Recommended Silviculture and Management Practices for Illinois Hardwood Forest Types

2016 Edition

In cooperation with:

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Introduction

The third revision of the *Recommended Silviculture and Management Practices for Illinois Hardwood Forest Types* manual is intended to serve as a guide for consulting foresters and agency professionals assisting Illinois private forest landowners committed to sustainable timber production on their property. This manual may also prove useful for individuals who may wish to better understand the decision making process a forester employs when developing a silvicultural prescriptions.

The revised manual employs updated language and the benefit of many years of research and insights on the realities of Illinois forest management and how these have changed since the 1960s and 70s when the manual was last updated. References have been made to important “new” tools including prescribed fire, herbicides, and crop tree release. Attention has also been devoted to the evolving impacts of invasive species management.

The revised manual addresses a wide breadth of information regarding Illinois silviculture and management. The authors of this revision synthesized material from a number of sources in an attempt to create a unique document that best serves the individuals who manage Illinois forests. If a reader is in search of more detail on the topics covered we recommend the following publications for more information:

Overall status of Illinois forests:

Crocker, S.J., and others. 2013. Illinois' forest resources, 2010. RB NRS-86. Newtown Square, PA: USDA Forest Service. 52 p.

General forest management principles for private landowners:

Palmer, B. 2003. Forest Management for Missouri Landowners. Missouri Department of Conservation. 116p.

Silvics of species in found Illinois and recommended management:

Wisconsin Department of Natural Resources. 2013. Silviculture and Forest Aesthetics Handbook, 2431.5. 797p.

Johnson, P.S., Shifley, S.R., Rogers, R. 2009. The ecology and silviculture of oaks. 2nd Edition. CABI Publishing. 580p.

Influence of prescribed fire on oak:

Brose, P.H., Dey, D.C, Waldrop, T.A.. 2014. The fire-oak literature of eastern North America: synthesis and guidelines. GTR. NRS-135. USDA Forest Service. 98p.

Management of young plantations:

IFA Technical Advisory Committee. 2014. We planted all these trees, now what? Illinois Forestry Association. 18p.

Best management practices for Illinois forests:

Holzmueller E.J. and P. Deizman. 2012. Forestry Best Management Practices. 3rd Edition. Illinois Department of Natural Resources. 78p.

Control of common invasive species in Illinois:

Gage, K. 2014. Management of southern Illinois invasive plants. River to River Cooperative Weed Management Area. 36p.

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General Conditions of Illinois Forests

Illinois is home to over 4.5 million acres of forest land, nearly 85% of which is privately owned. While this is only approximately a third of estimated amount of forest prior to European settlement, forest cover has increased 12% statewide since the 1940s. Most of the forest in Illinois lies in the southern portion of the state as well as along the western half near the Illinois and Mississippi Rivers.

Hardwood tree species dominate Illinois forests and a majority (65%) of the forested area is classified as upland oak or mixed oak, consisting largely of white oak, black oak, red oak, and hickory species in the overstory. The next largest forest type in Illinois is the mixed bottomland group which comprises nearly 23% of the forest land in the state. American elm, green ash, eastern cottonwood, as well as silver maple and sycamore are commonly found species within this group. While the aforementioned species dominate the forested landscape, Illinois contains over 100 native species of trees.

Overall, most (75%) of the forest land in Illinois is considered mature (> 40 years of age). Only 16% of Illinois forest is in the poletimber stage and even less (8%) is in the seedling-sapling stage. While this unbalanced distribution threatens future production potential, the dominance of mature stands does correspond to increased annual growth and volume in these large-diameter stands since the 1960s. Despite the increased growth, annual removals have declined in Illinois since the 1980s by nearly 15%, part of which may be attributed to an unfavorable economic environment compared to neighboring states.

Conversely, mortality has more than doubled over the same time period indicating an underutilization of Illinois forests. Some of this increased mortality may be attributed to the loss of short-lived, mature species such as black oak. Others factors include the high elm mortality due to Dutch elm disease. This disease is caused by an exotic pathogen and the spread is facilitated by native and exotic elm bark beetles. Exotic pests and pathogens are becoming an increasing concern in Illinois forests, as well as throughout the rest of the country. Trees that are attacked by these pests and pathogens are oftentimes very susceptible to mortality because they have little to no natural resistance to these pests and few, if any, cost effective control measures exist. Emerald ash borer is another example of an exotic pest that threatens Illinois forests. First reported in 2006, this pest is now found in over half of the state. Native ash species offer little resistance to emerald ash borer and recent ash mortality rates have quadrupled since to the 1980s. Exotic, invasive plant species are also becoming more problematic in Illinois forests. These species, such as bush honeysuckle and autumn olive, impede regeneration of desirable tree species on forested sites. This situation, as well as the presence of other exotic pests and pathogens will continue to be of significant concern to Illinois foresters and landowners in future years.

In addition to the impact of exotic species, the other primary issue of concern in Illinois forests is the decline of oak dominance. Oak dominated forests comprise a majority of area and volume within Illinois forests. Oak serves as a key habitat component for a number of wildlife species and is also one of the most economically valuable species found in these forests. While oak continues to dominate the overstory, a paucity of oak regeneration threatens the perpetuity of this forest type. Decreased cutting intensity and fires suppression have led to a loss of oak seedlings and sprouts in the understory capable of replacing mature overstory trees. In undisturbed sites presently dominated by oak, shade tolerant species such as elm and sugar maple are more likely to develop. Maintaining a healthy oak resource will depend upon successful seedling regeneration and sapling development, processes presently not functioning adequately across most forest acreage. Attempts to offer a solution to mitigate this problem are offered in this manual.

Recognized Forest Types and Importance of Site Quality

Insofar as possible forest types are defined or delineated on the basis of site capability, potential and land use history. This site-type concept recognizes the large differences in productive capacity and optimum species composition of different sites, with consideration for the human influences that shaped the current composition. Often the present species composition does not accurately reflect the true potential of the site. Therefore, type based on present species alone does not necessarily reflect the site's true potential in terms of growth, desirable stocking, and composition. This is true in part because past cutting, fire (or lack thereof), and grazing have altered the composition of the stands and in part because some species occur naturally on a wide range of sites. Meaningful silvicultural and management practices cannot be logically set up except on the basis of site capability.

The forest site-types for southern Illinois are shown in Table 1 while the likelihood of finding sawtimber trees in northern and southern Illinois are shown in Table 2. An assessment of site quality will help determine the potential of the stand, which is the next essential step in making good management recommendations. Key variables include tree species composition and soil characteristics impacting water drainage and availability.

Foresters use site index, a value determined from the height of trees at a fixed age, to provide an assessment of an area's ability to grow trees and, thus, its timber-producing potential. An area with a low site index has less timber-producing potential and, therefore, does not warrant as much money, time, and effort invested as an area with a higher index.

Figure 1. The adjacent forest stands in the photos provide multiple stewardship benefits including wildlife habitat, watershed protection, carbon sequestration, and recreational opportunities. However, potential site productivity of each stand differs considerably, illustrating the importance of site index when determining management options. Both stands are approximately 80 years old and have the same site history. Although both stands have a similar species composition and are classified as oak-dominated forest types, the site index for Stand 1 (left) is 69’ and 43’ for Stand 2 (right). While tree density is similar between stands one and two (160 versus 180 trees/acre, respectively) volume in Stand 1 (5,050 bd ft/ac) is more than double that of Stand 2 (2,400 bd ft/ac). Management efforts to improve timber production should be concentrated in Stand 1 as it will bring about a far greater return on the investment.

Table 1. Forest site-types of Illinois

Forest Site Type	Usual Topography	Mature Tree Height	Site Index[1]	Common Tree Species
Upland sites				
Mixed hardwoods	Coves, stream margins, lower northerly slopes, and breaks along streams in claypan region.	85’ +	Oak: 70+ Yellow-Poplar: 80+	Yellow-poplar, northern red, white, and black oak, hickory, black gum, sugar maple, ash, and beech.
Mixed oak	Southerly and upper northerly slopes, and rolling land and wet flat in claypan region.	75 to 85’	Oak: 55 to 70	White, black, northern red, scarlet, and southern red oaks, hickory, black gum, and pin oak.
Oak-hickory	Ridge tops and upper southerly slopes, and dry flat lands in claypan region.	50 to 75’	Oak: <55	Black, white, scarlet, and post oaks, and hickory.
Bottomland sites				
Cottonwood	Alluvial river and stream front lands; well-drained.	110’ plus	Cottonwood: 100 +, Other species: 100+	Cottonwood, willow, sycamore, box elder, green ash, sweetgum, silver maple, elm, Shumard and cherrybark oaks, and river birch.
Mixed soft hardwoods	Primary and secondary bottomland; moderate to well-drained.	90 to 110’	Cottonwood: 90+, Other species: 90+	Silver maple, green ash, sycamore, sweetgum, elm, cottonwood, cherrybark and swamp white oaks, and box elder.
Mixed hard hardwoods	Level backwater bottoms with heavy soils; poorly drained.	80 to 100’	Other species: 80+	Hickory, pecan, pin, swamp white, and cherrybark oaks, green ash, elm, silver maple, black gum, and cypress.

[1]Average height of dominant trees on an even-aged site at age 50.

Table 2. Likelihood of finding sawtimber-sized trees in natural stands by site-types in southern and northern Illinois.

