UT Extension
SP679

Professional Hardwood Notes
Technical Information on Hardwood Silviculture for Foresters

Two-Age System and Deferment Harvests

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The two-age system is designed to maintain two distinct age classes in a forest. This system is generally initiated using a deferment harvest, sometimes referred to as a shelterwood or clearcut with reserves (Figure 1). The deferment harvest retains a limited basal area of canopy trees while allowing the majority of the area to regenerate. The harvest initially creates a stand that contains scattered or small groups of older trees, typically one rotation length in age, surrounded by a regenerating age class. The canopy trees that are left are termed reserve trees. At the end of a second rotation length the stand contains a limited number of large reserve trees, two rotation lengths in age, and a larger number of trees that are one rotation length in age.

Figure 1. Typical two-aged stand after a deferment harvest and site preparation treatment.

The two-age system is a viable method for managing many hardwood stands where longer-lived species are present. The system provides for vigorous regeneration and the development of average size and valued sawtimber trees and a significant component of older and larger high-value veneer and grade sawtimber trees. The system also provides for structural components that are lacking in even-aged stands. These structural components can benefit wildlife populations and provide old-growth characteristics. Like any silvicultural option, the two-age system has benefits and constraints and is not appropriate for every management objective or stand condition. The system does provide landowners and managers with options not available with other systems; however, proper implementation is required.

Benefits and Constraints of the Two-Age System

The two-age system initiated by a deferment harvest provides a number of benefits, including:

- Development of large-diameter sawtimber or veneer trees
- Production of a wide range of forest products from pulp to veneer in the same stand at the same time
- Ability to regenerate shade-intolerant and intermediate-shade-tolerant species

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- Improved aesthetics compared to clearcutting
- Increased structural diversity and retention of habitat components compared to clearcutting
- Increased initial revenue compared to other types of non-clearcut regeneration techniques
- Development of old-growth structural characteristics
- Maintenance of sexual reproduction in reserve trees throughout the entire rotation and the ability to "life boat" species that would otherwise be eliminated if the area was clearcut

While the two-age system has several benefits, it also has several constraints and effects that must be considered prior to its prescription, including:

- Lack of appropriate long-lived species to maintain the system
- Forest fragmentation and habitat effects similar to clearcutting
- Reduction in initial revenues compared to clearcutting and possibly diameter-limit harvests
- Limited development of shade-tolerant species
- Damage to new age-class trees if a portion of reserve trees are removed prior to the end of the second rotation length

The benefits and constraints of the system must be carefully considered before prescribing its use. One of the more important issues that determine if the two-age system is an appropriate silvicultural option is the presence of relatively long-lived species. If these species are not present, then the two-age system is probably not appropriate and traditional even-age or group selection methods should be considered if shade-intolerant and/or intermediate-shade-tolerant species are managed. However, if the system meets management objectives and can be used with the species present, then a deferment harvest and the use of the two-age system represents a reasonable regeneration alternative.

The two-age system requires the long-term retention of reserve trees, and their characteristics and selection are critical for successful implementation of the system. Reserve-tree characteristics can vary considerably and are based on management objectives. Regardless, the reserve trees must be able to maintain themselves when challenged with an open environment. The selection of the reserve trees, their individual characteristics, position in the landscape, number and distribution must be carefully determined and managed. Research and operational experience has provided information on a number of these criteria for several of the more important hardwood species and forest types.

Deferment Harvests

Two-aged stands are typically developed using a deferment harvest. However, deferment harvests are also used as a means of establishing even-aged stands, so it is important to understand how deferment harvests differ based on their intended purpose. When deferment harvests are used for developing even-aged stands, the initial reserve tree densities are relatively high, around 30 square feet of basal area per acre, compared to reserve tree densities recommended for the two-age system. Trees are removed 10 to 15 years after the initial harvest, leaving only the regenerating age class. This type of deferment harvest differs from a traditional shelterwood in that the density of reserve trees is less than that of a shelterwood overstory and the reserve tree density is not intended to affect (or shelter) the regenerating age class. Most often this type of deferment harvest is used to alleviate the bleak appearance of a clearcut (Figure 2). When a deferment harvest is used for aesthetic purposes, the characteristics of the reserve trees are less important and rigorous than when the deferment harvest is being used in the two-age system. When implementing a deferment harvest as part of the even-age system, the reserve trees should contain enough surviving merchantable volume (and value) that a commercial harvest can be used to remove them 10 to 15 years after the initial harvest. Issues such as longevity of the species selected are not important considerations of reserve trees in deferment harvests when used in the even-age system.

