FDs37

FDs37 – Southern Dry-Mesic Oak (Maple) Woodland

Natural Disturbance Regime, Stand Dynamics, and Tree Behavior

Summary and Management Highlights

Southern Dry-Mesic Oak (Maple) Woodland (FDs37) is a common hardwood community found almost entirely within the Minnesota & Northeast Iowa Morainal Section (Figure 1.). A few outlying stands are documented in the Red River Prairie Section where topography or lakes offered some protection from prairie fires. Detailed descriptions of this community are presented in the DNR Field Guides to Native Plant Communities of Minnesota.

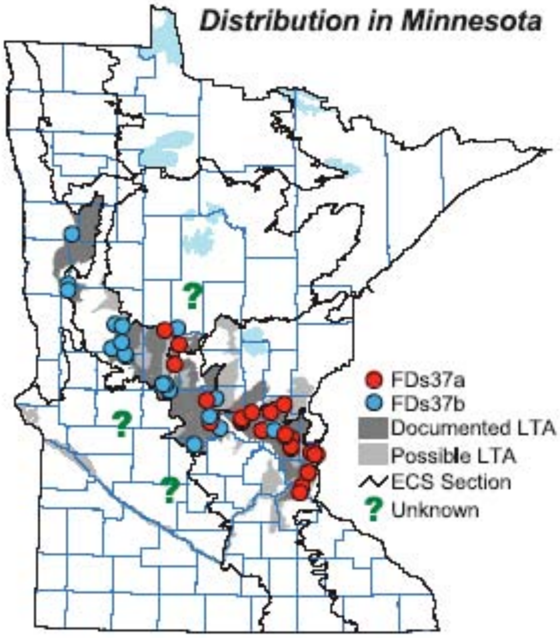


Figure 1. The range of FDs37 forests in Minnesota (shaded) and distribution of releve samples (red and blue dots).

Commercial Trees and Management Opportunities

As a commercial forest, FDs37 sites offer a modest selection of crop trees and several possible structural conditions. Northern pin oak, bur oak, northern red oak, and white oak are all ranked as excellent choices as crop trees by virtue of their frequent occurrence and high cover when present on FDs37 sites (see Suitability Tables). Red maple, quaking aspen, big-toothed aspen, paper birch, and green 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. Black cherry is ranked as just a fair choice of crop tree. Our data suggest that black cherry rarely produces saw logs on these sites, but stands can be managed to maintain their presence as minor trees for purposes other than timber production.

Among these species the oaks were the dominant native trees that have occupied FDs37 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)**. Aspen are likewise native to FDs37 sites but occurred naturally at lower abundance. The consequence of commercial logging and settlement in the past century has been to promote much more aspen at the expense of oak. The consequence of fire suppression has been to allow ingress of some mesic, fire-sensitive species such as red maple and perhaps ironwood. It seems to us that modern land use has encouraged advance tree regeneration in the understory, whereas the historic condition probably favored shrubs like American hazelnut and gray dogwood if not grassy openings. The list of trees with good advance regeneration is long **(R-2)**, and species like black cherry, red maple, and ironwood that were essentially absent in historic times are now the most successful. The increased abundance of these trees complicates our interpretations and the use of natural regeneration models as silvicultural strategies.

Although our interest is in silviculture, it is clear that FDs37 sites offer management opportunities apart from wood products. In circumstances where wood production is a secondary goal, FDs37 sites offer an excellent opportunity to provide habitat for “prairie” plants and habitat for wildlife adapted to prairie-brushland. Both prairie and prairie-brushlands have been nearly eliminated from Minnesota’s landscape due to agricultural development, and FDs37 sites could at least temporally provide “lifeboat” habitat. Where FDs37 occurs on sand, it is clear that some of the more exposed and drier inclusions are sand prairie (UP System) that harbor some of the state’s rarer plants. Because of their prairie heritage, FDs37 have rich soils in comparison to forests.

This presents silvicultural obstacles, most relating to competition, that make it difficult to fully stock clear-cut sites within a few years of harvest without extraordinary effort in site preparation.

Natural Silvicultural Approaches

In the historic landscape, most FDs37 woodlands (79%) were in the young growth-stage **(PLS-1)**. Roughly these woodlands were under 75 years old, meaning that few trees achieved large diameter. At this time fires, whether intense stand-initiating ones or milder surface fires, killed oak stems and created lots of open and large-gap habitat for regeneration of oaks and aspen – which probably didn't seem physiologically so different from the shrubs. The essence of this disturbance was incredible selection among small-diameter stems for those that were most resistant to fire. Physical attributes like thick, insulating bark and the capacity to invest resources below ground were adaptive, explaining the great success of bur oak and oaks in general. We doubt that FDs37 woodlands in their natural condition were at all attractive to the logger inasmuch that most woody tissue was unavailable below ground, incorporated in rather useless small-diameter stems, or in ill-formed trees. To the prairie homesteader, these woodlands were a Godsend of fuel wood, hunting opportunity, and season-long production of nuts and berries. Thus, managing these woodlands naturally is silviculturally distasteful if we insist that they contribute to the industry of northern forests. However, there are opportunities if the focus is on fuel wood production and an emphasis on a few quality logs per acre. The selective nature of disturbance in young woodlands is more akin to tending practices and improvement harvesting than silvicultural systems. Here, tending would favor individual trees expected to produce merchantable lumber and improvement harvests would aimed at removing fuel wood and providing growing space for crop trees. Tending would include also continuous efforts to establish vigorous oak seedling-sprouts and elimination of tolerant hardwoods. A prescription could involve several entries spanning many years in preparation for commercial removal of trees. The actual pattern of removal would resemble a shelterwood to promote the recruitment of oak seedling-sprouts and improved growth of retained crop trees. The natural shelterwood system of removing the canopy above good advance regeneration would be the preferred strategy.

