Chapter 51

Red Maple Cover Type

6/2/2022
Last Full Revision: 2/12/2019
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.

TABLE OF CONTENTS

List of Figures

List of Tables

1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
Red maple comprises 50% or more of the basal area in pole timber and sawtimber stands, or 50% or more of the stems in seedling and sapling stands.

Red maple is most common in New England, Middle Atlantic States, Upper Michigan, and Northern Wisconsin. Recognition of red maple as a separate cover type generally is attributed to disturbances that release red maple advance regeneration and residuals which may respond rapidly. Dramatic increases in current red maple distribution can be attributed to establishment following a variety of disturbances such as land clearing, fire suppression, windthrow, and insect/disease outbreaks (Abrams 1988). The decline of American elm *(Ulmus Americana)* as a result of Dutch elm disease and the selective removal of northern red oak *(Quercus rubra)*, yellow birch *(Betula alleghaniensis),*quaking aspen *(Populus tremuloides),*and sugar maple *(Acer saccharum)* have also contributed to increasing the proportion of red maple stocking in many stands.

Associated Species
Throughout its range, red maple is associated with more than 70 different commercial tree species. It's more common associates include balsam fir *(Abies balsamea),* white pine *(Pinus strobus),* sugar maple, beech *(Fagus grandifolia),* yellow birch, paper birch *(Betula papyrifera),* eastern hemlock *(Tsuga canadensis),* eastern hophornbeam *(Ostrya virginiana),* northern white-cedar *(Thuja occidentalis),* aspen *(Populus grandidentata* and *P. tremuloides),* black ash *(Fraxinus nigra),* pin cherry *(Prunus pensylvanica),* black cherry (P. *serotina),* northern red oak *(Quercus rubra),* American elm, silver maple *(Acer saccharinum),* and swamp white oak *(Quercus bicolor).* (Burns & Honkala 1990)

1.2 Silvical Characteristics

The primary source for the following descriptions and tabular summary is from Silvics of North America (Burns & Honkala 1990).
http://www.na.fs.fed.us/pubs/silvics_manual/volume_2/acer/rubrum.htm

Flowering and Fruiting
Red maple is one of the first trees to flower in the spring, generally several weeks before vegetative bud break. The flowers are small, with slender stalks, red or rarely yellowish, with petals; they appear from March to May depending upon elevation and latitude. Trees can flower and bear seed at an early age; 4-year-old trees have produced seed. Flowering occurs on all branches in the well-lit upper portion of the crown. Characteristically, the non-flowering branches are slow growing and lack vigor.

Red maple flowers are structurally perfect. The species is polygamo-dioecious. Thus, some trees are entirely male, producing no seeds; some are entirely female; and some are monoecious, bearing both male and female flowers. On monoecious trees, functioning male and female flowers usually are separated on different branches. Sex of the flower is not a function of tree vigor. The species shows a tendency toward dioeciousness rather than toward dichogamy

Germination
The fruit, a double samara, ripens from April to June before leaf development is complete. After ripening, seeds are dispersed for a 1- to 2-week period during April through July. The seed does not require pre-germination treatment and can germinate immediately after ripening. The small winged fruits disperse efficiently in the wind. While seed dispersal distance is variable, the height of seed release can impact the actual distance a seed travels. Germination may be 75 to 80 percent in 2 to 6 days. Total germination is often 85 to 91 percent.

Seedling Development
Red maple has few germination requirements. The seed can germinate with very little light, given proper temperature and some moisture. Most seeds generally germinate in the early summer soon after dispersal. Shading by a dense overstory canopy can depress first-year germination; then second-year germination is common. Germination is epigeal.

Vegetative reproduction: Red maple stumps sprout vigorously. Inhibited, dormant buds are present at the base of red maple stems. Within 2-6 weeks after a stem is cut, these inhibited buds are stimulated. Fire can also stimulate these buds. The number of sprouts per stump increases with stump diameter to a maximum of 23-30 cm (9-12 in), and then decreases among larger trees (Solomon 1967). Compared to oak species, stump sprouting with red maple does not decrease in relation to residual basal area and peaks in partial harvest treatments (Atwood 2009). Stumps of younger trees tend to produce taller sprouts. Sprouts grow faster than seedlings, and leaf and internode size is greater. As competition increases, growth rates slow. Many sprouts have poor form and rot present. Also, the attachment of a sprout to the stump is often weak because the base of the sprout grows over the stump bark and the vascular connection between them is constricted. Regeneration by seedling sprout may be especially successful. Generally, the species' great sprouting capacity makes it suitable for coppicing and accounts for its tendency to be found in sprout clumps.

Growth and Development
Red maple height growth starts relatively early in the spring, radial growth starts late in the season. Radial growth then proceeds rapidly, becoming half complete in 50-59 days and fully complete in 70-79 days. Early crop tree release of red maple seedlings and sprouts is feasible in young, even-aged stands. It should be done when the new stand has crown closure and crown dominance is being expressed.

Growth during early life is rapid but slows after trees pass the pole stage. Red maple responds well to thinning. In upper Michigan, thinning was more effective than fertilization for stimulating red maple growth. In the north, the young red maple trees grow faster than sugar maple, beech, or yellow birch, but slower than aspen, paper birch, or white ash

Fire

Red maple is very sensitive to fire injury, and even large trees can be top killed by a fire of moderate intensity. The fire-killed trees sprout vigorously, however, and red maple may become a more important stand component after a fire than before one (Burns & Honkala 1990).

Longevity

Red maple is a short- to medium-lived tree and seldom lives longer than 150 years. It reaches maturity in 70-80 years. Average mature trees are 18-27 m (60-90') in height and 46-76 cm (18-30") in diameter.

Table 51.1. Summary of selected silvical characteristics

Flowers	March-May polygamo-dioecious (i.e. bisexual and male flowers on some plants, and bisexual and female flowers on others)
Seed Ripens	Immediately upon seed fall, late May – early June
No. seeds/lb.	Approx. 23,000
Seed dispersal	Primarily wind dissemination, gravity
Minimum Seed-Bearing Age	4 years
Good Seed Years	Every 2-3 years
Average Seed viability	80%
Cold Stratification	Not required
Seedbed Requirements	Moist mineral soil (wide tolerance of conditions)
Germination	Most germination occurs in early summer soon after dispersal. Dense shade can delay to the second year. The seed can germinate with very little light given proper temperature and some moisture (>36% moisture content).
Seedling development	Fastest root growth on moist soils. Slow shoot growth under closed canopy.
Vegetative reproduction	Pole timber and smaller sized trees sprout readily. Inhibited, dormant buds are always present at the base of red maple stems
Shade Tolerance	Mid-tolerant, can survive with slow growth under closed canopy.
Maximum individual tree longevity	Approximately 150 years

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/or quantity of red maple 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, aspect, position on the slope, and soil characteristics.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

The following considerations may be taken into account when making management recommendations.

3.1 Landscape Considerations

3.1.1 Historical Context

When the General Land Office Public Land Surveys (PLS) were conducted in Wisconsin (1832-1866), red maple was a relatively minor component of most forests, representing less than 5% of surveyed trees in the northern hardwood-white pine-hemlock forests (Nowacki et al, 1990). However, since that time, pre-settlement northern hardwood-conifer and pine forests that converted to oak or aspen following cut-over have had a steadily increasing red maple component (Nowacki etal 1990).

Red maple is a generalist species and can probably thrive on a wider range of soil types, textures, moisture, pH, and elevation than any other forest species in North America (Hutnik & Yawney 1961). In northern Wisconsin and Michigan, red maple grows on sites ranging from dry, sandy outwash plains to wet bottomlands and swamp edges. In upper Michigan and New England, red maple grows on ridge tops and dry sandy or rocky upland soils and in almost pure stands on moist soils and swamp borders (Reynolds etal 1979). The distribution of red maple has been described as bimodal, with a primary importance peak on dry-mesic sites and a secondary peak on wet-mesic sites (Curtis 1959). Fast growth rates, regular and abundant seed production, minimal seed-bed requirements, delayed germination, and intermediate shade tolerance have allowed red maple to outcompete other species in mixed hardwood stands, especially where growing space had been vacated by American elms (Ulmus *Americana* L.) (Powell & Erdmann 1980). Red maple is also a prolific sprouter that competes strongly on disturbed sites, and is now considered to be an important resource in the Lake States (Crow & Erdmann, 1983).

Red maple is favored when fire is suppressed and, in many of the forests where it occurs it has increased in dominance dramatically during the past decades. The fire interval for red maple is long (many decades to centuries) and low-intensity surface fires are typical. A thin-barked species, red maple is susceptible to damage, top-kill and mortality from fire. Saplings are more susceptible than larger, older individuals with thicker bark. Fire effects vary according to season of burning; red maple is most susceptible in late spring to early summer. Red maple often responds rapidly to disturbances such as fire. Top killed seedlings and trees sprout vigorously and rapidly from dormant buds on the root crown and seedling establishment readily occurs from surviving trees or from seeds carried by wind. This species may assume increased prominence after a single (unrepeated) fire.

There are several agents which can impact the abundance and quality of red maple on the landscape. In addition to fire injury, red maple is susceptible to defects and/or mortality resulting from leaf diseases, mechanical injury, insect feeding, and attack by sapsuckers. Red maple is also a desirable browse species for white tail deer and reproduction can be suppressed in areas with high deer populations (Burns & Honkala 1990).

3.1.2 Current Context

Today, red maple is one of the most abundant and widespread trees in eastern North America. It grows from southern Newfoundland, Nova Scotia, and southern Quebec to southern and southwestern Ontario, extreme southeastern Manitoba, and northern Minnesota; south to Wisconsin, Illinois, Missouri, eastern Oklahoma, and eastern Texas; and east to Florida. The species is native to most regions of the eastern United States. The most notable exception is the Prairie Peninsula, where red maple is absent from the bottom land forests of the Corn Belt, though it grows abundantly in similar situations and species associations both to the north and south of the peninsula. It is a native species in Wisconsin, distributed throughout the state in a wide range of habitats, but it does best in wet or dry forests. It is not as prominent in mature mesic forests.

Red maple grows in a wide variety of habitats throughout Wisconsin. However, over 90% of red maple growing stock volume is located in northern and central Wisconsin (WDNR 2012). Over 50% of the red maple acreage is found within the Forest Transition and North Central Forest Ecological Landscapes. An additional 11% is found in the Central Sand Plains Ecological Landscape.

The volume of red maple has increased significantly since 1983. This is a result of both natural succession and relatively low mortality as compared to the average for all species. The red maple resource is aging with the volume of large trees increasing over the last two decades (WDNR, 2012) (Figure 51.1). Mortality rates have also increased over that time; however, red maple has a much lower ratio of mortality to growth than the statewide average. Whereas red maple makes up about 12% of all volume of trees in Wisconsin, it accounts for only 4.2% of total mortality (WDNR 2012).

Maintaining a desirable age-class distribution is a landscape-level consideration. A relatively stable age class structure, including all developmental stages, maximizes benefits to wildlife by providing a range of structural conditions. It also contributes to diversified economic interests by supplying different types of materials, including pulp, poles, sawlogs, and veneer.

Table 51.2. Distribution of red maple timberland acreage in Wisconsin.

Ecological Landscape	Approximate Area of red maple timberland - acres
Central Lake Michigan Coastal	15,736
Central Sand Hills	9,099
Central Sand Plains	100,431
Forest Transition	227,818
North Central Forest	249,645
Northeast Sands	59,790
Northern Highland	40,850
Northern Lake Michigan Coastal	36,600
Northwest Lowlands	13,938
Northwest Sands	24,551
Southern Lake Michigan Coastal	1,618
Southgeast Glacial Plains	6,793
Superior Coastal Plain	37,850
Western Coulees and Ridges	60,808
Western Prairie	1,593
Total	887,120

The amount of red maple on the landscape has increased significantly over the last few decades. However, the age class structure has remained fairly steady with a majority of acreage in the middle age classes and fewer acres in the youngest and oldest age classes. The age class distribution of red maple appears to be shifting from the younger middle age classes to the older middle age classes as the red maple resource ages (Figure 51.1). In addition, the number of growing stock trees in the youngest age class is very low, indicating the possibility of future decline of the red maple resource in Wisconsin (Figure 51.2).