When a deferment harvest is used in the two-age system, the reserve tree density is much lower than when used with the even-age system. Typically, reserve tree density is not above 15 square feet of basal area per acre and the selection criteria for these trees are more rigorous than when a deferment harvest is used to establish an even-aged stand.

Shelterwood Harvests and the Two-Age System

The two-age system also can be initiated using a shelterwood. In this instance, the shelterwood overstory density is adjusted to encourage the proper regeneration of intermediate-shade-tolerant species (typically 45 to 60 square feet per acre). After regeneration establishment, normally 10 to 20 years, the shelterwood overstory should be reduced to 10

Figure 2. Simulated comparison of a clearcut and a deferment harvest showing the aesthetic differences between the methods.

to 15 square feet per acre. The remaining trees are termed reserve trees and this method of regeneration is referred to as an irregular shelterwood. Whether to use an irregular shelterwood or a deferment harvest to develop a two-aged stand is based on the regeneration requirements at the time of the initial harvest. The irregular shelterwood is used to encourage intermediate-shade-tolerant species and a deferment harvest is used to establish shade-intolerant and intermediate species. One problem with the irregular shelterwood is that is requires that enough volume and value be retained in the stand to allow for a commercial harvest 10 to 20 years after the initial cut, while still retaining 10 to 15 square feet of basal area per acre. Regardless, the end result is the same – a two-aged stand is developed with a limited number of reserve trees being maintained for two rotation lengths with the remainder of the stand occupied by a younger regenerating age class.

Basics of the Two-Age System

The challenge of implementing the two-age system is to ensure that both age classes maintain long-term growth and development. This requires that the older reserve trees be carefully selected to ensure survival and maintain growth and vigor over a second rotation and that their density (number or basal area) is limited so that they will not significantly hinder regeneration of the younger age class over the long-term.

In its simplest form, the two-age system is initiated by a deferment harvest typically retaining between 10 to 15 square feet of basal area per acre. This level of retention is especially important, as all of the reserve trees are left for the entire second rotation length. Initial research involved the use of much higher basal areas, in some cases as high as 30 to 35 square feet per acre. However, as research progressed it became apparent that these basal areas dramatically affected the long-term height growth of the regenerating age class. Research also found that the regenerating stems directly under the reserve tree crowns were stunted with a large number exhibiting significant sweep and stem deformation. By limiting the reserve tree densities, both of these problems can be minimized.

Generally, the 10 to 15 square feet of basal area per acre of reserve trees is obtained through the retention of scattered individual sawtimber-sized (> 10 inches dbh) stems. The large area between reserve trees leaves abundant room for regeneration to flourish in full sunlight over an extended period, in many cases over an entire rotation length. This allows the initial 10 to 15 square feet of basal area of reserve trees to be retained for a second rotation length, with the majority of the trees in the regenerating age class experiencing minimal impacts from the reserve trees. Reserve trees can also be grouped rather than retained as scattered individuals. The grouping of reserve trees has advantages in certain situations, including protection from wind-throw, and the minimization of deformation of regenerating stems compared to leaving scattered individual trees. However, in all cases the intent is to provide two distinct age classes, with the older class providing as little interference with the young age class as possible. This is especially true if volume growth and timber quality are objectives.

At the end of the second rotation, all of the large reserve trees are harvested, as well as the majority of the trees that are one rotation length in age. Only 10 to 15 square feet of this one rotation age class is left as reserve trees for the next rotation. Cultivation of these future reserve trees should be considered during intermediate treatments.

Reserve Tree Criteria

Reserve tree criteria are based on management objectives. For example, the system can be used to initiate the development of old-growth forests, maintain mast production for wildlife, as well as develop large, high-value sawtimber and veneer trees. Each of these objectives will produce a different set of reserve tree characteristics and criteria. In some instances, a specific characteristic can meet the needs of more than one objective.

The majority of the interest and research in the two-age system and deferment harvests is focused on timber objectives. To this end, the primary characteristics of individual reserve trees include:

- long-lived commercial species
- appropriate crown characteristics including live crown ratios (typically > 40 for hardwoods), well-balanced crown proportions and overall crown vigor
- stem form and maintenance of potential veneer or high-quality sawtimber
- ability to withstand harvest
- located to avoid wind-throw and other post-harvest perturbations

These characteristics help assure that the reserve trees emerge unwounded from the deferment harvest, respond positively in growth and vigor after the harvest, maintain themselves and their value to the end of the next rotation, and can withstand environmental stresses associated with the open-grown status of the reserve trees. If objectives other than timber are being considered, then reserve tree characteristics are often altered. For example, leaving trees that are heavy mast producers may be important for wildlife objectives. Regardless, the reserve trees need to be carefully selected to ensure that they survive and provide the required benefits.

