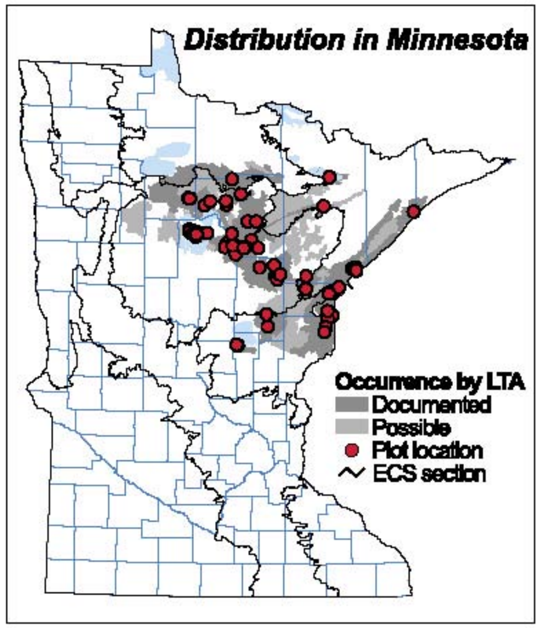
MHn47

MHn47 – Northern Rich Mesic Hardwood Forest

Natural Disturbance Regime, Stand Dynamics, and Tree Behavior

Summary and Management Highlights

Northern Rich Mesic Hardwood Forests (MHn47) are a common hardwood community found mostly within the Northern Minnesota Drift and Lake Plain and Western Superior Uplands ecological Sections of Minnesota. Outliers occur on the highlands above Lake Superior. Detailed descriptions of this community are presented in the DNR Field Guides to Native Plant Communities of Minnesota.



The range of MHn47 forests in Minnesota (shaded) and distribution of releve samples (red dots).

Commercial Trees

As a commercial forest, MHn47 sites offer a selection of hardwood crop trees, but few possible structural conditions if management is to favor the natural condition of mature, multi-layered, mesic-hardwood forest. Sugar maple, basswood, and yellow birch are all ranked as excellent choices as crop trees by virtue of their frequent occurrence and high cover when present on MHn47 sites (see Suitability Tables). Paper birch, northern red oak, and black ash are ranked as good crop trees, and stands can be managed to perpetuate these trees as co-dominants, especially when present or with evidence of former presence (e.g. stumps) in a particular stand. White cedar and red maple are ranked as just fair choices of crop trees, but stands could be managed to maintain their presence as minor trees for purposes other than timber production.

Among these species, paper birch, basswood, yellow birch and sugar maple were the dominant native trees that have occupied MHn47 sites for a long time and have had the opportunity through successive generations to adapt to physical conditions typical of these sites **(PLS/FIA-1)**. Quaking aspen, white spruce, balsam fir, and white pine are likewise native to MHn47 sites but occurred naturally at lower abundance. The consequence of fire suppression, commercial logging, and settlement in the past century has been to promote much more basswood and understory ironwood than was usual, mostly at the expense of paper birch and yellow birch. Past history and land use as also encouraged the ingress of species that were not significant in native MHn47 stands such as red maple, black ash, green ash, and red oak. However, the increased abundance of these trees is modest and not likely to complicate our interpretations and the use of natural regeneration models as silvicultural strategies. On MHn47 sites, all silvicultural strategies must consider the ever-present component of sugar maple that is dominant in all growth-stages and unchanged from pre-settlement times.

Natural Silvicultural Approaches

A significant proportion (33%) of native MHn47 stands were young forest <55 years old **(PLS-1)**. Given that less than 2% of MHn47 forests were described as having been burned or windthrown, it is clear that destructive agents other than these obvious events were involved to create so much young, small diameter MHn47 forest. We suspect disease, more so than anything that a surveyor might have described as a catastrophe. What seems clear from the historic records is that young, re-initiated MHn47 stands were patchy and created a mixture of situations where seeding, sprouting, and release of advance regeneration worked together to initiate the next forest. It is highly unlikely that re-initiated MHn47 forests resembled something as uniform or as large as a clear-cut. Patch cutting and variants of seed-tree cutting could approximate the level of canopy removal and natural pattern of disturbances that created young MHn47 forests. Paper birch and basswood where the species that did well historically in rather open conditions on MHn47 sites. Red oak and yellow birch should recruit well somewhere between large-gaps and open conditions.

In the historic landscape, 31% of the MHn47 stands were transitioning between the young and mature growth-stages **(PLS-1)**. Roughly these were stands 55-75 years old. At this time, senescence of the initial-cohort quaking aspen, paper birch, and basswood created regeneration opportunities for trees ranging from single-tree gaps to large gaps up to an acre. Several silvicultural systems could be used to approximate the natural loss of initial-cohort trees and regeneration typical of transitioning MHn47 forests. Selective harvesting matches best the small-gap mortality pattern, and on MHn47 sites would favor sugar maple over all other species. All other MHn47 trees recruited well in large gaps. Patch cutting, variants of seedtree, variants of shelterwooding, and group selection could all work depending upon current stand conditions. More than anything, the pattern and vigor of the initial-cohort trees to be removed or reserved would dictate the system to be applied.

Most of the MHn47 landscape (37%) was forest older than 75 years **(PLS-1)**. The hallmark of these forests was the steady establishment and recruitment of trees in gaps. For a little-disturbed community dominated by sugar maple, it is amazing that only sugar maple exhibited only the traits of a small-gap regeneration strategist. Thus, we suspect that the natural pattern of tree mortality in the mature and very old growth-stages created both large and small gaps. This is not so different then from the transition, except that gap formation was steady in comparison to the more synchronous decline of and initial cohort. The same silvicultural systems could be employed as mentioned for the transition, but perhaps completed in several entries. From their performance in modern forests **(R-2)**, it is clear that sugar maple, basswood, and ironwood would perform well in the small gaps created by selective harvesting. Group selection and variants of shelterwooding would approximate large-gap canopy removal and favor paper birch, yellow birch, red oak, basswood, and black ash.

Management Concerns

MHn47 communities occur mostly on medium textured soils where there are serious concerns about heavy equipment compacting or rutting the soil. On stagnation moraines and till plains, this community consistently occurs on loamy till that is capped with wind-deposited silt loam. These soils are highly susceptible to compaction; they require long drying periods because they hold water so effectively; and they are likely to rut because the surface is stoneless and often saturated above denser till below. On some till plains, the surface is sandy loam and often gravelly, which diminishes the risk of compaction and rutting. Unless soil tests prove otherwise, just the occurrence of the MHn47 community itself is a reliable indicator that frozen soil conditions are needed for logging operations. Locally, the distribution and abundance of yellow birch is a fair indicator of the siltier and more sensitive soils that should be avoided.

On dissected glacial lake sediments, the parent material is stratified silt and clay. Slopes that dissect the sediments tend to be better drained but the texture of surface soils are unpredictable and usually sensitive to compaction. Also, some strata in the glacial lake sediments are conductive aquifers resulting in side-hill seeps that are structurally weak even when the surrounding landscape is largely frozen. Flatter terrain is too poorly drained for summer operations. Thus, unpredictability of the dissected lake plain makes the risk of compaction, rutting, and erosion too high for anything but frozen soil operations and possibly requiring cable skidding.

Occasionally, MHn47 forests occur on stony till overlying glacially scoured bedrock. Soil texture ranges from coarse sandy loam to quite silty. Field verification of the texture is required to determine if compaction is a concern or not. The bouldery parent material often gains enough skeletal strength from stones to support heavy equipment. In such cases, rutting is not likely.

The landscape balance of growth-stages and stand ages for the MHn47 community is considerably different than it was historically. Today, there is much less young forest (<55 years) and substantially more mature forest (>95 years) than in pre-settlement times **(PLS/FIA-1)**. This is surprising given the general trend of shortening natural rotations in managed forests in Minnesota. It is important to remember that MHn47 forests were not re-initiated by coarse-scale catastrophic events like fire and windthrow. A substantial amount of old forest legacy was passed on to young forests. Except for yellow birch, most trees occur at similar abundances in all growth-stages under 195 years. However, the direction of change for any species seems consistent and predictable in the course of stand maturation. The most likely effect of management has been to coarsen the scale of stand age differences. We envision regeneration in 1-10 acre patches as a reaction to pockets of disease or perhaps prolonged vernal ponding. The more mobile animals might not have perceived great habitat differences among young, transitioning, or mature MHn47 forests as patches of each were very evenly represented (roughly a third each, **PLS-1**) across expansive landscapes such as the Guthrie Till Plain, Goodland Delta, and Sugar Hills.

The most concerning compositional change has been the loss of both paper and yellow birch. In our experience, MHn47 sites are capable of producing extraordinary, large-diameter, high-quality birch. It seems as if a natural disturbance agent is somehow missing as both birches require substantial sunlight for establishment on MHn47 sites, as evidenced by their poorer than usual regeneration under a canopy **(R-2)**. A missing disturbance might also explain the landscape trend of more mature forest. Gone also are the conifers. This is most evident in the mature and very old growth stages where balsam fir, white spruce, and especially white pine were a small but significant component of older MHn47 forests **(PLS/FIA-1)**. The loss of birch and conifers could be linked to soil problems rather than disturbance. Unlike most deciduous trees, birch share some mychorrizal associates with conifers. A potential culprit is the earthworm. MHn47 sites are base-rich and the deciduous litter is prime worm food. In a landscape with a variety of mesic hardwood forest communities, worm infestations are predictably worse on MHn47 sites. We do not yet understand how worms affect the fungi or even if they affect the mychorrizae important to birch and conifers. Understanding the effects of these worms is an important silvicultural challenge in managing MHn47 forests. The loss of birch and conifers has resulted in a rather even increase in all other species. Most evident is the increase in basswood along with more modest rises in ironwood, red maple, black ash, green ash, and red oak. No increasing species has been so overwhelmingly favored as to pose a management concern.

Natural Disturbance Regime

Natural rotation of catastrophic and maintenance disturbances were calculated from Public Land Survey (PLS) records at 1,579 corners within the primary range of the MHn47 community. At these corners, there were 4,205 bearing trees comprising the species that one commonly finds in MHn47 forests.

The PLS field notes described about 1% of the MHn47 landscape as recovering from stand-regenerating fire. All such records were of burned-over lands. From these data, a rotation of 1,820 years was calculated for stand-replacing fire.

Elsewhere in the MHn47 landscape, the surveyors described lands as windthrown without suitable-sized trees for scribing. Such corners were encountered at about 1% of the time, yielding an estimated rotation of 1,970 years for windthrow.

Far more common at MHn47 sites were references to what we have interpreted as some kind of partial canopy loss, without any explicit mention of fire or windthrow. Most references were to sparse forest or scattered timber with distances to bearing trees that were intermediate between the distances for burned/windthrown lands and what is typical for fully stocked mesic hardwood forests. About 2% of the survey corners were described as such, resulting in a calculated rotation of 330 years for disturbances that maintained some early and mid-successional trees on MHn47 sites. Corners described as burned (13) or windthrown (12) are roughly equal and very low, suggesting that surface fires and partial windthrow played a small role in MHn47 forests.

Natural Rotations of Disturbance in MHn47 Forests Graphic	
	Banner text over photo
Catastrophic fire photograph	**1,820 years**
Catastrophic windthrow photograph	**1,970 years**
Partial Canopy Loss, photograph	**330 years**

Compared to other mesic hardwood (MH) communities in Minnesota, MHn47 rotations of catastrophic disturbance are similar in that they exceed the longevity of any initial cohort species. The rotations of both stand-regenerating fire (1,820 years) and windthrow (1,970 years) suggest that neither was particularly important on MHn47 sites. Natural stand dynamics involved many generations of trees and favored species like sugar maple that can regenerate in small gaps caused by the demise of a single tree or a few trees. The rotation of 330 years for maintenance disturbance is the longest of northern MH forests away from the protective climate along Lake Superior (MHn45). The correlation of this community with silty soils may explain the very low levels of disturbance. Because of the high water-holding capacity of silt, MHn47 soils were probably saturated throughout spring fire season. Also, soil water tends to “hang” at the contact between the silty loess caps and underlying parent material. This probably promotes rather deep rooting and windfast trees.

Natural Stand Dynamics & Growth-stages

Following stand-regenerating fire or possibly windstorms, young MHn47 forests exhibited modest, but distinctive compositional change from that of the older, parent community. Young forests included a significant legacy of late-successional trees, and older forests maintained enough early successional trees for them to increase in abundance after a disturbance **(PLS-1)**. Quaking aspen, paper birch, and basswood are favored in young forests, and most compositional change is the result of their successive decline beginning with the a decline in aspen and basswood followed by a decline in paper birch, thus creating a period of transition characterized by significant compositional change **(PLS-4)**. Unlike many other hardwood communities, MHn47 forests show continued and directional change throughout the mature growth stage that was just slightly slower than observed in the transition stage. Changes in mature forests were the result of steadily increasing amounts of sugar maple and white pine. Incredibly, most of the important MHn47 trees had their greatest regenerative success in the young growth-stage **(PLS-5)** ... even though they are quite different with regard to shade-tolerance, successional position, and regeneration strategy. The post-disturbance MHn47 environment must have offered quite a variety of conditions for seeding, sprouting, and release of advance regeneration. The tendency of old MHn47 stands to have scattered, large white pines is the primary reason we chose to recognize and describe a very old growth-stage.