Mature FDs37 woodlands covered about 21% of the historic landscape **(PLS-1)**. Our vision of these woodlands is a skeletal presence of large oaks standing above one to several cohorts of younger trees dating to surface fires. Most likely these were large, thick-barked, old bur oak veterans that were nearly impervious to fire. Disease and rot entering fire-scars probably initiated their demise. We doubt that these trees were at all well-formed, sound, or of commercial interest historically. Protecting crop trees during numerous tending entries and allowing some crop trees to reach old age is the natural strategy. Bringing trees to this point requires tending, pruning, and management of the canopy to discourage excessive branching. Any of the selective harvesting systems and possibly patch cuts would reasonably match the natural canopy dynamics that led to scattered trees of large diameter and potentially high quality. It is important to note that there are few species native to FDs37 sites that will regenerate in such small openings. Thus, the ecology of most FDs37 trees doesn't match the usual assumption of advance regeneration responding to the removal of a few trees unless considerable effort has been made to manage advance regeneration of oaks prior to harvest. Among the native trees in mature woodlands, red oak and white oak are the species with the phenotypic plasticity to retain the desired growth-form for sawtimber.

Management Concerns

Many FDs37 stands occur on level, well-sorted lacustrine sand on the Anoka sand plain. In this situation, there is little concern of soil-compaction. Only when the soil surface is saturated and above frost is there a chance of rutting. Less often, the FDs37 community occurs on gravelly or sandy inclusions within stagnation moraines. In our experience, these are just local deposits of outwash with the same, low potential for compaction and rutting. Along the Minnesota river and sometimes on the stagnation moraines, FDs37 stands occur on steep bluffs that dry out due to their southern aspects. In this situation the parent material is compactable till, but good drainage coupled with the tendency of these soils to dry by exposure, means that the soils are rarely at a moisture content that promotes much plasticity. Erosion is the greater concern on these FDs37 bluffs. Constructing designated haul roads, using water bars, and laying culls parallel to contours are all encouraged mitigating practices.

The landscape balance of growth-stages and stand ages for the FDs37 community is not much different than it was historically **(PLS/FIA-1)**. Today, there is slightly less young forest (<75 years) and slightly more mature forest (>75 years) than in pre-settlement times. The overall loss of FDs37 woodlands to agriculture is a greater concern than any imbalance of age-classes. Today's young woodlands, do not resemble the oak openings of the past because fire has been eliminated as an influencing factor. This has resulted in dramatic compositional change that might be of concern. Where logging has replaced fire as the disturbing agent, the effect has been to conversion to aspen. What seems more serious in managed stands is the seeming loss of oak rootstocks, meaning the opportunity to manage oak on these sites by simple coppicing methods seems to be evaporating, and restoration of such rootstocks seems to be silviculturally challenging and expensive. FDs37 stands that have been protected are succeeding to more mesic forest conditions, albeit rather slowly in comparison to oak-dominated MH communities. Ingress of red maple, paper birch, ironwood, and possibly green ash will complicate any efforts to restore or maintain oak in unmanaged situations. Fundamentally, fires did an incredible amount of "work" in FDs37 woodlands to maintain oak – an amount that is difficult for agencies to justify with the current markets and the workload is beyond the capacity of most private landowners. We will continue to lose the natural conditions of FDs37 woodlands until such conditions are valued and restoring those conditions is primary management objective.

Natural Stand Dynamics

Natural Rotations of Disturbance in FDs37 Forests Graphic	
	Banner text over photo
Catastrophic fire photograph	**110 years**
Catastrophic windthrow photograph	**7,680 years**
Partial Canopy Loss, photograph	**12 years**

Natural rotation of catastrophic and maintenance disturbances were calculated from Public Land Survey (PLS) records at 2,620 corners within the primary range of the FDs37 community. At these corners, there were 5,626 bearing trees comprising the species that one commonly finds in FDs37 woodlands.

The PLS field notes described about 14% of the FDs37 landscape as recovering from stand-regenerating fire. Unlike FD communities with conifers, a small fraction of the land was described as totally burned over. Rather the surveyors described post-fire situations mostly as sparse forest, scattering timber, openings, and thickets. From these data, a rotation of 110 years was calculated for stand-replacing fire.

Elsewhere in the FDs37 landscape, the surveyors described lands as windthrown and lacking suitable-sized trees for scribing. Such corners were extremely rare, encountered far less than 1% of the time, yielding an estimated rotation of 7,680 years for windthrow. Thus, wind played virtually no role in regenerating FDs37 forests at the stand scale.

Far more common at FDs37 sites were references to what we have interpreted as some kind of partial canopy loss, without any explicit mention of fire or windthrow. The surveyors used a variety of terms to describe these forests such as sparse forest, scattering timber, openings, thickets, and barrens, where distances to bearing trees were intermediate between the distances for burned/windthrown lands and what is typical for fully stocked oak woodlands. An incredible 43% of the survey corners were described as such, resulting in a calculated rotation of just 12 years for disturbances that maintained early and mid-successional trees on FDs37 sites. That more corners were described as burned (14) compared to windthrown (5) suggests that surface fires were the more prevalent cause of partial canopy loss; however, it is clear that these forests were so chronically disturbed that the surveyors found little occasion to find fire or wind damage as noteworthy or unusual.

All of the FDs communities in Minnesota have very similar disturbance regimes. Catastrophic replacement had a rotation of just over 100 years, and maintenance events were nearly 10 times as common as catastrophes. All species of oak could easily live from one catastrophe to the next, never abandoning their well-established and possibly ancient rootstocks. The paucity of wind damage (rotation >> 1,000 years) is puzzling because windthrow was common in nearby MH forests, which share many of the tree species. Early researchers noted and measured the tendency of MHs37 trees bordering the Big Woods (MHs39) to become progressively shorter towards the prairies that surrounded the Big Woods. Apparently these shorter trees were quite windfirm in comparison to their taller relatives in the mesic forests.