	Upland Sites							**Bottomland Sites**					
	Mixed hdws.		Mixed oak		Oak-hickory			Cottonwood		Soft hdws.		Hard hdws.	
	So.	No.	So.	No.	So.	No.		So.	No.	So.	No.	So.	No.
Ash, White	C	C	O	R	N	O	Ash, green	O	O	C	C	C	O
Basswood	R	O	N	R	N	N	Birch, river	C	O	O	C	N	C
Beech	C	R	O	N	R	N	Box-elder	C	C	C	C	O	C
Cherry, Black	O	C	R	C	N	O	Cottonwood, eastern	C	C	C	O	R	C
Cucumber	R	N	N	N	N	N	Cottonwood, swamp	R	N	R	N	O	R
Gum, black	C	N	C	N	O	N	Cypress	R	N	R	N	O	R
Hackberry	O	C	R	O	N	O	Elm	C	C	C	C	C	C
Hickories	C	C	C	C	C	C	Gum, sweet	O	N	C	N	O	O
Maple, sugar	C	C	O	O	R	R	Gum, tupelo	N	N	R	N	C	N
Oak, black	C	C	C	O	C	C	Hickories	R	R	O	O	C	R
Oak, blackjack	N	N	R	R	C	C	Honey locust	R	R	O	C	O	R
Oak, bur	R	O	R	O	N	O	Maple, red	R	R	O	R	R	R
Oak, pin	R	N	C	N	O	N	Maple, silver	O	C	C	C	O	O
Oak, post	R	N	O	R	C	C	Oak, bur	N	O	R	O	O	N
Oak, N. red	C	C	C	C	O	R	Oak, cherrybark	R	N	O	N	C	R
Oak, S. red	O	N	C	N	O	N	Oak, overcup	N	N	R	N	O	N
Oak, scarlet	O	N	C	R	C	R	Oak, pin	R	R	O	O	C	R
Oak, shingle	N	R	R	O	R	C	Oak, Shumard	O	N	C	N	N	O
Oak, white	C	C	C	C	C	O	Oak, swamp chestnut	R	N	R	N	O	R
Redcedar	R	R	O	R	O	R	Oak, swamp white	R	R	O	O	O	R
Sweetgum	O	N	N	N	N	N	Oak, willow	R	N	O	N	O	R
Walnut, black	O	C	O	O	R	R	Pecan	N	R	O	R	C	N
Yellow-poplar	C	N	O	N	R	N	Sugarberry	O	N	C	N	C	O
							Sycamore	C	O	O	C	R	C
							Willow, black	C	O	O	R	R	C

[1]C – commonly found, O – occasionally found, R – rarely found, N – never found, So. – Southern Illinois, No. – Northern Illinois

Characteristics of Hardwood Species

The basic knowledge of the silvical characteristics of different species that is needed by a practicing forester is shown in the following tables. This material, supplemented with unpublished observations by Illinois foresters, has been summarized in tabular form for the more important timber species (Tables 3 and 4). Key characteristics of these species such as growth, form and bole branching habits are provided in Tables 5 and 6.

Figure 2. Hickory is a common timber species in Illinois that is moderately resistant to fire.

Table 3. Relative rank in shade tolerance, ability of seedlings to sprout, and susceptibility to fire injury for important Illinois timber species on upland sites.

Relative shade tolerance[1]	**Seedling sprouting ability**[2]	**Resistance to fire injury**[3]
Intolerant		
Yellow-poplar	Low	Low
Black cherry	Moderate	Moderate
Scarlet oak	High	High
Black walnut	Low	Moderate
Intermediate		
Redcedar	None	Low
Black oak	High	High
Blackjack oak	High	High
S. red oak	High	High
N. red oak	High	High
Post oak	High	High
White ash	Low	Moderate
White oak	High	High
Bur oak	High	High
Basswood	Moderate	Low
Tolerant		
Black gum	Low	Moderate
Hickories	Moderate	Moderate
Hackberry	Low	Moderate
Sugar maple	Low	Moderate
Beech	High	Low

[1]Shade tolerance is the relative ability of a species to move from seedling or sprout to mature tree in a subordinate canopy position. Species are arranged in order of increasing tolerance in this region and on sites suitable to the species.

[2]Ability to sprout after natural dieback of tops. All hardwood seedlings and saplings will sprout after top is killed by fire or cutting.

[3]Related to thickness of bark

Table 4. Relative rank in shade tolerance, ability of seedlings to sprout, and susceptibility to fire injury for important Illinois timber species on bottomland sites.

Relative shade tolerance[1]	**Seedling sprouting ability**[2]	**Resistance to fire injury**[3]
Intolerant		
Eastern cottonwood	Low	High
Swamp cottonwood	Low	High
Black willow	Low	Moderate
Cypress, bald	Low	Low
Sycamore	Low	Low
Pin oak	High	Low
River birch	Low	Low
Sweetgum	Moderate	High
Honey locust	Low	Low
Willow oak	High	Low
Tupelo gum	Moderate	Low
Intermediate		
Cherrybark oak	High	Moderate
Shumard oak	High	Moderate
Red maple	Moderate	Low
Silver maple	Moderate	Low
Bur oak	High	High
Overcup oak	High	High
Swamp chestnut oak	High	High
Swamp white oak	High	High
Tolerant		
Green ash	Moderate	Moderate
Hickories	Moderate	Moderate
Pecan	Moderate	Moderate
Box elder	High	Low
Elm	Moderate	Moderate
Sugarberry/Hackberry	Low	Moderate

[1]Shade tolerance is the relative ability of a species to move from seedling or sprout to mature tree in a subordinate canopy position. Species are arranged in order of increasing tolerance in this region and on sites suitable to the species.

[2]Ability to sprout after natural dieback of tops. All hardwood seedlings and saplings will sprout after top is killed by fire or cutting.

[3]Related to thickness of bark

Table 5. Relative growth, form, and bole branching characteristics of important Illinois timber species on upland sites.

Species and nominal height[1]	Juvenile height growth rate[2]	Diameter growth rate[2]	Crown form[3]	Bole Branches[4]
90-110 FEET				
Ash, white	G	G	I	F
Basswood	G	G	I	I
Gum, black	M	G	I	I
Hickories	M	S	I	I
Oak, black	G	G	I	I
Oak, N. red	G	G	I	F
Oak, S. red	M	M	I	I
Oak, scarlet	G	G	I	M
Oak, white	M	M	I	I
Yellow-poplar	E	E	E	F
70-90 FEET				
Beech	S	S	I	I
Cherry, black	M	M	I	F
Maple, sugar	S	S	I	I
Walnut, black	M	M	D	I
LESS THAN 70 FEET				
Hackberry	M	M	D	M
Oak, blackjack	S	S	I	M
Oak, post	S	S	I	M
Redcedar	S	S	E	M

[1]Final total height on better sites where commonly found
[2]E—Excellent G—Good M—Moderate S—Slow
[3]E—Excurrent D—Delinquescent I—Intermediate
[4]F—Few I—Intermediate M—Many

Table 6. Relative growth, form, and bole branching characteristics of important Illinois timber species on bottomland sites.

Species and nominal height[1]	Juvenile height growth rate[2]	Diameter growth rate[2]	Crown form[3]	Bole Branches[4]
100-120 FEET				
Ash, green	G	G	I	F
Cottonwood, eastern	E	E	E	F
Cypress	M	M	E	I
Gum, sweet	G	E	E	M
Gum, black	M	M	E	I
Hickories	M	S	I	I
Honey locust	M	M	I	I
Maple, silver	G	G	I	M
Oak, bur	M	M	I	I
Oak, cherrybark	G	G	I	F
Oak, Shumard	G	G	I	F
Sycamore	E	E	I	F
80-100 FEET				
Cottonwood, swamp	G	G	I	F
Birch, river	G	G	D	M
Elm	M	M	D	M
Maple, red	M	G	I	M
Oak, overcup	S	S	I	I
Oak, pin	G	E	E	M
Oak, swamp chestnut	M	M	I	I
Oak, swamp white	M	M	I	I
Oak, willow	G	E	E	I
Willow, black	E	E	I	I
LESS THAN 80 FEET				
Box elder	G	G	D	M
Sugarberry	M	M	D	M

[1]Final total height on better sites where commonly found
[2]E—Excellent G—Good M—Moderate S—Slow
[3]E—Excurrent D—Delinquescent I—Intermediate
[4]F—Few I—Intermediate M—Many

Desirable Species Composition

The species best adapted to the climate and site-type, and generally the most valuable for sawlogs and veneer logs, are listed in Tables 7 and 8. These species are biologically most successful on these site-types and are suitable for both wood products and maintenance of multiple use benefits including watershed, protection, recreation, and wildlife.

Figure 3. White oak is one of the most valuable and abundant timber species in Illinois.

Table 7. Desirability ranking' of species by site-types for production of timber in Illinois on upland sites.

	Higher value	**Moderate to low value**	**Little or no commercial value**
Mixed Hardwoods	Yellow-poplar	Black gum	Sassafras
	White oak	Beech	Dogwood
	Northern red oak	Basswood	Mulberry
	Black walnut	Hackberry	Hophornbeam
	Sugar maple	Elm	Blue-beech
	Black oak		
	White ash		
	Scarlet oak		
	Hickory		
	Black cherry		
Mixed Oak	White oak	Post oak	Blackjack oak
	Black oak	Sugar maple	Sassafras
	Northern red oak	Black gum	Dogwood
	Bur oak	Beech	Mulberry
	Scarlet oak	Persimmon	Hophornbeam
	Chinkapin oak	Elm	Blue-beech
	Yellow-poplar	Redcedar	
	Hickory		
	White ash		
Oak-Hickory	White oak	Post oak	Blackjack oak
	Black oak	Shingle oak	Black gum
	Southern red oak	White ash	Sassafras
	Scarlet oak	Hickory	Persimmon
	Pin oak	Redcedar	Dogwood
			Hard maple
			Red maple
			Beech

[1]Arranged in approximate order of present desirability. The ranking considers (1) stumpage value and (2) growth rate, form, and vigor on sites indicated. For example, black walnut logs are more valuable than those of yellow-poplar, but yellow-poplar is faster growing, has a better form and easily dominates the better sites. Any species may have a high value for aesthetic, wildlife, or other specific uses.

Table 8. Desirability ranking' of species by site-types for production of timber in Illinois on bottomland sites.

	Higher value	Moderate to low value	Little or no commercial value
Cottonwood	Cottonwood	Willow	Box elder
	Green ash	Elm	
	Sycamore	Sugarberry	
	Sweetgum	River birch	
	Silver maple		
Mixed soft hardwoods	Sweetgum	Pecan	Box elder
	Green ash	Swamp white oak	
	Silver maple	Elm	
	Cherrybark oak	Sugarberry	
	Shumard oak	Hickory	
	Cottonwood	Red maple	
	Sycamore	Pin oak	
	Cypress	Honey locust	
Mixed hard hardwoods	Black walnut	Post oak	Box elder
	Cherrybark oak	Shingle oak	
	Green ash	White ash	
	Pecan	Hickory	
	Pin oak	Redcedar	
	Willow oak		
	Blackgum		
	Cypress		
	Bur oak		
	Swamp white oak		
	Swamp chestnut oak		
	Silver maple		

[1]Arranged in approximate order of present desirability. The ranking considers (1) stumpage value and (2) growth rate, form, and vigor on sites indicated. For example, black walnut logs are more valuable than those of yellow-poplar, but yellow-poplar is faster growing, has a better form and easily dominates the better sites. Any species may have a high value for aesthetic, wildlife, or other specific uses.

