Chapter 40

Northern Hardwood Cover Type

Last Full Revision: 12/12/2018
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter.

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition

The northern hardwood cover type is defined as any combination of sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), basswood (*Tilia americana*), white ash (*Fraxinus americana*), and yellow birch (*Betula alleghaniensis*) that comprises more than 50% of a stand's basal area in sawtimber and pole timber stands or more than 50% of the stems in sapling and seedling stands.

Sugar maple typically is the dominant species in northern hardwood stands in Wisconsin. In eastern Wisconsin, beech sometimes is dominant. Basswood is the most common associate of sugar maple, but only occasionally dominates. White ash and yellow birch are common minor associates, but only rarely dominate stands. Red maple is also a common associate and when dominant is a separate cover type.

The northern hardwood and central hardwood upland forest cover types are differentiated as follows:

Northern hardwood type:

- Any combination of the five major species can dominate any stand, but typically sugar maple is the predominant overstory species. Though formerly not distinguished from the northern hardwood cover type, stands with more than 50% red maple are classified as the red maple cover type.
- Important associates unlikely to occur in the central hardwood type are beech, yellow birch, hemlock, and fir.
- Occurs throughout Wisconsin but is most common north of the tension zone.

Central hardwood type:

- Any combination of the five major northern hardwood species cannot be predominant.
- Tree species playing relatively greater compositional roles are oaks (especially white oaks), hickories, elms, ashes, red maple, black cherry, black walnut, butternut, hackberry, and box elder,
- In Wisconsin, it occurs within and south of the tension zone, commonly on sites submitted to long-term repeated disturbance.

Associated Species

Within the northern hardwood cover type, the predominant associates in Wisconsin currently are red maple (*Acer rubrum*), red oak (*Quercus rubra*), hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), and balsam fir (*Abies balsamea*) (Kurtz *et al.* 2017). Many other tree species occurring in Wisconsin can be found as occasional associates in northern hardwood stands.

1.2 Silvical Characteristics[1]

1.2.1 Sugar Maple

In Wisconsin, sugar maple has the greatest net growing-stock volume of all tree species with the; nearly 2.5 billion cubic feet on forest land (Kurtz *et al.* 2017). This represents about 15% of the total hardwood volume and 11% of the total (net growing stock) wood volume growing in Wisconsin's forest lands (Schmidt 1997; Kotar *et al.* 1999; Kurtz *et al.* 2017). According to the 2017 FIA, sugar maple's net growing-stock volume increased 8.6% % since 1996.

Sugar maple is one of the most shade tolerant of the major forest species in the state. Trees respond to release from extreme and prolonged suppression. It is regionally significant as a late-successional dominant on dry-mesic to wet-mesic sites.

In Wisconsin the site index (SI_{50}) mostly ranges from 40-80, but on average to better sites (suitable for growing quality sawtimber) is typically 55-70. Where site index is less than 50, quality sawtimber development generally is not a stand management option (Erdmannn 1986).

Sugar maple trees produce abundant and viable seed every 1-5 years; flower crops can be predictive of seed crops. Seeds are dispersed in the fall and early winter, lay dormant (undergoing stratification) on the forest floor during winter, and generally germinate in spring once the required temperatures are reached. The extremely low germination temperature (34^0F), high germinative capacity, and frequent good seed years facilitate abundant seedling crops. Early survival is enhanced by the vigorous development of a strong radicle (root) that has the strength and length to penetrate heavy leaf litter and reach mineral soil during the moist period in early spring (often under the snow). However, the young root system is rather shallow and fibrous, making seedlings sensitive to moisture stress and surface moisture conditions.

Seedlings are relatively slow growing. Some overstory shade (30-90% full sunlight) improves growth and survival of natural seedlings until 2-4 feet in height. Dense shade (<10% full sunlight) can result in poor growth and higher mortality. Full sunlight (>90%) also can result in poor growth and higher mortality due to moisture stress.

Sugar maple tree and stand growth rates can be expected to vary geographically and by site quality. Growth is somewhat slower than for most associated species, but relatively large sizes and old ages can be attained. Tree radial growth rates are strongly influenced by site quality, stand density, and tree age. In general, radial growth rates are greater on better sites, in less dense stands, and in younger stands. DBH growth rates can range from 1-4 inches per decade; 1 inch is typical for mature unmanaged stands, 1-2 inches is average for mature managed stands, 2-3 inches is the maximum measured for sawtimber trees, and 3-4 inches is the maximum for pole timber trees (Crow *et al.* 1981). In DBH, trees frequently reach 24 inches, older trees can reach 30-36 inches, while the maximum recorded is 84 inches. In general, throughout stand development, tree diameter growth continues at a decreasing rate

[1] Mostly from Burns and Honkala 1990 (Crow 1990; Erdmannn 1990; Godman *et al.* 1990; Schlesinger 1990; Tubbs and Houston 1990; Harlow 1991). More sylvicultural information on Table 40.1.

with increasing age and size. Height growth also slows with increasing age and becomes negligible at about 140-150 years. Trees average 12 inches/year height growth for their first 30-40 years of life. Sugar maple commonly attains 60-90 feet in height, older trees can reach 120 feet, while the maximum is 135 feet tall. Sugar maple trees can reach 300-400 years of age. In relict old growth forests the average age of canopy trees often ranges from 120-170 years, but trees 250-300 years old are common (Frelich and Lorimer 1991; Singer and Lorimer 1997; Lorimer 2001).

Stand basal area growth of 2.0-2.5 (ranges 1.5-3) ft^2/acre/year is typical for managed stands on average to better sites in the Lake States. Similarly, typical values for net volume growth are 60-90 ft^3/acre/year, and 200-300 (ranges 100-400) bdft/acre/year (Crow *et al.* 1981). Net growth equals mortality when basal area exceeds 125 sq.ft./acre in stands dominated by sugar maple (Hutchinson 1992). Example total yields from average, well-stocked stands of northern hardwood dominated by sugar maple on medium to good sites in the lake states are: 3,500 – 6,000 bdft/acre at 80 years, 7,000 – 11,000 bdft/acre at 120 years, 10,000 – 14,000 bdft/acre at 160 years, and 12,500 – 16,500 bdft/acre at 200 years.

1.2.2 Beech

In Wisconsin, beech is a minor species, representing less than 1% of the total net growing-stock volume on forest land (Schmidt 1997; Kotar *et al.* 1999; Kurtz *et al.* 2017). In Wisconsin, there are an estimated 18.5 million American beech 5 inches DBH or larger on forest land (Kurtz *et al.* 2017). Beech occurs only in the eastern quarter of the state, where it reaches its western range limit. Here, it occurs almost exclusively on mesic sites. Beech is moisture demanding, but intolerant of flooding.

Beech trees produce abundant viable seed every 2-8 years (the flowers are susceptible to damage by spring frosts). Seed are dispersed in the fall after the first heavy frosts, lie dormant (undergoing stratification) on the forest floor during winter, and generally germinate in spring to summer once the preferred temperatures are reached. Early survival is enhanced by the vigorous development of a strong radical (root) that has the strength and length to penetrate heavy leaf litter and reach mineral soil. However, seedlings are sensitive to moisture stress and surface moisture conditions.

Beech trees less than 4 inches DBH can produce vigorous and successful stump sprouts. Beech can also produce abundant root sprouts (suckers), and this can be an important mode of regeneration. Suckering is stimulated primarily by injury to the roots. Beech limbs can root when layered. Root grafting among beech trees is common.

Beech is very tolerant of shade, similar to sugar maple. Seedlings are slow growing, shallow rooted, and susceptible to desiccation. Best growth and survival are demonstrated under moderate shade (partial canopies and small, protected openings). In dense shade, seedlings can be abundant, but growth is slow (e.g., 2 feet tall at 10 years and 5 feet at 20 years). In full sunlight, growth and survival are poor. Seedlings are seldom severely browsed by deer.

Beech is a slow growing, long-lived species. Site index is lower than for any of its hardwood associates in the Lake States. Average diameter growth rates for pole and small sawtimber trees typically range from 0.8 inches/decade in unmanaged forests, to 1.7 inches/decade in managed forests, to 2.6 inches/decade in relatively open-grown conditions. Typically (within natural range), beech trees grow to 60-90 feet tall and 2 feet DBH. The maximum dimensions recorded within its range are 161 feet tall and 6 feet DBH. Trees can attain ages of 300-400 years.

1.2.3 Basswood

In Wisconsin, basswood has the seventh greatest net growing stock volume of all tree species; over 1 billion cubic feet on forest land estimated by the 2017 forest inventory and analysis (Kurtz *et al.* 2017). Since 2004, basswood sawtimber net volume has increased by 37% and growing stock by 17% since 2000-2004. Basswood is known to improve soil fertility; the leaves contain high levels of calcium, magnesium, nitrogen, and potassium.

Basswood trees produce abundant seed every 1-2 years. Seed are dispersed in the fall, and usually fall within 1-2 tree lengths of the parent tree. The seed lie dormant requiring both scarification and cold stratification to break dormancy. Seed viability is poor; common problems are parthenocarpy (production of fruit without seed), insects, rodents, and rotting of seed. In a study in northern Wisconsin, only 2 percent of the identifiable seed found in the litter were sound (Godman and Mattson 1976). In some situations, viable seed can lie on the ground for over five years (if not damaged) without germinating while still maintaining viability.

Basswood is a prolific stump sprouter. Most trees less than 4 inches DBH and more than half of sawtimber trees will produce vigorous stump sprouts. Sprout regeneration can be managed for sawtimber, but early thinning of sprouts is needed to promote rapid growth and quality development. It is recommended to thin sprout clumps to 1-2 stems before they reach 10 years of age.

Basswood is tolerant of shade, but less so than sugar maple, beech, and hemlock. Shading influences seedling growth and survival. Partial shading aids seedling establishment and early survival, but heavy shade will limit growth and development. Once established, seedlings grow most vigorously in full sunlight. Basswood is able to maintain itself as an associate in late successional forests and in managed uneven-aged forests primarily through vigorous sprouting and rapid sprout growth. This sprouting ability also facilitates maintenance under even-aged management systems.

Basswood is a large, rapidly growing tree. Within its range, it typically grows to 70-130 feet tall. It often reaches a DBH of 24-48 inches. The maximum dimensions recorded within its range are 140 feet tall and 7 feet diameter. Basswood grows faster than most of the other northern hardwood species. On a given site, basswood often exceeds sugar maple, beech, and yellow birch in site index by 5-10 feet. Tree radial growth rates are strongly influenced by site quality, stand density, and tree age. In comparison to unmanaged stands, basswood radial growth rates have been nearly doubled by applying crop tree release and moderate single-tree selection cuts. “Relatively narrow bark ridges and V-shaped fissures, with new light-colored inner bark visible in the fissures, represent a high-vigor basswood. In contrast, low-vigor trees have scaly bark with wide bark ridges and shallow, short fissures, frequently producing a rather smooth surface" (Burns and Honkala 1990). Basswood trees can reach more than 200 years of age.

1.2.4 White Ash

In Wisconsin, white and green ash together represent nearly 4% of the total net growing-stock volume on forest land (Kurtz *et al.* 2017). Since 2009, white ash has increased 12% in net volume and 78% in sawtimber volume since 2004. White ash typically grows as an associate in other forest cover types, and only rarely as a dominant. With the impacts from Emerald Ash Borer on the ash resource, it is expected that the ash representation in the state to decline.

White ash trees produce abundant and moderately viable seed every 3-5 years; flower crops can be predictive of seed crops. Seed are wind dispersed up to 460 feet in fall to early winter. The seed lay dormant (requiring moist, cool stratification) on the forest floor during winter. Germination usually occurs in spring to summer, but some seed may delay germination for 2-3 years.

White ash is shade tolerant when young, but intermediate when older. In dense shade, seedlings can survive for several years, but exhibit minimal growth. Seedlings can be abundant in the understory of northern hardwood stands, but generally do not grow into the overstory unless a canopy gap that provides increased light is created. Advanced regeneration can quickly capture newly formed canopy gaps. About 45% of full sunlight provides ideal conditions for early growth and development. Partial shade provides ideal conditions for seedling establishment, but once established increased sunlight provides for optimal development and vigorous growth.

White ash grows faster than most of the other northern hardwood species. On a given site, it often exceeds sugar maple, beech, and yellow birch in site index by 3-10 feet.

White ash is a rapidly growing tree that exhibits strong apical dominance. In height, it typically grows to 70-90 feet, but the maximum recorded within its range is 125 feet tall. In diameter, older trees can reach 24-36 inches DBH, while the maximum recorded is 84 inches.

1.2.5 Yellow Birch

In Wisconsin, yellow birch represents only about 1% of total net growing-stock volume on forest land (Kurtz *et al.* 2017). Net growing stock volume of yellow birch has decreased on timberland by 1% since 2000-2004 on forest land and by 4% since 1996 on timberland (Kurtz *et al.* 2017). It typically grows as an associate in other forest cover types, and only occasionally as a compositional dominant.

The successful germination of yellow birch seed and the establishment of abundant and vigorous seedlings depend on an adequate seed supply, favorable weather, a proper seedbed, adequate light, and control of competition. Yellow birch trees produce abundant seed every 2-3 years. Seed are wind dispersed in fall to winter. Most seed lands within 330 feet of the parent tree, but some seed can be blown across the snow up to 1300 feet or more. Seed viability is highly variable and germinative capacity generally is low. Seed problems include parthenocarpy (fruit without seed), hard frosts, insects, and disease. Pre-chilling and light can improve germination. Germination requires moisture and warm temperatures, and typically occurs around early June. Seedlings also require an adequate and consistent supply of moisture and are susceptible to moisture stress. The optimal seedbed is disturbed and moist humus or mixed humus mineral soil with minimal competition. In undisturbed stands, favorable seedbeds include decaying wood (mossy logs, rotten stumps), windthrown hummocks, and even cracks in boulders. Yellow birch also can colonize sites with moist mineral soil following disturbance by catastrophic fire, logging, and blowdowns. On undisturbed forest floors, yellow birch radicals cannot pierce the hardwood leaf litter and the seedlings become susceptible to desiccation. Yellow birch benefits from soil disturbance and requires openings in the canopy.

Yellow birch is intermediate in shade tolerance and is a gap phase species. The optimal light level for seedling development and growth is approximately 50% full sunlight. After 5 years of age, yellow birch grows and develops best in full overhead sunlight. Yellow birch cannot compete with sugar maple under dense forest canopies.

Yellow birch is a slow growing, long-lived species. Average site index at age 50 years is 55-65. Growth rates tend to decline as trees age. Diameter growth of less than 1 inch/decade is common in unmanaged stands and in managed uneven-aged single-tree selection stands. Overhead light and crown expansion space facilitate growth and vigor. Release and thinning can significantly improve growth rates. Crop tree release can improve diameter growth up to 3 inches per decade in saplings, and diameter growth of 75% in poletimber, and 45% in sawtimber. Under intensive even-aged management, 18-inch trees can be grown in less than 90 years. Typically, yellow birch trees grow to 70-100 feet tall and 24-30 inches DBH. Maximums measured within its range are 114 feet tall and 60 inches DBH. In unmanaged forests, most growth (height and diameter) is completed by 120-150 years of age. Yellow birch trees commonly reach 300 years old and can surpass 350 years.

Table 40.1. Summary of selected silvical characteristics.

	Sugar Maple	Beech	Basswood	White Ash	Yellow Birch
Flowers	March-May Polygamous	April-May Monoecious	June (May-July) Perfect	April-May Dioecious	Pistillate catkins May (Apr.-June) Monoecious
Fruit Ripens	Sept.-Oct. 1(2) seeded double samara	Sept.-Nov. 2(3) Nuts/Bur	Sept.-Oct. 1(2) seeded Nutlike drupe	Sept.-Nov. 1 seeded Samara	August-Sept. Strobile
No. of seeds/lb	7000 samaras/lb	1600 seed/lb	5000 seed/lb	10,000 seed/lb	450,000 seed/lb
Seed Dispersal	Fall to early winter. Wind dispersed up to 330 feet.	Fall. Near tree. Jays, rodents, and gravity can enhance dispersal.	Fall. Wind and gravity rarely disperse seed more than 1-2 tree lengths.	Fall to early winter. Wind dispersed up to 460 feet.	Fall to winter. Wind dispersed up to 300-1300 feet or more.
Good Seed Years	Every 1-5 years	Every 2-8 years	Every 1-2 years	Every 3-5 years	Every 2-3 years
Seed Bearing Age	20 years – minimum; 40-60 years – light crops; 70-100 years – moderate crops; >100 years – heavy crops.	Good crops by 40 years; abundant by 60 years.	Generally, 15-100 years.	20 years minimum. Good crops usually begin at about 30-40 years.	Generally, 30-40 years is minimum, and 70 years begins optimum.
Seed Viability	Prolific seeder. High viability. On forest floor doesn't remain viable beyond first year.	High viability.	Poor viability. Impermeable seed coat. Can remain viable on forest floor >5 years.	Moderate viability.	Prolific seeder. Viability highly variable; generally poor; usually best in good seed years.
Germination	Pronounced dormancy, requiring 1-3 months stratification. Spring; best at 34^0F; poor at $>50^0$F.	Pronounced dormancy, requiring stratification. Spring to early summer; best at 59^0F.	Pronounced dormancy, requiring 3-4 months stratification. Requires scarification. Spring to summer; best at 68^0F.	Pronounced dormancy, requiring 2-3 months stratification. Spring to summer; best at 84^0F.	Typically June; requires moisture and warm temperatures; best at 60-85^0F.
Seedbed Requirements	Moist undisturbed leaf litter, humus, or	Moist undisturbed leaf litter, humus, or	Moist with variable substrate	Moist leaf litter, humus, or mineral soil.	Disturbed and moist humus or mixed humus mineral

	Sugar Maple	Beech	Basswood	White Ash	Yellow Birch
	mineral soil; often under snow.	mineral soil; poor on wet sites.			soil with minimal competition. Also, moist mineral soil, decaying wood, and cracks in boulders.
Vegetative Reproduction	Seedlings sprout readily. Stump sprouts decrease with increasing tree size.	Seedlings and saplings produce vigorous stump sprouts. Prolific root sprouter. Also layers.	Wide range of diameter classes produce prolific and vigorous stump sprouts.	Seedlings and saplings produce vigorous stump sprouts.	Seedlings and saplings produce vigorous sprouts. Larger stems sprout poorly.
Seedling development	Best growth when light levels are 30-90% full sunlight. Dense shade or full sunlight can result in poorer growth and higher mortality. Sensitive to moisture stress.	Moderate shade facilitates best survival and growth. Dense shade slows growth. Full sunlight results in poor growth and survival. Sensitive to moisture stress.	Partial shade facilitates initial survival and establishment. Dense shade limits growth. Once established, (nearly) full sunlight facilitates vigorous growth.	Establishment and early growth best at about 50% full sunlight. Dense shade limits growth. Once established, (nearly) full sunlight facilitates vigorous growth.	Establishment, growth, and development best at about 50% full sunlight. Dense shade limits growth. Sensitive to moisture stress.
Shade Tolerance	Very tolerant. Good survival and response to release.	Very tolerant. Good survival and response to release.	Tolerant.	Tolerant when young, then becoming intermediate.	Intermediate.
Maximum Longevity	300-400 years	300-400 years	200-250 years	250-300 years	300-400 years

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Landowner goals and management objectives should be identified in a sustainable forest management framework, with consideration to the local and regional landscape. Prior to the development and implementation of silvicultural prescriptions, landowner goals and objectives need to be clearly defined and management units (stands) must be accurately assessed.

The silvicultural systems described are designed to promote the balance of quality and quantity in northern hardwood stands. These silvicultural systems may be modified to satisfy other management objectives, but vigor, growth and stem quality could potentially be reduced.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.1 Landscape Considerations

The northern hardwood and hemlock-hardwood forest types were historically the 'matrix' communities (the most abundant and connected forest communities) of the northern Wisconsin landscape. Although northern hardwood forests are still abundant and widespread, they have undergone many changes during the past century. Considerations are related to the loss, simplification, and fragmentation of forested land, and other human-induced changes in ecosystem structure or function.

Management Recommendations at the Landscape Level

- Consider landscape composition and structure, including species composition; successional and developmental stage; age structure; stand/patch size; type, intensity, and pattern of fragmentation; habitat diversity; NTMB populations and habitat needs; and common/uncommon management techniques.
- Increase the representation of hemlock, yellow birch, basswood, and white pine.
- Increase structural diversity within stands (i.e., large trees, large cavity trees, large snags, large downed woody debris, and variable gap sizes).
- Manage larger stands where it is possible to coalesce adjacent northern hardwood or hemlock-hardwood stands.
- Increase the representation of large patches of older uneven-aged forest.
- Increase the representation of older trees and stands and later developmental stages (i.e., old forest and old-growth).
- Apply a variety of management techniques, including old-growth reserves, managed old forests, extended rotations, uneven-aged management, even-aged management, and the maintenance of reserve trees.
- Apply adaptive uneven-aged management that considers variability in application, including gap size and distribution, diameter distribution, cutting cycle, coarse woody debris management, and reserve tree management.
- Favor uneven-aged management (with even-aged patches), to increase and manage diversity within the northern hardwood forest type.
- Control deer and limit herbivory.
- Limit permanent fragmentation caused by development (e.g., roads and landings).

3.1.1 Historical Context

When the General Land Office Public Land Surveys (PLS) were conducted in Wisconsin (1832-1866), forests dominated by northern hardwood and hemlock-hardwood covered about 15.2 million acres (43.7% of the state) (Frelich 1995). Schulte *et al.* (2002) conducted a quantitative analysis of PLS data and found that these forest types were dominant on 42-46% of forested area in northern Wisconsin. Across the landscape, these forests existed with all age-classes and developmental stages represented, but older age-classes and advanced developmental stages were dominant. Frelich (1995) estimated that 89% of the northern hardwood forest was 120 years old or older. Old forests featured multi-layered canopies, large quantities of dead wood, trees with cavities and broken branches and trunks, and tip-up mounds on the forest floor.

Northern hardwood forests historically contained a large component of hemlock. Within its range in northern Wisconsin, hemlock made up about 21% of basal area (based on GLO data) and was the most common tree species in many areas. Yellow birch was typically the second-most dominant tree, with sugar maple ranking third. Basswood, ironwood, and white pine were other common associates of the historic forest. Hemlock still exists as a component of the northern hardwood forests but is greatly reduced from levels found in the 1800s. FIA data show that it currently makes up about 3% of basal area in the northern forest (Schmidt 1997).

Wind disturbance was the primary factor in regenerating northern hardwood forests. Wind disturbance occurred mostly as small and medium-sized gaps that may have impacted 5.7 to 8.5 percent of the northern hardwood and hemlock-hardwood forests during a decade (Frelich and Lorimer 1991; Dahir and Lorimer 1996). Most canopy gaps were small (<0.1 acre), created by windthrow of one to a few large trees. Moderate intensity disturbances are defined as those that removed 30-50% of the forest canopy in a decade (Craig Lorimer, pers. comm., 2006). These disturbances occurred at average return intervals of 325 to 410 years; heavier disturbances were associated with longer return intervals. Moderate intensity disturbances were likely responsible for creating much of the cohort structure observed in old growth forests (Bourdo, E. A. 1983; Loucks 1983; Frelich and Lorimer 1991). Gap expansion processes, competition for soil moisture and nutrients (Loucks 1983), and drought events may have also contributed to development of cohorts. Catastrophic windthrows may have impacted about an additional 0.7 percent of the forest each decade on average (Canham and Loucks 1984). Wind disturbance is less of an impact in today's younger and less structurally diverse forests. Small canopy gaps are now being created in some locations through adaptive silvicultural techniques but are still thought to be relatively scarce. A lack of small gaps can impact some species of concern, like the Canada warbler.

Fire is known to have occasionally followed windthrow in the historic northern hardwood forests. Fire would have been more likely to impact northern hardwood forests that bordered fire-prone conifer forests or grasslands. The interiors of northern hardwood and hemlock-hardwood forests were, and still are, quite fire-resistant due to their mesic nature. Roth and Fernow (1898) noted that on loam and clay lands, “where the heavy hard woods and Hemlock predominate... the ground and litter is usually damp. Fires run only during exceptionally dry seasons.” Fire is also a factor that historically limited northern hardwood forests from expanding onto more xeric sites, or in some cases, onto otherwise suitable sites that were frequently impacted by fires originating in adjacent areas.

There are many questions about the effects of Cutover-era fires in northern hardwood forests. Land managers have noted that some lower-quality hardwood sites appear to be degraded and have speculated that past fires played a role. There is little information on exact locations or intensity of fires in northern hardwood; however, the overall impact can be partially deduced from historic writings. Roth and Fernow (1898) describes conditions in northern counties at that time, noting that hemlock-hardwood forests suffered fire damage where pine “slashings” caught fire. White pine was a large component of many hemlock-hardwood forests. It was typically cut selectively with considerable damage to the remaining timber, much of which died and created fuel loads in addition to the pine slash, thus allowing fire to carry into the hardwood forest. Hardwood adjacent to cutover pineries were also more likely to burn. Areas that were further away from pineries, with less of a white pine component, escaped heavy fire damage. By 1900, fires were less frequent because nearly all the pines had been cut, and fire suppression programs were developing (although not fully in place until the late 1920's).

Northern hardwood was the last forest type to be heavily logged during the Cutover. Hemlock and hardwood were harvested between about 1900 and 1930, usually by clearcutting or high-grading. These forests were initially accessed for hemlock bark, which was peeled in the woods during the spring and early summer and shipped to tanneries. The hemlock logs were generally used for lumber or pulp, although some were left to rot in the woods when demand was low or were used as fill beneath railroads. After a stand was accessed for hemlock bark, removal of hardwood soon followed, often during the following winter (Corrigan 1978). Selective logging began in the 1920s, and although much of this was high-grading, some longer term sustained-yield management also emerged.

FIA records show that northern hardwood forests have been increasing in extent during the past several decades. In 1968, the maple-basswood forest type group occurred on about 3.5 million acres; in 1983 it occupied about 4.1 million acres, and by 1996 had increased to about 5.3 million acres (Schmidt 1997). Although northern hardwood forests are occupying increasingly larger areas, they are still considerably reduced in extent from historic times, and their structure and diversity have been greatly changed.

3.1.2 Current Context

Age-Class Distribution

Maintaining a desirable age-class distribution is a landscape-level consideration. A relatively stable age class structure, including all developmental stages, maximizes benefits to wildlife by providing a range of structural conditions. It also contributes to diversified economic interests by supplying different types of materials, including pulp, poles, sawlogs, and veneer. The average age of northern hardwood forests in Wisconsin increased between 1983 and 1996 because of increased acreage in the middle classes. However, acreage occupied by the oldest age classes decreased during this time period.

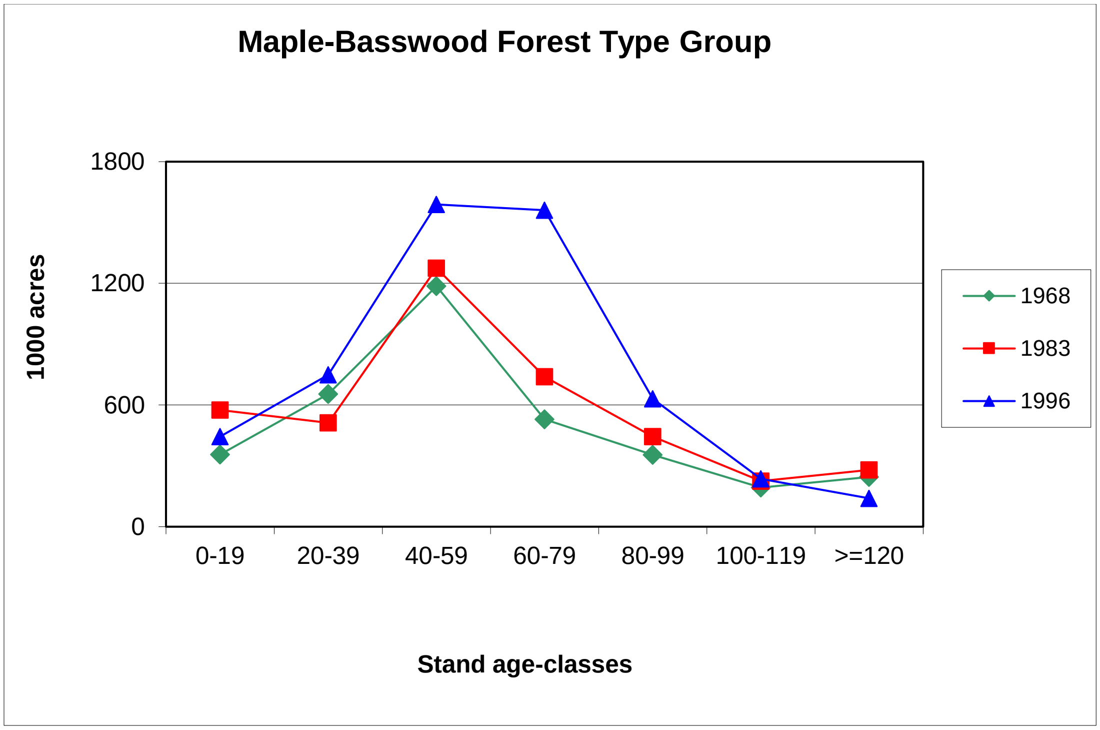


Figure 40.1. Forest age-class distribution for the maple-basswood cover type in Wisconsin, from FIA measurements taken in 1968, 1983, and 1996 (1000 acres).

3.1.3 Forest Simplification

Forest simplification refers to a loss of species diversity and structural diversity, and an increased dominance of fewer species. The increase in sugar maple dominance that is occurring in northern hardwood forests is an example of simplification, as is the lack of features like large woody debris and tip-up mounds. Sugar maple is outcompeting conifers and other species that were common in the historic forests. Regeneration of hemlock and yellow birch are problematic in many cases, and basswood is also decreasing in abundance. Strict application of the single-tree selection method is probably a factor that increases sugar maple's dominance (Crow *et al.* 2002). White-tailed deer herbivory can give sugar maple a competitive advantage (Anderson and Loucks 1979; Frelich and Lorimer 1985), contribute to declines in some native plant species, and lead to homogenization of species composition among sites (Rooney *et al.* 2004). The northern hardwood forests have lost most of their Canada yew, a formerly widespread evergreen shrub that provided structural diversity. These changes occur at the stand level but have cumulative effects at broader spatial scales.

At the landscape level, simplification and homogenization occur when forested patches become similar in size, shape, and composition. Land uses have led to homogenization and reduction of patch sizes, and creation of patch shapes that are less complex (Mladenoff *et al.* 1993). The cumulative effects of stand-level simplification make composition similar among patches. This is unlike the mosaic of forest patches found in remnant old growth hemlock-hardwood forests, where some are dominated by hemlock, some by sugar maple, and some a mixture of the two (Crow *et al*. 2002).

3.1.4 Fragmentation and Edge Effects

Fragmentation effects have been described in the Aspen Chapter and are also a landscape-level consideration in northern hardwood management. Even-aged management in northern hardwood forests has effects beyond the immediate area, bringing increased light and heat into the adjacent forest and attracting a different suite of species. Some of the species attracted to open and early successional forest patches compete with or prey upon species characteristic of interior northern hardwood forests.