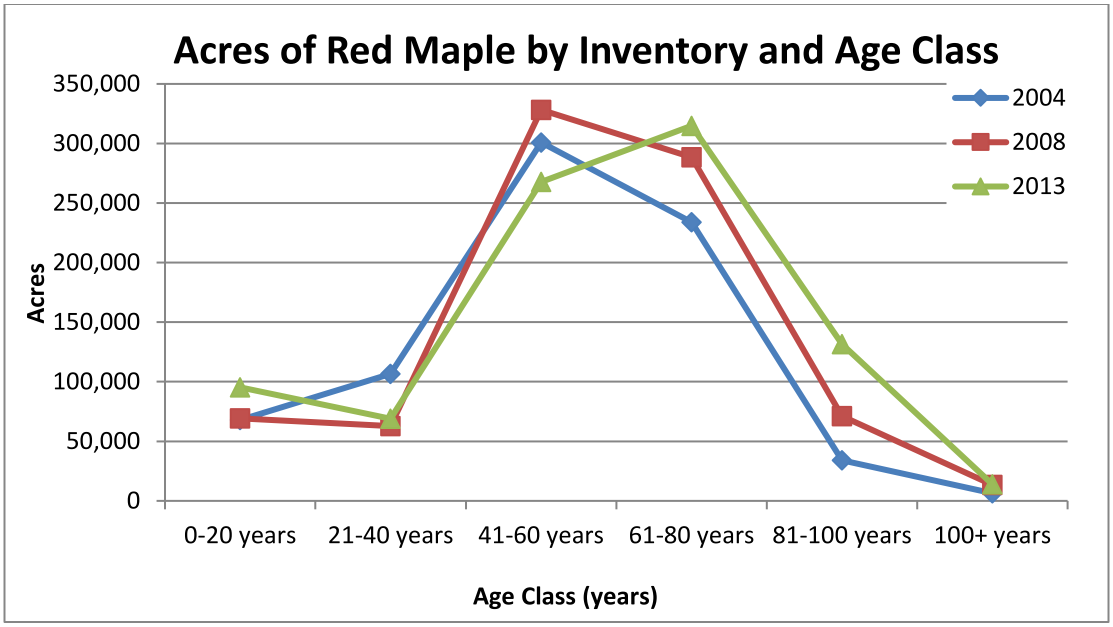


Figure 51.1. Acres of red maple by inventory and age class (FIA).

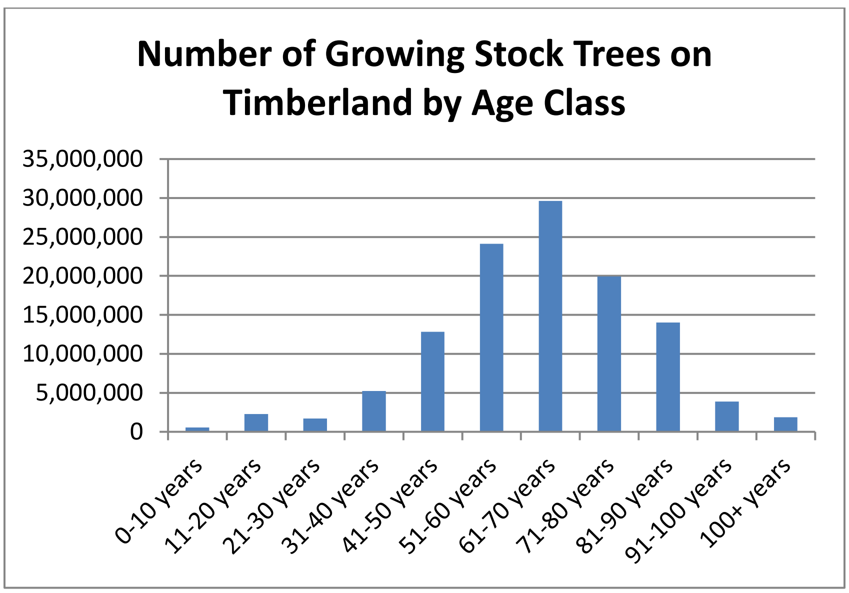


Figure 51.2. Growing stock trees on timberland by age class.

3.1.3 Climate Change

Red maple is one of the most abundant and widespread trees in eastern North America. Current modeling of tree response to climate change under high and low emissions scenarios suggests that the range and extent of red maple will remain largely the same, however, the abundance will decline and the optimum latitude/suitable habitat will move to the south (Iverson & Prasad 2002, Landscape Change Research Group 2014). Red maple shows little change in % area occupied, but a large change in average importance value. It currently occupies much of the eastern US, with higher importance values to the north. After climate change, the estimated importance values would be higher along the more southern Ohio and Mississippi River Valleys relative to its current prominence in northern locations (Iverson & Prasad, 2002; Iverson et al, 2008). Due to a wide tolerance for climatic conditions, red maple is likely to remain as a component of forests in Wisconsin, though importance values may diminish.

3.1.4 Hydrology

Red maple grows on diverse sites, from dry ridges and southwest slopes to peat bogs and swamps. It commonly grows under the more extreme soil-moisture conditions either very wet or quite dry. The species does not show a strong affinity for either a north or a south aspect. It is also common in swampy areas, on slow-draining flats and depressions, and along small sluggish streams.

3.1.5 Forest Simplification

Forest simplification refers to a loss of species diversity and structural diversity, and an increased dominance of fewer species. The increase in maple dominance that is occurring in northern hardwood forests is an example of simplification, as is the lack of features like large woody debris and tip-up mounds. At the landscape level, simplification and homogenization occur when forested patches become similar in size, shape, and composition. Land uses have led to homogenization and reduction of patch sizes, and creation of patch shapes that are less complex (Mladenoff et al. 1993). The cumulative effects of stand-level simplification make composition similar among patches. This is unlike the mosaic of forest patches found in remnant old growth forests. As an opportunistic, shade tolerant species, with the ability to grow slowly for long periods of time awaiting release, red maple may be a resilient component of forests where structural and compositional diversity have declined. Red maple dominance in these simplified stands may be at the expense of other sub-climax, pioneer species that are not as shade tolerant and long lived like aspen and white birch (Burns & Honkala 1990).

3.1.6 Landscape Pattern, Fragmentation and Edge Effects

Fragmentation describes certain kinds of landscape structure. Inherent fragmentation describes landscapes that are naturally heterogeneous due to the physical environment, such as landscapes with numerous small lakes and wetlands dispersed throughout a pitted outwash plain. Permanent fragmentation refers to long-term conversion of forest to urban, residential, or agricultural uses. Habitat fragmentation is defined as a disruption of habitat continuity, caused by forest harvesting or natural disturbance, which creates a mosaic of successional stages within a forested tract. This kind of fragmentation is shorter-term, affecting species while the forest regrows, and is a consideration in red maple management in northern Wisconsin. Red maple regeneration is generally accomplished through the use of even-aged management, and dispersion of clear-cuts throughout the forest creates differences in forest structure that are a type of habitat fragmentation.

In Wisconsin and elsewhere, the loss of forest habitat has a larger impact on species than shorter-term habitat fragmentation. However, area of habitat loss is often correlated with measures of fragmentation (e.g., patch size, distance between patches, cumulative length of patch edges, etc.), making it difficult to quantify their separate effects. Habitat loss may result from second homes, or urban and industrial expansion. A drastic change in land cover, such as that which occurs after a clear-cut harvest, represents a short-term loss of habitat for some species and a gain for others, including red maple which is a pioneer species. Dispersal can be affected if species or their propagules cannot cross or get around the open land, and cannot find suitable habitat within it. The small, winged red maple seeds are dispersed efficiently by wind and can travel some distance. Though seed fall drops off rapidly with distance from stand edge or clear-cut opening. Seed dispersal, shade-tolerance, and relative longevity compared to other early successional species make red maple somewhat tolerant of disturbance and fragmentation, though if habitat is lost due to permanent land use changes red maple could decline locally.

3.1.7 Incorporating Ecological Complexity into Red Maple Management

Forest management generally simplifies forest structure and composition with some negative impacts in terms of biodiversity and resilience. Thus, maintaining structural and ecological complexity is increasingly an objective of sustainable forest management. The integration of complexity into forest management would involve designing harvest operations that maintain or enhance the capacity of forests to adapt to changing conditions, like climate change. Operationally, managing for complexity involves protecting or restoring complex patterns in forest structure. Red maple often grows slowly for long periods of time until it is released by small and large canopy gaps created by disturbance. Management regimes which maintain complexity by mimicking natural disturbance and creating gap habitat within the forested landscape will be beneficial to increasing red maple as a component of the stand and increasing age class diversity within the stand.

3.1.8 Summary of Landscape Considerations

- Red maple is one of the most abundant and widespread trees in eastern North America and thrives on a wider range of soil types, textures, moisture, pH, and elevation than any other forest species in North America.
- Red maple has increased on the landscape since pre-settlement times and it continues to increase as a component of Wisconsin’s forests.
- In northern Wisconsin and Michigan, red maple grows on sites ranging from dry, sandy outwash plains to wet bottomlands and swamp edges. Red maple distribution is bimodal, with a primary importance peak on dry-mesic sites and a secondary peak on wet-mesic sites.
- Red maple is a pioneer species that is more shade tolerant and longer lived than other early successional species such as aspen.
- Red maple is favored when fire is suppressed and, in many of the forests where it occurs it has increased in dominance dramatically during the past decades.
- Red maple is likely to maintain its current range under climate change. However, it’s abundance within that range is expected to decline and the optimal latitude is expected to shift south.
- Red maple is a widely used landscape tree due to brilliant fall coloring. It can also be used for syrup making and it is a highly desirable species for wildlife browse.

3.2 Site and Stand Considerations

3.2.1 Soils

Red maple can probably thrive on a wider range of soil types, textures, moisture, pH, and elevation than any other forest species in North America. The red maple type occurs on a wide range of soil conditions, from sand to clay and from dry to wet. Its range covers soils of the following orders: Entisols, Inceptisols, Ultisols, Alfisols, Spodosols, and Histosols. It grows on both glaciated and nonglaciated soils derived from granite, gneisses, schists, sandstone, shales, slates, conglomerates, quartzites, and limestone.

Best growth is demonstrated on mesic to wet mesic sites with loamy or sandy loam soils but growth potential is good for many sites except for excessively dry or poorly drained. Higher site indices are noted on soils that have an accumulation of fine textured soils (Haag etal. 1989). Red maple trees develop a greater vertical rooting structure (root fan) in this soil type capitalizing on additional water and nutrients.

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

Red maple has become nearly ubiquitous across sites with varying moisture and nutrient regime being dubbed a "super generalist". Figure 51.3 displays its wide range in eastern North America, found as far north as Newfoundland and south to Florida. In Wisconsin, it is commonly found across the state in nearly every habitat with varying trends in density. This distribution is in contrast to pre-European settlement where red maple existed mainly in poorly drained areas.

