Chapter 46

Swamp Hardwood Cover Type

WISCONSIN
DEPT. OF NATURAL RESOURCES

Last Full Revision: 8/6/2013
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
Any combination of black ash (*Fraxinus nigra*), green ash (*Fraxinus pennsylvanica*), red maple (*Acer rubrum*), silver maple (*Acer saccharinum*), swamp white oak (*Quercus bicolor*), and elms (*Ulmus spp.*) comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. This type occurs on wetlands characterized by periodic inundation (fluctuating water table near or above the soil surface) and nearly permanent subsurface water flow.

Swamp hardwood stands are often composed of relatively pure black ash, although mixed stands are commonly found. Black ash with its rapid growth rate initially, dominates the structure and composition in this cover type. In old growth black ash stands, an uneven age structure with gaps is usually exhibited depending on the natural disturbance regime at the site (wind throw and flooding).

Northern and Southern Hardwood Swamp are the plant communities mentioned in the Endangered Resources section of this chapter. The latter tends to be more represented in the southern part of the state having more green ash and silver maple as a component within the forest.

Similar but distinct community types are:

- Bottomland hardwood forests occur on floodplains and some terraces mostly in southern part of the state. Defining species are silver maple, green ash, swamp white oak, American elm, river birch (*Betula nigra*), and cottonwood (*Populus deltoides*).
- On uplands with somewhat poorly drained to moderately well drained mineral soils, some stands can be dominated by species typical of the swamp hardwood cover type (red maple, black ash and elm), however these are not swamps. In comparison, trees on these sites generally exhibit significantly improved vigor and productivity.

Associated Species
Associates in swamp hardwood communities include: aspen (*Populus spp*.), white birch (*Betula papyrifera*), yellow birch (*Betula alleghaniensis*), balsam fir (*Abies balsamea*), northern white cedar (*Thuja occidentalis*), hemlock (*Tsuga canadensis*),white pine (*Pinus strobus*), white spruce (*Picea glauca*), black spruce (*Picea mariana*), and tamarack (*Larix laricina*).

Differences in species composition are dependent on variation in site, soils and duration of high water. Black ash-dominated swamps are adapted to more stagnant water with reduced oxygen content whereas, green ash is more likely to occur with moving, oxygen rich water. Due to the presence of emerald ash borer (EAB) in the upper Midwest, the domination of black and green ash on swamp hardwood sites is expected to decline.

1.2 Silvical Characteristics

1.2.1 Black Ash

Black ash is a relatively small, slow growing tree of northern swampy woodlands. Black ash grows most commonly on peat and muck soils in bogs, along streams or in poorly drained areas which are often seasonally flooded. Black ash can tolerate semi-stagnant conditions but best growth occurs when water is moving through the soil so that the soil remains aerated even though it is saturated. Black ash has a shallow and fibrous root system well adapted to high soil moisture conditions. It has the ability to tolerate intermediate to high levels of shade when older but the seedlings are somewhat shade-intolerant. Studies in Minnesota have indicated tolerance to prolonged periods of suppression (D'Amato personal communication).

Commonly, the largest trees reach 60-70 feet tall and 12-24 inches dbh. Maximum life expectancy ranges from 150 to 320 years. In many stands the largest trees are only 8-10 inches dbh. Growth rates are slow with site index at base age 50 years ranging from 50 to 80 feet in northern Wisconsin and Michigan. In many stands black ash is often outgrown by its associates, especially balsam fir, red maple and northern white cedar.

Black ash is polygamous and flowers in May and June during or just prior to leaf out. Seeds disperse from July through October. Good seed crops occur infrequently. Seeds remain dormant during their first year and must undergo a period of warm followed by cold stratification. Seeds normally germinate in their second year but may remain viable in the seed bank for more than 8 years. Black ash seedlings exhibit slower growth than associated species such as red maple.

Black ash regenerates from seed, readily stump sprouts, and is reported to produce root suckers following cutting. However, Tardif and Bergeron (1999), state that root suckering in black ash has never been quantified nor are there any references with empirical data.

Black ash is very tolerant of low oxygen levels but is intolerant of flooding well into the growing season. Massive dieback of overstory and sometime understory can result from extended periods of high water. An adaptation to this occurrence is the long dormancy period of black ash seeds. Other adaptations include hypertrophied lenticels (oversized pores on woody stems that foster gas exchange between and plants and atmosphere) and rapid stomatal closure. Flooding extent has even been found to dictate the mode of regeneration for black ash and can lead to reduced levels of radial growth in years following prolong flooding (Tardif 1997). Heavy flooding usually results in vegetative reproduction by stump sprouting, whereas seed origin regeneration is usually fostered with less prolonged flooding.

1.2.2 Green Ash

Green ash is the most widely distributed of the American ashes. In Wisconsin it occurs most often in the eastern counties bordering Lake Michigan. Green ash grows naturally on moist bottom lands and stream banks. However, it is widely planted and is also a very popular ornamental tree.

Green ash may be the most adaptable of all the ashes growing on sites ranging from frequently flooded clay soils to sandy soils with limited moisture availability. However, it is found most commonly on alluvial soils along rivers and streams and less frequently in swamps. Green ash is less tolerant of flooding.

Green ash is dioecious. A high percentage of the male and female trees flower annually and many of the female trees produce seeds each year. Seeds ripen in late September or early October. Seeds are dispersed by wind short distances from the parent tree and may germinate in the spring following seed fall or lie dormant in the litter for several years. Under ideal open grown conditions seedlings grow rapidly with reports of 12” height growth the first year and another 18” the second year. Green ash may also reproduce vegetatively. Stumps of sapling and pole sized tree sprout readily.

Little data exists for growth rates under natural stand conditions. In the northern part of its range green ash can reach 50-60 feet tall and 18-24” DBH. Maximum life expectancy is about 175 years.

In Wisconsin green ash varies from intolerant to moderately tolerant of shade. It is usually an early successional species. However, some studies in the southern part of its range have shown that advanced reproduction can be maintained in the understory for more than 15 years and responds well to release.

1.2.3 Red Maple

Red maple, commonly referred to as soft maple in Wisconsin, is one of the most widespread tree species of eastern North America. It reaches the western and northern extent of its range in Wisconsin. Red maple grows on a wide range of soil types, textures and moisture regimes. It is common in swampy areas, on slow draining flats and depressions and along small slow flowing streams. Red maple can occur in almost pure stands on moist soils and swamp borders.

Red maple flowers from March through May and is a prolific seed producer yielding between 12,000 and 91,000 seeds per tree. A seed crop occurs nearly every year and a bumper crop once every two years. Seeds ripen quickly and begin dispersing during April through July. Seeds are dispersed by wind and may begin germinating immediately after ripening. Given proper temperature and moisture conditions red maple seeds can germinate with very little light. Second year germination is common if the overstory canopy is too dense. Moist mineral soil is the preferred seed bed.

Red maple seedlings are moderately tolerant to tolerant of shade and are often very abundant. Seedlings respond well to overstory disturbance such as disease, windthrow and harvesting. Red maples also stump sprout vigorously especially in stumps less than 12” diameter. Under favorable conditions seedlings can grow 1 foot in the first year and up to 2 feet per year for the next few years. Stump sprouts can grow as much as 3 feet in the first year but soon slow down to the same rate as seedlings.

Red maple is a short to medium lived tree, maturing in 70-80 years and seldom living longer than 150 years. An average red maple tree may reach 60-90 feet tall and 18-30” DBH.

Red maple is a pioneer or subclimax species and is more shade tolerant and longer lived that other early successional species. Seedlings are more shade tolerant than larger trees and can exist in the understory for several years. These seedlings respond rapidly to release and can occupy over-story space before being replaced by longer lived more shade tolerant species.

1.2.4 Silver Maple

Silver maple is a medium lived, rapidly growing tree common in the eastern U.S. Maximum life expectancy is about 130 years. Its native range covers most of Wisconsin except for the far north and northwestern parts of the state. Silver maple is most commonly found on stream banks, flood plains and lake edges where it grows best on better drained, moist alluvial soils. It is only occasionally found in swamps, gullies and small depression of slow drainage. Silver maple seedlings are adapted to survive long periods of inundation in bottom lands where flooding is common.

Silver maple begins to flower as early as February and continues flowering into May. Seeds ripen and disperse beginning in April and ending by June and are most often dispersed by wind and occasionally by water. Seeds may begin germinating immediately after dispersal. Moist mineral soil with considerable organic matter is the preferred seed bed. Initially, seedlings grow rapidly, 12-36" in the first year, but cannot compete with overtopping vegetation in subsequent growing seasons. First year seedling mortality is high if they are not released.

Prolific sprouting from root collars and lower stems is characteristic of silver maple. Stumps of 12" diameter or less sprout readily.

Depending on site quality and location the shade tolerance of silver maple ranges from moderate to very intolerant. In general it is considered tolerant on good sites and intolerant on poor sites.

1.2.5 Swamp White Oak

Swamp white oak is a midsized, rapidly growing tree occurring on lowlands, along edges of streams and in swamps subject to flooding. In Wisconsin its native range includes approximately the south half of the state where it is more common in swamps. Swamp white oak is long lived and may reach 300 to 350 years of age.

Swamp white oak is typically found on poorly drained mineral soils, organic soils ranging from muck to peat or alluvial soils. These soils are found in areas which are periodically inundated. However, it is not found where flooding is permanent.

Swamp white oak reach seed bearing age at about 20 years. The trees flower from May through June with acorns maturing in about 1 year. Acorns fall during September and October and begin germinating soon after. Good seed crops occur every 3-5 years. Seedlings develop best on better drained lowland soils. Swamp white oak will also sprout very well especially when stump diameter is less than 11 inches.

Swamp white oak is a midsized tree averaging 60-75 feet tall and 24-36 inches DBH. It usually grows in a mixture with other bottom land species and is only abundant locally.

The tree is of intermediate shade tolerance and seedlings will become established under moderate shade.

1.2.6 American Elm

American elm (*Ulmus americana*) is most notable for its susceptibility to the wilt fungus, Dutch elm disease. Because of the disease American elm comprise a much smaller percentage of large diameter trees than in the past. Dutch elm disease has virtually eliminated elm from future silvicultural considerations. Although elm is no longer significant as an overstory tree, it can still make up a significant part of the understory and seedling layers. American elm may be perpetuated for generations even though the average life of the trees is likely to be reduced.

American elm is found throughout eastern North America. It is found most commonly on flats and bottom lands but is not restricted to these sites. In the Lake States it is also found on plains and morainal hills as well as bottom lands and swamp margins.

American elm grows best on well drained loams. However, it grows on many different soil groups including well drained sands, organic bogs and poorly drained clay. Soil moisture greatly influences growth rates. Growth is poor in well drained sands and where the summer water table is less than two ft below the soil surface.

Flowering begins in April and May in the Lake States. Seeds ripen and fall by mid-June. American elm are prolific seed producers after about 40 years of age. Seeds are dispersed by wind and most fall within 300 feet of the parent tree.

Seeds usually germinate within 6-12 days after they fall. Germination is best with temperatures between 68-86 degrees F on a mineral soil seed bed, but can also become established on moist litter, moss and decayed logs or stumps.

Seedlings grow best with about 1/3 to full sunlight conditions. Seedlings can withstand flooding in the dormant season but die if flooding is prolonged into the growing season. Compared to other lowland tree species elm is only intermediately tolerant to complete inundation.

Moderately shade tolerant as a seedling but it becomes very intolerant as a sapling and pole-sized tree. Without release, vigor declines dramatically once trees are more than 2-4 DBH. Isolated trees are growing into sawtimber size classes on somewhat poorly drained soils.

American elm seldom grows in pure stands and there is no information on stand yields. On wet soils elm may grow to 40-60 feet tall and live for 175 – 300 years if not infected with Dutch elm disease. If infected, some trees can live for about 30-40 years before the tree is severely stressed and dies. Elm is of intermediate shade tolerance and responds well to release.

Table 46.1. Summary of selected silvical characteristics[1].

Species	Black Ash	Green Ash	Red Maple	Silver Maple	Swamp White Oak	American Elm
Flowers	May - June Polygamous	April-May Dioecious	March - May Polygamo-dioecious	Feb. - May Dioecious	May to June Monoecious	April – May Perfect
Fruit Ripens	June – Sept. single samara	Sept.-Oct Single samara	April - June Double samara	April - June 1 seeded samara	Sept- Oct. Acorn	April – June Winged samara
No. of seeds/lb	7000 samaras/lb	17,200 seed/lb	22,800 seed/lb	10,000 seed/lb	120 seed/lb	71,000 seed/lb
Seed Dispersal	July – Oct. Wind dispersed >300 feet.	Late Sept - Winter. Wind > 300 feet	April - July. Wind.	Early Summer. Wind and Water	Sept – Oct. Animal	Mid June Wind
Good Seed Years	Every 1-8 yrs	Annually	Annually	Annually	Every 3-5 years	2-3 yrs.
Seed Bearing Age	30-40 yrs.	20 yrs.	12-15 yrs.	11 years.	20 yrs.	15-40 yrs
Seed Viability	8 yrs.	1-7 yrs	good	poor	poor	poor
Germination	Warm/cold stratification to break dormancy – germination in 2nd year. Rate:7%	Cold stratification – dormant embryo until 2nd yr. Rate:80%	Early summer soon after dispersal Rate: 77%	Immediately after maturity Rate: 99%	Soon after falling Rate: 50-90%	Soon after falling. Rate:65%

[1]Information extracted from Burns etal 1990 and USDA 2008

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Management objectives should be identified in accordance with landowner goals within a sustainable forest management framework, which gives consideration to a variety of goals and objectives within the local and regional landscape. The silvicultural systems described herein are designed to promote the optimum quality and quantity of swamp hardwood timber products. Modifying these silvicultural systems to satisfy other management objectives could potentially result in reduced vigor, growth and stem quality. The habitat type is the preferred indicator of site potential. Other indicators of site potential include site index, water table and soil characteristics. It is recommended not to rely on site index alone.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.1 Landscape Considerations

Deciduous hardwood swamps occur on lake plains, glacial tills, and flat to pitted glacial outwash where the surface falls at or below the water table and, as a result of their topographic requirements, tend to be distributed as scattered, discrete bodies on the landscape, rarely covering extensive contiguous areas. These stands are seasonally inundated with water at or near the surface much of the year. Soils have relatively high organic matter and generally consist of a shallow layer of muck or peat over mineral soil. Though swamp hardwoods can also be found on fine sands and loams underlain by clays (Dunn & Stearns 1987; Christensen et al, 1959; Wright, 1965).

3.1.1 Historical Context

When the General Land Office Public Land Surveys (PLS) were conducted in Wisconsin (1832-1866), black ash dominated wetland forests were approximate 4% of the landscape. Prior to the introduction of Dutch elm disease in the 1950's, American elm was a major component of the swamp hardwood community type, especially in southern Wisconsin. Today, elm is much less abundant, comprising only about 5% of total stems in these communities (Dunn, 1985).

A recent analysis was conducted of species historically present in our current swamp hardwood stands. State and county forest reconnaissance data from November 2011 were intersected with data from the US General Land Office's Public Land Survey of the mid-1800s. There were 3,898 stands typed as swamp hardwood (SH) that intersected with 1319 "witness trees" at 606 survey posts. Although there are limitations to using the witness tree data (e.g., see Schulte and Mladenoff, 2001), some inferences can be drawn when the data are examined across a broad, statewide perspective.

As with many locations in the north, it appears the representation of conifers in these stands is much less than it was historically. Cedar and tamarack were the most commonly reported species at these 606 survey posts, followed by hemlock, then roughly equal numbers of yellow birch and black ash trees (Figure 46.1).