Fragmentation is a term used to describe certain kinds of landscape structure. “Inherent fragmentation” describes landscapes that are naturally heterogenous due to characteristics of the physical environment, such as an area with numerous small lakes and wetlands dispersed throughout a pitted outwash plain. “Permanent fragmentation” refers to long-term conversion of forest to urban, residential, or agricultural uses. Roads can also create permanent fragmentation. “Habitat fragmentation” is defined as a disruption of habitat continuity, caused by human (e.g., tree cutting) or natural disturbance, creating a mosaic of successional stages within a forested tract. This kind of fragmentation is a shorter-term effect on species, and at a site level, impacts them during the time it takes for the forest to regrow. At a landscape scale, the aggregated amount and continuing nature of human disturbance may result in relatively high levels of habitat fragmentation.

In Wisconsin and elsewhere, the loss of forest habitat has a larger impact on species than shorter-term habitat fragmentation. Habitat loss is often correlated with measures of fragmentation (e.g., patch size, distance between patches, cumulative length of patch edges, etc.), making it difficult to quantify their separate effects. Habitat loss may result from second homes, utility or transportation corridors, and urban or industrial expansion. A drastic change in land cover, such as that which occurs after a clearcut harvest, represents a short-term loss of habitat for some species and a gain for others. Dispersal can be affected if species or their propagules cannot cross or get around the open land, find suitable habitat within it, or successfully compete with disturbance-adapted species.

Some species are "area-sensitive", requiring large patches of relatively homogenous habitat. The American marten and Northern Goshawk are examples of species that utilize larger areas of older northern hardwood forest.

3.1.5 Summary of Landscape Considerations

When deciding whether to actively manage a northern hardwood stand, and if so, which silvicultural practices to apply, consider the following factors:

- What are the characteristics of the broader-scaled ecological unit (LTA or Subsection) around the stand?
- Is the ecological unit already fragmented by either habitat or permanent fragmentation or by inherent fragmentation (a heterogenous landscape that contains a wide variety of habitat types, wetlands, and/or water bodies)?
- In even-aged management, are there opportunities to aggregate individual cuts to reduce the overall amount of edge?

- Are there NTMB's of concern in the surrounding LTA, which ones are they, and how is the proposed management likely to affect them?
- Is the area around the stand a large patch of older northern hardwood forest? Large forest patches with older age-class structure are scarce and managing for interior NTMB's may be an important consideration.
- What kinds of silvicultural techniques have been commonly applied in the surrounding LTA or Subsection in recent years, and are there techniques that may be beneficial in creating underrepresented kinds of forest structure?
- How much of the landscape has been harvested recently? Are there sufficient amounts of closed-canopy, interior forest habitat available for interior forest NTMB's and other area-sensitive species?
- Consider emulating gap-phase windthrow in selection management of uneven-aged northern hardwood.
- Are there issues with herbivory in the vicinity (e.g., lack of regeneration of hemlock, yellow birch, or Canada yew; excessive browsing of lilies and orchids)? If so, consider fencing or large block management to reduce deer impacts.
- What is the age class distribution of northern hardwood in the broader-scaled ecological unit? Are there opportunities for providing a scarce successional stage?
- Are there opportunities for fencing to help restore understory and shrub components?
- Are there opportunities for increasing components of hemlock, yellow birch, or basswood?

3.2 Site and Stand Considerations

3.2.1 Soils

The northern hardwood cover type develops and grows best on mesic sites with well drained to moderately well drained loamy soils; the very best soils are deep, well drained, silt loams. However, it occurs on a wide range of soil conditions, from well drained to somewhat poorly drained and from sands to clays. Dry, excessively drained sands and wet, poorly drained soils generally do not support the development of northern hardwood stands. Soil pH can range from 3.7 to 7.3, but a pH between 5.5 and 7.3 is most common.

Northern hardwood frequently occur on finer textured soils on which vehicle travel can result in soil compaction. Soil compaction and rutting have been shown to decrease seedling and sapling growth in many forest types although specific effects depend on soil type and moisture content (NCASI 2004). The total area devoted to landings, roads, and trails should be minimized to limit the loss of productive area. Pre-planned skidding routes and landing areas should be used to limit the total area affected by vehicle travel and skid trails should be re-used in future entries wherever possible. Road layout guidance such as that found in the Wisconsin Forest Management Guidelines (WDNR 2003) should be used to minimize impact on hydrology and limit erosion and sedimentation. Harvesting when the soil is frozen or dry can reduce compaction. Increasing the interval for re-entry into stands may partially mitigate the effects and reduce the occurrence of compaction and rutting, although soil compaction is not readily ameliorated and effects can persist for several decades (NCASI 2004).

Impacts of Equipment and Infrastructure
The cumulative effects of infrastructure development and soil compaction in forests have been studied in other parts of the country and found to be correlated with changes in hydrologic regimes, surface drainage patterns, and soil moisture. The negative ecological effects of soil compaction and rutting, and of forest roads, are well known at fine scales, but these issues have not been studied in an integrated fashion on larger landscapes in our area. Roads and utility corridors have been implicated in the spread of non-native invasive plants. They also act as barriers to the movement of some species, create fragmentation and edge, and can attract human disturbances.

3.2.2 Site Quality

Assessing site productivity can be achieved through the evaluation of the Forest Habitat Type Classification System (FHTCS), soil site analysis, or through determination of site index. The FHTCS provides qualitative site productivity assessment and limited quantitative productivity data. The use of the FHTCS is limited to the period of active understory vegetation growth. Habitat types may be estimated during non-growing seasons using correlation with soil types and landforms, but these methods are less accurate than direct field determination. Broad-scale quantitative site productivity correlation with FHTCS is available through analysis of Wisconsin FIA data (Kotar *et al.* 1999). For more detailed discussion on FHTCS see Ch. 12.

Accurate assessment of site index is another method of determining site productivity. Site index and stand age determinations are important factors in even-aged management of northern hardwood. Northern hardwood present challenges for accurate site index determination because of the difficulty in reading increment cores from diffuse porous species and in determining trees that were not previously suppressed. More precise determination of tree age, height, and site index may be accomplished through felling of representative trees (USDA 2005). Additional discussion on site index considerations and proper measurement can be found in Chapter 11.

3.2.2.1 Range of Habitat Types

The northern hardwood cover type currently is much more common in northern than in southern Wisconsin. About 89% of sugar maple net growing stock volume occurred within the northern habitat type groups. For the other northern hardwood, 94% of yellow birch volume, 74% of basswood volume, 73% of beech volume, and 57% of white/green ash volume occurred within the northern habitat type groups (FIA 2016).

Northern Wisconsin Habitat Types
In northern Wisconsin, the occurrence and relative growth potential of the northern hardwood cover type, and of the individual species comprising the type, vary by habitat type groups and habitat types.

The northern hardwood cover type is currently the predominant cover type occurring on mesic sites in northern Wisconsin. It is of common occurrence on the dry-mesic and the mesic to wet-mesic habitat type groups. It generally does not develop on the very dry to dry, dry to dry-mesic, and wet-mesic to wet groups (Table 40.2 and Table 40.3).

Table 40.2. Northern hardwood tree species – estimated relative occurrence by northern habitat type group.

Northern Habitat Type Groups	Estimated Current Relative Occurrence for NH Species				
	Sugar Maple	Beech[1]	Basswood	White/Green Ash	Yellow Birch
Very Dry to Dry	*	*	*	*	*
Dry to Dry-mesic	*	*	*	*	*
Dry-mesic	***	*	***	**	*
Mesic	****	**	***	**	**
Mesic to Wet-mesic	***	*	***	**	**
Wet-mesic to Wet	*	*	**	**	**

**** Major Dominant, *** Major Associate, ** Minor Associate, * Rarely Occurs (or does not occur)
1 – Beech occurs only in extreme eastern Wisconsin

Table 40.3. Northern hardwood cover type – estimated relative growth potential by northern habitat type group and habitat type.

Northern Habitat Type Groups	Estimated Relative Growth Potential for NH Cover Type				
	None to Very Poor	Poor	Fair	Good	Excellent
Very Dry to Dry	PQE PQG PQGCe PArV PArV-U PArVAo QAp				
Dry to Dry-mesic	PArVHa PArVAm PArVAa PArVAa-Vb PArVAa-Po PArVPo				
Dry-mesic		TFAa AVCl AVVb AVDe AVb-V	ACl AVb AAt ATFPo		
Mesic				AFVb ATM ATFD ATFSt	AAs ATD ATDH AHVb AFAd AFAl ACaCi AOCa AH
Mesic to	PArVRh		ArAbCo	ATAtOn	

Wet-mesic	ArAbVC ArAbVCo ArVRp ArAbSn		TMC ASnMi AAtRp	ASaI ACaI AHI	
Wet-mesic to Wet	All Sites (no habitat types)				

Southern Wisconsin Habitat Types

In southern Wisconsin, the occurrence and relative growth potential of the northern hardwood cover type, and of the individual species comprising the type, vary by habitat type groups and habitat types.

The northern hardwood cover type currently is common (along with central hardwood and oak cover types) only on mesic sites in southern Wisconsin. It is a relatively uncommon cover type, but potentially can develop and become more common, within the dry-mesic, dry-mesic to mesic, dry-mesic to mesic (phase), mesic (phase), and mesic to wet-mesic habitat type groups. It generally does not develop on the dry and wet-mesic to wet groups (Table 40.4 and Table 40.5).

Table 40.4. Northern hardwood tree species – estimated current relative occurrence by southern habitat type group.

Southern Habitat Type Groups	**Estimated Current Relative Occurrence for NH Species**				
	Sugar Maple	Beech[1]	Basswood	White/Green Ash	Yellow Birch
Dry	*	*	*	*	*
Dry-mesic	**	*	**	**	*
Dry-mesic to Mesic	***	*	***	***	*
Dry-mesic to Mesic (phase)	**	*	**	**	*
Mesic (phase)	**	*	**	**	*
Mesic	****	**	****	***	**
Mesic to Wet-mesic[2]	*	*	***	***	**
Wet-mesic to Wet[2]	*	*	**	***	*

**** Common Codominant, *** Major Associate, ** Minor Associate, * Rarely Occurs (or does not occur)

1 – Beech occurs only in extreme eastern Wisconsin

2 – All sites – Habitat types not defined

Table 40.5. Northern hardwood cover type – estimated relative growth potential by southern habitat type group and habitat type.

Southern Habitat Type Groups	Estimated Relative Growth Potential for NH Cover Type			
	None to Poor	Fair	Good	Excellent
Dry	PEu PVGy PVG PVCr PVHa			
Dry-mesic	ArDe-V ArDe	AQVb-Gr ArCi ArCi-Ph AArVb AArL		
Dry-mesic to Mesic			AFrDe AFrDeO ATiFrCi ATiFrVb ATiDe ATiDe-Ha ATiDe-As	
Dry-mesic to Mesic (phase)			AFrDe(Vb) ATiFrVb(Cr) ATiCr(O) ATiCr(As) ATiDe(Pr)	
Mesic (phase)			ATiFrCa(O)	ATiAs(De)
Mesic			ATiSa-De ATiSa	ATTr AFTD AFH ATiFrCa ATiCa-La ATiCa-Al ATiCa ATiH AFAs-O AFAs
Mesic to Wet-mesic	PVRh			

3.2.3 Interfering Vegetation

The presence of native species such as Pennsylvania sedge (*Carex pennsylvanica*), ironwood (*Ostrya virginiana*), and other woody and herbaceous competitors can provide unique challenges when attempting to establish desirable northern hardwood regeneration. Research in the Lakes states has documented these species as a difficult challenge in managing this cover type. The abundance of these competitors is influenced by factors such as herbivory, past land use (grazing), earthworm infestation and other site characteristics. Treatment and management of such stands must begin with a thorough assessment of stand conditions including sedge coverage (%), regeneration, browse severity, and any other factors that may be a cause of inadequate regeneration establishment. The following is a summary of recommendations for treatment of sedge and ironwood based on trials and research conducted in the region.

Sedge Competition and Management: Pennsylvania sedge is considered interfering if it covers more than 30% of a stand's understory (Marquis 1986). It commonly establishes on disturbed sites through rigorous rhizome growth creating a relatively continuous ground cover, inhibiting seedling establishment and development. In spring, Pennsylvania sedge is one of the earliest *Carex* species to flower, making it easier to identify.

Several Wisconsin and Michigan field trials to control Pennsylvania sedge have been documented. Each method has attributes that must be considered in relation to goals and objectives for each stand (Table 40.6). Based on Wisconsin trials, Pennsylvania sedge treatment applied just before or after a regeneration harvest provides the best opportunity for regeneration success, especially when timed with good sugar maple seed crop. Emphasis should be placed on treating only portions of the stand where regeneration is desired. This minimizes treatment cost, reduces overall stand disturbance, and may increase the long-term success of the treatment. Stand wide treatments may be necessary based on other factors such as high deer numbers and the natural regeneration system employed. Stand wide applications in areas with high deer numbers may produce and saturate the area with high quality food, thus allowing some tree regeneration to overcome browsing (Randall 2005). In addition, utilizing lower residual basal areas 50-60ft/acre and "cribbing" by leaving tops may also allow tree regeneration to quickly grow past browse height.

Based on the Wisconsin and Michigan field trials, the most effective methods to control sedge are:

- Foliar herbicide application
- Foliar herbicide application/scarification
- Scarification

Foliar Herbicide Application: The intent of a foliar herbicide application is to set back sedge mats and prepare a seedbed for other native plant species and tree regeneration. Careful evaluation and planning should be done to ensure that the benefits outweigh the costs, economic and ecological.

Foliar herbicide applications should occur after spring ephemerals return to dormancy and other vegetation is fully grown, through the end of the growing season. Applications just after leaf-off have shown to have inconsistent results. When successful, foliar herbicide applications have been shown to adequately control sedge and have very little effect on non-target species. Applications have been successful at providing Pennsylvania sedge control for 3-4 years. Examples of such treatments can be found at the WI DNR silvicultural trials web page (WDNR 2018).

Foliar Herbicide Application & Soil Scarification: Combining soil scarification with an herbicide application is recommended if regeneration is also a management goal. This can be especially beneficial for light seeded species such as yellow birch. Scarification is best conducted using a straight blade, salmon blade or root rake mounted on a dozer to scrap the treated sedge at away exposing mineral soil. An important consideration is to plan the scarification and herbicide application accordingly. Typically, herbicide applications need to occur a week or more prior to scarification. It may also be advantageous to apply a pre-emergent herbicide after scarification if sedge re-establishment is a concern. This application is typically best suited for canopy gaps, group & patch applications.

Soil Scarification: The use of scarification to control sedge should be reserved for sites with sensitive species that require additional protection or properties where herbicide application is restricted. This recommendation is based on past applications that have shown scarification provides adequate canopy gap control approximately 30% of the time and often encourages establishment of noxious weeds (WDNR 2003). Scarification is best conducted using a dozer/blade to scrap the sedge mat away exposing mineral soil. The goal of scarification is to break up the sedge mat to provide exposed mineral soil for 2-3 growing seasons. This method is best suited to canopy gaps, groups, and patches or wherever regeneration is desired.

Table 40.6. Sedge control method comparison.

Treatment	Overall Effectiveness (WDNR 2002)	Summer Application	Fall Application	>2-year control	Stand Application	Group / Patch	Shelterwood	Woody Control Needed
Herbicide Foliar	81%	R	C	R	R	R	R	C
Foliar Herbicide & Scarification	60 %	R	C	C	C	R	R	R
Scarification	30%	R	R	N	N	R	C	R

R = Recommended; C = Conditionally recommended (See sedge & ironwood management for more detail); N= Not Recommended Note, prescribed fire is not recommended for Pennsylvania sedge control due to poor effectiveness (WDNR 2003).

Ironwood Competition and Management: The treatment of ironwood and other similar woody species can be especially difficult due to their ability to regenerate after a disturbance. Ironwood and other (undesirable) woody plants are considered interfering if there are more than eight stems of any size found within a 1/385 ac plot (6’ radius) (Marquis 1986). Several methods to control ironwood have been documented in the literature and local trials. Each method has positive and negative attributes that must be considered in relation to the landowner objectives and silvicultural goals for each stand (Table 40.7). It is also necessary to evaluate the size and density of the targeted ironwood as well as the necessity to treat an entire stand or portions such as canopy gaps, groups and patches. This will help ensure that the proper treatment method is applied, and desired control is obtained.

Herbicide Application: The intent of an herbicide application to control ironwood is to either release established regeneration or reduce competition allowing regeneration to establish. Typically, applications are broadcast foliar applications or single stem applications such as cuts stump, basal bark and “hack and squirt.”

Broadcast applications are typically intended to reduce competition and allow regeneration to establish. This treatment is typically a broad-spectrum foliar application and will result in the unwanted take of desirable species. To reduce unwanted take of desirables it may be advantageous to conduct a foliar spot application focusing on individual stems or small groups of stems. Treatments are best suited for stands that have short ironwood (<4.5 tall) depending on application method & equipment limitations. Treatments in harvested stands should not occur until ironwood that was cut or smashed during harvesting has sprouted. This typically occurs after the first summer following the harvest. Foliar applications should take place after full leaf expansion through leaf off. Through observation this treatment is considered to have a 69% effectiveness (Personal communication Schultz)

Single stem applications are typically intended to release established regeneration. Foliar spot applications, cut stump, basal bark, girdling w/ herbicide and hack and squirt treatments are all practical application methods depending on stand conditions and desired results. Because these methods can be very labor intensive and logistically difficult to implement efficiently, they are often not preferred for large scale applications. Foresters who use these treatments find success to be greater than 90% (Personal communication Schultz).

Herbicides labeled specifically for the control of woody species & applicable application type is preferred, always follow label instructions for safety and mixing. Refer to herbicide applications for sedge if control of herbaceous vegetation is also desired along with ironwood.

Mowing: Mowing using a masticating & rotary head will temporarily reduce ironwood competition. However, trials have shown that ironwood sprouted quickly, with multiple stems and shortly outcompeted desirable seedlings that established. Masticating heads are generally preferred over rotary heads because of their ability to shatter the ironwood stems which is thought to provide better results. Use of a masticating mower on rocky sites is very costly due to repairs and is seen as economically unfeasible long term. Foresters who use this method find through observation that they obtain effective control 63% of the time.

Blade Scarification & Pulling: The use of a dozer mounted salmon blade and root rake provides ironwood control and seed bed preparation. The main objective is to destroy ironwood, this is most effectively done by fully uprooting it. Stems that are not fully uprooted often sprout, limiting the long-term effectiveness. During harvest operations harvesters can also effectively uproot ironwood using the felling head to grasp and pull stems.

Additional Methods: These methods are commonly used but have not been evaluated and have varying degrees of success:

- Prescribed Burning (54% effective)
- Manual Felling with high stumps (>2.5’) stump height (59% effective)
- Running over with logging equipment during a timber sale (38 % effective)
- Grazing/Browsing

Table 40.7. Ironwood control method comparison.

Treatment	Overall Effectiveness (WDNR 2002)	Summer Application	Fall Application	>2 year control	Stand Application	Group / Patch	Shelterwood	Herbaceous Control Needed
Herbicide Foliar	69%	R	N	R	R	R	R	R
Single Stem Herbicide	90%	R	PR	R	R	R	R	N
Mowing	63%	PR	R	PR	R	R	R	N
Blade Scarification & pulling	38%	R	R	PR	R	R	R	PR
High Stump (>2.5') Manual Felling	59%	R	R	R	R	R	R	N

R = Recommended; P = Provisionally recommended (See sedge & ironwood management for more detail); N= Not Recommended

3.2.4 Wildlife

Northern hardwood comprises the highest acreage of the northern forest and management decisions affecting stand composition will also affect wildlife use. Maintaining and enhancing the assemblage of wildlife species in the northern forest depends on maintaining a healthy and diverse forest system. The five tree species that define the northern hardwood type provide a variety of benefits to wildlife. Associated tree and shrub species in northern hardwood stands also provide important wildlife benefits. There has been a trend toward greater dominance of sugar maple in the northern hardwood type. This simplification of the type can have negative consequences for wildlife dependent on a diversity of plant species.

Diversity of tree species and structure in the northern hardwood type contribute to the utility of the type for forest wildlife. Vertical structure, the arrangement and quantity of multiple layers in the forest, is of great importance. The forest floor, shrub layer, and sub-canopy along with associated tree species in the canopy contribute as much to wildlife use in the northern hardwood type as do the tree species definitive of the type. The potential for development of cavity trees and coarse woody debris in this type adds to the potential for wildlife use of the type. Harvesting systems appropriate to the northern hardwood type can be conducive to protection of sensitive natural features such as vernal pools, seeps, riparian areas, and microhabitat features such as rock faces.

Ground flora can be affected by silviculture. Studies of changes in ground flora following forest management activities in northern hardwood are few. Some existing results show initial increases in diversity and coverage (see summaries in (Roberts and Gilliam 2003) that are largely due to responses of common species (Crow *et al.* 2002). Some ground flora found in northern hardwood stands are light-sensitive and benefit from the shading provided by a closed canopy. Some of these plants are rare and management actions to protect them should be followed. Even-aged management techniques could be expected to have a greater impact on some sensitive forest interior herbs than uneven-aged techniques. Litter found on the forest floor that can be disturbed by harvesting activities can provide important wildlife benefits.

However, some ground layer plants benefit from moderate disturbance and increased sunlight. Opening the canopy through harvesting techniques that provide a variety of different sized canopy gaps may help encourage a diversity of ground layer plants.

The shrub layer provides foraging and nesting opportunities. It also will increase the use of some mature stands by species more commonly found in early-successional habitats. This component of the vertical structure of a stand can be provided both by shrubs and by tree regeneration. Silvicultural techniques providing light penetration will help in the development of the shrub layer. Conifer species in the understory can be of particular importance to many wildlife species. This is best illustrated in increases in nesting by some neotropical migrant songbirds though many other wildlife species use conifers.

Diversity of tree species in the sub-canopy and canopy will increase wildlife use of a stand. Retention of yellow birch, ash, and associated mid-tolerant tree species in sugar maple stands is desirable. If oak is present, it will contribute greatly to wildlife use of the stand and should be maintained. Conifers, particularly hemlock and white pine, should be retained.

The management objective for optimum quality sawlogs lends itself to producing large trees and many Wisconsin wildlife species take advantage of these large trees. Uneven-aged management can create a diversity of conditions for a variety of niches. Because a wide variety of tree sizes are available in stands managed under uneven-aged regimes, cavities and den trees can accommodate the full range of cavity-using wildlife species

Amphibians are well represented in the northern hardwood type. Coarse woody debris and litter on the forest floor helps maintain amphibian populations. Vernal pools provide productive breeding areas due to the absence of fish. Those pools with thick moss that may harbor four-toed salamander need special management in and around the site. Pools with wood frogs and other salamanders can actually increase productivity if they are opened to sunlight, as long as the surrounding land contains coarse woody debris. These pools also contribute microhabitat diversity and they should be protected to prohibit harvest operations within the basin of these small wetlands. Retention of dead or dying trees is important to promote the recruitment of coarse woody debris in the future. Compaction of the litter and soil in the vicinity of vernal pools should be avoided.

According to Robbins (1991), 66 species of Wisconsin birds use northern hardwood forests for breeding habitat. An additional 11 species use this habitat when a conifer component is found in association with the northern hardwood species. Representatives of most guilds with the exception of grassland and wetland species can be found in some developmental stage of the northern hardwood type. The northern forest of Wisconsin is an important source breeding area for many species of songbirds declining in other portions of the species' ranges. Because the northern hardwood type is found throughout Wisconsin, some southern species are included in the list of breeding birds. Because these southern species reach the northern extent of their range in Wisconsin, conservation of their breeding habitat might be considered particularly important. Cavity-nesting birds are particularly well represented in the northern hardwood type.

Mammals using the northern hardwood cover type range from shrews and bats to black bears. Though higher populations of game animals can be found in other cover types, the northern hardwood type contributes habitat for deer and elk. Horizontal and vertical structural diversity can be great in the northern hardwood type. Uneven-aged management creates the possibility of developing significant amounts of coarse woody debris utilized by a variety of forest wildlife.

Because of the opportunity for long rotations and the development of large trees, use of northern hardwood stands by cavity-using wildlife is an important feature. Many large-bodied cavity-using wildlife and some colonial roosting species use cavities in trees 18" or greater in diameter. Examples include pileated woodpecker, turkey vulture, fisher, several bat species, and black bear.

Even-aged harvest systems in the northern hardwood type resulted in many of the stands we currently manage. Northern hardwood regeneration following a clearcut or shelterwood can provide many of the habitat requirements of early-successional dependent wildlife. Even-aged management may also help increase the representation of the less tolerant northern hardwood associated tree species in areas where dominance of sugar maple is a concern.

Habitat management for wildlife in the northern hardwood type should capitalize on the diversity possible in the type. The five major tree species definitive of the northern hardwood type as well as the variety of associates found in the type provide many options for wildlife. Tree species diversity should be encouraged within stands when possible. Habitat types and species assemblages dictate the extent to which this is possible but silvicultural techniques to promote diversity should be followed. Structural diversity can be encouraged through a variety of potential management and regeneration techniques.

A variety of canopy gap sizes to allow for the development of vertical structure within the stand should be included in cutting prescriptions if wildlife production is a goal. Retain as much diversity of tree species as possible within northern hardwood. Trees such as yellow birch and hemlock are particularly important. Large trees, cavity trees, and snags all provide important wildlife habitat attributes and should be retained. Microhabitats within the northern hardwood type can contribute disproportionately to wildlife populations and diversity. These features should be identified and protected. Land managers working in the type should be particularly sensitive to wetland features, rock outcrops, and populations of sensitive plants.

<u>Summary of Recommendations</u>

Encourage habitat diversity:

- Tree species diversity especially mid-tolerants and conifers
- Current and future cavity trees
- Current and future snags
- Downed woody debris
- Large trees
- Vertical structure
- Horizontal structure (variety of stand/patch sizes)
- Variety of age-classes (a variety of gap sizes will contribute)

Protect special features:

- Wetland features including vernal pools, seeps, and riparian areas
- Populations of rare plants or animals
- Topographical features such as cliff faces or rock outcrops

Effects of Management on Neotropical Forest Migrants

During the past 20 years, there have been a number of studies that attempt to explain the decline of many neotropical migrant bird species (NTMB's) associated with forested landscapes. One segment of this research investigates the impact of edges and fragmentation generated by forest management.

Landscapes like those of southern Wisconsin were the focus of many NTMB studies conducted during the 1980's (building upon earlier studies going back to the 1950’s). These areas have relatively high levels of permanent fragmentation due to agricultural and urban land uses. Most of this fragmentation creates "hard" edges, or abrupt changes between habitat types, such as when woodlands adjoin farm fields. Bird populations within these fragmented woodlots are heavily impacted by nest predation and by high levels of nest parasitism by brown-headed cowbirds. These populations are generally "sink" populations, maintained by recruitment of individuals from "source" populations. (“Source” areas have stable or growing populations that produce emigrants, while “sinks” are dependent upon immigrants to sustain their population size.)

Northern Wisconsin forests have different levels and types of fragmentation as compared with southern Wisconsin. The amount of edge in the northern forest is determined primarily by timber management and its associated infrastructure, and secondarily by permanent fragmentation associated with development.

Forests and associated wetlands of the northern lake states are important habitats - they support some of North America's highest densities and most diverse assemblages of breeding birds (Howe *et al.* 1996). This region is also thought to support source populations of many NTMB's.

Edge and fragmentation studies conducted since the 1990's have devoted more attention to predominantly forested landscapes. Most researchers tested whether hard edges would affect avian productivity as they did in agricultural settings. Predictably, edge effects in forested landscapes are more complex and local than those found in agricultural landscapes. Interspecific competition and predation rates are more significant than nest parasitism. This is partly because cowbird abundance is lower in northern Wisconsin (but can be locally important near agricultural areas). Predators of the northern forests include fishers, skunks, raccoons, foxes, Common Crows, Blue Jays, a variety of other birds, and assorted small mammals. They are the most important demographic factor limiting nest success.

(Flaspohler *et al.* 2001a) studied edge effects generated by clearcuts (6 years or less) adjacent to large stands of older deciduous forests in Wisconsin. Hermit Thrush and Ovenbird, forest interior species that nest on the ground, had lower nest success within 300m of hard edges generated by clearcuts. Forest interior birds that nest in the canopy nested at lower densities within 50 meters of clearcuts, but at higher densities between 50 and 300 meters. American

Robin and Rose-breasted Grosbeak, species known to be less sensitive to edge, had higher nest densities near recent clearcuts. Predation was the leading cause of nest failure for both ground and canopy nesting birds. A related study of Ovenbirds determined that while nest density was similar between edges and interior, predation and mean clutch size were both highest near edges. Therefore, net productivity was similar (Flaspohler *et al.* 2001b). We do not know whether this result applies to other species. More research is needed in this region to better understand local predator populations and how they affect nesting success of NTMB’s.

Creation of edge and fragmentation in a landscape often benefits generalist bird species that are adapted to a variety of habitats. Many of these species (e.g. House Wren, Gray Catbird, American Crow, Blue Jay) are egg predators, and crows and jays also prey on nestlings, but their overall effects on local bird populations are not well known. Hamady (2000) found that Black-throated Blue Warblers, a forest gap-dependent species associated with shrub layers, declined in Upper Michigan landscapes with increasing habitat fragmentation because of competition with forest generalist species.

Current research also suggests that vegetation patterns in forest-dominated landscapes can affect the composition of avian communities within individual forest stands. In northeast Wisconsin, forested stands in landscapes with greater amounts of upland open land, as well as higher levels of fragmentation as indicated by measures of landscape pattern, had a lower abundance of edge-sensitive NTMB's (McRae 1995). Amounts of open land were correlated with landscape pattern measures, making it difficult to quantify these effects separately. Pearson and Niemi (2000) sampled mature aspen stands in Minnesota to determine whether both within-stand habitat characteristics and landscape patterns influenced breeding bird abundance in a forested landscape. Habitat specialists (Blackburnian Warbler and Magnolia Warbler) were found in aspen if there was a conifer component retained in the stand and also a large conifer component in the surrounding landscape (up to 1/3-mile radius). Forest generalists (Veery and Ovenbird) were less influenced by conifer components in landscapes. Retaining appropriate landscape-level conditions for certain habitat specialists should prove beneficial to their populations.

The overall effect of habitat fragmentation and edge on NTMB's in northern Wisconsin is not clear. Population estimates suggest that this region is a source population for many NTMB's and other bird species. Generation of excessive amounts of edge and habitat fragmentation within a landscape will be beneficial to some generalist NTMB's but may prove detrimental to source populations of forest interior NTMB's, many of which are of higher conservation concern. Local research results are difficult to extrapolate, appearing to vary by ecosystem type. Additional local research is needed to determine how even-aged management of northern hardwood affects patterns of interspecific competition and nest predation.

<u>Effects of Different Silvicultural Techniques on Neotropical Forest Migrants</u>

Information about effects of uneven-aged management on NTMB’s is scarce. A study conducted in northern hardwood in central Ontario suggested that lack of canopy closure in stands with repeated selection harvests could become a limiting factor for some species. Researchers found species-specific differences in breeding season abundance in stands recently harvested (1-5 years), versus stands harvested earlier (15-20 years) and stands in reserves (harvested more than 30 years ago) (Forests *et al.* 2004). This landscape differed from that of Wisconsin in that rock outcrop occupied a significant part of the area.

A study on the Ottawa National Forest compared 40 acre plots in old growth, managed old growth, uneven-aged selection, and even-aged shelterwood treatments (Andres 1996). Plots were not replicated, but some species richness, composition, and abundance differences were reported among the four plots. The old-growth plot had the highest number of breeding bird territories, and the selection treatment had the second highest.

King and DeGraaf (2000) compared bird species distribution among clearcut, shelterwood, and unmanaged northern hardwood forests in New Hampshire. Again, species-specific differences in bird abundance were apparent. The authors recommended that a variety of management techniques should be used in a landscape to maintain bird species diversity.