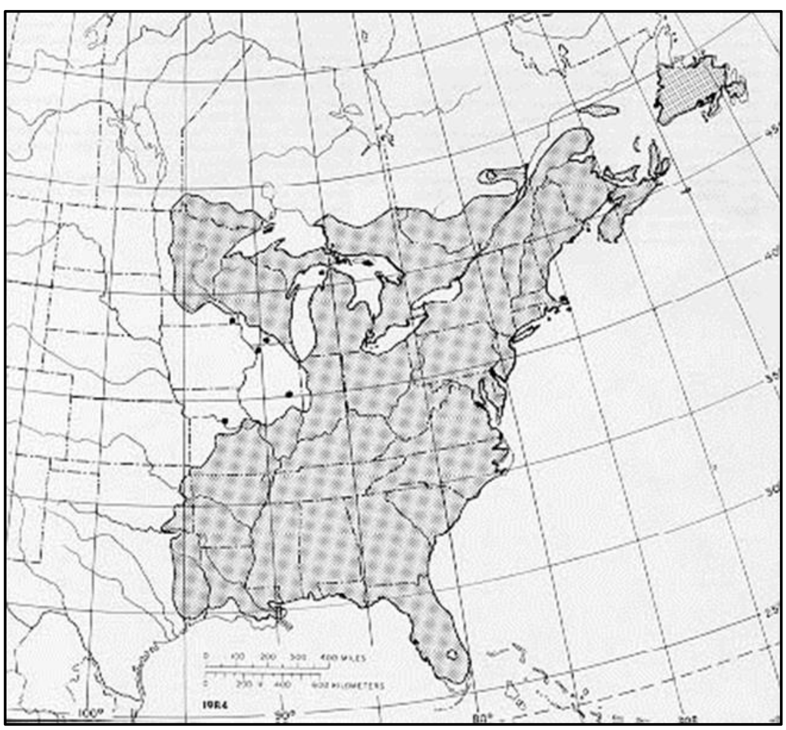


Figure 51.3. Native range of red maple (Burns & Honkala 1990).

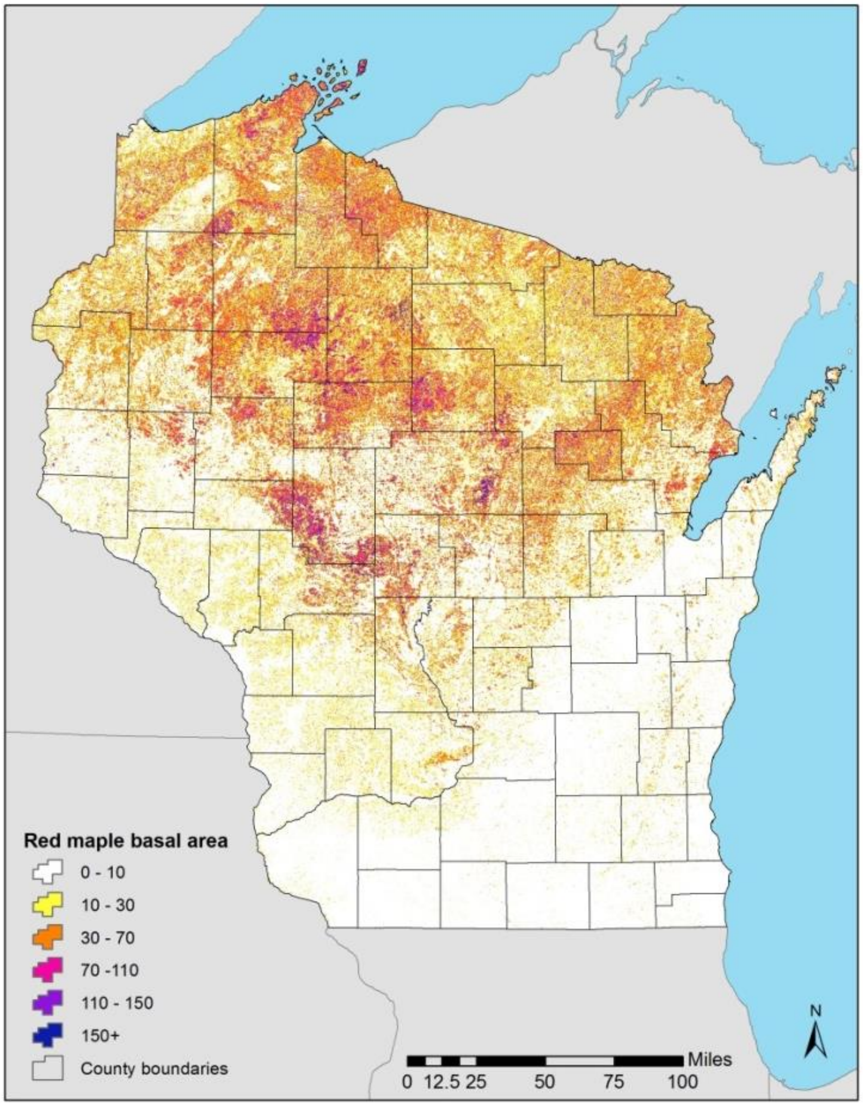


Figure 51.4. Red maple stocking (sq. ft./ac.) in Wisconsin (Wilson et al. 2013).

Red maple is an important component in many cover types, although pure red maple stands represent only a small percentage of forested timberland. Figure 51.4 displays current red maple stocking variation (square feet per acre) throughout Wisconsin (Wilson et al. 2013). It is found to a greater extent in aspen stands (24% of aspen cover type) and as little as 2% in the mixed pines/ hardwood cover types. The pure red maple cover type occupies approximately 2% of Wisconsin's total forest land acreage (Miles 2009).

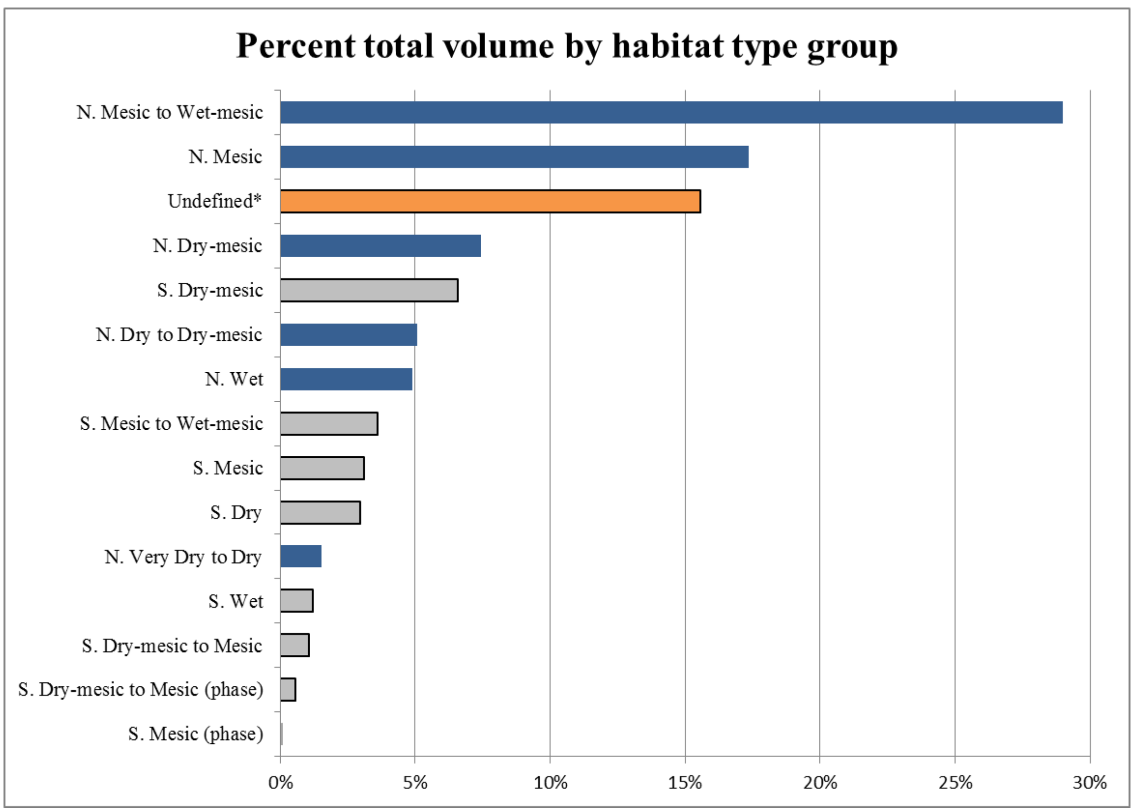
Red maple appears to be a "super-generalist" due to its low resource requirements. It shows characteristics of both early and late successional species (Abrams 1998). Throughout its range, red maple thrives on many landforms, in many different soil conditions, and under widely varying moisture and light regimes. Red maple occurs on lands forms as different as dry ridges and swamps, on soil textures varying from sands to clays, on soils with PH ranging from highly acidic to near neutral, and from high light to deeply shaded sites (Abrams 1998).

The red maple cover type has the potential to develop on all upland habitat type groups and most habitat types in Wisconsin but its actual distribution and productivity across sites vary considerably. Overstory and understory composition of red maple stands vary significantly between southern and northern Wisconsin. Within each region, composition also varies across the range of sites where red maple forests occur, from dry to mesic to wet.

For each of the following habitat type groups, typical red maple forests are described in terms of dominant trees and principal associates. These descriptions of characteristic overstory associations are derived primarily from analysis of Forest Inventory and Analysis (FIA) data and the Forest Habitat Type Classification System (FHTCS) (Kotar & Burger 1996, Kotar etal 2002). Characteristic soil textures are also identified. Northern and southern regions and site types are derived from the FHTCS. Exceptions to these typical conditions should be expected as many red maple sites may still be recovering from recent disturbance. The complete list of habitat types where red maple is a represented can be referenced in the Forest Habitat Type books for both northern and southern Wisconsin (Kotar & Burger 1996, Kotar etal 2002).

Northern Habitat Type Groups

About 77% of red maple volume occurs in northern habitat type groups. This species occurs on all northern groups with the most volume in northern mesic to wet mesic (28%) and northern mesic having slightly less (17%). (Figure 51.5)



*Due to past disturbance, forest habitat type classification on many red maple sites may be problematic

Figure 51.5. Percent volume of red maple from by habitat type groups (Miles 2014).

The northern mesic to wet mesic habitat type is associated with loess plains and moraines (especially ground moraines), poorly drained silt loams and loams but can still be nutrient rich. Red maple can be the dominant species within this habitat type group however sugar maple and aspen are most common. Associated species that exist with red maple in this habitat type group include basswood, black ash, elms, oaks, white ash and yellow birch. Competition from shrubs and grass can be heavy. Some common habitat types include ATAtOn, ArAbCo, TMC, ACaI, ASaI. The first two habitat types are more productive having site index >60.

The northern mesic habitat type group is associated with end/recessional and ground moraines. Occurs on well drained sandy loam and loam soils and the nutrient regime is medium to rich. Associated species in this habitat type group include sugar maple, aspen, red oak, basswood, white ash. This group tends to have a diverse and competitive shrub layer. Management will depend mostly on interpretation of the composition and present condition of the stand. Some common habitat types with red maple present include ATM, ATD and AOCa. These types tend to be more productive having SI > 60.

In the northern dry mesic habitat group, red maple represents about 7% of the volume. This group is associated with end/recessional moraines and outwash and occurs on well drained sandy loam soils. Some habitat types in this group include ParVAaPO, ParVa, AAT, AVVib, and ACl. These stands tend to have lower site index < 60. Associated species includes white and red pine and red oak. Red maple in these stands usually is a result of fire suppression.

<u>Southern Habitat Type Groups</u>
About 23% of red maple volume occurs on southern habitat type groups. This species occurs on all southern habitat type groups with the most volume on southern dry-mesic and smaller volumes on southern dry.

In the southern dry mesic habitat type group, red maple represents about 7% of the volume. The associated soils include silt caps over sandstone, till or loam and typically have a site index of 60 or higher. In the Western Coulees and Ridges landscape, these stands are typically oriented north and east and in shelter coves. These stands often originated from oak stands that were subject to selective cutting, pasturing, or storm damage. Some common habitat types are ArCi-Ph, AARVb.

In the southern dry habitat type group, red maple represents about 3% of the volume. The associated soils include loess over sandstone or outwash. Terrain is generally flat to gently rolling in some areas. In the Western Coulee and Ridge landscape red maple in this habitat type group tends to occur on south and west oriented slopes and the stands are less productive having site index < 60. These stands often developed from oak and pine stands after fire suppression and selective harvests. Some common habitat types are PEu, PVG, and PVCr.

3.2.5 Wildlife

Red maple stands are found throughout the state on both wet and dry sites but this distribution and current stocking levels of red maple are recent phenomena and wildlife species are generally not dependent on red maple. Pure stands are not common. Recommendations for practices that might benefit wildlife can be found in the chapters on Central Hardwood and Swamp Hardwood. To a lesser extent, practices found in the Northern Hardwood and Oak chapters might apply as red maple is a common associate in both of those types.