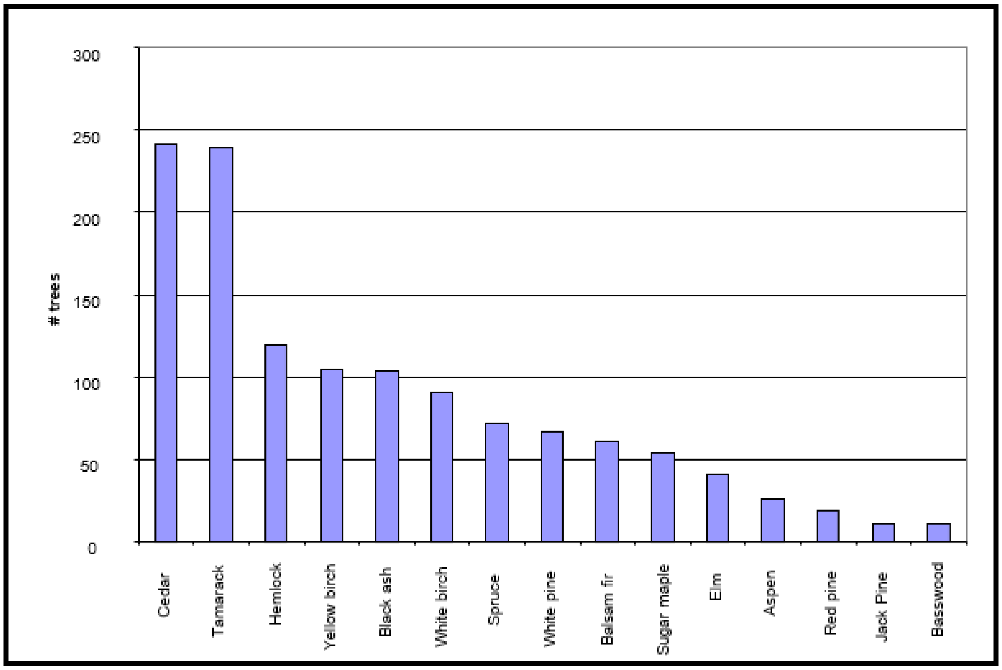

Figure 46.1. Witness trees by species that intersect with swamp hardwood stands on state and county lands from November 2011 recon data. Only species with 10 or more trees are shown (comprises 96% of the 1,319 trees).

Summarizing trees that were present at the time of Euro-American settlement can be useful for exploring the ecological capabilities of an area. This information can be helpful if there is a desire to restore an area of swamp hardwoods, especially given the anticipated impacts of emerald ash borer on black ash, the current canopy dominant in the majority of these stands. Unfortunately, some of the major species that were present historically are now difficult to regenerate in almost any conditions. For example, hemlock and yellow birch appear to have been present in many of these stands in the North Central Forest, similar to many parts of that Ecological Landscape. These species were reported much less often in the Northwest Lowlands Ecological Landscape, where cedar was most often reported. Table 46.2 describes the distribution of the witness trees by Ecological Landscape.

Table 46.2. Witness trees by Ecological Landscape that intersect with swamp hardwood stands on state and county lands from November 2011 reconnaissance data. Only tree species with five or more total witness trees and only the 13 Ecological Landscapes with swamp hardwood stands in the November 2011 reconnaissance data are shown.

Species	# Witness Trees	Central Lake Michigan Coastal	Central Sand Hills	Central Sand Plains	Forest Transition	North Central Forest	Northeast Sands	Northern Highland	Northern Lake Michigan Coastal	Northwest Lowlands	Northwest Sands	Southeast Glacial Plains	Superior Coastal Plain	Western Coulees and Ridges
Aspen	26		3			3	4		2	5	4	1	4	
Balsam fir	61				7	25	6			12	6		5	
Basswood	11		1		1	2				1		3	3	
Black ash	104	2		2	3	22	20	1	4	30	12	7	1	
Black oak	6		6											
Bur oak	8		1		2					3		2		
Cedar	241	12	0	0	8	93	34	2	19	49	7	2	15	0
Elm	39					8	5		1	4	2	11	5	3
Hemlock	119	1			9	94	12		3					
Jack Pine	11			1			5			3	2			
Pine (undifferentiated)	6					6								
Red pine	19						12				7			
Spruce	72				3	19	9		2	23	6	1	9	
Sugar maple	54				1	27	5			15	2	2	2	
Tamarack	239	4	2		5	51	47	9	9	60	30	19	3	
White ash	5		1			3						1		
White birch	90	1			3	30	16		2	24	3		11	
White cedar	51					12				33	6			
White oak	5		4									1		
White pine	67			1	9	12	19			19	7			
Yellow birch	105				8	65	5	2	6	14	2		2	1

3.1.1 Current Context

Today the black ash\American elm\red maple forest type accounts for about 5% of the all the forest land in Wisconsin. Although this forest type can be found in lake plains, stream terraces, and depressional areas throughout Wisconsin, more than 80% of these stands are located in northern Wisconsin, primarily in the North Central Forest and Forest Transition Ecological Landscapes (USDA 2009) (Figure 46.2).

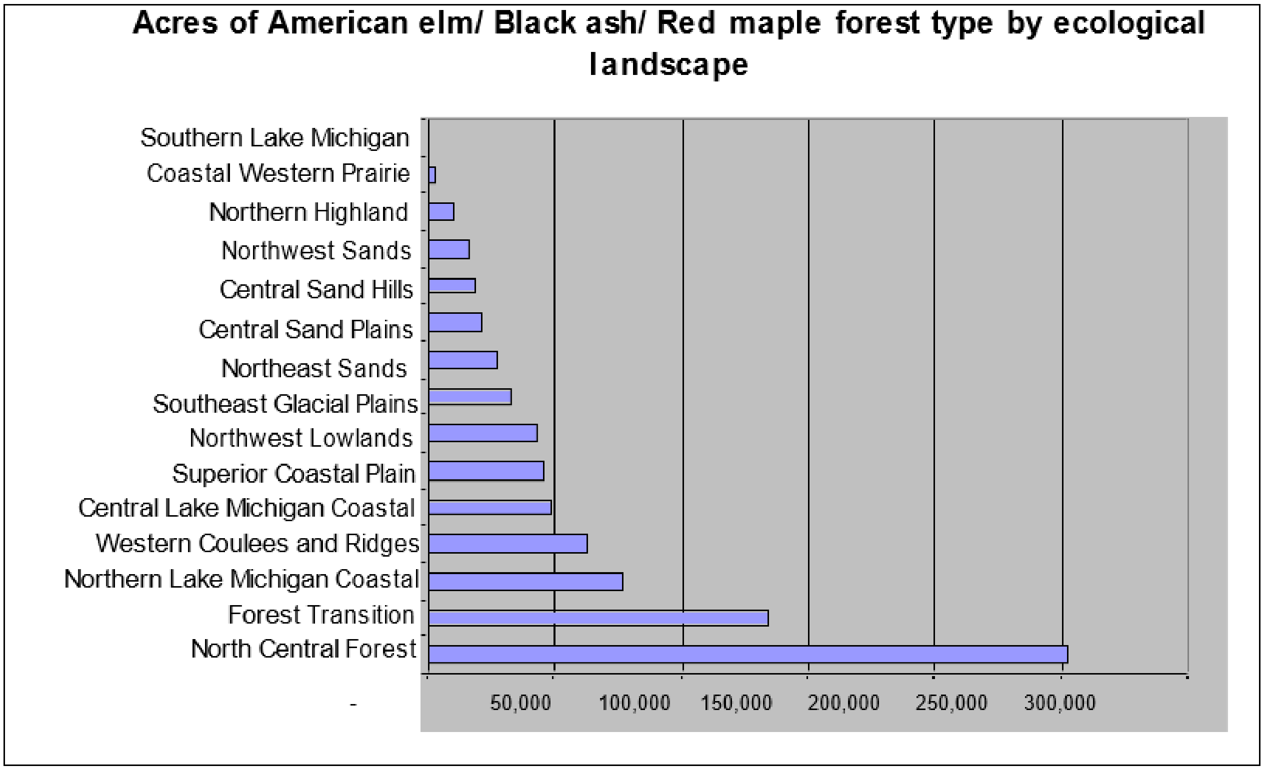

Figure 46.2. Acres of swamp hardwood cover type by ecological landscape.

Maintaining a desirable age-class distribution is a landscape-level consideration. A stable age-class structure that includes all developmental stages maximizes benefits to wildlife by providing a range of structural conditions and economic interests by supplying a range of materials such as pulp, fuel wood, and sawlogs. While the average age of swamp hardwood forests in Wisconsin increased slightly between 2004 and 2009 as a result of increased acreage in the oldest age classes, the majority of swamp hardwood acreage is still concentrated in the middle age classes (Figure 46.3).

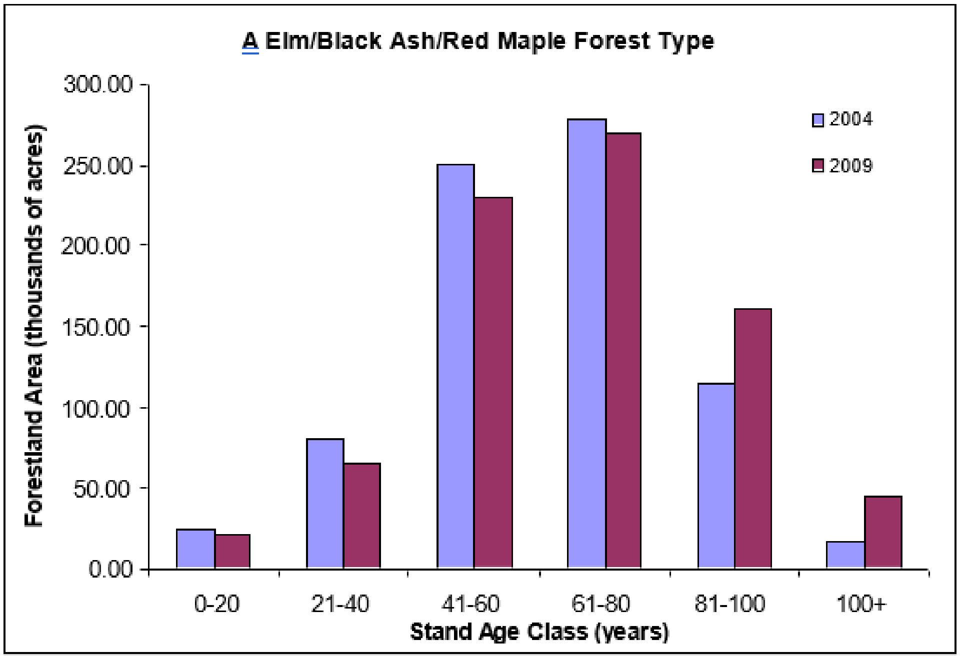

Figure 46.3. Forest age-class distribution for the elm/black ash/red maple cover type in Wisconsin, 2004 and 2009 (USDA 2009).

3.1.3 Hydrology

In swamp hardwoods, it is important to understand the hydrology and water flow. A watershed is made up of surface drainage (streams) and underlying subsurface geologic framework (aquifer) that constitute the terrestrial portion of the hydrologic cycle. Water is constantly moving through a watershed with inflow from precipitation and outflow by evapo-transpiration and discharge into basin outlets. Flowing from high hydraulic heads to areas of low hydraulic heads creates the groundwater pump. In this hydrologic process, trees facilitate the process by uptake of water through their root system and transpiring through their leaves. If there is complete or even partial removal of the trees at a given site, the water cycle is impacted.

Concerns about impacts from harvesting in forested wetlands can be addressed by first understanding the characteristics of this cover type. Swamp hardwood sites are different than bottomland hardwood sites in that the hydroperiod has a very predictable pattern associated with spring thaw and prolonged storm events. They are often hydrologically open, connected to a wetland matrix (other wetlands) and are somewhat dependent on overland water flow for nutrients. It is also helpful to understand the climate, surrounding geology and landform, soils, and aquifer type before applying the silvicultural prescription. Recommendations regarding hydrology considerations are outlined in the Management Considerations section of this chapter.

3.1.4 Disturbance Regime

Seasonal flooding is the primary disturbance in hardwood swamps. Standing water is usually present in the spring and drained by late summer. Flooding extent has been found to influence the mode of regeneration for black ash whereby heavy flooding usually results in vegetative reproduction by stump sprouting, and sexual reproduction is found with less prolonged flooding (Tardif et al., 1994). In addition, black ash has adapted to stagnant water and low oxygen levels associated with swamp depressions but is intolerant of flooding well into the growing season. Massive dieback of understory and sometimes overstory vegetation can result from extended periods of high water in hardwood swamps. An adaptation to these extended periods of high water is the long dormancy period (up to eight years) of black ash seeds (Wright and Rauscher, 1990).

Drought disturbance also impacts hardwood swamps. While drier periods that expose the saturated organic soils are essential for regeneration, xeric stress is harmful to shallow rooting black ash seedlings (Tardif et al. 1994). As a result, swamp hardwood communities are relegated to depressions, and low-level terrain near rivers, lakes, or wetlands, which experience seasonal flooding and where because of the high water-retaining capacity of peat soils, soil moisture is maintained throughout the growing season.

Other large-scale disturbances were most likely infrequent. In Minnesota, large windthrow and fire events in northern hardwood swamps had a rotation of 370 and 1,000 years, respectively (MNDNR 2003). However, small-scale windthrow events are common in these systems due to shallow rooting in muck soils. The uprooting of individual trees creates microtopography that results in fine-scale gradients of soil moisture and increases floristic diversity. In addition, beaver activity is a localized source of periodic disturbance in these systems. Dam-building activities alter hydrology by causing either prolonged flooding or lowering of the water table depending on the location of the forest in relation to the dam (Curtis 1959, Heinselman 1963, Jeglum 1975). Beaver can also generate canopy gaps in these systems by cutting down large trees.

In general lowland forests have received somewhat less human disturbance than many upland forest types because their economic potential as sources of lumber is relatively low compared to other forest types. However, many of the southern lowland forests have been cut and drained for agriculture. In the north there were few attempts at drainage for agriculture, and logging and fire were the primary human caused disturbances (Curtis, 1959).

3.1.5 Summary of Landscape Considerations

- Monitor and control invasives. Continue and support biological control research to manage invasives that are present and prevent spread of additional invasives.
    - Use Best Management Practices and other sustainable forest community management practices to prevent detrimental soil and water impacts.

- Use adaptive management techniques to restore forest structure and composition; monitor and share results.
- Manage recreational uses so they do not harm the environment.
- Protect significant areas from hydrological changes from road construction and development. Restore hydrology where needed and/or appropriate.
- Preserve large blocks of habitat in a matrix of other forest types
- Consider opportunities to increase a diversity of tree species in this type

3.2 Site and Stand Considerations

3.2.1 Soils

The swamp hardwood cover type occurs on forested wetlands (swamps) characterized by periodic inundation (fluctuating water table near or above the soil surface) and nearly permanent subsurface water flow. Seasonal and yearly fluctuations in depth of saturation can be considerable. Soils are poorly drained to very poorly drained and are subject to ponding. These soils commonly have a “depth to water table” of zero inches and can occur in basins, depressions, flats, and drainage ways.