3.2.4.1 Deer and Herbivory Effects

In the northern hardwood forest, browsing by white-tailed deer is partly the cause of:

- Reduced regeneration and growth of some tree species, and changes in species composition (possible economic impact in areas of high deer abundance).
- Local extirpation of some understory plant species, and changes in the relative abundance of others. Species most likely to be impacted are those that are less common.
- Reduction of habitat diversity and contribution to forest simplification.
- Indirect effects on other wildlife that depend on understory plants and shrubs (WDNR 1995).

3.2.5 Endangered, Threatened and Special Concern (ETS) Species

Most typical northern hardwood management would not affect Endangered Resources (species listed in the Wisconsin Natural Heritage Inventory [NHI] Working List) (WI DNR 2018). However, in cases where ETS species are found in northern hardwood they may be affected by excessive canopy removal. Many ETS species have habitat requirements that need moist environments protected from the direct sunlight of mid-summer and the desiccating effects of wind. Seventy-two species on the NHI working list occur regularly in northern hardwood stands.

Several species, which are found in a variety of habitats, use northern hardwood primarily for foraging. Several other species use northern hardwood as breeding habitat, but also use many habitats. Several species are found only in northern hardwood.

Wide-ranging species that utilize northern hardwood for foraging:

> Timber wolf *Canis lupis,* northern myotis *Myotis septentrionalis,* eastern pipistrelle *Pipistrellus subflavus, w*oodland vole *Microtus pinetorum,* Arctic shrew *Sorex arcticus, p*ygmy shrew *Sorex hoyi, w*ater shrew *Sorex palustris, b*obcat *Lynx rufus, g*reat gray owl *Strix nebulosa,* Cooper's hawk *Accipiter cooperi,* and rhinoceros beetle *Xyloryctes jamaicensis.* The remaining species use northern hardwood as breeding sites and can be more directly influenced by stand management decisions.

Certain rare and uncommon plant species (not all are ETS listed species) are associated with mesic interior hardwood forests. Some of these plant species are poorly adapted to increased light and desiccation and their response to disturbance is unknown; they may grow and mature slowly, produce few propagules, disperse only short distances, or require a specialized pollinator (Meier *et al.* 1995). Several studies conducted elsewhere in the eastern United States indicate that some herbaceous species associated with late-successional hardwood stands may require 72 to more than 150 years to recover to pre-disturbance abundance and distribution after a major canopy-opening disturbance (Flaccus 1959; Maclean and Wein 1977; Duffy and Meier 1992). Matlack (1994) found that proximity to old forest was associated with the presence of shade-tolerant understory herbs in previously farmed successional oak-hickory forests, indicating that recolonization was likely important in maintaining their populations. Even-aged management techniques could be expected to have a greater impact on some sensitive forest interior herbs than uneven-aged techniques; other factors to consider include patch size, distance from potential colonists in older forest, presence of pollinators and dispersal agents, and time for population recovery before the stand is re-entered. Given the nearly complete lack of empirical information on the fate of rare and uncommon herbs in our area, research and monitoring is warranted.

The following is a list of some of the ETS species associated with northern hardwood stands, their general habitat preferences, and known locations in the state where they have been found:

<u>Plants</u>

- Allegheny vine *Adlumia fungosa* (special concern): This plant has a narrow habitat niche growing on ledges imbedded in northern hardwood forests. Most records are from Door County although it could be found throughout the range of northern hardwood. Keeping shade on the ledges would be the primary consideration. Single-tree selection should accommodate the needs of this plant.
- Assiniboine sedge *Carex assiniboinensis* (special concern)
- Pale sedge *Carex pallescens* (special concern)
- Long-spur violet *Viola rostrata* (special concern): These grass-like sedges and the violet can be difficult to identify and may be more common than recorded. They can be found in shaded hardwood across the range of northern hardwood. Selection (single-tree or group) harvesting in the winter is probably compatible with these species.
- Blunt-lobed grape-fern Botrychium oneidense (special concern): These plants of maple/basswood forest are found in moist depressions or along boggy edges. The fern seems to tolerate slight to moderate disturbance, although it still needs shade. Populations have increased in grazed woods or where ground fires have occurred. Selection harvesting including treatment of the shrub layer may enhance populations.
- Braun's holly fern *Polystichium braunii* (state-threatened)
- Green spleenwort *Asplenium viride* (state-endangered)
- Maidenhair spleenwort *Aspenium trichomanes* (special concern)
- Fragrant fern *Dryopteris fragrans* (special concern): All four species grow on wet cliffs or rocky wet talus. All need shade and moisture to thrive. Due to the limited habitat available, most foresters will not encounter these species, however, for those that do,

the management is straight forward. Keep shade on the plants and keep moisture on the roots. Special management should occur within 100 meters of the plant populations. Single-trees could be removed from within the 100-meter area, but the site should be managed for shade on the rare plants rather than applying silviculture to the stand. The surrounding uplands should be managed to avoid soil drying – single-tree selection and group selection would be the most compatible.

- Broad beech fern *Phegopteris hexagonaptera* (special concern): A more southerly plant but can be occasionally found in northern hardwood. This fern prefers sunny, more open spots in moist woods. The populations may be enhanced by selective harvest (single-tree or group), if the landings and skid trails avoid most of the plants.
- Broad-leaved twayblade *Listera convallaroides* (special concern): Another plant that requires very cool soil. It is found almost exclusively on mosses or in springy areas in hardwood or hardwood/conifer areas in counties bordering Lake Superior. Single-tree winter harvesting that leaves most of the canopy intact in the winter is probably compatible.
- Christmas fern *Polystichium acrostichoides* (special concern)
- Glade fern *Diplazium pycnocarpon* (special concern)
- Mingan's moonwort *Botrychium minganense* (special concern)
- Cooper's milkvetch *Astragalus neglectus* (state-endangered): Not much is known about the habitat requirements for these species other than they grow in hardwood and hardwood-conifer forest. If the plant is found in a stand, the forester should contact the BER botanist to develop a management strategy.
- Crinkled hairgrass *Deschampsia flexuosa* (special concern): This grass is found mainly along the coast of the Great Lakes, but occasionally in northern hardwood stand on dry soils. Presumably the more dappled shade found in dry soil hardwood would indicate a tolerance for selection harvest, but the site should be monitored.
- Cucumber-root *Medeola virginiana* (special concern): A plant found on medium nutrient soils on moraines and under beech, sugar maple and/or hemlock. This is another plant potentially affected by deer browse. Cucumber-root is affected in growth and reproductive capability by the light found in large gap edges and compaction but increases in small gaps. The plant favors small gaps and the presence of tip-up mounds. Selection harvesting during frozen conditions with gaps limited to two tree lengths can accommodate cucumber-root.
- Drooping sedge *Carex prasina* (state-threatened): This sedge grows in wet wooded areas and along streams. Sites where the sedge is found remain wet due to springs or seeps. The plant is found primarily in the Baraboo Hills, Blue Hills, Door County and along the St. Croix River. Yellow birch and skunk cabbage are primary associates. Removal of single trees is probably acceptable, but more important is conducting forestry on the surrounding stands that does not affect the water table.
- Foamflower *Tiarella cordifolia* (state-endangered): Of the six known populations, four are on U.S. Forest Service land and two are on private land. This spring bloomer's habitat is stream banks, especially with cobble, and in ravines where cool air drainage and substrate water flow is present. Common tree associates are black ash, yellow birch, sugar maple and conifers. Primary threats are drying of the forest floor, soil compaction, garlic mustard invasion, and beaver. Suggested management on the national forest is to establish a 100-foot buffer around the population and use selection

uneven-aged harvest in the surrounding uplands. The site should be monitored for garlic mustard and beaver activity.

- Great toothwort *Cardamine maxima* (special concern): The only known location is a rich deciduous forest in Ashland County. Searches for the plant should occur in from mid-May to mid-June. Single-tree selection harvesting is probably compatible with this plant.
- Green-leaved rattlesnake plantain *Goodyera oblongifolia* (special concern): This evergreen rosette is mostly found in spruce-fir forest, but it does occur in hardwood/conifer stands. The plant requires very cool soil; thus it is limited to far northern Wisconsin. It is known to die after even-aged harvest. Another concern is collecting by orchid enthusiasts, which almost always dooms the plant. An appropriate strategy would be to use single-tree selection harvesting during periods when snow is on the ground.
- Handsome sedge *Carex formosa* (state-threatened): This sedge grows in moist calcareous soil in deciduous woods. The plant is found only in the Northeast Region. It prefers light dappled shade and should be accommodated by light single-tree selection harvesting.
- Large-leaved sandwort *Moehringia macrophylla* (state-endangered): Only two colonies of ten plants were known from the Penokee and Gogebic Ranges in 1999 down five populations from 1994. The plant lives on cliffs or mossy bluffs. Some botanists speculate that while the plant needs moisture and some shade, they may be influenced by too much shade. The known populations should have specific management plans developed for the sites.
- Little goblin moonwort or Goblin fern *Botrychium mormo* (state-endangered): This minute fern is associated with a thick (greater than 3 inches) organic horizon, also known as the O horizon or litter layer, and dense shade. Forest generally needs to be mid-aged to old, in order for this thick of an O horizon to develop. It is most commonly found in AH, AOCa, ATD, ATFD habitat types without hemlock and especially where pit and mound microtopography is found. The plant is sensitive to soil compaction and is eliminated when the litter layer is significantly reduced. The plant apparently can tolerate individual tree selection, but the effects of equipment need more research. Populations should be marked so vehicles would not travel over the plants. The effect of exotic earthworms in this species needs further research.
- Male fern *Dryopteris filix-mas* (special concern): Habitat for this fern in Wisconsin is the shade of sugar maple, ironwood or choke cherry in a rather open forest growing on 10 to 20% slopes on basalt. In other words, very limited habitat is available in Wisconsin. Management recommendations are unknown, but an adaptive management approach that incorporates light thinning around male fern populations may increase habitat availability.
- Northern lungwort *Mertensia paniculata* (special concern): The habitat is damp woods near the shore of Lake Superior. Little is known regarding species management however, moist soil appears to be most important. Consideration for maintaining water flow in surrounding stand management maybe critical.
- Pinedrops *Pterospora andromedea* (state-endangered): This parasitic plant on pine roots is occasionally found in rich humus under white pines. The plant can be found in predominately hardwood forest with a white pine component. Management recommendations are to maintain a high level of shade (single-tree selection) and avoid

soil compaction. These saprophytic plants depend on humus and roots to attain nutrients and may not flower every year.

- Purple clematis *occidentalis* (special concern): The plant is found on rocky, often calcareous slopes, in hardwood forest. The populations can fluctuate dramatically and are usually found on edges. Group selection next to existing populations may provide additional habitat.
- Ram's-head lady-slipper *Cypripedium arietinum* (state-threatened): This small orchid is most often found in conifer swamps, but it has also been recorded from mixed forests of maple, aspen, white birch, pines and balsam fir. The plant is mostly found in dappled shade with very little competition from understory vegetation. The key element is the presence of marl or lime-rich soils. In hardwood, it seems to prefer a mid-succession forest that has experienced a ground fire or a balsam die-off. As with most orchids, this plant is sensitive to deer browse and soil compaction by equipment. Single-tree selection or group selection harvest should be compatible if soil compaction is kept to a minimum.
- Smith melic grass *Melica smithii* (state-endangered): One known population in the Gogebic range, however conditions elsewhere on this range and the Penokee's are favorable for this species. The grass is found under sugar maples in rather dense shade. Light single-tree selection harvest would presumably be compatible with this grass.
- Snow trillium *Trillium nivale* (state-threatened): This showy flower grows in rich calcareous soils in the presence of beech/maple/basswood. Woodlot grazing is a major problem. Single-tree selection is apparently compatible with this species although harvest should be prohibited from early March through late spring.
- Spreading wood-fern *Dryopteris expansa* (special concern): This fern reaches its southern distribution in Wisconsin and requires cool moist conditions for its persistence. Very limited single-tree selection simulating individual tree gaps should retain this species in the stand.
- White ground cherry *Leucophysalis grandiflora* (special concern): The plant is found in sandier habitat types including northern hardwood. It generally appears many years after a disturbance, especially ground fires, during early to mid-succession, but is seldom found in coppice or clearcut harvest areas. Management of known populations with regenerative fire may be an option for this species.
- White mandarin *Streptosus amplexifolius* (special concern): This plant of the lily family is found with sugar maple, hemlock, and mixed conifer/hardwood in ravines and coves in hilly areas near Lake Superior. The plant is a favorite food of white-tailed deer and appears to have a reproduction bottleneck with small population sizes. The plant is capable of persisting with selection harvesting. The need for relatively large metapopulations indicates management units of 300 to 1000 acres are needed to accommodate this species.

<u>Animals</u>

- American marten *Martes americana* (state-endangered): This species has been reintroduced to the state with populations centered in two locations – the Nicolet National Forest and the Great Divide Ranger District of the Chequamegon National Forest. This species optimal habitat is old conifer forest with numerous windfalls and an abundance of spruce and fir. Marten's will also use old northern hardwood forest if they have numerous hollow trees and a significant conifer component. Stand management should promote snag and conifer retention however, range wide management plans are needed to address the needs of the species more so than stand recommendations.

- Appalachian pillar *Cionella morseana* (special concern)
- Brilliant granule *Guppya sterkii* (special concern)
- Boreal top *Zoogenetes harpa* (special concern)
- Black striate *Striaura ferrea* (special concern)
- Dentate supercoil P*aravitrea multidentata* (special concern): These five terrestrial snails appear to have very restricted habitats, cliffs, rocky talus and seeps. We do not know much about their life history nor their habitat requirements. In general, moisture is key. Where they are found, management should be light with consideration to maintain adequate soil, cliff or rocky talus moisture.
- Bald eagle *Haliaeetus leucocephalas* (special concern)
- Northern goshawk *Accipter gentilis* (special concern)
- Osprey *Pandion haliaetus* (state-threatened)
- Red-shouldered hawk *Buteo lineatus* (state-threatened): All of these raptors should have their active nest sites protected from disturbance during the nesting season. Moreover, to protect these species, they need management considerations that go well beyond silvicultural stand applications and nest site protection. Refer to forest raptor management guidance documents.
- Common goldeneye *Bucephala clangula* (special concern)
- Common merganser *Mergus merganser* (special concern)
- Red-breasted merganser *Mergus serrator* (special concern): All three of these species are very common in winter, but a sparsely found breeding in Wisconsin. All three nest in cavities, especially those found adjacent to large lakes or rivers. One common merganser nest was documented at the bottom of a 25-foot-deep tree cavity. Leave existing cavity trees and future cavity trees when planning a harvest.
- Four-toed salamander *Hemidactylium sculatum* (special concern): This amphibian lays its eggs in April in dense mosses (>1.5 inches in depth, including sphagnum mosses) at either the edges of ephemeral and/or fishless wetlands or in dense mosses growing on large downed woody debris over the water. Upon hatching, the larvae drop into the water and develop until they metamorphose in July or August. Because dense moss is essential to this species, tree cutting should be limited in these wetlands and a 75-foot buffer. This species is also highly dependent on large-diameter (>10") coarse downed woody debris on the forest floor. Forest management in areas surrounding the breeding wetland buffers should plan for the continuous accumulation of large downed woody debris to accommodate this rare forest-dependent species.
- Great blue heron *Ardea herodias* Rookeries (special concern): Avoid harvest in active rookeries. Winter harvest of trees in close proximity to the rookery could occur.
- Northern ring-necked snake *Diadophis punctatus* (special concern): This species is nocturnal living underground, under logs or rocks and is seldom seen. Special management prescriptions are lacking but keeping the forest floor moist with numerous large woody debris and rocks should accommodate this species.
- West Virginia white *Pieris virginiensis* (special concern): This butterfly is found in northern hardwood forests with adults in flight from mid-May to early June. The larvae

feed on toothwort. Management recommendations are lacking, however, identification of patches of toothwort within stands and avoiding equipment compaction could help with enhancing the species populations.

- Wood turtle *Clemmys insculpta* (state-threatened): Prefers hardwood forest or wet meadows associated with moderate to fast-current streams with sandy or gravel substrates. South-facing sand riverbanks are used for nesting. Best Management Practices for Water Quality addresses most of the management issues. Timber sale design should also keep equipment, especially landings away from the sandy nesting sites. Maintain small sandy openings within 200 feet of the river.

Rare Neotropical Migratory Birds

The followed three species have individual stand management silvicultural options that can be employed; however, a stand-by-stand approach may not help these species. All three species probably need to be managed at a large scale. The model for ruffed grouse management areas should be developed to address the needs of these species. Management blocks of 300 to 2,000 acres could be established around known dense populations. The purpose would be to manage the forest to accommodate the needs of the target species.

- Acadian flycatcher *Empidonax virescens* (state-threatened): This small flycatcher of southern interior forest is moving north in Wisconsin. The species prefers large tracts of mature hardwood forest with semi-open understory, with most territories near streams or in ravines. Management of the largest blocks of northern hardwood forest in southern Wisconsin using single-tree selection should accommodate this species.
- Black-throated blue warbler *Dendroica caerulescens* (special concern): This understory warbler nests north of a line from Green Bay to Spooner. Its preferred habitat is dense under story saplings and shrubs primarily in deciduous forest. Populations are most often found in mature to old hardwood forests and reach their highest densities in thickets formed after blowdowns. Stand management should release densely packed but suppressed saplings by single-tree or group selection.
- Cerulean warbler *Dendroica cerulea* (state-threatened): This southern warbler prefers mature to old-growth hardwood of maple, basswood and especially red oak. Cerulean Warbler's are found almost exclusively in the upper canopy. Most of the breeding records are south of a line from Marinette to Spooner, however, they have been recorded in every county of the state. This warbler can tolerate light timber harvest as long as 70% or more of the canopy remains. The most pressing need is for management considerations to cover blocks of potential habitat with a focus on the habitat requirements for this species.

Other rare species may occur in northern hardwood stands considered for harvest. Many of these species will be found in specialized habitats such as rock outcrops, cliffs, ephemeral ponds, and seeps. If an NHI occurrence or species verification is identified, contact the appropriate person according to the Department protocol. Information on species and habitat can be found at the Bureau of Endangered Resources page on the Wisconsin DNR website.

3.2.6 Economic Issues

Forest Products

The primary species that comprise the northern hardwood cover type are utilized for a wide variety of forest products, including pulpwood, biomass, sawlogs, and veneer.

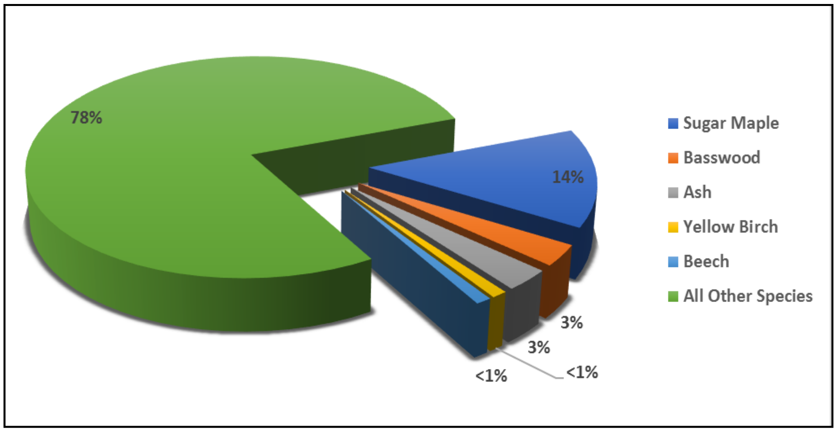


Figure 40.2. Statewide roundwood production percentages from 2009-2012.

Figure 40.2 highlights the proportion of statewide roundwood production generated from primary northern hardwood tree species. Sawlogs and veneer totaled approximately 30% of all northern hardwood production. Northern hardwood outputs from the primary wood-using mills tend to be highest in northeastern Wisconsin, followed by northwestern, central, southwestern, and southeastern Wisconsin. These production rates and each species' commercial value can fluctuate substantially based on resource availability, consumer trends, housing construction, export markets, and other market conditions.

Mill operations and raw material preferences have also experienced notable changes in the past few decades. In general, sawlog preferences have moved to smaller logs due to changes in mill equipment capacity and to target the upper grade material often found in younger, more vigorous trees. Some facilities no longer accept logs 30" and larger. Mixed hardwood pulpwood markets are generally more sensitive to changes in the supply chain, such as increased haul costs, the loss of a consuming mill, or other constraints that impact the flow of roundwood. Regional pulpwood markets vary considerably throughout the state and represent just one of the market forces foresters need to consider when developing silvicultural prescriptions.

Sugar maple has the highest growing stock volume of any species in Wisconsin, with volumes steadily rising since 1956, primarily in sawtimber-size trees. The fine-textured, dense wood of sugar (hard) maple has a high commercial value, particularly in the better-quality grades of lumber, veneer, and in figured grains such as birdseye or curly maple. The light-colored wood of sugar maple is most commonly used for lumber. A large proportion of heartwood discoloration can therefore have a significant impact on its commercial value.

Assessing Tree Value Growth

Forest managers are often interested in assessing the financial value or rate of value growth in trees and stands of trees. This information can be used to inform management decisions, such as when to rotate an even-aged stand to maximize financial performance or at what diameter trees reach financial maturity in an uneven-aged stand (e.g., single-tree selection). These financial analyses have been the subject of much discussion and debate in northern hardwood, due to the high commercial value of quality northern hardwood lumber.

It is important for foresters to have a basic understanding of the relationship between assessing tree size/quality and hardwood tree value. Tree diameter and merchantable height, in large part, determines tree volume, as well as the product class (e.g., pulpwood, sawlog, veneer). Tree diameter and ultimately log diameter will in part differentiate log grades, since defects that reduce quality will have a greater impact on small logs. Foresters should understand these standard size thresholds for product classes and tree/log grades but realize that these “standards” may vary based on markets and systems utilized. For hardwood sawtimber, the quality of the stem is at least as important as its size in determining a tree’s value. Most timber objectives for northern hardwood prioritize the development of stem quality through sound management. Detailed information on assessing stem quality and the risks/impacts of specific defects can be found in the Stem Quality and Forest Health sections of this chapter.

The following tree-level and stand-level financial considerations will highlight some of the general conclusions from a variety of research and financial analysis studies conducted in northern hardwood. The difficulty in presenting detailed financial data is that the parameters used often outdate quickly. For more detailed information on these studies see the reference section of this chapter. These considerations should be used in the context of a silvicultural prescription that incorporates clearly defined landowner goals and site conditions.

Tree-Level Financial Considerations

- Grade increase has the greatest effect on value – keep trees that can increase in grade. Greatest rates of value growth are in the poles and small sawtimber, as these trees are entering potentially higher grades and/or rapidly increasing in merchantable height (Godman and Mendel 1978; Buongiorno and Hseu 1993; Reed and Mroz 1997; Webster *et al.* 2009).
- Consider removing trees that have reached their highest-grade potential, within the context of the silvicultural prescription. Remember to consider size increases into veneer grades, especially on high quality sites (Webster *et al.* 2009).
- Single-tree selection identifies a maximum tree diameter, which may be based on the financial maturity of a tree species – that point at which the rate of value increase falls below the landowner’s desired rate of return. Financial maturity for sugar maple may vary from 15-30” DBH (Godman and Mendel 1978).
- Approximate financial maturity for long-lived northern hardwood ranges from 18-24” DBH on high quality sites, and 16-18” DBH on moderate quality sites (Leak *et al.* 2014).
- Assessing financial maturity or the rate of value growth may be dictated by more than just tree diameter. Foresters need to consider multiple factors, including species, tree age, size, defect impacts, growth rate, ability to jump grade, and site conditions. For

example, keeping more vigorous trees that can substantially increase in diameter and/or merchantable height can improve financial performance (Reed and Mroz 1997; Webster *et al.* 2009).

- Fungal infections and cracks are the quality-degrading defects most associated with losses in tree value in sugar maple and yellow birch (Havreljuk *et al.* 2014).
- Large heart size or dark heart in sugar maple significantly impacts log grade potential. Predicting the extent of heartwood discoloration in standing sugar maple trees is difficult. Current studies attempting to correlate heart size to tree and site characteristics have been inconsistent. In general, most studies have found that the amount of discolored wood increases with increasing tree diameter, but the proportion or ratio of discolored wood to white wood is not consistently related to tree diameter (Erickson *et al.* 1992; Yanai *et al.* 2009; Germain *et al.* 2015; Dey *et al.* 2017).

<u>Stand-Level Financial Considerations</u>

- Uneven-aged selection systems (e.g., single-tree selection) produce greater merchantable heights than even-aged systems (Strong *et al.* 1995).
- Selection systems using medium residual basal areas, ranging from 60-90 ft^2/acre in trees ≥5” DBH, generally produce the best balance between growth and tree grade improvement, along with high net present value (Niese *et al.* 1995; Strong *et al.* 1995; Leak *et al.* 2014).
- Even-aged management of northern hardwood may be a viable choice from a financial perspective, particularly where landowner goals, stand conditions, or site quality do not lend themselves well to uneven-aged management. Currently little published financial data exists on even-aged northern hardwood management.

Uncontrolled and severe diameter-limit cutting can initially produce the highest harvest volumes and undiscounted value, but long-term it produces the poorest grade trees and lowest economic returns (Erickson *et al.* 1990; Niese *et al.* 1995). Controlled diameter-limit cutting with improvement cutting in lower size classes was suggested to limit the negative impacts (Buongiorno *et al.* 2000).

3.2.7 Operational Considerations

The cumulative effects of infrastructure development and soil compaction in forests have been studied in other parts of the country and found to be correlated with changes in hydrologic regimes, surface drainage patterns, and soil moisture. The negative ecological effects of soil compaction and rutting, and of forest roads, are well known at fine scales, but these issues have not been studied in an integrated fashion on larger landscapes in our area. Roads and utility corridors have been implicated in the spread of non-native invasive plants. They also act as barriers to the movement of some species, create fragmentation and edge, and can attract human disturbances.

3.2.8 Vernal Pools

Where northern hardwoods grow on finer textured soils and/or somewhat poorly drained soils, inclusions may be found where seasonal ponding of water occurs. These ponds are called “vernal pools” (Rogers and Premo 1997). Vernal pools are characterized as small, seasonal, ephemeral, pools or ponds that lack predatory fish (Colburn 2004). Due to the lack of predators, these pools are important areas for amphibians and invertebrates to reproduce. The actual size used as definitional criteria of these “small” pools is debatable. Rogers and Premo described size range of vernal pools as “from a puddle to an acre or more.” Vernal pools contain species of aquatic flora and fauna not found throughout the terrestrial matrix of the remaining stand of northern hardwood. The frequency and distribution of vernal pools are of importance to their function in maintaining or enhancing biodiversity. Some vernal pools should be buffered to protect amphibian foraging and breeding habitat. Harvesting should avoid felling trees into or skidding through these vernal pools and avoiding rutting in the nearby vicinity. These areas should be delineated in some manner prior to beginning harvesting. Vernal pools may not be apparent at certain times of the year due to their ephemeral nature and the lack of standing water or during periods of snow cover.

4 STAND MANAGEMENT DECISION SUPPORT

This section offers two tools to help the forester assess and characterize the stand after field reconnaissance data is collected. With this data, the forester can then review landowner objectives and silviculture methods in effort to develop the desired future condition.

4.1 Stand Inventory

In depth and accurate stand assessment will facilitate discussion of management options and objectives in relation to realistic and sustainable management goals. There are several tools available to use in a northern hardwood stand assessment, some of which are included in the appendix of this chapter (e.g., Northern Hardwood Checklist and Northern Hardwood Tally Sheet). Factors to recognize during stand assessment include, but not limited to, the considerations in Table 40.8.

Stand composition and structure assessment can be attained by various inventory procedures. Individual tree species and diameters should be tallied when using either fixed-radius or the more common variable-radius inventory plots. An example variable-radius plot tally sheet to determine species composition and stand structure by size class is provided in Table 40.23. Other similar tally sheets and methods exist. The number of current and potential AGS per acre should also be tallied.

Residual crown cover or crown closure is an important factor when implementing even-aged shelterwood seeding cuts. One method to assess residual crown cover is to utilize fixed area plots and tally crown areas of individual trees. Tree crown areas vary due to a variety of influences and past disturbances such as weather-related events, fire, and root damage. Average tree crown areas by species and DBH for northern hardwood are listed in Table 40.24. Included with Table 40.24 are instructions for a sample shelterwood marking exercise using fixed area plots to determine residual crown areas (USDA 2005). Another tool to visually measure crown cover is a densiometer. Both spherical and flat densiometers use a grid-layout on a mirrored surface. Densiometers are used by counting the number of grid-cells occupied by reflected crowns. Densiometers are most effective when used during leaf on conditions.

Table 40.8. Northern hardwood stand inventory considerations.

Species Composition	
Stand Quality	Acceptable/unacceptable growing stock
Site Potential	Habitat type Soil characteristics Site index
Natural Regeneration	Species; stems/ac; distribution, height Deer browse Health and vigor
Stand Structure	Seedling sapling, pole, small/med/large saw Age-class distribution
Average Stand Diameter	
Total Basal Area	
Overstory Tree Vigor	Crown condition Crown class Growth increment
Competing Vegetation	Pennsylvania sedge Ironwood Invasive species *Rubus spp.*
Past Management History	
Stand Health	Tree diseases Tree pests Animal damage

4.2 Key / Checklist for Evaluating Cover Type Stand Management Options

The Northern Hardwood Stand Management Checklist is a tool designed to help identify management options prior to developing a silvicultural prescription. The checklist along with instructions can be found in the appendices (Table 40.22). The checklist is arranged by stand assessment topic (ex. Landowner Objective, Site Potential / Operability) with 2-6 true or false questions. The forester answers each question by checking (✓) the true or false box to the right of the question. When all questions within a topic have been tallied in each column, the forester then reviews the silviculture management options based on the assessment findings. Due to the complex character of both stands and management, checklist results should be considered collectively, along with other stand data and professional judgment when evaluating management options to best achieve a desired future condition (DFC).

4.3 Cover Type Decision Model

The northern hardwood decision models outline initial considerations in the development of a management plan by integrating silvics, site capabilities (soil, habitat type, competition, regeneration, successional pathways), methods (timing/sequence), site history, and timeline at growth stages under ideal conditions. Sustainable forestry practices must be based on compatible landowner objectives and the capability of each site. Each of these factors should be considered when approaching these models. Detailed considerations of a silviculture method are discussed under the narrative of each method in this chapter and page number is referenced in the model. Within the decision models, both even-aged and uneven-aged management objectives are considered.

Across the spectrum of northern hardwood stands in Wisconsin, there is a range of quality and conditions. Quality can be affected by many things such as stand history, storm damage and site conditions (e.g., soils, hydrology, landform). Using both the northern hardwood checklist (Table 40.22) and northern hardwood decision model (Figure 40.3 and Figure 40.4) offer a wide variety of considerations in making a management decision with the landowner objective in mind.