Natural Stand Dynamics & Growth-stages

Following stand-regenerating fire, the overall pattern of change in FDs37 woodlands involved very little compositional succession of the common trees. Essentially all of the initial-cohort species occur in older woodlands at similar abundance **(PLS-1)**. In fact, quaking aspen and perhaps black cherry, are the only species not likely to have individuals capable of living from the beginning to the end of the short successional cycle of about 110 years (see Natural Disturbance Regime). The basic pattern of change is for modest change following catastrophic fire until about the 80-year age-class, and virtually no change in the relative abundance of species thereafter **(PLS-4)**. Our interpretation is that differences in fire intensity could drive the modest succession that we see. It is possible that catastrophic fires were destructive enough to result in the establishment of some new stems (especially aspen), and subsequent surface fires affected composition by winnowing exposed or inherently fire-sensitive individuals from the initial-cohort. Unlike true forests, compositional succession in woodlands involves “canopy” dominants that are not trees, which makes reconstruction from tree databases like the PLS survey notes problematic. Our best guess is that compositional succession involved mostly a change in the herbaceous layer from sun-loving, prairie species to those favored in the shade as the shrub canopy closed.

Structural maturation of FDs37 woodlands was far more impressive than its compositional change. The surveyors used a variety of terms to describe described these woodlands, which were almost always recovering from fire. Only half of the survey corners assigned to the FDs37 community were described by the surveyors as forest-like. The remaining half was variously described as scattered timber, openings, barrens, or thickets. It is clear also that brush and brushy growth-forms of the trees (e.g. oak grubs) were an integral component of their structural descriptions of the FDs37 community. It is significant that the shrub flora for FDs37 woodlands includes more species than the list of common trees. American hazelnut, beaked hazelnut, and gray dogwood are capable of forming a canopy of greater extent than most of the trees. Given this level of shrub competition, it is not surprising that the stocking of trees was rather sparse. In young FDs37 woodlands the mean distance to bearing trees was 50 feet, which is far sparser than the 20-30 feet typical of true MHs forest. Older FDs37 woodlands had mean distances to bearing trees at 54 feet, meaning that old woodlands were a bit sparser than young ones. Self-thinning of the initial aspen component would be enough to explain this modest change in density. Our impression is that succession was initiated by the death of trees connected to well-established, if not ancient rootstocks and that the initial-cohort was almost entirely sprouts. Because most of the common trees sprout from the root collar, there was little difference in density or composition between young and mature FDs37 woodlands.

Young Growth-stage: approximately 0-75 years

About 79% of the FDs37 landscape in pre-settlement times was covered by woodlands estimated to be under 75 years old **(PLS-1)**. Post-fire woodlands were patches of prairie, brushland, and trees. The treed areas were mostly (80%) of mixed composition, involving combinations of bur oak, quaking aspen, and red oak. The tendency to be mixed is no doubt a consequence of the fact that mature FDs37 woodlands were also mixed, and that post-fire regeneration was accomplished largely through sprouting from parent trees. This is a significant departure from northern and central FD woodlands where the post fire environment tends to often result in monotypic conditions related to the establishment of new stems via aspen suckering and pine seeding. When young FDs37 survey corners were monotypic it was almost always a case where all attending trees were bur oak. Amazingly, there were no cases where all trees were quaking aspen, which gives us the impression that aspen filled in among oaks at a fine scale, and perhaps surveyors favored oaks as bearing trees.

In the historic landscape, an amazing amount (13%) of FDs37 woodland was interpreted to be recovering from recent fire **(PLS-3)**. Wind played virtually no role in regenerating FDs37 woodlands, as less than a percent of the landscape was described as recently windthrown. Bur oak was the obvious benefactor of fire, with 71% relative abundance of stems recovering from the burn. An amazing feature of these woodlands is that the relative abundance of trees directly following fire is quite comparable to their abundance throughout the young and mature growth-stages **(PLS-1)**. It looks as if the distribution of trees in FDs37 woodlands is invariant, and that the only real difference between a young and old woodland is the diameter and height of the aerial stems. The density and distribution of oak rootstocks must have been set by ecological factors (soils, climate, etc.) that vary over much longer periods of time, than that of fire-driven succession. Modest fluctuations of other species about the stable oak population are what causes young woodlands to be slightly different in composition from mature ones. Young woodlands had higher abundance of quaking and big-toothed aspen stems, probably because of their ability to reproduce by suckering. The modest presence of black cherry in the young growth-stage was probably a consequence of fire resulting in some establishment from its pervasive seed bank. The exposure of mineral soil and reduced competition seems to have resulted in some establishment of pin oak; however, it is possible that the surveyors were more inclined to call small oaks pin oak (Spanish oak, jack oak) and larger ones black or red oak which we consider to be all red oak within the range of the FDs37 community.

For this community it is important to point out that the ordination technique that we used to identify growth-stages is sensitive to absence more so than difference in relative abundance values. In colloquial language, the computer “figures” that the difference between 0% in one age class and 1% in the other, is considerably more “important” than a species having 2% abundance in one age-class and 3% in the other – even though the absolute difference is 1% in both cases. For FDs37, the presence of northern pin oak, black cherry, and a few miscellaneous species in the young growth-stage and their absence in the mature growth-stage **(PLS-1)** had some importance in our defining the two growth-stages in ordination space **(PLS-4)**. We did not eliminate the low abundance species from the analysis, because it seems plausible that catastrophic fires provided enough free growing space for the establishment of some species that have little chance of surviving subsequent surface fires.

Mature Growth-stage: approximately >75 years

About 10% of the historic FDs37 landscape was mature woodland where the rate of successional change slowed to virtually nothing **(PLS-4)**. Stands in this stage were far more likely to be mixed (83%) than monotypic (17%). Patches of pure bur oak or white oak were the most common monotypic conditions. Nearly all mixed corners involved some combination of bur oak, white oak, basswood, or elm, with occasional references to quaking aspen.