Stocking

The stocking guides in Tables 9 and 10 give the approximate most desired density for even-aged stands. They assume that the trees are reasonably well distributed and that the diameter distribution generally follows a bell-shaped curve.

Proper stocking of a stand will maximize growth of the entire stand while promoting good stem form and quality for the individual trees. Too few trees will result in the underutilization of site resources which will decrease future stand yields. Additionally, low stocking discourages height growth and encourages trees to retain lower branches, which also decreases future timber yield as well as timber quality. Understocked stands are typically more vulnerable to invasive species proliferation. Conversely, too many trees, or overstocking, will result in intense competition that stagnates the development of the stand and slows individual tree growth. Stagnated stands are also most vulnerable to damage resulting from drought events and other climatic stressors.

If a forest is determined to have adequate stocking on a relatively poor site, the best option is to let the stand grow to economic maturity, as there is little that can be done to improve the current crop of trees. If the stand is understocked and on a fair to good site, the extent of understocking will help guide the choice of either allowing a period of further growth before overstory removal (slightly understocked) or an immediate overstory removal (grossly understocked).

Table 9. Target stocking (per acre) by diameter to maximize growth on a site over time; upland even-aged forests for Illinois by site type.

	Mixed hardwoods		Mixed Oak		Oak-Hickory	
Mean tree DBH of stand	**Trees**	**Basal area**	**Trees**	**Basal area**	**Trees**	**Basal area**
Inches	*Number*	*Sq. ft.*	*Number*	*Sq. ft.*	*Number*	*Sq. ft.*
2	400	9	400	9	400	9
4	300	26	300	26	300	26
6	220	43	210	41	210	41
8	170	59	150	52	140	49
10	120	65	105	57	95	52
12	88	69	80	63	70	55
14	68	73	60	64	54	58
16	54	75	48	67	42	59
18	44	78	40	71	34	60

Table 10. Target stocking (per acre) by diameter to maximize growth on a site over time; bottomland even-aged forests for Illinois by site type.

	Cottonwood & Soft Hardwoods		Hard Hardwoods	
Mean tree DBH of stand	**Trees**	**Basal area**	**Trees**	**Basal area**
Inches	*Number*	*Sq. ft.*	*Number*	*Sq. ft.*
2	220	5	400	9
4	150	13	300	26
6	100	20	200	39
8	90	31	160	56
10	80	44	110	60
12	70	55	80	63
14	60	64	62	66
16	50	70	50	70
18	45	80	-	-
20	40	87	-	-

Forest Management Process

The general steps required to put a particular forest or woodland into a condition of high productivity are as follows:

1. Determine forest conditions with an inventory including species, density, diameter distribution, and tree classes. The inventory includes an assessment of the overstory as well as understory conditions. Special attention should also be given to the potential impacts of invasive plant species and exotic pests and pathogens. Site-types should be mapped and will usually correspond to topography or other landscape features such as roads.
2. Determine the owner's objectives for the woodland including the products and/or services to be produced and the kind of forest cover desired. This should be generally consistent with the present and potential economic and marketing conditions of the locality.
3. Develop a forest management plan according to the IL FDA guidelines.
4. Implement the plan.
5. After plan implementation, examine and monitor the residual stand for future growth and development. Examine the regeneration areas for success of reproduction. Adapt plan based on assessment of conditions resulting from prescribed plan management actions and impacts of any unexpected events.

Management of Immature Stands

Crop tree release

Managing central hardwood stands for timber involves a balance between providing enough space for eventual crop trees to grow to their full potential while allowing full stocking of trees to help the crop trees grow straight and providing enough shade so that less desirable vegetation cannot gain a foothold in the understory. For this reason, it is just as important to provide growing space for crop trees by removing competitors while recognizing that removing additional trees may be counterproductive. In this section we will discuss considerations for selecting crop trees, removing important competitors and managing the parts of the stand where there are no crop trees.

Identifying the trees within the stand having the most potential to produce valuable timber and giving them room to grow to their potential can have a significant long-term impact on timber production. Therefore, in the middle years of stand development, we focus most of our attention on individual trees, including how to identify the individuals you want to keep and those that can be cut to improve the stand. First, be sure there are species present having timber production potential (Tables 7 and 8). Second, check to see if these species require release (Table 11). Third, ensure that tree health and form are adequate to assure tree survival and responsiveness to more resources as provided by thinning. Lastly, these individuals must be suitable to attain maturity at the location where they are growing (Table 2).

Site Quality

Site productivity is an important determinant of crop tree release suitability. Unless there has been a history of abusive land use, highly productive sites often have the greatest likelihood of having potential crop trees. Within complex topographies, seek out potential crop tree-producing areas. Especially consider locations where soils are protected from droughts by virtue of their slopes facing away from the afternoon sun or in lower positions within the landscape.

Table 11. Need for release by species and site for crop trees Illinois[1].

Upland Site Types					
Mixed hardwoods		**Mixed Oak**		**Oak- Hickory**	
Height of crop trees same as competition	*Crop trees overtopped by competition*	*Height of crop trees same as competition*	*Crop trees overtopped by competition*	*Height of crop trees same as competition*	*Crop trees overtopped by competition*
Need release[2]	Need release	Need release	Need release	Need release	Need release
Black walnut	Black walnut	Hickory	Scarlet oak	Hickory	Scarlet oak
Hickory	Yellow-poplar		Black oak	Post oak	Black oak
Do not need release	White ash	Do not need release	Red oak	Do not need release	Post oak
White oak	Black, red oak	White Oak	White oak	White oak	White oak
Black, red oak	White oak	Black Oak	Hickory	Black oak	Hickory
White ash	Hickory	Red oak		Scarlet oak	
Yellow-poplar	Basswood	Scarlet oak			
Sugar maple					
Bottomland Site Types					
Mixed soft hardwoods				**Mixed Hard Hardwoods**	
Need release	Need release			Need release	Need release
Cottonwood	Cottonwood			Hickory	Silver maple
White oak	Sycamore			White oak	Black gum
Red oak	Silver maple			Red oak	Green ash
Do not need release	Sweetgum			Black gum	Red oak
Sweet gum	Green ash			Do not need release	White oak
Sycamore	Red oak			Silver maple	Hickory
Silver maple	White oak			Green ash	
Green ash					

[1] Assuming no overhead canopy; at least 75 percent of full sunlight on regenerating area.
[2] First species listed most in need of release; arranged in decreasing order of need.

On very productive sites, oaks are often overgrown by well-formed individuals of other timber producing species. Here you may want to focus your management or at least give some consideration to these fast growing non-oak crop trees. Less desirable, poorly formed, or sub-dominant competing trees can be removed from around crop trees if they are suppressing crown expansion and therefore slowing potential growth. In these stands, oaks may represent only a small portion of the overall stand. Management can be focused on retaining the few good oak trees without losing emphasis on improving crop trees of other valuable timber species.

In stands of intermediate productivity, recognize that timber production may be only a secondary objective. Before investing in crop tree release, be sure that stocking objectives are still met once trees have been removed. If so, and tree removal is still desired, carefully determine whether crop tree release will pay off in the form of better crop tree growth or the development of regeneration. A common management mistake is releasing trees that will not benefit from release in terms of sufficiently improved growth and quality to produce merchantable timber.

On very unproductive sites, which are often dominated by oak, trees sometimes do not grow tall and/or are poorly formed (not straight and tall). Here, soil conditions inherently limit utility of these sites and timber production may not be a realistic goal. Limited crop tree release may be considered strictly with the expectation that wildlife benefits, via larger crowns and greater mast production, are a primary objective for these lands.

Selecting Crop Trees

The most important criterion for releasing a crop tree is whether the physical effort and sacrifice of other trees will in fact provide a net benefit. Thus, you want to ensure the crop trees you select are both truly superior to those you sacrifice and that they will respond positively to release. Keep in mind, most trees in a stand will be the same age, but may vary markedly in size. The difference in size among trees of the same species may be genetic. In this case, provide at least some of the trees with the best genetics the opportunity to produce offspring that will eventually become the primary timber producing trees into the future.

A common mistake is releasing crop trees when they are too young. When you remove competitors from around a healthy young tree, its branches tend to become larger and natural self-pruning, where lower branches die and fall off, may not occur or become delayed. These branches may interfere with the development of straight, branchless tree trunks that are needed for timber trees. A common rule of thumb is to wait until a tree is about thirty-five to forty feet tall before making it the focus of a crop tree release operation. Avoid the temptation to release oak trees that appear unhealthy at the expense of sound non-oaks. There is nothing wrong with releasing a taller, thicker, more dominant tree of a different species to maintain some diversity in the stand. Generally, crop tree release even within very healthy stands will release in the range of 20 to no more than 75 trees per acre. Many times, these trees will be clumped in only a limited area of the stand. In portions of the stand where no potential crop trees are found, no active management for short term timber quality enhancement is needed. Also, avoid the temptation to release trees that will not reward you with greater value. Not only is this operation unnecessarily time consuming, it may introduce too much light to the understory and result in the need for costly understory control in the years to come once regeneration becomes the focus for management.

The following criteria are general guidelines for determining tree characteristics for crop tree selection. However, they should not be used rigidly. The forester's knowledge of local variations should be given full consideration when the trees are classified.

1. The tree is of a desirable species for the site.
2. The tree should appear sufficiently healthy so that it can be expected to live at least 20 more years
3. There should be little or no evidence of persistent insect infestation or disease.
4. A dominant or co-dominant crown, receiving sunlight from both directly above and some from the side. The crown should be well-developed, of vigorous appearance, and with a crown ratio not less than 40 percent for sawtimber trees and 25 percent for pole trees.