DBH and Crown Characteristics of Reserve Trees

To ensure harvest survival and long-term growth response, reserve trees are generally selected from dominant and co-dominant crown classes. Figure 3 shows examples of good and poor two-age reserve tree candidates. Note the live crown ratio (lcr) of more than 40 percent and the well-balanced crown shape of the good-candidate trees (column A). Research has found that some species (ex. white oak) exhibit dieback and mortality when the lcr is below 30 percent. Poor candidates (Figure 3B) generally have thin or deformed crowns, dead major canopy branches, flat-topped crowns or lcr's below threshold levels. Most reserve trees should come from dominant and co-dominant trees, because sub-dominant trees often have significant vigor problems as indicated by their crown characteristics. There are instances where intermediate crown class trees have sufficient characteristics to warrant consideration as reserve trees. However, these trees need to be carefully evaluated to ensure that they possess the correct characteristics and they are able to survive the harvest.

While there is a need to select reserve trees from the main canopy, this should be done with an eye to minimizing timber value of the reserve trees. Holding reserve trees of significant monetary value when not necessary decreases timber revenues and reduces money available for management. Table 1 compares the stumpage value of reserve trees of average dominant/co-dominant size to those selected with the smallest diameters and value that still meet reserve tree criteria for vigor and future value. The data from these seven upland oak hardwood tracts (encompassing 25 different stands) indicate that significant increases in timber revenues can be generated if dbh is considered in selecting reserve trees. However, considerations that minimize value and thus diameter of reserve trees should not outweigh considerations of vigor, value and the ability to survive harvests.

Figure 4 shows the relationship between the average dbh of potential reserve trees by species compared to the average dbh of dominant and co-dominant trees in seven upland hardwood tracts on the Cumberland Plateau in eastern Kentucky. The bold diagonal line shows a 1:1 relationship between the average dbh of reserve trees and average dbh of dominant and co-dominant trees. This means that reserve trees, if they were of the same size as dominant and co-dominant trees, would lie along this 1:1 line. The average minimum diameter at breast height (dbh) targets are shown by dashed lines, representing the average minimum dbh of reserve trees of each species group compared to the average dbh of all of the dominant and co-dominant trees in the stand.

Figure 3. Comparison of good (column A) and poor (column B) reserve tree candidates associated with a deferment harvest. Note overall crown size, balance and live crown ratios of the two sets of reserve tree candidates.