Views and Summaries for MHn47 sidebar	
PLS-1	**Summary of historic growth-stages:** relative abundance of bearing trees
PLS-2	**View line-graph of historic change:** bearing tree abundance across age-classes
PLS-3	**Summary of historic disturbance:** abundance of bearing trees at burned, windthrown or disturbed sites
PLS-4	**View historic rates of change:** ordination of bearing tree age-classes
PLS-5	**Summary of historic regeneration:** Species ratings regarding their ability to regenerate after disturbance, in gaps, and beneath a canopy
R-1	**Summary of tree suitability for a Native Plant Community:** Species ratings based upon modern forests
R-2	**Summary of understory recruitment in modern forests:** indices of species' success in the understory
FIA-1	**Summary of regeneration in modern forests:** FIA trees in multiple-cohort situations
PLS/FIA-1	**Summary of differences between modern and pre-settlement forests:** relative abundance of bearing trees and FIA trees by growth-stage.

Early in the process of stand maturation, MHn47 stands achieved tree densities that were fairly stable. Temporal change in tree density followed the textbook concept of young, small-diameter forests being tightly packed – followed by older, large-diameter stands with trees more widely spaced. Presumably, crown competition among canopy trees causes this. Young MHn47 forests under 55 years had mean distance of just 16 feet from survey corners to the bearing trees. This is tighter than usual for MHn communities. It would seem that whatever synchronously killed trees on MHn47 sites left advance regeneration intact. Transitioning forests 55-75 years old had bearing trees 17 feet away from their corners on average. Even in the mature growth-stage (75-195) tree density was still high as bearing trees were only about 19 feet from their corners. Only in the old growth stage were bearing trees at the more usual spacing of 23 feet. Perhaps this was the effect of the white pine supercanopy.

Young Growth-stage: approximately 0 – 55 years

About 13% of the MHn47 landscape in pre-settlement times was covered by forests estimated to be under 55 years old **(PLS-1)**. About 68% of the survey corners in young stands were of mixed composition, which is quite low for hardwoods in general and a bit surprising given that older MHn47 growth-stages were more than 90% mixed. Thus, an effect of stand regenerating disturbance in MHn47 forests was to create regeneration opportunities that could favor a single species. Trees with quite different ecology could find themselves as the sole species at survey corners. Sugar maple, basswood, quaking aspen, and red oak were about equally present in monoculture. Whatever happened to regenerate MHn47 forests must have been variable in effect. Some disturbances must have released a lot of sugar maple and basswood advance regeneration. In other cases, disturbances favored the usual pioneering species like quaking aspen, paper birch, and red oak.

Our impression is that the post-disturbance environment in MHn47 forests was naturally patchy. In no way could fire have had the homogenizing effect that it can in fire-dependent forests, creating large areas of similar, mineral soil surfaces where quaking aspen and jack pine can totally dominate. It is the nature of MHn47 sites and northern hardwood sites in general to occur on topographically variable landforms where slope, depth to water-perching soil horizons, soil drainage class, and density of included wetlands vary at a fairly fine scale and can affect the behavior and effect of wildfire. We believe also that these site variants have some control over the distribution and abundance of ever-present, native disease vectors (e.g. *Armillaria*) that weaken roots and tree boles. The patchy nature of these diseases and weakened trees probably allowed for a patchy response of MHn47 forest to windthrow and rarely the effectiveness of surface fires. Our general impression is that the "average" stand-regenerating event in MHn47 affected just a little more than half the site, leaving substantial amounts of legacy from the parent forest in the form of both trees and advance regeneration.

Perhaps most important is to recognize just how rare young MHn47 forests were. According to the PLS notes, just 3% of the whole MHn47 landscape was disturbed to any degree **(PLS-3)**. Our interpretation of what young MHn47 forests were like is based on an incredibly sparse set of direct descriptions and inferential data.

Transitional Stage: approximately 55 – 75 years

About 31%, of the historic MHn47 landscape was forest undergoing considerable compositional change **(PLS-1)**. This transition was driven the successive decline of quaking aspen, basswood, and then paper birch, which is matched mostly by increases in yellow birch and some white pine. Stands in this stage were more often mixed (91%) than monotypic. Monotypic conditions were represented mostly by survey corners where all bearing trees were sugar maple or basswood. At survey corners with mixed composition, sugar maple was the most cited species and it was mixed with a wide variety of trees including early successional species like paper birch, quaking aspen, and basswood, and also later-successional trees like yellow birch and a surprising amount of balsam fir. The decline of the initial-cohort aspen, birch, and basswood starts early in the young growth-stage and continues throughout the transition stage. Much of the compositional movement which characterizes transitions **(PLS-4)** was the result of their differential demise, falling at varying rates while yellow birch dramatically increased. The demise of quaking aspen was rapid and coincident with basswood, but basswood's rate of fall was slower. On the heels of this event was the decline of paper birch, which was far slower because it had limited success replacing itself until age 80 **(PLS-5)**.

Because the decline of the initial-cohort involves several species and because it was happening about a core presence of sugar maple **(PLS-1)**, we doubt that there was much synchronous mortality and formation of large canopy gaps. Of the initial-cohort species, quaking aspen was the most likely to have coincident mortality due to its clonal nature. Yellow birch seems to be the direct benefactor of aspen decline as its rise mirrors aspen's fall. The relative abundance of yellow birch rose from trace amounts in the young growth-stage to nearly 17% in the 60 year age-class. This spike in yellow birch recruitment was the main reason we chose to start the transition stage at 55 years. White pine was the species that seemed to react more directly to the slow demise of paper birch during the transition stage. This trend of white pine replacing paper birch continued into the mature growth-stage.

Mature Growth-stage: approximately 75-195 years

About 35% of the historic MHn47 landscape was mature forest **(PLS-1)** where the rate of successional change slowed **(PLS-4)**. Stands in this stage were far more likely to be mixed (93%) than monotypic. Patches of pure sugar maple, basswood, and yellow birch were most common. Nearly all mixed corners involved sugar maple mixed with some other tree. Trees mentioned most often as sharing a survey corner with sugar maple were basswood, yellow birch, and paper birch. The list of associated species though is long, suggesting that mature MHn47 forests supported many species of trees at low abundance.

More than any other hardwood community in the northern floristic region, mature MHn47 forests resembled the classic concept of climax forest. The appearance and functioning of these forests revolved around a stable base of sugar maple at about 30% relative abundance and basswood at about 10% relative abundance **(PLS-2)**. Their "hold" or dominance of these species on MHn47 sites would have been most evident in the understory, especially among saplings as sugar maple, basswood, and ironwood have excellent success recruiting saplings and all other species have only fair or poor ability to do this **(R-2)**. Sugar maple, especially, was poised and ready to fill small gaps in the canopy. More than any other tree, sugar maples occurred at subcanopy diameters in the presence of larger bearing trees.

However, MHn47 forests were never became pure stands of sugar maple in spite of maple's obvious success and dominance. All other species of importance showed far better performance in large gaps or open conditions. Yet such open conditions were rarely described by the surveyors (see Disturbance Regime). Our interpretation is that the stable composition of mature MHn47 forests was sustained by maintenance disturbances that (1) created both large and small gaps, (2) were a predictable and steady attribute of the MHn47 landscape, and (3) were rarely perceived by the surveyors as a noteworthy disturbance. Most obvious to us is the fact that the landforms and soils where MHn47 forests are the matrix vegetation perch and retain more vernal water that other upland forest communities in the northern floristic region. It is probably significant that black ash and yellow birch are important in modern forests and that American elm, white spruce, and white cedar had some importance historically. The minor tree components of MHn47 forests, lean towards species that are successful in wetter situations. It seems possible that cyclic episodes of prolonged ponding could weaken groups of trees and occasionally provide the light conditions that the minor species needed for regeneration opportunities. Alternatively, it is possible that the formation of gaps involving a few trees to a few acres of trees was biologically mediated. Most likely are pockets of native diseases such as *Armillaria* because the distribution of species or specific genotypes occur at the correct scale. It may be significant that MHn47 sites in northern Minnesota have been the core refuge of sugar maples for the past four millennia, far longer than suspected for other hardwood communities where the unchecked expansion of sugar maple is likely the consequence of fire suppression. The abundance of sugar maple on MHn47 sites has hardly changed in spite of the considerable influences of fire suppression and logging **(PLS/FIA-1)**. Perhaps sugar maple and its hardwood associates after many generations of trees and little disturbance, become more attuned to inherent sources of mortality and gap size rather than being dependent upon external sources like fire and wind.

Very Old Growth-stage: approximately >195 years

Very little of the historic MHn47 landscape, just 2%, was estimated to have been MHn47 stands older than 195 years **(PLS-1)**. All of the survey corners with these large old trees were mixed in composition. This growth-stage represents a rather arbitrary time period when MHn47 forests escaped major disturbance for a long time. It is the culmination of slow, but steady gains of sugar maple and white pine that started in the mature growth-stage. We believe that MHn47 stands this old had a discontinuous super canopy of white pine over a continuous canopy of hardwoods dominated by sugar maple.

Trees that one would find in the initial cohort – paper birch, aspen, and basswood – are barely present in very old MHn47 forests. As discussed above, maintenance disturbance must have been involved in maintaining these species even though they were very infrequent. Their persistence in very old forests allowed for slight presence to translate into considerable success after stand-regenerating disturbance.

A curiosity is the behavior of white spruce and balsam fir on MHn47 sites. Neither species is important today in MHn47 forests, which is why they were not covered in the MHn47 species accounts. Historically though, both species show their typical behavior on upland sites in the northern floristic region. In the transition stage there is a pulse of balsam fir recruitment, to as much as 14% relative abundance followed by its collapse and persistence at about 1-2% abundance. White spruce, as usual, ingresses at about age 80 **(PLS-5)** and seems well on its way towards dominance in the following age-classes. Usually, the ingress of these species is a sure sign that they will be important, if not dominant in very old forests (but see also MHn35). On MHn47 sites though, they eventually disappear and sugar maple emerges as the ultimate climax species. We don't know why.

Growth Stage Key

Understanding natural growth-stages is important because it offers the opportunity to maintain stands indefinitely by mimicking maintenance disturbance regimes, or to direct succession during transitional episodes of mortality and replacement by other species. Use the following descriptions to determine the growth-stage of the stand you are managing.

Young Forests	∞
Transitional Forests	∞
Mature Forests	∞
Old Forests	∞

Tree Behavior

Tree “behavior” is an important element of silviculture and we are interested in it because we want to predict how a tree or stand of trees will respond given a management activity. For example, can we increase the relative abundance or yield of certain crop trees by doing this? Will individual trees grow, die, branch, make seeds, sprout, etc. if we do that?

Behavior is influenced by many things comprising a wide variety of scientific disciplines such as: genetics, physiology, population ecology, and community ecology. Tradition has been to focus on the first three of these as they are properties of a species. Nearly all silvicultural information is currently organized about species – but most authors admit that species properties vary substantially as they interact with other plants and the environment.

Our Native Plant Community (NPC) Classification allows us to contemplate a few elements of community-dependent behavior which can then be blended with the traditional silvics to create a fuller understanding of tree behavior. We view our NPC Classification as an empirical measure of the mind boggling interaction of trees with soil moisture conditions, nutrient availability, competing plants, diseases, pests, and wildlife that occupy the same place. Using this framework is an important paradigm shift because maintenance of these complex interactions is now a stated goal in forest management – in contrast to agricultural approaches where disrupting these interactions was the primary means of getting uniform and desired responses from crop trees.

To this end, we have performed analyses using Public Land Survey records, FIA subplots, and releves to answer three very basic questions as to how trees behave in their community context:

∞ Suitability – for each NPC Class, how often and in what abundance do we see certain tree species in stands where there has been no obvious effort to silviculturally alter abundance or remove competition?

∞ Succession – for each NPC Class, what was the natural reaction to fire and windthrow and how did the different species succeed one another?

∞ Regeneration strategies – for each common species within a NPC Class, what were/are the natural windows of opportunity for regeneration throughout the course of succession?

Sugar Maple

- ***excellent habitat suitability rating***
- ***late-successional***
- ***small-gap (large-gap) regeneration strategist***
- ***regeneration window at 0-50 years***

Suitability

MHn47 sites provide ***excellent habitat*** for sugar maple trees. The perfect ***suitability rating*** of 5.0 for sugar maple is influenced mostly by its incredibly high presence (98%) as trees on these sites in modern forests **(R-1)**. When present, sugar maple is an important co-dominant and usually dominant tree, contributing 42% mean cover in mature stands. The ranking is perfect, because no other tree or plant has a higher presence and cover on MHn47 sites as sampled by releves. Northern mesic hardwood communities in general offer excellent-to-good habitat for sugar maple (see Suitability Tables). Sugar maple is the highest ranked tree when in occurs in the better drained communities: MHn47, MHn45, MHn35.