5. The crown should contain no more than one dead branch three to six inches in diameter and no dead branches larger than six inches.
6. The bole should be reasonably straight without deductible sweep or crook and free of holes, rotten knots or branch stubs.
7. A tree earning at least four percent interest in terms of growth value and having the quality and vigor characteristics which justify carrying it to full rotation size.
8. The butt log should be free of defects or epicormic branches in first 8-16 feet of trunk. The merchantable height, actual or potential, must conform to site capacity for the species and current market demands specific to your area.
9. Little to no butt scars are visibly present.
10. The tree must be root-firm.

Releasing crop trees

When releasing a crop tree, remove enough competitors so that crown competition will be avoided for several years. Usually, this means cutting or killing trees that are touching the crown of a crop tree. If two potential crop trees have touching crowns, consider leaving both trees and merely removing competitors around them. There are no hard and fast rules regarding thinning intensity, but a reasonable guide is removing enough competitors to prevent spreading crop tree crowns from contacting the also growing crowns of the next competing trees. These will typically be the nearest neighbors that have dominant or co-dominant crowns.

Felling with a chainsaw, girdling mechanically and chemicals may all be used to deaden or remove crop trees depending on personal preference and resources. In middle-aged stands, most trees are somewhat small and felling can be tricky. Directional felling techniques are most effective in larger trees to beware the danger of cutting these small stems. Fatal accidents resulting from felling trees in the 6 to 10 inch diameter range occur disproportionally because these trees are hard to control. People cutting them down are less attuned to the danger associated with these smaller trees than they are with bigger, but easier to control, mature trees.

Conclusion

The results of a crop tree release may not be clearly evident until a few years later. If carefully selected, crop trees will have produced a larger crown than would be the case if no release had taken place. A larger crown translates to more seed production and a faster growing trunk and the potential to produce timber at an earlier age. If trees are selected carefully, your stand should be healthier and better able to withstand the stresses of drought and disease. Continue to monitor your stand to ensure that invasive species or other vegetation that will interfere with desirable regeneration does not become established as an unintended consequence of removing non crop trees. Also, consider further treatment if crop trees again become vulnerable to competition from non-crop trees.

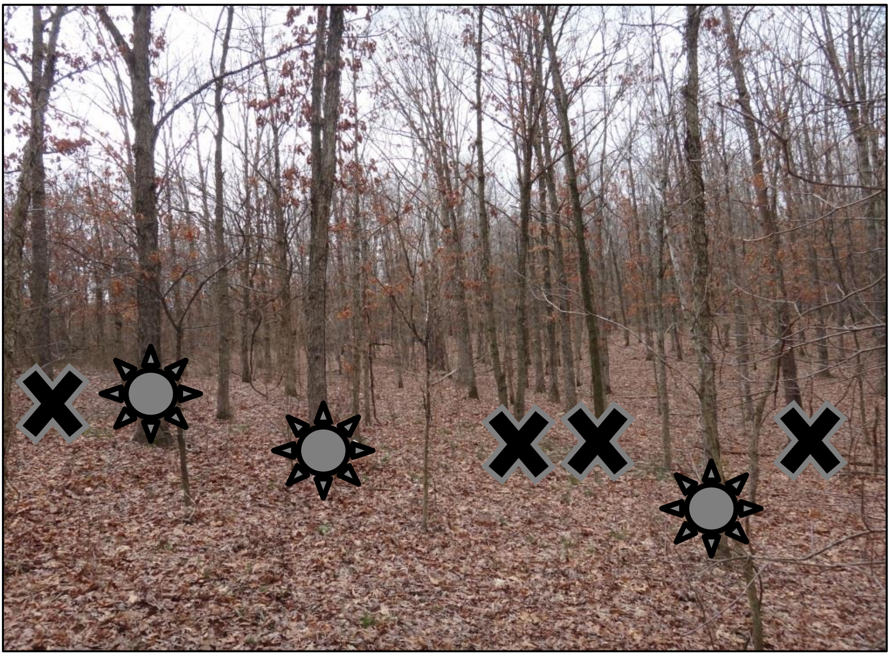

Figure 4. Potential trees for release are indicated by a sun icon while trees marked for removal are indicated by an “x” in this immature oak stand. Only the most vigorous individuals should be released by removing the competitors that touch the crown of the crop tree.

Partial overstory density reduction (uniform thinning) in immature stands

In fully stocked, immature stands where sustained timber production is the primary management objective, wide scale reduction of overstory tree density may be considered in the following instances

1. The health and vigor of the stand will be compromised by overcrowding unless density is reduced (stand health)
2. The presence of diseased trees within the stand is compromising the health of the other trees within the stand (sanitation)
3. Enough trees have matured as timber to justify a harvest and failure to harvest these individuals now will result in their loss of value (salvage)
4. The majority of potential timber producers are approaching maturity and the time has come to initiate the regeneration process (regeneration)
5. There is a compelling reason to remove many individuals in order to strongly change the species composition or the structure of the stand.

Partial overstory density reduction, or uniform thinning throughout the stand to maintain stand health, is widely practiced in the forests in the western United States where even aged stands of conifers are growing slowly due to overcrowding. These trees are prone to severe stress, especially during droughts, and are prone to catastrophic insect outbreaks that may kill all trees within the stand. The fire risk posed by these desiccated trees is also used as justification for overstory removal. However, in all but the least productive timber producing stands in Illinois, this is typically neither necessary nor beneficial to timber production objectives. In some plantations of hardwood trees, thinning may prove necessary in the future but in most cases, self-thinning will either occur or a crop tree release model will more likely be sufficient. Similarly, removing some diseased trees is used to slow the spread of diseases where pathogens gain a foothold on specific trees. However, there are no examples for such disease problems in Illinois at this time. If a hardwood planting has become stagnant, before investing time and money in partial overstory removal, be certain that the stand development problems are indeed solvable by density reduction. In many instances, stagnation occurs due to diminished site productivity through previous land use, trees of poor genetic quality, long-term suppression, or a mismatch between crop tree species and site conditions. In any of these cases, partial overstory removal may not result in a meaningful growth response.

A more common scenario where partial overstory removal is justifiable in mixed species forests is when some of the trees, or sometimes all the individuals of a characteristically short-lived species, reach maturity before most of the rest of the stand. Delaying harvest of these individuals would result in their loss to decay or disease. In these instances harvesting these individuals through partial overstory removal might be warranted, provided this is consistent with long term management goals.

Regardless the objective for partial overstory removal, selection of trees for cutting should be based on the following criteria:

1. A visibly declining growth rate. Tracking the diameter growth of representative trees or using an increment borer provides the most objective indication of tree diameter growth. However, using an increment borer can reduce merchantable value of logs so care should be taken when sampling trees destined for sale.
2. Poor or declining crown vigor. Live crown ratio less than 25-30 percent, or presence of dead or dying branches in the crown, can provide a useful indication that trees may soon be dying or otherwise prone to loss of timber value.
3. Imminent mortality due to disease outbreak or epidemic. In these instances, harvesting susceptible trees must be compatible with protecting the value of the remaining trees as well as protecting the future of the species within the stand.

When conducting felling, skidding or hauling operations during partial overstory removal, loggers need to be especially careful to avoid injuring the trees destined to remain in the stand. When most trees are left standing, these may present formidable obstacles to loggers. The lighter the cutting operation, the more crowded the stand remains and the greater the chance that some trees will be injured. On the other hand, the consequences of intensive harvesting must also be considered; enough trees being retained to achieve forest management objectives. If planned cutting treatments are creating large gaps in the overstory, then regeneration of desirable canopy trees needs to become a primary consideration. In most cases, partial overstory removal will take no more that 30 percent of the basal area of the stand.

Whether or not regeneration is the reason for overstory removal, new plant growth will almost certainly result and this may impact regeneration development in the future. Presence of invasive plant species, both native and exotic, may drastically impact stand development. Also, seedlings and saplings of shade tolerant tree species often grow or proliferate in response to a newly opened canopy. Unless further action is taken, these individuals are now positioned to become the new canopy dominants. Following uniform thinning, stands should be monitored for several years to ensure that the forest understory consists of desirable vegetation or is not becoming inhospitable to the development of desirable vegetation in the future. Keep in mind that in most immature stands, focusing thinning around a small number of potential crop trees is the only economically viable form of partial overstory removal (see *Crop tree release*). Furthermore, uniform partial canopy removal often commits the manager to addressing the development of potentially undesirable understory vegetation. This is especially true if these species are already present within the stand, even in small numbers.

Management of Mature Stands

Harvesting

A forester who is contemplating a harvest must first determine the maturity of the timber. There are several traits in a tree that determine sawlog value. A forester needs to be able to recognize these traits to make well-informed decisions before involving a timber buyer. In order to be merchantable, a sawlog tree must meet the following criteria:

- Desirable species
- Minimum top diameter of 6 to 12” at the small end of the log
- At least 8 to 10’ long
- Generally free of large branches
- Straight and free from crooks and sweep
- Generally free of major defects, such as rot, knots, seams and foreign objects such as nails and wire

Determining how much of the overstory to remove requires careful consideration of which objectives the landowner has in mind. There may be a single or multiple land-use objectives ranging from wildlife habitat, aesthetics, recreation and timber production. Once these priorities have been established, the kind of work needed depends on the individual forest stand’s stage of development, species composition, and current tree condition. Forest improvement work should be prioritized for stands with the best potential and hence, the greatest return on the investment.

Poor cutting practices

For a variety of reasons poor harvesting practices are commonplace in Illinois. Historically, these practices generally take two forms: (1) “high grading” by removing only the best trees and (2) “diameter limit cutting”. High grading is the removal of the best trees and while leaving all the poorest ones. Typically this practice only removes a few trees per acre and is one of the biggest mistakes a landowner can make as it does not make any provisions for regeneration of better timber species and quickly leads to a forest that no longer produces valuable timber. Foresters, loggers, and landowners alike are all guilty in the prevalence of this practice in Illinois woodlots. Many well intentioned landowners approve of this practice because with the removal of only a few trees it "saves" their woodlot and does not "ruin" the forest like a clearcut would. Loggers prefer the practice because it allows them to remove the most valuable trees, decreasing the time and effort required to removes low quality trees that are worth very little.