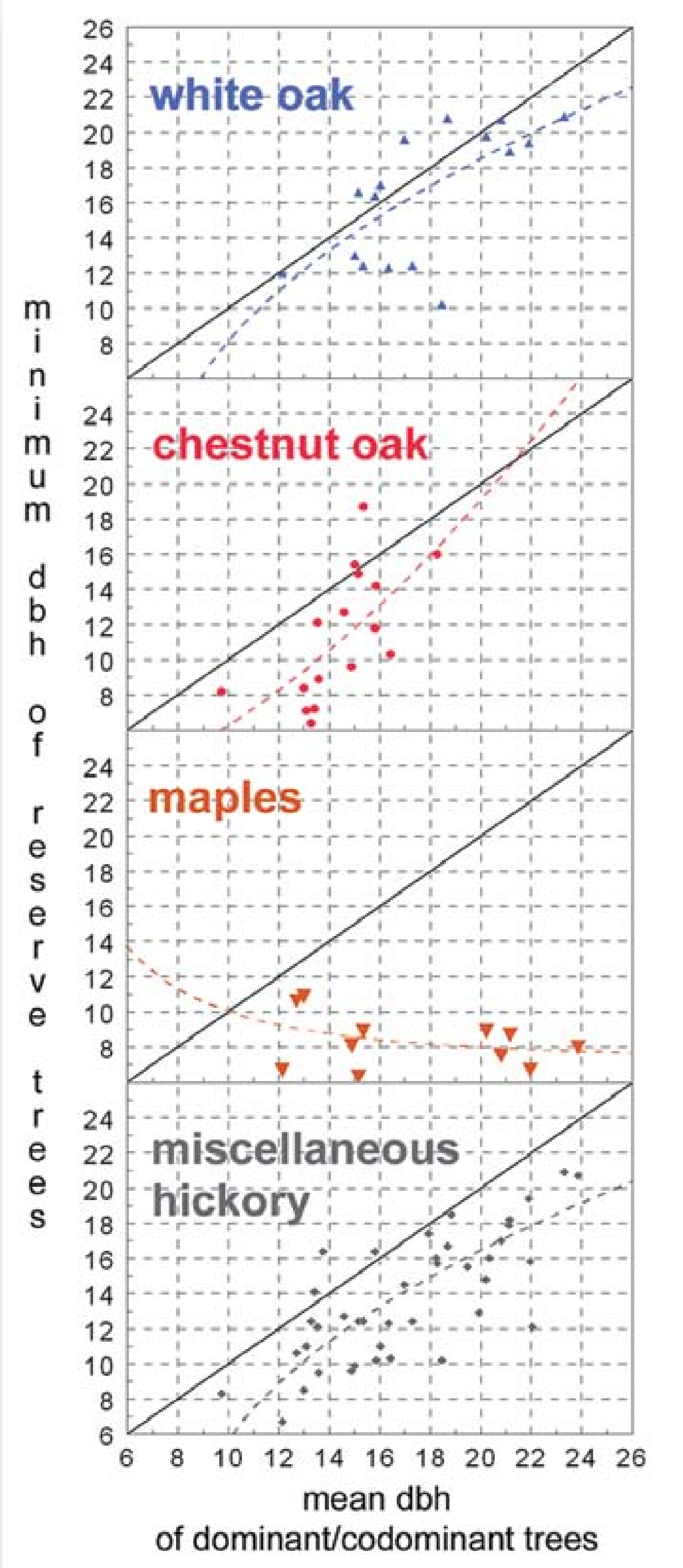

Figure 4. Minimum average dbh for reserve trees for species groups based on the average dbh of dominant and co-dominant trees in each stand for seven tracts on the Cumberland Plateau in eastern Kentucky. The diagonal line shows a 1:1 relationship.

Table 1. Stumpage value per acre of reserve trees (20 ft^2/acre basal area) of average dominant and co-dominant dbh compared to reserve trees of minimum dbh that meet criteria for timber objectives for seven tracts in eastern Kentucky.

	Average DBH		Minimum DBH	
Tract	$/acre	Percent of sale	$/acre	Percent of sale
1	301.50	23.0	238.59	18.4
2	334.09	32.1	186.85	16.9
3	289.03	22.6	245.00	20.2
4	322.82	22.5	223.97	22.5
5	328.41	17.9	273.72	14.6
6	281.36	23.3	248.41	20.7
7	327.63	32.5	189.79	13.9
Mean	312.12	24.8	229.48	17.1

In the case of white oak, appropriate reserve trees were very close in dbh to the average dominant and co-dominant trees, generally not deviating more than 3 inches in dbh from the dominant and co-dominant average. It should be noted that many stands in these seven tracts contained large numbers of intermediate and overtopped white oak trees. However, they did not possess the crown characteristics required for retention as reserve trees and the average minimum diameter for reserve white oak trees was relatively close to the average dbh of dominant and co-dominant trees. The potential reserve maples are significantly less in dbh (resulting from their shade tolerance) than the average size of dominant and co-dominant trees. However, it is improbable that many of these potential reserve trees could survive logging and would not typically be selected as reserve trees.

Unfortunately, when the two-age system was first used in the United States, reserve tree selections were made so that their dbh's were minimized, having as little impact as possible on timber receipts from the deferment harvest. However, problems quickly arose with the reserve trees' ability to satisfy long-term timber objectives.

Figure 5 shows the difference in dbh between reserve trees that were marked according to proper reserve tree criteria provided (open circles) and reserve trees that were marked with the primary objective of not significantly altering timber revenues at the time of harvest (+). Note that the dbh for the latter group of trees falls well below the average dbh of appropriate reserve trees when the average dbh of dominant and co-dominants reaches 14-16 inches. Essentially, to avoid timber volume and value being left in reserve trees in these tracts, appropriate reserve tree criteria were ignored, leading to the selection of small-diameter, sub-canopy trees. Unfortunately, these small-diameter trees did not possess the necessary attributes for two-age reserve trees. These data indicate that when the average size of the main canopy trees reaches grade-sawtimber size, some merchantability can be expected to be unavoidably retained in the reserve trees. Results from research and operational trials indicate that it is important to maintain proper reserve tree criteria and only minimize the diameter of reserve trees once other criteria have been considered.

Once the average dbh of reserve trees and their basal area has been determined, approximate reserve tree spacing can be established (Table 2). The determination of an approximate spacing is helpful in marking individually scattered reserve trees, providing field personnel with a reasonable target to assist in maintaining the proper level of retention.