Wildlife uses red maple as a food source, structural support for nesting, and as cover. Red maple seeds are an important food source for small mammals and some species of song birds. Twigs, bark, and leaves are used by browsing and gnawing mammals and red maple can be an important source of food for deer in Wisconsin. Red maple flowers early in spring and insects attracted to those flowers make up an important food source for birds during migration and prior to the breeding season.

Sapling/seedling stands can be used as early-successional habitat by a wide range of species in even-aged management systems. Regeneration of red maple in gaps and patch clearcuts provide structural diversity to stands and are used by wildlife for food and shelter.

On some sites, generally mesic or wet-mesic, red maple attains large size and may reach a diameter at breast height of up to 30 inches. It is a good cavity tree and can provide this habitat feature for a considerable length of time as both a live tree and as a snag. While cavities in large trees are important regardless of where they occur, red maples in lowland situations may particularly benefit wood ducks, barred owls, and some bat species.

Management of red maple stands incorporating any of the suitable silvicultural systems will benefit wildlife. Even-aged systems utilizing clearcut, coppice, or shelterwood regeneration will create early-successional habitat. Thinnings and regeneration using patch or gap clearcuts or single tree selection will favor wildlife use by species adapted to mature forests or heterogeneous forest landscapes. Regardless of the silvicultural system used, green tree retention provides critical wildlife habitat and should be incorporated into prescriptions both as single trees and aggregates.

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 in lowland red maple stands. This may be less of a concern on dry sites.
- Monitor stands for invasive species and tailor silvicultural treatments to minimize the possibility of providing competitive advantages for these species particularly in lowland stands. Reed canary grass and buckthorns are major problems in some areas of the state.
- Take advantage of opportunities to protect and provide cavity and snag habitat suitable for a variety of wildlife species.

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

There are no Wisconsin Endangered, Threatened, or Special Concern species (ETS) known to rely, exclusively, on red maple. Further, red maple grows on a wide variety of sites; it can occur in virtually every forested natural community type in Wisconsin, from the driest to the wettest types. Historically, its dominance on any given site would likely have been short-lived since it would either get replaced by more shade-tolerant species or would be set back by disturbance. Combined, these factors make it difficult to generalize about rare species associated with the red maple cover type. Nevertheless, rare species can be found in many stands containing red maple, and it can contribute to stand species diversity and provide cavity trees, snags, and other habitats used by various species.

Dry-mesic forests (northern and southern types) often contain varying amounts of red maple, but it can also play an important role in hardwood swamps and other wetland types such as floodplain forests. In addition, red maple can be abundant in very dry forests of the north along with northern pin oak and/or jack pine. “White Pine-Red Maple Swamp” is a natural community type known from central Wisconsin (e.g., Central Sand Plains Ecological Landscape) where red maple is the co-dominant species, along with white pine. These forests can be important for red-shouldered hawk, northern goshawk, and hooded warbler, along with some uncommon plants that are no longer considered rare enough to be tracked by the department such as long sedge (*Carex folliculata*) and bog fern (*Thelypteris simulata*).

Recent research in Wisconsin has shown that cracks in red maple can provide summer (daytime) roosting habitat for bats, including the northern long-eared bat (*Myotis septentrionalis*), a species proposed for federal listing as of this writing. Individual trees do not have to be large to be used by bats; for example, 33 bats were observed exiting a crack in a 9” red maple in one evening in 2014.

Whether a red maple stand is likely to support rare species will depend on certain stand characteristics, including its location in the state, the composition of the surrounding landscape (i.e., its “ecological context”), stand age, stand species composition, stand structural complexity, and whether certain microhabitats are present. For example, some rare plants are found on rocky ledges or near seeps. Often microhabitats that support rare species in forests can be accommodated without precluding active timber management in the majority of the stand; examples include moist or dry cliffs, ponds and small wetlands, seeps or other aquatic features, and pockets with prairie or barrens vegetation. The prairie remnants can support rare plants and, sometimes, associated rare invertebrates like butterflies or moths, so site preparation considerations are needed to maintain these habitats.

In general, efforts to maintain large forest blocks, a diverse set of tree species including conifers where appropriate, large cavities and other dead wood, and protection of the microhabitats discussed previously can also benefit a number of species in red maple forests.

More information on rare species associated with Wisconsin’s forests can be found on the department’s web site (*dnr.wi.gov* keyword “biodiversity”). Each of Wisconsin’s natural communities is described, as well as rare plants and animals associated with each of them.

Handbook users are encouraged to submit sightings for species on the NHI Working List (*dnr.wi.gov* keyword “NHI”). Electronic forms are available for this purpose, and documenting these observations helps improve our collective knowledge regarding these species.

3.2.7 Economic Issues

Red maple is utilized by primary wood-producing industries as a pulpwood, biomass, or sawn product and is considered a soft maple. The wood is close grained and as such it is similar to that of sugar maple, but its texture is softer, less dense, and has a poorer figure. High grades of red maple wood can be substituted for sugar maple. In Wisconsin, production of red maple veneer logs is limited with predominantly curly red maple sorted and sold to veneer mills.

Due to the wide range of site conditions on which red maple can occur, quality and economic value are important management considerations. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning quality, vigor, and mortality. This applies both to the highest product possible and the point in time at which a stand reaches production of that product. While ultimately a rotation age will fall within the generally accepted red maple rotation age range, other factors should also be considered in determining whether the stand has achieved its maximum economic value.

One consideration is landowner objectives. With many products possible, objectives must adapt to site capability as informed by site productivity. For some landowners a wildlife objective may promote a shorter rotation and focus on fiber management rather than saw log potential. Other landowners may have an objective focused on aesthetics which may result in a longer rotation and a focus on saw log production. Desired rate of return on timber investment can also play a role (Grisez & Mendel 1972). If the site is not capable of quality saw log production, objectives would need to be reexamined.

Another important consideration is past management and its effect on current stand origin and the resulting stem quality. As a historically non preferred species, many current red maple stands were not regenerated with red maple as the target cover type. As a result, some red maple stands are the result of poor management and can be stocked with formerly suppressed and/or intermediate trees as well as poor quality dominants and codominants, released with full or partial overstory removal. Other factors which can impact current stand potential based on past management include:

- Seed origin vs. stump sprout: Seed origin tend to have less internal defect than that of coppice/stump sprout origin.
- Harvest history: When was the first entry? What were residual stocking levels after the first entry, second, third, etc.? Was tree retention planned? Are current trees vigorous? Past mismanagement or lack of management may limit current options based on stem quality.

A further consideration is the optimal stem size to capture the most value. In general as the size of the stem increases past its optimum product, log grade and quality have the potential to diminish. Based on conversations with many Wisconsin mills (2014), there is a consensus that due to stand history (i.e. conversion from aspen, high grading, woodlot grazing, etc.) defect is more prevalent in red maple trees with an average 18" – 24" DBH. The primary defects found as a tree increases in diameter are an increase in heart size, color, staining, and ring shake, all of which are major issues in lumber grade.

Given current markets, another consideration is diameter. Based on conversations with many Wisconsin pulp and chipper mills (2014), many are unable to accept wood over 24" dia. due to mechanical limitations in the debarking and chipping process.

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. Red maple stand assessment should include quantifying variables such as:

- Present species composition
    - Canopy, shrub, and ground layers
    - Sources of regeneration
    - Potential growth and competition
    - Potential non-red maple 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. Site index for red maple provided in the appendix.
- Site history
    - Stand origin (seedling, sprout)
    - Management history
- Hydrology
- Topography
- Stand and site variability
- Damaging insects and diseases, herbivory
- Special considerations: watershed, BMPs, rare species, archaeology, landscape

4.3 Cover Type Decision Model

The red maple decision models below outline initial considerations in the planning process for 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.

The primary focus for red maple stands are timber production and maintenance of the type, or conversion to other species appropriate to various sites where red maple stands are found. Habitat type and site index are the two primary factors recommended to evaluate red maple stands. Many other site factors may influence red maple growth and stand quality. To further evaluate sites for potential management, it is recommended to consider the characteristics or site conditions defined for dry, dry-mesic, mesic, and wet-mesic. Stand/site conditions are defined in the following text which includes site index, soils, habitat type, and past disturbance.

<u>Dry Stands</u>
Stand/site conditions of dry red maple stands (SI < 60) may include: shallow bedrock, ridge tops, glacial outwash, outwash terraces, and valley alluvium, and dry habitat types. Fiber management is recommended on dry sites.

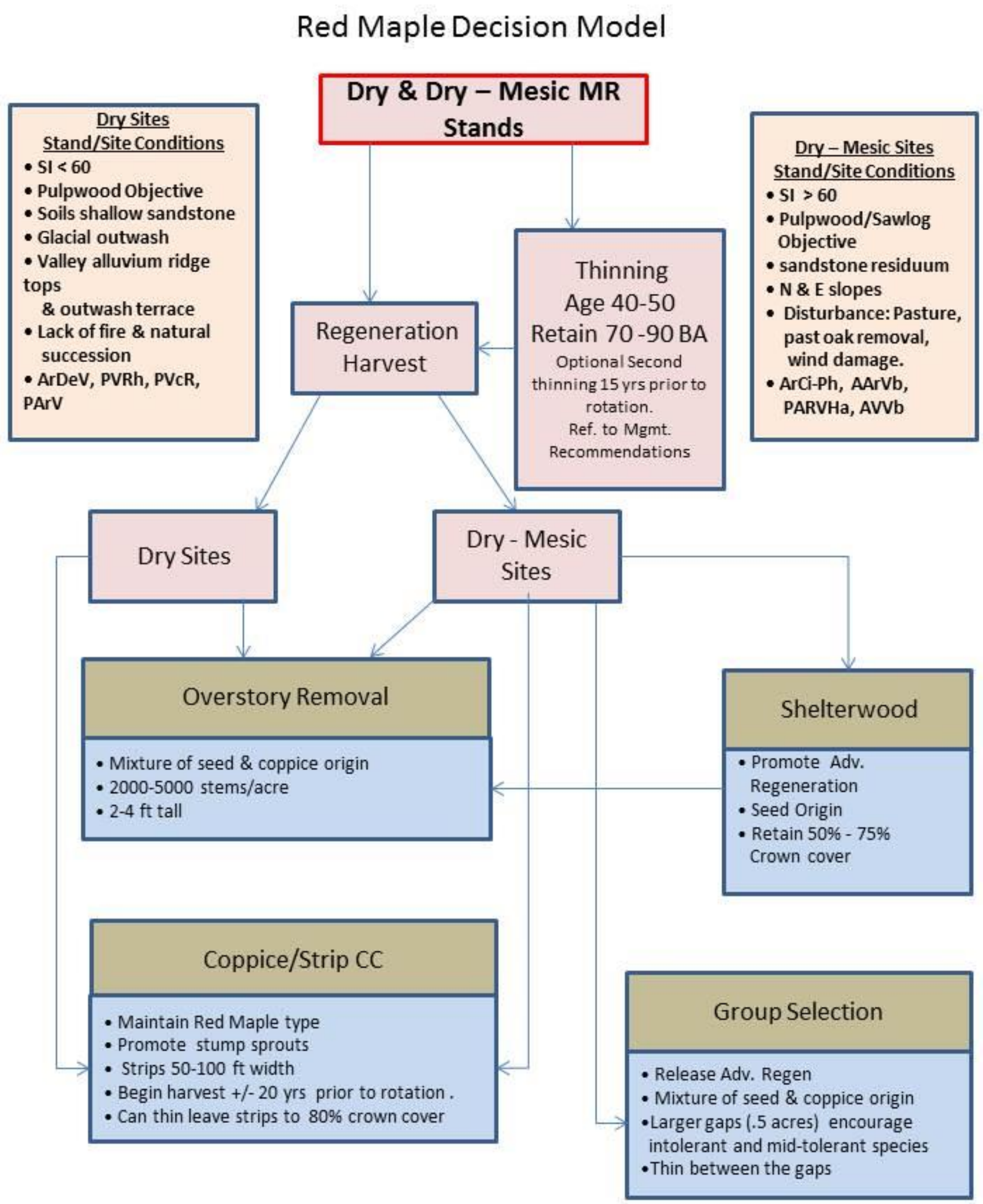
<u>Dry –Mesic Stands</u>
Stand/site conditions on dry-mesic sites (SI > 60) may include: sandstone residuum soils, north and east slopes, and dry-mesic habitat types. Dry-mesic sites may have sawlog potential however fiber management is an option. Both are viable alternatives based on stand objectives and site capability.