In diameter limit cutting the operator cuts all the merchantable trees to a low diameter limit, and leaves all the culls, low quality trees, and poor species to occupy the area. Diameter limit cuts have proven to be unsuccessful for the regeneration of desirable timber species on most sites in Illinois. On the surface, it may appear that removing the big trees and allowing the smaller ones to grow would be a successful strategy for good forest management. In reality, the smaller trees left on site are often the wrong species or, if a desirable species, in too poor of condition to develop into future timber trees. Diameter limit cutting is also notorious for removing merchantable trees during their prime growing years or before they have reached their full economic maturity

Once implemented, the long term implications of both of these practices may not be observed for several years. However, high grading and diameter limit cutting practices fail to plan for regeneration of the stand following harvest and cheats the landowner out of future revenue potential. These practices should be avoided in Illinois forests.

Selective harvesting

The term "selective harvesting" or "select cutting" gets used loosely by many individuals involved in the forestry industry. Generally it is considered the opposite of clearcutting, but it can mean many things to many people as it depends on which trees are selected for harvest. The selection of individual trees frequently does not ensure the best silvicultural practices are being utilized for a particular stand. The difference between a properly executed partial removal that encourages regeneration of desirable species and a select cut that highgrades the stand can be subtle to the untrained eye, although the effects may last for decades. Caution should be exercised with the recommendation of a selective harvest. Landowners should discuss with their forester and/or logger how the prescribed canopy removal will ensure the development of desirable species in a new stand following the harvest. In most cases the smaller trees left following a harvest will not develop into desirable timber species and a new cohort must be established through complete or partial overstory removal, and when necessary, follow up management practices such as prescribed fire and thinning.

The myth of unevenaged management

Many forest landowners own wooded property for reasons other than timber production. Understandably, they prefer the aesthetics and amenities of mature forest provide and are naturally drawn to the concept of unevenaged management. This management strategy allows for a range of age and size classes in the forest. Harvests call for frequent light cutting of overstory trees after which smaller trees will take their place in the canopy. This is not a successful management strategy for Illinois forests. Despite the attempts of many researchers and practitioners to implement this philosophy in Illinois, all results indicate that Illinois forests are typically too productive to allow for the regeneration of desired timber species with this management strategy. Short term successes in creating unevenaged stand structure have quickly resulted in degradation of stand species composition and development of unsustainable tree size class distributions.

Invasive species

When considering any overstory removal, be especially wary of invasive plant species that are commonly present under the canopy as a few inconspicuous individuals. Canopy removal typically hastens the expansion of existing plants and increases the potential of these problematic plants to produce seed. It is best to address these threats to desirable forest stand development immediately through spot applications of herbicide and continued monitoring with the goal of weakening, or ideally, eliminating, problem species from the site. Delaying management only gives these species the opportunity to strengthen their toehold within the stand. It is also easier to deal with threatening species before overstory removal. At this time, moving through the stand is less difficult and it is easier to see and destroy small individuals or colonies before they become reproductively mature. A further consequence of delaying action against undesirable vegetation is that windstorms or other natural canopy disturbance will, without warning, achieve the same high light conditions that favor expansion of these exotic species under a tangle of downed branches and trees. Addressing problem species without delay also means less chemical herbicide needs to be applied to achieve understory protection.

Recommended practices for the removal of mature trees

The following sections in this guide are designed to assist foresters and landowners determine when a tree is considered mature (see *Maturity guides for overstory removal*), and once mature, determine how best to regenerate the stand to ensure future timber production. If regeneration is present or anticipated from seed and/or stump sprouts the overstory should be removed entirely to release the regeneration (see *Releasing regeneration with complete overstory removal*). If desired species are not present in the understory then partial overstory removal accompanied by any necessary follow up treatments should be conducted (*see Establishing regeneration with partial overstory removal* and *Treatments to accompany or follow partial overstory removal*). Due to the variable topography and stand conditions in a relatively small area in Illinois forests, it's possible that a mixture of these practices could be performed across the landscape in conjunction with a harvest. For example, a landowner could completely remove the overstory to encourage yellow-poplar on mesic, north facing slopes, but only partially remove the overstory on drier, southwest facing slopes to encourage oak regeneration. If a landowner who owns a larger area, e.g. >50 acres, wishes to retain an undisturbed forest component on their property they should consider harvesting only a portion of their property a given time.

Maturity guides for overstory removal

When managing for timber production harvesting is recommended when trees reach maturity. Maturity can be based on several factors including tree biology and economics. In Illinois most tree species are biologically mature (annual growth is maximized) by 50 to 70 years of age. Carrying trees past this age is risky because in addition to growth reduction, losses due to rot from fungal pathogens begin to increase exponentially and trees are less likely to produce viable seed or stump sprouts.

Economic maturity typically occurs before biological maturity. This is based on an alternative rate of return for the capital tied up in the trees. The approximate economic maturity guides in Tables 14 and 15 are based on a four percent alternative rate of return. For example, a sawlog quality yellow-poplar tree on a good upland site will seldom earn 4 percent interest once it has attained 24" in diameter at breast height. A forester can determine this rate for individual trees if necessary. Economic guidelines for timber maturity are shown in Table 14 for upland sites, and in Table 15 for bottomland sites.

Maturity size differs by species and sites because both affect growth rate. Generally as site quality decreases, the diameter at which trees attain maturity also decreases.

Economic maturity in this sense does not consider any silvicultural benefits of cutting a tree or group of trees. Implementation of recommended silvicultural practices often involves removal of some trees which are below maturity size in order to meet management goals. Size criteria from Tables 14 and 15 should only be used as guides.

Table 14. Economic maturity[1] guides by species and site-types in terms of tree diameter at breast height for Illinois hardwoods on upland sites.

Site-Type	**Species**	**Sawlog trees**	**Veneer quality trees**
Mixed Hardwoods	Yellow-poplar	20-24	24-28
	White oak	20-24	24-28
	Northern red oak	20-24	24-28
	Basswood	20-24	-
	Black oak	19-23	24-28
	Southern red oak	19-23	24-28
	Scarlet oak	19-23	-
	Black walnut	19-23	22-26
	White ash	18-22	-
	Black cherry	18-22	22-26
	Hickory	18-22	-
	Sugar maple	18-22	22-24
Mixed Oak	White oak	18-22	22-26
	Black oak	18-22	22-26
	Northern red oak	18-22	22-26
	Southern red oak	18-22	22-26
	Scarlet oak	17-21	-
	White ash	16-20	-
	Hickory	16-20	-
	Yellow-poplar	16-20	-
	Redcedar	12-14	-
	Post oak	16-18	-
Oak-Hickory	White oak	16-20	-
	Black oak	16-19	-
	Southern red oak	16-19	-
	Scarlet oak	15-18	-
	Post oak	15-18	-
	Hickory	15-18	-
	Redcedar	10-12	-
	Blackjack oak	10-12	-

[1] Tree size when rate of value return due to growth falls below approximately 4%.

Table 15. Economic maturity[1] guides by species and site-types in terms of tree diameter at breast height for Illinois hardwoods on bottomland sites.

Site-Type	Species	Sawlog trees	Veneer quality trees
Cottonwood and Soft Hardwoods	Cottonwood	24-28	-
	Green ash	22-24	-
	Sycamore	24-26	26-28
	Sweetgum	24-26	26-28
	Silver maple	24-26	26-28
	Willow	20-22	-
	Elm	20-22	-
	Sugarberry	18-20	-
	River birch	16-18	-
	Cypress	24-28	-
	Cherrybark oak	24-26	26-28
	Shumard oak	24-26	26-28
	Swamp white oak	22-24	24-26
	Red maple	20-22	-
Hard Hardwoods	Cherrybark oak	22-24	24-26
	Green ash	20-22	-
	Pin oak	18-20	-
	Willow oak	18-20	-
	Bur oak	20-22	-
	Swamp white oak	20-22	22-24
	Swamp chestnut oak	20-22	22-24
	Overcup oak	18-20	-
	Blackgum	20-22	-
	Cypress	22-24	-
	Silver maple	22-24	-
	Elm	20-22	-
	Hickory	20-22	-
	Pecan	20-22	-
	Sugarberry	18-20	-
	Honey locust	18-20	-
	Swamp cottonwood	16-18	-

[1] Tree size when rate of value return due to growth falls below approximately 4%.

Releasing regeneration with complete overstory removal

Canopy removal to allow a new generation of seedlings, saplings and sprouts to assume a dominant position in the stand is the most dramatic action in sustainable timber management. It finalizes the transition from managing a primarily mature stand to that of managing a primarily immature stand. In some instances, complete canopy removal is preceded by one or more partial canopy removals and perhaps management of the understory and midstory (see *Establishing regeneration with partial overstory removal*). Complete overstory removal is not appropriate for the regeneration of all species (Tables 16 and 17), and should only be undertaken when the likelihood of securing forest renewal is great; as evidenced by the combination of potential future regeneration developing from seed, sprouting potential of cut stems, and development of adequate advance regeneration (Tables 18 and 19).

Regeneration from seed

Regeneration of shade intolerant timber species such as cottonwood or yellow-poplar may be absent prior to complete overstory removal (Tables 16 and 17). In order to successfully regenerate, most of these species large canopy openings are needed. Furthermore, seed of desired tree species must to come into contact with bare mineral soil if new seedlings are needed to achieve regeneration objectives (see *Role of loggers during the harvest*). Seed from light seed species such as sycamore may travel up to 500’ and establish in the complete overstory removal openings while seed from tree species with heavy and relatively immobile seed such as black walnut may need to already be present on the site (Tables 18 and 19).

Stump sprouting

Canopy removal often generates many stumps that sprout and produce new stems (Tables 3 and 4). Provided the cut trees are not too old to produce a viable sprout, these individuals may contribute significantly to the pool of available regeneration. Capturing the potential of these sprouts to benefit the next stand requires cutting stumps low enough to allow the remaining wood to decay in such a way as to not jeopardize development of sprout into a healthy new tree. New sprouts should be well attached to the root collar so that their diameter growth comes into little or no contact with the decomposing stump. Caution should be employed when encouraging new sprout formation as well since cutting stumps too low can mean loss of all sprouting potential.