Stem Form and Quality of Reserve Trees

Stem form and future tree quality and value are important criteria for reserve tree selections where

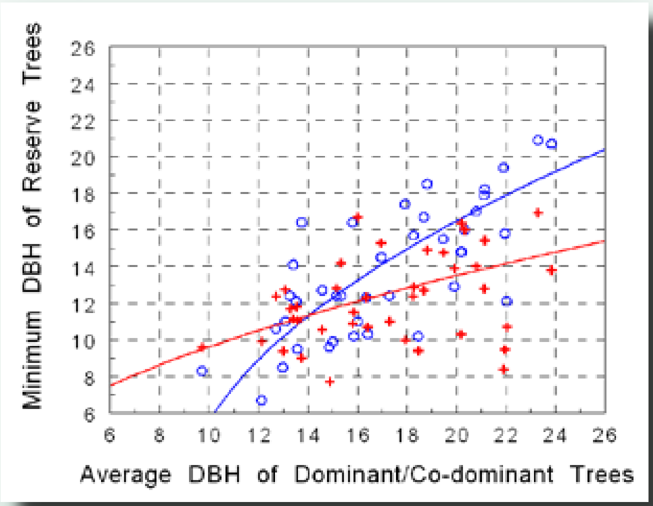

Figure 5. Comparison of average dbh of appropriate upland hardwood reserve trees (open circles and blue line) and the average dbh of inappropriate reserve trees (plus signs and red line) that were retained to avoid reduction in timber revenues with little concern to long-term reserve tree growth.

Table 2. Spacing (feet) between scattered reserve trees.

Reserve Tree DBH	Ft² Basal Area per Acre of Reserve Trees		
	10	15	20
	------------ feet ------------		
6	29	24	21
8	39	32	28
10	49	40	34
12	58	48	41
14	68	56	48
16	78	64	55
18	88	72	62
20	97	80	69
22	107	88	76
24	117	96	83
26	127	103	90
28	136	111	97
30	146	119	103

timber is an objective. Stems should be straight, free of rot and have limited defect indicators on the butt log. Typically, reserve trees should be capable of producing veneer-quality logs or high-quality sawlogs when they are ultimately harvested (potential U.S. Forest Service (USFS) tree grade =1). One of the problems associated with exposing reserve trees is a potential loss in their long-term timber quality due to the development and maintenance of mainstem branches that can degrade tree quality and value. These branches develop from epicormic buds that form epicormic branches, and if retained long enough, become large branches that can significantly degrade timber value.

Research has shown that the basal area retention recommended for deferment harvest (10 to 15 square feet of basal area per acre) provides for regeneration that quickly grows up around butt logs. The developing regeneration quickly reduces light levels near the boles of reserve trees, leading to shedding of many epicormic branches that initiate due to the harvest. It is important to remember that the epicormic branches are formed from suppressed buds that are present on the trees prior to harvest. They are defect indicators or are associated with defect indicators prior to the harvest and only become added problems when they sprout and the resulting epicormic branches remain long enough to become large branches. This results in prolonged knot formation. Upper logs are at greater risk for degrade compared to the butt logs in a deferment harvest. Regardless, it is important to understand which defect indicators harbor suppressed buds that can turn into epicormic branches and can potentially result in long-term degrade.

Table 3 provides information on defect indicators that provide a risk for epicormic branching in white and chestnut oak. Only a few of the defect indicators on the bark of these species contain suppressed buds resulting in epicormic branches. Figure 6 shows epicormic branches originating from a suppressed bud cluster on the butt log of a white oak reserve tree one year after a deferment harvest. Those marking reserve trees should understand the risks associated with epicormic branching and be able to recognize defect indicators that harbor suppressed buds in the species being marked.

Other Risk Indicators and Factors

Reserve trees should also be able to withstand stress-inducing factors such as challenges from insects, pathogens and disease complexes. While it is not possible to plan for attacks from all insects and diseases, it is prudent to plan for challenges from known problems. For example, potential defoliations by gypsy moth and endemic insects should be considered where appropriate. In some instances, crown characteristics have been shown to be associated with a trees' ability to withstand the initial front of gypsy

Figure 6. Multiple epicormic branches developed from a suppressed bud cluster on the butt log of a white oak reserve tree one year after deferment harvest.