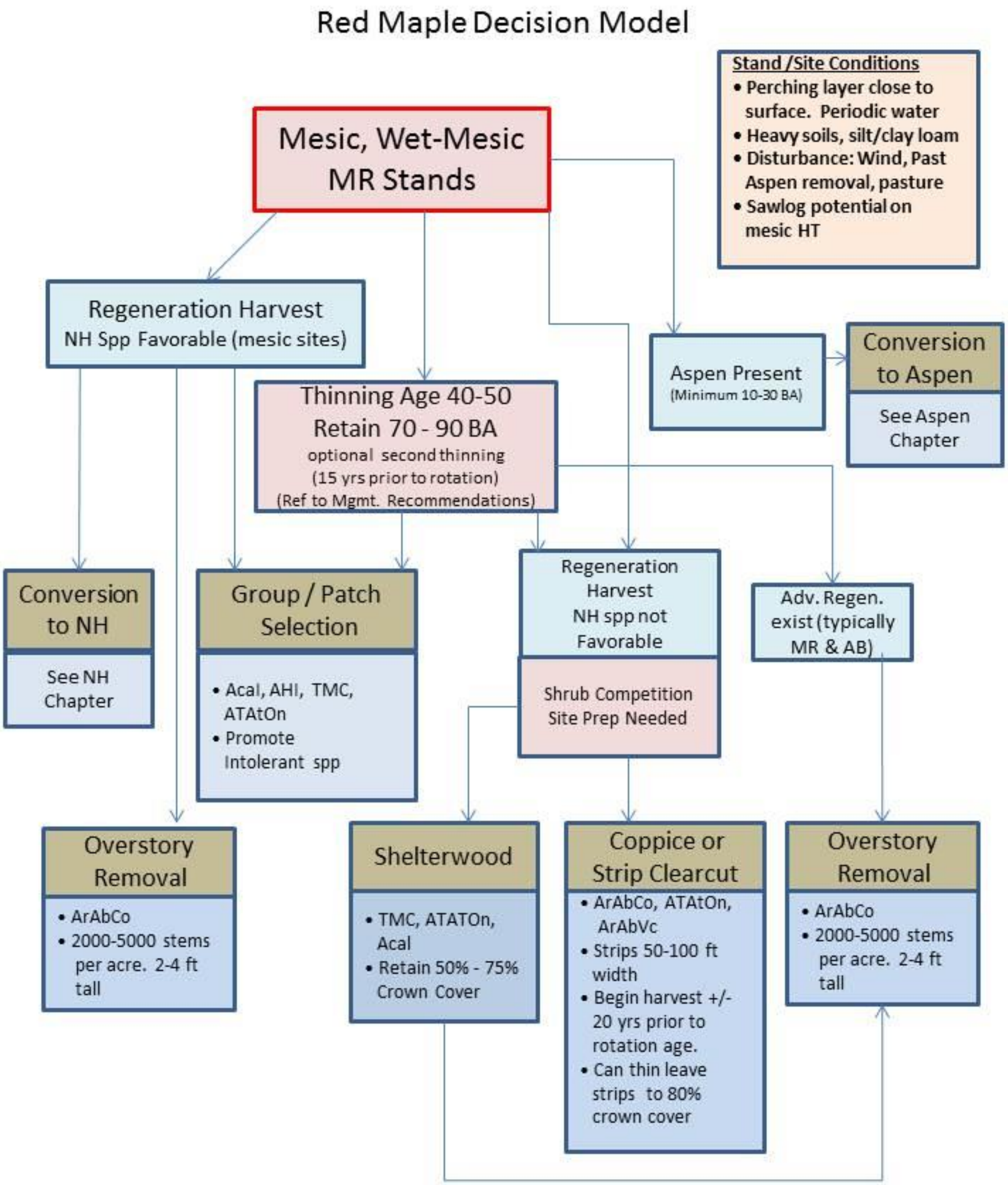
<u>Mesic Stands</u>
On mesic sites red maple is not the climax species and is often managed as a component of another cover type. If a red maple stand is present in this habitat type range, consider transitioning to another cover type, especially northern hardwood. Sawlog potential is optimal on mesic habitat types.

<u>Wet- Mesic</u>
Stand/site conditions on wet-mesic sites may include heavy (silt/clay) soils, perched water close to surface, and periodic surface water. Competition (grass, hazel, musclewood) may be a factor on these sites. On wet-mesic sites, fiber management is recommended however many sites may have sawlog potential.

Even-aged silvicultural systems are commonly recommended for the management of red maple on dry, dry-mesic, and wet-mesic stands to emphasize fiber management. Sawlog potential may exist on dry-mesic and wet-mesic but is optimal on mesic sites.

Past disturbance has shaped many of today's red maple stands. Red maple stands on dry sites are commonly the result of fire suppression and natural succession. On dry-mesic sites fire suppression, oak removal, storm damage and grazing have played a role in shaping these stands. On wet-mesic sites aspen removal, Dutch elm disease, storm damage (wind), and grazing have favored red maple.




Red Maple Decision Model
Stand /Site Conditions
• Perching layer close to surface. Periodic water
• Heavy soils, silt/clay loam
• Disturbance: Wind, Past Aspen removal, pasture
• Sawlog potential on mesic HT
Mesic, Wet-Mesic MR Stands
Regeneration Harvest
NH Spp Favorable (mesic sites)
Thinning Age 40-50
Retain 70 - 90 BA
optional second thinning
(15 yrs prior to rotation)
(Ref to Mgmt. Recommendations)
Aspen Present
(Minimum 10-30 BA)
Conversion to Aspen
See Aspen Chapter
Conversion to NH
See NH Chapter
Group / Patch Selection
• Acal, AHl, TMC, ATAtOn
• Promote Intolerant spp
Regeneration Harvest
NH spp not Favorable
Shrub Competition
Site Prep Needed
Adv. Regen. exist (typically MR & AB)
Overstory Removal
• ArAbCo
• 2000-5000 stems per acre. 2-4 ft tall
Shelterwood
• TMC, ATATOn, Acal
• Retain 50% - 75% Crown Cover
Coppice or Strip Clearcut
• ArAbCo, ATAtOn, ArAbVc
• Strips 50-100 ft width
• Begin harvest +/- 20 yrs prior to rotation age.
• Can thin leave strips to 80% crown cover
Overstory Removal
• ArAbCo
• 2000-5000 stems per acre. 2-4 ft tall

5 SILVICULTURAL SYSTEMS

A silvicultural system is a planned program of vegetation treatment during the entire life of a stand. Silvicultural systems typically include three basic components: intermediate treatments (tending), harvesting, and regeneration. Relatively little information is available regarding silvicultural systems for the red maple type. Most of the information in this section is adapted from northern hardwood silviculture as well as red maple trials and field experience in Wisconsin. Previously, the red maple cover type was not considered independent of the northern hardwood cover type. With the red maple type, silvicultural systems are frequently adapted to meet site-specific and species-specific conditions.

With the goal of regenerating red maple as well as shade intolerant to mid-tolerant species, even-aged management is the preferred method. The even-aged regeneration methods generally accepted and supported by literature are:

- Overstory Removal
- Strip Clearcut/Coppice
- Shelterwood

With the goal of regenerating red maple as well as shade tolerant species, uneven-aged management may be suitable. The uneven-aged regeneration method generally accepted and supported by literature is:

- Group and/or Patch Selection

5.1 Seedling/Sapling Stands

Once established, red maple seedlings and saplings exhibit optimal vigor (growth and health) when exposed to (near) full sunlight. Seedlings and saplings in free-to-grow conditions have the greatest potential to survive and to maximize growth and productivity. To ensure full stocking while developing stem quality, the stocking of desirable species should be more than 5,000 per acre of well distributed seedlings >3' tall (Erdmann 1986).

5.2 Intermediate Treatments

5.2.1 Non-Commercial Intermediate Treatments

Where sawlog production is a management objective, the development of individual tree quality is a principal concern. Stand and tree quality depends on many factors. In many situations it may be necessary to enhance stand development with non-commercial intermediate treatments or timber stand improvement practices (TSI). For details on these methods refer to Chapter 23, Intermediate Treatments. Within the red maple cover type, TSI is often a combination of some or all of the following practices:

5.2.1.1 Weeding

This practice eliminates or suppresses competing plants (trees, shrubs, vines, and herbaceous vegetation) within a stand. Most often these plants are aggressive shrubs and herbaceous species that retard advance regeneration or prevent the establishment of desirable regeneration. Intensive management techniques may be required to control competition and establish regeneration. Within the red maple cover type, trees and shrubs which are commonly weeded include:

- Ironwood (*Ostrya virginiana*)
- Hazelnut (*Corylus americana*, *C. cornuta*)
- Witchhazel (*Hamamelis virginiana*)
- Musclewood (*Carpinus caroliniana*)
- Prickly ash (*Zanthoxylum americanum*)
- Common buckthorn (*Rhamnus cathartica*)
- Glossy buckthorn *(Rhamnus frangula*)
- Bush honeysuckles (*Lonicera tatarica, L. morrowii, L. x bella*)

5.2.1.2 Liberation

This practice releases a young crop of desirable seedlings and/or saplings by removing less desirable, older, overtopping trees. With red maple, this often entails the removal of poor quality trees to favor the advancement and quality of young, vigorous and potentially valuable trees. Retention of some wildlife trees may be desirable for non-timber goals.

5.2.1.3 Cleaning

This practice releases desirable seedlings and saplings from undesirable tree species in the same age class. It is used to control a stand's species composition and to improve growth and quality of crop trees.

5.2.3 Thinning

5.2.3.1 Non-Commercial Thinning and Improvement

Crown thinning in non-commercial pole timber stands favor crop trees by removing adjacent crown competitors. This allows crop trees to develop full, vigorous crowns necessary for improving growth and quality. This is often referred to as "crop tree release." With young red maples, release may not affect height growth and can delay natural pruning. It can however help these trees retain their dominant or codominant crown position (Trimble 1974).

5.2.3.2 Commercial Thinning and Improvement

Intermediate thinning is used in red maple stands to control stand density, structure, and composition between stand regeneration and final harvest. , The primary objectives of intermediate thinning in red maple stands are:

1. To increase the rate of growth of residual trees
2. To concentrate growth on the most desirable trees
3. To improve species composition
4. To salvage losses that would occur as a result of competition and suppression.
5. To generate income during the stand rotation
6. To enhance forest and tree health

As is true for other species and cover types, thinning does not significantly alter the gross production of stand volume but does concentrate growth on desirable trees. With red maple, both survival and crown class ascension of codominant, intermediate, and suppressed trees are improved by thinning (Rentch 2009). Being sensitive to crown position, the amount of red maple which can be expected in future stands depends not only on number of stems, but also on the distribution of stems among crown classes (Ward 1993). Unlike uneven-aged selection harvesting, reproduction is not a management concern.

Thinning can be difficult, especially on wetter sites, due to operability concerns. When thinning is considered, implement when 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 51.6) to help determine timing and level of thinning.

When or whether to thin a stand depends on site capability, management objectives, stand conditions, and operability. Intermediate thinning should be implemented at least 20 years prior to rotation. Reduce stand residual basal area to the prescribed stocking level (80 percent crown cover for first entry) using the even-aged stocking guide for red maple (Figure 51.6). Thinning should free crop trees from poor quality main canopy competition with crown thinning or thinning from above. Red maple stands should be thinned to 70-90 sq. ft. residual basal area.