Advanced regeneration

Adequate hardwood regeneration consists of seedlings and saplings of timber species that are healthy, straight, and capable of becoming long-lived, canopy dominant trees. Following complete overstory removal, this cohort of new stems becomes the new stand. To ensure sustainability of timber production for this stand, these individuals must be sufficiently well-distributed across the site to prevent the site from being captured by less desirable species.

If the goal of the complete overstory removal is to regenerate the stand with advanced regeneration, several criteria must be met. The first criteria is making sure that regeneration consists of species that are well adapted to the site, not just in the understory, and capable of growing to timber size and form (Tables 7 and 8). The second concern is making certain these individuals are of sufficient vigor to respond to the additional light, water availability and nutrients that will be present once the overstory is removed. A common mistake for many landowners is to assume understory trees that have been suppressed for long periods of time, particularly those of shade intolerant species, will flourish following canopy removal. These stems are typically poor candidates to assume a dominant role in the stand and will most likely continue to linger in a suppressed position while also suppressing the development of seedlings of more desirable species. These chronically suppressed Individuals can be identified by a thin layer of leaves concentrated at the top of a flat, sparse crown, spindly twisted stems, and trees with thick, corky bark relative to faster growing trees for that species.

The next consideration is making certain regeneration is well-established and not vulnerable to loss from predation or damage from subsequent management. For example, saplings that are short enough to be browsed by deer may not be relied upon to fully regenerate the stand in locations vulnerable to depredation. Also, if the use of prescribed fire is anticipated, seedlings must be sufficiently established to ensure their resprouting in the event of top kill due to the burn. Fire intensity varies greatly from stand to stand and is also highly subject to widely fluctuating weather and fuel conditions. The key to incorporating fire into a regeneration system is making sure fire damages competing understory and midstory vegetation to a greater extent than that of desired species. Alternately, selective herbicide treatments should focus on eliminating enough competitors to permit desired individuals to capitalize on canopy removal (see *Encouraging regeneration with prescribed fire and thinning*).

Timing of canopy removal is another important consideration to achieve a new stand dominated by vigorous young trees of desirable species composition. Prematurely removing the canopy may reduce the representation of preferred species in the new stand by not permitting sufficient time for advance regeneration to develop to adequate size and number. For example, most oak species must accumulate in a partially opened stand as seedlings and sprouts before they are in a position to benefit from canopy removal (see *Establishing regeneration with overstory removal*). On the other hand, excessively delaying canopy removal may cause loss of valuable time for the new stand to grow. More importantly, the developing regeneration cohort may become suppressed if grown under shade for too long and then be less responsive to increased light availability once the overstory is removed. Stems of shade tolerant species have a limited amount of time before they will die in the absence of canopy release. Watch out for signs of suppression in developing regeneration and consider whether further delaying canopy removal will be rewarded by development of new regeneration to replace the loss and decline of older regeneration languishing in the understory.

Present and likely future impacts of overstory removal on plant growth need to also be fully considered. Even if regeneration is already present in adequate amounts, the response of competing vegetation to overstory removal must be considered. If these non-timber producing competitors are capable of capitalizing on canopy opening with aggressive new growth, or are already overtopping the more desired species, then heavy cutting may result in the need for expensive interventions to control competing vegetation and restore timber production potential. If desired regeneration is small, then it is vulnerable to competition both from existing vegetation as well as that of fast growing trees, vines, or shrubs that may arise as a result of canopy removal and overtake existing regeneration. In these instances further management may be needed (see *Encouraging regeneration with prescribed fire and thinning*).

Role of loggers during the harvest

When it is time for canopy removal to occur, the logger plays an important role in determining the composition and health of the new stand. In some instances, every effort should be made to reduce the impact of logging on the newly established seedlings and saplings. In other cases, it is advantageous for the logging operators to destroy the aboveground portions of the regenerated trees, allowing new stems to sprout anew from the root collar or roots of these damaged individuals. In this case, the logger should be encouraged to traffic widely throughout the stand. This practice maximizes the number of stems impacted while also minimizing the impact on the forest floor in any given part of the stand. The fate of branches and other structurally complex logging debris may play a role in the development of the new stand. Downed tree crowns left intact may act to restrict deer movement and protect developing seedlings and saplings from predation. On the other hand, breaking down the crowns to increase accessibility will make subsequent forest operations, such as herbicide application or felling residual stems, much easier.

Logger interactions with the soil environment is another important consideration, wet season logging increases exposed mineral soil and hastens the development of new seedlings for most tree species. This should be viewed as undesirable if sufficient regeneration is already present. If there are patches of the stand where regeneration is not adequate, then consider trafficking these areas more intensively to encourage the development of a new regeneration cohort. Logging during excessively wet soil conditions should, however, be avoided if this results in loss of traction by logging equipment. A result is churning of the soil can include soil compaction, changes in on-site water flow patterns, erosion, and sediment movement (for further information please see the Forestry Best Management Practices manual by the IL DNR).

Residual trees

Complete overstory removal causes all available light, water and nutrients available on the site to fuel growth and development of the new stand. This option results in hundreds of new stems which will eventually be reduced to several tens of trees to form the canopy of the next mature stand. It maximizes opportunities for thinning and increases the likelihood that shade intolerant species will play an important role in this new stand. Residual trees also may use the newly available space to expand their crowns outward in all direction, increasing their shade impact on the site, suppressing regeneration, and producing no timber.

Despite the negative impact on future timber development, many landowners opt to retain some residual trees. These individuals provide structural diversity and habitat critical for some wildlife species. Residual trees may also serve as a source of seed and continued reproductive potential. Decisions to retain residual trees must take into consideration this balance between present needs and future timber potential to arrive at workable choices. Focusing retention of residual trees in parts of the stand unlikely to produce timber and leaving maximum resources in portions of the stand with the highest timber value may be a useful compromise to consider.

In all cases, interacting variables such as tree seedlings, competing vegetation, predator populations, weather and understory light availability must go into the decision making process as to when regeneration should be released. Also to be considered are other management practices, if any, that should occur prior to, during, or after canopy removal to ensure success of released regeneration. While general guidelines are offered here, it is critical to consult with an experienced forester to help anticipate the consequence of the various management options on regeneration development.

Table 16. Recommended removal intensity to perpetuate selected upland timber species in Illinois.

Species	Overstory removal intensity
Ash, white	Complete
Basswood	Complete
Beech	Partial
Black cherry	Complete
Black Gum,	Complete
Hackberry	Complete
Hickories	Complete if advanced regeneration present, otherwise partial to establish regeneration
Maple, sugar	Partial
Oaks	Complete if advanced regeneration present, otherwise partial to establish regeneration
Redcedar	Complete
Sweetgum	Complete
Walnut, black	Complete
Yellow-poplar	Complete

Table 17. Recommended removal intensity to perpetuate selected bottomland timber species in Illinois.

Species	Overstory removal intensity
Ash, green	Complete
Birch, river	Complete
Box-elder	Complete
Cottonwoods	Complete
Cypress	Complete if advanced regeneration present, otherwise partial to establish regeneration
Elm	Complete
Gum, sweet	Complete
Gum, tupelo	Complete
Hickories	Complete if advanced regeneration present, otherwise partial to establish regeneration
Honey locust	Complete
Maple, red	Partial
Maple, silver	Complete
Oaks	Complete if advanced regeneration present, otherwise partial to establish regeneration
Pecan	Complete if advanced regeneration present, otherwise partial to establish regeneration
Sugarberry	Complete
Sycamore	Complete
Willow, black	Complete

Table 18. Requirements for natural regeneration of the more important desirable upland species.

Species	Advanced reproduction	Seed supply	Germination condition	Reaction to competition	Opening size for good growth	Growth rate on suitable sites & in openings recommended	Treatments sometimes needed
Yellow-poplar	Seldom present; must depend on new reproduction.	Abundant nearly every year if seed trees within 400-500 feet; seed viable in litter 3-4 years.	Moist bare soil, thin or freshly disturbed litter and moist soil. Best if seed is mixed with soil and litter.	Intolerant to overtopping competition and will live only 3-4 years if completely overtopped.	Diameter equal to height of overstory trees or greater	Sapling height 15-25 feet 10 years after harvest cut. With equal start will out-grow all competing species	Scarification of ground in early spring. Best to log in late winter or spring. Release from overtopping competition.
White oak	Seldom present. Occurs as seedling sprouts which die and re-sprout periodically.	Abundant every 2-4 years if seed trees within-100 feet, longer distances by squirrels.	Litter not seriously inhibiting. Fallen leaves cover acorns which germinate in the fall.	Tolerant to competition. Will live many years under canopy but grows slowly.	Three-fourth height of overstory trees or greater	Sapling height 10-20 feet 10 years after harvest cut.	Release if advanced reproduction overtopped by undesirable species.
Black, scarlet, northern and southern red oaks	Seldom present. Occurs as seedling sprouts which die and re-sprout periodically.	Abundant every 2-4 years if seed trees within-100 feet, longer distances by squirrels.	Litter not seriously inhibiting. Fallen leaves cover acorns which germinate in the fall.	Tolerant to competition. Will live many years under canopy but grows slowly.	Three-fourth height of overstory trees or greater	Sapling height 10-20 feet 10 years after harvest cut but generally slightly faster than white oak	Release if advanced reproduction overtopped by undesirable species.

Table 18. Requirements for natural regeneration of the more important desirable upland species (continued).