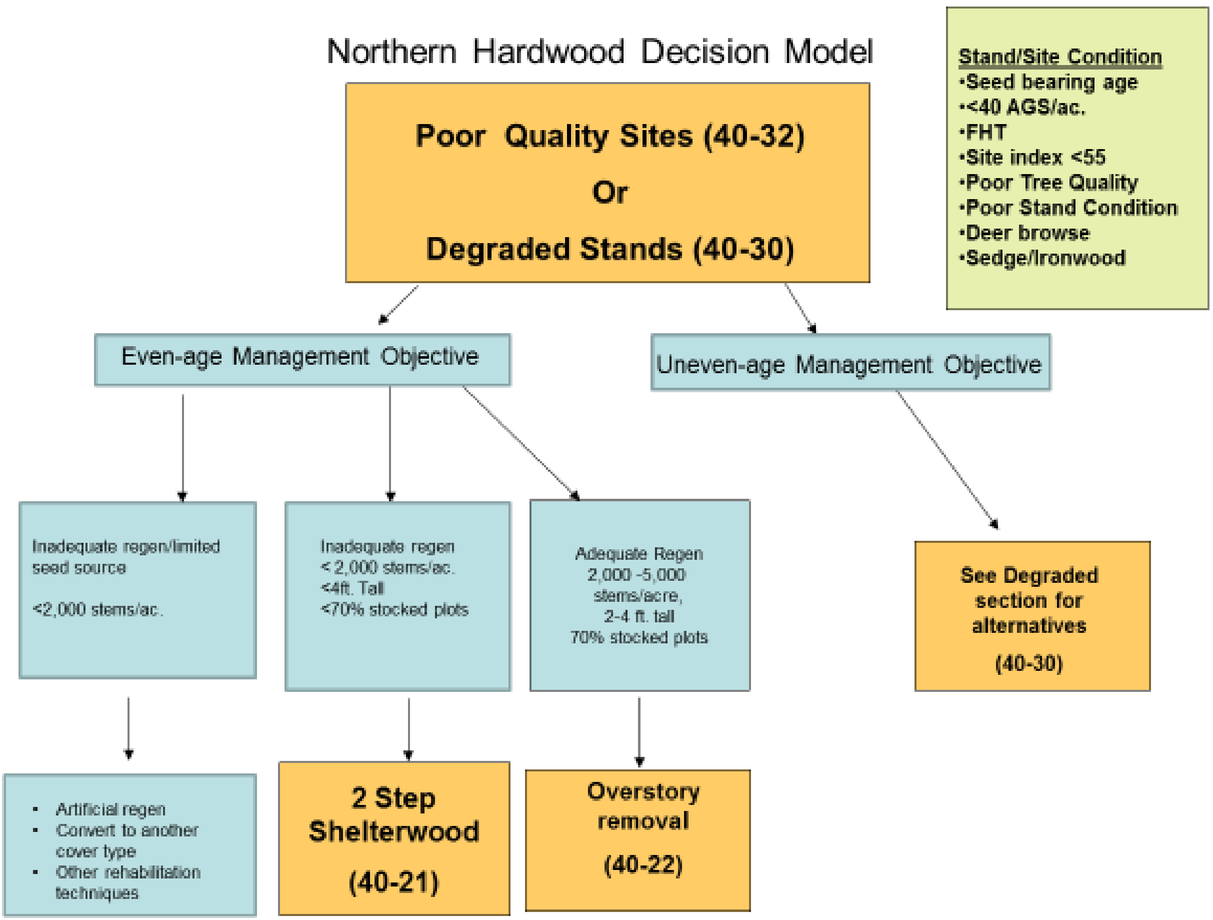


Figure 40.3. Decision model for poor quality or degraded stands.

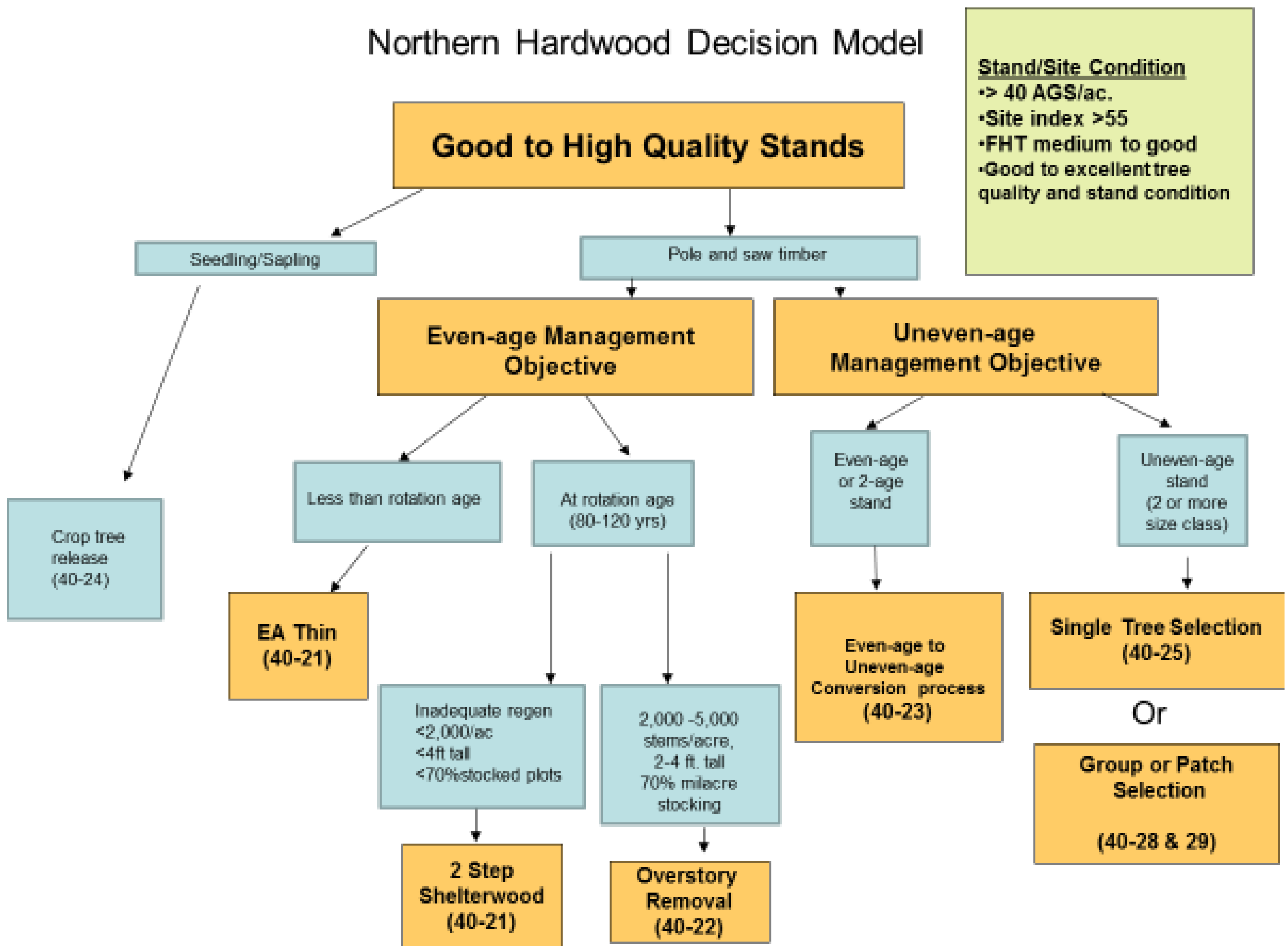


Figure 40.4. Decision model for good to high quality stands.

5 SILVICULTURAL SYSTEMS

Uneven-aged (sometimes called all-aged) silvicultural systems are commonly recommended for the management of northern hardwood. Even-aged silvicultural systems may also be utilized to produce high quality products and to encourage mid-tolerant species that can increase tree species diversity and improve production on poor quality sites. Intermediate treatments are used to promote quality stem development and stand vigor. The generally accepted natural regeneration and management alternatives include (Table 40.10):

- Single-tree selection (uneven-aged)
- Group selection (uneven-aged)
- Patch selection (uneven-aged) – conditionally recommended
- Shelterwood (even-aged)
- Overstory removal (even-aged)

5.1 Seedling / Sapling Stands

Following establishment, seedlings/saplings have potential to exhibit optimal growth and quality. To ensure full stocking while developing stem quality, the stocking of desirable species should be a minimum of 2,000 - 5,000 per acre of well distributed seedlings >3' tall (Erdmannn 1986). Early in sapling development, natural pruning of lower limbs minimizes forking and maximizes quality of potential AGS trees. Cultural practices, such as weeding and other release treatments in sapling stands can improve stand composition and growth. Marquis *et al.* (1992) recommends precommercial thinning only if valuable stems are overtopped by poor quality individuals.

Release treatments may be implemented in young stands of northern hardwood to enhance growth on potential AGS and to eliminate competition from undesirable species. Increased bole lengths can be achieved with natural pruning due to increased stem density. Release of yellow birch can significantly improve growth and survival in young (10-20 year old) even-aged stands (Hutchinson 1992). For best growth and quality, 10-year-old shade tolerant AGS should be cleaned to an 8-foot radius around their boles (5 foot beyond their crown (Erdmannn 1986). Stump sprouts should be thinned early before potential AGS reach 3 inches in diameter. Leave one to two sprouts per clump, as widely spaced as possible. Individual sprout characteristics to favor include low sprouts originating less than six inches above ground, U-shaped stem attachment, well developed crown, large size, good form, and healthy (Hutchinson 1992).

In many situations, existing seedling/sapling stands do not contain sufficient numbers or adequate size of preferred species. One option is to consider altering stand objectives to accept a less desirable species composition. Changing markets (e.g., aspen, red maple) and landscape species dynamics (e.g., emerald ash borer) often alter our understanding of how desirable species are defined. Another option is to interplant the stand with desirable species. Interplanting or "enrichment planting" is often used to establish or increase the number of desirable species in degraded stands. This approach may also be used to introduce genetically superior hardwood (Clatterbuck 2006). Mechanical or chemical competition control will improve the long-term survival and viability of planted trees.

5.2 Intermediate Treatments

5.2.1 Stem Quality

The development of individual stem quality (and ultimately financial value) in northern hardwood stands is paramount for many timber management objectives no matter which silvicultural system is utilized. Managing for quality is a long-term process functioning at both the stand and individual tree level. It is important at all stages of stand and tree development.

Multiple stand and tree-level factors influence stem quality. The quality of a hardwood stem is determined by its size, form, and the imperfections or defects that impact the useable wood. Foresters should attempt to understand these factors and use silvicultural practices to positively influence stem quality development over the entire life of a stand.

<u>Stand-Level Factors</u>
Stand-level factors that influence stem quality can include site quality, species composition, stand history, stand structure, and stand density. Northern hardwood occur over a wide range of sites in Wisconsin and the potential to grow quality stems will vary by site capability and species. What constitutes the ideal tree in one location may not be achievable on a different

site. Species composition can influence stem quality too. Shade tolerant species, like sugar maple, generally have the greatest number of defects, while faster growing mid-tolerant species, like basswood, ash, and northern red oak, have fewer defects and less forking (Godman and Books 1971; Erdmannn 1986). The forest habitat type classification system can help to assess the relative growth potential of individual northern hardwood species across sites. Habitat type is often a more reliable tool to assess site capability than site index, especially in uneven-aged stands where accurate site index determination is not possible. The current stem quality within a stand may not be a good indicator of site capability either. Many stands in Wisconsin have a history of damaging agents such as grazing, insects, disease, ice, wind, and poor harvesting practices that have degraded stem quality.

Stand density and structure are important factors controlling stem quality in northern hardwood due to their influence on main stem forking and epicormic branching. During the seedling and sapling stage, high numbers of stems per acre (e.g., 2000-5000 stems/acre) help limit stem forking and improve long-term quality prospects. Replicated studies for northern hardwood management practices related to density and structure have been conducted on the USDA Forest Service, Argonne and Dukes Experimental Forests. One such study (i.e., Cutting Methods Study) in place for over 60 years has tested alternative residual basal areas under uneven-aged management of 60, 75, and 90 ft^2/acre in trees ≥5” DBH. Marking focused on harvesting in all overstocked size classes based on uneven-aged principles and the order of removal developed by Eyre and Zillgitt (1953) and Arbogast (1957). To date, seven harvests have been implemented and data recorded on each treatment. The 75 ft^2/acre treatment provided the best balance between adequate diameter growth and tree grade improvement (Erdmannn 1986; Strong *et al.* 1995; Kern *et al.* 2014). Repeated cuts to residual basal areas of 60 ft^2/acre or less reduced stem quality and potentially reduced merchantable log heights, while residual basal areas of 90 ft^2/acre or greater reduced diameter growth rates. Other studies have reported similar density recommendations for single-tree selection systems in northern hardwood, generally ranging from 60-90 ft2/acre in trees ≥5” DBH (Arbogast 1957; Kern *et al.* 2014; Leak *et al.* 2014). Stand structure or diameter distribution also influences stem quality. While quality northern hardwood can be grown under both even and uneven-aged systems, uneven-aged management results in greater merchantable log heights for shade tolerant species like sugar maple (Erdmannn 1986).

Tree-Level Factors

Tree-level factors that influence stem quality include both tree vigor and stem defects. Vigor can be defined as healthy, well-balanced growth or the relative capacity of a tree to increase in size (Ontario Ministry of Natural Resources 2004). Trees that exhibit vigorous growth and the ability to rapidly increase in size generally have less forking, greater merchantable heights, and fewer branch related defects (Erdmannn 1986). Foresters should assess the potential vigor of a tree by evaluating characteristics such as crown class, crown silhouette, live crown ratio, foliage condition, and bark characteristics and then use these traits to select crop trees that have the highest potential for future growth and value. Epicormic branching is an example of a defect that is vigor related. Epicormic branch sprouts originate from dormant buds embedded in the bark of many hardwood species. Bud dormancy is controlled by growth regulators (auxins) which are produced by the terminal buds. Trees lacking a healthy, vigorous, and large crown, such as suppressed and intermediate trees in the understory or crowded overstory trees in unmanaged, even-aged stands, do not produce sufficient regulators to prevent epicormic sprouting. Some intermediate and co-dominant trees may develop epicormic sprouts after the stand is first thinned. (Erdmannn 1986; Hutchinson 1992). More information on evaluating tree vigor can be found in Chapter 24 of the Silviculture Handbook.

Stem defects can include deviations from normal stem form (i.e., sweep and crook) and imperfections that impact the slab zone, quality zone, or heart center of a log (e.g., forks, knots, seams, rot, stains, holes, etc.) (Carpenter *et al.* 1989). Common northern hardwood defects include, but are not limited to:

- **Forking** can affect all northern hardwood but is most common in opposite-branched species such as maples and ashes. Forking not only is a stem defect, but it increases the risk of crown or stem breakage. Forking is often caused by an insect called a bud miner which is present in stands from the seedling stage through maturity. Forks are less common in uneven-aged stands than in even-aged stands. Fork correction occurs continually in uneven-aged stands due to taller overstory trees shading out part of the fork. For this reason, uneven-aged stands can generally develop greater merchantable log heights. In even-aged stands fork correction occurs when shade from crowns of adjacent trees causes one side of the fork to lose vigor and the other to acquire dominance. Even-aged stand density should be maintained at or above recommended residual levels to correct forks. Thinning stands heavy to sugar maple prior to 40 years of age or below recommended stocking levels will cause forks to increase in size and increase the time required for correction.
- **Sugar maple borer** is a long-horned wood boring beetle causing defect due to larval galleries and associated wood discoloration and decay. Maple borer damage can be mitigated by maintaining well-stocked stands and removing over mature, low-vigor trees.
- **Seams and cracks** are splitting or separation of the bark extending into the wood and can be open or overgrown with callus tissue. They can be found on all northern hardwood species, but are most common on ash, yellow birch, and sugar maple. Open cracks are more likely to be associated with significant decay and discoloration and have a large negative influence on tree value (Havreljuk *et al.* 2014).
- **Cankers** are localized areas of dead bark and cambium, commonly caused by fungi that infect wounds. Large cankers are often associated with significant decay and discoloration, especially if conks (fruiting bodies) are present.
- **Epicormic branches** are shoots arising from dormant buds on the stem of many northern hardwood species, often following sudden exposure to increased light levels. Trees lacking healthy, vigorous, large crowns are most susceptible. Some species, such as northern red oak and American beech, are also more prone to epicormic branching.
- **Wounds** are any injury to a tree that exposes the cambium or wood beneath the cambium. Wounds can be caused by mechanical damage, fire, animals, birds, or insects. Careless felling in well-stocked stands can result in numerous wounds and be the entry points for further insect and disease damage. The significance to stem quality and value will depend on the tree species, age and size of the wound, causal agent, and other factors.
- **Dark heart** refers to a dark stain or discoloration that forms in the center of sugar maple trees. Large heartwood discoloration is a serious defect because it reduces the amount

of light-colored wood that gives maple its commercial value. The discoloration at the center of sugar maple trees is caused by injury which allows fungi or bacteria to enter (Germain *et al.* 2015). The amount of heartwood discoloration in standing sugar maple trees is difficult to predict and will vary based on the time since injury and the ability of the tree to compartmentalize the injury.

- **Armillaria Root Disease** is caused by a root rot fungus (*Armillaria* spp.) that can infect trees stressed by drought, multiple defoliations, and other factors. Trees declining due to armillaria should generally be harvested before decay and mortality occur.

Multiple resources for defect identification, impacts, and prevention are available in the forest health section of this chapter, as well as in USFS Agricultural Handbook No. 678 – Defects in Hardwood Timber (Carpenter *et al.* 1989).

<u>How to Assess Current and Potential Stem Quality</u>
Foresters must be able to evaluate individual trees and stands of trees for their current and potential stem quality to develop prescription alternatives and make informed marking decisions. Two common types of systems that evaluate standing trees are tree grade and growing stock classification.

The **hardwood tree grades** developed by Hanks (1976) are often utilized as a standard measure for timber product stem quality, although numerous other grading systems exist (Table 40.9). Hank's tree grades evaluate the current <u>standing</u> tree quality in the butt log to help predict lumber grade yields or simply to quantify tree quality in a forest inventory (note- they are not used to appraise value due to variability in timber markets). Tree grading does not help evaluate the quality potential in smaller diameter trees.

Growing stock classification systems are field tools designed to help foresters assess and rate individual trees based on their quality, risk, and vigor characteristics. Information on the growing stock class, in combination with other crop tree selection and silvicultural prescription criteria, can be used to guide both the selection of cut/leave trees, as well as inform stand-level assessments of growing stock quality. Growing stock classification systems do evaluate the potential of smaller diameter trees to increase in volume, form, quality, and value. A Growing Stock Classification for Timber Management field tool is provided in Chapter 24 of the Wisconsin Silviculture Guide. Past versions of the northern hardwood chapter referred to "crop tree" using the definition adapted from The Lake States Manager's Guide for Northern Hardwood (USDA 2005). This new version will use of the term "AGS" in place of crop tree following the Growing stock classification system guidance in Chapter 24.

Table 40.9. Hardwood tree grades for factory lumber (Hanks 1976).

Grade factor	Tree grade 1			Tree grade 2		Tree grade 3
Length of grading zone (ft.)	Butt 16			Butt 16		Butt 16
Length of grading section (ft.)	Best 12			Best 12		Best 12
DBH, minimum (in)	16			13		10
Diameter, minimum inside bark at top of grading section (in)	13	16	20	11	12	8
Clear cuttings (on best 3 faces)						
Length, minimum (ft.)	7	5	3	3	3	2
Number on face (maximum)		2		2	3	Unlimited
Yield in face length (minimum)	5/6			4/6		3/6
Cull deduction, including crook and sweep but excluding shake, maximum within grading section (percent)	9			9		50

5.2.2 Thinning

Thinning is an intermediate treatment applied in northern hardwood stands. Use thinning until rotation aged is reached, in stands which will be managed on an even-aged basis or as part of the even-aged to uneven-aged conversion process. In the appendices, there are two optional even-age stocking charts to reference when determining target residual stocking. (Strong 2005) modified a chart that depicts stocking levels represented by trees per acre and Leak *et al.* (2014) developed a chart that depicts target stocking levels represented by relative density.

When thinning stands, determine which trees to favor (future growth) and which trees to cut by following the recommended sequence of removal (also see Chapters 23 and 24 for discussion). This sequence will often vary depending on landowner goals, stand management objective and the silviculture treatment:

1. Risk – Cut high risk of mortality, failure or loss of quality/value
2. Release acceptable growing stock (AGS) trees
3. Vigor – Cut low vigor trees
4. Adjust residual stand stocking to improve stand growth:
    - Remove poor stem form and quality
    - Remove less desirable tree species
    - Improve spacing

Pole-Sized Stands (Avg. DBH 5-11”) (adapted from Erdmann 1986)

- Don’t thin stands dominated by sugar maple until at least 40 years old to prevent low merchantable log heights.
- Full crown release (approximately 7’) of 40-60 AGS per acre. Leave an adjacent tree crown to shade and correct small forks (<2”) if needed.
- Thin through remaining stand. Use stocking charts and tables (in the appendices) to determine target residual basal area.
- If first thinning and average DBH 5-9 inches, then reduce stocking level to 80% crown cover and wait until crown closure and lower branch mortality on AGS before the next thinning (possibly 20 years).
- If second or later thinning or if average DBH >9”, then reduce stocking level to 90% crown cover and wait 10-15 years until crown closure and lower branch mortality on AGS before the next thinning.

Sawlog-Sized Stands (Avg. DBH >11”) (adapted from Erdmann 1986)

- Partial crown release (1-3 sided) of 40-60 AGS per acre (see Chapters 23 & 24)
- Thin through remaining stand to stocking level at 90% crown cover
- Wait 10-15 years for next thinning.

5.3 Natural Regeneration Methods

Management recommendations include generally accepted methods to convert northern hardwood stands from an even-aged to an uneven-aged (single-tree selection) system. The *conversion process* requires specific stand manipulation techniques that are implemented over a long-term period. In addition, recommendations on managing degraded northern hardwood stands and stands on poor quality sites are addressed later in this chapter. The *conditional recommended method* (patch selection) refers to a method applied to stands that meet a given condition such as having advanced regeneration present. For further consideration, there are alternative management methods mentioned later in the chapter. Comparison of the characteristics of the even-aged and uneven-aged management systems is provided in Table 40.11

Table 40.10. Recommended natural regeneration methods.

Forest Cover Type	Coppice	Clearcut	Seed Tree	Overstory Removal	Shelterwood	Group Selection	Patch Selection	Single-Tree Selection
Northern Hardwood	NR	NR	NR	R	R	R	CR	R

R- Recommended; CR – Conditionally Recommended; NR- Not Recommended

Table 40.11. Comparison of relative characteristics between even-aged and uneven-aged (single-tree selection) silvicultural systems on good to excellent sites (USDA 2005).

Even-aged	Uneven-aged (regulated)
Requires a rotation, with the elimination of the previous stand and establishment of a new stand	Continuous maintenance of a mature and structurally diverse forest
Provides opportunity for less shade tolerant species when combined with seedbed preparation	Favors shade tolerant species, especially sugar maple
Requires a different basal area target for every thinning depending on average tree diameter and species composition	Basal area target remains constant for every entry (thinning, harvesting, and regenerating at each entry)
Removes many small trees in each thinning	Removes fewer trees and larger trees at each entry
Early thinnings are all pulpwood and could be economically marginal	Timber products are mainly sawlogs with a small amount of pulpwood
A half to two-thirds of periodic growth can be sold while stocking is building	Nearly all the volume growth at each entry can be sold once the stand is regulated
Butt rot, resulting from winter sunscald of 1-3-inch diameter saplings on exposed sites, can reduce volume and grade in sugar maple and other species	Sunscald rarely occurs
Merchantable height will usually be less than two 16-foot logs in sugar maple	Merchantable height can be two to three 16-foot logs in sugar maple due to fork correction
Ideal for fiber production. Can produce high yields of high-quality logs of mid-tolerant species	Produces the optimum balance of quantity and high-quality logs in tolerant species such as sugar maple
Provides excellent habitat during the first 10-15 years of stand development for wildlife that prefer dense cover and browse	Provides increased structure favorable for some wildlife

5.3.1 Even-Age Regeneration Methods

5.3.1.1 Shelterwood

The shelterwood regeneration method is used to manipulate the overstory to create conditions favorable for the establishment and survival of desirable tree species. The shelterwood regeneration method is described in Chapter 21- Natural Regeneration. In northern hardwood stands, shelterwood should be considered for regeneration of even-aged stands or degraded stands (regardless of age structure), or to convert to another cover type.

The shelterwood method is comprised of multiple steps:

- preparatory cut (optional)
- seed or seeding cut
- overstory removal.

The preparatory cut is applied to increase tree vigor, crown area, and seed production. The preparatory cut is optional and it may not be needed if seed sources are well developed and spaced appropriately.

The seeding cut alters crown cover and spacing, ideally leaving a high, uniform crown cover (50-70%) in the residual overstory. A uniform residual stand is often difficult to achieve in the field as the desired and acceptable seed sources may be irregularly located. When marking the seeding cut, the crown area of target leave trees should be considered. Crown area can vary substantially between diameters and species. A useful tool to help determine and achieve target crown cover is the shelterwood calculator located on the WDNR internet site. Once the target crown cover is determined, it is recommended that leave trees are marked to target crown cover. Desirable leave tree characteristics include dominant/codominant crown position, mature seed producer, desirable species, good form, vigor and quality. Greater residual crown cover may be necessary if severe competition from interfering vegetation is anticipated. Lesser crown cover is recommended when mid-tolerant species are included in desired regeneration.

Additional considerations while using this method include site prep, timing and undesirable vegetation (scarification, mowing, or herbicides). Site preparation can be useful in a variety of situations such as lower quality hardwood; stands with an oak component; or when interfering vegetation is a problem. Also consider timing the seed cut and site preparation to production of good seed crops. Once regeneration objectives are achieved, overstory removal method is the next step in this process described in the following section.

5.3.1.2 Overstory Removal

Overstory removal is an even-aged regeneration method where the canopy is removed, placing advance regeneration in a “free to grow” position. Overstory removal is typically applied when a stand is degraded or mature and adequate desirable regeneration is present.

Sufficient established regeneration is required prior for overstory removal. For northern hardwood stands, regeneration is considered “established” when seedlings reach a height of 2’-4’ tall. On some sites there may be exceptions due to deer browse or site quality. If deer browse is a problem, consider removing the overstory when regeneration is taller than 4' tall. Poor quality sites might require regeneration up to 15' tall, however, consider the potential of damage to the tall regeneration from harvesting.

Sufficient well distributed, established regeneration of 2,000 to 5,000 stems per acre or more is optimal prior to overstory removal. See Chapter 21 – Natural Regeneration for further information regarding adequacy of regeneration. Post-harvest, no more than 10% residual overstory crown cover is recommended to avoid a reduction in regeneration growth. Sufficient regeneration is not always achievable, especially in degraded stand situations or on poor quality sites. In these instances, the forester may consider other treatments such as supplemental planting or forgoing treatment.

Many factors can affect overstory removal success. To minimize damage to established regeneration, harvesting during the dormant or late growing season with frozen or dry soil conditions is optimal. Regeneration which is hardened off is more apt to respond positively if damaged. Regeneration may be further protected with snow cover. The lack of leaves in the overstory also helps prevent the "fly-swatter effect" damaging seedlings and saplings as trees are felled.

Equipment operators play a pivotal role in the success of overstory removal. A conscientious operator can limit understory damage to main operational corridors and areas where multiple trees can be processed. Regardless, some damage and loss of existing regeneration will occur. A forester needs to monitor and evaluate the above considerations to be certain that overstory harvest will be successful.

5.3.2 Uneven-Age Regeneration Methods

5.3.2.1 Single-Tree Selection

Single-tree selection has been widely prescribed for the northern hardwood cover type in Wisconsin since at least the 1950's (Eyre and Zillgitt 1953; Arbogast 1957). Commonly prescribed across Federal, State, County, and private lands, single-tree selection offers several advantages when considering options for northern hardwood management:

- Steady, periodic harvests of timber
- High quality sawtimber production
- Mitigation of aesthetic and ecological concerns associated with timber harvests, maintenance of continuous canopy cover.

For single-tree selection to be effective it must first be appropriate. Single-tree selection is broadly applicable for uneven-aged northern hardwood stand management assuming the following conditions are met:

- The site is dry-mesic or mesic, capable of quality sawtimber production
- Two or more age/size classes are present
    - Note: foresters should not assume that smaller diameter size classes are necessarily different age classes. At first glance many stand diameter distributions have a reverse J-shape and appear to support the use of single-tree

selection. This can be deceptive. Two examples, stands with reverse J diameter distributions that are not uneven-aged, are:
- even aged stands with a component of fast-growing shade intolerant trees overtopping northern hardwood
- stratified northern hardwood stands where size classes stratify and linger as intermediate and suppressed trees

- A quick way to differentiate between stratified and uneven-aged stands is to examine the following questions:
  - Does the live crown ratio average 45%-60% in all size classes? If “no” then the stand is likely even-aged, and conversion may be more appropriate (Nyland 2017).
  - Does the stand present a “green wall” of regeneration, not a “naked” understory? If “no” then the stand is likely even-aged, and conversion may be more appropriate (Nyland 2018).

- Are current age/size classes of sufficient quality to assume they will maintain or improve in quality? This is especially important for smaller age/size classes as a lack of smaller age/size class quality will lead to a lack of larger age/size class quality over multiple entries.
- Can regeneration be successfully established or released with each stand entry?

With single-tree selection, diameter distributions are commonly used to describe current stand structure. In North America, some of the earliest work regarding single-tree selection and diameter distributions was conducted in Lake States uneven-aged northern hardwood stands (Eyre and Zillgitt 1953; Arbogast 1957). This effort led to northern hardwood stand structure recommendations for sustained yield of high-quality products known popularly as the “Arbogast Curve”. Unique among single-tree selection structural recommendations, this work has been tested and verified through long term, replicated, research studies at The Dukes and Argonne Experimental Forests (Eyre and Zillgitt 1953; Arbogast 1957; Crow *et al.* 1981; Strong *et al.* 1995). A recommended residual stand structure is presented in the tables found in the appendices. Here they provide alternatives for scenarios where different maximum diameters or cutting entry intervals may be appropriate. This is not an exhaustive or complete list. Based on differing stand conditions and landowner objectives, other maximum diameters, residual basal areas and diameter distributions may be appropriate as well.

For northern hardwood stands managed with the single-tree selection method; regeneration, tending, and harvesting occur at each stand entry. Using current stand information, management involves moving the current stand closer to a predetermined set of target stand conditions. These conditions are summarized as BDq:
- Residual basal area (B): Commonly ranges between 60-90 ft^2 / acre
- Maximum tree diameter (D): Regularly ranges between 18” – 24”
- Target diameter distribution (q): Both the Arbogast Curve and q factors 1.3 – 1.5 are frequently used.

Stands are moved closer to their target condition by harvesting trees singly or in small clusters, maintaining or improving the residual stand while creating regeneration openings (canopy gaps). The key is in balancing productivity and quality. To aid foresters with implementation of single-tree selection, the following guide is adapted from Arbogast 1957 and T. Strong (USDA 2005):

- With current stand information in hand, identify a target residual basal area, diameter distribution, and maximum stand diameter per the BDq method. Utilize at least three size classes. Table 40-10 outlines recommended BDq targets with broad application in Wisconsin. Alternative BDq targets based on differing stand conditions and landowner objectives may be appropriate as well.
- Calculate the difference between target and actual stand conditions. This identifies both where (i.e., size classes) harvest priorities occur as well as how much (i.e., trees per acre, basal area, volume) to remove. Table 40.12 illustrates one method to quantify the difference.
    - In overstocked size classes, remove the lowest quality trees to achieve the recommended target density. Tree selection should be based on recommended removal or retention criteria.
    - In understocked size classes, remove only high-risk trees. To compensate for understocked size classes, additional basal area may need to be left in other size classes to the target stand condition.
        - Failure to recognize the importance of harvesting based on size class or basal area targets can lead to unintended consequences. If too few trees are retained, future yield and quality may be diminished due to low stocking. If too many trees are retained, regeneration can be compromised through insufficient disturbance.