Table 3. Butt log defect indicators, suppressed bud numbers and epicormic branching of white oak (*Quercus alba*) and chestnut oak (*Q. prinus*) reserve trees.[1]

	White Oak		Chestnut Oak	
Defect Indicator	**# Suppressed Buds**[2]	**# Epicormic Branches**[3]	**# Suppressed Buds**[2]	**# Epicormic Branches**[3]
live branch	10.02	2.50	0.00	0.00
multiple epicormic branches	9.14	1.14	0.00	0.00
single epicormic branch	7.67	1.33	0.17	0.17
suppressed bud cluster	4.73	0.95	0.28	0.09
single suppressed bud	0.04	0.01	0.00	0.00
dead branch (knot)	3.94	0.74	0.10	0.03
heavy distortion	0.12	0.03	0.00	0.00
medium distortion	0.00	0.00	0.00	0.00
light distortion	0.00	0.00	0.00	0.00
barrel swell	0.00	0.00	0.00	0.00
surface rise	0.00	0.00	0.00	0.00
bump	0.00	0.00	0.20	0.20
seam	0.00	0.00	0.00	0.00
bird peck	0.00	0.00	0.00	0.00
wound – old	0.00	0.00	0.00	0.00
wound – new	0.00	0.00	0.00	0.00

[1]Data collected from 2,340 defect indicators on 280 reserve tree butt logs on 8 tracts on the Cumberland Plateau in eastern Kentucky.
[2] # of live suppressed buds at each defect indicator
[3] # of epicormic branches produced at each defect indicator 3 years after harvest

moth invasion. These characteristics can be added to the list of reserve tree criteria. Another example is the issue of oak decline. Characteristics associated with oak decline should be included in the selection of oak reserve trees. Other factors involving wildlife considerations may need to be included in reserve tree criteria. For example, the need for bat habitat may require the retention of scaly-barked trees like shagbark hickory as reserve trees. All of these factors could alter the species of reserve tree candidates, crown condition and other reserve tree criteria.

Longevity of Reserve Trees

Longevity is an issue that must be thoroughly addressed in the selection of reserve trees. Table 4 provides a list of species, their mean operational ages and their suitability for use as reserve trees. While this list was developed from a survey of silvicultural experts in the eastern U.S., it does provide a general guideline for the appropriateness of species for consideration as reserve trees. Species that can not remain alive or maintain vigor through a second rotation length should not be considered as reserve trees. In some instances, this may preclude the use of the two-age system in stands dominated by short-lived species. It should be noted that these species might be appropriate for a deferment harvest associated with even-age management or as a part of an irregular shelterwood where they will be removed 10 to 20 years after the initial harvest.

Topographic Location of Reserve Trees

The topographic position of reserve trees can be important relative to their ability to withstand knockdown associated with harvest and/or windthrow, the most common post-harvest damage to reserve trees. Research in steep upland terrain has indicated that reserve trees, regardless of species, occurring on shallow soils or where soils are at or

Table 4. Estimated life expectancies (years) of common species in the eastern U.S.[1]

Species	Mean	Range	Species	Mean	Range
American beech	168	100-250	black walnut	131	75-200
white ash	129	80-150	sassafras	69	30-175
black cherry	115	70-175	black locust	75	15-150
bitternut hickory	133	100-150	Nuttall oak	125	80-163
mockernut hickory	127	75-175	southern white oak	127	80-150
shagbark hickory	137	80-200	pin oak	116	80-170
pignut hickory	117	60-200	water oak	130	80-200
sugar maple	162	75-225	swamp white oak	157	100-200
red maple	106	50-175	overcup oak	135	80-165
northern red oak	151	90-200	cottonwood	79	50-100
scarlet oak	105	65-150	black willow	65	40-100
black oak	129	75-200	pecan	117	60-200
chestnut oak	141	75-200	green ash	98	60-150
white oak	194	90-250	silver maple	78	50-100
cherrybark oak	139	90-200	water tupelo	123	90-175
post oak	137	70-190	baldcypress	264	150-500
bur oak	181	125-250	Virginia pine	76	40-125
sweetgum	112	80-125	shortleaf pine	110	75-150
blackgum	116	80-150	pitch pine	110	75-200
yellow-poplar	136	80-300	eastern white pine	140	75-200

[1]Ages developed from a survey of silvicultural experts in the eastern U.S. by Dr. George Hopper at the University of Tennessee, Department of Forestry, Wildlife and Fisheries

near saturation during periods of the winter are more susceptible to wind-throw.

Table 5 provides wind-throw data of more than 250 reserve trees from eight 20-acre deferment harvests. These harvests encompassed a range of topographic positions common to upland hardwood stands in the south and east. Wind-throw averaged less than 5 percent in hollows and lower slope positions and increased to 7 to 10 percent on ridges and upper slopes. The greatest wind-throw, 40 percent, was found on noses of ridges having relatively thin soils. While not indicated in the table, a high percentage of reserve trees growing directly on the banks of the exposed stream and drainage channels on these sites were also subjected to high wind-throw.