Young Growth-stage: 0-55 years

Historically, sugar maple was the dominant tree in young MHn47 stands **(PLS-1, PLS-2)**. Amazingly, young sugar maples represented 50% of the trees at survey corners described as burned **(PLS-3)**. This result is not at all consistent with its well-known sensitivity to fire. Sugar maple was also the dominant tree at windthrown corners, as it represented 45% of the trees at such survey corners. This result is expected if the effect of windthrow was to remove canopy trees and release the ever-present advance regeneration of sugar maple in older stands. This is also the tree's reaction to logging in modern forests as it is now common in young MHn47 forests **(PLS/FIA-1)**. It is important to note that the actual number of trees recorded at survey corners directly described as burned or windthrown is incredibly low, just 48 trees in 3,413 **(PLS-3)**. These data may be unreliable, and sugar maple most likely appeared at corners described as burned or windthrow because of legacy remnants of the parent stand. For such few direct observations of disturbed forests, there was a surprising amount of young MHn47 forest (33%), meaning that the surveyors didn't often ascribe any disturbance to the small-diameter stands **(PLS-1)**. Sugar maple regeneration coming in among larger trees was substantial (~18% of all bearing trees) post-disturbance window **(PLS-5)**. All occurrences of smaller-diameter maples were at survey corners of mixed composition. These young trees could come in under almost any other species, but did so more often beneath larger sugar maples and sometimes beneath basswood, paper birch, or red oak. Although it is tempting to dismiss what seems to be unusual behavior of sugar maple to low sample numbers in the initial age-class, the following age-classes are well-populated samples and they are obviously a continuation of sugar maple's immediate success in disturbed MHn47 forests. Our interpretation is that the success of sugar maple in the young growth-stage is the consequence of releasing the pervasive bank of seedlings common in older MHn47 forests. The historic reaction of the seedling bank to windthrow and modern reaction to canopy removal through logging is quite in line with this hypothesis. Regeneration of MHn47 stands by fire is problematic in that such fires needed to be intense enough to kill trees, but not eliminate the advance regeneration of sugar maple. We favor the idea that the effect of fire burning through hardwoods was patchy and at a fine scale, leaving enough of a maple legacy in wet depressions and swales to repopulate the stand. Alternatively, the surveyors were mistaken. A common field error is to mistake the jet black, maple boles and branches on the forest floor for charred wood. The black color comes from a fungus that lives on the surface of dead maple debris.

Transition: 55-75 years

As stands transitioned to mature conditions sugar maple abundance changes very little, dropping just a few percent **(PLS-1)**. Compositional change in MHn47 forests at this time was driven by the loss of initial-cohort paper birch and quaking aspen while the core, maple element remained fairly constant **(PLS-2)**. Small-diameter, sugar maple regeneration coming in among larger trees was common throughout the transition stage **(PLS-5)**. In most cases, young sugar maples were coming in under the declining canopy of initial-cohort paper birch and quaking aspen. However, there is a long list of species below which we recorded sugar maple regeneration, meaning that maple was having no problem replacing any species on MHn47 sites. Most sugar maple bearing trees were the smaller tree at transitioning survey corners.

We interpret this as good success at establishment and recruitment of seed-origin maples under a canopy, and initial development of the multi-layered structure that helps sugar maple dominate less-tolerant trees. This interpretation is strongly supported by sugar maple's perfect indices of regeneration in modern forests **(R-2)** and its performance on FIA plots **(FIA-1)** were it does well in all subordinate situations (12, 13, 23).

Mature Growth-stage: 75-195 years

The mature growth-stage is a period of slowed, but directional compositional change **(PLS-4)** during which sugar maple gradually increases to assert dominance on MHn47 sites. Sugar maple represents about a third of all trees at this stage, more than any other tree **(PLS-1, PLS-2)**. Its steady presence was the result of good establishment and recruitment for the first 80 years of stand maturation **(PLS-5)** followed by high survivorship. Surprisingly small-diameter sugar maple regeneration in mature stands was detected only in the 80-year age-class, whereas it was common throughout the young growth-stage and transition **(PLS-5)**. At this time, sugar maples were far more common as the smaller tree at a survey corner. We interpret this as sugar maple continuing to build its abundance in the subcanopy. When sugar maple was the smallest tree, it was coming in below any tree that can occur on an MHn47 site. At this stage, it was most common for sugar maple to be beneath paper birch and sometimes quaking aspen. Commonly it was building a subcanopy beneath itself and to some extent under basswood. We interpret this as sugar maple continuing to replace the remnants of initial-cohort aspen and paper birch and as demonstrating its ability to replace itself indefinitely on MHn47 sites. Sugar maples were successful in all strata of a mature MHn47 forest with any overstory composition.

Very Old Growth-stage: >195 years

The very old growth-stage years is a rather arbitrary time period representing the condition of MHn47 forests that have escaped major disturbance for a long time. It is the culmination of slow, but steady gains of sugar maple and white pine that started in the mature growth-stage. We believe that MHn47 stands this old had a discontinuous super canopy of white pine over a continuous canopy of hardwoods dominated by sugar maple. The relative abundance of sugar maple in the very old growth-stage is 43%, which is the highest for any species **(PLS-1)**. All sugar maple bearing trees were the smaller tree at the survey corner, and most were beneath larger white pines or yellow birch. This probably has more to do with our ability to model tree age by using diameters, as only white pine and yellow birch achieved large enough diameters to produce age estimates in excess of 195 years. The peak of sugar maple abundance in the very old growth-stage is the primary reason that we consider it to be a ***late-successional*** species on MHn47 sites.

Regeneration Strategies

Sugar maple's primary regenerative strategy on MHn47 sites is to develop a pervasive bank of seedlings capable of recruiting in ***small-gaps***. However, sugar maples were successful at this following almost any degree of canopy removal, ranging from catastrophic events to single-tree gaps. They were able to do this in the presence of any other species of tree, including other sugar maples. In the historic PLS data this interpretation is supported by: (1) the fact that sugar maple is important in the mature and very-old growth-stages of the community **(PLS-1, PLS-2)**, and (2) it is abundant at mature survey corners showing no canopy loss or disturbance **(PLS-3)**. The high percent of sugar maples as seedlings in subordinate canopy situations (situations 12 and 13) in the FIA data **(FIA-1)** is also a characteristic of species that tend to regenerate best in small gaps. The releve sampling of mature MHn47 forests shows that sugar maple is unequalled at establishing and recruiting individuals in all understory strata, eventually resulting in canopy dominance **(R-2)**.

The high abundance of sugar maple as poles in tree stands (situation 23) is quite characteristic of trees that do well in ***large-gaps*** **(FIA-1)**. The immediate presence of sugar maple in young MHn47 stands historically **(PLS-1)** is also a good indication that sugar maples responded positively to patchy canopy openings much larger than a small-gap. We believe that sugar maples can also do well in larger openings as long as the advance regeneration is present.

Historic Change in Abundance

Today, sugar maple is about as abundant and dominant on MHn47 sites as it was historically **(PLS/FIA-1)**. The very old growth stage is the only one to show a significant departure from historic conditions. However, the apparent decline of sugar maple in this stage is probably due to the extremely low number of FIA plots in very old, existing forests and unreliable calculations. Our interpretation is that MHn47 sites are such good maple habitat that any disturbance – fire, wind, or logging – has had little effect on altering sugar maple's hold on the land.

Basswood

- ***excellent habitat suitability rating***
- ***early successional***
- ***open (large-gap) regeneration strategist***
- ***regeneration window at 0-30 years***

Suitability
MHn47 sites provide ***excellent habitat*** for basswood trees. The ***suitability rating*** of 4.9 for basswood is influenced mostly by its very high presence (93%) as trees on these sites in modern forests **(R-1)**. When present, basswood is an important co-dominant tree, contributing 22% mean cover in mature stands. The ranking is second, behind sugar maple on MHn47 sites as sampled by releves. Northern mesic hardwood communities in general offer excellent-to-good habitat for basswood (see Suitability Tables). MHn47, MHn35, and MHn46 all offer the excellent opportunities for growing basswood and are equally good.

Young Growth-stage: 0-55 years
Historically, basswood was an important tree in young MHn47 stands **(PLS-1, PLS-2)**. During this stage its abundance peaked at 13% of all trees and for this reason we consider basswood an ***early successional*** species on MHn47 sites. Young basswood represented 23% of the trees at survey corners described as burned **(PLS-3)**. This result is consistent with its well-known ability to sprout when fire or another agent kills the main stem. Basswood was also successful at windthrown corners where it also represented 14% of the trees. Small-diameter basswood regeneration coming in among larger trees was abundant in the post-disturbance window **(PLS-5)**. Our interpretation is that a substantial bank of basswood seedlings and stump sprouts were available to re-colonize MHn47 stands following removal of the canopy.

Transition: 55-75 years
As stands transitioned to mature conditions basswood decreased in abundance **(PLS-1)**. We estimate that this decrease started immediately after disturbance and continued for the life of the stand until basswoods were minor co-dominants in old stands **(PLS-2)**. Small-diameter basswood regeneration was present in the early part of the transition stage until the 60-year age-class **(PLS-5)**, but not at levels as high as during the young growth stage. In most cases, young basswoods were coming in under quaking aspen and paper birch. We interpret this as good success at establishment and recruitment of seed-origin basswood under the declining canopy of less-tolerant hardwoods, but probably having less success under sugar maple. This is somewhat contrary to our observations in modern forests where basswood is doing well regenerating in maple-dominated stands **(R-2)**. However there are so few aspen- and birch-dominated MHn47 forests that it is hard to know if its establishment and recruitment would be even better under those circumstances.

Mature Growth-stage: 75-195 years
The mature growth-stage is a period of slowed, but directional compositional change **(PLS-4)** during which sugar maple gradually increases to assert dominance on MHn47 sites. During this stage, the abundance of basswood continued to decline, but very slowly **(PLS-1, PLS-2)**. Its presence was most likely the result of establishment and recruitment for the first 60 years of stand maturation **(PLS-5)** followed by good survivorship. Surprisingly, small-diameter basswood regeneration was not detected during the mature growth-stage, whereas it was common until stands were 60 years old **(PLS-5)**. At this time, basswoods were slightly more common as the smaller tree at a survey corner. We interpret this as basswood having some success in the subcanopy, relying more on survivorship than a large pool of small trees like sugar maple. When basswood was the smallest tree, it was most favored when coming in under paper birch. There were examples however, of basswood beneath almost any tree that can occur on an MHn47 site, including sugar maple. We interpret this as basswood demonstrating its ability to perpetuate itself as a minor species with sugar maple, and being able to do well in patches of MHn47 forests where sugar maple had yet to dominate.

Very Old Growth-stage: >195 years

The very old growth-stage years is a rather arbitrary time period representing the condition of MHn47 forests that have escaped major disturbance for a long time. It is the culmination of slow, but steady gains of sugar maple and white pine that started in the mature growth-stage. At this stage, basswood was a minor tree at 5% relative abundance **(PLS-1)**. We did not detect small-diameter basswood regeneration in this growth-stage **(PLS-5)**, but when basswoods were present at survey corners this old, they were always the smaller tree. This suggests to us that there was some basswood regeneration in very old forests, but none met our restrictive, half-diameter rule for inclusion in table **PLS-5**. In modern forests, basswood has excellent indices of regeneration and can clearly maintain a seedling bank under a canopy, which allowed it to persist at low abundance in very old MHn47 forests **(R-2)**.

Regeneration Strategies

On MHn47 sites basswood exhibits regenerative flexibility, which allows it to be a minor, but ever-present tree throughout the full course of stand maturation. Basswood sprouts effectively following disturbances that kill the main stem, and it is able to carry its density as a tree into young growth stages. Its slightly higher abundance in the young growth stage **(PLS-1)** could be due to the fact that that it was a much better at sprouting than sugar maple. Basswood also maintains a bank of seedlings capable of recruiting in gaps of any size. Basswoods were successful at this beneath other tree species and as well as under larger basswoods. We believe that basswood was most successful increasing its presence locally by sprouting after catastrophic disturbance and out-competing other trees in the ***open***. In the historic PLS data this interpretation is supported by the fact that basswood abundance peaks in the young growth-stage **(PLS-1, PLS-2)**, (2) it is more abundant at disturbed survey corners than in mature, undisturbed forests **(PLS-3)**, and (3) its primary window of regeneration was during the post-disturbance years **(PLS-5)**.

The modern data though, present a different regenerative picture for basswood on MHn47 sites. Basswood has excellent indices of establishment and recruitment under the canopy of modern forests **(R-2)**. These indices, 4.5 to 4.7, are quite in line with trees able to fill small canopy gaps. In stands sampled by FIA plots, basswood has high presence as poles in tree stands (situation 23), which is typical of species that prefer ***large-gaps*** for recruitment. Our general impression is that when co-existing with sugar maple, larger canopy gaps improve the chances of a young basswood out-competing advance regeneration of sugar maple.

Historic Change in Abundance

Today, basswood is more abundant and more dominant on MHn47 sites than it was historically **(PLS/FIA-1)**. Its populations have essentially doubled in historic time. Basswood now constitutes 20% of all trees in the young growth-stage compared to 13% historically. The increase is even more impressive in mature forests where it is now 26% of the trees compared to just 9% historically. Though it shows incredible gains in the very old growth-stage, the data there are too sparse for reliable conclusions. We believe that fire suppression, though infrequent historically, is the primary reason for seeing basswood populations increase on MHn47 sites at paper birch's expense. Its increases in the average stand (FIA) suggests that it responds well to typical logging practices on MHn47 sites. Its high presence as a tree in the releves **(R-1)** would indicate that it will probably continue to increase in abundance relative to other trees in unmanaged stands as well.

Yellow Birch

- ***excellent habitat suitability rating***
- ***mid- (late) successional***
- ***large-gap (open) regeneration strategist***
- ***regeneration window at 0-60 years***

Identification Problems

The PLS surveyors usually distinguished yellow from paper birch, but not always. Thus, interpretations of PLS data for the more common yellow birch on MHn47 sites should always be done knowing that some of these trees were likely paper birch. MHn47releve samples show that for plots with birch present: 10% have both species present; 30% are paper birch without yellow birch; 60% are yellow birch without paper birch. For this analysis, tree records were biased towards yellow birch because we assigned generic references to “birch” to yellow birch.

Suitability

MHn47 sites provide ***excellent habitat*** for yellow birch trees. The ***suitability rating*** of 4.8 for yellow birch is influenced mostly by its presence (43%) as trees on these sites in modern forests **(R-1)**. When present, yellow birch can be an important co-dominant tree, contributing 15% mean cover in mature stands. The ranking is third behind sugar maple and basswood on MHn47 sites as sampled by releves. Northern mesic hardwood communities offer excellent habitat (see Suitability Tables) for yellow birch *only* when the soils are silty. Otherwise yellow birch is just an incidental species. Both MHn47 and MHn45 occur in regions of Minnesota where soils are often silt-capped and the sites with abundant yellow birch.