Typical soils are mucks of highly variable thickness (several inches to several feet) over mineral soil of any texture. In some cases, the surface can be mucky mineral soil, and other soils may include mucky peat. Nutrient availability can be highly variable among sites and has a strong influence on community development and potential productivity. Nutrient availability is influenced by type of substrate, degree of decomposition of organic materials, run-off from adjacent stands and groundwater flow. In general, growth and productivity are improved by mineral soil of finer texture closer to the surface; greater decomposition of organic materials; better drainage; flowing and aerated water; and adjacent landform/soils. Although swamp hardwoods, particularly black ash, can tolerate semi-stagnate water flow and relatively nutrient poor conditions, the type does not generally develop on nutrient poor, acid peatlands (dysic histosols).

Harvesting practices need to be properly implemented when removing timber products from a swamp hardwood stand. Poor skidding technique and seasonal timing can reduce stem quality, root health, and soil productivity. When roots are damaged, the potential for windthrow may increase. Bole and branch damage can reduce log quality and grade and may also lead to decay.

When swamp hardwoods occur on muck soils, the area is susceptible to soil displacement and rutting when wet and to soil compaction when dry. Soil displacement, rutting, and compaction have been shown to decrease seedling and sapling growth in many soil types, although specific effects depend on soil moisture and content (NCASI 2004). Driving over the root system with heavy equipment can also cause root damage potentially causing severe dieback of residual trees. Harvesting when the soil is frozen or firm can reduce the potential for soil displacement, rutting, and compaction.

The total area devoted to landings, roads, and skid trails should be minimized to limit the loss of productive area. Designate skidding routes and landing areas to limit the total area affected by vehicle traffic. Primary skid trails should be reused in future entries, whenever possible.

Recommendations in the Wisconsin Forest Management Guidelines and Wisconsin Forestry BMPs for Water Quality Field Manual (WDNR 2010) should be used to minimize impacts of roads, landings, and skid trails on surface and sub-surface hydrology. In addition, the BMPs can help minimize soil erosion and sedimentation from roads and other forest management activities.

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

As defined here, forested wetlands generally occur on poorly drained to very poorly drained soils (as classified by NRCS). The substrate can be mineral or organic and is influenced by a fluctuating water table or periodic flooding. Seasonal and yearly fluctuations in depth of saturation can be considerable. Nutrient availability can be highly variable among sites, and has a strong influence on community development, growth and productivity, and habitat type classification. Forested wetland ecosystems comprise about 2,670,000 acres or 17% of Wisconsin's forest lands (USDA 2009). About 77% of these forested wetlands occur in northern Wisconsin.

Within Wisconsin, the swamp hardwood cover type represents approximately 25 to 30% of forested wetlands and occupies about 4 to 5% of statewide forest land acres (slightly over one million acres). In northern Wisconsin, swamp hardwood stands tend to be strongly dominated by black ash, with red maple often playing an important role. In southern Wisconsin, swamp hardwood stands tend to be dominated by green ash, silver maple and red maple, with black ash, American elm and swamp white oak often represented.

Forested wetland habitat types are being developed for Wisconsin and have been defined for Northern Region's 1-4. These sites are all grouped into the wet-mesic to wet habitat type group. Therefore, the swamp hardwood cover type only occurs on the wet-mesic to wet habitat type group (stands of similar composition can be found on the mesic to wet-mesic habitat type group, but the sites are better drained).

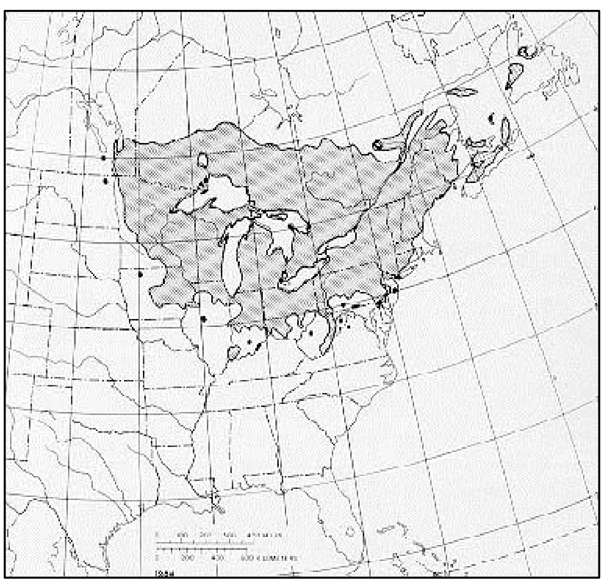

Figure 46.4. Black ash range map.

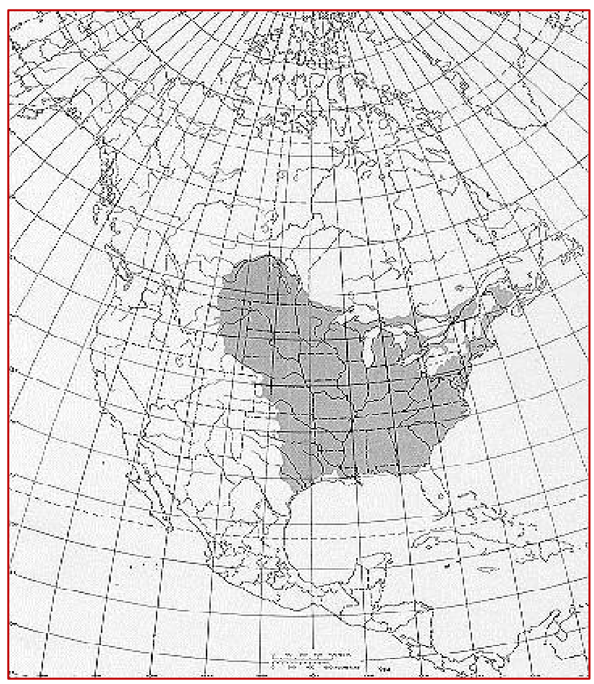

Figure 46.5. Green ash range map.

The dominant swamp hardwood species are most productive on nutrient medium to rich upland habitat types in the mesic and mesic to wet-mesic habitat type groups (moderately well drained and somewhat poorly drained soils). Table 46.3 presents average site index values for several swamp hardwood species on northern mesic to wet-mesic and wet- mesic to wet sites.

Within the wet-mesic to wet habitat type group (swamps), the occurrence and relative growth potential of the swamp hardwood cover type varies by habitat types. In general, as nutrient availability decreases the frequency of swamp hardwood occurrence and potential productivity also decrease. This is reflected in the understory vegetation component, hydrology, parent soil and depth of organic layer. Adjacent landform and soil substrate influence the habitat type also.

Table 46.3. Site index for some swamp hardwood species on wet sites (swamps) and wet- mesic uplands in northern Wisconsin (FIA 1996). Range represents the 95% confidence limits for the mean, and number in parenthesis is the number of observations.

Tree Species	Habitat Type Group	
	North Wet-mesic to Wet	North Mesic to Wet-mesic
Black Ash	47-51 (119)	59-66 (25)
Red Maple	54-61 (42)	64-67 (146)
Green Ash	60-67 (48)	64-72 (27)

Nutrient medium habitat types named after ashes, maples, and/or elms (e.g. FnArI or Fraxinus nigra-Acer rubrum/Impatiens capensis in region 3 and FnUB or Fraxinus nigra Ulnus Boehmeria in region 4) are commonly dominated by the swamp hardwood type and generally exhibit relatively better productivity. In comparison, swamp hardwood communities sometimes develop on nutrient poor to medium habitat types (e.g. AbFnThOs) but tend to exhibit relatively poor productivity. Nutrient poor to very poor sites (acid peatlands or dysic histosols) generally do not support swamp hardwood communities.

Other poor to medium nutrient habitat types in region 3 and 4 that are associated with swamp hardwood include:

- FnThAbAt (Fraxinus nigraThugaAbiesAthyrium)
- FnAbArOn (Fraxinus nigraAbiesAcer rubrumOnoclea)
- ThAbFnC (ThujaAbies Fraxinus nigraCoptis)
- AbFnThIx (AbiesFraxinus nigraThujaIlex)
- AbFnThOs (Abies balsamea-Fraxinus nigra-ThujaOsmunda)
- AbFnThAs (Abies balsamea-Fraxinus nigra-ThujaArisema)

3.2.3 Forest Health

Prior to the detection of emerald ash borer (EAB) in the upper Midwest, black ash was a commonly favored species in single tree selection regeneration harvests on swamp hardwood sites (Erdman et al. 1987; Tardif and Bergeron 1999). However, EAB is a potential threat to black ash stands. Managing for other associated species on swamp hardwood sites (e.g. balsam fir, yellow birch, red maple, hemlock, northern white cedar, etc.) may be a consideration due to the possibility of forest loss from EAB. As long as EAB persists without adequate biological control agents or effective management tactics, black ash may not be the optimal tree species especially in quarantined counties. Currently both Wisconsin and Minnesota are coordinating silviculture trials to further investigate options to build site level resiliency and reduce potential impacts. For more information, please refer to the EAB silvicultural guidelines.

With the emergence of EAB, conversion from black ash dominated swamp hardwood stands to another cover type may be a good alternative. Consult the EAB guidelines to determine appropriate management options. Stands with a large proportion of ash (such as a bottomland, swamp, or plantation) will be heavily impacted by EAB unless the ash component is drastically reduced. When planning harvesting activities, consider two alternatives: reducing the rotation age and changing what is considered a crop tree. If practical, reduce the ash component during regularly-scheduled stand entries, keeping the stand adequately stocked. Individual trees of other species may also be removed at the same time as EAB management activities if appropriate for the stand's management plan. Multiple stand entries may be needed to bring the ash component down to a suitable level where feasible. If the ash-dominated stand is at or near rotation age, consider regenerating the stand with a reduced proportion of ash.

3.2.5 Wildlife

Swamp hardwood stands are made up of a variety of tree species. The composition of the stand and resultant wildlife use is influenced by site characteristics. Wildlife benefits from swamp hardwoods include food from mast, twigs, and bark. In addition, some of the trees found in swamp hardwood host large numbers of insects which are a food source for birds and small mammals. The ground-layer vegetation is an important food source for browsers, particularly in the spring. This cover type is an important contributor of cavities as many of the trees found in swamp hardwoods are large and the dead wood of these trees are relatively rot-resistant. Bobcat, fisher, and pine marten use swamp hardwoods for foraging and for resting or den sites. Large stands of mature swamp hardwoods are suitable nesting habitat for forest raptors like northern goshawk and red-shouldered hawks. Poorly stocked or newly regenerated swamp hardwood stands provide important habitat for golden-winged warblers. Shallow rooted trees contribute to windthrow and openings in the forest canopy and increased vertical structure resulting from these openings benefit some wildlife species.

Invasive species are a concern for wildlife in this type. Reed canary grass can be present, particularly in a poorly stocked stand, and can be favored by management activities (WDNR 2009). Reed canary grass can dominate the ground-layer community to the exclusion of more valuable native species. It can also inhibit regeneration of the stand and establishment of understory shrubs. Cryptic invasion by buckthorn can take place over a number of years. Both of these invasives are difficult to remove and both can be favored by management. The utility of swamp hardwood stands for wildlife is diminished by invasive species and management practices that minimize or reduce invasive species will benefit wildlife.

This cover type can provide winter forage for white-tailed deer and other browsing species. While not primary food source, swamp hardwood species particularly willow are utilized by beaver. Most use of bark and twigs takes place in young stands. Canada warblers are ground-nesting insectivores associated with understory thickets. Management that increases understory woody material will benefit this species and other neotropical migrants.

Recommendations:

- Maintain diversity of tree species within stands and age classes within a landscape.
- Use best management practices to avoid hydrologic and soil compaction issues during silvicultural treatments.
- Monitor stands for invasive species and tailor silvicultural treatments to minimize the possibility of providing competitive advantages for these species. Currently, reed canary grass and buckthorns are major problems in some areas of the state.
- Maintain opportunities for green tree retention, snags, cavity trees, and coarse woody debris.
- Be aware of the possibility of forest raptor use of the stand. If nesting territories of SGCN species are identified, protection of nest trees and a modified marking and entry schedule might be warranted. WM or ER staff can provide recommendations on a site-specific basis. Because territories and nest trees can be used over a period of years, mapping these features is advised.

A list of opportunities, threats, priority conservation actions, and descriptions of rare plants and animals found in this type can be reviewed in the Northern Hardwood Swamp section of the Natural Communities listed in the Wildlife Action Plan. The Wildlife Action Plan is available on the WDNR website. The keywords “Wildlife Action Plan” in the search engine will take you to the appropriate webpage.

3.2.5.1 Deer and Herbivory Effects

White-tailed deer browse heavily on black ash seedlings and stump sprouts in swamp hardwood stands during the winter months. However, black ash can withstand moderate browsing (Erdmann et al 1987; Curtis, 1959). In the management section of this chapter the recommendation of established regeneration is 2 to 4 feet unless herbivory and hydrology issues are concerns.

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

The swamp hardwoods cover type corresponds to the (northern) Hardwood Swamp and Southern Hardwood Swamp natural community types (Epstein et al. 2002). The distribution of these two types appears to correspond roughly with the Tension Zone, and their species composition can differ. Hardwood swamps contain many important structural characteristics and unique microsites and can support rare species. They are more susceptible to negative impacts than many other forest types due to their wet, mucky soils, as well as their frequent connections to other wetland habitats and aquatic features.

Landscape context is an important consideration if the goal is to maintain or enhance biodiversity and swamp hardwood forests occur in a wide variety of ecological contexts. Swamp hardwood stands are often located near other wetland types or aquatic features, and there can be important ecotones and hydrological connections among adjacent communities. Planning management beyond the individual stand to include nearby and adjacent features would be best, including avoidance of fragmentation and hydrological disruption.

Hardwood swamps are often quite structurally diverse, and they contain numerous microhabitats not typically found in most other northern forest cover types. Some stands include seepages or streams, and most stands contain pools of water for at least portions of the year. These pools, along with the presence of hummocks (small hills of mosses and/or sedges) and other structural features can be important for some species. Since these features are often abundant, spread throughout the stand, and frequently hydrologically connected, they cannot be as easily accommodated through routine prescriptions as the special features found in other types (e.g., vernal pools in northern hardwoods). Maintaining overall structural diversity in the stand including a component of large trees, standing dead cavity trees, and coarse woody debris whenever possible is an important biodiversity consideration.

Hydrology is critical in these forests. As mentioned throughout the chapter, some stands are at risk of developing a raised water table following harvest. This flooding could, essentially, deforest the stand and remove habitat for many of the associated rare species. In places where maintaining biodiversity is the most important consideration, retaining some large, contiguous unharvested areas would be a good option. Landscape-scale planning could be used to identify these areas.

Hardwood swamps are susceptible to invasive plant infestations, including reed canary grass (*Phalaris arundinacea*), and buckthorns (*Rhamnus* spp). These are especially problematic in certain areas of the state and can negatively impact habitats for rare plants and animals.

Rare plants in swamp hardwood forests are often associated with certain habitat features, and several broad considerations are more or less universally important to these species. Harvests should be designed to avoid known rare plant locations. Where locations are unknown, it would be best to design timber sales to avoid dramatic changes to microclimate and reduce the potential for swamping wherever possible. As mentioned, avoiding impacts to hydrology and microhabitats, such as hummocks, is important for maintaining species' habitats. Compaction caused by logging equipment, especially along skid trails and log yards, could be expected to negatively impact habitats for long periods of time, so logging should be done in conditions that will have the least impact to the site.

Certain species could actually benefit from additional light, so logging that does not negatively impact the site could be beneficial for those plants. However, light is not a limiting factor in many stands due to sparse canopy cover.