Since red maple stands can differ widely in species composition, estimates of stocking based on stocking charts may be inaccurate and should be used with caution (Stout & Nyland 1986). Relative stand density (stocking), may be more accurately calculated directly from stand data using a species-specific tree-area ratio than with stocking charts (Table 51.5). If the relative density of a stand is calculated this way, a ratio can be developed for determining the desired residual basal area.

> *Example*: A red maple stand is inventoried with the aid of software that calculates relative density. Per this calculation the stand basal area is 130 sq. ft. and the relative density is 90%. The target residual relative density for this stand is 60% after an intermediate thinning. To estimate the residual basal area when marking the stand, a ratio is developed:
>
> Current RD/Current BA = Residual RD/Residual BA
> 90/130 = 60/X
> X=86.7

For ease of use in the field and assuming a negligible increase in mean diameter (quadratic) if thinned from above, 85 sq. ft. would be a useful guide for 60% relative density in this stand.

5.3 Natural Regeneration Methods

Table 51.3. Summary of natural regeneration methods.

FOREST COVER TYPES[1]	NATURAL REGENERATION METHODS							
	Coppice	Clearcut	Seed Tree	Overstory Removal	Shelterwood	Patch Selection (0.5-2.0)	Group Selection (0.1-0.5)	Single-tree Selection (<0.1 acre)
Red Maple	R	CR*	NR	R	R	R	R	CR

Note: **R** **Recommended practice**
CR **Conditionally recommended practice ()**
NR Not recommended practice
* See Regeneration Systems for more detail

5.3.1 Even-Age Regeneration Methods

When the goal of stand management is regenerating red maple as well as shade intolerant to mid-tolerant species, even-aged management is the preferred method.

5.3.1.1 Shelterwood

Even-aged management, using the shelterwood method, is typically implemented in dry mesic and wet mesic red maple stands to establish seed origin red maple and promote advanced reproduction (Erdmann 1986). In both situations, site preparation (chemical and/or mechanical) may be required for successful seedling establishment. 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).

Regeneration is usually accomplished using a two-step shelterwood. Initial harvesting (seed cut) is designed to provide proper crown closure and tree spacing depending on the preferred species composition, leaving a high, and 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.

If possible, consider timing the shelterwood cut and site preparation operations relative to the production of good seed crops. Site preparation on these sites can be difficult due to accessibility, 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 harvest and release established regeneration using the overstory removal methodology described below.

5.3.1.2 Overstory Removal

This 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. Red maple 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 competition concerns. To ensure full stocking while developing stem quality, the stocking of desirable species should be more than 5,000 per acre of well distributed seedlings >3' tall (Erdmann 1986). Overstory removal operations should be conducted during dry or frozen ground conditions in order to minimize the damage to advance regeneration. Careful skid trail design prior to harvesting activities will help protect seedlings from equipment damage. 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 the 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. Gradual or patch overstory removal may be necessary on wet-mesic sites where competition is an issue and patch of advanced regeneration exist. This variation can also be used to slowly convert a stand to a different composition.

5.3.1.3 Progressive Strip Clearcut/Coppice

Clearcutting is a method used to regenerate a standby the removal of most or all woody vegetation creating a (nearly) completely open area for seedling establishment. 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 are a consideration. Red maple stands that contain an aspen component may be managed using coppice/strip clearcut. Coppice/strip clearcut has been utilized with favorable results in many areas of Wisconsin. Most WDNR strip clearcut/coppice trials have shown that adequate regeneration establishes within 2 years. 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 seed previously dispersed, 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 seed trees and reserve trees.

Strip management recommendations:

- 1st and 2nd strip cuts: Remove all trees >1 inch dbh and retain only exceptional reserve trees for green tree retention purposes.
- 2nd and later strip cuts: Care should be taken to protect the regeneration in the previously cut strips.
- Last strip cut: 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.

5.3.2 Uneven-Age Regeneration Methods

Even-aged management is the preferred silvicultural system to manage and maintain the red maple cover type. Potential alternatives to even-age red maple management should be identified and evaluated in relation to sustainable land management goals, site quality/capability and stem quality. Higher quality sites with an adequate stocking of potential crop trees could theoretically be managed using modified uneven-aged management techniques such as single tree selection harvests.

Uneven-aged silvicultural systems, group selection and/or patch selection may be utilized for the management of red maple stands on the mesic and wet-mesic sites which have the potential for sawlog production. Though group and/or patch selection may be implemented based on stand volume regulation, it is easier to implement based on area regulation.

5.3.2.1 Group and/or Patch Selection

Group and/or patch selection may also be utilized to produce regeneration in small cohorts throughout a stand. Spatial distribution of groups and/or patches may be irregular and dictated by 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 and/or patch selection regeneration method in red maple stands is appropriate for promoting a higher preponderance of mid-tolerant shade species including Northern red oak, yellow birch, black ash or white pine. In addition, because red maple sprouting is consistent under partial cutting systems, is it likely that red maple will increase in abundance in future stands managed under these systems (Atwood 2009). Groups of trees are selectively or systematically removed to create holes the canopy ranging from 0.1 acres up to approximately 2.0 acres in size. Factors affecting the size of the opening include stand management objective, structure, quality, vigor, and shade tolerance of desired regeneration species.

Groups and/or patches often require site preparation and release of preferred species of regeneration from competition. Site preparation on these sites can be difficult due to operational considerations (swamping, rutting potential and further development of grass and other competitive species). 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. In application, openings are cleaned of all non-crop tree stems down to one inch in diameter. Create openings by removing groups of trees with poor stem form, vigor or quality, releasing desirable advance regeneration, or removing mature trees. The number of openings is dependent upon the landowner objectives and the size of the area being managed as well as the maturity of the overstory. During opening creation, thinning and crop tree release should occur throughout the remainder of the stand.

5.3.2.2 Single-Tree Selection[1]

Single tree selection may be a viable option on mesic to wet-mesic red maple sites where northern hardwood species are favorable. On these sites red maple is only a phase and northern hardwood management is a viable goal. With 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 40.15 and Table 40.16. For more information about application of single tree selection, see Chapter 40 Northern Hardwood Cover Type.

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 (single tree selection) by combining crop tree release, thinning and gap /group /patch formation techniques. Though there is no research on this conversion technique in red maple stands, this method could be applied in stands capable of sawlog production. Due to the lack of information about this management method in red maple, the currently recommended procedure to convert even-aged stands to uneven-aged structure is adapted from northern hardwood Argonne Experimental Forest studies. See page 40-17 for a discussion of conversion as applied to the northern hardwood cover type.

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

5.5 Rotation Lengths and Cutting Cycles

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, stand history, and biological condition.

Commonly the lower end of the rotation length range is defined by the age at which maximization or culmination 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. In addition, growth and mortality rates vary among stands and can be affected by many variables, including site characteristics, silvics, stocking, silvicultural methods, and units of measure.

Stands can be grown as long as vigor and net volume growth are maintained. Documenting the site and stand conditions are important when determining a rotation age for a stand. In application, foresters use crown class, dbh, and tree condition to evaluate vigor. Vigorous stands are generally stands that have been well-managed and consist of trees with well-developed crowns that hold a good position in the main canopy and exhibit smooth bark without epicormic branches. Stands with red maple trees that have had a good competitive position for extended periods of time are often capable of growing longer and maintaining productivity.

Different rotation lengths can result in increased production of some benefits and reduced production of others. Landowner goals and objectives will also inform rotation age determination. See the discussions under management considerations in the following sections to evaluate some benefits and costs (ecological, economic, social, and cultural) associated with different forest management strategies.

Table 51.4. Red maple recommended and extended rotation ages by habitat type group (1st and 2nd number represent the timber rotation age, and the 2nd and 3rd numbers represent the potential extended rotation age).

Habitat Type Group	Rotation*	Principal Product
Dry	50-80-*95*	Fiber
Dry-Mesic	50-90-*110*	Fiber, Sawlog
Mesic	50-90-*110*	Sawlog
Wet-Mesic	50-90-*110*	Fiber

* On all sites, individual trees and stands may maintain vigor longer or decline earlier than these rotation length guidelines. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning quality, vigor, and mortality. The numbers provided are based on general data, empirical evidence, and the best estimations of the authors and other contributors. Rotation ages may be shortened or extended (i.e. extended rotations may exceed 110 years) based on the considerations above.

5.6 Other Silvicultural Considerations

5.6.2 Cover Type Conversion

When considering natural conversion evaluating site condition is important. Knowledge of site factors such as soils, habitat type, existing vegetation and site potential will aid in decision making. Of high importance is the presence of a desired seed source. Some of the dominant species that may be considered in conversion include aspen and sugar maple. Other species that may be a component of these stands include black ash, white pine, oaks, and yellow birch. These species respond well to large gaps in the canopy for regenerating. Group selection, variations of shelterwood harvests, coppice with standards, and wide strip clearcuts (50-200 feet wide) are all viable options for natural conversion. Conversion of this type to conifers, aspen, or northern hardwood can be successful if regeneration criteria are met:

- Aspen conversion: 1-2 healthy aspen per acre required for coppice sprouting
- Northern hardwood conversion: Northern hardwood seedlings/saplings present (1,000 or more stems per acre is desirable) and habitat type and soils support good quality northern hardwood growth.
- Conifer conversion: Conifer component present in understory or in numbers that would support conversion in overstory.

Other species to consider for conversion include more shade tolerant species such as balsam fir, sugar maple, and hemlock. Small gaps in the canopy can be used to recruit regeneration. Regeneration systems that may work well for 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.

8 APPENDICES

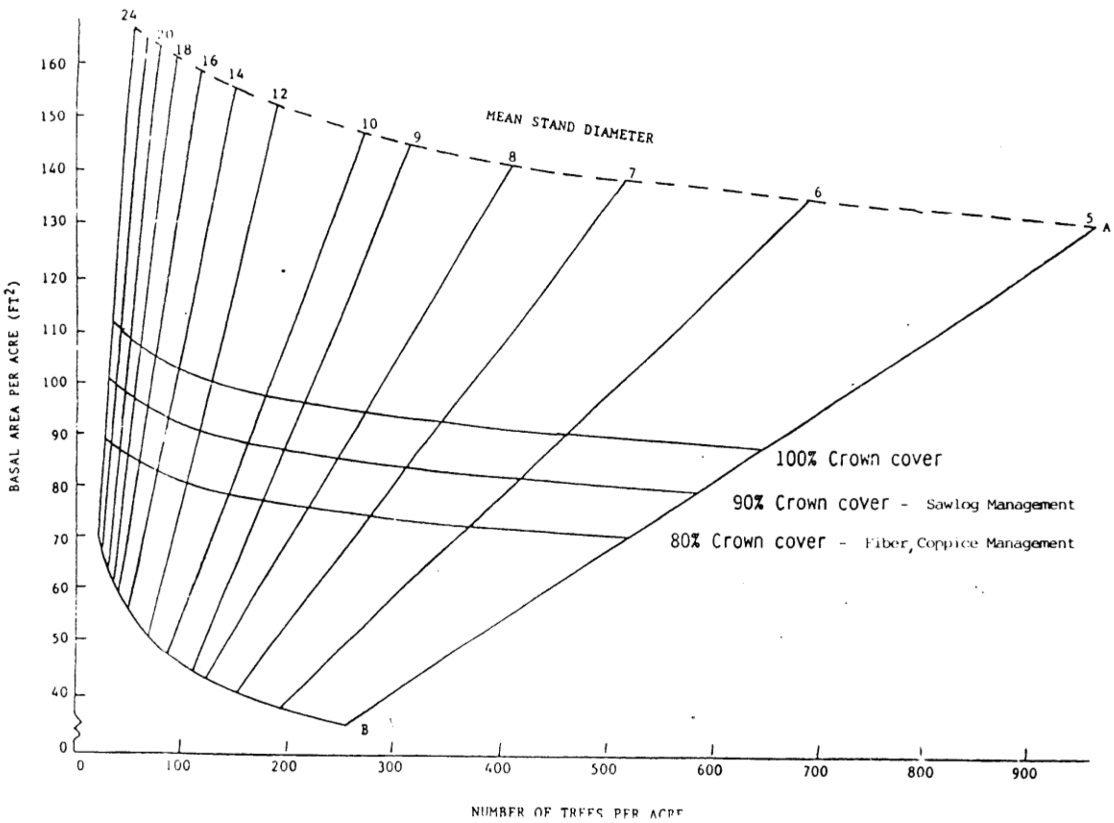


Figure 51.6. Red maple stocking chart.