Figure 7 shows a map indicating topographic positions where post-harvest wind-throw can be significant. It should be noted that harvest knock-down associated with manual felling in steep terrain is also more prevalent on relatively shallow soils. On topographic positions that are not suitable for the retention of exposed individual reserve trees, remove all of the trees or retain reserve trees in groups on these areas.

Table 5. Post-harvest wind-throw of upland hardwood reserve trees in eastern Kentucky based on topographic position.

Topographic position	Wind-throw percent
Cove/hollow	4.34
Lower slope	5.00
Upper slope	10.31
Ridge	7.69
Nose	40.01

Harvest Damage

Operational and research experience with deferment harvests indicates that reserve trees should be clearly marked so that they can be easily seen from all sides. Marking reserve trees rather than marking cut trees saves significant time and helps ensure a reduction in reserve tree harvest damage. On relatively gentle terrain, skidding should be controlled

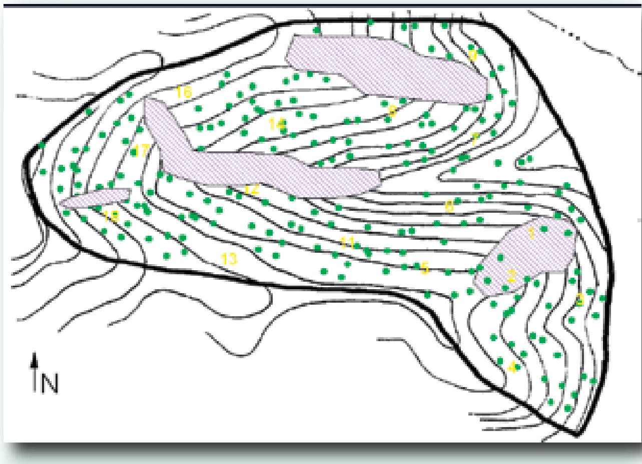

Figure 7. ***Topographic map of 30-acre deferment harvest in an upland hardwood tract in eastern Kentucky. Hatched areas indicate topographic positions associated with high wind-throw of reserve trees.***

to reduce basal wounding. In steep terrain, where manual felling is used, the majority of harvest damage will come from felling.

A recent study of harvest damage to reserve trees in two-age deferment harvesting on steeply sloping terrain in eastern Kentucky found that 78 percent of the damage was top damage, knock-down and bent-over stems from felling operations and only 22 percent of the damage was from basal wounding due to skidding. This study also found that reserve tree damage from logging firms previously engaged in clearcutting varied widely from 34 to less than 10 percent. Proper marking of reserve trees and placing a bounty on reserve tree damage in sales contracts substantially reduced damage to less than 10 percent.

The marking of reserve trees must also ensure that their location does not make their protection from harvest damage impossible. This concern is more important for harvests in steep terrain. For example, if reserve trees are marked directly down slope from large, leaning, cut trees, it may be difficult or dangerous for manual fellers to avoid reserve trees. Also, the smaller the reserve tree dbh is compared to cut tree dbh, the greater the propensity of damage to the reserves. All of these factors must be taken into account in the selection of individual reserve trees.

The season of harvest also will affect the wounding of reserve trees. Research on skidding damage of shelterwood overstory trees indicates that harvesting in the fall and winter yields significantly less wounding to residual stems compared to spring and growing-season harvests. This indicates that timing two-age deferment harvests from November through February will significantly reduce basal wounding.

Site Preparation of the Regenerating Age Class

The deferment cut will create an environment where initial stand regeneration is similar to that attained after a clearcut. Therefore, treatments to enhance natural regeneration should be prescribed. This could entail the use of a site preparation treatment to enhance natural regeneration or pre-harvest cultivation of oak advance regeneration using a midstory removal. Regardless, regeneration potentials should be considered prior to scheduling a deferment harvest. The timing of the harvest and associated site preparation treatments should be carefully considered to aid in maximizing the development of the regenerating age class.

Typically, post-harvest site preparation treatments entail the cutting of all residual commercial species other than the reserve trees and the deadening of noncommercial species. One exception to this prescription is that small-diameter residual stems shading or growing directly adjacent to reserve tree boles should be retained to shield butt logs. Also use of site preparation treatments in areas directly adjacent to reserve trees will yield little long-term value, because trees regenerating directly adjacent to reserve trees typically incur growth reductions and pronounced sweep due to overtopping effects of the reserve trees.

It is important when using herbicides in site-preparation treatments to take into consideration the species of the reserve trees. While rare, cases of significant herbicide damage have occurred to reserve trees when an extremely large number of stems of the same species or genera were being treated directly adjacent to reserve trees. Herbicide movement to reserve trees was suspected from root grafting between reserve trees and treated intermediate and overtopped crown class trees of the same species.