The most striking feature of mature FDs37 woodlands is that they were still dominated by the initial-cohort species. Other than the modest contribution of basswood and elm to mature woodlands, none of the common species are normally considered late-successional or particularly shade-tolerant, yet they were able to “hold” sites indefinitely without the benefit of catastrophic disturbance **(PLS-1, PLS-2)**. We believe that surface fires were responsible for conditions that allowed the persistence of these species on FDs37 sites. We calculated a rotation of just 12 years for surface fire, meaning that by the time a stand reached the mature growth-stage, it had probably experienced 6 surface fires and would likely experience many more while in the mature growth-stage. Because of chronic fire, there was no turnover of species favoring fire-sensitive, shade-tolerant trees. The concept of shade-driven succession had no application to FDs37 sites. The most compelling argument for this interpretation is the reaction of the community to having fire eliminated as an influencing factor. The result of turning off the fire spigot, has been to see all shade-tolerant species increase in importance, especially basswood, red maple, and ironwood **(PLS/FIA-1)**.

The only species to show much in the way of successional dynamics is white oak, as it steadily increases in abundance relative to other trees as FDs37 woodlands aged. Among the common trees, this is the only oak to not fit our idea that most trees had their origin as stump sprouts. In this case it looks like seed-origin establishment and subsequent recruitment beneath a canopy is required to explain its abundance in older woodlands. Silvics manuals and our releve data on the oaks common to this community show little difference among the species with regard to seedbeds, tolerance, and ability to recruit beneath a canopy **(R-2)**. Thus in modern forests, where the chronic regime of surface fire has been removed, all of the FDs37 oaks seem equal in their generally good ability to establish and recruit seedlings. The required hypothesis for white oak behavior must explain two things. First, why catastrophic fire killed white oaks more than the others. Second, why surface fires or other maintenance disturbances favored seed-origin white oaks over the others in older woodlands. Preferentially killing old white oaks is not difficult. More so than the other species, white oak loses its sprouting ability following cutting at about age 80 or at diameters larger than the typical 80 year-old tree (~12” and larger). Conveniently, this is almost exactly where we split the growth-stages, meaning that white oaks could re-sprout in young FDs37 woodlands, but not in mature ones. Also in Minnesota, white oaks are consistently infected by a fungus that removes nearly all of the corky bark, leaving it considerably less insulated from fire in comparison to bur oak. Thus catastrophically burning a mature FDs37 woodland could easily kill the white oaks >12” dbh at a time when vegetative reproduction was not likely. The second half of the necessary hypothesis is problematic – as we can think of no particular reason why white oak should show much greater success in establishing seed-origin trees than the other oaks, with or without the maintenance fires. Identification problems with white/bur oak or lack of data are not sufficient for us to discount what seems to be a fact – that white oak shows improved regeneration success and greater importance as FDs37 woodlands aged. Plenty of survey corners and releves were involved in the analysis of the FDs37 community, and the pattern of white oak gaining importance as stands matured is repeated in the FDs38 community, and MHs communities where white oak is a component tree.

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?

Northern Pin Oak & Northern Red Oak & their hybrids

- ***excellent habitat suitability ratings***
- ***early-successional***
- ***open (large-gap) regeneration strategists***
- ***regeneration window at 0-40 years***

Identification Problems

To some extent the PLS surveyors distinguished between northern pin oak (*Quercus ellipsoidalis*) and northern red oak (*Quercus rubra*). Northern pin oak was most often referred to as Spanish or jack oak; northern red oak was most often referred to as black oak or red oak, but red oak is the only species within the range of the FDs37 community today. In the tables and figures we maintain the separation – but within this region of Minnesota, northern pin oak and northern red oak hybridize freely and even the best botanists are forced to make judgments based on the preponderance of field characteristics one way or the other. Mercifully, we saw little difference between the species in either the historic or modern datasets. Thus, considering these species together should not result in silvicultural error.

Suitability

FDs37 sites provide ***excellent habitat*** for pin oak trees. The perfect ***suitability rating*** of 5.0 for pin oak is influenced mostly by its very high presence (62%) as trees on these sites in modern forests **(R-1)**. When present, pin oak is an important dominant or co-dominant tree, contributing 41% mean cover in mature stands. The ranking is perfect, because no other tree or plant has higher presence and cover on FDs37 sites as sampled by releves. Except for FDs36 forest, southern fire-dependent woodlands offer excellent habitat for pin oak (see Suitability Tables).

FDs37 sites also provide ***excellent habitat*** for red oak trees. The ***suitability rating*** of 4.9 for red oak is influenced mostly by roughly equal presence (36%) and mean cover-when-present (35%, **R-1**). This ranking is third, behind northern pin oak and slightly behind bur oak. Southern fire-dependent communities (FDs) offer good-to-excellent habitat for red oak (see Suitability Tables). The suitability ratings for red oak and pin oak are essentially the same other than red oak has good success in the FDs36 forest, whereas pin oak performs slightly better in the woodlands.

Young Growth-stage: 0-75 years

Historically, at about 18% relative abundance red/pin oaks were important trees young FDs37 stands recovering from stand-regenerating disturbance **(PLS-1, PLS-2)**. Young red/pin oaks represented 15% of the trees at survey corners described as burned, which is substantially less than the dominant bur oak **(PLS-3)**. These trees were less important following windthrow, but windthrow was not an important means of regenerating FDs37 woodlands. Because both species have peak abundance early in the young growth-stage and then slowly decline, we consider them to be ***early successional*** species on FDs37 sites. Small-diameter red/pin oak regeneration was abundant in the post-disturbance window **(PLS-5)**, with the initial age-class having the greatest abundance. This is typical of early successional species, and we interpret this as red/pin oak showing excellent ability to prolifically stump sprout and possibly establish a few seed-origin individuals in the post-fire environment. In the young growth-stage, there were no survey corners where all individuals were red or pin oak. They always occurred mixed with other species. Red oak was about equally present as the largest tree at a corner as it was as the smallest tree at a corner. Normally, we attribute this to a long window of establishment and recruitment. This could be true, but it is more likely that this is just differential growth of stump or seedling sprouts. Pin oak was always the smallest tree at a survey corner, which is usually the trait of a species able to fill growing space with some seed-origin trees. This could be true, but we suspect that the surveyors were more likely to identify slow-growing, stunted oak sprouts as pin oak. In either case, there was a clear preference for smaller-diameter red/pin oaks to come in among larger aspen, and sometimes bur oak. In the aspen case, it seems possible that these might have been seed-origin red/pin oaks as aspen seems to play the role of a cover crop over red oak in other communities. In the bur oak case, it just seems more likely to us that even small-diameter, 2-6” bur oaks tended to survive fire better than either red or pin oak. Thus, the bur oaks were probably residual advance regeneration or suppressed stems that had a head start on the young red/pin oaks.