Table 51.5. Even-age stocking levels for red maple stands by mean stand diameter, basal area, and number of trees per acre for specified crown covers after thinning.

Mean stand diameter[a] (In)	Crown area per tree[b] (Ft^2)	Basal area per tree[c] (Ft^2)	Crown cover (Percent of 43,560 ft^2/acre)					
			80 percent		90 percent		100 percent	
			Trees/Ac (No.)	BA/AC (Ft^2)	Trees/Ac (No.)	BA/AC (Ft^2)	Trees/Ac (No.)	BA/AC (Ft^2)
5	68	0.1364	512	69.9	577	78.6	641	87.4
6	95	0.1963	367	72.0	413	81.0	459	90.0
7	126	0.2673	277	73.9	311	83.2	346	92.4
8	161	0.3491	216	75.6	244	85.0	271	94.4
9	200	0.4418	174	77.0	196	86.6	218	96.2
10	243	0.5454	143	78.2	161	88.0	179	97.8
11	290	0.6600	120	79.3	135	89.2	150	99.1
12	340	0.7854	102	80.5	115	90.6	128	100.6
13	394	0.9218	88	81.5	100	91.7	111	101.9
14	452	1.0690	77	82.4	87	92.7	96	103.0
15	513	1.2272	68	83.4	76	93.8	85	104.2
16	578	1.3963	60	84.2	68	94.7	75	105.2
17	646	1.5763	54	85.0	61	95.7	67	106.3
18	718	1.7671	49	85.8	55	96.5	61	107.2
19	793	1.9689	44	86.5	49	97.3	55	108.2
20	872	2.1817	40	87.2	45	98.1	50	109.0
21	954	2.4053	36	87.9	41	98.8	46	109.8
22	1,039	2.6398	34	88.5	38	99.6	42	110.7
23	1,128	2.8852	31	89.1	35	100.3	39	111.4
24	1,220	3.1416	29	89.7	32	101.0	36	112.2

[a] For tree of average basal area

[b] Dominant and codominant high-quality forest grown red maple trees (Crown area = $3.478\ DBH^{1.844}$)

[c] BA/tree = $D^2 \times 0.00545415$

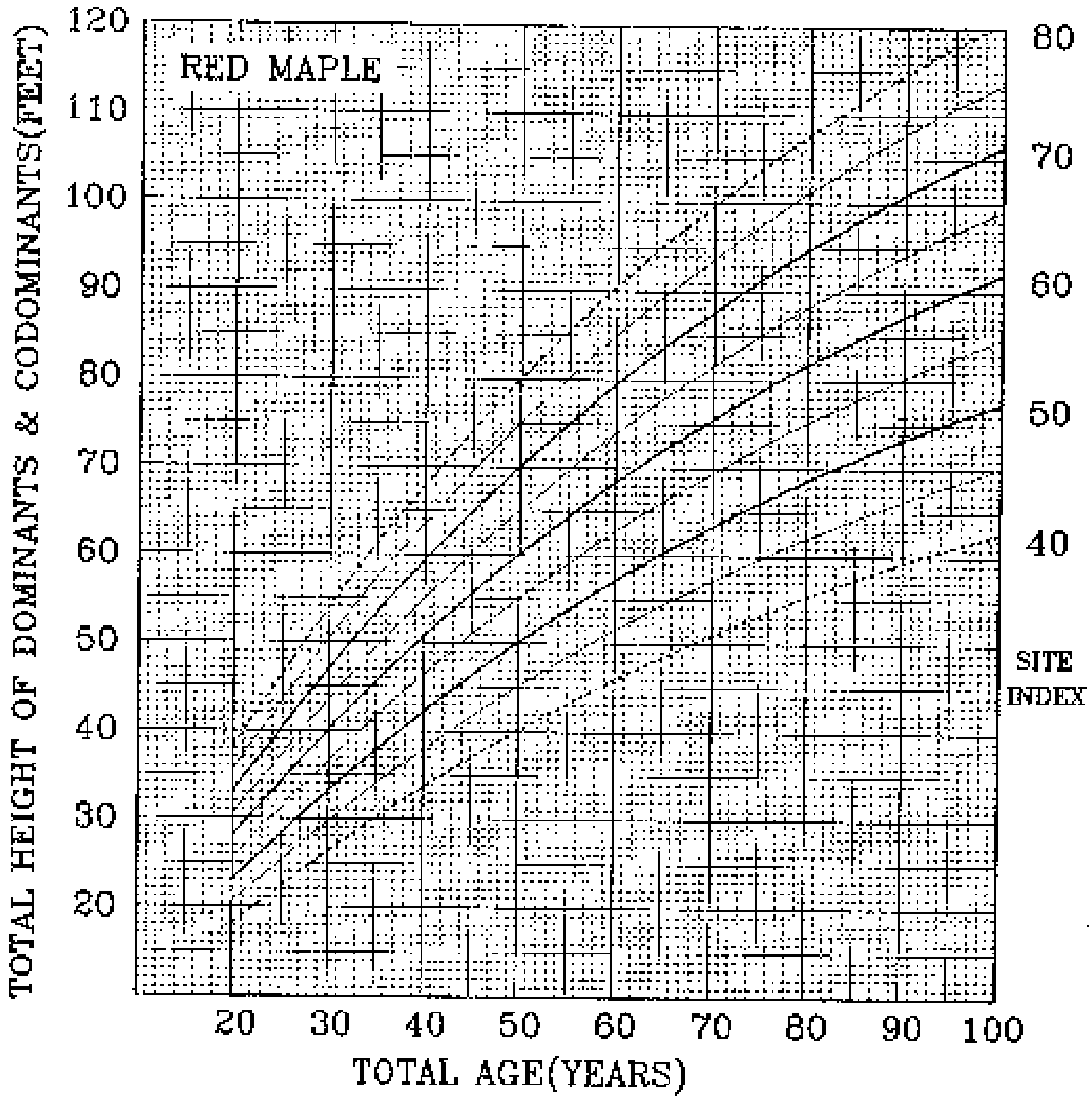


Figure 1.—Red maple (Carmean 1978)
Northern Wisconsin and Upper Michigan
114 plots having 438 dominant and codominant trees
Stem analysis, nonlinear regression, polymorphic
Add 4 years to d.b.h. age to obtain total age (BH = 0.0)

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	2.9435	0.9132	-0.0141	1.6580	-0.1095	0.99	0.49	2.0
SI	0.3263	1.0634	-0.0106	-1.2573	-0.0546	0.99	0.51	2.2

16

Figure 51.7. Site index curves for red maple in northern Wisconsin and upper Michigan (Carmean et al. 1989).

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
DEFOLIATING INSECTS	
MOTHS Baltimore bomolocha – *Bomolocha baltimoralis* Caterpillars from May to November	Usually, controls are not needed and not realistic Natural enemies play an important role in population control Maintain stand vigor by thinning when appropriate and encouraging species and structural diversity Avoid thinning one year prior or one year after defoliation Insecticides, with conservation of natural enemies, can be considered during severe and prolonged infestations. Use biorational insecticides if possible. Note: Late season defoliators do not damage trees as much as early season defoliators.
Definite-marked tussock moth – *Orgyia definite* Caterpillars from April to September	
Elm spanworm – *Ennomos subsignaria* Caterpillars from late May to early July	
Maple leaftier moth - *Epismus tyrius* Caterpillars in early summer	
Green-striped mapleworm – *Dryocampa rubicunda* Caterpillars from July to September	
Gypsy moth – *Lymantria dispar* Caterpillars in May and June	
Lesser maple spanworm – *Itame pustularia* Caterpillars from late May to July	
Linden looper – *Erannis tillaria* Caterpillars from late May to early July	
Maple looper – *Parallelia bistriaris* Caterpillars from late May to September	
Maple spanworm – *Ennomos magnaria* Caterpillars from late June to August	
Maple trumpet skeletonizer – *Catastega aceriella* Caterpillars from early July to early October. Feed inside a trumpet-shaped tube formed by folding a leaf.	
Orange-humped mapleworm – *Symmerista leucitys* Caterpillars from late July to September	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
The half-wing - *Phigalia titea* Caterpillars from May to July	
Ruby quaker – *Orthosia rubescens* Caterpillars from late April to early July	
Maple leafblotch miner – *Cameraria aceriella* Caterpillars from July to September	
Maple leafcutter moth – *Paraclemensia acerifoliella* Caterpillars from June to September. Older larvae cut two circular portions of a leaf and sew them together as a portable case.	
GALL FORMERS	
FLIES Ocellate gall midge - *Acericecis ocellaris* Eyespot galls formed by a midge larva in the spring. The red and yellow coloration is most intense in June.	Usually, controls are not needed and not realistic Maintain stand vigor
Gouty vein midge - *Dasineura communis* Cause greenish or reddish pouch galls on leaf veins in June.	
MITES Maple bladdergall mite – *Vasates quadripedes* Forms spindle and bladder galls on leaves that may lead to leaf distortion during outbreaks. Galls are noticeable in May when leaves have fully expanded. Galls change from green to pink to red and eventually black. Leaves may become deformed or drop when galls are numerous.	
TWIG BORERS	
Boxelder twig borer – *Proteoterus willingana* Caterpillar attacks dormant buds in fall and early spring, kills new shoots in May and June, and skeletonizes leaves in July.	Usually, controls are not needed and not realistic Maintain stand vigor

Disturbance Agent and Expected Loss or Damage	**Prevention, Options to Minimize Losses and Control Alternatives**
Maple twig borer moth – *Proteoterus aesculana* Caterpillars feed in the buds and terminal shoots in May and early June.	
SUCKING INSECTS	
Scale insects and aphids Heavy infestations cause leaf yellowing, premature foliage drop, and dieback of twigs and branches. These insects also produce honeydew which can lead to growth of sooty mold.	Usually, controls are not needed and not realistic Maintain stand vigor
BARK AND WOOD INSECTS	
METALLIC WOOD-BORING BEETLES *Actenodes acornis* Breeds in dry heartwood	Plant trees properly Avoid wounding trees Maintain stand vigor – do not operate in stands the year before, during, or year after stressful environmental (e.g. drought, flooding) or biological events (e.g. defoliation) Infested trees can be felled; then debarked or destroyed. Harvest during the fall and winter Promptly ship logs off landings during summer (within 2 weeks) Promptly process logs during summer or by spring (mid-April) if cut during winter
Chrysobothris sexsignata	
BARK BEETLES Columbian timber beetle – *Corthylus columbianus* Native ambrosia beetle that attacks the xylem of vigorously growing trees.	
LONGHORNED BEETLES Gall-making maple borer - *Xylotrechus aceris* Larvae bore into the sapwood and later the heartwood which weaken trees	
CLEARWING MOTHS Maple callus borer – *Sylvora acerni* Larvae bore into the sapwood	
FOLIAGE DISEASES	
Anthracnose – *Aureobasidium apocryptum* and *Discula campestris* Causes heavy leaf spotting and blotching. Anthracnose does not cause significant losses.	Favor resistant trees Ensure stands are not overstocked