Young Growth-stage: 0-55 years

Historically, yellow birch was present in just trace amounts in young MHn47 stands recovering from stand-regenerating events **(PLS-1, PLS-2)**. Young yellow birches were not recorded at all at survey corners described as burned **(PLS-3)**. Yellow birch represented 9% of the trees at windthrown corners, although the sample size is very small. Small-diameter yellow birch regeneration was common throughout the post-disturbance window **(PLS-5)**. Our interpretation is that there was some establishment of yellow birch in response to disturbance and that some was most likely released advance regeneration. Though the sample numbers are low, yellow birch appears as a tree near the conclusion of the young growth-stage.

Transition: 55-75 years

As stands transitioned to mature conditions yellow birch increased substantially in abundance **(PLS-1, PLS-2)**. We estimate that this increase started near the end of the young growth-stage until yellow birch abundance stabilized at about 15-20% near the conclusion of the transition stage. Small-diameter yellow birch regeneration was continuously present until about age 80 **(PLS-5)**. The small-diameter birch were inclined to come in among larger yellow birch, which is surprising given how little yellow birch was present in the young growth-stage. Otherwise, young yellow birch were mostly replacing initial-cohort quaking aspen.

Mature Growth-stage: 75-195 years

The mature growth-stage represents the time where yellow birch has its peak relative abundance at about 15% **(PLS-1, PLS-2)**, although it reached 30% in some individual age-classes. Because of this peak, we consider yellow birch to be a ***mid-successional*** species on MHn47 sites. Small-diameter yellow birch regeneration was essentially absent during this growth-stage **(PLS-5)**. At this time it was about as common for yellow birch to be the larger tree at a survey corner as compared to being the smallest tree at a corner. This is typical of a tree with a long window of steady recruitment. When it was the smaller tree it was much more inclined to be coming in among larger yellow birch than other species. Our interpretation is that monotypic pockets of yellow birch tended to form in older MHn47 stands. Our best guess is that these pockets were centered on included swales that are seasonally wetter than what is considered average MHn47 habitat. In modern mature forests, yellow birch shows surprisingly poor ability to establish seedlings under a canopy and only slightly better success at recruiting them to heights over 2m **(R-2)**. Getting light to the forest floor for enough yellow birch regeneration to account for 15% of the bearing trees in mature forests is problematic. Although there seems to have been some response to what we presume to be large gaps associated with the decline of initial-cohort quaking aspen, there really wasn't that much aspen in MHn47 forests. Yellow birch shows a good response to partial canopy loss in the survey notes (maintenance disturbance, **PLS-3**), but there is so little direct reference to fire or windthrow that it is hard to imagine that these were the only contributing factors to maintenance disturbances. For now, our best guess is that prolonged ponding could have weakened or killed enough trees around vernal basins to allow yellow birch some chances at regeneration. The landforms supporting MHn47 forest and yellow birch pond more water than other landforms. The basins themselves are siltier than the surrounding soils and have waterlogged wood, both of which are good seedbeds for yellow birch.

Very Old Growth-stage: >195 years
The very old growth-stage years is a rather arbitrary time period representing the condition of MHn47 forests that have escaped major disturbance for a long time. It is the culmination of slow, but steady gains of sugar maple and white pine that started in the mature growth-stage. At this stage, yellow birch was still an important tree at 9% relative abundance **(PLS-1)**. We did not detect small-diameter paper birch regeneration in this growth-stage **(PLS-5)**. At this time, yellow birch had balanced abundance as the larger or smaller tree at survey corners, which suggests that yellow birch had enough regeneration and recruitment in the understory to sustain a modest presence in very old MHn47 forests. When yellow birch was the smallest tree at a survey corner, it was among larger supercanopy white pines. Very old MHn47 forests must have had some openings larger than single-tree gaps as yellow birch has just poor ability to establish and recruit seedlings under a canopy in modern forests **(R-2)**.

Regeneration Strategies
Our interpretation of yellow birch's regenerative strategies on MHn47 sites is based mostly upon its performance in modern forests. It seems that it is most likely to fill ***large-gaps***. In the FIA data **(FIA-1)**, yellow birch regeneration is present *only* as poles beneath trees (situation 23). This is a property of trees that we normally consider large-gap strategists. The releve sampling of MHN47 stands older than about 40 years, shows that yellow birch is not at all able to develop a seedling bank **(R-2)**. Its regenerant and seedling indices are poor and more in line with trees that need to regenerate in the ***open***. In the historic PLS data the idea that yellow birch is a large gap strategist is supported by the fact that it responded to gaps during the decline of initial-cohort quaking aspen **(PLS-1)**, (2) it has high presence associated with partial-canopy maintenance disturbances **(PLS-3)**, and (3) its window of regeneration does extend into the gap window though it is better post-disturbance **(PLS-5)**. Our field experience tells us that yellow birch needs the steadily moist, silty or organic seedbeds for establishment, and needs openings at least at the large-gap scale (several trees) to have much hope of recruitment.

Historic Change in Abundance
Today yellow birch is in peril on MHn47 sites. Only trace amounts occur in young forests sampled with FIA plots (situation 11, **FIA-1**). Most evident is the loss of yellow birch in mature forests where it represented 15% of the PLS bearing trees, but now accounts for just 1% of the FIA trees **(PLS/FIA-1)**. No yellow birch were recorded in very old MHn47 FIA plots, whereas it was 9% of the trees historically. The fairly high presence of yellow birch as a tree in releves **(R-1)** and modest presence as regeneration **(R-2)** suggests that it has had better success in modern, unmanaged MHn47 forests than in the average managed stand. In either case, managed or not, the amount of young, yellow birch regeneration that we now see on MHn47 sites seems inadequate to replace the existing trees.

Paper Birch

- ***good habitat suitability rating***
- ***early successional***
- ***open (large-gap) regeneration strategist***
- ***regeneration window at 0-40 years***

Identification Problems

Often, the PLS surveyors distinguished yellow from paper birch, but not always. MHn47releve samples show that for plots with birch present: 10% have both species present; 30% are paper birch without yellow birch; 60% are yellow birch without paper birch. For this analysis, tree records were biased towards yellow birch because we assigned generic references to "birch" to the more common yellow birch. Thus our interpretation of paper birch's historic behavior is based upon explicit references to "paper birch" or "white birch" in the survey notes.

Suitability

MHn47 sites provide ***good habitat*** for paper birch trees. The ***suitability rating*** of 3.9 for paper birch is influenced mostly by its presence (24%) as trees on these sites in modern forests **(R-1)**. When present, paper birch can be an important co-dominant tree, contributing 10% mean cover in mature stands. The ranking is fourth among trees common on MHn47 sites as sampled by releves. Northern mesic hardwood communities in general offer excellent habitat for paper birch, except for MHn47 where the ranking is just good (see Suitability Tables).

Young Growth-stage: 0-55 years

Historically, paper birch was an important tree in young MHn47 stands **(PLS-1, PLS-2)**. During this stage its abundance peaked at 21% of all trees and for this reason we consider paper birch an ***early successional*** species on MHn47 sites. Young paper birch represented 15% of the trees at survey corners described as burned **(PLS-3)**. This result is consistent with its well-known ability to stump sprout when fire or another agent kills the main stem. Paper birch was also successful at windthrown corners where it also represented 14% of the trees present. Small-diameter, paper birch regeneration coming in among larger trees was common immediately after disturbance and throughout the post-disturbance window **(PLS-5)**. Our interpretation is that most regeneration was from stump sprouts, but the open conditions also allowed for the establishment of some seed-origin trees.

Transition: 55-75 years

As stands transitioned to mature conditions paper birch decreased in abundance **(PLS-1)**. We estimate that this decrease started immediately after disturbance and continued for the life of the stand until paper birch was a minor co-dominant in old stands **(PLS-2)**. At this time, paper birch was more often the largest tree at survey corners, but there were still some records of it as the smaller tree. This is typical of a species in slow decline. Small-diameter paper birch regeneration was present throughout the transition stage, but not at levels as high as in the post-disturbance window **(PLS-5)**. In most cases, paper birch regeneration was coming in under quaking aspen and older paper birch. We interpret this as limited success at establishment and recruitment of seed-origin paper birch under the declining canopy aspen and beneath itself. This is somewhat contrary to our observations in modern forests where paper birch shows almost no ability to establish seedlings under a canopy **(R-2)**. The gaps formed in the declining initial-cohort canopy must have been fairly large for paper birch to have regenerative success during the transition stage. Its success though, was limited and not enough to maintain the current population of trees.

Mature Growth-stage: 75-195 years

The mature growth-stage is a period of slowed, but directional compositional change **(PLS-4)** during which sugar maple gradually increases to assert dominance on MHn47 sites. During this stage, the abundance of paper birch continued to decline, but very slowly **(PLS-1, PLS-2)**. Its presence was most likely the result of modest but persistent establishment and recruitment for the first 80 years of stand maturation **(PLS-5)**. Small-diameter paper birch regeneration was not detected during the mature growth-stage **(PLS-5)**. At this time, paper birches were far more common as the larger tree at a survey corner compared to when it was the smaller tree. This is typical of a tree in decline. We interpret its presence as the smaller tree as it having some success in the subcanopy, but relying more on survivorship than a large pool of small trees as does sugar maple. When paper birch was the smallest tree, it was most favored when coming in under itself. Some paper birch regeneration could be due to birch's tendency to form rather pure pockets within the maple-dominated matrix of MHn47 forests. We believe that paper birch was able to perpetuate itself as a minor species in older MHn47 forests by doing well in patches where sugar maple had yet to totally dominate.

Very Old Growth-stage: >195 years

The very old growth-stage years is a rather arbitrary time period representing the condition of MHn47 forests that have escaped major disturbance for a long time. It is the culmination of slow, but steady gains of sugar maple and white pine that started in the mature growth-stage. At this stage, paper birch was a minor tree at 5% relative abundance **(PLS-1)**. We did not detect small-diameter paper birch regeneration in this growth-stage **(PLS-5)**. At this stage, paper birch was always present at survey corners as the larger tree, which suggests the conclusion of any regeneration to replace the old paper birch. This is quite consistent with the behavior of paper birch in modern, closed canopy MHn47 forests where it seems unable to often establish seedlings **(R-2)**.

Regeneration Strategies

On MHn47 sites paper birch exhibits regenerative flexibility, which allows it to be a minor, but ever-present tree throughout the full course of stand maturation. Paper birch sprouts effectively following disturbances that kill the main stem, and it is able to carry its density as a tree into young growth stages. Its higher abundance in the young growth stage **(PLS-1)** could be due to the fact that that it was a much better at sprouting than sugar maple. We believe that paper birch was most successful increasing its presence locally after catastrophic disturbance and out-competing other trees in the ***open***. In the historic PLS data this interpretation is supported by the fact that paper birch abundance peaks in the young growth-stage **(PLS-1, PLS-2)**, (2) it is common at disturbed survey corners **(PLS-3)**, and (3) its primary window of regeneration was during the post-disturbance years **(PLS-5)**. Paper birch has very poor indices of establishment and recruitment under the canopy of modern forests **(R-2)**. These indices (0.8-1.7) are quite in line with trees limited to regenerating in the open.

In stands sampled by FIA plots, paper birch has high presence as poles in tree stands (situation 23), which is typical of species that prefer ***large-gaps*** for recruitment **(FIA-1)**. Also, paper birch's long window of regeneration (to 80 years, **PLS-5**) suggests that it must have had some success in large gaps as initial-cohort aspen and birch died. Though this success was limited and not sufficient to maintain its population of trees, it was enough to leave some paper birch in older stands ready to re-colonize when MHn47 stands were finally disturbed.

Historic Change in Abundance

Today, paper birch is much less abundant on MHn47 sites than it was historically **(PLS/FIA-1)**. Paper birch now constitutes just 3% of all trees in the young growth-stage compared to 21% historically. The loss is less impressive but still significant in mature forests where it is now 5% of the trees compared to 13% historically. Although it shows some gain in the very old growth-stage, the data there are too sparse for reliable conclusions. We believe that fire suppression, though infrequent historically, is the primary reason for seeing less paper birch on MHn47 sites today. Its near absence in the average, young stand (situation 11, **FIA-1**) suggests that it might well be in peril as logging is not having the same effect that fire and windthrow did historically. Also, its low presence as regeneration in the releves **(R-1)** would indicate that it will probably continue to decline in unmanaged stands as well, most likely because it can't compete with sugar maple.

Northern Red Oak

- ***good habitat suitability rating***
- ***mid-successional***
- ***large-gap (open) regeneration strategist***
- ***regeneration window at 0-30 years***

Suitability
MHn47 sites provide ***good habitat*** for red oak trees. The ***suitability rating*** of 3.7 for red oak is influenced mostly by its presence (19%) as trees on these sites in modern forests **(R-1)**. When present, red oak is a minor co-dominant tree, contributing 10% mean cover in mature stands. The ranking is fifth among trees common on MHn47 sites as sampled by releves. Northern mesic hardwood communities in general offer good-to-excellent habitat for red oak within its native range (not MHn45). Among these, MHn47 is second to MHn35 in providing opportunities for managing red oak (see Suitability Tables).