- Repeat cutting on 10-20 year intervals (depending upon stand growth and volume requirements for operability).

Table 40.12. Example NH single-tree selection worksheet with targets of 85 ft^2, The Arbogast Curve, and a 24" maximum diameter.

			Current Stand		Residual Target					
	DBH	BA/tree	Total trees	Total BA	Target Trees	Target BA	Tree Difference	BA Difference	Harvest Ratio	Harvest BA
Poles	6	0.2			36.00	5.8				
	8	0.3			21.00	6.3				
	10	0.5			15.00	7.3				
		Class Total			72.00	19.4			**1 out of X tree(s)**	**XX BA**
Sm. Saw	12	0.8			11.00	7.9				
	14	1.0			10.00	9.9				
		Class Total			21.00	17.8			**1 out of X tree(s)**	**XX BA**
Lg. Saw	16	1.3			8.00	10.5				
	18	1.7			6.00	10				
	20	2.1			5.00	10.3				
	22	2.3			4.00	10.1				
	24	3.0			2.00	6				
		Class Total			25.00	46.9			**1 out of X tree(s)**	**XX BA**
Larger than maximum DBH	26	3.6			0.00	0				
	28	4.1			0.00	0				
	30	4.7			0.00	0				
	>30	5.0			0.00	0				
		Class Total			0.00	0			**1 out of X tree(s)**	**XX BA**
		Total			118.00	84.1				

Target residual basal area, maximum tree diameter, and diameter distribution are all flexible in application. The goal is to move closer to the target residual criteria. Using BDq targets provides a set of guidelines, rather than a strict regime for sustained yield regulation and is not intended to be rigid.

When choosing stand structure targets, foresters should keep the following points in mind:

1. The target residual structure and density should reflect a landowner's management goals and objectives.
2. The residual density and maximum diameter should be consistent with the intended cutting cycle length, with less residual stocking and smaller maximum diameters for longer cutting cycles.
3. The residual structure should provide an excess of trees to cut from across the diameter distribution at the end of each cutting cycle to insure consistent yields at regular intervals over multiple entries.
4. The choice of an appropriate set of targets must provide an attractive cut of salable material and ensure a good return on the investment of management if the enterprise has commercial objectives (Nyland 1986).

Recruitment of regeneration with single-tree selection occurs when openings or "canopy gaps" are created. Canopy gaps for regeneration (25-75' diameter) are created when large-crowned trees are harvested. Gaps serve to either release established regeneration or recruit a new cohort of seedlings. In stands where trees have not yet reached the maximum diameter, clusters of trees can be removed to mimic maximum diameter tree removal. Variation in canopy gap size (Table 40.13) can also promote a greater diversity of mid-tolerant species

(Strong 1998; Webster and Lorimer 2005). Since many stands contain a suppressed sapling component, cleaning gaps by cutting all poor-quality stems greater than 1” DBH may be appropriate.

5.3.2.2 Group Selection

Group selection is a feasible natural regeneration method over a wide range of sites, from dry-mesic to wet-mesic and nutrient medium to rich. This method tends to promote increased species diversity in northern hardwood stands as compared to single-tree selection. It is particularly useful for promoting species less tolerant of shade including yellow birch, northern red oak, basswood, red maple, white pine, and black cherry.

With group selection, clusters of trees are selectively or systematically removed to create regeneration openings (groups). Groups range in size from 0.1– 0.5 acre. (see Chapter 21, Natural Regeneration Methods). Factors affecting placement and size of a group include stand management objectives, current stand structure, stand quality, vigor, slope/aspect, competing vegetation and the silvics of desired species. The larger the group, the greater the potential representation of mid-tolerant and intolerant regeneration. In application, group openings are cleaned of UGS stems down to one inch in diameter. The number of groups and individual group “rotation length” are dependent upon landowner objectives, current stand age, stand condition, and stand area. Groups can be installed where tree quality is poor, trees are mature, or where adequate established regeneration is present. Groups often require site preparation or the release of preferred species regeneration. Thinning or tending may occur throughout the remainder of the stand. On steep topography, group selection is commonly employed without thinning or tending in the remainder of the stand, due to harvesting limitations.

Group selection generally achieves regulation utilizing area control, whereby a designated percentage of the stand is harvested in groups during each cutting cycle. When considering regulation of the stand assess the current stand age, desired rotation length, and the percentage of stand area to harvest at each entry.

5.3.2.3 Patch Selection

An alternative to group selection is patch selection. With patch selection, trees are periodically removed to create regeneration openings .5 – 2 acres in size. Unlike group selection, patch selection is only advisable when releasing established regeneration, not initiating regeneration. The spatial distribution of regeneration openings may be regular, or irregular as dictated by variations in stand condition, such as the age, size, vigor, quality, composition, and health of patches of trees. Patch selection is a conditionally recommended method, in that, advanced regeneration should be present before the method is applied.

There are some considerations, however, to patch selection. The size of the opening produces variable effects. The larger the group, e.g., 2/3 acre or larger, the more shade intolerant species can establish post-harvest such as aspen, pin cherry, paper birch, raspberry (Kern *et al.* 2017) and elderberry. Some of these species could be undesirable competitors. Foresters should also consider factors such as desiccation or stand drying once the overstory is removed. This can inadvertently result in the loss of advance regeneration.

5.3.2.4 Irregular Shelterwood

Stand age structure and cohorts are distinguishing characteristics in defining even-aged vs uneven-age stands. The main contrast is that even-age stands have trees of the same age class and uneven-age stand containing at least three age classes (Erdmannn 1986; Smith *et al.* 1997; Nyland 2003). However, intermediate structures with variable stand features have been widely acknowledged. The question arises on how to emulate that structure using a silviculture method.

Irregular stand structure usually develops from episodic or partial disturbance leaving behind a residual stand with variable sizes; several or grouped cohorts; diversity of species composition and spatial heterogeneity (Raymond *et al.* 2009). This variability has been recognized having ecological significance by providing diversity for a wide variety of species and known for encouraging growth on the most valuable trees.

One silviculture method to emulate this type of variability is irregular shelterwood. Although descriptions of this method vary, the common objective is to establish a new cohort that may be composed of mid-tolerant and tolerant species in the northern hardwood cover type. In addition, another characteristic of this method is having a longer or indefinite regeneration period than the regular (two step) shelterwood method described above. Earlier in this chapter we explained the (Femelschlag) expanding gap, irregular shelterwood method but other variants include *continuous cover* or *extended irregular shelterwood*. The intent is to create and release larger groups of multiple cohorts and have variable densities across the stand instead of the uniform spacing of residual seed trees in regular shelterwood method. In addition, longer retention period of residual trees is encouraged to prevent undesirable species and encourage a longer period of growth on the most valuable trees.

<u>Variations on the Method</u>
An uneven-aged variant to shelterwood is the expanding gap system, often described as at type of irregular shelterwood or “femelschlag.” Irregular refers to the potentially unbalanced distribution of age classes, arrangement of trees and the variable production of forest products. Like group and patch selection, the expanding gap system utilizes an uneven-aged, area control approach. Initial stand entries create openings to establish or release established regeneration. With this and subsequent entries, the margin of the opening may be modified (thinning, midstory removal, etc.) to release or establish desirable regeneration. Since the margin is modified by the presence of the opening itself, margin modification may not be necessary in all situations. At subsequent entries, established regeneration in the margin is released via overstory removal and a new margin is assessed for potential modification. With this method, the opening is gradually enlarged in concentric rings until the stand is completely harvested. Reserves may be utilized to further enhance structural diversity but are not required.

5.3.2.5 Even-aged to Uneven-Aged Conversion Process

Many northern hardwood stands in Wisconsin are even-aged and not regulated. They often lack several size classes, especially the seedling/sapling size class, due to a number of factors including closed canopy conditions, past stand management (thinning from below) and other regeneration limiting factors. Stands that are even-aged or two-aged may be converted to uneven-aged management by combining AGS release, even-aged thinning and canopy gap installation. Application of the conversion process will create stand conditions which initiate or release regeneration, improve stand quality, and develop a diverse diameter distribution. Modified to incorporate large gaps, it can encourage tree species diversity.

Key components of the even-aged to uneven-aged conversion process include installation of canopy gaps, crown release of acceptable growing stock (AGS) and thinning throughout the remainder of the stand. The recommended procedure to convert or adapt even-aged stands to single-tree selection is adapted from Argonne Experimental Forest studies, (USDA 2005; Erdmann 1986):

<u>First Entry into Even-Aged Stand</u>
Create canopy gaps and apply even-aged thinning with crop tree release:

Canopy Gaps: Create canopy gaps for regeneration on approximately 5-15% of the area at each entry. Gaps may be created by cutting large mature, defective and diseased trees or by removing groups of poor-quality poles. Canopy gaps may also be used to release desirable advance regeneration or be placed near a desirable seed tree. Undesirable regeneration and competing vegetation should be removed from the canopy gaps so that vigorous regeneration can develop from new seedlings or advance seedling or sapling reproduction.

Canopy gap creation may encourage species diversity. Smaller regeneration gaps generally favor shade tolerant species (sugar maple, beech, hemlock). Larger gaps may favor mid-tolerant species (e.g., yellow birch, white ash, oak) especially if placed near a potential seed tree. Site preparation may also be needed to reduce undesirable competing vegetation and prepare a suitable seed bed.

Canopy gaps >25’ in diameter are created when single large-crowned trees or clusters of trees are cut. Smaller gaps usually close quickly through crown expansion of dominant and codominant border trees and may reduce the recruitment of regeneration into the canopy (Goodbum 2004; Webster and Lorimer 2005). Smaller gaps tend to close within 10-12 years (WDNR 2003; Kern *et al.* 2017). Kern *et al.* (2017) suggest that regeneration may be enhanced if a variety of gap sizes and shapes are installed and by retaining biological legacies (snags, cavity trees, long lived conifers, coarse woody debris, etc.) within the gaps to enhance diversity.

Canopy gaps can be installed in a variety of ways (“on the fly,” grid system, random placement, other methods). Regardless of installation method it is important to ensure an adequate number of gaps, sufficient gap sizes to achieve objectives, and proper location by cutting large mature, defective and diseased trees, removing groups of poor-quality poles, or releasing desirable advance regeneration. Marking gaps in a different paint color may help identify gap location, where trees need to be harvested and where gap cleaning is necessary.

Table 40.13 references a wide range of canopy gap research (Erdmannn 1986; Leak 2004; USDA 2005; Webster and Lorimer 2005; Kern 2016) in North America. In addition to the size of gap, the table also summarizes the considerations of each size, referenced from the literature.

Table 40.13. Circular canopy gap sizes for regeneration in northern hardwood.

Diameter	Area (acres)	Considerations
25	0.011	Favors the most shade tolerant species; canopy closes quickly
30 - 40	0.016 – 0.029	Typical crown area of 18-26” DBH sugar maple trees (see Table 40.18).
50 - 60	0.045 – 0.065	For canopy recruitment of mid-tolerant species (Kern; Lorimer)
66	0.079	Preferred size for establishing regen and release of advanced regeneration
75	0.101	Small group selection. Potential for increased shrub competition. Consider site preparation and release needs.
118	0.251	Group selection (consider site preparation and release)
167	0.503	Upper range for group selection

Thinning: Apply even-aged thinning guidelines with crop tree release to the remainder of the stand. Select individual trees to retain considering their current and future bole quality. A critical consideration in marking the first entry is retaining and releasing trees that will increase in grade and merchantable height.

Some small pole-sized understory sugar maple trees in even-aged stands are the same age as the overstory trees but are slower growing. These intermediate and suppressed understory trees will reduce the future quality and value of the stand if retained for structure. Quality in the pole-size class can be improved by cutting heavily from below (closer to the B-line) when even-aged stands are first entered.

<u>Second Entry into Two-Aged Stand</u>
To facilitate the development of timber quality, the second cut should not be implemented until after crown closure and lower branch mortality occurs, possibly 15 to 20 years. The second cut should concentrate on improving basal area stocking in the uneven-aged target condition using the single-tree selection guidelines and developing quality small sawtimber. Create canopy gaps.

<u>Third and Fourth Entries into Uneven-Aged Structure Stands</u>
Depending on the stand conditions (determined by the stand assessment), it will probably require at least 3-4 cutting operations to develop a relatively well regulated and fully stocked

(by size class) uneven-aged stand. Future entries may occur at 10 to 15-year intervals and should concentrate on improving basal area stocking in the uneven-aged target condition using the single-tree selection guidelines. Create canopy gaps.

The decision to switch over to the single-tree selection method after implementing the EA to UA Conversion Process may be based on several site/stand conditions. For instance, the stand could lack regeneration where further gap installation could be an option in future entries. Also, stand structure in various size classes could still be lacking and need further development in various size classes. In any case, a thorough stand assessment is recommended before deciding on a silviculture method.

5.5 Rotation Lengths and Cutting Cycles

Rotation Definition
In even-aged silvicultural systems a rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria, including culmination of mean annual increment (CMAI), target size, attainment of a physical or value growth rate, and biological condition.

Choosing an Appropriate Rotation Age
Selecting when to rotate a stand is based on multiple considerations, including landowner goals, stand condition, and expected future growth. The rotation ages provided are guidelines based on literature, empirical data, and professional experience. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning quality, vigor, mortality, merchantability, stand growth and productivity. Different rotation lengths can result in increased production of some benefits and reduced production of others, and landowner goals will help inform the evaluation of the benefits and costs (ecological, economic, social) associated with different forest management strategies.

5.5.1 Even-Aged Management

Northern hardwood are usually managed to produce sawtimber on sites where relative potential productivity is good to excellent (sugar maple SI>60). The recommended even-aged rotation to balance high quality development, high growth rates (vigor), and economic risk is 80-120 years. Rotations up to 150 years can be considered (on excellent sites), but volume growth rates may decline, and economic risk will increase. On poorer sites (sugar maple SI<55) and unmanaged stands, recommended biological rotation ages (CMAI) may be somewhat shorter (80-100 years), however expect reduced quality, reduced growth rates, and increased mortality. Conversely, economic rotation ages (maximum net present value) may be reached earlier on good quality sites as growth rates are higher and upper grades are achieved sooner. Individual trees and stands may maintain vigor longer or decline earlier than these rotation length guidelines indicate.

5.5.2 Uneven-Aged Management

Uneven-aged management rotates individual trees or groups of trees rather than entire stands. For northern hardwood stands managed with the single-tree selection method; regeneration, tending, and harvesting occur at each stand entry. Stand management involves moving the current stand closer to a predetermined stand structure, summarized by the BDq target (see Single-Tree Selection section). The target structure identifies a maximum tree diameter (D) where mature trees are rotated from the stand based on financial, ecological, or other objectives.

The selection of an appropriate stand structure and associated maximum tree diameter for single-tree selection is flexible depending on stand conditions and landowner objectives. Table 40.15 provides a recommended stand structure using the “Arbogast Curve,” which is the most tested and prescribed structure in the Lake States. Table 40.17 provides alternatives for scenarios where a larger or smaller maximum diameter may be appropriate based on stand conditions (e.g., poor quality sites) and landowner objectives (e.g., desired products, market considerations, extended rotation). See the Single-Tree Selection and Economic Considerations sections of this chapter for more detailed discussion on stand structure options.

In stands managed with uneven-aged management, the cutting cycle re-entry interval generally ranges from 8 to 20 years based on landowner objectives, site quality, stand growth, and operability. Shorter cutting cycles can maintain higher tree growth rates but operability due to lower available volume per acre must be considered. Shorter, more frequent re-entries may increase the potential for degrading stand quality through stem damage and soil compaction. Conversely, shorter cutting cycles will allow for capture of more high risk and low vigor trees succumbing to mortality. Longer cutting cycles can maximize tree quality and reduce negative impacts, such as damage to residual trees, soil compaction, aesthetic impacts (e.g., reduced slash), and ecological impacts (e.g., habitat disruption).

5.5.3 Extended Rotation

Extended rotation involves growing stands beyond typical biological rotation ages yet younger than average tree life expectancy, with the objective of managing for both commodity production and the development of some ecological and social benefits associated with older forests. Ecological benefits of extended rotations can include an abundance of large trees, more diverse vertical structure, and greater levels of standing snags and coarse woody debris that support organisms associated with these structures. In northern hardwood, extended rotations are most compatible with uneven-aged management.

Appropriate stand structures can utilize a 24-plus to 30-plus inch maximum diameter. Longer cutting cycles generally would be appropriate. Additional ecological management techniques may be applied, such as the retention of reserve trees, management of coarse woody debris (large snags and downed rotting logs), and the encouragement of coniferous associates (especially hemlock and white pine).

5.6 Other Silvicultural Considerations

5.6.1 Managing “Degraded” Stands

Degraded stands can broadly be characterized as having a structure and quality that is poorer than what is generally expected on similar sites. Degraded stands differ from poor quality stands on poor quality sites in that their degraded condition resulted from a past event(s), not site deficiencies. These stands often have trees that are crooked, rotten, and/or diseased.

They also may have undesirable species composition, variable stocking, physical damage from previous logging or poor growth rate, and may lack desirable regeneration. Degraded stands are found growing on all sites; the level of their degradation is a function of both site quality and intensity of the degrading event. Degraded stands do not contain large volumes or numbers of desirable growing stock (Clatterbuck 2006).

Many stands throughout Wisconsin have been “degraded” or reduced in stand quality due to a multitude of factors (events) including poor harvesting techniques such as high-grading and diameter limit cutting, grazing, fire, and other biotic and abiotic agents (disease, insects, wind, ice). Many of these stands have either an abundance of poor-quality stems or some poor-quality larger diameter stems overtopping a younger stand (seedlings, saplings, or poles).

Degraded stands are a financial liability and landowners face a heavy cost in lost production opportunities due to poor stocking, reduced quality and vigor of residual trees and reduced future revenues due to prior cutting of the most desirable trees (Nyland 2014). Alternatives for improving stand conditions through commercial logging are limited by low stocking, low value, and an abundance of undesirable or nonmerchantable species. Inadequate stocking compromises growth potential and could make continued management financially unattractive (Kenefic and Nyland 2005). Thinning is usually not economically feasible in degraded stands because of the lack of acceptable growing stock (AGS) (Clatterbuck 2006). This is especially true in southern Wisconsin with a lack of small diameter wood markets. Kenefic *et al.* (2014) found that precommercial treatments such as crop tree release, timber stand improvement and supplemental planting were unlikely to increase stand values enough to compensate for the high cost of implementing the practices. However, left unmanaged, degraded stands are unlikely to improve much (McGee 1982).

A thorough stand assessment is required to determine the cause of the degraded condition as well as the site quality, species composition, stand age, stand structure, advance regeneration, and amount of AGS (using the growing stock classification system in Chapter 24). Below in the Key to Recommendations section, are the NH assessment checklist and Decision model tools to help the forester with the decision process. Technical research on stand degradation has been presented in a few ways. Bédard *et al.* (2014) did not consider a stand degraded if at least 40% of stocking was acceptable. Clatterbuck (2006) and McGee (1982) stated that stands were not considered seriously degraded if they contain at least 50 sq.ft. of basal area of acceptable growing stock per acre.

At some point in the degraded stand history, a decision must be made to either regenerate or rehabilitate these stands. If a stand’s degraded condition is due largely to site deficiencies, then little will be accomplished attempting to rehabilitate this stand. (Clatterbuck 2006). Stands considered for rehabilitation should contain 30-50 sq. ft. of basal area of AGS per acre or about 40 to 50 small saw-log per acre (Clatterbuck 2006; Erdmann 1986) (Table 41.14). The acceptable growing stock range referenced here (e.g., 40-50 AGS/acre) was based on work conducted by Clatterbuck, Erdmann, and past WDNR silviculture guides. Stands with less than 30 sq. ft. of basal area of AGS per acre should be regenerated (Clatterbuck 2006, McGee 1982). Although useful, Clatterbuck’s research and recommendations were developed for southern hardwood stands and not in the Lakes States.

Table 40.14. Acceptable Growing Stock (AGS) guidelines for defining degraded stands.

Basal Area (sq.ft./ac) AGS		AGS Trees per acre	Condition	Recommendation
> 50 sq.ft. AGS	OR	>50 AGS	Not degraded	Apply generally accepted silviculture methods
30-50 sq.ft./ac AGS		40-50 AGS	Degraded	Rehabilitate or regenerate
< 30 sq.ft./ac AGS		< 40 AGS	Severely Degraded	Regenerate

<u>Even-Aged Management Objective – Severely Degraded (<30 sq. ft./ac. AGS or <40 AGS/acre)</u>
If a sufficient number of AGS trees are not present in the stand or landowner objectives are better met by even aged management, then the stand should be regenerated as soon as possible to improve future stand quality. The stand may be regenerated as soon as it reaches seed bearing age. Even-aged management systems using either shelterwood or overstory removal are the preferred management options:

- If good quality, established, advance regeneration is lacking (< 2000 stems/acre, 2-4 feet tall, 70% stocked plots), then follow the process to regenerate the stand utilizing the shelterwood system.
- If adequate good quality, established, advance regeneration is present (2000-5000 stems/acre, 2-4 feet tall, 70% stocked plots), then follow the guidelines for overstory removal.

Depending on species composition and the landowner's objectives, the stand could be considered for other treatment options:

1. Artificial regeneration following generally accepted practices (Chapters 21 & 22).
2. Conversion to another cover type.
3. Other rehabilitation techniques: Various irregular shelterwood techniques may be used to better meet landowner objectives with given stand conditions - shelterwood with reserves, Femelschlag, low density shelterwood (Leak *et al.* 2014; Lussier and Meek 2014; Bédard *et al.* 2014). See chapter 21 for more even-age options.

<u>Uneven-Aged Management Objective - Degraded (30-50 sq.ft /ac. AGS or 40-50 AGS per acre)</u>
Stand rehabilitation involves improving the existing stand by harvesting less desirable trees and retaining desirable growing stock and securing & protecting desirable regeneration. (Clatterbuck 2006). In degraded stands, group selection harvest is an acceptable alternative. To initiate group selection, create canopy gaps up to 0.50 acres in size located in areas of poorest quality trees. This will maximize removal of undesirable trees while creating conditions that promote regeneration. Thin between groups to a minimum desired residual basal area concentrating on releasing trees to improve residual stand quality.

Depending on present species composition and the landowner's objectives, the stand could be considered for other treatment options:

- Artificial regeneration following generally accepted practices (Chapters 21 & 22); conversion to another cover type or other rehabilitation techniques such as conversion EA to UA; or patch/group selection.

5.6.2 Managing Stands on Poor Quality Sites

Poor quality sites may not be suitable for producing quality northern hardwood sawtimber. These sites might have thin or sandy soils and droughty conditions or may be too wet. Poor quality sites will typically have a site index less than 50-55 and are often found in the dry-mesic and wet-mesic, nutrient medium habitat type groups.

Many of the recommendations and research on northern hardwood management are based on studies conducted on good to very good quality sites such as the Argonne and Dukes Experimental Forests. The recommendation developed from these research sites may not apply as well on poorer quality sites.

Poor quality sites are not expected to grow high quality hardwood trees. Suitable management for hardwood on these sites includes pulpwood, limited sawtimber, fuel wood and chipping (McGee 1982). If continued northern hardwood management is the goal, consider even-aged management to encourage increased representation of mid-tolerant associates. These species generally offer greater potential growth and timber quality on these sites.

Group selection methods with larger patch sizes (up to 0.50 acres) may also promote mid-tolerant species. Group selection on these sites may require site preparation and release to achieve adequate regeneration of mid-tolerant species.

Depending on present species composition and the landowner’s objectives, the stand could be considered for other treatment options:

- Artificial regeneration following generally accepted practices (Chapters 21 & 22).
- Conversion to another cover type.
- Manage stand for other uses such as wildlife, aesthetics, watershed protection.

6 PRESCRIPTIONS

6.1 Development of a Prescription and Marking Guide

A silvicultural prescription is a site and stand-specific operational plan that describes the forest management objectives and activities for an area. It prescribes a series of silvicultural treatments to establish or maintain a free growing stand in a manner that accommodates the landowner objectives such as economics, wildlife and biodiversity, aesthetic and other.

Prescriptions are developed through a series of steps before implementation of treatments in the field. The first step of development is the stand assessment as referred to the Northern Hardwood Checklist (Table 40.22) in the appendix. This information is then analyzed along with landowner goals. This series of diagnostic steps is to develop a desired future condition for the target stand being managed. Development of a silviculture prescription considers evaluating all the alternatives to achieve the desired future condition. The northern hardwood checklist and decision model can help in that process.

Once the silviculture prescription is completed, an appropriate marking guide for the stand should be developed before the implementation stage of the process. Achieving the objectives of a silvicultural prescription ultimately relies on decisions tree markers make in the stand. Often stand conditions when marking (e.g., stocking levels, species composition, forest structure) can be quite variable. Minor adjustments and flexibility often occur. Before heading for the field, it is recommended that the marker(s) have a guide or format in hand. The marking guide is a form that can be used for many reasons: in the field to guide a marking crew for quality assurance and consistency, during field audits, and justification as a companion guide to the silviculture prescription.

A marking guide can be as brief or thorough as one develops. The guide can outline current site conditions, short and long-term landowner objectives. Marking instructions are highlighted such as silviculture method, residual density, species priority and AGS characteristics, installation of gaps (size and number), tree retention and other considerations during the marking implementation. For future consideration in development of a northern hardwood marking guide, see the marking examples in the appendix of this chapter (Table 40.25, Table 40.26, and Table 40.27). These examples are not intended to cover all site and stand conditions but offer considerations in development of a marking guide for a stand prescription.

7 APPENDICES

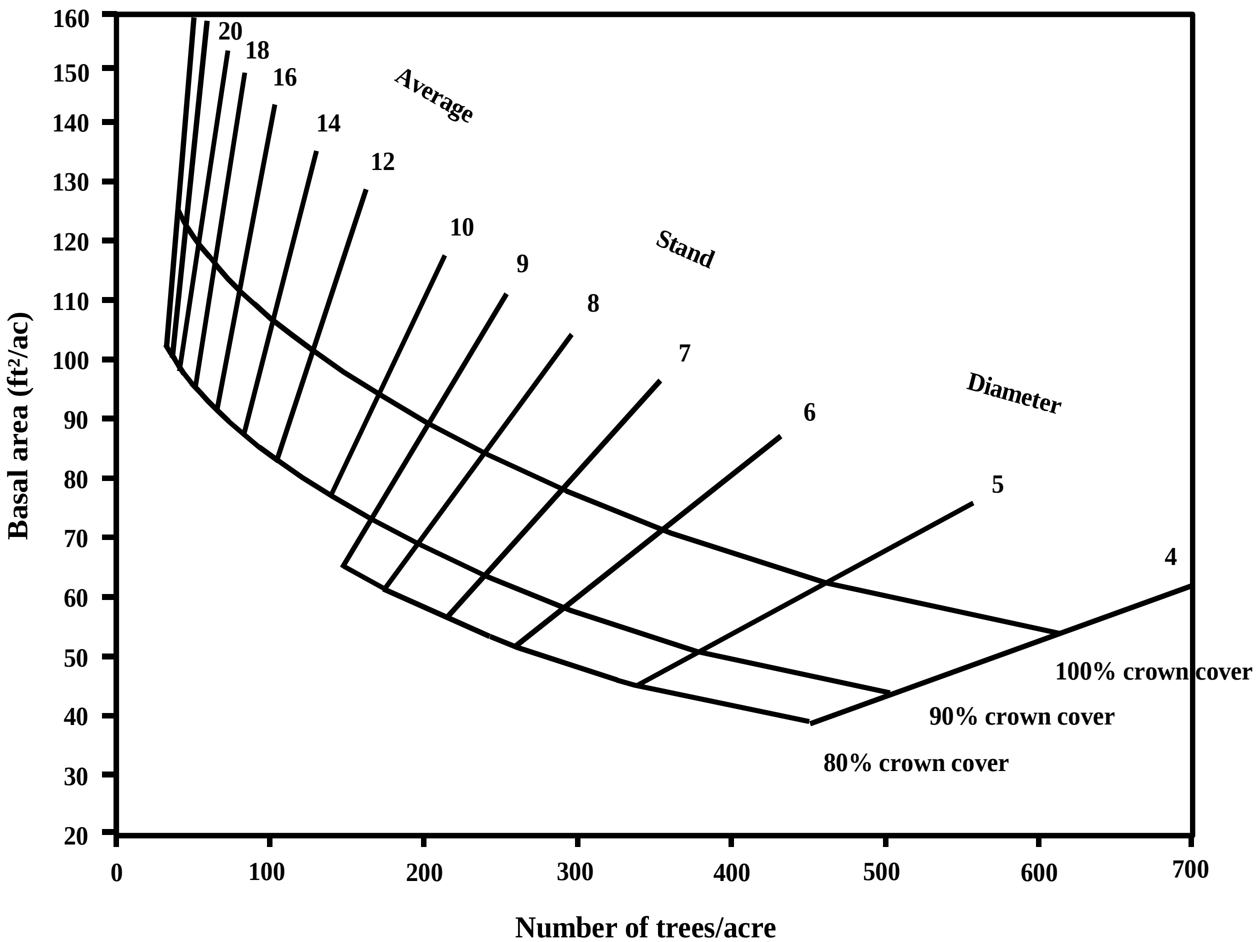


Figure 40.5. Stocking level chart for northern hardwood in even-aged stands (USDA 2005).

