or a rotated-sigmoidal distribution. A target structure is calculated and any trees in excess of that structure are removed. The assumption is that eventually the stand will recruit new age classes and fill in the desired structure. The problem with using this approach in an even-aged stand is that the result is a high grade operation. The diameters of an even-aged stand are normally distributed. By superimposing any sort of depletion curve on this structure, the largest trees are removed leaving all of the small diameter stems. Because all of these stems are of the same age, the best, most vigorous trees are removed and the least competitive trees are left as future growing stock and as the parent material for future generations.

Conversion to an uneven-aged structure differs markedly from the maintenance of an uneven-aged structure in that each age class should be treated individually during the conversion process. In effect, individual thinning regimes are prescribed to separate even-aged stands that just so happen to occupy the same site. Recall that the conversion prescription calls for leaving the best trees at the most uniform spacing possible. With each entry, the dominant age class became more and more uniform in diameter (Table 2). The same instructions are followed when the second age class is thinned to allow for the recruitment of a third age class. In effect, a thin from below was applied to each of the two age classes in the stand. This is only possible because each of the age classes is visually distinct from the other in height and diameter. The dominant canopy tiers have been very closely tended, so have a fairly narrow range of diameters; the newest age class is too young to have begun to stratify (Figs. 1–2).

Following conversion, the lines between the age classes eventually blur and treatment must be based on diameter structure because tree age is no longer recognizable. Canopy tiers become less distinct and the fastest growing trees in one age class overtake the slowest growers in the next older age class. An example of how this occurs is illustrated in Fig. 3. The diameter structure of four age classes evenly spaced 30 years apart (10–100 years) is shown. It is known that as the average diameter of an age class increases, so does the variation in diameter around that mean.

Figs. 1–2. Two years following the final cut in a conversion series (2002), three age classes are easily distinguished in terms of both height and diameter.

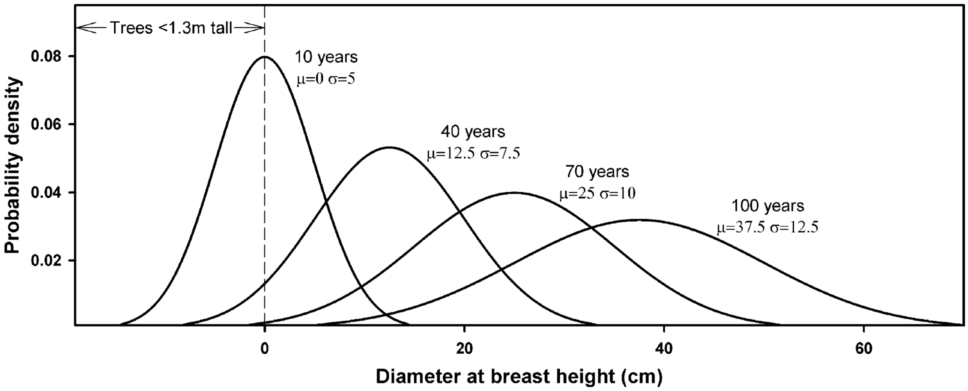

Fig. 3. Stylized diameter distributions from four age classes of trees established at 30-year intervals.

However, until this diameter variation within an age class is shown superimposed on that same variation within adjacent age classes, it is not obvious that a 100-year-old tree may be in the same diameter class as a 10-year-old stem. Fortunately, the 30:20:10 split of stocking among canopy tiers translates quite well to marking by target diameter structure following conversion. Allocating 30% stocking to the sawtimber size classes (trees > 25 cm DBH), 20% stocking to the pole size stems (12.5–25 cm DBH), and 10% stocking to the reproduction/sapling size class (<12.5 cm DBH) equates to a negative-exponential target diameter structure defined by a largest diameter tree of 45 cm and a *q*-value of 1.7 (for 5 cm diameter classes).

5. Summary

To recruit a new age class, total stand stocking must be reduced below B-level (full utilization of growing space). As a stand approaches full stocking, density dependent mortality begins to occur in the most subordinate trees. If allowed to occur, this trend will counter the conversion treatments and the stand will develop a more regular (even-aged) structure.

The goal at the end of conversion is to have vertically partitioned growing space among age classes/canopy tiers in a ratio of 30:20:10. This stand structure maintains a large proportion of the growing space in sawtimber and controls the density of small diameter trees, thus reducing the need for pre-commercial thinning. At the same time, this allocation provides sufficient growing space to the most subordinate age class ensuring sustainable recruitment into the overstory.

During the conversion period, each age class is distinct in height and diameter. Because they can be visually distinguished, each is treated as an individual entity. The least vigorous trees with the poorest form are removed from each age class; crop trees are chosen from the most desirable species at the most uniform spacing possible.

Following conversion, tree heights and diameters become more continuous; substantial overlap exists among the age classes and they are no longer recognizable entities. At this point uneven-aged management enters a maintenance phase. Until this time, managing the stand with a target diameter structure should not be considered. However, after the stand enters this phase, no other option is available. Growing space is allocated among three broad diameter classes in the same ratio as it was among age classes during conversion.

Acknowledgements

The author gratefully acknowledges the USDA Forest Service, North Central Research Station, RWU 4154 Ecology and Management of Central Hardwood Ecosystems, for their support of the research leading to the development of this paper. In particular, the assistance of Kenneth R. Davidson, Superintendent of the Sinkin Experimental, was invaluable in the establishment and maintenance of this project.

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