Table 46.4 includes a list of rare plants associated with swamp hardwoods in Wisconsin. Some of these species occur broadly across large portions of the state, while others are limited to only a couple of counties. Please consult the species and natural community web pages maintained by the Wisconsin DNR's Endangered Resources Program for more information (*https://dnr.wisconsin.gov* keyword "biodiversity").

Table 46.4. Select rare plant species that are associated with swamp hardwood stands, as well as their degree of association with the (northern) Hardwood Swamp or Southern Hardwood Swamp natural community types. Data are from the department's Endangered Resources Program, and scores are as follows: 3 = "significantly associated," 2 = "moderately associated" and 1 = "minimally associated." See the Wisconsin DNR web site for avoidance measures, management guidance, and other information on these species and natural communities (*https://dnr.wisconsin.gov*, keyword "biodiversity").

Common Name	Scientific Name	State Status	(Northern) Hardwood Swamp	Southern Hardwood Swamp
Ravenfoot sedge	*Carex crus-corvi*	END*		2
Rope dodder	*Cuscuta glomerata*	SC		1
Northern yellow lady's-slipper	*Cypripedium parviflorum* var. *makasin*	SC		2
Showy lady's-slipper	*Cypripedium reginae*	SC	2	
Clinton's woodfern	*Dryopteris clintoniana*	SC		3
Large-leaved avens	*Geum macrophyllum var.*	SC	2	
Butternut	*Juglans cinerea*	SC		1
Small forget-me-not	*Myosotis laxa*	SC	2	
Black tupelo	*Nyssa sylvatica*	SC		2
Bog bluegrass	*Poa paludigena*	THR**	3	
Northern wild-raisin	*Viburnum nudum var. cassinoides*	SC		2

* Known from two southeastern counties in Wisconsin
** Recommended for de-listing by the Endangered Resources Program, as of this writing.

Maintaining habitat for rare animals involves many of the previously discussed considerations. In addition, several of the species in Black ash stumpage values are typically lower due to market conditions and wetland harvesting operations. Stumpage values can be as much as 50% lower than mixed hardwood (maple) stumpage values depending upon current market conditions. Seasonal conditions (winter only harvests) can restrict wetland harvesting operations from year to year. In drought conditions, the soils may be dry and firm where harvest can occur. However, extreme caution and monitoring the site is necessary, and contract extensions may be needed for swamp hardwood stands.

Black ash is prone to ring shake. Ring shake is a splitting along the plane of the annual growth rings. Shake may be caused by an abrupt change in diameter growth rates such as when trees are released by a long-delayed thinning (Smith 1986). The presence of ring shake in a tree significantly degrades log quality. However, the possibility for ring shake should not preclude one from managing for high quality saw logs. Ring shake appears to be confined to the first 2-3 feet of the butt log and may be associated with the root flare or seams. The butt log should be given a generous amount of trim allowance so that shake may be "butted off" as needed (personal communications - Tim Lee – Log buyer et al).

3.2.7 Operational Considerations

Forests on sites that have a water table near the surface are sometimes subject to a rise in water tables after a harvest. The rise in water tables (also known as “swamping out”, “watering up”, or “wetting up”), occurs due to the loss of transpiration by trees, and the loss of direct evaporation that occurs when trees intercept precipitation. Plant roots and soil organisms are directly affected by the lack of oxygen that results from a water table rise. Increases in water table levels after harvests have been observed in many locations. Clearcutting in Quebec raised water tables on seven of eight study sites, with wetland/upland transition zones being more susceptible to rises (Dube et al. 1995), and another Quebec study found a correlation between the percent basal area removed and the amount of increase in water tables (Pothier et al. 2002; Erdman 1987).

Infrastructure (roads, skid trails, and landings) development and maintenance can have both immediate and cumulative impacts on forest soils and wetland hydrology. Studies have correlated these impacts with changes in hydrologic regimes, surface drainage patterns, and soil moisture (Jeglum 1975). The physical effects of soil compaction due to rutting can increase bulk density and impact the site hydrology.

Practices that will limit water table rises and compaction to some extent during forest management include:

- maintaining a partial tree canopy
- careful layout of skid trails and infrastructure to limit surface ponding
- retaining woody debris
- harvesting during frozen ground (pre-freezing skid trails)
- limit rutting by skidding over tops and debris and using high flotation equipment

rely on large blocks of forest, so keeping large, intact stands within a favorable context would provide the best habitat. In general, providing areas with mature forest, dense canopy cover, abundant cavities, and coarse woody debris would benefit numerous rare species associated with this forest type. Some of the species in Black ash stumpage values are typically lower due to market conditions and wetland harvesting operations. Stumpage values can be as much as 50% lower than mixed hardwood (maple) stumpage values depending upon current market conditions. Seasonal conditions (winter only harvests) can restrict wetland harvesting operations from year to year. In drought conditions, the soils may be dry and firm where harvest can occur. However, extreme caution and monitoring the site is necessary, and contract extensions may be needed for swamp hardwood stands.

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- limit rutting by skidding over tops and debris and using high flotation equipment

are only associated with swamp hardwood stands when certain features are present and in certain parts of the state. See the Bureau of Endangered Resources species and natural community Web pages for more information (*https://dnr.wisconsin.gov,* keyword “biodiversity”).

Table 46.5. Select rare animal species that are associated with swamp hardwood stands, as well as their degree of association with the (northern) Hardwood Swamp or Southern Hardwood Swamp natural community types. Data are from the Wisconsin Wildlife Action Plan, and scores are as follows: 3 = "significantly associated," 2 = "moderately associated" and 1 = "minimally associated." See the Wisconsin DNR web site for avoidance measures, management guidance, and other information on these species and natural communities (*https://dnr.wisconsin.gov*, keyword "biodiversity").

Common Name	Scientific Name	State Status	(Northern) Hardwood Swamp	Southern Hardwood Swamp
Birds				
American woodcock	*Scolopax minor*	SC/M	2	1
Black-billed cuckoo	*Coccyzus erythropthalmus*	SC/M	1	1
Blue-winged teal	*Anas discors*	SC/M		1
Blue-winged warbler	*Vermivora pinus*	SC/M		1
Canada warbler	*Wilsonia canadensis*	SC/M	3	
Golden-winged warbler	*Vermivora chrysoptera*	SC/M	2	1
Least flycatcher	*Empidonax minimus*	SC/M	2	1
Northern goshawk	*Accipiter gentilis*	SC/M	1	
Red-shouldered hawk	*Buteo lineatus*	THR	1	1
Rusty blackbird	*Euphagus carolinus*	SC/M		3
Solitary sandpiper	*Tringa solitaria*	SC/M		1
Veery	*Catharus fuscescens*	SC/M	3	1
Willow flycatcher	*Empidonax traillii*	SC/M		1
Wood thrush	*Hylocichla mustelina*	SC/M	1	1
Yellow-billed cuckoo	*Coccyzus americanus*	SC/M		2
Yellow-crowned night-heron	*Nyctanassa violacea*	THR		2
Herptiles				
Blanding's turtle	*Emydoidea blandingii*	THR*		2
Eastern Massasauga rattlesnake	*Sistrurus catenatus catenatus*	END		2
Four-toed salamander	*Hemidactylium scutatum*	SC/H	2	3
Gray ratsnake	*Pantherophis spiloides*	SC/P		2
Mink frog	*Rana septentrionalis*	SC/H	1	
Pickerel frog	*Rana palustris*	SC/H		2
Timber rattlesnake	*Crotalus horridus*	SC/P		2
Wood turtle	*Glyptemys insculpta*	THR	2	2
Mammals				
American marten	*Martes americana*	END	1	
Eastern red bat	*Lasiurus borealis*	SC/N	2	2
Gray wolf	*Canis lupus*	SC/P	2	1
Hoary bat	*Lasiurus cinereus*	SC/N	2	1
Moose	*Alces alces*	--	3	
Northern flying squirrel	*Glaucomys sabrinus*	SC/P	2	1
Northern long-eared bat	*Myotis septentrionalis*	THR	2	2
Silver-haired bat	*Lasionycteris noctivagans*	SC/N	2	1
Water shrew	*Sorex palustris*	SC/N	3	2
Woodland jumping mouse	*Napaeozapus insignis*	SC/N	2	2

* Recommended for de-listing by the Endangered Resources Program, as of this writing.

3.2.1 Economic Issues

Economic and operational conditions are important when managing in swamp hardwood. Although economics is important to consider, maintenance and protection of site productivity, optimum tree health and vigor, and encouraging diversity of species are very important in this cover type. The following considerations address log value and ring shake, water table, compaction and soil and site productivity.

Most swamp hardwood sites are dominated by small diameter material; although a very modest amount of high-quality saw logs are grown. Tree size and quality impacts the market and processing opportunities. Most of the swamp hardwood resource is a good fit for pulpwood, fuel wood/biomass and small diameter log markets.

Black ash stumpage values are typically lower due to market conditions and wetland harvesting operations. Stumpage values can be as much as 50% lower than mixed hardwood (maple) stumpage values depending upon current market conditions. Seasonal conditions (winter only harvests) can restrict wetland harvesting operations from year to year. In drought conditions, the soils may be dry and firm where harvest can occur. However, extreme caution and monitoring the site is necessary, and contract extensions may be needed for swamp hardwood stands.

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Infrastructure (roads, skid trails, and landings) development and maintenance can have both immediate and cumulative impacts on forest soils and wetland hydrology. Studies have correlated these impacts with changes in hydrologic regimes, surface drainage patterns, and soil moisture (Jeglum 1975). The physical effects of soil compaction due to rutting can increase bulk density and impact the site hydrology.

Practices that will limit water table rises and compaction to some extent during forest management include:

- maintaining a partial tree canopy
- careful layout of skid trails and infrastructure to limit surface ponding
- retaining woody debris
- harvesting during frozen ground (pre-freezing skid trails)
- limit rutting by skidding over tops and debris and using high flotation equipment

3.2.3 Ephemeral Ponds

Swamp hardwoods are wetlands with poorly drained to very poorly drained soils. Within swamp hardwoods, there may be inclusions of ephemeral ponds (also called vernal pools). Ephemeral ponds are small ponds of water that dry out seasonally. Ephemeral ponds provide important habitat for many amphibians and invertebrates. They also provide valuable habitat for many species of birds.

In swamp hardwoods, ephemeral ponds may occur as small open pools ringed by trees or as areas of open water with trees scattered through the pond. The frequency and distribution of ephemeral ponds influence their functional importance for maintaining or enhancing diversity.

Buffering ephemeral ponds can help to protect amphibian foraging and breeding habitat adjacent to ponds. When harvesting near ephemeral ponds, avoid felling trees into or skidding through these wetlands. Identifying these areas prior to harvesting can be helpful because ephemeral ponds may not be apparent at certain times of the year because of snow cover or lack of water.

3.2.4 Declining Stands

Concerns about black ash decline by forestry professionals in both Minnesota and Wisconsin have been noted. These stands exhibit trees with severe crown dieback, others with both dieback and epicormic branching. Field evaluation in Minnesota, showed that decline was greater on wetter sites, in stands of older trees, and in stands growing closer to roads (Palik et al 2009). A change in hydrology can permanently impact the growth and vigor in swamp hardwood stands and appears to severely impact black ash. Proper restoration of the impeded hydrology may improve the quality of these sites and should be considered.

4 STAND MANAGEMENT DECISION SUPPORT

4.1 Stand Inventory

In addition to clearly identifying landowner goals and objectives, in-depth and accurate stand assessment will facilitate discussion of management options and objectives in relation to realistic and sustainable management goals. Swamp hardwood stand assessment should include quantifying variables such as:

- Hydrology
- Present species composition

  - Canopy, shrub, and ground layers
  - Sources of regeneration
  - Potential growth and competition
  - Potential non-ash sources of regeneration

- Stand structure
  - Size class distribution and density
  - Age class distribution

- Stand and tree quality
- Site quality - The habitat type is the preferred indicator of site potential. Other indicators of site productivity include site index (should not be the only factor), soil characteristics, cubic ft./acre/year growth rate, and topographical characteristics. Site has a strong influence on volume growth and potential yield.
- Stand and site variability
- Invasive species – reed canary grass, phragmites, buckthorn and others
- Damaging insects, diseases
  - Proximity of known emerald ash borer (EAB) infestations

- Special considerations: watershed, BMPs, rare species, archaeology, landscape

4.3 Cover Type Decision Model

The swamp hardwood decision models below outline initial considerations in the development of a management plan and integrate the use of silvics, site capabilities (soil, habitat type, competition, regeneration, successional pathways), methods (timing/sequence), and timeline at growth stages under ideal conditions. Sustainable forestry practices must be based on compatible landowner objectives, the capability of each site and generally accepted silvicultural practices. Each of these factors should be considered when approaching these models. Included below are some observations from the Wisconsin swamp hardwood trials.

Not all swamp hardwood stands can or should be managed for timber production. Due to a raised water table, decreased transpiration, rare species, operability, invasive species, economic viability, and other concerns, each proposed stand should be carefully evaluated. To further evaluate sites for potential management, it is recommended to consider the characteristics or site conditions defined for low, medium and high-quality sites. Characteristics of low, medium and high-quality sites include, but are not limited to, soils, site index, lowland habitat type, stand vigor and hydrology.

Low Quality - Characteristics of low-quality sites may include SI< 40, impeded drainage, muck soils, poor to medium habitat types, and poor stand condition including top dieback, epicormic branching, and heart rot. These sites are prone to rising water table and competition. If management is still a consideration, consider stand age as a factor in deciding a silviculture method.

Medium Quality - On medium quality sites, characteristics may include SI 40-50, somewhat impeded drainage, muck over mineral or poorly drained mineral, poor to medium habitat types; and moderate stand condition. Many of these stands exhibit poor sawlog potential, the management consideration is for pulpwood production. On some sites there may be limited sawlog potential.