Expected Growth and Response of Reserve Trees

The exposed reserve trees, if selected correctly, will respond quickly to full release. Leaf area of reserve trees will increase, with a resulting increase in dbh and volume growth. While some degradation of upper logs will occur, the resulting increase in butt log diameter and value will more than offset the loss in sawlog height. Eight year post-harvest dbh measures from white oak and chestnut oak reserve trees found a doubling of annual growth for both species.

Average mean annual increment for white oak reserve trees was 0.277 inches compared to 0.118 inches for control trees. Chestnut oak responded the same as white oak, averaging 0.243 inches per year compared to 0.099 inches for control trees.

Reserve tree crowns will respond to the release as indicated by the above mentioned increases in dbh. Some species, such as northern red oak, cherrybark oak and yellow-poplar can be expected to significantly increase their horizontal crown area. Other species such as white oak will thicken and drop their crowns. Crown response indicates diameter growth increases, regardless of whether the crown increases in diameter or depth.

Use of Two-Age System for Maintaining Species at Risk

The two-age system can be used to maintain species in a stand that might be lost if even-aged or individual tree selection methods are used. This is especially true if canopy species are not properly regenerating. A widespread example is oak species on intermediate and high-quality sites. If advance regeneration is not present at the time of a regeneration harvest, then these species can be lost from the stand. This often occurs when clearcutting is used without the presence of oak advance regeneration. The two-age deferment harvest can be used to retain these species as reserve trees (where appropriate), allowing them to continue sexual reproduction and acorn production throughout the next rotation. Research has shown that properly selected reserve trees can create new advance regeneration that can be cultured prior to the second harvest, thus providing the potential for long-term maintenance of these species.

Marking Guidelines

The following guidelines are to be used in stand assessment for the two-age system and for the marking of reserve trees in deferment harvests associated with the two-age system.

1. Determine whether the two-age system is appropriate for the stand. The stand must contain species and tree ages that are capable of maintaining vigor if left for another rotation length. Stands that contain predominantly short-lived species are generally not suitable for deferment harvests or the use of the two-age system. The exception may occur when removal of a portion or all of the reserve trees associated with a deferment harvest is planned. In these instances, reserve trees that will be removed relatively soon after the harvest may be shorter-lived. However, reserve trees that will be retained until the end of the second rotation length must be long-lived (Table 4).

2. Delineate topographic positions that are not suited for the retention of reserve trees. These generally include areas with shallow soils or with other soil conditions that would lead to windthrow or knock-down during harvest. In these areas, mark all the trees for removal or leave reserve trees in groups (Figure 7 and Table 5).

3. Determine the average dbh of dominant and co-dominant trees in the stand and establish appropriate target diameters for reserve trees (Figure 4).

4. Determine spatial distribution of reserve trees. If left scattered throughout the stand, determine an approximate spacing of reserve trees given retention basal area (10 to 15 square feet of basal area per acre for long-term reserve trees). If reserve trees are to be grouped, determine the size of the groups (Table 2).

5. Based on objectives, determine other criteria for reserve trees of appropriate diameter including species, crown shape, lcr, stem form, defect indicators and other characteristics associated with management objectives. This coupled with the dbh guideline developed in step 3 provides individual tree marking guidelines for the stand.

6. Using the information from steps 1 through 5, mark reserve trees so they can easily be seen from all sides.

7. Do not mark reserve trees where they are likely to be unavoidably damaged during the harvest.

8. Specify harvest timing to avoid bark damage either due to felling or basal wounding attributable to skidding.

9. Provide incentives for reserve tree protection in harvest contracts. Harvests, regardless of terrain or harvest system, should damage less than 10 percent of the reserve trees. It is useful to specify a monetary penalty for reserve tree damage above this level.

10. Develop a site preparation prescription for the regenerating age class where appropriate. This could entail the use of post- or pre-harvest site preparation or the use of the oak shelterwood treatment where improvement of oak advance regeneration is required prior to a regeneration harvest.

Summary

The two-age system is a viable system for managing many hardwood stands where longer-lived species are present. The deferment harvest used to initiate the system can provide for vigorous and dense regeneration of the stand, while the carefully selected reserve trees provide a potential for large-diameter, high-quality timber production. The system can also be used as an aesthetic alternative to clearcutting and can provide long-term stand structural components that are often not present with even-age methods. These structural components can benefit wildlife populations and provide old-growth characteristics in the stands. Regardless, proper selection of the two-age reserve trees and appropriate site preparation treatments associated with the deferment harvest are critical to maximizing benefits from this system.

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