The immediate success of red/pin oaks following stand-regenerating fire in historic woodlands is almost certainly a function of their presence in the mature growth-stage **(PLS-1)**. It is important that unlike white oak, red and pin oaks retain their ability to sprout regardless of the diameter or age of the parent tree. Thus, most parent trees killed in a fire are likely to be represented in young woodlands by their sprouts. A reasonable explanation for the modest change in red/pin oak abundance throughout the course of stand maturation is that the parent trees simply replaced themselves. That is, a sprout from a large, well-established rootstock had a very good chance of rapid growth and recruitment and that smaller trees and advance regeneration had a very slight chance. The slightly higher abundance of red/pin oaks in the young growth-stage suggests that some red/pin oak sprouts survived long enough for some to reach bearing tree size (~4"), but even at pole-size root resources mattered in surviving surface fires. Our general vision of oak behavior in general in FDs37 woodlands is that mature woodlands had abundant advance regeneration in comparison to any mesic species. A young woodland must have appeared to be a sea of sprouts, some emanating from large and ancient rootstocks and others from what a seedling could muster in a few years (so-called "seedling sprouts"). Recruitment and ultimate success in the canopy was correlated with resources available in the rootstock and the number of sprouts they supported. This notion does mean that establishment, that is the actual timing circumstances surrounding the germination success of acorns, was not especially important. In fact, with this level of surface fire, there is no compelling reason to suspect that establishment was any better immediately after catastrophic fire than at any other time during succession. For all we know, cohorts of oak regenerants were tied more directly to dips in the populations of their seed predators, and chronic fires kept FDs37 sites receptive at all times.

Mature Growth-stage: >75 years

In mature FDs37 stands the relative abundance of red/pin oak had declined to an average of about 10% **(PLS-1)**. If we are to believe the surveyor identifications, pin oak declines to very low levels by the beginning of the mature growth-stage and red oak declined at a slower rate **(PLS-2)**. Neither species has much small-diameter regeneration during the period based upon our half-diameter rule **(PLS-5)**. At this time, it was about equally likely for red oak to be the smallest tree at a corner as it was for it to be the largest tree. Most often, smaller diameter red oaks were in the company of larger diameter bur, white, and other red oaks. This is different from the young growth-stage where it was more inclined to be below aspen. We believe that this represents the loss of initial-cohort aspen, leaving the longer-lived oaks that had similar but variable diameter growth. Our interpretation is that the red/pin oaks in the mature growth-stage were initial cohort-trees, and that their populations in the mature growth-stage were not subsidized by continued recruitment.

Surface fires maintained mature FDs37 woodlands, but it did not seem to translate into obvious cohorts as is often the case for pine woodlands. Because red/pin oak abundance increased after catastrophic fires, the surface fires must have encouraged some establishment but discouraged recruitment. We believe that the surface fires maintained a healthy population of red/pin oak seedlings and seedling-sprouts in mature woodlands. It is important to remember that these woodlands were incredibly brushy, and we envision seedling oaks as struggling to emerge from the shrub layer. Suppressed red/pin oak seedlings were probably consistently burned off by surface fires along with the brushy matrix. An element of chance must have been involved in the recruitment of red/pin oak, but it seems that those chances were far better after a catastrophic fire than after surface fires in mature woodlands. Perhaps, catastrophic fires offered a long-enough window of adequate sunlight, reduced shrub competition, and reduced fuel loads for some red/pin oak recruitment.

Regeneration Strategies

The primary regenerative strategy of red or pin oak on FDs37 sites is to dominate ***open habitat*** after stand-regenerating fires. In the historic PLS data this interpretation is supported by: (1) the fact that these trees had their peak relative abundance in the young growth-stage **(PLS-1)**, (2) they were important bearing trees at burned survey corners **(PLS-3)**, and (3) their peak recruitment was in the post-disturbance window **(PLS-5)**, with highest recruitment in the initial age-class **(PLS-2)**. Consistent with the open strategy is red oak's high presence in sapling and pole stands (situations 11 and 22) in FIA plots **(FIA-1)**. There are not enough records of pin oak in the FIA data to identify a strategy as the few occurrences had no pin oak in young or subordinate situations. This is puzzling, given the high presence of pin oak in the canopy **(R-1)** and understory **(R-2)** in the releve samples.

The releve sampling of mature FDs37 forests suggests, however, that red and pin oaks are able to function also as a ***large-gap*** strategists with generally good establishment and recruitment in the understory strata **(R-2)**. Red oak has fairly high presence as poles in tree stands (situation 23, **FIA-1**), which we also associate with species that tend to do well in large gaps.

It is important to note that our simplification of regeneration strategies is biased towards the amount of canopy removal that favors recruitment or release. We normally assume that if mineral soil seedbeds are to appear, they did so in conjunction with the canopy-removing disturbance. In FDn and FDc woodlands, we assume that germination, establishment, and recruitment of species needing mineral soil seedbeds happened in response to a single, canopy-removing event – an event that can be approximated with a single timber sale followed by attention to establishment of desired trees. In the case of FDs37 woodlands and oaks, fire was so common that seedbeds on these sites were always prepared for oak establishment. Successful establishment of oaks with enough root resources to respond to canopy release started with successful germination followed by several episodes where fire top-killed the seedlings which helps to "convince" the small oaks to invest resources below ground. Silvicultural approximation of this process requires several treatments aimed at establishing a bank of large-caliper seedlings or saplings. Creating the large-gaps or open conditions in a timber sale is the concluding treatment.