Species	Advanced reproduction	Seed supply	Germination condition	Reaction to competition	Opening size for good growth	Growth rate on suitable sites & in openings recommended	Treatments sometimes needed
Black walnut	Seldom present; must depend on new reproduction.	Abundant most years if seed trees within 75 feet. Sometimes longer distances by squirrels.	Litter not seriously inhibiting. Best to have seed covered by mineral soil.	Intolerant to overtopping competition.	Height of overstory trees or greater.	Sapling height 8-15 feet 10 years after harvest cut. Most competing species will outgrow it.	Distribute and cover seed; release seedlings from competition
Hickory	Usually present.	Abundant every 1-3 years if seed trees within 100 feet. Longer distances by squirrels.	Litter not seriously inhibiting. Abundant germination.	Tolerant to competition. Will live many years overtopped but grows slowly. More tolerant than white oak.	One-half height of overstory trees or greater.	Sapling height 10-20 feet 10 year after harvest cut, but generally slightly slower than oaks.	None
White ash	Usually present. Occurs as seedling sprouts which die and re-sprout periodically.	Abundant nearly every year if seed trees present within 300-400 feet.	Moist, bare soil thin or freshly disturbed litter and moist soil.	Moderately tolerant to competition, will live 8-10 years under canopy but make little growth. Does not persist for long periods like oak and hickory.	Three-fourth height of overstory trees or greater	Sapling height 10-20 feet 10 years after harvest cut. On good sites grows faster than white oak and hickory, but slower than yellow-poplar.	Ground scarification just before seed fall and release of advanced reproduction

Table 19. Requirements for natural regeneration of the more important desirable bottomland species.

Species	Advanced reproduction	Seed supply	Germination condition	Reaction to competition	Opening size for good growth	Growth rate on suitable sites & in openings recommended	Treatments sometimes needed
Sweetgum	Seldom present; must usually depend on new seedlings.	Abundant most years within 400-500 feet of seed trees. May also be carried by flood waters.	Moist, bare soil; thin or freshly disturbed litter; and moist soil.	Moderately tolerant to overtopping competition. Will live 6-8 years under canopy but grow slowly.	Height of overstory trees or greater.	Sapling height 15-25 feet 10 years after harvest cut. Slower than cottonwood and sycamore.	Ground scarification just before seed fall and release of seedlings.
Cottonwood	Seldom present; must depend on new seedlings.	Abundant every year; wide-spread on alluvial sites carried by water.	Mud or shallow water which recedes to mud.	Very intolerant to overtopping. Crown must be in nearly full light. Will not live under canopy.	Twice height of overstory trees or greater.	Sapling height about 50 ft. 10 years after harvest cut. Fastest growing species.	Eliminate competition and provide bare soil at time of seed fall.
Sycamore	Seldom present; usually depend on new seedlings.	Abundant most years within 400-500 feet of seed trees. May also be carried by flood waters.	Moist, bare soil; thin or freshly disturbed litter and moist soil.	Intolerant to overtopping competition. Will live only 2 or 3 years under canopy.	Height of overstory trees or greater.	Sapling height 20-30 feet 10 years after harvest cut.	Release from dense competition.

Table 19. Requirements for natural regeneration of the more important desirable bottomland species (continued).

Species	Advanced reproduction	Seed supply	Germination condition	Reaction to competition	Opening size for good growth	Growth rate on suitable sites & in openings recommended	Treatments sometimes needed
Silver maple	Seldom present; usually depend on new seedlings.	Abundant nearly every year within 300-400 feet of seed trees. Carried to some extent by flood waters.	Moist bare soil; thin or freshly disturbed litter and moist soil.	Moderately intolerant to overtopping competition. Will live 3-4 years under canopy but grow slowly.	Height of overstory trees or greater.	Sapling height 20-30 feet 10 years after harvest cut.	Release from dense competition.
Green ash	Often present in stands with green ash in overstory. Will form new stand after cutting if present.	Abundant most years if seed trees within 300-400 feet.	Moist bare soil; thin or freshly disturbed litter and moist soil.	Fairly tolerant to competition. Will live 8-10 years under canopy but make little growth until overstory cut.	Three-fourth height of overstory trees or greater.	Sapling height 20-30 feet 10 years after harvest cut.	Release from dense overtopping competition.
Black gum	Not dependable for reproducing stands.	Apparently abundant most years near seed trees.	Wet, bare soil. Seedlings often dense. Flooding soon after germination may cause failure.	Fairly tolerant to competition, but will not tolerate overtopping.	Three-fourth height of overstory trees or greater.	Sapling height 10-20 feet 10 years after harvest cut.	Open stagnated stands.

Table 19. Requirements for natural regeneration of the more important desirable bottomland species (continued).

Species	Advanced reproduction	Seed supply	Germination condition	Reaction to competition	Opening size for good growth	Growth rate on suitable sites & in openings recommended	Treatments sometimes needed
Pin, cherrybark, and Shumard red oaks	Seldom present. Occurs as seedling sprouts which die and resprout periodically.	Abundant every 2-4 years if seed trees within 100 feet, longer distances by squirrels. Pin oak most prolific; two good seed years in three.	Litter not seriously inhibiting. Acorns will germinate under litter in spring.	Moderately tolerant to competition. Will live many years under canopy as seedling sprouts but will not grow. Pin oak is most tolerant.	Height of overstory trees or greater. One and one-half height for pin oak.	Sapling height 15-25 feet 10 years after harvest cut.	Release if advanced reproduction overtopped by undesirable species.
Swamp white, swamp chestnut, overcup, and bur oaks	Seldom present. Occurs as seedling sprouts which die and resprout periodically.	Abundant every 2-4 years if seed trees within 100 feet, longer distances by squirrels.	Litter not seriously inhibiting. Fallen leaves cover acorns which germinate in the fall.	Moderately tolerant to competition. Will live many years under canopy but grows slowly.	Three-fourth height of overstory trees or greater.	Sapling height 10-20 feet 10 years after harvest cut.	Release if advanced reproduction overtopped by undesirable species.

Establishing regeneration with partial overstory removal

Desirable timber species differ in terms of the stand conditions needed to produce sufficient regeneration. In general, shade tolerant species grow slowly as seedlings and should be present in large numbers prior to final canopy removal (Table 16 and 17). In contrast, shade intolerant species generally require much light to advance beyond the small seedling stage. To reproduce a stand of these species, as much of the overstory as possible should be removed to prevent suppression (see *Releasing regeneration with complete overstory removal*). One of the biggest mistakes landowners make is removing too few trees during the harvesting process.

Consideration of the residual overstory trees

Removing some of a forest canopy sets in motion several important changes in the stand. Select trees for removal that are undesirable species or overmature species first. Leave sound, desirable species to provide seed for the next generation. Residual trees should be well spaced throughout the stand. Generally, about half of the initial basal area should be harvested during a partial overstory removal. Leaving more risks not having enough sunlight to encourage regeneration. Leaving less decreases the seed source for future desirable trees and may favor more early successional, shade intolerant species than are desired. This recommendation may be adjusted based on management objectives, present species composition, and status of regeneration.

The most immediate impact of a partial overstory removal is that remaining trees will become more exposed to wind and their vulnerability to breakage or uprooting will increase. Only windfirm trees should be considered for retention following partial cutting. Secondly, a tree that has been severely suppressed or is already near the end of its natural life, may produce a series of new sprouts from its bole. This may reduce the timber value of the tree. Removing competitors of weak trees with the hope of increasing their prospects for growth is risky, in that the released tree may be lost to damage or mortality prior to a second removal cut. Furthermore, weak trees are unlikely to gain additional timber value since they often lack the vitality needed to capitalize on the added resources provided as a result of release from competition.

If the released tree is vigorous and healthy, its crown will likely expand. This will translate into more rapid diameter growth, a larger crown that will cast more shade and potentially increased seed production. In these ways, the partial canopy opening will cause remaining trees to exert more influence on the stand beneath and around them, both as seed producers but also as a competitor to new offspring that could develop into the next stand. For these reasons, overstory trees should be retained only with careful consideration of the long term consequences.

Attention should be paid to avoid damage to the crowns and boles of residual trees. Both the forester marking the stand and the logger removing the timber play a critical role in this process. While some damage is unavoidable given the large crowns of hardwood trees and steep topography in some areas of Illinois, it is critical this damage is minimized because wounds created during harvesting serve as vectors for future fungal decay. Although these wounds may heal over, volume and quality will be compromised in future harvests.

Developing advanced regeneration

Partial overstory removal should be considered if there are an insufficient number of viable regeneration stems of shade intolerant and intermediate tolerant species presently in the understory in order to meet regeneration objectives (Tables 3 and 4) . If after several years of partial canopy opening, regeneration of desired species are still found to be inadequate, then further action may be needed to complement partial overstory removal (see section *Encouraging regeneration with prescribed fire and thinning*). Alternately, this method may not be a viable option for that particular setting. If you are not a forester you should consult with one to determine whether additional canopy opening, understory vegetation control, or artificial regeneration should be considered.

Partial canopy release will also stimulate the growth of undesirable understory vegetation that is already established or becomes established following the harvest. Depending on the composition of the understory, this growth may also occur at the expense of hoped for new regeneration. Consider controlling some or all of this new class of vegetation if it is not compatible with the management objectives for the next stand (see section *Encouraging regeneration with prescribed fire and thinning*).

How long should overstory trees be retained?

Leaving some trees in the overstory while regeneration is taking place can represent either a temporary or a long-term approach to stand structure management. A conventional shelterwood leaves some large trees in the overstory for approximately five to twenty years. Once the regeneration class is established, all or nearly all overstory trees are felled and merchantable trees removed. This approach allows the residual trees to influence establishment of the regeneration class but seeks to remove this influence as soon as this is assured. Removing all of the residual trees allows the new generation to fully occupy the stand and grow unimpeded.

An alternative to the conventional shelterwood, the irregular, or two age, shelterwood, allows regeneration to develop with some overstory trees remaining in place for several decades to continue their development among the regeneration. Trees selected for retention in the irregular shelterwood must show the potential to increase in value over the next several decades. These individuals are typically of intermediate to long-lived species that are not yet mature at the time of the first overstory removal. When selecting individuals to retain as the dominant crown class, careful consideration must be given to ensure that the crowns of these individuals will remain sufficiently small to allow for newly developing seedlings and saplings to grow into the overstory. To compensate for interference associated with the irregular shelterwood, foresters typically leave in the range of 10-30 ft^2 basal area per acre. If overstory interference with the developing regeneration is a concern, then strongly consider the conventional shelterwood where all large trees are eventually removed from the canopy, providing complete release to the newly developing generation.