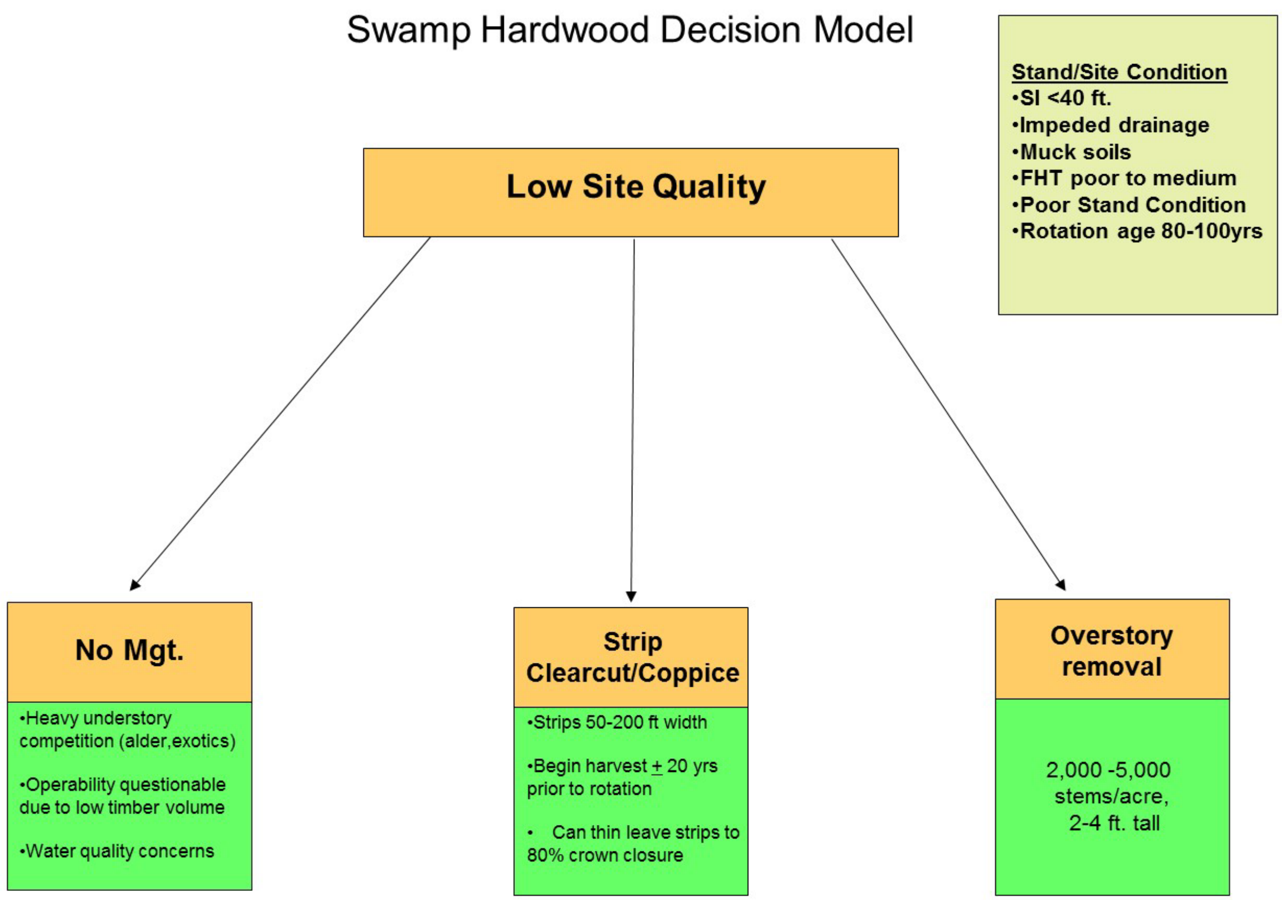
High Quality - On high quality sites, characteristics may include SI >50, good drainage to somewhat poorly drained mineral soil, medium to good habitat types and good stand condition. On these sites there is more potential to develop quality sawlogs but pulpwood production is still an option.

Even-aged silvicultural systems are commonly recommended for the management of low and medium quality stands to emphasize pulpwood rotation because sawlog potential is limited. It can be applied to high quality stands based on other objectives. The even-aged methods include shelterwood/overstory removal, strip clearcut/coppice and coppice with standards utilized for managing swamp hardwood on low to medium quality sites. As with these and any other methods, careful hydrology considerations should be applied when managing these sites.

Uneven-aged silvicultural systems, such as single tree selection and group selection may also be utilized for the management of swamp hardwood stands on the medium and high-quality sites and can develop sawlog quality. Conversion from even-aged to uneven-aged structure using similar northern hardwood applications has been utilized on some sites also.

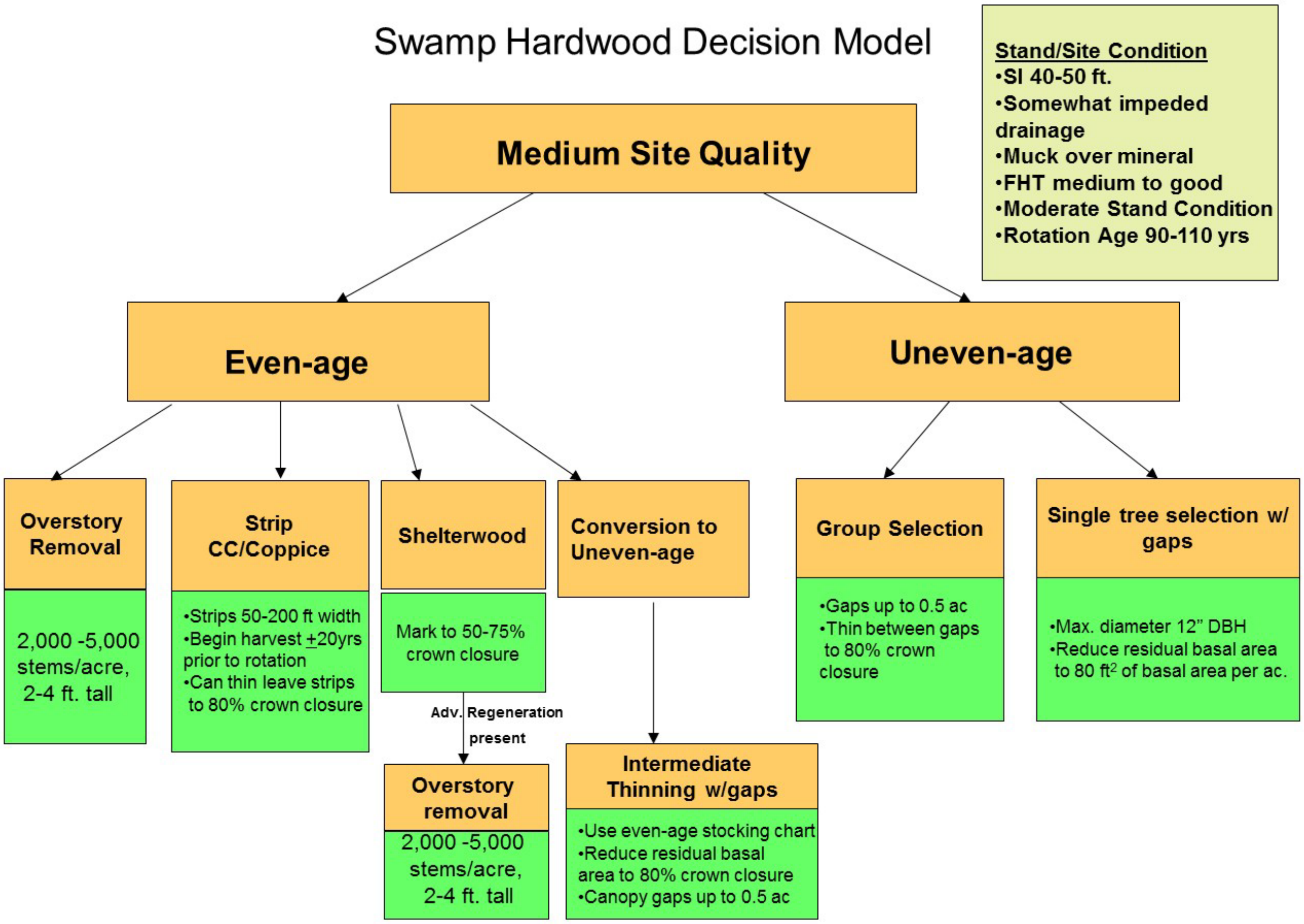
Across the spectrum of swamp hardwood stands in Wisconsin, there is a range of quality and condition observed. For instance, in the Northeastern region of the state the swamp hardwood mix of green/black ash can produce sawlog quality product on some sites. Also, in the Northern region there are some stands that have sawlog potential. However, for the most part, swamp hardwood stands in these regions have poor sawlog potential. There are 3 site quality categories to consider when assessing the proposed stand. This chapter offers management alternatives that can be applied to address this spectrum using either even-aged or uneven-aged (sawlog potential) methods.

Previous View



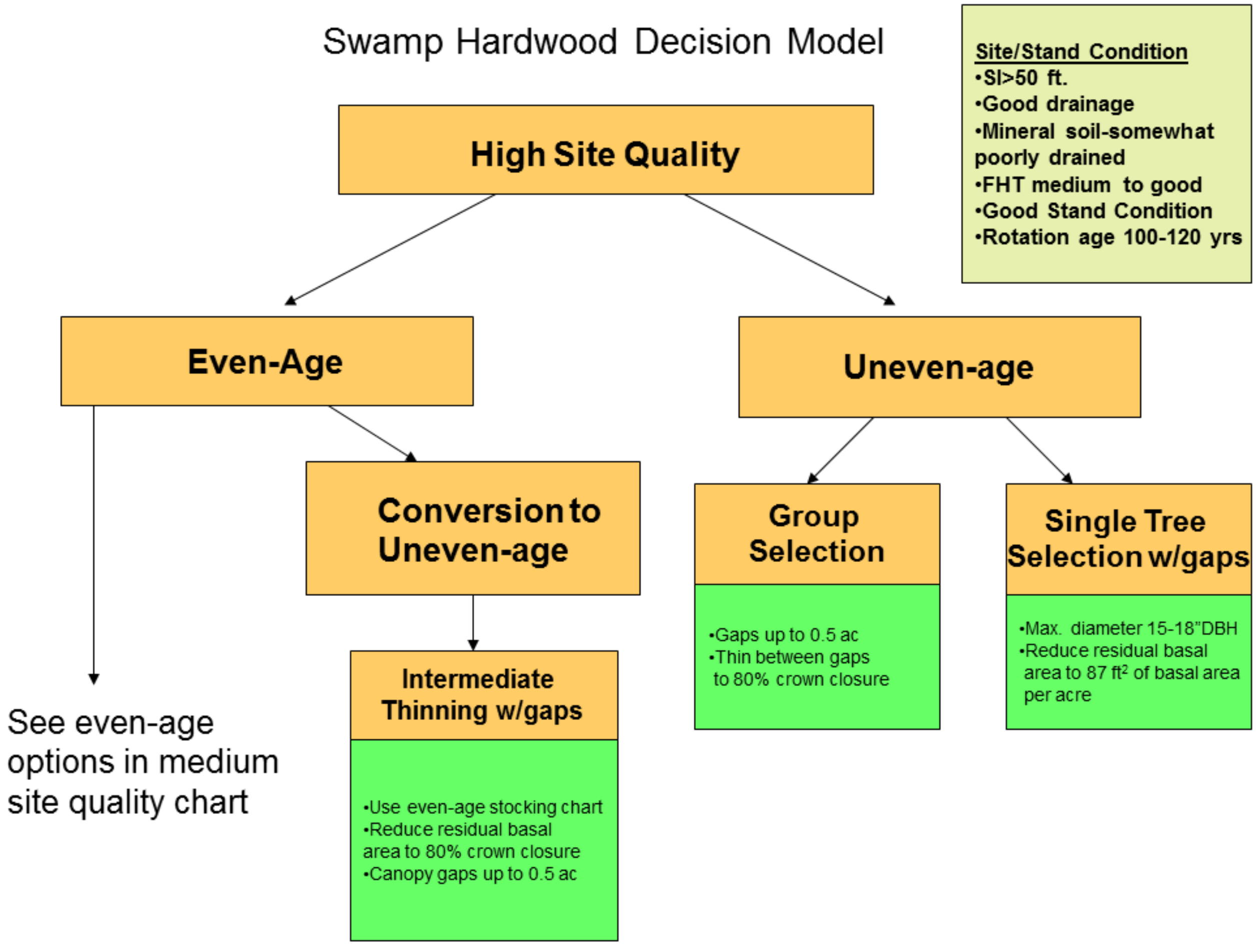
For low quality sites that are defined as having a site index of <40, impeded drainage, muck soils, poor to medium habitat types, and poor stand condition, options for management are even-aged management or no management. In some of these stands, tag alder may be dominant in the understory or other aggressive plants. Tag alder, although beneficial for wildlife, can be an aggressive competitor against tree regeneration. If tag alder, buckthorn, reed canary grass or other aggressive plants are the dominant understory >50%, they can take over the stand once released (Hoffman personal communication). In this case, either control of these species or no management should be considered.

In choosing one silviculture method over another, the forester should evaluate site conditions carefully. For example, a strip clearcut/coppice may be the method selected to minimize hydrology concerns while trying to increase regeneration. The overstory removal method may be used only if adequate advanced regeneration is present.



For medium quality sites that are defined as having a SI 40 – 50, somewhat impeded drainage, muck over mineral soils, poor to medium habitat types; and moderate stand condition, options for management are even-aged management through progressive strip clearcut or shelterwood or uneven-aged management through single tree selection or group selection. Medium site quality stands are quite prevalent in Northern Wisconsin and management trials have had some success. Uneven-age management may be an option in better quality stands or to minimize the spread of aggressive species such as tag alder, buckthorn, or reed canary grass (maintaining some canopy).

In choosing one silviculture method over another, the forester should evaluate site conditions carefully. For example, a strip clearcut/coppice may be the method applied to minimize hydrology concerns while trying to increase regeneration. The overstory removal method may be used only if adequate advanced regeneration is present. The shelterwood method may be applied when larger diameter trees are present and to increase regeneration.



For high quality sites that are defined as having a site index of SI>50, good drainage, mineral soils – somewhat poorly drained, medium to good habitat types, and good stand condition, options include either even aged or uneven-aged management. High quality stands have been observed in some parts of northern and northeastern Wisconsin. Characteristics of these high-quality stands include free flowing surface water (sheet flow), no impeded drainage (good culvert placement in road systems near the managed stands and no beaver dams), good annual diameter growth, vigorous crown, little or no epicormic branching. Most of the managed, high quality stands that were observed in the trials have been managed uneven-aged through single tree selection harvest.

In choosing one silviculture method over another, the forester should evaluate site conditions carefully. For example, a strip clearcut/coppice may be the method selected to minimize hydrology concerns while trying to increase regeneration. The overstory removal method may be used only if adequate advanced regeneration is present. For uneven-age methods, group selection may enhance tree diversity while single tree selection maintains tree vigor on higher quality sites.

5 SILVICULTURAL SYSTEMS

A silvicultural system is a planned program of vegetation treatment during the entire life of a stand. All silvicultural systems include three basic components: intermediate treatments (tending), harvesting, and regeneration. Very little information is available in the literature regarding silvicultural systems used in the swamp hardwood type. Much of the information in this section is adapted from case studies or silviculture trials in Wisconsin and incorporates some recommendations from the publication “Managing Black Ash in the Lake States” (Erdman et al. 1987). The case studies include 35 or more trials in swamp hardwood. Most trials were implemented on county forest lands, though a few are on state and private forest lands. The trials increase our understanding of ecological, silvicultural and hydrological impacts. Many of these trials are documented on the WDNR internet website:https://dnr.wisconsin.gov/topic/forestmanagement/silviculturetrials

5.1 Seedling / Sapling Stands

Once established, seedlings and saplings (especially black ash and red maple) exhibit optimal vigor (growth and health) when exposed to (near) full sunlight. Crop trees that are released to free-to-grow conditions have the greatest potential to survive and to maximize growth and productivity. Stocking should be maintained at 2,000 to 5,000 well distributed trees per acre (2 to 4 ft. tall) to ensure full stocking when pole-timber size is attained.

5.2 Intermediate Treatments

5.2.2 Non-Commercial Intermediate Treatments

5.2.2.1 Release

Release treatments may be implemented in young stands of swamp hardwoods to enhance growth on potential crop trees and to eliminate competition from undesirable species. Release treatments are probably not economically viable for swamp hardwoods, but if considering this method see the northern hardwood chapter.

5.2.3 Thinning

Intermediate treatments are generally designed to enhance individual tree growth, health, and quality, as well as stand composition, structure, and value. Thinning is a cultural treatment conducted in stands past the sapling stage to reduce stand density. It temporarily reduces stocking to concentrate growth on the more desirable trees. Thinning can impact stand growth, compositional and structural development, and economic yield. It provides the main method, implemented between regeneration and final harvest, to increase the economic productivity of stands. Normal thinning does not significantly alter the gross production of wood volume.