Historic Change in Abundance

Today, all oaks have reduced presence and abundance in the FDs37 community. According to the FIA data, pin oak has been all but extirpated from these sites in young woodlands **(PLS/FIA-1)**. Red oak too has seemingly declined from about 12% presence in young forests historically, to about 6% today. We believe that the decline in abundance in young woodlands is a consequence of managing these sites recently for pulpwood by coppicing and encouraging aspen. Mixed aspen and oak stands have been clear-cut at times when advance oak regeneration was inadequate. Both red and pin oak show slight increases in abundance in today's mature woodlands in comparison to historic times. In our experience, many of our oak-dominated woodlands older than about 80 years can be traced to failed attempts at agriculture on poor sites where the woodlands were exploited for building material and then grazed for some time. In either case, nearly a century of fire suppression has eliminated the chronic surface fire regime that enabled oaks to dominate FDs37 sites. We doubt that red and pin oak are in peril as some will persist by stump sprouting in stands managed for wood products. However, it is important to develop silvicultural strategies that include prescribed burning if these woodland are to maintain their native flora and remain oak-dominated.

Bur Oak

- ***excellent habitat suitability rating***
- ***mid-successional***
- ***large-gap (open) regeneration strategist***
- ***regeneration window at 40-60 years***

Identification Problems

The PLS surveyors referenced both bur oak and white oak as witness trees. In some cases, individual surveyors used both terms, which would suggest that they were able to distinguish the species. In other surveys, it seems clear that "white oak" was used in a generic sense for oaks lacking bristle-tipped leaf lobes, which includes both bur and white oak within the range of the FDs37 community. The releves show that for plots with either oak present: 21% have both species present; 18% are white oak without bur oak; 61% are bur oak without white oak. For the purpose of discussing the FDs37 community, we have chosen to believe the surveyor identifications as white oak references show considerable population change as stands matured. The fact that we see the same pattern of abundance change in other southern forests and woodlands suggests that the surveyors were at least consistent in differentiating the species if not always accurate. The modern data suggest little difference in their ecology.

Suitability

FSs37 sites provide ***excellent habitat*** for **bur oak** trees. The ***suitability rating*** of 4.9 for bur oak is influenced mostly by its high presence (67%) as trees on these sites in modern forests **(R-1)**. When present, bur oak is an important co-dominant tree, contributing 21% mean cover in mature stands. The ranking is second, following northern pin oak on FSs37 sites. All southern fire-dependent communities offer excellent habitat for bur oak (see Suitability Tables).

Young Growth-stage: 0-75 years

Historically, at 57% relative abundance bur oaks were frequent as bearing trees in young FSs37 stands **(PLS-1)**. These oaks represented an overwhelming 71% of the trees at survey corners described as burned, well ahead of any other species **(PLS-3)**. Oddly, when the relative abundance of bur oak is estimated by 10-year age classes, it has low abundance (~10%) in age-classes younger than 40 years **(PLS-2)**. The apparent discrepancy between the age-class data in **PLS-2** and the presence at burned survey corners in **PLS-3** is an artifact of our analysis rules whereby corners were assigned to age-classes based upon the largest diameter tree at the corner. Apparently, many of the bur oaks at burned survey corners had large enough diameters to place them in the age-classes older than 30 years. Small-diameter bur oak regeneration was abundant throughout the young growth-stage **(PLS-5)**. Nearly all of this was beneath larger-diameter bur oaks or quaking aspen. If gains were to be made by establishing new individuals where there was little bur oak originally, it probably occurred beneath aspen.

Mature Growth-stage: >75 years

In the mature growth-stage bur oaks had stable relative abundance between 50-60% **(PLS-1)**. If anything, they decreased slightly in abundance over this period as white oak became more important **(PLS-2)**. The tendency of bur oak to have peak abundance in the 50-70 year age-classes is the main evidence for us to consider it to be ***mid-successional*** – as it seems to replace some initial-cohort aspen and it seems less long-lived than white oak on FDs37 sites. In the mature growth-stage, there seems to be no recruitment of small-diameter trees. At this time it smaller diameter bur oaks were mostly among larger-diameter bur oaks, and beneath some red oak and elm. Our interpretation is that there was little subsidy of bur oak populations in mature stands by recruitment and that it was persisting due to longevity until about the 100-year age-class. Beyond 100 years, there is some decline in bur oak abundance.

Our general impression of bur oak is that by the time it reached 40-years of age, most individuals were impervious to fire. These were trees about 4" in diameter and most likely beset with the thick, corky, insulating bark typical of bur oak. Fires, catastrophic or not simply didn't kill many of these bur oaks, whereas the other oaks seemed to have been forced to re-sprout, and at least appear to be young based upon sprout diameters. Bur oak's dominant grip (55-57% relative abundance, **PLS-1**) on FDs37 sites was most likely set by the distribution of old, well-established root stocks.

Regeneration Strategy

The primary regenerative strategy bur and bur oak on FSs37 sites is to fill ***large-gaps***. They were most successful at this when gaps formed in the canopy of initial-cohort aspen or beneath other bur oaks. In the historic PLS data this interpretation is supported by: (1) the fact that bur oak abundance rises in response to the decline of the initial cohort aspen **(PLS-2)**, (2) they were abundant at survey corners showing partial canopy loss **(PLS-3)**, and (3) they showed peak establishment late in the post-disturbance window (40-60 years) rather than in the initial age-classes **(PLS-5)**. The high percent of bur oak poles under trees (situation 23) and in other gap situations (12 and 13) shows that bur oak can be successful in gaps **(FIA-1)**. The good regeneration indices (3.0-4.3) of bur oak in the understory of mature FDs37 woodlands is also most in line with trees that recruit well in large-gaps.