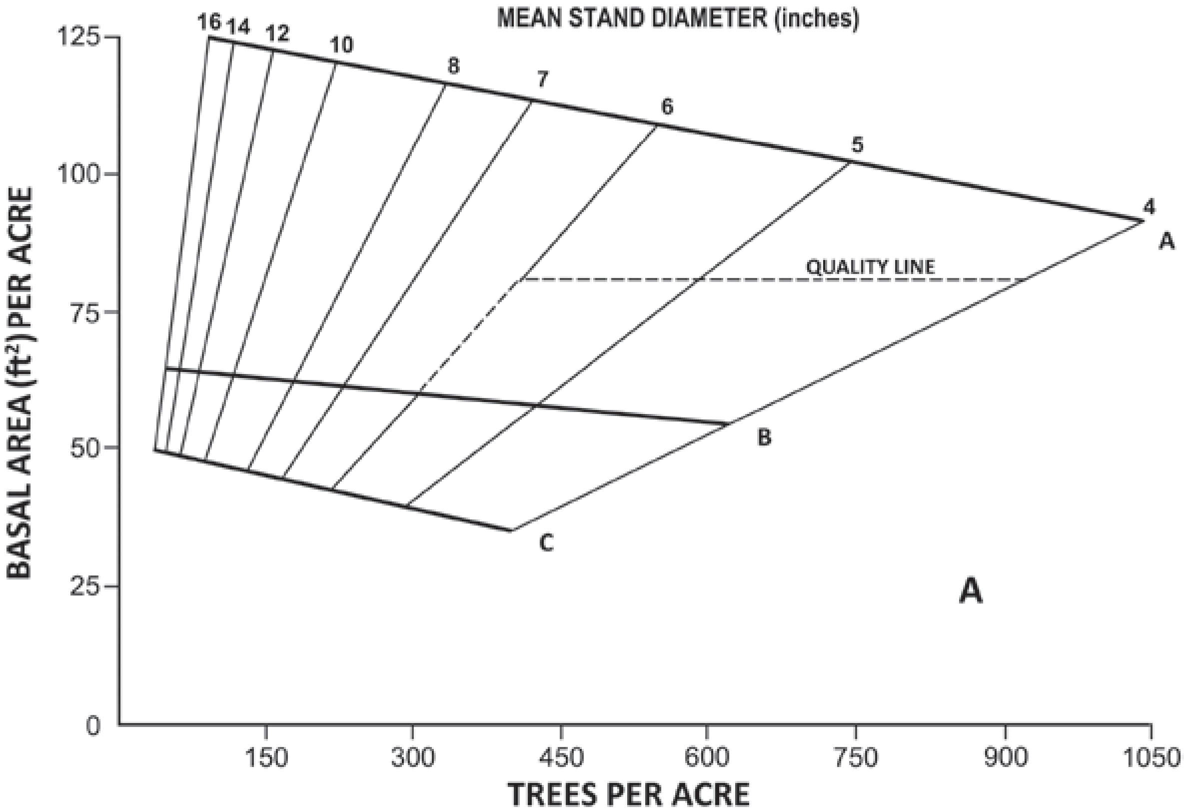
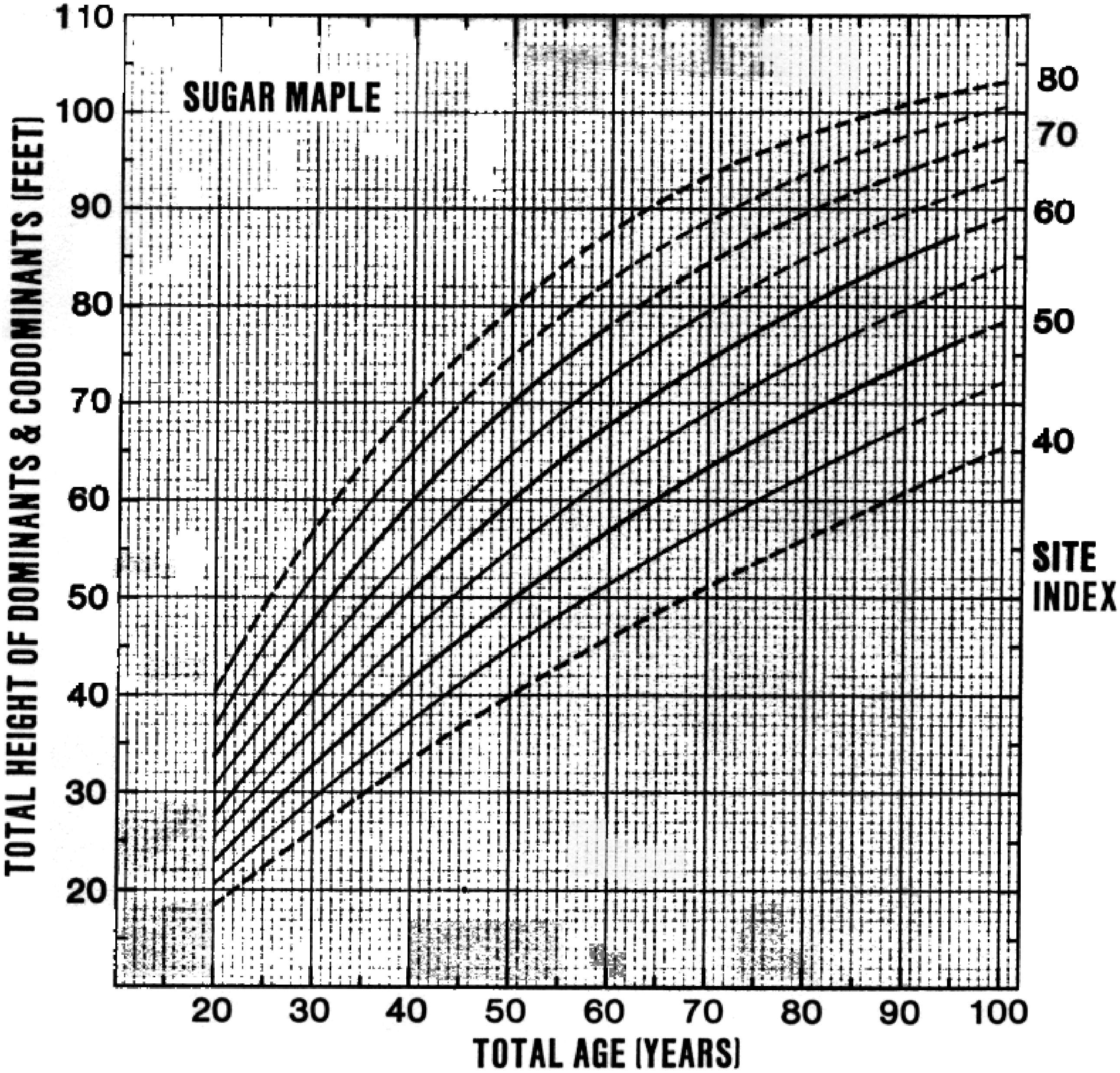


Figure 40.6. Optional stocking level chart for northern hardwood in even-aged stands (Leak *et al.* 2014).

Table 40.15. Recommended residual stocking per acre (trees≥5" DBH) for fully regulated uneven-aged stands (Arbogast 1957).

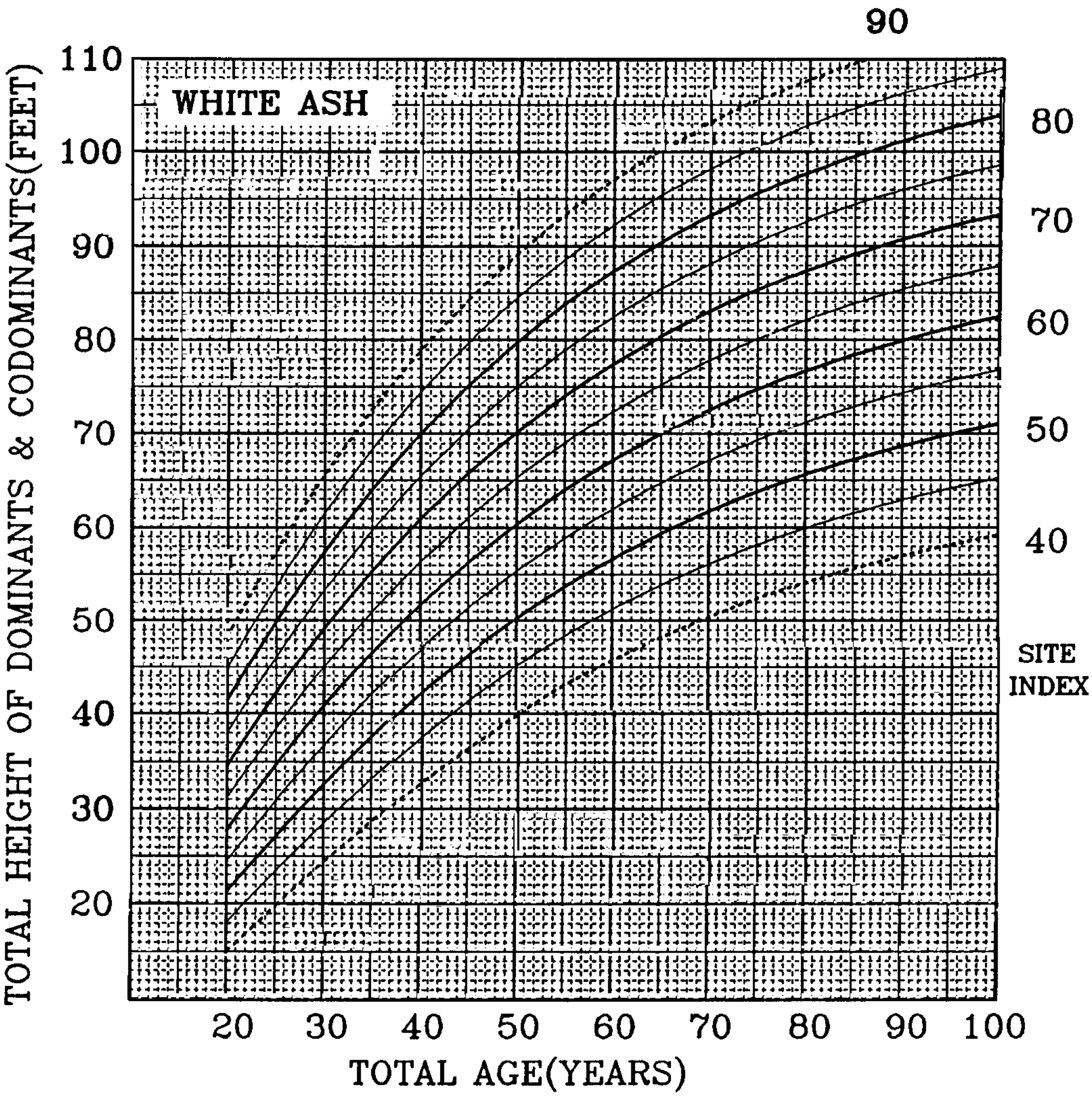
DBH (inches)	No. of Trees	No. of Trees by size class	Basal Area (square feet)	Basal Area by size class
5	21		2.9	
6	15		2.9	
7	12	65	3.2	16
8	9		3.1	
9	8		3.5	
10	7		3.8	
11	6		4.0	
12	5	28	3.9	22
13	5		4.6	
14	5		5.3	
15	4		4.9	
16	4		5.6	
17	3	17	4.7	26
18	3		5.3	
19	3		5.9	
20	2		4.4	
21	2		4.8	
22	2	8	5.3	20
23	1		2.9	
24	1		3.1	
Total (per acre)	118	118	84	84



Sugar maple (Carmean 1978)
Northern Wisconsin and Upper Michigan
177 plots having 721 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	6.1308	0.6904	-0.0195	10.1563	-0.5330	0.99	1.26	5.3
SI	0.1984	1.2089	-0.0110	-2.4917	-0.2542	0.98	1.90	6.7

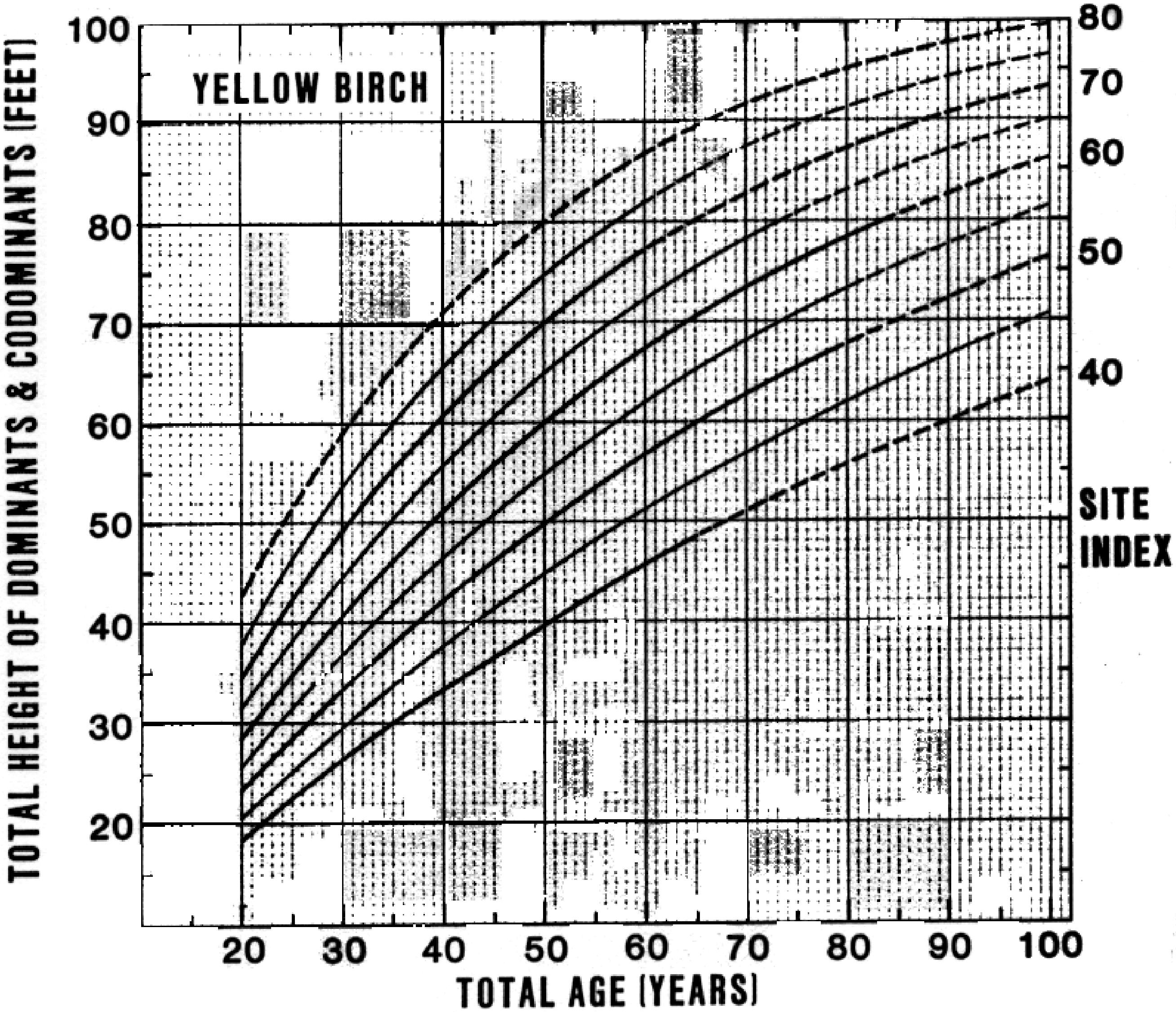
Figure 40.7. Site index curves for sugar maple in northern Wisconsin and upper Michigan (Carmean *et al.* 1989).



White ash (Carmean 1978)
Northern Wisconsin and Upper Michigan
73 plots having 275 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	4.1492	0.7531	-0.0269	14.5384	-0.5811	0.99	1.37	5.1
SI	0.1728	1.2560	-0.0110	-3.3605	-0.3452	0.99	1.99	9.5

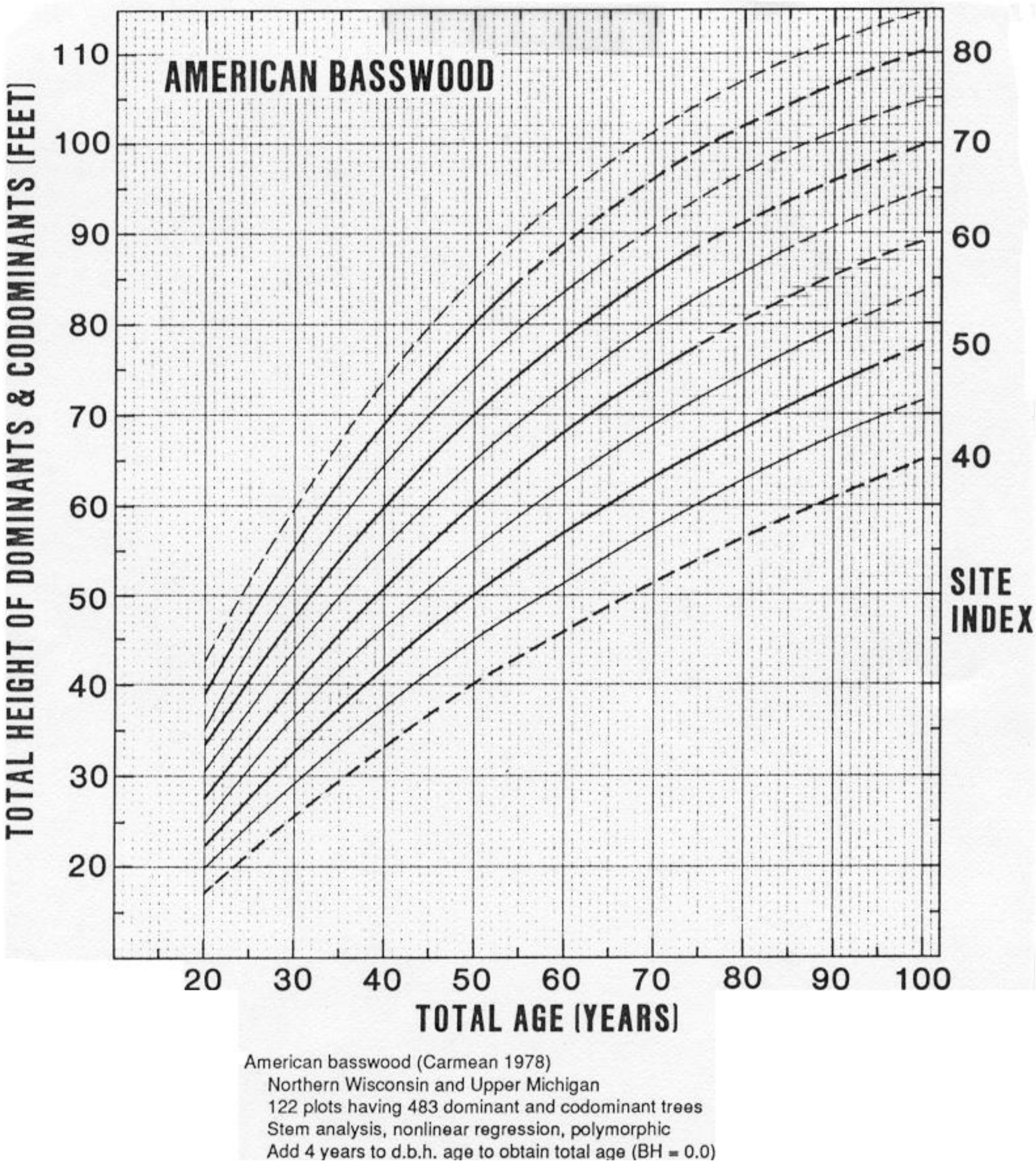
Figure 40.8. Site index for white ash in northern Wisconsin and upper Michigan (Carmean *et al.*, 1989)



Yellow birch (Carmean 1978)
Northern Wisconsin and Upper Michigan
119 plots having 459 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	6.0522	0.6768	-0.0217	15.4232	-0.6354	0.99	1.29	5.0
SI	0.1817	1.2430	-0.0110	-3.0184	-0.3180	0.98	2.05	7.7

Figure 40.9. Site index curves for yellow birch in northern Wisconsin and upper Michigan (Carmean *et al*., 1989).



	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	4.7633	0.7576	-0.0194	6.5110	-0.4156	0.99	0.70	2.7
SI	0.1921	1.2010	-0.0100	-2.3009	-0.2331	0.99	1.24	4.5

Figure 40.10. Site index curves for basswood in northern Wisconsin and upper Michigan (Carmean *et al*., 1989).

Table 40.16. Alternative residual basal area targets for regulated stands with differing cutting cycles (Nyland 2017).

	Cutting Cycle		
	15 yrs.	20 yrs.	25 yrs.
Diameter Class (in.)	Basal Area (ft^2 / acre)		
2"-5"	10	10	10
6"-11"	25	20	30
12"-16"	35	30	25
18+"	15	10	0
Total	**85**	**70**	**65**

Table 40.17. Alternative residual stocking levels for single-tree selection with different maximum tree size classes (prepared by T. Strong 2005).

	Maximum Tree Size Class					
DBH (inches)	**18"**		**24"**		**30"**	
	No. of Trees	Basal Area	No. of Trees	Basal Area	No. of Trees	Basal Area
2	118	2.6	118	2.6	118	2.6
3	53	2.6	53	2.6	53	2.6
4	31	2.7	31	2.7	31	2.6
Sub-Total	**202**	**8**	**202**	**8**	**202**	**8**
5	22	3.0	21	2.9	12	1.6
6	19	3.7	15	2.9	11	2.2
7	17	4.5	12	3.2	9	2.4
8	15	5.2	9	3.1	8	2.8
9	13	5.7	8	3.5	7	3.1
Sub-Total	**86**	**22**	**65**	**16**	**47**	**12**
10	11	6.0	7	3.8	6	3.3
11	10	6.6	6	4.0	5	3.3
12	9	7.0	5	3.9	5	3.9
13	8	7.3	5	4.6	4	3.7
14	7	7.4	5	5.3	4	4.3
Sub-Total	**45**	**34**	**28**	**22**	**24**	**19**
15	6	7.3	4	4.9	3	3.7
16	5	7.0	4	5.6	3	4.2
17	4	6.3	3	4.7	3	4.7
18	4	7.0	3	5.3	2	3.5
19			3	5.9	2	4.0
Sub-Total	**19**	**28**	**17**	**26**	**13**	**20**
20			2	4.4	2	4.4
21			2	4.8	1	2.4
22			2	5.3	1	2.6
23			1	2.9	1	2.9
24			1	3.1	1	3.1
Sub-Total			**8**	**20**	**6**	**15**
25					1	3.4
26					1	3.7
27					1	4.0
28					0.5	2.1
29					0.5	2.3
30					0.5	2.4
Sub-Total					**4.5**	**18**
Total ≥5"DBH	**150**	**84**	**118**	**84**	**94.5**	**84**

Table 40.18. Even-age stocking levels for northern hardwood by mean stand diameter, basal area, and number of trees per acre for specified crown covers after thinning (USDA 2005).

Mean Stand Diameter (in)	Crown area/tree (ft2)	Basal area/tree (ft2)	Crown cover (percent of 43560 ft2/acre)			
			80 percent		90 percent	
			Trees/ac (No.)	BA/ac (ft2)	Trees/ac (No.)	BA/ac (ft2)
4	78	0.0873	447	39	503	44
5	104	0.1364	335	46	377	51
6	133	0.1963	262	51	295	58
7	164	0.2673	212	57	239	64
8	199	0.3491	175	61	197	69
9	238	0.4418	146	65	165	73
10	279	0.5454			141	77
11	325	0.66			121	80
12	373	0.7854			105	83
13	422	0.9218			93	86
14	480	1.069			82	87
15	536	1.2272			73	90
16	598	1.3963			66	92
17	662	1.5762			59	93
18	728	1.7671			54	95
19	803	1.9689			49	96
20	881	2.1817			44	97
21	952	2.4053			41	99
22	1035	2.6398			38	100
23	1120	2.8852			35	101
24	1207	3.1416			32	102

Table 40.19. Even-age stocking levels (residual basal area (ft²/ac) for northern hardwood with various amounts of basswood by mean stand diameter (inches) for specified crown covers after thinning (USDA 2005).

Percent of basswood (*Tilia americana*)								
	20		**40**		**60**		**80**	
Crown cover (percent of 43,560 ft²/ac)								
DBH	**80**	**90**	**80**	**90**	**80**	**90**	**80**	**90**
5	57	64	62	70	70	78	79	89
6	61	69	67	76	75	84	84	95
7	65	73	71	80	79	89	89	100
8	69	77	75	85	84	94	94	106
9	72	81	79	89	87	98	98	110
10		84		93		103		115
11		88		96		106		119
12		91		100		110		123
13		94		103		113		127
14		97		106		117		130
15		99		109		120		134
16		102		112		123		137
17		105		114		126		140
18		107		117		129		143
19		109		119		131		146
20		112		122		134		149
21		114		124		137		152
22		116		127		139		154
23		118		129		141		157
24		120		131		144		159

Table 40.20. Even-age stocking levels (residual basal area (ft²/ac) for northern hardwood with various amounts of red oak and /or red maple by mean stand diameter (inches) for specified crown covers after thinning (USDA 2005).

Percent of red oak (*Quercus rubra*) and/or red maple (*Acer rubrum*)								
	20		**40**		**60**		**80**	
Crown cover (percent of 43,560 ft^2/ac)								
DBH	**80**	**90**	**80**	**90**	**80**	**90**	**80**	**90**
5	55	62	59	66	63	71	68	76
6	59	66	62	70	66	74	70	79
7	62	70	65	73	68	77	72	81
8	65	73	68	76	71	80	74	83
9	68	77	70	79	73	82	76	85
10		80		82		84		87
11		82		84		86		88
12		85		87		88		90
13		87		89		90		91
14		90		91		91		92
15		92		92		93		93
16		94		94		94		94
17		96		96		96		95
18		98		98		97		96
19		100		99		98		97
20		102		101		99		98
21		104		102		101		99
22		105		103		102		100
23		107		105		103		101
24		109		106		104		101

Table 40.21. Even-age stocking levels (residual basal area (ft²/ac) for northern hardwood with various amounts of hemlock by mean stand diameter (inches) for specified crown covers after thinning (USDA 2005).

Percent of eastern hemlock (*Tsuga canadensis*)								
	20		**40**		**60**		**80**	
Crown cover (percent of 43,560 ft2/ac)								
DBH	**80**	**90**	**80**	**90**	**80**	**90**	**80**	**90**
5	48	53	44	49	41	46	38	43
6	52	59	49	56	47	52	44	50
7	57	64	54	61	52	59	50	56
8	61	69	59	67	57	65	56	63
9	65	73	64	72	62	70	61	69
10		77		76		76		75
11		81		81		81		81
12		84		85		86		87
13		88		89		91		92
14		91		93		96		98
15		94		97		100		103
16		97		101		105		109
17		100		105		109		114
18		103		108		113		119
19		106		111		117		124
20		109		115		122		129
21		111		118		126		134
22		114		121		129		139
23		116		124		133		144
24		119		127		137		149

Table 40.22. Checklist for evaluating northern hardwood stand management options.

This decision tool is designed to help identify management options prior to developing a silvicultural prescription. Due to the complex character of both stands and management, checklist results should be considered collectively, along with other stand data and professional judgment, when evaluating management options to best achieve a desired future condition (DFC).

Instructions: Within each stand assessment topic (ex. Landowner Objective, Site Potential / Operability) there are 2-6 true or false questions. Answer each question by checking (✓) the true or false box to the right of the question. If you do not have sufficient information to make an informed decision, leave the question blank. When all questions within a topic have been reviewed, tally true and false answers and circle the assessment answer at the bottom of the column with the most checked boxes. When ties occur, use your professional judgement to decide between assessment answers. If curious, you might also assess multiple option sets using both assessment answers for a topic.

When all assessment topics have been reviewed, transfer assessment answers to page 2. Circle the assessment answers below each assessment topic which correlate to page 1 answers. Use the table to locate the Options Set which matches your answers. X's indicate options worthy of consideration. In some cases, X^1, X^2, and X^3 indicate a unique condition which is briefly described below the table. Note, the assessment topics: Deer Browse, Interfering Vegetation, and Enrichment are located on a separate table, below the main table.

	TRUE	FALSE
Objectives		
Landowners favor maintenance of a structurally diverse stand. For aesthetics or other reasons, they wish to avoid large scale overstory removal.		
Wildlife habitat focus is not dense cover (ex. ruffed grouse) or browse production (ex. deer).		
Timber income from stand should be regular, every 10-15 yrs., avoiding periods longer than 20 years without timber revenue.		
Harvest options are limited due to a lack of small diameter timber markets. Harvests are mainly sawtimber with limited amounts of other products.		
	Uneven-**A**ged	**E**ven-**A**ged
Site Potential / Operability		
Soils are sands (dry) or clay, poorly drained soils (wet)		
N WI - If known, the stand's forest habitat type classification is **Very Dry to Dry-Mesic**: PQE, PQG, PQGCe, PArV, PArV-U, PArVAo, Qap, PArVAm, PArVHa, PArVAa, PArVAa-Vb, PArVAa-Po, PArVPo, AVVb, AVCl, TFAa, AVDe, AVb-V, ACl, AVb, AAt, or ATFPo		
N WI - If known, the stand's forest habitat type classification is **Mesic to Wet-mesic** : PArVRh, ArAbVC, ArAbVCo, ArVRp, ArAbSn, ArAbCo, TMC, AAtRp, ASnMi, or ATAtOn		
S WI - If known, the stand's forest habitat type classification is **dry to dry-mesic**: ArDe-V, ArDe, AQVb-Gr, ArCi, ArCi-Ph, AArVb, AArL, PEu, PVGy, PVHa, PVCr, or PVG		
Site Index is < 55		
Slopes limit the use of CTL / mechanized processors		
	Poor-**F**air	**G**ood-Excellent
Stand History		
Indications of past high grading evident (ex. poor quality residual trees, patchy distribution of overstory trees)		
Indications of past cattle grazing (ex. barbed wire fence on stand boundary, prevalence of thorny understory)		
Storm damage present (ex. many damaged trees in the stand, crown breakage, lots of trees on ground)		
Insect and/or disease problems are a threat to the stand.		
Stand level evidence of crown dieback or loss of tree / stand vigor		
	Limiting	**N**ot **L**imiting
Stand Stocking & Quality		
Relative density is above the B-line (greater than 60%) or above 80% canopy cover		
≥40 acceptable growing stock (AGS) trees per acre		
35% or more of the stand's relative density is comprised of acceptable growing stock (AGS) trees		
	Sufficient	**N**ot **S**ufficient

	TRUE	FALSE
Stand Age / Structure		
Stand is dominated by stems less than 5" DBH (overstory)		
Stand does not have 2 or more WDNR size classes with sufficient quality (i.e., AGS) for continued management		
Individual tree live crown ratio tends to decrease across crown classes, highest with dominant and lowest with overtopped trees. The understory looks "naked" and lacks advance regeneration.		
Stand consists of a single size class or multiple size classes but only one has potential for improvement		
	Single **C**lass	**M**ulti-**C**lass
Regeneration		
≥2000 seedlings, at least 4' tall, per acre		
Seedlings and saplings are well distributed in the stand (≥70% of regeneration plots are stocked)		
Regeneration is vigorous, few saplings have lost a dominant leader		
Saplings are predominantly less than 15' tall		
Seedling / sapling species composition meets stand management goals		
	Stocked	**N**ot **S**tocked
Deer Browse		
More than 50% of palatable tree and shrub regeneration is browsed (≥BSI 4)		
The understory is dominated by ironwood, buckthorn, Eurasian honeysuckle, or other non-native trees and shrubs.		
Stump sprouts and seedlings are hedged, a distinct browse line has developed in the stand.		
	Browse	**N**o **B**rowse
Interfering Vegetation		
Interfering plants, including Penn. Sedge, etc., are infrequent (<30% cover) or do not pose a problem for initiating or advancing seedlings and/or saplings		
Ironwood, buckthorn, Eurasian honeysuckle, raspberries, blackberries or other problematic trees and shrubs are largely absent from the stand.		
	Not **I**nterfering	**I**nterfering
Enrichment		
Seed sources for shade-tolerant and mid-tolerant tree species other than sugar maple, red maple, and balsam fir (i.e., basswood, yellow birch, red oak, hemlock, etc.) are largely absent, not well distributed		
Seedling/sapling composition not projected to fare well with climate change (see https://forestadaptation.org/Northwoods_treehandouts)		
	Uniform	**V**aried

	Stand Assessment Answers					Silvicultural Systems						
	Site Potential	Stand History	Stand Stocking and Quality	Age / Structure	Regeneration	Landowner Objective: Uneven-Aged Management				Landowner Objective: Even-Aged Management		
Option Set	Poor-Fair / Good-Excellent	Limiting / Not Limiting	Not Sufficient / Sufficient	Multi-Class / Single Class	Stocked / Not Stocked	Single Tree Selection (40-X)	Single Tree Selection Conversion (40-X)	Group Selection / Conversion (40-X)	Patch Selection / Conversion (40-X)	Tending / Intermediate Thinning (40-X)	Shelterwood (40-X)	Overstory Removal (40-X)
1	Poor-Fair	Limiting	Sufficient	Multi-Class	Stocked			X	X	X		X
2	Poor-Fair	Limiting	Sufficient	Multi-Class	Not Stocked			X		X	X	
3	Poor-Fair	Limiting	Sufficient	Single Class	Stocked			X	X	X		X
4	Poor-Fair	Limiting	Sufficient	Single Class	Not Stocked			X		X	X	
5	Poor-Fair	Limiting	Not Sufficient	Multi-Class	Stocked			X	X			X
6	Poor-Fair	Limiting	Not Sufficient	Multi-Class	Not Stocked			X			X	
7	Poor-Fair	Limiting	Not Sufficient	Single Class	Stocked			X	X			X
8	Poor-Fair	Limiting	Not Sufficient	Single Class	Not Stocked						X	
9	Poor-Fair	Not Limiting	Sufficient	Multi-Class	Stocked			X	X	X		X
10	Poor-Fair	Not Limiting	Sufficient	Multi-Class	Not Stocked			X		X	X	
11	Poor-Fair	Not Limiting	Sufficient	Single Class	Stocked			X	X	X		X
12	Poor-Fair	Not Limiting	Sufficient	Single Class	Not Stocked			X		X	X	
13	Poor-Fair	Not Limiting	Not Sufficient	Multi-Class	Stocked			X	X			X
14	Poor-Fair	Not Limiting	Not Sufficient	Multi-Class	Not Stocked						X	
15	Poor-Fair	Not Limiting	Not Sufficient	Single Class	Stocked			X	X			X
16	Poor-Fair	Not Limiting	Not Sufficient	Single Class	Not Stocked						X	
17	Good-Excellent	Limiting	Sufficient	Multi-Class	Stocked	X		X		X		X
18	Good-Excellent	Limiting	Sufficient	Multi-Class	Not Stocked	X		X^1		X	X	
19	Good-Excellent	Limiting	Sufficient	Single Class	Stocked		X	X		X		X
20	Good-Excellent	Limiting	Sufficient	Single Class	Not Stocked		X	X^1		X	X	
21	Good-Excellent	Limiting	Not Sufficient	Multi-Class	Stocked		X^3	X	X			X
22	Good-Excellent	Limiting	Not Sufficient	Multi-Class	Not Stocked			X^2			X	
23	Good-Excellent	Limiting	Not Sufficient	Single Class	Stocked		X^3	X	X			X
24	Good-Excellent	Limiting	Not Sufficient	Single Class	Not Stocked		X^3	X^2			X	
25	Good-Excellent	Not Limiting	Sufficient	Multi-Class	Stocked	X		X	X	X		X
26	Good-Excellent	Not Limiting	Sufficient	Multi-Class	Not Stocked	X		X^1		X	X	
27	Good-Excellent	Not Limiting	Sufficient	Single Class	Stocked		X	X	X	X		X
28	Good-Excellent	Not Limiting	Sufficient	Single Class	Not Stocked		X	X^2		X	X	
29	Good-Excellent	Not Limiting	Not Sufficient	Multi-Class	Stocked			X	X			X
30	Good-Excellent	Not Limiting	Not Sufficient	Multi-Class	Not Stocked			X^2			X	
31	Good-Excellent	Not Limiting	Not Sufficient	Single Class	Stocked		X^3	X	X			X
32	Good-Excellent	Not Limiting	Not Sufficient	Single Class	Not Stocked		X^3	X			X	

X^1 Condition: Group selection may require seed bed site: preparation.
X^2 Condition: Possibly degraded, may require planting in addition to site preparation.
X^3 Condition: Thin where appropriate, focus gaps on existing regeneration or poorly stocked areas. Planting may be required.