Thinning can be difficult, especially on wetter sites, due to operability concerns. When thinning is considered, implement when basal area stocking is above 100% crown cover. Reduce stocking to a density near 80% crown cover, choosing a residual basal area that will accommodate landowner objectives. A general rule of thumb is do not remove >35% of the basal area in any one thinning operation. Refer to the stocking chart (Figure 46.6) to help determine timing and level of thinning. When to thin depends on management objectives, stand conditions, and operability.

Intermediate thinning should be restricted to stands that are economically viable, at least 20 years prior to rotation and should contain at least 100 square feet of basal area. First, reduce the residual basal area to the prescribed stocking level (80 percent crown cover for first entry) using the even-aged stocking guide for black ash (Figure 46.6) The thinning is made from below and frees crop trees from poor quality main canopy competition as suggested below. Black ash has a narrower crown than other swamp hardwood species, thus a 5-foot crown release is recommended. Subsequent thinning to 90 percent crown cover should be delayed until crowns close and lower branches die on crop trees. Crop tree selection criteria and standard order of removal are defined below.

Crop tree selection criteria:

- Low risk of mortality or failure (main stem breakage)
- Good crown vigor
    - Dominant or codominant trees
    - Good silhouette and healthy leaves
    - Full concentric crown

- Good stem quality
- Desirable species

Trees may also be selected for retention to achieve other objectives, such as aesthetics or wildlife management.

Select trees to cut, following the standard order of removal.

Standard order of removal (with EAB imminent see EAB guidelines for order of removal especially in the quarantined counties):

- High risk of mortality or failure (unless retained as a wildlife tree)
- Release crop trees
- Low (lower) crown vigor
- Poor (poorer) stem form and quality
- Less desirable species
- Improve spacing

5.3 Natural Regeneration Methods

Note: The following recommendations assume the management objective is to maximize quality and quantity of swamp hardwood pulpwood and sawlogs. For declining stands or stands on poor quality sites see considerations discussion. If EAB is imminent, address management by referring to the EAB silviculture guidelines.

For landowners with the goal of maintaining shade intolerant to mid-tolerant species, even-aged management is the preferred method where hydrology is easier to control. The even-aged regeneration methods generally accepted and supported by literature are:

- Overstory removal
- Strip clearcut/coppice

- Shelterwood

Where maintenance of mid-tolerant species is a goal on medium to high quality sites, uneven-aged management may be suitable. The uneven-aged regeneration methods generally accepted and supported by literature are:

- Single tree selection
- Group or patch selection

5.3.1 Even-Age Regeneration Methods

5.3.1.1 Shelterwood

Even-aged management, using the shelterwood method, is implemented in medium- and high-quality swamp hardwood stands to enhance less shade tolerant species such as black ash, yellow birch, red maple and white pine (Erdmann 1986). While stands are maturing, intermediate even-aged thinning guidelines should be followed. Stand rotation is based on landowner objectives, species present, site quality, tree vigor and stand condition, and requires the presence of adequate established regeneration (see rotation length section). As with all methods, hydrology considerations should be a priority at these sites.

Regeneration is usually accomplished using a two-step shelterwood. Initial harvesting (seed cut) will provide proper crown closure and tree spacing depending on the preferred species composition leaving a high, uniform crown cover of 50 - 75 % in the residual shelterwood overstory. Retain vigorous, high quality (best phenotypes) dominant and codominant trees to serve as seed sources.

Consider timing of the shelterwood cut and site preparation operations relative to the production of good seed crops. Site preparation may be needed for regeneration to be successful. Site preparation on these sites can be difficult due to swamping, rutting potential and further development of swamp grass and other competitive species. Site preparation can be accomplished via mechanical or chemical methods, prescribed burning, or a combination of these techniques. The intent is to provide a moist, mixed seedbed of mineral soil and humus in addition to reducing competition. Complete the final removal and release established regeneration using the overstory removal methodology described below.

5.3.1.2 Overstory Removal

This even-aged method removes all or a portion of the canopy placing established, advanced regeneration in a free to grow position. Gradual or patch overstory removal may be necessary on wet sites to reduce the chance of raising the water table, causing damage or mortality to regeneration. Swamp hardwood regeneration is considered established when it reaches sufficient height, usually 2 to 4 feet tall, however, taller established regeneration may be needed to address deer browse and hydrology concerns. Sufficient established regeneration of 2,000 to 5,000 or more well, spaced seedlings and low stump sprouts per acre is optimum prior to considering overstory removal. Overstory removal operations should be conducted during the winter or fall during non-growing season and preferably with frozen or dry soil conditions in order to minimize the damage to the regeneration. Overstory removal is typically conducted when the canopy is at or near rotation age or in degraded stands with adequate advanced regeneration.

General considerations in the application of overstory removal method are: overstory health, condition and composition; potential risk of raising the water table on wet sites; adequate stocking, distribution, vigor; site capability; existing and potential competition including invasive species.

5.3.1.3 Progressive Strip Clearcut/Coppice

Clearcut is an even-aged regeneration method used to regenerate a stand by the removal of most or all woody vegetation during harvest creating a (nearly) completely open area leading to the establishment of an even-aged stand. Progressive strip clearcut is a variation of the clearcut method. The stand is removed using a series of strips harvested over two or three entries, usually covering an equal area on each occasion. The entire stand level strip removal process is completed within a period of time not exceeding 20% of the intended rotation (creating an even-aged stand). This method is recommended
when hydrology, regeneration and less frequent entries is a consideration

Typically, the uncut area serves as the primary seed source for regenerating the cut strip (and to maintain the water table). The clearcut strips are often oriented so that they are at right angles to the direction of seed-dispersing winds. Additional regeneration can come from previously dispersed seed, trees cut during each strip harvest operation, natural seeding from nearby stands, and stump sprouting (coppice). Regeneration is established during or following stand removal. There is the option of having the uncut strip harvested up to 80% crown closure so long as damage does not occur to the residual trees.

Recommended process:

1. Cut first ½ or 1/3 of stand in strips approximately 50 (to 200) feet wide. Strip orientation and width is dependent on road layout, stand shape, windthrow concerns, and hydrology. Wait until well established regeneration is 2 to 4 ft. tall and 2,000 – 5,000 stems per acre.
2. Cut next adjacent strip 50-200 feet wide. Cut strips should be located adjoining the previously cut strips.
3. Wait until well established regeneration is 2 to 4 ft. tall (unless there are browse or hydrology concerns) and at 2,000 – 5,000 stems per acre.
4. Cut final strips, retaining reserve trees for green tree retention.

<u>Strip management recommendations:</u>

- When the first and second strip cuts are implemented, remove all trees >1-inch dbh, and retain only exceptional reserve trees, if present, for green tree retention purposes.
- When the second and third strip cuts are implemented, care should be taken to protect the regeneration in the previously cut strips.
- When the third (last) strip cut is implemented, remove all trees >1-inch dbh, but consider retaining seed trees and reserve trees.
- Consider the timing of the strip cuts relative to the production of good seed crops, seed dispersal and germination, and site preparation operations.

5.3.1.4 Coppice with Standards[1]

An even-aged regeneration method is designed to naturally regenerate a stand using vegetative reproduction from stump sprouts. Standards or reserve trees of a desirable seed source (red maple, yellow birch, white pine, white spruce, tamarack and cedar where available) are left for several purposes such as maintenance of water table, wildlife considerations or to promote conversion to a different species composition. Leaving 20% crown cover or more for reserves in scattered or in aggregated patches are recommended for green tree retention purposes and to maintain hydrologic function and prevent swamping.

Considerations:

- This method should be carefully considered due to hydrology and regeneration concerns.
- Coppice regeneration harvests should occur fall to winter to encourage increased number and vigor of stump sprouts the following spring. During the coppice regeneration harvest, remove all trees >1-inch dbh; retain only desirable reserve trees.
- Sprouts can be abundant and vigorous when young, vigorous trees are cut with stump heights of less than 12 inches; sprouting can be significantly less in older stands (>100 years).
- Following cutting, stump sprouts can be abundant, but mortality during the first several years can be high; deer browsing can be a significant limiting factor.
- When necessary, herbicides can effectively control competing vegetation; of particular concern is the control of tag alder, buckthorn and reed canary grass. With these species, either no management or uneven-aged system may be applicable.
- Reserve trees may be susceptible to windthrow.

In many trials it has been documented that several swamp hardwood species (black and green ash, red maple, yellow birch, elm) produce abundant stump sprouts. Black ash has a fast growth rate from the stump and can put on as much as 5 feet in the first year (Schmidt personal communication).

5.3.2 Uneven-Age Regeneration Methods

Tardif and Bergeron (1999) and Erdman (1987) describe pure, uneven-aged black ash stands on wet, nutrient rich sites. They described the age and size distributions as an inverted “J” shape characteristic of old-growth forests at equilibrium or of self-sustaining “climax” populations. In Wisconsin, two-aged and multi-aged black ash stands are commonly observed in the field. Black ash appears to readily capture canopy gaps created as individual trees die off or groups of trees are windthrown. In fact, Tardif and Bergeron (1999) speculate that most black ash enter the canopy as a result of small disturbances – i.e. due to tree by tree replacement. Their data also shows that in old growth black ash stands seed and sprout reproduction is sufficient to result in self maintenance of the population following the mortality of mature trees. In addition, black ash advanced regeneration is often observed under a full black ash canopy. All of which seem to indicate that black ash may be more tolerant of

[1] Management practice that may have potential for application in managing swamp hardwoods but has not been widely utilized and tested.

understory conditions than previously thought and may lend itself to uneven-aged management on better quality sites.

5.3.2.1 Single-Tree Selection

Single tree selection may not be the best alternative for low and some medium quality sites depending on the landowner objective. Considerations in selecting this method may include economic feasibility and operability. With the single tree selection, regeneration is established by creating canopy gaps with each entry. Gaps (25-75’ diameter) may be created by cutting large crowned trees or groups of low vigor/poor quality trees. All poor-quality residual stems larger than 2 inches DBH must be cut in these gaps so that vigorous regeneration can develop. Residual stand structure recommendations can be found in Table 46.8 and Table 46.9. The following recommended guidelines should be followed when using single tree selection (adapted from Erdman 1987):

- Follow basal area guidelines (Table 46.8 and Table 46.9). Recognize current and target structures. For medium sites use a 12” maximum tree size and on high quality sites use a 15-18” maximum tree size class (developed for black ash).
- In overstocked size classes cut the poorest trees to obtain the recommended density and release crop trees.
- Follow the recommended order of removal, as mentioned above.

Most second growth stands require about three periodic harvests to achieve desirable stocking and structure conditions before they are fully regulated to uneven-aged sustained yield and growth.

5.3.2.2 Group Selection

Group selection may also be utilized to produce regeneration in groups throughout a stand. Spatial distribution of groups may be irregular and dictated by small variations in stand conditions, such as the vigor, health, and size of individual and small groups of trees. Site quality will determine the potential for high quality products. Other considerations in selecting this method may include economic feasibility and operability.

The group selection regeneration method in swamp hardwoods is appropriate for promoting a higher preponderance mid-tolerant species including yellow birch, red maple or white pine. Groups of trees are selectively or systematically removed to create medium sized gaps in the canopy of swamp hardwood stands ranging from 0.1 acres up to approximately 0.5 acres in size. Factors affecting the size of the opening include stand management objective, structure, quality, vigor, and shade tolerance of desired regeneration species.

Group patches often require site preparation and release of preferred species of regeneration from competition. Site preparation on these sites can be difficult due to swamping, rutting potential and further development of swamp grass and other competitive species. This method may not be the best alternative if species such as buckthorn and reed canary grass is present. These species will quickly establish and dominate the gap. Site preparation can be accomplished via mechanical or chemical methods or a combination of these techniques. The intent is to provide a moist, mixed seedbed of mineral soil and humus in addition to reducing competition.

The number of groups and rotation length are dependent upon the landowner objectives and the size of the area being managed. In application, group openings are cleaned of all non-crop tree stems down to one inch in diameter. Groups of trees cut to create openings are those of poorest stem form, vigor and quality or are at rotation age. Consider location of gaps relative to existing advanced regeneration or in relation to where there is need for developing regeneration within the stand. During group opening creation, thinning and crop tree release occurs throughout the remainder of the stand. Refer to the northern hardwood chapter regarding this method.

5.3.2.3 Even-aged to Uneven-Aged Conversion Process

Stands that are even-aged or two-aged may be converted to uneven-aged management by combining crop tree release, thinning and canopy gap formation (conversion) techniques. The conversion to uneven-aged in swamp hardwood has not been well documented. This method suggested in the flowchart should be applied in high quality stands only. Crop tree release enhances growth and crown development on potential crop trees. Many even aged stands have closed canopy conditions which prevent or limit establishment and recruitment of multiple age classes. Installing canopy gaps will create proper growth conditions for regeneration and recruitment of new regeneration. Due to lack of information utilizing this method in swamp hardwood, the currently recommended procedure to convert even-aged stands to uneven-aged structure comes from the northern hardwood chapter and adapted from the Argonne Experimental Forest studies.

1. Crown release 40-60 crop trees per acre. Pole sized crop trees should receive a 4-sided, 5’ crown release (black ash). Sawtimber sized crop trees should receive a 1-3 sided crown release (see chapters 23 & 24).
2. Create canopy gaps for regeneration on approximately 10% (range of 5-15%) of the area at each entry. Canopy gaps can range in size from 30 to 60 ft. in diameter. The percentage of area in regeneration gaps is based on the frequency and size of gaps. Recommended targets for size and quantity of gaps are 4, 35’ gaps per acre (9% of stand area) or 6, 30’ gaps per acre (10%). Occasionally, larger gaps can be included to encourage the representation of mid-tolerant species (e.g. 1, 35’ gap and 1, 60’ gap occupy 9% of an acre). Gaps should be created by cutting groups of high risk or relatively poor-quality stems. Within the gaps all poor-quality stems >1” DBH should be cut to facilitate vigorous regeneration.
3. Apply even-aged thinning guidelines to the remainder of the stand; follow the order of removal.
4. Wait 15 to 20 years for the next entry. To facilitate the development of timber quality, the next cut should not be implemented until after crown closure and lower branch mortality occurs in crop trees.
    - If stand is predominantly pole to small sawtimber sized, then repeat the conversion process.
    - If stand is predominantly medium sawtimber sized, then apply target structure for uneven-aged single-tree selection guidelines. It is necessary to compensate for understocked size classes by maintaining stocking in other overstocked size classes to meet the total target goal of 80 sq ft/acre on medium quality sites and 87 sq ft/acre on high quality sites.

- 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.

5.5 Rotation Lengths and Cutting Cycles

Even-Aged Silvicultural Systems

In even-aged silvicultural systems the 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, mean size, age, attainment of particular minimum physical or value growth rate, and biological condition. Ideally, the lower end of the rotation length range would be defined by the age at which maximization of mean annual increment (MAI) growth occurs. The upper end of the rotation length range would be defined by the average stand life expectancy. However, very little objective data exists identifying these endpoints in general and even less by site type.

Swamp hardwoods are usually managed to produce sawtimber on sites (see Table 46.8 and Table 46.9) where relative potential productivity is good (black ash SI>50). The recommended even-aged rotation to balance high quality development, high growth rates (vigor), and economic risk is 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 (black ash SI<50), recommended rotation ages may be somewhat shorter, because reduced vigor and growth will make managing for sawtimber products difficult. Individual trees and stands may maintain vigor longer or decline earlier than these rotation length guidelines indicate. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning quality, vigor, mortality, and merchantability. See Table 46.6 below to review site characteristics. The numbers provided are based on general data, empirical evidence, and the best estimations of the authors and other contributors.