Young Growth-stage: 0-55 years
Historically, red oak was not an important tree in young MHn47 stands recovering from stand-regenerating disturbance **(PLS/FIA-1)**. Young red oak were present at no survey corners described as burned **(PLS-3)**. A single red oak was present at a windthrown survey corner, accounting for 5% of the trees in that sparse sample. Windthrow was not an important means of regenerating red oak in MHn47 forests. Young corners with red oak trees present were almost always some combination of red oak and almost any other MHn47 tree. Small-diameter red oak regeneration coming in among larger trees was present in the post-disturbance window at low, but detectable levels **(PLS-5)**. In modern forests, red oak shows good ability to establish seedlings under a canopy, but poor ability to recruit them to heights above 2m unless a canopy gap forms over them **(R-2)**. Our interpretation is that post-disturbance red oaks in young MHn47 forests were likely a mixture of stump sprouts and released advance regeneration.

Transition: 55-75 years
As stands transitioned to mature conditions red oak abundance peaks at about 5% in age-class 70. However, when averaged across growth-stages there was little more red oak during the transition than in the young growth-stage as both rounded to 2% **(PLS/FIA-1)**. Because of this peak and slightly higher abundance in the transition stage, we consider red oak to be a ***mid-successional*** species on MHn47 sites. We believe that some of this peak was the consequence of red oaks established in the young growth-stage just outliving initial-cohort quaking aspen and perhaps paper birch. Small-diameter, red oak regeneration was still detectable in the early years of the transition stage and young red oaks were coming in among larger trees up until about age 60 **(PLS-5)**. In most cases red oak regeneration was still coming in under aspen or larger red oaks. We interpret this as limited success at establishment and recruitment of seed-origin oak under a partial canopy of initial-cohort trees. Also, it seems likely that the collapse of the initial-cohort aspen released red oak seedlings established during the young growth-stage.

Mature Growth-stage: 75-195 years
The mature growth-stage is really the last episode where we have adequate numbers of bearing trees to interpret the historic behavior of red oak. The relative abundance of red oak declines throughout the growth-stage, but the percentages are low and it would be more accurate to describe its presence as at sustainable, background abundances in the vicinity of 1-2% **(PLS/FIA-1)**. Small-diameter red oak regeneration was not detected during the mature growth-stage **(PLS-5)**. At this time, red oaks were equally common as the smaller or larger tree at the survey corners. When red oaks were the smaller tree, they most often were under sugar maple. In modern forests, it is fairly common to see red oak seedlings under sugar maple, but it is very uncommon to see them recruit to tree heights unless they are in a substantial canopy gap. Our interpretation is that a few red oaks in mature MHn47 forests can result in a seedling bank, but several-tree openings are required for them to have a chance of becoming a tree. Given the paucity of red oak in mature and very old MHn47 forests, such openings must have been rare.

Very Old Growth-stage: >195 years
The very old growth-stage years is a rather arbitrary time period representing the condition of MHn47 forests that have escaped major disturbance for a long time. It is the culmination of slow, but steady gains of sugar maple and white pine that started in the mature growth-stage. At this stage, we encountered just a few red oak bearing trees. The data are insufficient for interpretation.

Regeneration Strategies
Red oak's primary regenerative strategy on MHn47sites is to fill ***large-gaps***. It was most successful at this when gaps formed in the canopy of declining initial-cohort quaking aspen and to some extent paper birch. In the historic PLS data this interpretation is supported by: (1) the fact that red oak abundance peaks in response to the decline of the initial cohort species **(PLS-2)**, (2) it is most abundant at survey corners showing partial canopy loss **(PLS-3)**, and (3) it shows measurable establishment in a gap window **(PLS-5)**. The high percent of red oak poles under trees (situation 23) in the FIA data **(FIA-1)** is also a characteristic of species that tend to regenerate best in large gaps. The releve sampling of mature MHC26 forests shows that red oak has some success beneath a canopy. Its regenerant and seedling indices are excellent, however its sapling index is poor **(R-2)**. This means that there is a bottleneck in red oak recruitment as it has difficulty getting seedlings to heights over 2m. The bottleneck and poor sapling index is typical of large-gap species.

It is important to note though that red oak was also present in young MHn47 forests and that its window of establishment was best in the post-disturbance years. Red oak clearly has regenerative strategies that allow it to perform in ***open*** habitat as well. Our interpretation is that the best opportunity for seed-origin oaks was in large-gaps, and stump sprouts served as a reliable mechanism to re-colonizing MHn47 forests destroyed by fire or wind.

Historic Change in Abundance
Today, there is more red oak on MHn47 sites than there was historically, but it is still a minor species **(PLS/FIA-1)**. Most evident is the increase of red oak in mature stands, where now it has 7% relative abundance compared to 2% historically. The FIA sampling shows very little red oak regeneration (>1" diameter) and most records are of mature trees (situation 33, **FIA-1**). This is typical of a species having problems regenerating. This is quite consistent with the releve sampling where we also saw little oak at heights between 2 and 10m **(R-2)**. Red oak's presence of 14% at FIA subplots is quite comparable to its 19% presence in the releves **(R-1)**, suggesting little difference between managed and unmanaged stands. Its 50% presence in the seedling layers in releves is a bit surprising, and suggests that red oak could increase in abundance if the right circumstances for release happened. Apparently these circumstances are only rarely met in modern harvests, and hardly at all in unmanaged situations. Our interpretation is that logging or land use practices some 50-100 years ago were more likely to favor red oak than it was favored naturally or by today's practices.

Black ash

- ***good habitat suitability rating***
- ***mid- (late) successional***
- ***large-gap regeneration strategist***
- ***regeneration window at 30-70 years***

Identification Problems

The PLS surveyors did not distinguish between black and green ash. Thus, interpretations of PLS data for the more common black ash should always be done knowing that some of these trees were likely green ash. MHn47 releve samples show that for plots with ash present: 15% have both species present; 22% are green ash without black ash; 63% are black ash without green ash. We consider black and green ash to be ecologically similar on MHn47 sites and most silvicultural strategies would work for either species.

Suitability

MHn47 sites provide ***good habitat*** for black ash trees. The ***suitability rating*** of 3.3 for black ash is influenced mostly by its presence (19%) as trees on these sites in modern forests **(R-1)**. When present, black ash is a minor co-dominant tree, contributing 8% mean cover in mature stands. The ranking is sixth among trees common on MHn47 sites as sampled by releves. Northern mesic hardwood communities offer good-to-excellent habitat (see Suitability Tables) for black ash *only* when the soils are moist (MHn44 and MHn46) or rich and silty (MHn47). Otherwise black ash is just an incidental species.

Young Growth-stage: 0-55 years

Historically, black ash was present in just trace amounts in young MHn47 stands recovering from stand-regenerating events **(PLS-1)**. No young black ash were recorded at survey corners described as burned **(PLS-3)**. Black ash represented 9% of the trees at windthrown corners, but the sample size is very small. Small-diameter black ash regeneration was detectable at low abundance near the conclusion of post-disturbance window **(PLS-5)**. Our interpretation is that there was very limited regeneration of black ash under the initial-cohort paper birch, basswood, quaking aspen, and sugar maple. Though the sample numbers are low, black ash appears only as regeneration throughout the young growth-stage, which is typical of an ingressing species.

Transition: 55-75 years

As stands transitioned to mature conditions black ash increased slightly in relative abundance. We estimate that this increase started near the end of the young growth-stage until black ash abundance peaks at about 4% between age-classes 70-90 years. Small-diameter black ash regeneration was detectable in the G-1 gap window corresponding with the transition stage **(PLS-5)**. The sample size though is too small to make assumptions about the trees it was replacing.

Mature Growth-stage: 75-195 years

The mature growth-stage represents the time where black ash has its peak relative abundance at about 4% between age-classes 70-90 years, but it averaged just 1% across the entire mature growth-stage **(PLS-1)**. Because of this peak, we consider black ash to be a ***mid-successional*** species on MHn47 sites. Early in the mature growth-stage, black ash established during the transition were recruiting to tree size. It was more common for these black ash to be the smaller tree at a survey corner, which is consistent with the idea of black ash increasing its presence in mature MHn47 forests. When it was the smaller tree at survey corners, it showed a fairly strong preference for coming in among birch, and it didn't seem to matter if it was paper birch or yellow birch. Our interpretation is that black ash was always present in included wetlands, which are common throughout MHn47 stands. It would seem that black ash had some success coming in under the birch that often ring these wetlands. In modern mature forests, black ash shows good ability to establish seedlings, but they have only a fair chance of recruiting to heights taller than 2m **(R-2)**. Getting light to the forest floor for enough black ash recruitment to account for its presence as a tree in mature forests is problematic. Although there seems to have been some response to what we presume to be large gaps associated with the decline of initial-cohort quaking aspen, there really wasn't that much aspen in MHn47 forests. Black ash shows a good response to windthrow and partial canopy loss in the survey notes **(PLS-3)**, but there is so little direct reference to fire or windthrow in general that it is hard to imagine that these were the only contributing factors to maintenance disturbances. For now, our best guess is that prolonged ponding could have weakened or killed enough trees around vernal basins to allow black ash some chances at recruitment.

Very Old Growth-stage: >195 years

The very old growth-stage years is a rather arbitrary time period representing the condition of MHn47 forests that have escaped major disturbance for a long time. It is the culmination of slow, but steady gains of sugar maple and white pine that started in the mature growth-stage. At this stage, black ash was a minor tree at 2% relative abundance **(PLS-1)**. We did not detect small-diameter paper birch regeneration in this growth-stage **(PLS-5)**. Because black ash persists into very old MHn47 forests, we consider it to be secondarily a ***late-successional*** species.

Regeneration Strategy

Black ash's primary regenerative strategy on MHn47 sites is develop a bank of seedlings under a closed canopy and then to recruit trees when ***large-gaps*** develop over the advance regeneration. In the historic PLS data the idea that black ash is a large gap strategist is supported by the fact that it responded to gaps during the decline of initial-cohort quaking aspen **(PLS-1)**, and (2) its main window of regeneration is the G-1 gap window **(PLS-5)**. In the FIA data **(FIA-1)**, black ash regeneration has its peak presence as poles in tree stands (situation 23), which is a property of large-gap strategists. The releve sampling of MHn47 stands older than about 40 years, shows that black ash is able to develop a seedling bank **(R-2)**. Its regenerant and seedling indices are good (3.3) and quite in line with trees that regenerate in large gaps. Black ash's fair sapling index (2.2) indicates that it has some difficulty recruiting seedlings to heights over 2m. This too, is a property of large gap strategists in that the seedlings are commonly present under a canopy, but recruitment is unlikely unless large gaps form over them.

Historic Change in Abundance

Today black ash is considerably more abundant on MHn47 sites than it was historically, but it is still a minor tree. Most evident is the increase of black ash in young forests where it represents 6% of the FIA trees, but accounted for just 1% of the PLS bearing trees **(PLS/FIA-1)**. Its 3% presence in modern mature stands is also a significant increase from its 1% presence historically. Some of the increase in the young growth stage could be green ash, as it responds more favorably than black ash to logging and disturbance in general.

(PLS-1) Historic Abundance of MHn47 Trees in Natural Growth-stages

Table values are relative abundance (%) of Public Land Survey (PLS) bearing trees at corners modeled to represent the MHn47 community by growth-stage. Growth-stages are periods of compositional stability during stand maturation. Arrows indicate periods of compositional change during which tree abundances increase or decrease substantially. Yellow, green, and purple shading groups trees with abundance peaks in the same growth-stage. Percents on the bottom row represent a snapshot of the balance of growth-stages across the landscape *ca.* 1846 and 1908 AD.

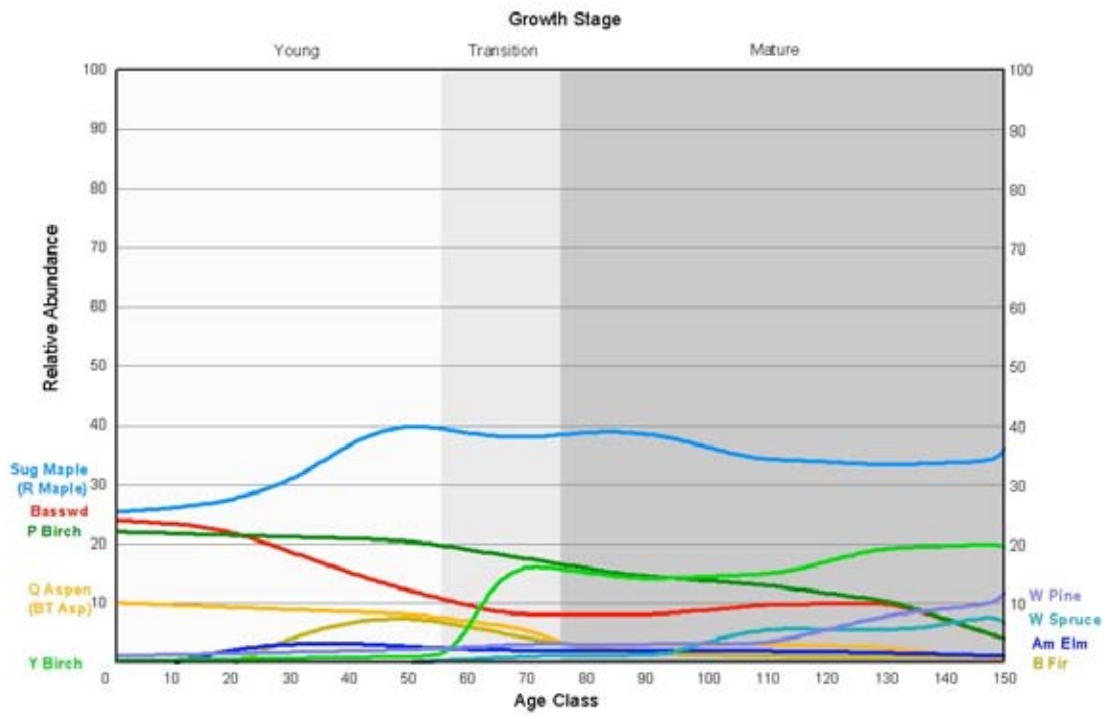
Dominant Trees	Forest Growth Stages in Years				
	0 - 55	55 - 75	75 - 195	~ 195	> 195
	Young	T1	Mature		Very Old
Paper Birch	**21%**		**13%**		**5%**
Basswood	**13%**		**9%**		**5%**
Quaking Aspen	**8%**		**3%**		**–**
Yellow Birch	**–**		**15%**		**9%**
White Spruce	**1%**		**3%**		**–**
Balsam Fir	**5%**		**5%**		**2%**
Sugar Maple	**38%**		**35%**		**43%**
White Pine	**1%**		**6%**		**32%**
Miscellaneous	**13%**		**11%**		**4%**
Percent of Community in Growth Stage in Presettlement Landscape	**33%**	**31%**	**35%**		**2%**

PLS-1
Trees included in Table PLS-1 are species with greater than 3% relative abundance in at least one growth-stage. Species that are now abundant in MHn47 forests, but were rare historically appear in Table **PLS/FIA-1**.