NOTES:

Table 40.23. Northern hardwood stand exam tally sheet.

Property of Forest					Comp. No.	~~Stand No.~~	Date	Estimator
Section	T.	R.	Description	Acres	Primary		Secondary	Understory

Plot	Species Code						Total Cord	Trees/Acre				Basal Area				
								C	A	U	Regen 0-5	Pole 5-9	SS 10-14	MS 15-19	LS 20+	Total
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
Cord ~~Total Saws~~																

	P	SS	LS	P	SS	LS	P	SS	LS	P	SS	LS	P	S	L	P	S	L	Tree Diameters	Habitat Type
Basal Area Total Acre																				
BA/ Ac																				

No. of 16 – foot logs BAF 10

	Sp	1/2	1	1 ½	2	2 ½	3	BD/FT
Small ~~Sawtimber~~ 10-14		3 7 10 13 16	~~6-12~~ 18 24 30 36 42 48 54 60 66 72 78 94	~~9-17~~ 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115	13 26 39 52 65 78	15 30 45 60 75 90	
		3 7 10 13 16	~~6-12~~ 18 24 30 36 42 48 54 60 66 72 78 94	~~9-17~~ 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115	13 26 39 52 65 78	15 30 45 60 75 90	
		3 7 10 13 16	~~6-12~~ 18 24 30 36 42 48 54 60 66 72 78 94	~~9-17~~ 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115	13 26 39 52 65 78	15 30 45 60 75 90	
		3 7 10 13 16	~~6-12~~ 18 24 30 36 42 48 54 60 66 72 78 94	~~9-17~~ 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115	13 26 39 52 65 78	15 30 45 60 75 90	
		3 7 10 13 16	~~6-12~~ 18 24 30 36 42 48 54 60 66 72 78 94	~~9-17~~ 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115	13 26 39 52 65 78	15 30 45 60 75 90	
		3 7 10 13 16	~~6-12~~ 18 24 30 36 42 48 54 60 66 72 78 94	~~9-17~~ 26 35 43 52 61 70 78 96 104 113	10 21 32 42 52 63 73 84 95 105 115	13 26 39 52 65 78	15 30 45 60 75 90	
Med. Sawtimber 15-19	Sp	1/2	1	1 ½	2	2 ½	3	
		4 8 12 ~~16-20~~	7 14 21 28 35 41 48 55 62 69 76 82 89 96 102	10 19 28 38 48 57 67 76 85 95 105 114 123 133	12 23 35 47 58 70 82 94 105 117 129 140	14 28 42 56 70 84 98	17 33 49 66 83 99	
		4 8 12 ~~16-20~~	7 14 21 28 35 41 48 55 62 69 76 82 89 96 102	10 19 28 38 48 57 67 76 85 95 105 114 123 133	12 23 35 47 58 70 82 94 105 117 129 140	14 28 42 56 70 84 98	17 33 49 66 83 99	
		4 8 12 ~~16-20~~	7 14 21 28 35 41 48 55 62 69 76 82 89 96 102	10 19 28 38 48 57 67 76 85 95 105 114 123 133	12 23 35 47 58 70 82 94 105 117 129 140	14 28 42 56 70 84 98	17 33 49 66 83 99	
		4 8 12 ~~16-20~~	7 14 21 28 35 41 48 55 62 69 76 82 89 96 102	10 19 28 38 48 57 67 76 85 95 105 114 123 133	12 23 35 47 58 70 82 94 105 117 129 140	14 28 42 56 70 84 98	17 33 49 66 83 99	
		4 8 12 ~~16-20~~	7 14 21 28 35 41 48 55 62 69 76 82 89 96 102	10 19 28 38 48 57 67 76 85 95 105 114 123 133	12 23 35 47 58 70 82 94 105 117 129 140	14 28 42 56 70 84 98	17 33 49 66 83 99	
Lg. Sawtimber 20+	Sp	1/2	1	1 ½	2	2 ½	3	
		4 8 12 16 20	7 15 22 29 36 43 51	10 20 30 40 49 59	12 25 37 50 62 75 87	15 30 ~~44 59~~	17 34 51 68	
		4 8 12 16 20	7 15 22 29 36 43 51	10 20 30 40 49 59	12 25 37 50 62 75 87	15 30 ~~44 59~~	17 34 51 68	
		4 8 12 16 20	7 15 22 29 36 43 51	10 20 30 40 49 59	12 25 37 50 62 75 87	15 30 ~~44 59~~	17 34 51 68	
		4 8 12 16 20	7 15 22 29 36 43 51	10 20 30 40 49 59	12 25 37 50 62 75 87	15 30 ~~44 59~~	17 34 51 68	
Remarks:						Total		
						Average/Acre		

Invasive Spp.

Soils & Hydrology

Remarks:
Crown vigor/Dieback –
Age Class Dist. – EA/2A/UA
Seedling Bank -
Penn. Sedge -
Ironwood -
Past mgt. -
% Deer browse – 0, 25, 50, 75, +75
Basal Area/acre/year growth rate

TJP/PRA Rev. 06/27/16
Hardwood

Table 40.24. Tree crown area (ft²) by species and DBH (USDA 2005).

DBH (in)	Hardwood[1]	Red oak - red maple	Basswood	Hemlock
5	92	65	52	133
6	122	92	71	163
7	156	122	91	193
8	193	157	114	224
9	232	196	138	256
10	274	239	164	287
11	319	286	192	319
12	366	337	221	352
13	415	392	252	385
14	467	451	285	418
15	521	513	319	451
16	577	580	354	484
17	635	650	392	518
18	695	723	430	552
19	757	801	470	586
20	821	882	511	621
21	886	967	554	655
22	954	1055	598	690
23	1024	1147	643	725
24	1095	1243	690	760
25	1168	1342	738	795
26[2]	1242	1445	787	831
27[2]	1319	1551	837	866
28[2]	1397	1661	889	902
29[2]	1476	1775	941	938
30[2]	1558	1891	995	974

[1]Hardwood includes sugar maple, yellow birch, white and black ash.
[2]Crown areas of these diameters are extrapolated.
[3]Data derived from even-aged, forest grown, dominant and co-dominant trees in northern WI and MI. Unpublished data from T. Strong and G. Erdmann, USFS, NCFRS, Rhinelander, WI.

Instructions for a sample shelterwood marking exercise:
Lay out a 0.4-acre square plot (132 feet on a side) in the stand you are marking. To reach 60 percent crown cover in the practice plot you will need an accumulated crown area of 10,454 ft² (43,560 ft²/acre for 100 percent crown cover X 0.4-acre X 60 percent). Mark residual trees and tally the diameter, species, and crown area. Make sure the residual trees are well-spaced, low risk, and the desired species. Accumulate the crown area until reaching 10,454 ft². Visualize what the remaining crown cover would look like with all unmarked trees cut and proceed to mark through remaining stand.

Note: The following 3 marking guides are a few examples for a forester to consider as a template. These are not intended to address every site or stand but rather to offer ideas in developing a marking guide.

Table 40.25. Marking guide example #1 – Single-tree selection.

TIMBER SALE MARKING GUIDE
WDNR Draft 05_01_2017

District	Property	Code				County
ND	Chequamegon-Nicolet NF					Florence

Sale Name	Sale Number	Tract Number
Dolphin	GNA 2120-12	

Site Considerations

EXISTING STAND CONDITION - BA & TREES / ACRE BY SPECIES AND DBH (WDNR NED-3 data, measured 05/18/16)

	5" – 11"		12" – 15"		16" – 22"		>22"		**Total**	
	BA	Trees	BA	Trees	BA	Trees	BA	Trees	**BA**	**Trees**
Sugar Maple - ACSA	32.0	75.5	22.0	25.0	22.0	13.4	2.0	0.7	78.0	114.5
Red Maple- ACRU	4.0	8.4	8.0	9.5	5.0	3.0	0.0	0.0	17.0	20.9
Basswood - TIAM	1.0	1.8	1.0	0.9	7.0	4.6	1.0	0.3	10.0	7.7
Red Oak - QURU	0.0	0.0	0.0	0.0	3.0	1.5	4.0	1.1	7.0	2.6
Yellow Birch - BEAL	0.0	0.0	2.0	2.6	2.0	1.2	0.0	0.0	4.0	3.7
Paper Birch - BEPA	0.0	0.0	2.0	2.2	1.0	0.6	0.0	0.0	3.0	2.8
Aspen - POGR4	1.0	1.8	0.0	0.0	0.0	0.0	1.0	0.3	2.0	2.1
Balsam Fir - ABBA	2.0	10.2	0.0	0.0	0.0	0.0	0.0	0.0	2.0	10.2
White Pine - PIST	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.4	1.0	0.4
Total	40.0	97.7	35.0	40.2	40.0	24.2	9.0	2.8	**124.0**	**164.8**

Stand 12 is a mixed northern hardwood stand located north of Indian Road, northeast of the Beaver Creek. The stand is likely an even-aged or two aged stand. While all size classes are represented, age class diversity is largely absent. The overstory is dominated by sugar and red maple. The maple is of poor quality, with most stems exhibiting forks, seams, bumps or cankers. Mid-tolerant species like basswood and yellow birch are also present. Scattered red oak can also be found. The oak is of exceptional quality. Large, super-canopy white pines are in the eastern portion of the stand, along the intermittent stream and banks. Although the growing stock quality is poor, the stand does have a good diameter distribution and proportion of sawtimber. The stated management objective is for uneven-aged management through single tree selection.

The soils in the stand consist of Wabeno/Goodman silt loam throughout the majority of the interior, with some Padus sandy loam around the edges. Mudlake silt loam is found in the stream valley. There are some slopes that may approach 30% along the intermittent stream (see prescription map). Despite the rich soil and AOCa/ATD habitat types, the overall quality of the growing stock is poor and the relative growth potential is average (SI 60 ACSA3). Perhaps some of the growing stock quality is a result of distant management practices. Management records state that the stand was cut in 1977 and 1997, but there was a conspicuous lack of stumps observed in the field. Stand density averages 124 ft^2 / acre of basal area with an average stand diameter of 11.7". Basal areas throughout the stand are consistent, ranging from a low of 90ft^2 to a high of 160ft^2. The current inventory did not have any snags fall within the sample plots, but some snags were noted in the stand. The understory is open in the south and north ends of the stand, while the remainder contains a dense understory of balsam fir 10 to 20 feet tall. Some sugar maple saplings, 10 to 30 feet tall, can be found, especially in the more open areas.

An intermittent stream, not displayed on available maps, was discovered in the north and east portion of the stand during the field inspection. The stream channel was GPS'd and is displayed on the prescription map. A field inspection for cultural resources was also conducted, with the results discussed below.

Short Term Silvicultural Objectives
• Utilize uneven-aged conversion harvests (gap establishment and thinning) to reduce stocking, initiate new age classes, and improve growth, quality, and health while moving the stand toward desired diameter distribution over future entries. • Create gaps to recruit and release established regeneration and to create additional age (size) classes, and to promote the establishment and development of mid-tolerant tree species. • Provide timber products to local operators

Desired Future Condition
• To encourage and maintain an uneven-aged northern hardwood stand with high structural class diversity. A long-lived conifer component of white pine is to be protected and maintained within the stand. • To have trees in the stand growing at an optimum rate and which are resilient to insect and disease attacks.

Marking Instructions		
Treatment Method: Single-Tree Selection	**Target Residual Density:** 80 ft^2/acre	**Estimated Treatment Acres:** 39

Marking Instructions		
Treatment Method: Single-Tree Selection	**Target Residual Density:** 80 ft^2/acre	**Estimated Treatment Acres:** 39

Species / Marking Priority

- Designate all merchantable ironwood, white birch, balsam fir and aspen for harvest.
- Harvest to an average 80 ft^2 residual BA in trees greater than 5" DBH, Recognizing 4 size classes (*G59*)
    - Remove 15 ft^2 in the 5"-11" (approx. 1 of every 4 trees)
    - Remove 15 ft^2 in the 12"–15" class (approx. 1 of every 2 trees)
    - Remove 5 ft^2 in the 16"–22" size class (approx. 1 of 5 trees)
    - Remove any high-risk trees in the 22+" size class

Leave tree Priority

- To foster diversity and resiliency, favor yellow birch, northern red oak, and basswood over sugar maple for retention.
- Reserve all white pine.
- Reserve all snags and live den trees, up to 10 per acre unless they present a safety concern

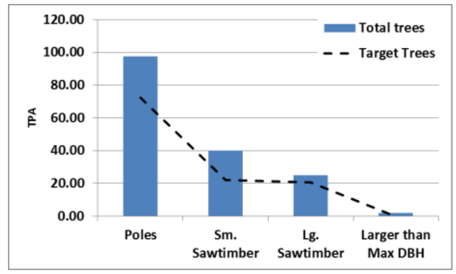
Canopy Gaps

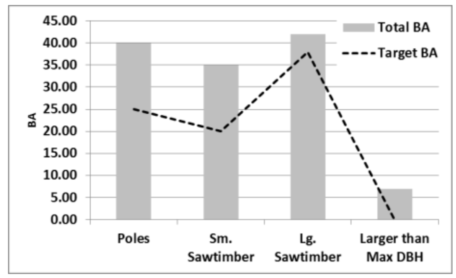
- Through marking the stand to size class targets, create no more than four 25 to 40-foot canopy gaps per acre. Removal of 1-2 large trees or groups of smaller trees will accomplish this target.
- Establish 1 canopy gap approximately 60-feet in diameter every 2 acres (*G57*).
- Locate gaps in areas where regeneration is abundant, stem quality is poor, or where potential mid-tolerant seed trees occur (i.e., red oak).
- In all gaps, cut poor quality stems larger than 1" DBH (*G58*).

Tree Marking and Boundary Designation Methods:

- **Orange Paint:** Harvest boundaries, excepting boundaries bordering public roadways, will be marked *<u>with orange paint</u>*, including boundaries protecting reserved areas or other areas from harvesting.
- **Blue Paint:** Individual trees will be marked for removal *<u>using blue paint.</u>*
- **Yellow or Purple Paint:** If 60' gaps are designated prior to harvest, mark boundary or trees within the gap *<u>with yellow or purple paint</u>*.
- **Red Paint:** Mark the private boundary along the northern edge of the stand *<u>with red paint</u>*.

Size Class	Desired TPA	Existing TPA	Excess TPA	Trees to Mark
5"-11"	73	98	25	1 of 4
12"-15"	22	40	18	1 of 2
16"-22"	21	25	4	1 of 5
22" +	0	2	2	H. Risk





Timber Sale Design Features and Remarks

Operating Requirements:

- Harvesting may occur only during the winter or under frozen ground conditions. At the WDNR National Forest Liaison's discretion, this may be waived during dry summer or fall conditions. In any event, harvesting may not occur between March 15 and July 15 to protect nesting songbirds (*M3*).

Soil/Watershed

- The intermittent stream located in the stand flows from the northwest to the southeast. There is a very distinct flow channel upstream, but this dissipates downstream until the flow becomes dispersed and moves completely underground. Establish a 35-foot RMZ along this stream and keep it out of the sale. Locate the boundary line further back from the RMZ as necessary to avoid steep slopes. Do not dispose of or pile slash in the RMZ. Operate wheeled or tracked equipment in the RMZ only when the ground is frozen or dry. The stream can only be crossed during frozen ground conditions.

Scenery

- Establish a 10-foot slash removal zone adjacent to the private land on the north end of the stand (*G302*).

- Up to 100’ from the edge of the road(s), within the area visible from the road, keep the slash height less than or equal to 24 inches (*G308*).

Endangered, Threatened, and Sensitive Species

- No endangered, threatened or sensitive species were identified within the sale area or through Forest Service records.

Non-Native Invasive Plants or Animals

- There are no known non-native invasive plants or animals in the stand.

Cultural Resources

- Screening was completed and historic sites 09060200337 and 09060200389 were shown as being near the stand (*G262*). A field inspection was conducted, and it was discovered that the GIS locations of these sites are inaccurate. Site 337 is located where site 389 is shown, and 389 is located further south than that. Both sites are removed from the sale area and should not be impacted by sale activities, but sale access will be prohibited from FS Roads 603284 and 603283 to protect these sites (*M7*).

Miscellaneous

- Stand access is off Indian Road (FS Road 2178) via old logging roads, some of which are undocumented.
- The stand boundary has been modified slightly to reflect a more accurate private land border.
- A snowmobile trail traverses a portion of the logging road that will be used to access the stand. Warning signage will need to be posted during the snowmobile season.

Prepared by: Paul Schultz	**Title:** Forester	**Date:** 08/01/2016

Timber Sale Map

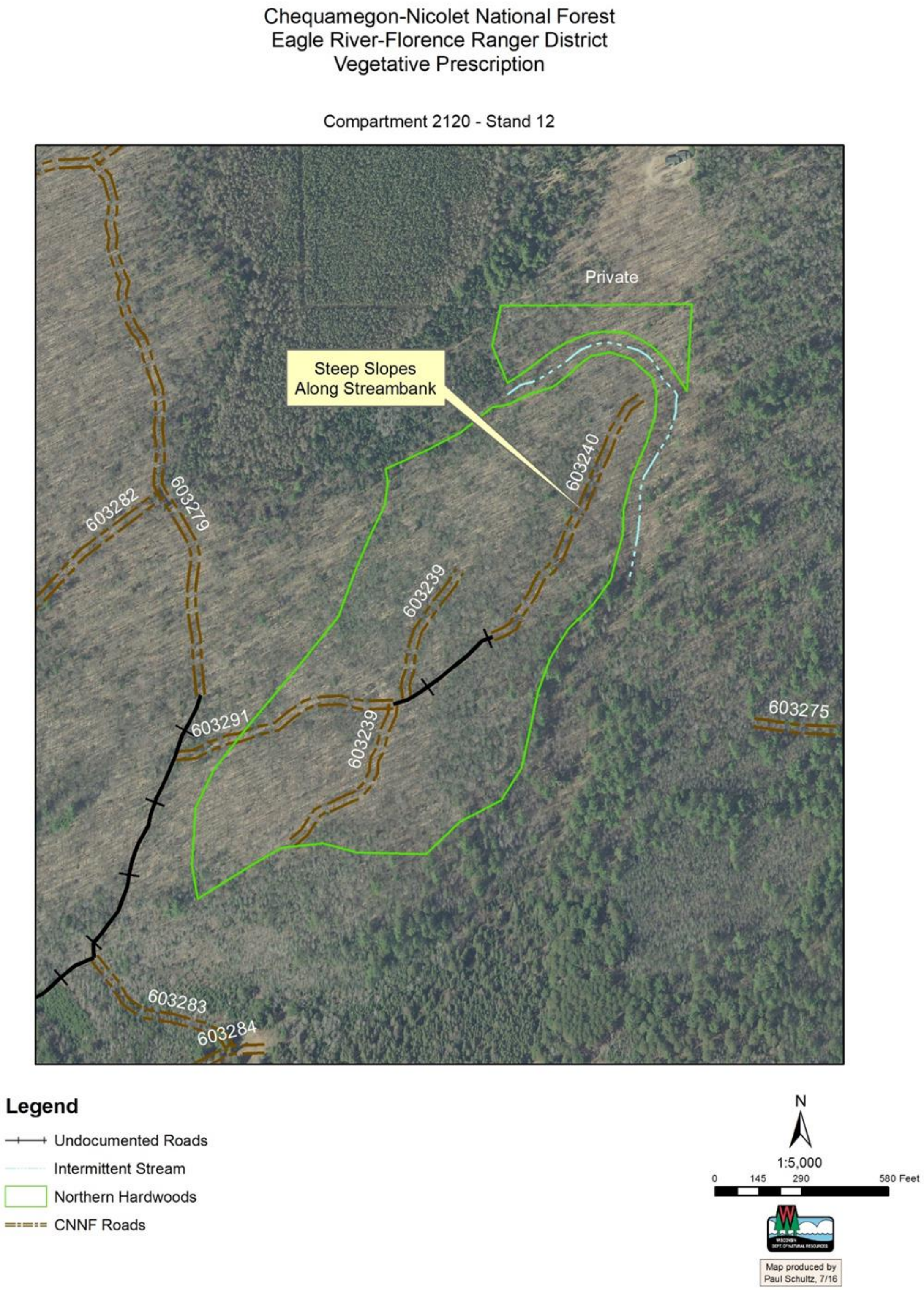


Table 40.26. Marking guide example #2 – Even-aged to uneven-aged conversion process.

Property: Lincoln Sale name: Underdown Lake	Comp #: 127	Stand #: 6	Acres: 91

Prescription: Stand is even aged, primarily NH pole timber with a small saw timber component. The goal is to improve the overall quality of the stand and develop uneven aged structure by releasing advance regeneration where possible and creating canopy gaps to maintain some species diversity.

Treatment: Even age to uneven age conversion/single-tree selection (thinning (comm, pre-comm), single-tree selection (with gaps, groups, patch), even to uneven age conversion, shelterwood, seed tree)

Goal density: 70-90 basal area (basal area/crown cover/trees per acre, etc.)

Retain:

AGS/Crop trees/seed trees: Crown release of AGS trees, two side of saw and at least two of pole timber trees (crown release, number per acre, characteristics of trees)

Wildlife trees: Goal of 3 per acre, cavity trees and poor-quality oversize oaks (number per acre of cavity/den, mast producer)

Desirable species: Poor quality oversize oaks for wildlife trees (oak, BY)

Understocked size classes: Large saw timber (less strict on quality?)

Special considerations: Large white pine legacy trees (Historic sites, snags, nest trees, RMZ, ephemerals, legacy trees, etc.)

Remove:

Risk trees: High risk trees unless there is high wildlife potential, financially mature trees DBH = 20"+ (mortality risk, financially mature)

UGS: Low quality trees to release AGS trees (remove low quality to release AGS, improve spacing)

Undesirable species: Saw timber size white ash and declining white birch (discriminate against ash)

Overstocked size classes: Pole timber (stricter on quality?)

Designated species to cut: All ironwood, merchantable aspen and balsam fir (Cut all A, fir, BW etc.)

Gap, group, patch: Approximately 10% of area in 30-60' canopy gaps, several UGS or large trees (Size and number per acre)

Other:

Paint Color Code: Red = sale boundary, Green = prescription change, Blue = property/sale boundary

Table 40.27. Marking guide example #3 - Example northern hardwood multi-treatment marking guide for a complex stand with financial objectives (Mike Demchik, University of Wisconsin – Stevens Point).

Marking Guidelines Template (Example)

Property: Sample NH stand	**Comp #:**	**Stand #:**	**Acres:**
John Doe Property	1	3	45

Stand and Site Information:

This is a 90-year-old northern hardwood stand that has variable density throughout the stand. Regeneration is variable ranging from 0-3,000 stems per acre greater than 4’ in height.

Habitat type: ATM
Soil type: Padus Sandy Loam
Stand Density: Basal area is variable throughout stand ranging from 50-135 ft^2/acre.

Avg. Diameter distribution:

Poles:	10 ft^2/acre
Small saw:	20 ft^2/acre
Medium saw:	60 ft^2/acre
Large saw:	30 ft^2/acre

Small and medium sawtimber size classes are predominantly AGS

Stand Objectives (short and long-term):

- Encourage and maintain uneven-aged NH stand
- Harvest saw logs at financial maturity
- Develop future AGS saw logs by releasing crowns
- Recruit and release regeneration

Treatment Method(s) Description:

Using a combination of even and uneven-aged silvicultural methods (variable stand), use the treatment guide below to adapt marking to match stand conditions. Marking will focus on releasing saplings and poles with good growth potential. Maintain at least 60 ft^2/acre. Look for opportunities to release or develop areas with well-established advance regeneration, 2’-4’ in height.

Treatment Method Guide: The intent of this guide is to provide a set of treatment methods for northern hardwood sites that have a high degree of variability in condition across a single stand. The guide provides timber marking crews with basic guidance when considering heterogenous nature of some northern hardwood sites.

Structure			System	Marking Instructions
Overstory	Midstory	Advance Regeneration		
mature (any quality)	good quality	any	EA to UA Conversion (Consider **STS** where stand structure exists)	Install new gaps, up to 20% of the stand area in gaps Cut mature and high risk Release desirable mid-story trees Maintain at least 60 ft^2 basal area Note: objectives may consider marking towards a prescribed structure
mature (any quality)	poor quality or minimal	good	Shelterwood	Maintain desirable seeding trees to prescribed canopy cover; remove midstory
			Group Selection	Install groups 60 feet diameter or larger
			Overstory Removal	Remove overstory and midstory
immature (good quality)	good quality	any	Thin from above & below	Focus harvest on release of AGS
	poor quality or minimal	any	Thin from below	Focus harvest on release of AGS
immature (poor quality)	any	any	Do nothing	Wait until commercial
			Overstory Removal	Remove overstory and plant artificial if necessary

Notes to use this guide:

- Financial maturity: sugar maple is 18-24” DBH on the best high-quality sites with quality stems, but can be substantially smaller on poor quality sites; generally trees that have reached their highest grade and product class in the lower half of the bole.
- Good quality: one or more 8-foot (plus trim) pieces are grade 1 sawlogs or better.
- Poor quality: only capable of grade 2 or less sawlogs
- Immature: one or more pieces in the lower half of the bole will increase in product class.
- Maintain diversity by leaving species such as yellow birch, hemlock, white pine and other species.

Marking Priority Guide: To use the marking priority guide, a basic knowledge of log grading specifications is needed (both general and relevant to the local markets). As a general rule, for single-tree selection to be an economically stable system, trees with good quality potential need to be released at each stand entry. The guide below can promote long-term timber quality improvement under many stand conditions. This marking guide is for stands where uneven-aged management is viable; in many stand conditions, even-aged silviculture may be a more feasible alternative.

<table>
<tr><th colspan="2"></th><th colspan="2">Should Keep</th><th>Subject to Goals</th><th colspan="2">Should Take</th></tr>
<tr><td rowspan="3">QUALITY</td><td>Tree quality</td><td>Exceptional</td><td>Good</td><td>BA tree</td><td>Moderate-Poor</td><td>Very Poor</td></tr>
<tr><td>Number of 8’4” or longer sections in the lower half of the tree capable of increasing in product class with increase tree growth (i.e., increase from pulp to bolt/sawlog etc.).</td><td>2+</td><td>1</td><td colspan="3">0</td></tr>
<tr><td>Is the merchantable portion of the tree likely to decline in grade by next stand entry?</td><td colspan="3">No</td><td colspan="2">Yes</td></tr>
<tr><td rowspan="3">RISK</td><td>Likelihood of stem failure</td><td colspan="3">Low</td><td colspan="2">Moderate-High</td></tr>
<tr><td>Overall health</td><td colspan="3">Healthy</td><td colspan="2">Moderate or declining</td></tr>
<tr><td>Stem rot/decay (location)</td><td colspan="2">None</td><td>Minor or high in tree</td><td colspan="2">Significant or low in tree</td></tr>
<tr><td rowspan="3">VIGOR</td><td>Crown radius</td><td colspan="2">At least 0.75 feet of crown radius for every inch of DBH</td><td colspan="3">Less than 0.75 feet of crown radius for every inch of DBH</td></tr>
<tr><td>Foliage condition</td><td colspan="2">Healthy</td><td colspan="3">Poor</td></tr>
<tr><td>Bark character</td><td colspan="2">Indicates fast growth</td><td colspan="3">Indicates slow growth</td></tr>
</table>

Simplified (easy and quick) grade rules: Grading specifications for logs vary between mills. Hanks (1976) provided the basis for tree grading and Great Lakes Timber Professionals Association (2016) Official Grading Rules for Northern Hardwood and Softwood Logs and Tie Cuts followed similar guidance with minor variation in specifications.