Uneven-Aged Silvicultural Systems

In uneven-aged systems, the method is designed to regenerate and maintain uneven-aged stands by removing some trees at regular intervals. Trees are removed in various size classes, either singly or in small groups. An uneven-aged stand is maintained by periodically regenerating new age classes while manipulating the overstory structure to facilitate continual development of quality growing stock. Stand regeneration is achieved by periodically manipulating the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. Regeneration cuts, thinning, and harvesting usually occurs simultaneously. Generally, most regeneration is seed origin, although a component can be vegetative.

The selection of the appropriate stocking guide and cutting interval depends on site quality, species, growth rates, operational considerations, and landowner goals. On high quality sites where management goals attempt to achieve an optimal balance of sawtimber quality and quantity, the 15-18” inch maximum size class stocking guide is recommended (Table 46.8). If stocking in the maximum diameter class is too low or other poorer quality trees are present, then the vigorous, low risk, high quality trees should be retained even if well beyond the maximum diameter.

In stands managed under uneven-aged management, the cutting cycle re-entry interval generally ranges from 15 to 20 years based on landowner objectives, site quality, and growth. Shorter cutting cycles can maintain higher tree growth rates but operability (costs and benefits) 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

Management goals for extended rotations attempt to balance economic, social, and ecological management goals. While timber production is still an important value, increased emphasis is placed on other values, such as aesthetics, wildlife habitat, and biodiversity. Typically stocking guides utilize a 15-18-inch maximum tree size class (Table 46.8) or larger. Longer cutting cycles can be appropriate using ecological management techniques 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). The recommended extended rotation age is 100 – 150 years on sites where there may be a variety of objectives. On some green ash or mixed green/black ash sites observations in northeastern Wisconsin indicate that vigor can be maintained longer. On other sites there may be hydrology or rare species considerations where extended rotation is recommended.

Table 46.6. Review of site characteristics and rotation ages for low, medium and high-quality stands.

Low site quality	**Medium site quality**	**High Site quality**
Impeded drainage	Somewhat impeded	Medium to Good drainage
Muck soils	Muck over mineral soil	Mineral soil
Poor stand condition	Moderate stand condition	Good stand condition
Poor to medium habitat type	Poor to medium habitat type	Medium to good habitat type
Rotation age: 80-100 yrs	**Rotation age:** 90-110 yrs	**Rotation age:** 110-120

5.6 Other Silvicultural Considerations

5.6.2 Cover Type Conversion

When considering natural conversion evaluating the site conditions and potential are important. Knowledge of the site factors such as soils, lowland habitat type, existing vegetation and productivity potential will aid in deciding to use this method. Of high importance is the presence of a desired seed source. Some of the dominant species that maybe be considered in conversion include red maple, yellow birch, and tamarack. Other species that may be a component of these stands include white birch, white pine, swamp white oak, silver maple, and

American elm. These species respond well to large gaps in the canopy for regeneration recruitment. Group selection, variations of shelterwood harvests, coppice with standards, and wide strip clearcuts (50-200 feet wide) are all viable options for natural conversion.

Other species to consider for conversion include more shade tolerant species such as balsam fir, hemlock, and white cedar. Small gaps in the canopy can be used to recruit regeneration. Silviculture systems that may work well for regenerating these species include shelterwood harvests, narrow strip clearcuts (30-60 feet wide), coppice with standards and single tree selection. Regenerating some of these recommended species can be difficult but refer to each species cover type chapter when considering natural conversion. In extremely wet stands where tag alder is predominant in the understory, conversion to another cover type species will be very difficult to achieve.

With artificial regeneration, it's important to once again evaluate the site conditions such as soils, existing vegetation and site potential. Depending on the site evaluation, species to consider include tamarack, northern white cedar, red maple, yellow birch, hemlock, black spruce, and white spruce. Shallow rooted species will have the greatest growth and survival on these sites. Tamarack may be the best option because it grows well in wet conditions and is less likely to be browsed. Northern white cedar will require some form of protection from herbivory (mainly from deer). Red maple may work on mineral sites and sites that are not extremely wet. Black and white spruce may be a good option since they will not be browsed as heavily. Knowing the lowland habitat type will aid the manager in deciding what alternative cover type to promote. Site preparation may be needed in these stands when using artificial regeneration. Site preparation methods include alder shearing and harvesting operations to allow adequate conditions for seedlings. Due to the high planting costs and herbivory (deer) some species may not be viable options in all stands. Refer to the Artificial Regeneration chapter for more information on planting.

5.6.3 Diameter Limit Harvest

Diameter limit cutting is harvesting all trees above a set diameter regardless of the impact on stand structure, stand quality, tree quality, species composition, or regeneration needs. At times referred to as a "selective cut", the only consideration is diameter as opposed to specific criteria employed in a true single tree selection harvest under the uneven-aged silviculture system. Diameter limit harvesting usually removes the most vigorous and best seed producing trees. After a diameter limit harvest, the residual trees that were in a subordinate crown position are subjected to lower stem quality and epicormic branching (Fajvan, 2002). The few diameter limit harvest trials in swamp hardwood that were documented in the Wisconsin trials, appeared to "swamp out" as a result of the harvest and little tree regeneration remaining. The residual (suppressed) trees at these sites eventually died from stress. Diameter limit harvest is not considered a generally accepted silvicultural practice that results in sustainable forestry because of these considerations.

8 APPENDICES

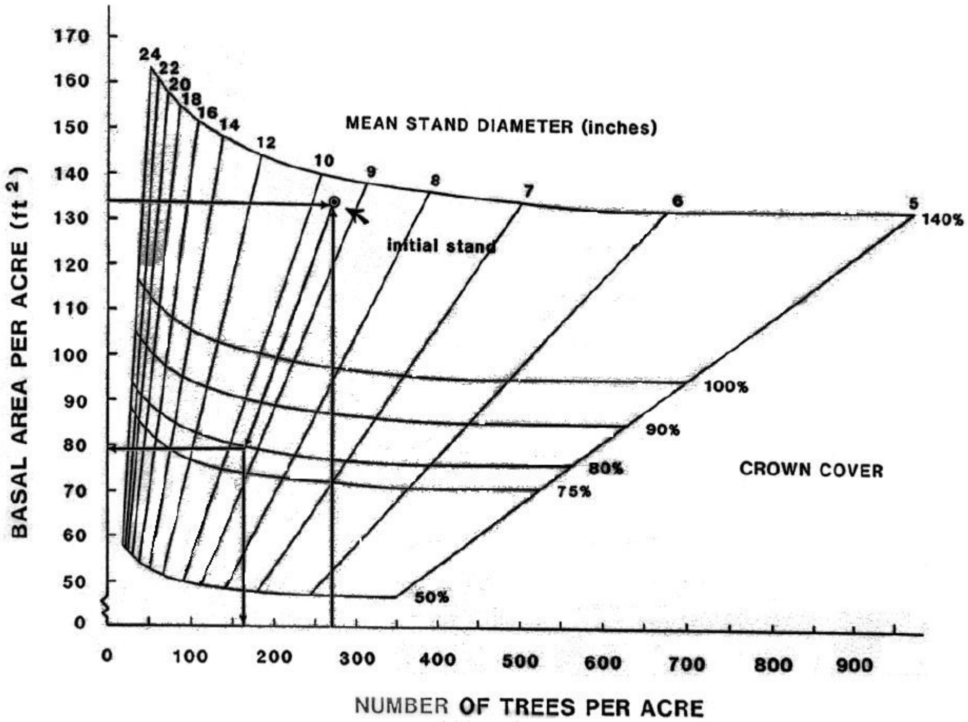


Figure 46.6. Even-aged stocking levels for black ash by crown cover, basal area and trees per acre for specific average stand DBH classes (Erdman et al. 1987).

Table 46.7. Even-aged stocking level table for black ash by crown cover, basal area and number of trees per acre for specified DBH classes (Erdman 1987).

SU.nd	Crown cover (rcent of 43,560 tt2/A)									
(In.)	Trees	SA	Trees	IJA	Trees	IJA	Trees	T!A	Trees	:Il:
	No./A	Ft2/A	tlo./A	Ft2/A	Wo./A	Ft2/A	No./A	Ft2/A	No./A	Ft2/A
5	348	47.4	522	71.2	556	75.9	626	85.3	696	94.9
6	242	47.6	363	71.3	388	76.1	436	85.6	485	95.1
7	180	48.1	270	72.2	288	77.u	324	86.6	360	96.2
8	140	48.8	210	73.1	223	78.0	251	87.8	279	97.5
9	112	49.5	168	74.2	179	79.2	202	89.0	224	98.9
10	92	50.2	138	75.3	147	80.3	166	90.4	184	100.4
11	77	50.9	II6	76.4	123	81.5	139	91.7	154	!01.8
12	66	51.6	99	77.4	105	82.6	118	92.9	131	103.2
13	57	52.3	85	78.5	91	83.7	102	94.1	II3	104.6
14	50	53.0	74	79.4	79	84.7	89	95.3	99	105.9
15	44	53.6	66	80.4	70	85.8	79	96.5	87	107.2
16	39	54.2	58	81.3	62	86.7	70	97.6	7!;1	108.4
17	3:)	54.8	52	82.2	56	87.7	63	9I.7	70	109.6
18	31	55.4	47	83.1	50	88.6	56	99.7	63	110.8
19	28	55.9	43	83.9	45	89.5	51	100.7	57	III.9
20	26	56.5	39	84.7	41	90.3	47	I01.6	52	112.9
21	24	57.0	36	85.5	38	91.2	43	102.6	47	114.0
22	22	57.5	33	86.2	35	92.0	39	103.5	44	115.0
23	20	58.0	30	87.0	32	92.7	36	104.3	40	115.9
24	19	58.4	28	87.7	30	93.5	33	105.2	37	116.9

!I Expected blacash crown area-7.6483 + 3.8952 d.b.h. I.7974 Where d.b.h. fs fn fnches; basis n = 37 forest!Jrown trl:!eS that have a d.b.h. at leastas large as the aerage sta.nd d.b.h.; R2•0.89. Values for the 20-inch and larger d.b.h. classes hdve been projected be.)'ond our data base.

Table 46.8. Desired residual stocking for high-quality sites after individual tree selection harvest, 15-18-inch maximum diameter class. Adapted from Erdman 1987 and T. Strong 2005.

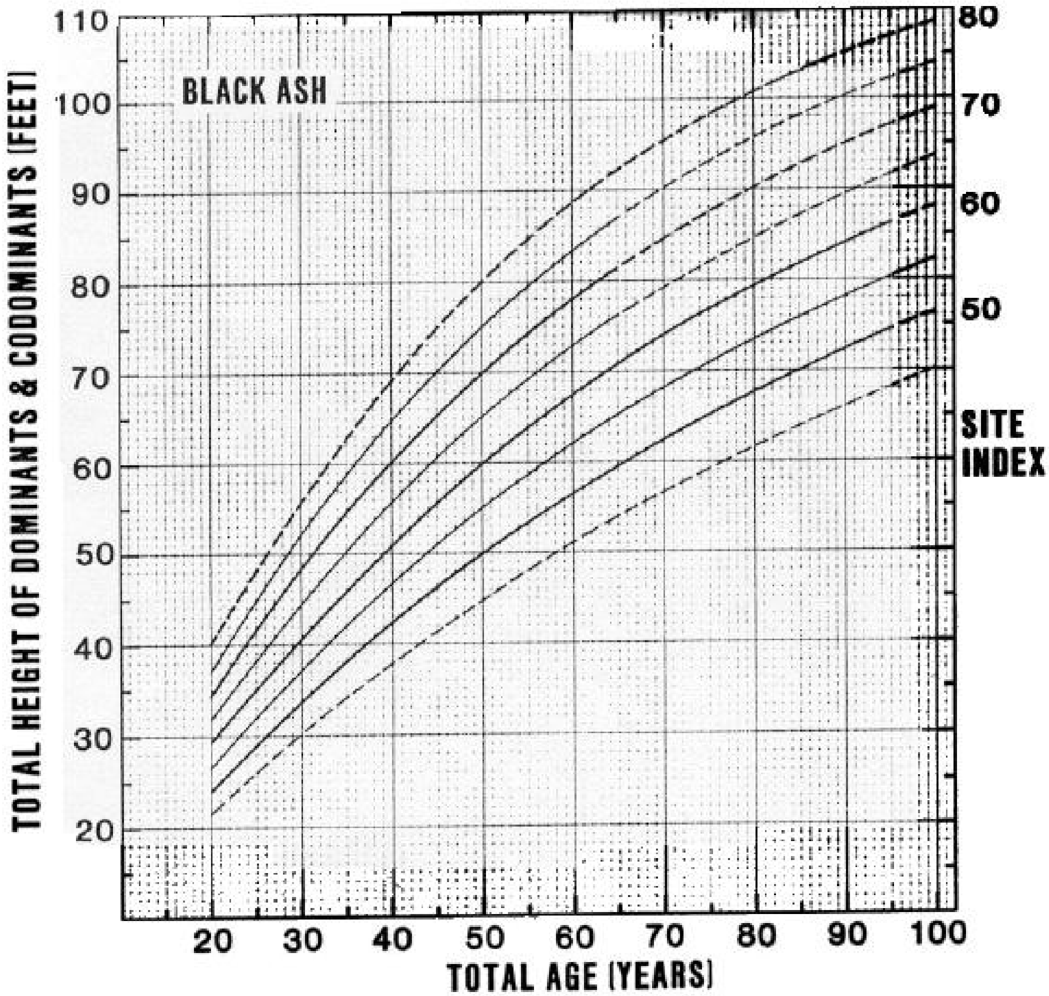
DBH Classes	Trees/Acre	Basal Area/Acre
Poles		
5	22	3.0
6	19	4.0
7	17	5.0
8	15	5.0
9	13	6.0
Sub Total	86	23
Small Saw		
10	11	6.0
11	10	7.0
12	9	7.1
13	8	7.4
14	7	8.0
Sub Total	45	36
Med. Saw		
15	6	7.4
16	5	7.0
17	4	6.3
18	4	7.1
Sub Total	19	28
Total	150	87

Stocking recommendations are based on max tree size of 15-18” DBH, Q factor of 1.1, Residual crown cover of 80%.

Table 46.9. Desired residual stocking for medium-quality site after individual tree selection harvest, 12-inch maximum diameter class. Adapted from Erdman 1987.

DBH Classes	Trees/Acre	Basal Area/Acre
Poles		
5	69	9.3
6	53	10.3
7	41	10.8
8	31	10.9
9	24	10.6
Sub Total	218	51.9
Small Saw		
10	18	10.1
11	14	9.4
12	11	8.6
Sub Total	43	28.1
Total	261	80

Stocking recommendations are based on a max tree size of 12 inches at DBH, Q factor of 1.3, Residual Basal Area of 80 square feet for trees 4.6 inches at DBH and larger.



Black ash (Carmean 1978)
Northern Wisconsin and Upper Michigan
39 plots having 143 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	4.2286	0.7857	-0.0178	4.6219	-0.3591	0.99	0.70	2.4
SI	0.2388	1.1583	-0.0102	-1.8455	-0.1883	0.99	0.99	3.4

Figure 46.7. Site index curves for black ash in northern Wisconsin and upper Michigan (Carmean et al. 1989).