Bur oaks were also successful regenerating in the ***open*** after catastrophic fires. In the historic PLS data this is most evident by its high abundance in the young growth-stage **(PLS-1)**, and (2) its incredible abundance at burned survey corners **(PLS-3)**. The high abundance of poles in pole stands (situation 22) is also consistent with a tree that performs well in the open **(FIA-1)**. We believe that almost all of bur oak's success in open habitat was from stump sprouts. Our guess is that recruitment of new seedling or seedling-sprout individuals occurred in ***large-gaps*** in older woodlands.

It is important to note that our simplification of regeneration strategies is biased towards the amount of canopy removal that favors recruitment or release. We normally assume that if mineral soil seedbeds are to appear, they did so in conjunction with the canopy-removing disturbance. In FDn and FDc woodlands, we assume that germination, establishment, and recruitment of species needing mineral soil seedbeds happened in response to a single, canopy-removing event – an event that can be approximated with a single timber sale followed by attention to establishment of desired trees. In the case of FDs37 woodlands and oaks, fire was so common that seedbeds on these sites were always prepared for oak establishment. Successful establishment of oaks with enough root resources to respond to canopy release started with successful germination followed by several episodes where fire top-killed the seedlings which helps to "convince" the small oaks to invest resources below ground. Silvicultural approximation of this process requires several treatments aimed at establishing a bank of large-caliper seedlings or saplings. Creating the large-gaps or open conditions in a timber sale is the concluding treatment.

Historic Change in Abundance

Today, bur oak remains a component of FSs37 woodlands, but its current status is substantially diminished from historic times **(PLS/FIA-1)**. In the young growth-stage, it historic dominance of 57% of all trees has been reduced to just 7%. Similarly, the historic abundance of 55% of all trees in mature forests is now just 12%. We believe that the decline in bur oak abundance is a consequence of managing these sites for pulpwood by coppicing and encouraging aspen. Mixed aspen and oak stands have been clear-cut at times when advance bur oak regeneration was inadequate. We believe that modern management has resulted in the loss of large bur oak rootstocks, which were the historic underpinnings of FDs37 sites. Any recovery will require silvicultural strategies to establish new individuals and long-term plans to promote their persistence.

White Oak

- ***excellent habitat suitability rating***
- ***late-successional***
- ***large-gap regeneration strategist***
- ***regeneration window at 50-70 years***

Identification Problems

The PLS surveyors referenced both bur oak and white oak as witness trees. In some cases, individual surveyors used both terms, which would suggest that they were able to distinguish the species. In other surveys, it seems clear that "white oak" was used in a generic sense for oaks lacking bristle-tipped leaf lobes, which includes both bur and white oak within the range of the FDs37 community. The releves show that for plots with either oak present: 21% have both species present; 18% are white oak without bur oak; 61% are bur oak without white oak. For the purpose of discussing the FDs37 community, we have chosen to believe the surveyor identifications as white oak references show considerable population change as stands matured. The fact that we see the same pattern of abundance change in other southern forests and woodlands suggests that the surveyors were at least consistent in differentiating the species if not always accurate. The modern data suggest little difference in their ecology.

Suitability

FSs37 sites provide ***excellent habitat*** for white oak trees. The ***suitability rating*** of 4.7 for white oak is influenced mostly by its presence (31%) as trees on these sites in modern forests **(R-1)**. When present, white oak is an important co-dominant tree, contributing 24% mean cover in mature stands. The ranking is fourth, following northern pin oak, bur oak, and northern red oak on FSs37 sites. Other than FDs37, southern fire-dependent communities offer excellent habitat for white oak (see Suitability Tables).

Young Growth-stage: 0-75 years

Historically, at 8% relative abundance white oaks were an important bearing tree in young FSs37 stands **(PLS-1)**. These oaks represented 15% of the trees at survey corners described as burned, which is a distant second to the dominant bur oak **(PLS-3)**. Similar to bur oak, the relative abundance of white oak (~3%) seems depressed in 10-year age classes younger than about 50 years (<3%) **(PLS-2)**. The apparent discrepancy between the age-class data in **PLS-2** and the presence at burned survey corners in **PLS-3** is an artifact of our analysis rules whereby corners were assigned to age-classes based upon the largest diameter tree at the corner. Apparently, many of the white oaks at burned survey corners had large enough diameters to place them in the age-classes older than 40 years. White oak differs from bur oak in the younger age classes by having almost no small-diameter regeneration until to 50-year age-class **(PLS-5)**. This is a bit surprising in that white oak was an abundant tree in mature woodlands. Presumably this is a consequence of white oak tending to lose sprouting ability, more so than bur oak, at diameters >12" and ages over 80 years. The peak of white oak recruitment was still within the young growth-stage between 50-70 years. At this time it was four times more likely that white oaks would be the smallest tree at the corner as it was for it to be the largest tree. This pattern is associated with ingress and the establishment of new trees, which is a departure from our interpretation of red/pin and bur oaks where we suspect vegetative origin was predominant in the recruitment windows. When white oak was the smaller tree at survey corners, it was coming in among larger diameter red oak and aspen.

Mature Growth-stage: >75 years

In the mature growth-stage white oaks steadily increased in relative abundance **(PLS-1, PLS-2)**. This is the pattern of a late-successional species, and in the absence of shade-tolerant mesic hardwoods it must have appeared that white oak was the climax species along with bur oak at roughly equal abundance in age-classes >120 years. It is important to note though that very few FSs37 stands reached such ages (~10%). It is also important to realize that survey corners estimated to be that old, were most likely composed of large-diameter veteran bur and white oaks among a matrix of considerably younger second- or third-cohort oak sprouts dating to surface fires. In the mature growth-stage we detected no small-diameter white oak regeneration using our half-diameter rule **(PLS-5)**. White oaks could be the smaller tree at survey corners, but by now it was considerably more likely that they were the large-diameter dominant at the corner. This change from the young growth-stage where it seemed to be a small-diameter ingressor, suggesting that in the mature growth-stage, white oak was persisting due to the tendency of larger-diameter tree to survive surface fires and due to its inherent longevity. Also at this time, it is now far more likely for smaller diameter white oaks to be under other white oaks. This means, that some rather pure groves of white oak tended to form in the mature growth-stage. Our interpretation is that white oak's importance in the mature growth-stage is that large-diameter trees were more resistant to surface fires than other trees in the community, with the exception of bur oak. If there was some gain in abundance through establishment and recruitment, it was occurring in patches where white oak was forming rather pure groves.