Public Land Survey linked text

(PLS-2) Abundance of trees throughout succession in MHn47

Caption: Graphed for the different species of MHn47 trees is their relative abundance (%) as PLS bearing trees by age class. The data were initially smoothed from adjacent classes and then by visually fitting lines to illustrate general trends.



Documentation for Figure PLS-2

**Public Land Survey linked text

(PLS-3) Historic Abundance of MHn47 Trees Following Disturbance

Table values are raw counts and (percentage) of Public Land Survey (PLS) bearing trees at survey corners likely to represent MHn47 forests. The columns represent our interpretation of disturbance at the survey corners. Shading associates trees that peak in the same disturbance category.

Tree	Burned		Windthrown		Maintenance		Mature	
Sugar maple	13	50%	10	45%	18	43%	1437	43%
Basswood	6	23%	3	14%	7	17%	432	13%
Ironwood	3	12%	0	0%	0	0%	65	2%
Black ash	0	0%	2	9%	2	5%	55	2%
Northern red oak	0	0%	1	5%	3	7%	80	2%
White cedar	0	0%	1	5%	3	7%	107	3%
Paper birch	4	15%	3	14%	5	12%	700	21%
Yellow birch	0	0%	2	9%	4	10%	443	13%
Red maple	0	0%	0	0%	0	0%	4	0%
Total (% of grand total, 3413)	26	1%	22	1%	42	1%	3323	97%

PLS-3

Table PLS-3 includes only trees ranked as having excellent, good, or fair suitability for MHn47 sites. Tree sums will not match the totals in the Natural Disturbance Regime text, because trees of poorer suitability were included in that analysis.

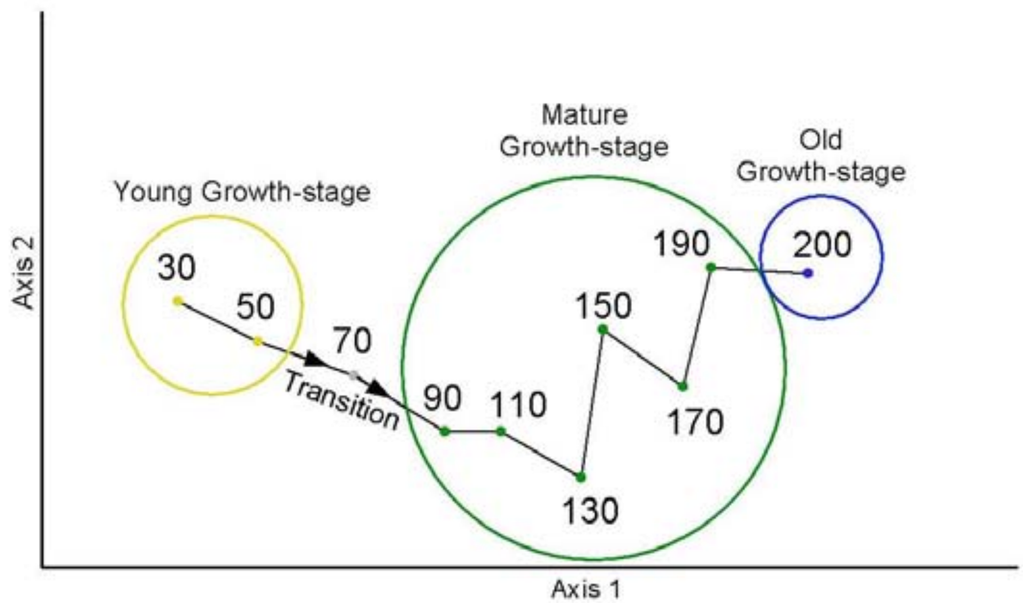
PLS survey corners were assigned to four disturbance categories:

1. The burned category is based upon explicit reference by the surveyors to burned timber or burned land.
2. The windthrown category is based upon explicit reference by the surveyors to windthrown timber.
3. The maintenance category includes corners with structural conditions requiring chronic disturbance (e.g. barrens, openings) OR forest where bearing tree distances match more closely the distances observed in the other structural categories. This category is our inference of partial canopy loss.
4. The mature category includes corners with no explicit or implicit reference to disturbance and has bearing trees at distances typical of fully stocked forest.

Public Land Survey linked text

(PLS-4) Ordination of Historic MHn47 Age-classes

The distance between age-class points reflect change in composition from one age-class to another. Long distances between age-classes indicate species mortality and replacement by other species. Short distances suggest little change in composition. Circled are growth-stages where we interpreted little change. Age-classes not in circles and with arrow connections represent episodes of significant compositional change.



PLS-4

For each PLS survey corner we estimated stand age based on the diameter of the largest tree. The corners were placed into 20-year age-classes for this analysis. We used coarse age-classes mostly because the surveyors tended to estimate diameters coarsely in even inches. For each age-class the relative abundance of each bearing tree type was calculated and used to characterize and ordinate the age-classes. Detrended Correspondence Analysis provided the smoothest ordinations, meaning that the age-classes tend to sequentially track across the ordination plot. There is always some subjectivity and uncertainty in placing the seams between growth-stages and transitions in these diagrams. When uncertain, we placed seams that match process transitions (self-thinning to density-independent mortality, ingress of shade-tolerants, etc.) described in more general models of stand dynamics in silvicultural literature.

(PLS-5) Historic Windows of Recruitment for MHn47 Trees

Windows of recruitment are stretches of contiguous age classes where Public Land Survey (PLS) trees recruit to acceptable bearing tree size (~4" dbh) in the presence of trees twice their diameter. We interpret this as their establishment in response to canopy conditions that change during the course of natural stand maturation. The table presents species' peak recruitment window and comparative success in post-disturbance, gap, and ingress windows.

Initial Cohort	Species	Peak years	P-D 0-50 yrs	G-1 50-90 yrs	I-1 90-130 yrs	G-2 >130 yrs
Yes	Basswood	0-30	Excellent	Poor to 60	--	--
Yes	Quaking Aspen	0-30	Excellent	Poor to 50	--	--
Minor	Red Oak	0-30	Good	Poor to 60	--	--
Yes	Paper Birch	0-40	Fair	Poor to 80	--	--
Yes	Sugar Maple[1]	0-50	Excellent	Good to 80	--	--
No	American Elm	20-40	Good	Poor to 70	--	--
No	White Pine	40	Poor at 40	--	--	--
No	Balsam Fir	30-50	Good after 30	--	--	--
Minor	Yellow Birch	0-60	Good	Good to 80	--	--
Minor	Black Ash	30-70	Poor	Poor to 70	--	--
No	White Cedar	80-90	--	Fair 80-100	--	--
No	White Spruce	120-150	--	Poor after 70	Fair	Good

Recruitment windows from ordination PLS-4:

- **P-D:** post-disturbance filling of understocked areas, 10-50 years
- **G-1:** gap filling during decline of initial-cohort paper birch and quaking aspen with some basswood, 50-90 years
- **I-1:** ingress of seedlings under canopy of sugar maple, yellow birch, and paper birch, with some basswood balsam fir, and white pine, 90-130 years
- **G-2:** gap filling during decline of paper birch, basswood, balsam fir, and yellow birch, >130 years

-- : No trees were recorded as < half the diameter of the largest bearing tree. A property of PLS data is that diameter variation among bearing trees at the same corner decreases with increasing diameter. Corners estimated to be older than about 100 years only rarely have subordinate bearing trees and should not be taken to mean that small diameter trees didn't occur at all.

Shading: light yellow = trees with peak regeneration immediately after disturbance; **gold =** trees with peak regeneration later in the P-D window; **light green** = trees with peak regeneration in gaps formed during the decline of the initial cohort; **purple** = trees with peak regeneration by ingress under a mature canopy or by filling small gaps in old forests

1. Sugar maple bearing trees couldn't be segregated from red maple in the PLS notes for this community. The sugar maple data probably include some red maple, which we consider ecologically similar to sugar maple.

PLS-5

Recruitment windows were defined from ordinations of age-classes (PLS-4) that illustrate rates of compositional change. Windows are strings of contiguous age-classes where the rate of change is either consistently high or low.

Post-disturbance windows (P-D) are strings of contiguous age classes that start at age zero and during which we observe little compositional change.

For windows showing lots of compositional change (G-1, G-2) we assume gap-filling because canopy species are declining and being replaced by subordinate trees of another species.

Mid- and late-successional windows showing little compositional change (I-1, I-2) represent episodes of seral stability and subordinate trees are assumed to have established themselves by ingress under a canopy.

After setting post-disturbance, gap, and ingress windows from the ordinations, we calculated how often trees are were found in a subordinate condition during those episodes. A tree was considered subordinate when its diameter was less than half that of the largest tree at a PLS corner. Our assumption is that subordinate trees are younger than the larger diameter trees and that they could not have been established in response to a stand-regenerating disturbance.

Initial-cohort trees that rarely show diameter subordination are true pioneers that regenerate almost entirely in response to stand conditions after catastrophic fire, wind, or flooding.

Initial-cohort trees that show diameter subordination are presumed to have some regenerative ability under stand conditions not associated with the stand-initiating disturbance. For initial-cohort species in forest classes, such windows represent and a shift in regenerative strategy, e.g. from post-disturbance sprouting to seeding into understocked areas. For initial-cohort woodland species, such windows represent a persistent strategy in naturally long windows of recruitment where trees are replacing brush or grass.

For species not in the initial cohort, the windows define the timing of a tree's ability to ingress beneath a canopy or to fill gaps created when canopy species senesce. Ingress or gap-filling windows can end or continue indefinitely depending upon species' reaction to stand maturation processes that result in smaller gaps, deepening shade, increasingly organic seedbeds, and increased likelihood of infection by diseases or pests.

(R-1) Suitability ratings of trees on MHn47 sites

This table presents an index of suitability for trees in MHn47 forests. The index is based upon releve samples from modern forests. Trees that occur often (high percent presence) and in abundance (high mean percent cover when present) have high suitability indices. Suitability ratings indicate our interpretation of likely success of natural regeneration and growth to crop tree status with little silvicultural manipulation.

Dominant canopy trees of MHn47			
Tree	**Percent Presence as Tree**	**Mean Percent Cover When Present**	**Suitability Index***
Sugar maple (Acer saccharum)	**98**	**42**	**5.0**
Basswood (Tilia americana)	**93**	**22**	**4.9**
Yellow birch (Betula alleghaniensis)	**43**	**15**	**4.8**
Paper birch (Betula papyrifera)	**24**	**10**	**3.9**
Northern red oak (Quercus rubra)	**19**	**10**	**3.7**
Black ash (Fraxinus nigra)	**19**	**8**	**3.3**
White cedar (Thuja occidentalis)	**10**	**9**	**2.6**
Red maple (Acer rubrum)	**9**	**9**	**2.4**
*Suitability ratings: **excellent**, **good**, **fair**			

R-1

Suitability ratings indicate our interpretation of likely success of natural regeneration and growth to crop tree status with little silvicultural manipulation. Statewide suitability tables are available at: link to Tree Tables Field Version.pdf.

What we know of the behavior of trees and their suitability for sites is based upon a classification[1] of thousands of vegetation (releve) plots in Minnesota's native forests. The classification is purely empirical, based upon the occurrence and abundance of all vascular plants in these plots. For the purpose of land management, we have identified 52 basic forest Classes that are not only vegetationally different, but also have interpretable differences in parent material, landform, soil texture, soil moisture regime, and hydrology. The premise of this approach is that the NPC classification has captured the "realized" niche[2] of our trees and provides a field tool for recognizing the physical and competitive environment of forest sites.

The releve plots come from stands of trees older than 40 years through old-growth. The majority of sampled stands are 60 to 80 years old, and most plots were collected over the past 10 years. This means that we are most often observing tree success that reflects regeneration conditions *ca.* 1930-1960 and survival conditions since that time. We are assuming that most of the site conditions important to trees are the same now as then, or at least within their range of natural variability[3]. Thus, predictions of suitability from this table should always be considered in light of modern conditions that depart from past reference conditions.

A second consideration is that our sample plots were of natural forests. Here natural means that the vegetation is mostly composed of native plants and that enduring effects of human activity are not obvious. Most stands sampled have been logged and many grazed. We are assuming that current stand composition includes most of the plants and other trees with which a tree has coexisted in the past. The effect of these plants on the tree species under consideration may be mutualistic or competitive. Also, the effect of these plants on individual trees can change as the tree undergoes physiological changes as it matures. Altering the effects of these plants to benefit certain trees at the appropriate times during their maturation is the essence of silviculture. Because we sampled natural stands with little evidence of manipulation, high ratings imply little need for silvicultural intervention or tending. Conversely, trees with low ratings for certain NPCs will require intensive silvicultural effort.