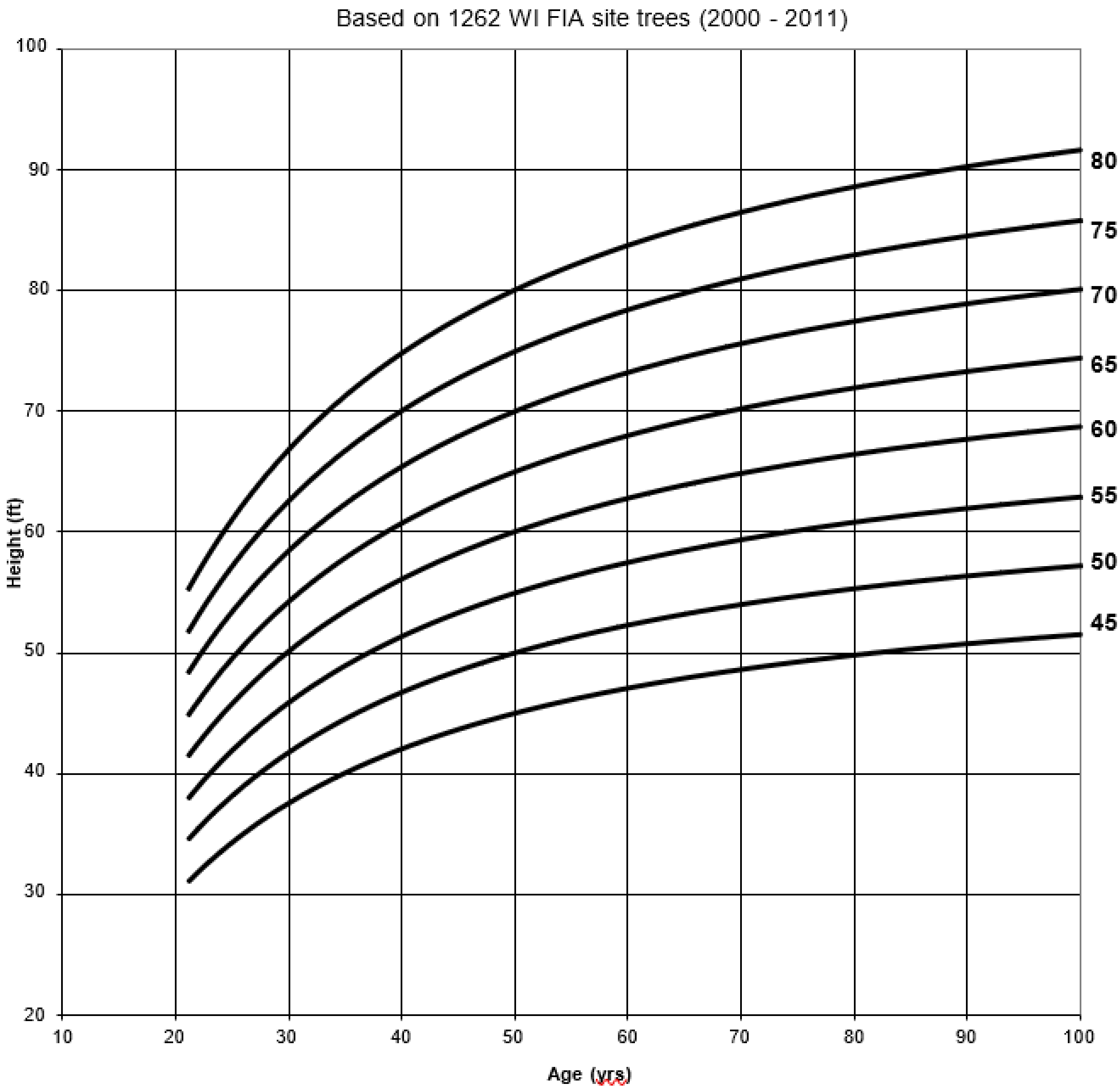


Figure 46.8. Site index curves for green ash in Wisconsin (FIA 2010). Anamorphic curve is based on Wisconsin FIA data.

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

Species included in this table are black ash, green ash, red maple, silver maple, willow, and alder.

For elms spp., refer to the Central Hardwoods Chapter. For swamp white oak, refer to the Oak Chapter. For animal and mechanical issues, please refer to the pest table under the Northern Hardwood Chapter (Ch. 40). For invasive plants, refer to the invasive plant appendix of this handbook.

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
DEFOLIATING INSECTS			
Blackheaded ash sawfly – *Tethida barda* **Brownheaded ash sawfly** - *Tomostethus multicinctus* **Spiny ash sawfly** - *Eupareophora parca* Larvae feed gregariously on young ash and ornamentals. Heavily infested trees can be defoliated in 1 – 2 weeks.	ash	- Natural enemies play an important role in population control - Insecticides, with conservation of natural enemies, can be considered during severe infestations	
Striped alder sawfly – *Hemichroa croceas* Young larvae feed gregariously. All but the midveins are eaten.	alder and birch	- Though an exotic pest, control measures have not been considered necessary	
Willow sawfly – *Nematus ventralis* Can completely defoliate willows, especially young trees	willow		
Woolly ash aphid – *Prociphilus fraxinifolii* Honeydew, sooty mold, and distorted leaves indicate aphid damage. This aphid feeds on the underside of leaves and terminals and produces noticeable white fuzz on leaves and stems.	ash	- Natural enemies play an important role in population control	
Woolly alder aphid – *Paraprociphilus tesselatus* Sucks plant juices, but causes little damage. Produces noticeable white fuzz on leaves and stems. This is an aesthetic issue and does not affect tree health greatly.	Silver maple in early summer; alder in late summer	- Control not suggested.	
Ash plant bugs – *Tropidosteptes* spp. Discolored, distorted, and stunted expanding leaves and stippled older leaves are indications of ash plant bug feeding. Causes moderate to severe levels of leaf drop.	ash		

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
Alder Flea Beetle – *Altica ambiens* Larvae skeletonize alder leaves in late summer.	alder	No known control measures exist.	
Imported Willow Leaf Beetle - *Plagiodera versicolora* Skeletonize and chew holes in leaves. Cause light to severe leaf damage.	Willows and poplars		
Greenstriped mapleworm – *Dryocampa rubicunda rubicunda* Defoliation from this caterpillar is noticed in late July and early August. Late season defoliators do not damage trees as greatly as early season defoliators.	Red maples; sometimes other maples	Natural controls help reduce outbreak populations	
Fall webworm – *Hypantria cunea* Defoliate trees and make tents towards branch ends in later summer. Late season defoliators do not damage trees as greatly as early season defoliators.	hardwoods	Natural enemies are important for controlling populations	
Forest Tent Caterpillar – *Malacosoma disstria* Widespread heavy defoliation occurs periodically at intervals of 5-15 years. An outbreak usually lasts 2-5 years. Stressed trees may die after defoliation. Healthy trees may die after being defoliated for several years in a row.	hardwoods	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 proportions of susceptible species.	
Ashleaf gall mites – *Aceria* spp. Induce leaves to grow kidney-shaped galls on their upper surfaces. This is an aesthetic issue and does not negatively affect tree health	ash	Control not suggested.	
Maple gall mites (eriophyid mites) Erineum galls, bladder galls, and spindle galls grow on leaf surfaces. This is an aesthetic issue and does not negatively affect tree health	maples	Control not suggested.	

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
FLOWER & SEED INSECTS			
Ash flower gall mite - *Aceria fraxiniflora* Attack male flower clusters, causing them to swell and deform into galls. Old galls turn dark-colored. Little harm is imparted to the tree. This is an aesthetic issue and does not negatively affect tree health	male ash	Control not suggested.	
Ash seed weevils – *Lignyodes* species Great proportions of seeds can be destroyed by these weevils. Female adults leave puncture marks on seeds.	ash and lilac seeds	Natural controls keep populations in check	
BARK AND WOOD INSECTS			
Scale Insects			
Oystershell scale - *Lepidosaphes ulmi* **European fruit lecanium** - *Parthenolecanium corni* Honeydew, sooty mold, and dieback indicate scale infestation. Scales attach to branches and suck sap and look like small (~3 mm) elongated or round bumps.	Ash		
Woolly alder aphid – *Paraprociphilus tesselatus* Sucks plant juices, but causes little damage. Produces noticeable white fuzz on leaves and stems. This is an aesthetic issue and does not negatively affect tree health.	alder in late summer	Control not suggested.	
Flatheaded Borers			
Emerald ash borer – *Agrilus planipennis* An extremely threatening exotic metallic wood borer. Larvae destroy the cambium layer.	ash	Refer to the EAB management guidelines	
Flatheaded appletree borer – *Chrysobothris femorata* Larvae destroy the phloem and heartwood of young and weakened trees. Initial damage may result in dieback; trees may die.	ash and other hardwoods	Plant trees properly Avoid stressing trees	

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
Roundheaded Borers			
Redheaded ash borer - *Neoclytus acuminatus* **Banded ash borer** - *Neoclytus caprea* Infest weakened or recently cut ash. The larvae create tunnels in the sapwood and adults leave round exit holes.	Weakened or recently killed ash and other hardwoods	Avoid stressing trees Process recently cut logs promptly	
Clearing Moths			
Ash borer (terminal and trunk borer) - *Podosesia syringae* First feed in early summer on terminals causing forking; then bore into trunks damaging sapwood. Adult leave circular exit holes. Can cause mortality. **Banded ash clearwing** - *Podosesia aureocincta* Causes similar damage to trees as the ash borer.	ash	Natural enemies reduce populations Avoid wounding trees Remove heavily infested trees	
Carpenterworm –*Prionoxystus robiniae* Tunnel into the heartwood of trunks and large branches. Tunnels allow the entry of wood decaying fungi.	Ash, oak, poplar, and other hardwoods	Keep stands well-stocked Avoid wounding trees Remove heavily infested trees	
Bark Beetles			
Eastern, northern, and white-banded ash bark beetles - *Hylesinus* species Typically attack weakened and recently cut ash. Females make egg galleries across the wood grain, and adults leave 1-mm round exit holes. The overwintering stage in the adult.	ash, typically weakened or recently killed	Infested trees can be felled; then debarked or destroyed.	
Ash cambium miner - *Phytobia spp.* Maggots mine cambium in branches, trunks, and roots and are most commonly found near the base of the trunk. The mines often zigzag across the sapwood surface.	ash		

<table>
<tr><th>Disturbance Agent and Expected Loss or Damage</th><th>Host(s)</th><th>Prevention, Options to Minimize Losses and Control Alternatives</th><th>References</th></tr>
<tr><td colspan="4">FOLIAGE DISEASES</td></tr>
<tr><td>Ash Leaf Spot -Mycosphaerella effigurata and M. fraxinicola
Initially, small flecks and spots form on leaves; later, these dead areas coalesce and form irregular blotches. Expect this disease after prolonged cool, wet weather. These fungal pathogens do no create significant losses in forests.</td><td>ash</td><td rowspan="5">□ Intraspecies variation in resistance exists – favor resistant ash
□ Ensure stands are not overstocked</td><td></td></tr>
<tr><td>Tar Spot – Rhytisma
This fungus grows black spots on leaves, particularly in the lower canopy. Tar spot does not causes significant losses.</td><td>maples</td><td></td></tr>
<tr><td>Ash anthracnose – Gnomoniella fraxini (syn. Discula fraxinea)
Brown leaf blotches form. Expect this disease after prolonged cool, wet weather. Ash anthracnose does not create significant losses in forests but can cause some leaf loss.</td><td>ash</td><td></td></tr>
<tr><td>Maple anthracnose – Discula spp., Aureobasidium apocryptum, and Colletotrichum gloeosporioides
Causes heavy leaf spotting and blotching. Anthracnose does not cause significant losses.</td><td>maples</td><td></td></tr>
<tr><td>Ash rust - Puccinia sparganioides
Yellow-orange spots on leaf surfaces, yellow spots on petioles and new twig tissue, leaf distortion, and twig galls are symptoms. This disease can cause dieback. Expect this disease in areas that are prone to fog where ash and cordgrass grow in close proximity to each other.</td><td>ash and cordgrass (Spartina spp.)</td><td></td></tr>
<tr><td colspan="4">CANKERS / CANKER ROT</td></tr>
<tr><td>Nectria canker - Neonectria galligena
This canker is a target-shaped depression on the trunk, killing bark, cambium, and the outer sapwood. Wood decay associated with nectria cankers is rare. If the canker affects >50% of the stem's circumference, there is a high probability of failure.</td><td>hardwoods</td><td>□ Avoid wounding trees during cool, humid conditions</td><td></td></tr>
</table>

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
Canker Rots			
Hispidus canker - *Inonotus hispidus* First rots heartwood, but eventually rots sapwood and kills the cambium. It forms an elongate, bark-covered, perennial canker and annual, yellowish to reddish conks.	ash, maple, willow, and other hardwoods	□ Avoid wounding trees □ Remove 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.	
Inonotus glomeratus Produces white to light brown spongy heart rot and kills sapwood and cambium. Forms black, sterile conks.	maple, beech, paper birch, balsam poplar, hemlock	□ Avoid wounding trees □ Remove 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.	
DECAY			
White Rots			
Perenniporia fraxinophila (=Fomes fraxinophila) Produces white mottled heart rot in trunks and larger limbs. Forms a perennial, bracket-shaped conk.	Ash		
Mossy-top conk – *Oxyporus populinus* This fungus forms a spongy, straw-colored white rot in heartwood and sapwood	maple, primarily	□ Avoid wounding trees □ Remove tree if decay in the main stem results in <1” of sound wood around the tree for every 6” in diameter (see FHP Guidelines, Northern Hardwood Chapter)	
Phellinus igniarius Causes white heart rot. Forms hoof-shaped, perennial conks with cracked, black upper surfaces.	hardwoods		
Ganoderma lucidum Forms a white rot of sapwood in major roots and butt logs. Annual, reddish conks grow from the base of trees or out of major roots.			

Disturbance Agent and Expected Loss or Damage	Host(s)	Prevention, Options to Minimize Losses and Control Alternatives	References
Brown Rot			
Sulfur Shelf – *Laetiporus sulphureus* Leaves brown cubical rot in the roots and trunk. Conks are shelf-like, annual, and yellow to orange.	hardwoods	- Avoid wounding trees - Remove tree if decay in the main stem results in <1" of sound wood around the tree for every 6" in diameter (see FHP Guidelines, Northern Hardwood Chapter)	
Ring Shake	Black ash		
WILTS, YELLOWS, AND DECLINES			
Ash Yellows – *phytoplasmas* Light green to yellow foliage, reduced growth, tufted foliage, epicormic branches, dieback, and witches' brooms growing from the root collar are symptoms. Susceptible saplings can die in 1 – 3 years. Expect to see this disease more frequently at stand edges.	ash and lilac	- Harvest trees with more than 50% crown dieback within five years - Remove other infected trees during harvests - Encourage species diversity	How to Identify and Manage Ash Yellows in Forest Stands and Home Landscapes. 1994. USDA FS. NA-FR-03-94.
Black ash decline Growth loss, yellowing, dieback, and mortality are symptoms. Drought is likely responsible for inducing decline. Preliminary research indicates decline is more severe on wetter sites and in trees older than 100 years. Also, winter with little snow cover could induce decline.	ash	- Avoid regenerating ash on droughty sites	Relating Black Ash (Fraxinus nigra) Decline and Regeneration to tree Age and Site Hydrology. USDA FS. EM Proposal: NC- EM-07-02
ABIOTIC DAMAGE			
Spring frost damage Can cause sparse foliage and leaf drop by damaging developing buds and leaves in the spring.	all species		
Winter frost damage Fine roots can be killed by frost during winters with little snow cover. This results in canopy dieback.	all species		
Drought stress Thin crowns, tufted foliage, and dieback are symptoms of drought stress.	all species		
Flooding Dieback, early fall color development, and mortality are symptoms after flooding.	all species		

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