Disturbance Agent and Expected Loss or Damage	**Prevention, Options to Minimize Losses and Control Alternatives**
Tar Spot – *Rhytisma acerinum* This fungus grows black spots on leaves, particularly in the lower canopy. Tar spot does not causes significant losses.	
Venturia Leaf Blotch – *Fusicladosporium humile* Causes round reddish-brown to dark brown lesions on leaves. Lesions combine to kill large areas of leaves.	
WILT	
Verticillium Wilt – *Verticillium dahlia* and *V. albo-atrum* Causes wilt, leaf curling and drying, yellowing, defoliation and green-gray streaking in sapwood.	Generally not a problem in a forested setting Favor immune or resistant hosts like conifers, oaks, hickories, birches, etc.
CANKERS/ CANKER ROT	
Cerrena unicolor Causes discrete or diffuse cankers, white rot of sapwood and dieback in trees weakened by wounds or environmental stress. Small, white to greenish gray, hairy, bracket shaped mushrooms on bark.	Avoid wounding trees Harvest during the winter or dry part of summer Remove trees infected with canker-rotting fungi Trees infected with canker rots may provide excellent den trees. Consider leaving an occasional canker-rotted tree as a cavity tree for wildlife. Shorten rotation age
Eutypella canker – *Eutypella parasitica* Target shaped cankers that may have the margins greatly expanded to resemble to head of a cobra. Fungal reproductive structures may cause bark on the canker to be black. Cause wood decay.	
Hispidus canker - *Inonotus glomeratus* First rots heartwood, but eventually rots sapwood and kills the cambium. Fungus forms an elongate, bark-covered, perennial canker. Annual conks are yellowish to reddish. Heart rot is spongy and white to light brown.	
Hypoxylon canker – *Kretzschmaria deusta* Causes basal cankers associated with butt rot. Internal rot appears as reddish brown wood	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
discoloration and light-colored decay. Conks are large, lumpy groups of grayish white (early), or copper brown to brown or black (advanced) fungal structures.	
Nectria canker - *Neonectria galligena* Causes a target-shaped depression on the trunk and kills bark, cambium, and the outer sapwood. Wood decay associated with nectria cankers is rare.	
Valsa canker – *Valsa ambiens* Causes elongate, shallow cankers on stems and branches. Bark in the center of cankers usually contains many small, gray to white reproductive bodies. Does not typically kill trees and only affects branches < 10cm diameter typically.	
DECAY	
White Rots Mossy-top conk – *Oxyporus populinus* This fungus forms a spongy, straw-colored white rot in heartwood and sapwood	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 Northern Hardwoods Chapter 40 Section 8.1 for FHP Guidelines) Trees with decay may provide excellent den trees. Consider leaving an occasional decayed tree as a cavity tree for wildlife.
Phellinus igniarius Causes white heart rot. Forms hoof-shaped, perennial conks with cracked, black upper surfaces.	
Lacquered polypore - Ganoderma lucidum Causes white rot of sapwood in major roots and butt logs. Annual, reddish conks grow from the base of trees or out of major roots.	
ABIOTIC DAMAGE	
Spring frost damage Can cause sparse foliage and leaf drop by damaging developing buds and leaves in the spring.	
Winter frost damage	

Disturbance Agent and Expected Loss or Damage	**Prevention, Options to Minimize Losses and Control Alternatives**
Fine roots can be killed by frost during winters with little snow cover. This results in canopy dieback.	
Drought stress Thin crowns, tufted foliage, and dieback are symptoms of drought stress.	
Flooding Dieback, early fall color development, and mortality are symptoms after flooding.	

9 REFERENCES

Abrams, Marc D. 1998. The red maple paradox. BioScience 48(5): 335–364.

Atwood, Chad J; Fox, Thomas R; Loftis, David L. 2009. Effects of alternative silviculture on stump sprouting in the southern Appalachians. Forest Ecology and Management 257 (2009) 1305–1313.

Baker, W.L. 1972. Eastern Forest Insects. U.S.D.A. Forest Service Miscellaneous Publication No. 1175

Bartlett, T. (2011) BugGuide. http://bugguide.net/node/view/15740.

Burns, Russell M.; Honkala, Barbara H.; [Technical coordinators] 1990. Silvics of North America: Volume 2. Hardwoods. United States Department of Agriculture (USDA), Forest Service, Agriculture Handbook 654

Carmean, Willard H.; Hahn, Jerold T.; Jacobs, Rodney D. 1989. Site index curves for forest tree species in the eastern United States. General Technical Report NC-128. St. Paul, MN: U.S. Dept. of Agriculture, Forest Service, North Central Forest Experiment Station

Crow, T.R. 1983. Comparing biomass regressions by site and stand age for red maple. Can. J. For. Res.-Rev. Can. Rech. For. 13(2): 283-288.

Crow, Thomas R. and G.G. Erdmann, 1983, Weight & Volume Equations and Tables for Red Maple in the Lake States, Research Paper NC-242, USDA Forest Service, N.C. Forest Experiment Station, Washington, D.C.

Curtis, J.T. 1959. The vegetation of Wisconsin: an ordination of plant communities. Univ. of WI Press, Madison

Erdmann, G.G. 1986. Developing quality in second growth stands. In: Proceedings of the northern hardwood resource: management and potential conference; 1986 August 18-20; Houghton, MI; Michigan Technological University: 206-222.

Erdmann, G.G., Crow, T.R., and Rauscher, H.M. 1980. Managed even-aged red maple growth and yield study: study plan. USDA Forest Service North Central Forest Experiment Station, Rhinelander, WI.

Erdmann, G.G., Crow, T.R., and Rauscher, H.M. 1988. Foliar nutrient variation and sampling intensity for Acer rubrum trees. Can. J. For. Res.-Rev. Can. Rech. For. 18(1): 134-139.

Erdmann, Gayne G., R. M. Peterson, Jr., and R.R. Oberg, 1985, Crown Releasing of Red Maple Poles to Shorten High-Quality Sawlog Rotations, USDA Forest Service, Washington, D.C.

Erdmann, G.G., Peterson, R.M., and Oberg, R.R. 1985. Crown releasing of red maple poles to shorten high-quality sawlog rotations. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 15(4): 694-700.

Eyre, F.H., 1989, Forest Cover Types, Society of American Foresters, Washington, D.C.

Grisez, Ted J.; Mendel, Joseph J. 1972. The rate of value increase for black cherry, red maple,and white ash. Res. Pap. NE-231. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 26 p.

Haag, C.L., Johnson, J.E., and Erdmann, G.G. 1989. Rooting depths of red maple (Acer rubrum L.) on various sites in the Lake States. U.S. Department of Agriculture, Forest Service, North Central Experiment Station, St. Paul, MN.

Haag, C.L. 1987. The influence of soil-site factors on productivity of even-aged red maple stands in Michigan and Wisconsin. College of Natural Resources. University of Wisconsin, Stevens Point, WI. p. 269.

Hutnik, R.J. & H.W. Yawney. 1961. Silvical characteristics of red maple (*Acer rubrum*). USDA Forest Service, Station Paper 142. Northeastern Forest Experiment Station, Upper Darby, PA. 18p

Iverson, L.R. and A.M. Prasad. 2002. Potential redistribution of species habitat under five climate change scenarios in the eastern US. Forest Ecology and Management 155: 205-222.

Iverson, L.R., A.M. Prasad, S.N. Matthews, and M. Peters. 2008. Estimating potential habitat for 134 eastern US tree species under six climate scenarios. Forest Ecology and Management 254: 390-406.

Johnson, J.E., Haag, C.L., and Goetsch, D.E. 1986. Forest floor biomass and nutrients in red maple (Acer rubrum L.) stands of Wisconsin and Michigan. In Transactions, Wisconsin Academy of Science, Arts & Letters. Volume 74: pp. 142-146.

Johnson, James E., C.L. Haag, J. G. Bockheim, and G.G. Erdmann, 1987, Soil-Site Relationships and Soil Characteristics Associated with Even-Aged Red Maple (Acer rubrum) Stands in Wisconsin and Michigan, Forest Ecology Management P75-89.

Johnson, J.E., Haag, C.L., Bockheim, J.G., and Erdmann, G.G. 1987. Soil-site relationships and soil characteristics associated with even-aged red maple (Acer rubrum) stands in Wisconsin and Michigan. Forest Ecology and Management 21(1-2): 75-89.

Johnson, W.T. and Lyon, H.L. 1991. Insects That Feed on Trees and Shrubs, Second ed., revised. Cornell University Press.

Kotar, J, Burger, T.L. 1996. A guide to forest communities and habitat types of Central and Southern Wisconsin. Madison, WI: University of Wisconsin, Department of Forestry. 376 p.

Kotar, John, J.A. Kovach, and T.L. Burger. 2002. A Guide to Forest Communities and Habitat Types of Northern Wisconsin 2nd Ed., University of Wisconsin-Madison and Wisconsin Department of Natural Resources, 217 PP.

Londo, H.A., Strong, T.R., Soares, H., and Reed, D.D. 1999. Thinning effects on basal area growth of red maple (Acer rubrum L.). In 12th Central Hardwood Forest Conference. Edited by J. W. Stringer, and D. L Loftis. U.S. Department of Agriculture, Forest Service, Southern Research Station, Lexington, KY. p. 293.

Miles, P.D. Tue May 13 15:19:02 CDT 2014. Forest Inventory EVALIDator web-application version 1.6.0.00. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station. [Available only on internet: http://apps.fs.fed.us/Evalidator/evalidator.jsp]

Nowacki, G.j., M.D. Abrams, and C.G. Lorimer. 1990. Composition, structure, and historical development of northern red oak stands along an edaphic gradient in north-central Wisconsin. Forest Science 36: 276-292

Powell, D.S. and G.G. Erdmann. 1980. Red Maple. In F.H. Eyre (Ed.), Forest Cover Types of the United States and Canada. Society of American Foresters, Washington, D.C., 148 pp.

Rentch, James S.; Miller, Gary W.; Gottschalk, Kurt W. 2009. Crown class dynamics of oaks, yellow-poplar, and red maple after commercial thinning in Appalachian hardwoods: 20-year results. NJAF. 26(4): 156-163.

Rose, A. H., and Lindquist, O. H. 1997. Insects of Eastern Hardwood Trees. Natural Resources Canada Canadian Forest Service. Ottawa. Forestry Technical Report 29.

Reynolds, P.E., J.E. Murphy, and T.G. Siccama. 1979. Red Maple *Acer rubrum* Silvcultural Practices. Forest Notes 135 (winter): 2-27 (Society for the Protection of New Hampshire Forests, Concord, NH)

Sinclair, W. A. and Lyon, H. H. 2005. Diseases of Trees and Shrubs. Second ed. Cornell University Press.

Solomon, Dale S.; Blum, Barton M. 1967. Stump sprouting of four northern hardwoods. Res. Pap. NE-59. Upper Darby, PA: U. S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 13 p.

Stout, S.L., and R.D. Nyland. 1986. Role of species composition in relative density measurement in Allegheny hardwoods. Can J. For. Res. 16: 574-579.

Strong, T.F., and Erdmann, G.G. 2000. Effects of residual stand density on growth and volume production in even-aged red maple stands. Canadian Journal of Forest Research-Revue Canadienne De Recherche Forestiere 30(3): 372-378.

Strong, T.F., Hubbell, A.E., Weise, A.H., and Erdmann, G.G. 2006. Effects of crown release on growth and quality of even-aged red maple stands. Northern Journal of Applied Forestry 23(4): 229-233.

Trimble, G.R. 1974. Response to crop-tree release by 7-year-old stems of red maple stump sprouts and northern red oak advance reproduction. USDA For. Serv. Res. Pap. NE-303.

Wagner, D.L. 2005. Caterpillars of Eastern North America. Princeton University Press.

Ward, Jeffery S.; Stephens, George R. 1993. Influence of crown class, diameter, and sprout rank on red maple (*Acer rubrum* L.) development during forest succession in Connecticut. In: Gillespie, Andrew R.; Parker, George R.; Pope, Phillip E.; Rink, George: eds. Proceedings of the 9th Central Hardwood Forest Conference; Gen. Tech. Rep. NC-161. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 342-352

Wilson, Barry T.; Lister, Andrew J.; Riemann, Rachel I.; Griffith, Douglas M. 2013. Live tree species basal area of the contiguous United States (2000-2009). Newtown Square, PA: USDA Forest Service, Northern Research Station. http://dx.doi.org/10.2737/RDS-2013-0013

Wisconsin Department of Natural Resources (WDNR). 2012. Forest Resources Annual Report and Publications. Retrieved May 13, 2014. (http://dnr.wi.gov/topic/ForestBusinesses/publications.html)