For this analysis we created a very simple index to estimate suitability. This index is the product of percent presence and percent cover when present. For example, there are 256 sample plots of Northern Mesic Hardwood Forest (MHn35). Basswood trees over ten meters tall (~33 feet) occur in 164 of these plots, thus its percent presence as a tree is (164/256)*100= 64.1%. The mean cover of basswood trees on those 164 plots is 15.0%. Thus, its index is 64.1*15.0=962.

To communicate our estimates of suitability, we ranked the indices of plants that often occur (>5% presence) in a community and divided that ranking into 5 equal parts to create five suitability classes: excellent, good, fair, poor, and not suitable. Continuing the example above, 113 plants were ranked for MHn35 and basswood had the 8^{th} highest ranking, placing it in the excellent class along with 22 other plants.

To estimate relative suitability, we simply expressed the rank order of a tree's index among all of the trees that occur in that community. In the above example, sugar maple was the only tree with a higher index than basswood, thus basswood's rank is 2.

1. Minnesota Department of Natural Resources (2003). Field Guide to the Native Plant Communities of Minnesota: the Laurentian Mixed forest Province. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program. MNDNR St. Paul, MN.

2. Oliver, C.D. and B. C. Larson. 1996. Forest Stand Dynamics, update edition. John Wiley & Sons, Inc.

3. Landres, P.B., P. Morgan, and F.J. Swanson. 1999. Overview of the use of natural variability concepts in managing ecological systems. Ecological Applications 9:1179-1188.

4. Forest Inventory & Analysis Plots 1977, 1990, 2002. North Central Research Station, 1992 Folwell Ave, St. Paul, MN 55108

(R-2) Natural Regeneration and Recruitment of Trees in Mature MHn47 Stands

This table presents an index of regeneration for MHn47 trees in four height strata: regenerants, seedlings, saplings and trees. The index is based upon releve samples of modern, mature forests. Index ratings express our interpretation of how successful tree species are in each stratum compared to other trees that one commonly finds in MHn47 communities. Changes in the index values from one stratum to another can be used to estimate regenerative bottlenecks, whether establishment (R-index) or recruitment (SE-, SA-, or T-indices).

Natural regeneration indices for germinants, seedlings, saplings, and trees common in the canopy of Northern Rich Mesic Hardwood Forest – MHn47

Trees in understory	% presence R, SE, SA	R-index	SE-index	SA-index	T-index
Sugar maple (Acer saccharum)	100	5.0	5.0	5.0	5.0
Basswood (Tilia americana)	83	4.7	4.7	4.5	5.0
Ironwood (Ostrya virginiana)	75	4.5	4.7	4.5	2.8
Northern red oak (Quercus rubra)	50	3.3	3.3	1.7	3.3
Black ash (Fraxinus nigra)	45	3.3	3.3	2.2	3.3
Yellow birch (Betula alleghaniensis)	24	1.5	1.7	2.5	4.5
Red maple (Acer rubrum)	23	2.8	2.5	2.0	2.8
Paper birch (Betula papyrifera)	8	0.8	0.8	1.7	4.0
White cedar (Thuja occidentalis)	4	0.0	0.0	1.3	3.3

Index ratings: **Excellent**, **Good**, **Fair**, **Poor**, N/A

% presence: the percent of 112 MHn47 sample plots with that species present under 10m (33 feet) tall (R, SE, SA layers)
R-index: index of representation as true seedling or under 10cm (4 inches) tall
SE-index: index of representation as seedlings over 10cm and under 2m (0.3-6.6 feet) tall
SA-index: index of representation as saplings 2-10m (6.6-33 feet) tall
T-index: index of representation as a tree >10m (33 feet) tall
All indexes: equally weight (1) presence, (2) mean cover when present, and (3) mean number of reported strata, the frequency distributions of which are segmented equally by area into 5 classes.

R-2
The releve method of sampling forest vegetation describes explicitly how trees occur at different heights. We modified raw releve samples by interpreting the occurrence of trees in four standard height strata: germinants 0-10cm tall, seedlings 10cm-2m tall, saplings 2-10m tall, and trees taller than 10m.

The releve samples all come from forests with an established canopy, so this dataset documents the presence and cover of trees in strata that have formed during the process of stand maturation, i.e. understory development.

We created an index to measure roughly the regenerative success of a tree in each stratum. The index is the product of (1) percent presence in that stratum for all releves classified as that community, (2) mean percent cover of that species when present in a stratum, and (3) the mean number of different strata reported in the releves when that species is present.

The indices for all trees were ranked, the range was then scaled to range between zero and 5. The index ratings of excellent, good, fair, poor, and not-applicable are the 5 whole number segments of the index.

(FIA-1) Structural Situations of Trees in Mature MHn47 Stands

This table presents percentages of structural situations for trees as recorded in Forest Inventory Analysis (FIA) subplots that we modeled to be samples MHn47 forests. The purpose of the table is to provide a general impression of how often a species is seen certain regenerative situations: canopy of a regenerating forest (situations 11, 22), in the subcanopy (situations 12, 23), or in the seedling bank below a remote canopy (situation 13). The situation of trees in older stands at tree height (33) provide no insight about regeneration. Species are ordered by the sum of their percents in 12 and 13 situations, which generally ranks them as would shade-tolerance ratings. The total number of trees counted for each species is presented to provide a sense of reliability.

Species	Tree Count	Structural Situations					
		11	22	12	23	13	33
Yellow birch	**7**	**-**	**-**	**-**	**14%**	**-**	**86%**
White cedar	**3**	**-**	**-**	**-**	**67%**	**-**	**33%**
Paper birch	**67**	**1%**	**15%**	**-**	**36%**	**1%**	**46%**
Northern red oak	**93**	**1%**	**3%**	**-**	**9%**	**2%**	**85%**
Basswood	**508**	**1%**	**6%**	**7%**	**24%**	**11%**	**50%**
Quaking Aspen[1]	**44**	**-**	**9%**	**9%**	**7%**	**11%**	**64%**
American elm[1]	**35**	**-**	**17%**	**3%**	**23%**	**23%**	**34%**
Red maple	**60**	**3%**	**18%**	**12%**	**22%**	**10%**	**35%**
Sugar maple	**454**	**2%**	**13%**	**10%**	**22%**	**26%**	**28%**
Black ash	**41**	**-**	**15%**	**17%**	**32%**	**29%**	**7%**

Canopy Situations
- **11** = Sapling in a young forest where saplings (dbh <4") are the largest trees
- **22 =** Poles in a young forest where poles (4"<dbh<10") are the largest trees
- **33 =** Trees in a mature stand where trees (>10"dbh) form the canopy

Subcanopy Situations
- **12 =** Saplings under poles
- **23 =** Poles under trees

Understory Situation (remote canopy)
- **13 =** Saplings under trees

1. Quaking aspen and **American elm** were recorded only in the historic PLS data.

FIA linked text

(PLS/FIA-1) Abundance of MHn47 trees in Pre-settlement and Modern Times by Historic Growth-stage

Table values are relative abundance (%) of trees at Public Land Survey corners and FIA subplots modeled to represent the MHn47 community and estimated to fall within the young, mature, and old growth-stages. Arrows indicate increase or decrease between historic growth-stages only and for the more common trees. Green shading and text was used for the historic PLS data and blue was used for the FIA data. Percents on the bottom row allow comparison of the balance of growth-stages across the pre-settlement landscape (*ca.* 1846-1908 AD) and the modern landscape (*ca.* 1990 AD).

Dominant Trees	Forest Growth Stages in Years								
	0 - 55		55 - 75		75 - 195		~ 195	> 195	
	Young		T1		Mature			Very Old	
Paper Birch	21%	3%			13%	5%		5%	11%
Basswood	13%	20%			9%	26%		5%	47%
Quaking Aspen	8%	8%			3%	4%		–	0%
Balsam Fir	5%	1%			5%	2%		2%	21%
White Spruce	1%	3%			3%	0%		–	0%
Sugar Maple	38%	35%			35%	32%		43%	11%
Yellow Birch	–	0%			15%	1%		9%	0%
White Pine	1%	0%			6%	0%		32%	0%
Ironwood	3%	10%			1%	8%		2%	0%
American Elm	3%	2%			2%	3%		0%	0%
Red Maple	0%	4%			--	3%		0%	0%
Black (Green) Ash	1%	6%			1%	3%		2%	0%
Bur Oak	--	1%			1%	2%		0%	10%
Red Oak	2%	3%			2%	7%		0%	0%
Miscellaneous	4%	4%			4%	4%		0%	0%
Percent of Community in Growth Stage in Presettlement and Modern Landscapes	33%	19%	31%	25%	35%	56%		2%	0%

Natural growth-stage analysis and landscape summary of historic conditions is based upon the analysis of 1,579 Public Land Survey records for section and quarter-section corners. Comparable modern conditions were summarized from 1,206 FIA subplots that were modeled to be MHn47 sites.

Public Land Survey linked text
FIA linked text

Silviculture Systems for MHn47: No arrow - least favorable, ⇧ Favorable, ⇧⇧ Very Favorable

	Silviculture Systems	Clearcut	Patch Cutting	Group Seedtree	Dispersed Seedtree	Uniform Shelterwood	Group Shelterwood	Irregular Shelterwood	Group Selection	Strip Selection	Single Tree Selection
	Regeneration Strategy										
Sugar Maple	small-gap (large-gap)										
Basswood	open (large-gap)										
Yellow Birch	large-gap (open)										
Paper Birch	open (large-gap)										
N. Red Oak	large-gap (open)										
Black Ash	large-gap										

Forest Health

Sugar Maple

Agent	Growth stage	Concern/ Effect
Armillaria root disease	All stages	Mortality
Maple borer	Pole-sized and larger	Volume loss/ degrade
Stem cracks	"	Volume loss
Stem decay	"	Volume loss

WATCHOUTS!

∞ When thinning, discriminate against maples with maple borer galleries and/ or stems with cracks.

∞ When planning intermediate or final harvests, write sale specifications to penalize wounding of residual trees and supervise sale closely to prevent wounding. The major entry points for decay fungi include mechanical wounds to the bole, dead branches, and dead or broken tops.

Basswood

Agent	Growth stage	Concern/ Effect
Armillaria root disease	All stages	Mortality
Stem decay	Pole-sized and larger	Volume loss

WATCHOUTS!

∞ When planning intermediate or final harvests, write sale specifications to penalize wounding of residual trees and supervise sale closely to prevent wounding. The major entry points for decay fungi include mechanical wounds to the bole, dead branches, and dead or broken tops.

Paper Birch

Agent	Growth stage	Concern/ Effect
Armillaria root disease	All stages	Mortality
Forest tent caterpillar	"	Defoliation
Bronze birch borer	Pole-sized and larger	Mortality
Inonotus canker & decay	"	Volume loss
Stem decay	"	Volume loss

WATCHOUTS!

∞ Declining birch stands should be harvested within two years to prevent loss of the sites to invading brush species.

∞Avoid thinning in birch during a drought and/or defoliation event. It is best to wait one growing season after the drought or defoliation is over to thin or harvest.

∞ Maintain optimal stocking in high-value stands to avoid mortality losses due to bronze birch borers and Armillaria root disease.

∞ Attempt to maintain a closed canopy in existing stands because soil temperature increases of as little as 4E can cause root death leading to tree mortality.

∞ Promote dense regeneration to help shade the soil and prevent excessive temperatures.

∞ The presence of fruiting bodies of Inonotus canker (sterile conk of birch) indicates serious decay. The presence of two fruiting bodies on a single stem usually indicates that the stem is cull due to decay.

∞ When planning intermediate or final harvests, write sale specifications to penalize wounding of residual trees and supervise sale closely to prevent wounding. The major entry points for decay fungi include mechanical wounds to the bole, dead branches, and dead or broken tops.

Red Oak

Agent	Growth stage	Concern/ Effect
Armillaria root disease	All stages	Mortality
Oak wilt	"	"
Defoliators (FTC, GM, etc.)	"	Predispose to mortality
Deer/ rodent browse	Seedlings and saplings	Mortality, topkill
Two-lined chestnut borer	Pole-sized and larger	Mortality
Stem decay	"	Volume loss

WATCHOUTS!

∞ Protect seedlings and saplings from browse damage.

∞ Avoid thinning oaks during a drought and/or defoliation event. It is best to wait one growing season after the drought or defoliation is over to thin or harvest.

∞ Maintain optimal stocking in high-value stands to avoid mortality losses due to two-lined chestnut borers and Armillaria root disease.

∞ If oak wilt is known to occur within one mile of the stand, prevent overland spread of oak wilt by not allowing thinning, harvesting, trail building, pruning or other activities that wound oaks from April 1st to July 15th.

∞ If oak wilt is present in this stand, several precautionary steps must be made prior to thinning or harvest. Please contact your Regional Forest Health Specialist for assistance.

∞ When planning intermediate or final harvests, write sale specifications to penalize wounding of residual trees and supervise sale closely to prevent wounding. The major entry points for decay fungi include mechanical wounds to the bole, dead branches, and dead or broken tops.