Considerations for the removal of the remaining overstory

Conventional shelterwood

The conventional shelterwood attempts to balance competing desires to assure regeneration development and partial overstory retention. A common concern is waiting until the regeneration is fully established before removing the canopy dominant trees. Too often, a managers desire to delay canopy removal results in suppression and sometimes loss of significant numbers of the regeneration class. Furthermore, excessive waiting for regeneration to grow results in lasting damage of regeneration by logging equipment used to fell and remove the remaining overstory. Then there is little flexibility to relieve the understory from competition caused by the remaining overstory trees. Carefully and continuously monitor the stand to ensure that the window to complete the canopy removal phase of the operation is not missed.

Irregular shelterwood

Complete overstory removal is delayed for several decades in the irregular shelterwood. However, the responsibility of the present manager is even greater in this system, given the greater potential of remaining trees to suppress the next generation. Continued monitoring of understory conditions and the willingness to sacrifice overstory trees that threaten new stand development are continued investments that typically must be passed on to the next generation of landowner or more as a continued investment in active stewardship.

Treatments to accompany or follow partial overstory removal

Encouraging regeneration with prescribed fire and thinning

In most productive Illinois forests, especially where fire has long been suppressed, a midstory consisting of noncommercial shade tolerant tree species and saplings and pole size individuals of potential overstory species, has become a prominent part of the forest. The midstory often suppresses desirable timber species, including oak, that are typically not shade tolerant, from developing beyond the seedling stage (Tables 3 and 4). Following a partial overstory removal harvest, many of these midstory trees may still be present as they are oftentimes left because they little to no timber value. Removal of these shade tolerant stems will increase light to the forest floor which in turn increases the likelihood of the regeneration of desirable timber species (Tables 7 and 8). Depending on the size of the midstory species, stand topography, and accessibility to the site, removal of these shade tolerant competitors may be accomplished by prescribed fire or thinning.

Managing the light environment is only one component of regeneration development. Conditions on the forest floor may also need to be managed in order to facilitate tree seed germination and growth. In the several months surrounding initial canopy removal, light discing may help expose mineral soil, relieve some competitive stress and ensure that newly germinated seedlings are well-placed within the seedbed. Treatments are usually only needed in those portions of the stand where competition is a problem. Beware that moving equipment around the stand may have unintended consequences of spreading or facilitating development of invasive vegetation unless proper sanitation practices are observed. Careful use of herbicides or prescribed fire may play a substitutive or complimentary role for increasing new seedling development where discing is not practical. Here again, careful monitoring and action when necessary can help foster release of a new generation of healthy, timber producing trees.

Prescribed fire

Fire has played an important role in shaping forests in Illinois. Most famously, wildfires have been associated with damaged and destroyed timber, resulting in its banishment from most lands. For decades the success of fire suppression programs resulted in a bounty of unblemished timber. More recently, the changes in forest species composition resulting from the prolonged absence of fire has led many foresters to carefully reintroduce fire as a regeneration tool.

Prescribed fire is a forest improvement tool that works in several ways. If undesirable midstory stems are small, generally no larger than saplings, prescribed fire may play a significant role in reducing the density of these species and promoting the development of fire tolerant species such as oak. Prescribed fire is also used to reduce the duff layer on the forest floor and reduce the amount of coarse woody debris. Duff removal allows acorns to reach mineral soil, become established, and find earlier access to sunlight.

Most oak species are well-adapted to fire and can continue developing a tap root over the duration of several well-timed fires, until gaining the momentum to produce a fire-resistant sapling that will gain a competitive advantage. Once seedlings are established, prescribed burning serves to selectively suppress species that are less adapted to fire at the expense of those that can withstand it.

Burning may be conducted during different times of the year with smoke management, ease of containment, available labor, and desired intensity serving as points of consideration. Prescribed fire is not a panacea and should be considered only one component of an integrated regeneration system where overstory light and midstory vegetation control and invasive species management are typically necessary and complementary practices.

The frequency of burns needed to encourage and develop regeneration can seldom be predetermined. Once regeneration begins to develop, prescribed burning may need to be delayed until enough seedlings of desirable species are large enough to withstand scorching. Fire kills seedlings of even the most fire adapted species if applied too soon. Consequently, the timing of burns must consider the interplay among the numbers and size of both desired and undesirable species.

Cautions

Generally prescribed fire should be conducted following a partial overstory removal to limit damage to mature timber. If prescribed fire is conducted in the presence of maturing crop trees, every effort must be made to remove fuel from the base of these individuals to protect them from scorching, bark injury and subsequent loss of wood value due to fire damage. Typically, simply cutting or raking away woody fuels is sufficient to achieve this goal. Repeated fires will reduce the fuel load so that fire intensity is lower and less likely to do damage to the boles of crop trees. However, if fire intensity becomes too low, the beneficial effects of fire for controlling competing vegetation will diminish or become lost until sufficient fuel loads again accumulate.

Figure 6. Low intensity prescribed fire in an upland oak dominated forest. Fires such as these are often used to promote oak regeneration.

Thinning

If stems of competing trees are too large, even species considered sensitive to fire will be able to survive intense fires and the benefits of burning may be lost or muted. In this instance thinning may be an alternative method for removal. Additionally, thinning may be more appropriate in situations where prescribed fire is undesired or cannot be easily implemented. Thinning accomplishes many of the intended benefits attributed to fire but, through its use of cutting and herbicides, is able to control competitors that have become too large to be impacted by prescribed burning. Most hardwood species will resprout following cutting and this treatment can be accompanied by an herbicide application to prevent this from occurring. Herbicide only treatments, e.g. hack-and-squirt, can also be used in place of cutting to kill undesirable trees but caution should be exercised with this option as it leaves many standing dead trees which become future hazards.

As with prescribed fire, thinning should be conducted following a harvest. The reasoning for this is twofold. First, even though midstory trees are not marked for removal, a harvest will reduce the density of these stems with the development of roads and skid trails as well as felling of the large overstory trees. Secondly, thinning tends to decrease accessibility within a stand and if it occurs before a harvest a logger will be less likely to bid on these jobs as they are more difficult to cut.

One exception to this rule is the removal of grape vines in a stand. High densities of grape vines reduce forest growth and tree regeneration. These should be cut and sprayed with herbicide prior to harvest as the treatment will not decrease logger access within the stand. If the stand will not be cut within the next five years herbicide application may not be necessary as these vines do not persist in shaded understories.

Combining prescribed fire and thinning

Thinning can be labor intensive, expensive and time consuming. Prescribed fire does not kill larger trees and has a narrower range of conditions in which it can be implemented. Combination of thinning and prescribed fire may be an option to cost effectively remove undesirable shade tolerant species and promote desirable oak regeneration.

When prescribed fire and thinning may not be appropriate

Prescribed fire and/or thinning following a partial overstory removal may not be necessary following a harvest. An assessment of the midstory layer and developing understory species should be done two to three years after a harvest to determine the next steps towards developing a well-stocked timber stand. If adequate regeneration of a timber species is present avoid implementing treatments to shift species composition to a different timber species. For example, if following a harvest, a stand is dominated by yellow-poplar regeneration do not burn the stand to favor oak regeneration. Concentrate management efforts in areas where the timber species regeneration is low and more likely to benefit the future forest.

Figure 7. The combination of a partial overstory removal harvest followed by a prescribed fire and thinning has resulted in the dominance of oak species in this immature hardwood stand.

Invasive Species in Managed Stands

Invasive species have been proliferating throughout Illinois forests and may potentially come to dominate any or all layers of forest vegetation. In particular, any practice that increases light to the understory or midstory, as is needed to develop regeneration of desirably species, including fire, may also result in the proliferation of exotic plant species. As most of these species are in a state of range expansion at the time of writing this document, it is impossible to predict exactly to what extent a particular species will be a problem. As invasive species proliferation continues, locally-appropriate strategies will be developed and adapted by foresters. In the meantime, forest land owners need to recognize that invasive species as a fact of life in forest ownership. At the very least, practicing good sanitation and preventing invasive species spread are critical parts of responsible forest ownership. Particularly, walking through uninfested stands every year or two and killing individuals of invasive species can effectively delay or prevent invasion for the foreseeable future. This practice is especially important as a follow up to burning, harvest or thinning operations, or in the years following storm damage that creates gaps in the overstory. There are several resources to assist with the identification and control of invasive plant species in Illinois, e.g. *Management of Invasive Plants of Southern Illinois* by the River to River Cooperative Weed Management Area. Managing invasive species now can prevent the need to invest significant revenues from harvesting back into the stand to protect the integrity of the ecosystem and the health of the timber resource.

Appendix

Tree classes

Tree classes are useful guides when recommending treatments because they reflect the stand condition and help identify the trees that should be left, harvested or culled.

The tree classes include only pole and sawtimber-sized trees; seedlings and saplings are not included. The tree classes are partially subjective and classifying trees is dependent upon the forester's knowledge and experience.

1. Acceptable Growing stock
    a. Good growers: Trees of desirable species having the vigor, growth rate, form desirable position in the stand, and quality to justify carrying them until economic maturity. These embody the classic definition of crop trees which would be cleared of competition and encouraged to grow taller and straighter.
    b. Temporary growers: Sound, good risk trees of merchantable species growing at an acceptable rate but which should be harvested before full biological maturity because their form, bole length, or quality does not meet standards for rotation crop trees.
2. Unacceptable growing stock
    a. Mature crop trees: Generally low risk, sound, good quality trees that have reached economic maturity (see Tables 14, 15). These trees are at or near biological maturity for the species, site, and product being grown. Crop trees, by definition, are carried to the full harvest size or age and have the characteristics of "good growers."
    b. Sound, low quality trees: These are low risk, sound trees but with poor form, short boles, or excessive defect. They are

earning and will continue to earn a low rate of return in relation to the space they occupy.

c. High risk trees: Trees which have a low or negative rate of return and which, because of age, size, rot, or other conditions, may die or lose value before the next cut.

3. Unmerchantable trees:
    a. Cull trees: Trees which are not merchantable now for any product except fuelwood and are not expected to be merchantable in the future for the harvestable products. These trees must not useful for any other management objectives either, such as habitat (den trees) or mast production. Note that cull trees may also be identified as those which shade the forest floor, creating competitive conditions for shade-intolerant species.

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