- 4 side clear (with qualifiers) = potential veneer
- 5-7 ft clear cuts = potential grade 1
- 3 ft clear cuts = potential grade 2
- anything poorer should be targeted subject to landowner goals

7.1 Forest Health Guidelines - Forest Health Protection (FHP)

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
DEFOLIATING INSECTS			
Basswood leafroller – *Sparganothis pettitana* Heavy infestation of this insect, often together with other spring defoliators occasionally causes severe defoliation.	Basswood	Maintain healthy forests through proper forest management	
Birch Leafminer – *Fenusa pusilla* Browning of leaves. Repeated heavy leafmining weakens trees to become susceptible to bronze birch borer.	Birch	No direct control practical Monitor heavily defoliated stands for birch dieback.	Birch Leaf Miner. P. Pellitteri. 1997. Univ. of Wisc. Ext. A2117
Bruce Spanworm – *Operophtera bruceata* Occasional outbreaks of repeated heavy defoliation in early spring may cause twig/branch dieback and mortality	Sugar Maple, Beech	Maintain healthy forests through proper forest management Monitor defoliated stands for possible salvage	Pest alert: Bruce Spanworm. USDA FS NA-FB/P-26
Forest Tent Caterpillar – *Malacosoma disstria* Widespread heavy defoliation occurs periodically at intervals of 5-15 years. An outbreak usually lasts 2-5 years.	Northern Hardwood	Maintain healthy forests through proper forest management During an outbreak, insecticide applications can be an option to minimize the damage on highly valuable stands with high proportion of susceptible species.	Forest Tent Caterpillar in the Upper Midwest. 2001. USDA FS NA-PR-02-01
Gypsy Moth – *Lymantria dispar* Widespread heavy defoliation occurs periodically at intervals of 5-15 years.	Northern Hardwood except ash (gypsy moth does not feed on ash)	Maintain healthy forests through proper forest management During an outbreak, insecticide applications can be an option to minimize the damage on highly valuable stands with high proportion of susceptible species.	Gypsy Moth Silvicultural Guidelines for Wisconsin. C. Brooks and D. Hall. 1997. DNR PUB-FR-123
Introduced Basswood Thrip – *Thrips calcaratus* Occasional outbreaks of early spring defoliation may cause growth loss, branch dieback, and mortality	Basswood	Maintain healthy forests through proper forest management Conduct salvage or presalvage harvest of declining trees to minimize economic losses.	How to Identify Introduced Basswood Thrips. 1992. USDA FS NA-FR-01-92
Linden looper – *Erannis tiliaria* Although this spring defoliator is commonly found on a northern hardwood stand, outbreaks are infrequent.	Northern hardwood	Maintain healthy forests through proper forest management	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston, et. al. USDA FS General Technical Report NE-129
Maple Leafrollers – *Sparganothis acerivoran; Acleris chalybeana* Occasional outbreaks of spring defoliation may cause twig dieback. A combination of this pest and multiple defoliators together with some pathogens and adverse weather factors may cause maple blight (see maple blight under decline).	Sugar Maple	Maintain healthy forests through proper forest management	Studies of Maple Blight. 1964. Univ. Wis. Agr. Exp. St. Res. Bull. 250
Maple Webworm – *Tetralopha asperatella* Occasional outbreaks of summer defoliation may cause twig dieback. A combination of this pest and multiple defoliators together with some pathogens and adverse weather factors may cause maple blight (see maple blight under decline).	Sugar Maple	Maintain healthy forests through proper forest management	Studies of Maple Blight. 1964. Univ. Wis. Agr. Exp. St. Res. Bull. 250
Saddled Prominent – *Heterocampa guttivitta* Occasional outbreaks of repeated heavy defoliation in mid-summer may cause twig/branch dieback. A combination of this pest and multiple defoliators together with some pathogens and adverse weather factors may cause maple blight (see maple blight under decline).	American Beech, Sugar Maple, Yellow Birch	Maintain healthy forests through proper forest management During an outbreak, insecticide applications can be an option to minimize the damage on highly valuable stands with high proportion of susceptible species.	Saddled Prominent. 1987. P. Rush and D. Allen. USDA FS Forest Insect & Disease Leaflet 167.
LATE SEASON DEFOLIATORS			
American daggermoth – *Acronicta americana* **Orange-humped mapleworm** – *Symmerista leucitys* **Green-striped mapleworm** – *Dryocampa rubicunda* **Maple trumpet skeletonize**r – *Epinotia aceriella* **Variable oakleaf caterpillar** – *Heterocampa manteo* Defoliation by multiple defoliators occasionally causes severe defoliation. Late season defoliator complex may result in growth loss but mortality is rare.	Basswood, Beech, Maple	Maintain healthy forests through proper forest management No chemical control is necessary	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston, et. al. USDA FS General Technical Report NE-129

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
SCALE INSECTS			
Lecanium Scale – *Parthenolecanium* spp. This insect sucks plant juice, causing twig and branch dieback, and growth loss.	Northern Hardwood	Chemical control is impractical, and usually unnecessary.	Scale Insects of Trees and Shrubs. R. Wawrzynski and M. Ascerno. 1999. Univ. Minn. Ext. FO-01019.
Beech Scale (Beech bark disease) - *Cryptococcus fagisuga and Neonectria spp.*	American Beech	Remove low vigor and/or rough bark beech. Retain vigorous trees with smooth bark Maintain healthy forests through proper forest management A small percentage of beech are resistant to beech bark disease so don't remove all beech.	Biology and Management of Beech Bark Disease. D. McCullough, R. Heyd, J. O'Brien. 2005. Michigan State Univ. Ext. E-2746.
WOOD BORERS			
Sugar Maple Borer – *Glycobius speciosus* Value loss through wood decay and discoloration, initiated by larval feeding. Stem breakage at point of attack.	Sugar Maple	Maintain healthy forests through proper forest management. Maintain well-stocked stands. Remove overmature, low-vigor trees. Monitor sugar maple on stand edges and along roads, especially trees that are recently exposed to full sunlight. See FHP Table 2 for specific recommendations related to impact.	How to Identify and Control the Sugar Maple Borer. W. Hoffard. 1978. USDA FS. NSEFES.
Bronze birch borer – *Agrilus anxius* Branch dieback. Mortality. Infestations are more successful and widespread during years of drought.	Birch (Yellow birch is less susceptible compared to white birch)	Maintain healthy forests through proper forest management. Thinning should be done with care to minimize stand disturbance.	Bronze Birch Borer. S. Katovich et. al. Forest Insect & Disease Leaflet 111. USDA FS.
Emerald Ash Borer – *Agrilus planipennis*	White, Green, and Black Ashes	Evaluate stand characteristics to determine management alternatives, utilizing recommendations in the Emerald Ash Borer Silviculture Guidelines document. Conduct salvage or pre-salvage harvest of declining trees to minimize economic losses. Retaining a small ash component will be beneficial for ecological purposes, species diversity, wildlife habitat, and seed production.	Wisconsin emerald ash borer website http://emeraldashborer.wi.gov

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
FOLIAGE DISEASES			
Anthracnose – multiple Anthracnose causing fungi (see reference) Irregular dead blotches on foliage. Growth loss.	Northern Hardwood	Direct control is impractical and usually unnecessary. Silvicultural measures to encourage air circulation may reduce infection.	Anthracnose Diseases of Eastern Hardwood. F. Berry. 1985. Forest Insect & Disease Leaflet 133
Tar Spot – *Rhytisma* spp. One to multiple black, shiny, tar-like spots on foliage. Growth loss.	Maple	Direct control is impractical and usually unnecessary.	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston, et. al. USDA FS General Technical Report NE-129
CANKERS/CANKER ROT[1]			
Nectria Canker – *Nectria cinnabarina* Trunk deformity and growth loss (all ages). Although it rarely causes mortality, a tree may break off at the point of canker.	Northern Hardwood	Silvicultural control measures are based on percent of infected trees in stand (see reference). Most infections occur when trees are 12-20 years old. Conduct improvement cut after age 20.	How to Identify and Control Nectria Canker of Hardwood. R. Anderson. 1978. USDA FS
Eutypella Canker – *Eutypella parasitica* Trunk deformity and growth loss (all ages). Although it rarely causes mortality, a tree may break off at the point of canker.	Sugar Maple	Avoid wounding. Spores can be produced and infections can occur from spring through fall. Spore dispersal can be minimized by placing cankers face down on the forest floor.	How to Identify and Minimize Damage Caused by Eutypella Canker of Maple. K. Robbins. 1979. USDA FS. NA-FR-10 Eutypella canker of maple: Ascospore discharge and dissemination. Phytopathology 69:130-135
Canker Rots *Inonotus obliquus* (birch) *Cerrena unicolor* (maple & oak) *Inonotus glomeratus* (maple) *Phellinus everhartii* (oak) *Inonotus hispidus* (oak) Wood decay. Entry through wounds. These fungi are not compartmentalized and continue to attack newly formed wood.	Sugar Maple, Beech, Birch	Minimize wounding. Remove canker-rot infected trees during thinning. Trees infected with canker rots may also provide excellent den trees. Consider leaving an occasional canker-rotted tree as a cavity tree for wildlife.	A Photo Guide to the Patterns of Discoloration and Decay in Living Northern Hardwood Trees. A. Shigo and E. Larson. 1969. USDA FS Research Paper NE-127
WILT DISEASES			
Ash Yellows – Phytoplasma Tufted foliage. Crown thinning. Slow growth. Branch dieback. Mortality. White ash that become infected when young do not grow to merchantable size. Most merchantable sized diseased trees live for at least 5-10 years. More common in urban settings or in small woodlots that adjoin agricultural fields.	Ash	No known way to prevent or cure this disease. Harvest trees with more than 50% crown dieback within 5 years. Remove other infected trees during harvests.	How to Identify and Manage Ash Yellows in Forest Stands and Home Landscapes. 1994. USDA FS. NA-FR-03-94.
Sap Streak Disease – *Ceratocystis coerulescens* Early fall color and progressive dieback. Tree mortality and wood discoloration. Fungus is soil-borne; infection occurs through root and basal wounds.	Sugar Maple	Minimize basal and root wounds Remove infected trees Harvest for pulp or firewood	How to Control Sapstreak Disease of Sugar Maple. K. Kessler. 1978. USDA FS
ROOT DISEASE			
Armillaria Root Disease (Shoestring root rot) – Armillaria spp. Stringy white rot. Dieback and mortality, especially during drought years or following 2 or more years of defoliation (all ages).	Northern Hardwood	Maintain stand in healthy condition. Harvest declining trees before mortality and decay take place.	R. Williams, *et al*. 1986 USDA Forest Service, Forest Insect and Disease Leaflet 78

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
ANIMAL DAMAGE			
Sapsuckers (*Sphyrapicus varius*) Value loss through wood decay and discoloration. Occasional tree mortality.	Northern Hardwood	Leave attacked tree in place. It will concentrate most of the attacks on one tree.	How to Identify Sapsucker Injury to Trees. M. Ostry. 1976. USDA FS. NSEFES.
Voles/Mice (*Microtus* spp.) Mortality of reproduction through stem girdling in grassy plantations.	Northern Hardwood	Control grass first five years	Animal Damage to Hardwood Regeneration and Its Prevention in Southern Ontario. F.W. Von Althen. 1983. Information Report 0-X-351.
Rabbits/Hares (*Sylvilagus* spp./*Lepus americanus*) Mortality of reproduction through stem girdling.	Northern Hardwood	Control usually unnecessary	Animal Damage to Hardwood Regeneration and Its Prevention in Southern Ontario. F.W. Von Althen. 1983. Information Report 0-X-351.
Squirrels (*Sciurus* spp., *Tamiasciurus hudsonicus*, *Glaucomys* spp.) Gnawing on bark of maple saplings occasionally causes tree mortality. Squirrels also tend to feed on the edges of fungal cankers. Entire branches may be debarked and can die.	Northern Hardwood	Control usually unnecessary Population management by hunting	Animal Damage to Hardwood Regeneration and Its Prevention in Southern Ontario. F.W. Von Althen. 1983. Information Report 0-X-351.
White-tailed Deer (*Odocoileus virginianus*) Browsing can cause mortality, deformity, or reduced growth rates of seedlings. Preferential browsing can alter forest composition. Antler polishing can shred bark and can cause deformity or mortality of small trees.	Forests, including Northern Hardwood	Population management by hunting Fencing (exclusion) Tree shelters, bud caps, and repellents	Controlling Deer Damage in Wisconsin. S. Craven *et al*. 2001. UW Extension G3083. Animal Damage Management Handbook. 1994. USDA FS. PNW-GTR-332.
Livestock Potential impacts include: soil compaction, root and stem wounding, reduced tree vigor and sap production, mortality and deformity of seedlings, and altered forest composition. Damage can be severe when soil is saturated or grazing is heavy (large populations or extended time periods).	Forests, including Northern Hardwood	Eliminate or limit livestock from forests.	Sugarbush Management: A Guide to Maintaining Tree Health. 1990. D. Houston *et al*. USDA FS GTR-NE-129. Wisconsin Forest Management Guidelines. 2003. WDNR PUB-FR-226.
European Earthworms (*Lumbricus, Dendrobaena, Octolasion, and Aporreclodea* species) Declines in native understory plant species and tree seedlings follow the invasion of non-native earthworms. They rapidly decompose the leaf litter that makes up the duff layer, leaving a bare soil surface inhospitable to tree seedlings and other plants that germinate in the duff or require it for protection. Partial recovery occurs after the invading front has passed and the earthworms become naturalized.	Forests, including Northern Hardwood	Prevent new earthworm introductions. Don't transplant plants and trees into areas where earthworms are not present. Dispose of extra fishing bait in the trash. Experts recommend limiting deer populations in areas with new invasions to avoid stacking stresses on flora.	http://www.stolaf.edu/depts/biology/mnps/papers/hale2001202.html http://www.extension.umn.edu/yardandgarden/YGLNews/YGLN-Mar0103.html

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
ABIOTIC and MECHANICAL DAMAGE			
Storm damage Limb and trunk breakage. Decay and discoloration through wounds.	Northern Hardwood	See FHP Table 2 for specific recommendations related to impact.	Caring for ice-damaged woodlots and plantations. 1999. Ontario Extension Notes
Cold injury Cold injury occurs when the winter temperature falls to approximately -35° F or colder. Species' sensitivity varies. Injury is typically manifested by patches of dead (brown and black) cambium. In spring, affected trees will have reduced bud break and may have epicormic sprouts.	Northern Hardwood	Monitor for dieback in upper and outer crown. If more than 50% of the crown dies, expect decline to continue to mortality.	
Late Spring Frost Damage This phenomenon is unpredictable and occurs when temperatures dip below freezing during bud expansion, break and when foliage is just emerging. Foliage turns black and wilts. Twig dieback can occur. New lateral buds can break within 4 weeks after damage.	Northern Hardwood	In frost pockets, expect injury to new expanding growth during years with late spring frost. Monitor for dieback in upper and outer crown. If more than 50% of crown dies, expect decline to continue to mortality.	
Drought Symptoms of drought include premature defoliation, thin crowns, subnormal leaf size and in severe cases, wilting foliage. If drought persists for more than one year, dieback of the upper and outer crown may occur.	Northern Hardwood	Monitor for dieback in upper and outer crown. If more than 50% of crown dies, expect decline to continue to mortality. Hardwood take longer to recover from drought than conifers. Improvement in crown may not be noticeable for a year after normal precipitation returns.	
Logging damage Wounds. Limb and trunk breakage. Decay and discoloration through wounds.	Northern Hardwood	Careful felling and skidding, directional felling techniques, careful harvest plan layout. Limit harvest activities to times when soil is frozen or dry enough as to minimize soil compaction. See FHP Table 2 for specific recommendations related to impact.	
DECLINE			
Maple blight Maple blight was first reported in Florence County in 1957. Affected trees suffer branch dieback, foliage chlorosis and wilt, epicormic sprouting and tree mortality. It is caused by a combination of stand conditions, weather, insects and diseases. Maple blight causes up to 30% mortality of pole and sawlog sized trees and up to 50% mortality of saplings.	Sugar Maple	Maintain healthy forests through proper forest management. In known problem areas where defoliation has caused tree mortality, reduce maple in overstory to less than 35% of the trees. Monitor stands for possible salvage.	Studies of Maple Blight. 1964. Univ. Wis. Agr. Exp. St. Res. Bull. 250

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
INVASIVE PLANT SPECIES			
Amur Maple *Acer ginnala* A tall shrub or small tree that can outcompete and displace other flora. Foliage turns bright red in fall.	Northern Hardwood and other upland forests. Tolerates shade. Prolific stump sprout reproduction and viable seeds.	Mechanical removal of small infestations Cut stump and treat with glyphosate or basal bark spray stem with triclopyr.	https://dnr.wi.gov/topic/Invasives/fact/AmurMaple.html
Amur Cork Tree *(Phellodendron amurense)* A tree species that can outcompete native tree seedlings and displace shrub and herbaceous layers. Allelopathic and produce chemicals that can affect surrounding vegetation.	Forests, including Northern Hardwood, and open lands.	Prioritize control of female (fruiting) trees first Herbicides applied by hack-and-squirt, basal bark spray, or cut stump treatment are effective Trees can be controlled by girdling.	https://dnr.wi.gov/topic/Invasives/fact/AmurCorkTree.html
Bishop's Goutweed, Snow-on-the-Mountain, Bishop's Weed *Aegopodium podagraria* Aggressively invades forests and forest edges. Outcompetes native herbaceous layer, reduces tree seedling germination and inhibits tree seedling establishment. Spreads through rhizomes.	Forests, including Northern Hardwood.	Hand pull removing as much of the rhizome as possible and disposing of plant material. Plant pieces will readily resprout. Foliar application of glyphosate	https://dnr.wi.gov/topic/Invasives/fact/Bishop'sGoutweed.html
Buckthorn. Common Buckthorn and Smooth (Glossy) Buckthorn (*Rhamnus cathartica* and *R. frangula*) Tall shrubs form dense thickets that outcompete and displace other flora. There is some evidence that they are also allelopathic. Seeds are spread by birds, and in mud on equipment.	Forests, including Northern Hardwood, and open lands. Smooth buckthorn is more restricted to wet and wet-mesic areas.	Monitor to ensure early detection. Clean equipment before entering the forest. Small plants can be eradicated by hand pulling. Large shrubs can be mechanically removed, cut and stump-treated, or controlled with a basal bark application. Foliar sprays should be restricted to fall months when buckthorn is still actively growing but other species are dormant, to avoid impacts to non-target vegetation. Trichlopyr may be more selective than glyphosate. In areas with high water tables, use herbicides labeled for use over water. Continued monitoring and follow-up are needed after treatment.	https://dnr.wi.gov/files/pdf/pubs/fr/fr0216.pdf
Burning Bush, Winged Euonymus, Spindle Bush *Euonymus alatus* Prolific seeder, can invade forests and forest edges. Not palatable by deer. Straight species and the cultivar "Nordine" are considered invasive, while other cultivars are not. Leaves turn bright red in fall.	Forests, including Northern Hardwood. Can dominate the shrub layer in hardwood forests.	Hand pull seedlings, using a weed wrench for larger plants Foliar spray using glyphosate in early summer Cut stump herbicide treatments	https://dnr.wi.gov/topic/Invasives/fact/Euonymus.html
Bristly Locust *Robinia hispida* Shrub or small tree. Forms dense thickets with extensive small thorns/bristles all over the plant. Seeds remain viable in the soil for up to 10 years.	Forests, including Northern Hardwood, invades forest edges.	Pull small plants, use weed wrench on larger shrubs to remove all roots. Monitor for resprouting. Cut stump or basal bark herbicide techniques in fall with glyphosate or triclopyr.	https://dnr.wi.gov/topic/Invasives/fact/BristlyLocust.html
Bush Honeysuckles *Lonicera* species Forms dense shrub thickets that outcompete and displace other flora. Seeds are spread by birds, and in mud on equipment.	Forests, including Northern Hardwood, and open lands.	Monitor to ensure early detection. Clean equipment before entering the forest. Small plants can be eradicated by hand pulling. Large shrubs can be mechanically removed, or cut and stem-treated. Foliar spray using glyphosate in spring, prior to emergence of native plants. In areas with high water tables, use herbicides labeled for use over water.	https://learningstore.uwex.edu/Assets/pdfs/A3924-03.pdf
Garlic Mustard *Alliaria petiolata* A major invasive plant that outcompetes herbaceous flora and tree seedlings. There is some evidence of allelopathy to beneficial mycorrhizae. Small seeds spread easily on equipment and clothing.	Forests, including Northern Hardwood. One of the few invasive understory plants to thrive in full shade.	Use preventative measures; clean equipment and clothing before entering the forest. Monitor to ensure early detection. Small infestations can be eradicated by hand pulling, or by repeatedly cutting the flower stalk close to the soil surface before flowering begins. Spray with glyphosate in spring or fall to kill basal rosette; avoid non-target species.	https://dnr.wi.gov/topic/invasives/fact/garlicmustard.html
Hedgeparsley, Japanese Hedgeparsley *Torilis japonica* Herbaceous perennial in the carrot family, invades forests.	Forests, including Northern Hardwood.	Pull or mow prior to flowering Glyphosate or triclopyr herbicides can be effective in early spring.	https://dnr.wi.gov/topic/invasives/fact/japanesehedgeparsley.html

Disturbance Agent and Expected Loss or Damage	Host	Prevention, Options to Minimize Losses and Control Alternatives	References*
INVASIVE PLANT SPECIES			
Japanese Barberry *Berberis thunbergii* Has potential to limit forest regeneration as it becomes more abundant. With a concerted effort, potential remains to suppress this species. It can outcompete and displace other flora. Its thorns make it difficult to work or recreate in an infested area.	Forests and semi-open areas, including Northern Hardwood. Tolerates full shade.	Mechanical removal in early spring is recommended for small infestations. Wear thick gloves. Glyphosate or triclopyr herbicides can be effective. Avoid impacts to non-target vegetation.	https://dnr.wi.gov/topic/invasives/fact/japanesebarberry.html http://tncweeds.ucdavis.edu/moredocs/berthu02.pdf
Japanese Knotweed *Polygonum cuspidatum* Outcompetes and displaces other flora. Early emergence, height, and density allow it to shade out other vegetation and limit tree regeneration. Not yet widespread in Wisconsin. Difficult to eradicate once established.	Northern Hardwood forests, riparian forests, open lands with mesic or wet-mesic conditions.	Repeated cutting (3x per growing season) provides control but may not eradicate a stand. The herbicide glyphosate can be effective, especially applied in fall. Continued monitoring and follow-up are needed after treatment.	https://dnr.wi.gov/topic/invasives/fact/japaneseknotweed.html
Hemp Nettle *Galeopsis tetrahit* Annual plant. Invades from forest edges into disturbed areas of forests. Spreads rapidly along skid trails, scrapes and new roads.	Forest edges, Mesic forests, skid trails, forest roads.	Dig or hand pull when in flower bud stage. Dispose of plants in landfill. Seeds can still mature after the plant has been pulled.	https://dnr.wi.gov/topic/Invasives/fact/HempNettle.html https://www.uwgb.edu/biodiversity/herbarium/invasive_species/galtet01.htm
Norway Maple *Acer platanoides* A tree species that can outcompete and displace other flora, including sugar maple seedlings. The sap is not suitable for maple syrup. Identification is difficult, as morphology is ambiguous with sugar maple. Flattened seed cavity is distinctive. Norway maples may or may not have milky sap.	Northern Hardwood and other upland forests. Tolerates shade. Prolific stump sprout reproduction and viable seeds.	Pull seedlings. Cut stump and treat with glyphosate or basal bark spray stem with triclopyr.	http://www.dnr.state.mn.us/invasives/terrestrialplants/woody/norwaymaple.html
Oriental Bittersweet *Celastrus orbiculatus, Celastrus loeseneri* Vine can girdle trees, can shade out a tree, and can add weight to the crown of the tree causing branches to break. Sprouts vigorously from root crowns and root fragments.	Forests, including Northern Hardwood. Can grow under dense forest canopy.	Dig out or hand pull seedlings. Cut the base of the vines strangling trees, allowing upper foliage to die back, use cut stem treatment with glyphosate or triclopyr Cut or mow starting in the spring and every 2 weeks throughout the year to exhaust root reserves. Basal bark treatment with glyphosate or triclopyr Cut stem treatment with triclopyr Foliar spray with glyphosate or triclopyr	https://dnr.wi.gov/topic/invasives/fact/orientalbittersweet.html http://learningstore.uwex.edu/Assets/pdfs/A3924-25.pdf
Pennsylvania Sedge *Carex pennsylvanica* This native sedge can impact northern hardwood regeneration by forming impenetrable mats on the forest floor. Physical impedance is the mechanism by which damage occurs. Past management may have contributed to development of existing sedge mats; increases in size and density after opening the forest canopy have been observed.	Mesic forests, including Northern Hardwood.	There is limited information on control. Fire, herbicide, scarification, or tilling (particularly on roadbeds or landings) may be effective in some situations.	https://mnfi.anr.msu.edu/abstracts/ecology/Pine_barrens.pdf http://www.ecologyandsociety.org/vol7/iss2/art10/main.html

Table 40.28. Northern hardwood trees: common defects, signs of defect, and evaluation of potential impacts on risk, vigor and value.

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Canker Localized area of dead bark and cambium; wood behind canker may or may not be decayed. Commonly caused by fungi. Fungal cankers are a source of spores that may infect healthy trees.	Canker affects >50% of the stem's circumference or >40% of the stem's cross section. Horizontal crack on a canker face. >20% of combined circumference of the stem and root collar are affected by butternut canker. White pine blister rust canker on main stem but located below crown where stem failure would leave a minimal crown.	Decay associated with large canker (affects >50% of stem's circumference). Fruit body visible in the canker's face. Extent of decay and discoloration will vary depending on organisms involved. Basswood infected with Nectria canker, if multiple infections on the main stem are common.
Wounds Any injury to tree that exposes the cambium or wood beneath cambium.		Maple, white and yellow birch: 1 or more wounds ≥50 in^2 or ≥30% of tree's circumference. >1 sugar maple borer wound (discoloration associated with borer typically limited to 24" above and 12" below). >2 large (>5") branches broken close to the stem. Codominant ripped from stem.
Decay Wood that is missing or structurally compromised. Canker rot fungi are not compartmentalized and will cause significant decay.	Decay in main stem results in <1" of sound wood for every 6" in diameter; must have 2" of sound wood for every 6" DBH if there is also a cavity present. Decay or cavity affects >40% of the stem's cross-section. Tree infected with a canker-rot fungus (see next column).	Tree infected with a canker-rot fungus including but not limited to: *Inonotus obliquus (birch),* Cerrena unicolor (maple & oak), Innonotus glomeratus (maple), Phellinus everhartii (oak) *Inonotus hispidus (oak).*
Cracks (open, can see into the tree at least an inch) A split through the bark, extending into the wood. Wood fibers are not fused. Cracked stems or branches cause the affected area to act as 2 or more separate beams, weakening mechanical support. Open cracks are more likely to be associated with decay and discoloration.	Crack goes completely through a stem or is open for >4-6' (length). Two open cracks occur on the same stem segment. The stem has an open crack in contact with another defect such as decay, a canker, or weak union.	>1 face with open crack or seam or any spiral crack.

[1] There is a high probability that the defect will cause a significant reduction in value over a 15-year period; rate of decay/stain development varies by species. Defect may be limited to localized area.

DEFECT	High Probability of Mortality or Failure (high risk)	High Probability[1] of Degrade due to Defect
Weak Union Union with ingrown bark between stems; wood fibers are not fused. Weak unions are characterized by an acute angle between stems.	Stump sprouts joined above ground in V-shaped union and associated with a crack, showing failure has already begun.	Large (>8” diameter stems) tight union that is either cracked or decayed or associated with another defect. Could result in failure; stain and decay will vary.
Structural Compromise Unusual form typically initiated by storm damage.	Leaning tree with recent root lifting. Leaning tree with a horizontal crack, long vertical crack, or buckling wood on the underside of the tree. New leader formed in response to a dead or broken top. Risk increases as top gets larger and stem decays at break point.	
Root Defects Loss of structural support due to root rot, wounding, severing or any other factors that cause root mortality.	More than 33% of roots severed, decayed or otherwise compromised. Stump sprouts with a tight union where root structure is not sufficient to support stems.	>3 root wounds within 4’ of the main stem; each wound encompasses >30% of root diameter.
Crown Density/Dieback/Leaf Condition Crown symptoms are often showing a response to poor root health, stress such as defoliation or drought or infestation by cambium-mining beetles. Large dead branches/tops/codominants keep wound “open”; decay will advance more rapidly with an open wound. Failure of dead wood is unpredictable. Could cause damage upon failure.	50% of the crown dead, unless loss of crown is due to stem breakage. 75% of leaves subnormal in size or abnormal in color. (excluding iron chlorosis.) Signs of cambium miners such as the two-lined chestnut borer or bronze birch borer.	Multiple large (>5” diameter) dead branches, dead top or codominant (>10” diameter).

[1] There is a high probability that the defect will cause a significant reduction in value over a 15-year period; rate of decay/stain development varies by species. Defect may be limited to localized area.

Summary of Principles Related to Discoloration and Decay Development

Jane Cummings Carlson

1. Wounding: the death of large branches, sprouts or codominants; and any activity that exposes the cambium to air and moisture initiate discoloration in trees with naturally white wood throughout.
2. After wounding, discoloration may be caused by bacteria, oxidation of phenolic compounds and degradation of the cells by fungi.
3. Discoloration and decay typically do not move throughout a tree as it ages but are compartmentalized and limited to tissue present at the time of wounding. Known exceptions to this include trees that are infected with canker-rot fungi.
4. Discoloration tends to form in vertical columns, tapered at the ends.
5. The further the wound or breakage is from the main stem, the lower the chance discoloration and decay will occur to the main stem.
6. Discoloration resulting from a broken top or split stem will progress downward and be limited to the diameter of the tree at the time of wounding. Rate of spread is variable; approximately 4 inches per year has been noted in sugar maple if wound is significant (> 40% of circumference).
7. Wounds initiated in the spring will form callus more quickly than wounds initiated in the fall but if the wounds are the same size, the discoloration resulting from both wounds will likely be similar after 3 years.
8. The presence of prior defects appears to influence the rate of formation (hasten) of additional discoloration from newer wounds.
9. Trees with lower starch content (i.e., defoliated) tend to be more negatively impacted by wounds, as there is a reduced rate of callus formation. Vigorous trees may slow or halt the discoloration/decay process more readily than trees of poor vigor.
10. Decay and discoloration are more likely and more extensive in wounds that remain open; decay and discoloration move more slowly after wounds are closed.
11. Volume of discoloration and decay increases with increasing wound width; wound area is a good indicator of value loss.
12. Wounds are initiation points for cracks.
13. Factors such as site, genetic controls, wound type, frequency of wounding, host species and microorganisms present all potentially influence wound closure and in turn the rate and severity of discoloration and decay development.

Table 40.29. Summary of guidelines related to stain and decay development.

Species	Issue	Rule of Thumb
Maple, No. Hdwds.	Oxyporus populinus Ganoderma applanatum Canker rots	Decay 2-4' above and below Decay 4-6' above and below Decay 5-7' above and below
Sugar Maple	Rate of vertical development of discoloration.	Wound 20% of circumference: 1"/yr. 30% of circumference: 2"/yr. 40% of circumference: 4"/yr. These numbers are for upward movement from a basal wound, downward movement may be slower.
	Decay/discoloration severity	Age, severity and proximity to other wounds all influence volume of discoloration and decay.
	Sugar Maple Borer Wounds	Discoloration more likely when both a horizontal and vertical trail is present. Discoloration/decay columns typically limited to 24" above and 12" below the scar.
	Discoloration common in larger/older trees.	Large Dead branches appear to result in physiologically induced discoloration in the main stem. This is also influenced by the presence of certain microorganisms.
Yellow Birch	Rate of development of column of decay	5 years: column length equal to wound length 15 years: column length 2 X wound length 20 years: column length 3-5 X wound length

Slower decay → **Faster decay**

Hickory, Sugar Maple **White, Red Oak** **Cherry**	**Ash**	**Red Maple** **Black Oak**	**White Birch** **Basswood**	**Yellow Birch** **Beech, Aspen**

Less discoloration (with same wound size/severity) → **More discoloration**

Hickory, Ash **Oak** **Cherry**	**Basswood**	**White Birch**	**Sugar Maple**	**Red Maple** **Yellow Birch**

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