MHn47 Acceptable Operating Season to Minimize Compaction and Rutting

Primary Soils	Secondary Soils	Not Applicable

Surface Texture [1]	Drainage [2]	Depth to Semipermeable Layer (inches) [3]	Landscape Position [4]	Acceptable Operating Season [5]	
				Compaction	Rutting
Coarse (sand & loamy sand)	Excessive & Somewhat Excessive	Not Applicable	Top, Mid-slope, Level	All	All
			Toe & Depression	Wf > Sd > Fd > W > S	All but spring break up
	Well	> 12	Any	Wf > Sd > Fd > W > S	All but spring break up
		< 12	Top, Mid-slope, Level	Wf > Sd > Fd > W > S	Wf > Sd > Fd > W > S > F
			Toe & Depression	Wf > Sd > Fd > W	Wf > Sd > Fd > W > S > F
	Moderately Well	> 12	Top, Mid-slope, Level	Wf > Sd > Fd > W > S	Wf > Sd > Fd > W > S > F
			Toe & Depression	Wf > Sd > Fd > W	Wf > Sd > Fd > W > S
		< 12	Any	Wf > W	Wf > Sd > Fd
	Somewhat Poor	Any	Any	Wf > W	Wf > Sd > Fd
	Poor	Any	Any	Wf	Wf > Sd
Medium (sandy clay, silty clay, fine sandy loam, clay loam, sandy clay loam, silty clay loam, loam, v fine sandy loam, & silt loam)	Excessive & Somewhat Excessive	Not Applicable	Top, Mid-slope, Level	Wf > Sd > Fd > W > S	Wf > Sd > Fd > W > S > F
			Toe & Depression	Wf > Sd > Fd > W	Wf > Sd > Fd > W > S > F
	Well	> 24	Any	Wf > Sd > Fd > W	Wf > Sd > Fd > W > S > F
		< 24	Top, Mid-slope, Level	Wf > Sd > Fd > W	Wf > Sd > Fd > W > S > F
			Toe & Depression	Wf > W	Wf > Sd > Fd > W > S
	Moderately Well	> 24	Top, Mid-slope, Level	Wf > W	Wf > Sd > Fd > W > S
			Toe & Depression	Wf	Wf > Sd > Fd > W
		< 24	Any	Wf	Wf > Sd > Fd > W
	Somewhat Poor	Any	Any	Wf	Wf > Sd > Fd
	Poor	Any	Any	Wf	Wf > Sd
Fine (clay & silt)	Excessive & Somewhat Excessive	Not Applicable	Top, Mid-slope, Level	Wf > Sd > Fd > W > S	Wf > Sd > Fd > W > S > F
			Toe & Depression	Wf > Sd > Fd > W	Wf > Sd > Fd > W > S > F
	Well	> 24	Top, Mid-slope, Level	Wf > Sd > Fd > W	Wf > Sd > Fd > W > S > F
			Toe & Depression	Wf > W	Wf > Sd > Fd > W > S
		< 24	Any	Wf > W	Wf > Sd > Fd > W
	Moderately Well	> 24	Top, Mid-slope, Level	Wf > W	Wf > Sd > Fd > W
			Toe & Depression	Wf	Wf > Sd > Fd
		< 24	Any	Wf	Wf > Sd > Fd
	Somewhat Poor	Any	Any	Wf	Wf > Sd > Fd
	Poor	Any	Any	Wf	Wf > Sd
Peat & Muck	Poor	Any	Any	Wf	Wf
	Very Poor	Any	Any	Wf	Wf

Plants below indicate wetter inclusions in MHn47 that are more susceptible to compaction and rutting. They are listed in descending order of presence.

Lady fern (*Athyrium filix-femina*)
Jack-in-the-pulpit (*Arisaema triphyllum*)
Mountain maple (*Acer spicatum*)
Yellow birch (C) (*Betula alleghaniensis*)
Nodding trillium (*Trillium cernuum*)
Black ash (U) (*Fraxinus nigra*)
Common oak fern (*Gymnocarpium dryopteris*)
American elm (U) (*Ulmus americana*)
Alpine enchanter's nightshade (*Circaea alpina*)
Yellow birch (U) (*Betula alleghaniensis*)

(U) – understory **(C) - canopy** **Footnotes on back**

Foot Notes

1. Surface Texture and Landform Affinity – the dominant texture within 12 inches of the mineral soil surface, listed in ascending order of moisture holding capacity; landforms are listed when distinct associations with soil texture are evident

2. Soil Drainage
   Excessive – water moves very rapidly through the soil; saturation does not occur during the growing season except for brief periods

   Somewhat Excessive – water moves rapidly through the soil; saturation occurs greater than 60 inches below the surface but within the rooting zone periodically during the growing season

   Well – water moves readily through the soil; saturation occurs 40 inches or more below the surface during the growing season

   Moderately Well – water saturation occurs within 20 to 40 inches of the surface periodically during the growing season

   Somewhat Poor – water saturation occurs within 20 inches of the surface periodically during the growing season

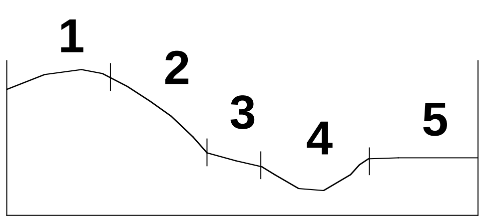
   Poor – water saturation occurs within 10 inches of the surface for most of the growing season

   Very Poor – water saturation occurs at the surface or within 10 inches of the surface for most of the growing season

3. Semipermeable Layer – any feature that retards downward water movement such as: hardpan, clay layer, bedrock, contrasting soil texture.

4. Landscape Position

   1 – Top
   2 – mid-slope
   3 – toe
   4 – depression
   5 – level



5. Acceptable Operating Season
   Listed in order of decreasing preference and increasing risk for compaction based on duration of dry conditions

   Wf Winter with frozen soil - ground is frozen enough to support heavy equipment

   Sd Dry Summer – extended periods without rain during the growing season when surface soil is dry; delay operations for brief periods after rain

   Fd Dry Fall - extended periods without rain in the fall when surface soil is dry; cease operations when significant rain occurs (1”-2” cumulative)

   W Winter – the ground is snow covered or partially frozen

   S Summer – the growing season; delay operations for a brief period after rain

   F Fall – after leaves fall until the ground is snow covered or frozen

   Sp Spring – after the frost goes out until herbaceous forest plants have reached full size (commonly two to three weeks after tree canopy leaf-out); delay operations during break-up

   The presence of an intact duff layer and slash on the surface together with use of low ground pressure equipment may help reduce the risk, severity, and extent of compaction.

Public Land Survey linked text

Natural stand dynamics and disturbance were evaluated using data from the original Public Land Survey (PLS) of Minnesota. The investigation begins by selecting from all section corners in the state, the set that possibly occurred on sites of the Native Plant Community (NPC) under consideration. Selected corners had to: occur on landforms (LandType Associations, LTAs) where we have modern samples of the community, have the full set of 4 bearing trees, have bearing trees typical of the community (>30% frequency in our sample set), and NOT have trees atypical of the community (<5% frequency). It is possible for an individual corner to contribute to the analysis of more than one community but more often, corners were eliminated from all analyses because of atypical species combinations. This commonly happens in Minnesota because of the incredible amount forest acreage in riparian edge between terrestrial forest and wetlands or lakes. Also, the glaciated terrain of Minnesota results in many sharp contacts between sorted materials and till, creating System-level changes in forest communities and further elimination of survey corners from the analysis.

From this set of corners for a NPC we assigned a stand age to the corner based upon the diameter and modeled age of the largest/oldest tree present. Presumably, the age of the oldest tree at a corner is a minimum estimate of how long the stand has avoided a catastrophic disturbance. Corners were then placed into 10-year age classes with the exception of the initial 15-year class that matches the 15-year disturbance “recognition window” used to calculate the rotations of fire and windthrow. Experience shows that when applied to PLS data, a 15-year window for catastrophic disturbance and a 5-year window for maintenance disturbance results in a reasonable match with far more reliable, but local studies of disturbance using techniques of fire-scar analysis, stand origin mapping, and the analysis of charcoal in varved lake sediments. Small diameter (<4”) bearing trees were “forced” into age class 0-15 when they occurred at corners described as burned or windthrown. Otherwise, corners were assigned to age classes when the diameter of the oldest tree would lead us to believe that it was between 15-25 years old, 25-35 years old, etc. The fundamental property of an age-class in our analyses is the relative abundance of the component species.

By ordinating age-classes (PLS Figure 4) we can discover natural periods of stability known as growth-stages, as well as periods of instability known as transitions. Summarizing data by growth-stages and transitions allows us to present a general model of stand dynamics and succession for the NPC Classes. Such models can be presented in tabular (PLS Table 1) or graphic form (PLS Figure 2).

It is important to remember that ***this is a landscape composite of tree abundance by age. One should not expect a particular stand of a certain age to match exactly the composition suggested by the table or graphic.*** A universal result in habitats with several tree species is that the younger age classes are highly variable and often monotypic, presumably the result of variation in the intensity and type of regenerating disturbance. As stands age, they become more mixed, often to the point where the relative abundance of trees in the landscape age-classes match what one sees in a stand.

Modern Forest linked text

Releve Samples

Releves are large (400m2) sample plots that we used to sample ecologically intact and generally mature forests in Minnesota. This means that most of the stands sampled were regenerated from events that pre-date the Forest Inventory Analysis (FIA, below) and post-date the Public Land Survey (PLS) data (above). The releves are the basis for the Native Plant Community (NPC) classification itself. For silvicultural interpretation releve data were used to develop two important concepts.

First, releves were used as a means of determining just how well adapted the different species of trees are to living with other plants in the NPC and to important soil characteristics like drainage and water-holding capacity. Based upon how often we find certain trees in a community and how abundant it is when we do find it, we created an Index of Suitability for trees (Table R-1). The most important use of this table is understanding the variability of ecological potential that trees have among the different NPCs. This table was used to define the set of trees to be addressed in this document.

Secondly, releves were used to interpret of the ability of trees to regenerate and then recruit germinants to taller strata beneath a canopy. Indices of seedling (SE-index) and sapling (SA-index) success allows the tree species to be ranked by their success in recruiting germinants to seedling (<2m) or sapling (2-10m) status whereby one extreme is characterized by species capable of ingress and growth under a full canopy, versus species that seem to need the full sunlight and soil conditions that follow major disturbance and opening of the canopy (Table R-2).

For more information on the releve method and NPC Classification:

Link to the releve handbook.
Link to the NPC Field Guides

FIA Samples

Forest Inventory Analysis (FIA) data were used to confirm aspects of species behavior interpreted from the Public Land Survey analyses and also to provide a general feeling for just how much Minnesota's forests have changed after a century of management. Because comparison to PLS analyses was a major goal, FIA subplots were treated as point samples similar to PLS survey corners. For abundance comparisons (e.g. Table PLS/FIA-1) , FIA subplots were "reduced" to approximate PLS section corners by selecting randomly a tree > 4" dbh in each quadrant around the point. For structural comparisons (e.g. Table FIA-1) all trees at FIA subplots were used. In both cases PLS data and FIA data were pooled and analyzed by the same computer programs so that comparisons could be made.

Similar rules were used for deciding which FIA plots and subplots and PLS survey corners could belong to a dataset for each forested NPC Class. The FIA analysis began by selecting from all FIA subplots the set that possibly occurred on sites of the Native Plant Community (NPC) under consideration. Selected subplots had to: occur on landforms (LandType Associations, LTAs) where we have modern samples of the community, have trees typical of the community (>30% frequency in our sample set), and NOT have trees atypical of the community (<5% frequency). If FIA plots, with either 10 or 4 subplots, were heterogeneous with regard to subplot community assignments, only the subplots with the dominant NPC were used. If no NPC occurred on more than 3 of 10 or 2 of 4 subplots (i.e. 30% or more), then entire FIA plot was eliminated from the analysis. It is possible for an individual subplot to contribute to the analysis of more than one community but more often, subplots were eliminated from all analyses because they didn't meet plot homogeneity rules. This commonly happens in Minnesota because of the incredible amount forest acreage in riparian edge between terrestrial forest and wetlands or lakes. Also, the glaciated terrain of Minnesota results in many sharp contacts between sorted materials and till, creating System-level changes in forest communities and further elimination of FIA plots from the analysis.

From this set of subplots for a NPC we assigned a stand age to the corner based upon the diameter and modeled age of the largest/oldest tree present. Presumably, the age of the oldest tree at a subplot is a minimum estimate of how long the stand has avoided a catastrophic disturbance. Corners were then placed into the same age-classes as were the PLS survey corners: 0-15, 15-25, 25-35, etc. The fundamental property of an age-class in our analyses is the relative abundance of the component species. From this dataset it is possible to perform analyses parallel to those done for PLS bearing trees. Table PLS/FIA-1 is such a comparison of tree abundance by growth-stage.

The FIA data were too sparse to construct a table similar to PLS-5 so that we could guess at regeneration windows based upon diameter subordination. The main reason for this is that quaking aspen dominates a lot of modern forests and populations of most conifers have crashed in historic times. For example, FIA plots retrieve very little data for trees like jack pine and tamarack, even on sites that were historically dominated by these trees. By simplifying the FIA data into just three broad diameter classes, we were able to perform a similar analysis (Table FIA-1) that can confirm or cause us to re-examine our interpretations of table PLS-5.

A great advantage of FIA data is the re-sampling of plots from one inventory cycle to another. The fate of individual trees on these plots can thus be tracked and we can examine how stand conditions might have influenced their survival or mortality. By the time FIA plots were winnowed by homogeniety rules and assigned to 52 forested plant communities, the total number of tracked trees is rather low ... especially for minor species of some communities and for the conifers that have declined significantly in the past century. Because of the low sample numbers, we present no summary tables for observed mortality or survivorship. However, these are real observations that were not dismissed in writing the individual species accounts in this document. These observations are very useful in confirming or dismissing our inferences about mortality and replacement in the PLS data.

For more information on the FIA methods and inventory in Minnesota:

Link to the USFS website, north central