Regeneration Strategies

The primary regenerative strategy of white oak on FSs37 sites is to fill ***large-gaps***. They were most successful at this when gaps formed in the canopy of initial-cohort aspen or pin oak, or later in succession, beneath other white oaks. In the historic PLS data this interpretation is supported by: (1) the fact that white oak abundance rises in response to the decline of the initial cohort trees **(PLS-2)**, (2) they were abundant at survey corners showing partial canopy loss **(PLS-3)**, and (3) they showed peak establishment late in the post-disturbance window (50-70 years) rather than in the initial age-classes **(PLS-5)**. The good regeneration indices (3.2-3.7) of white oak in the understory of mature FDs37 woodlands is also most in line with trees that recruit well in large-gaps.

White oaks were also successful regenerating in ***small-gaps***. In the PLS data this is most evident by its high abundance in the mature growth-stage **(PLS-1)**, and (2) its peak abundance at mature corners where we presume no recent disturbance **(PLS-3)**. The general fact that stands seemed to accrue white oak as they became very old-aged **(PLS-2)**, makes us believe that there was at least modest establishment and recruitment under rather shady conditions.

It is important to note that our simplification of regeneration strategies is biased towards the amount of canopy removal that favors recruitment or release. We normally assume if mineral soil seedbeds are to appear, they did so in conjunction with the canopy-removing disturbance. In FDn and FDc woodlands, we assume that germination, establishment, and recruitment of species needing mineral soil seedbeds happened in response to a single, canopy-removing event – an event that can be approximated with a single timber sale followed by attention to establishment of desired trees. In the case of FDs37 woodlands and oaks, fire was so common that seedbeds on these sites were always prepared for oak establishment. Successful establishment of oaks with enough root resources to respond to canopy release started with successful germination followed by several episodes where fire top-killed the seedlings which helps to "convince" the small oaks to invest resources below ground. Silvicultural approximation of this process requires several treatments aimed at establishing a bank of large-caliper seedlings or saplings. Creating the large-gaps or open conditions in a timber sale is the concluding treatment.

Historic Change in Abundance

Today, white oak appears to be nearly extirpated from FSs37 woodlands **(PLS/FIA-1)**. In the young growth-stage, its historic abundance of 8% of all trees is in stark contrast to the FIA estimate of none. More important is the near loss of white oak in mature woodlands where it once was important (25% relative abundance), and is now barely 1% of the trees at FIA subplots. The releves paint a substantially better picture for white oak as it was present in both the overstory and understory of about a third of the stands **(R-1, R-2)**. This suggests that white oak is doing well in rather undisturbed FDs37 woodlands, but there seem to be very few undisturbed stands in the landscape. FDs37 woodlands are disturbed by both grazing and logging. In the latter case, we believe that the decline in white oak abundance is a consequence of managing these sites for pulpwood by coppicing and encouraging aspen. The selective pressure of grazing on white oak or any other FDs37 species is unknown, whether by native species or farm animals. Regardless, we believe that modern management has resulted in the loss of large white oak rootstocks, which were historic underpinnings of FDs37 sites. Any recovery will require silvicultural strategies to establish new individuals and long-term plans to promote their persistence.

Red Maple

- ***good suitability***
- ***late-successional***
- ***small-gap (large-gap) regeneration strategist***
- ***regeneration window at 70-90 years***

Identification Problems

The PLS surveyors did not distinguish between red and sugar maple. Although sugar maple occurs within the general region of the FDs37 community, the releve samples reported no sugar maple. It is probably safe to assume that surveyor references to “maple” were red maple within the historic range of FDs37.

Suitability

FDs37 sites provide ***good habitat*** for red maple trees. The ***suitability rating*** of 3.7 for red maple is influenced mostly by its presence (29%) as trees on these sites in modern forests **(R-1)**. When present, red maple is a minor co-dominant tree, contributing 10% mean cover in mature stands. This ranking is fifth among trees common on FDs37 sites. FDs37 is the only FDs community that provides habitat for red maple.

Young Growth-stage: 0-75 years

Historically, red maple was nearly absent from young FDs37 stands recovering mostly from fire **(PLS/FIA-1, PLS-2)**. Red maple did not appear as a bearing at any disturbed survey corners **(PLS-3)**. Small-diameter red maple regeneration appears at low, but measurable amounts in the 70-90 year age-classes **(PLS-5)**. Our interpretation is that the initial small-diameter trees were able to invade FDs37 forests late in the young growth-stage from seed sources in nearby mesic-hardwood (MHs) forests. Given red maple’s excellent ability to establish and recruit seedlings beneath a canopy in modern forests **(R-2)**, it seems possible that limited establishment beneath dense shrubs or self-thinning aspen was characteristic of the historic forest. Today, red maple has about 2-3% relative abundance in young FDs37 forests recovering from logging.

Mature Growth-stage: >75 years

Red maple first appears as a small-diameter bearing tree at the seam between the young and mature growth-stage **(PLS-2)**. Still, it never amounted to even a full percent of the trees in mature FDs37 woodlands **(PLS/FIA-1)**. Red maple’s excellent performance in regenerating strata in modern forests supports the idea that red maple could maintain modest presence in older stands through regeneration and recruitment **(R-2)**.Our best guess is that red maple had limited success in patches of old forest missed by surface fires. In the FIA data, red maple abundance continuously rises as stands age, suggesting to us that it is ***late-successional*** on these sites.

Regeneration Strategies

Red maple’s primary regenerative strategy on FDs37 sites is to fill ***small-gaps***. Be believe that it was most successful at this by establishing seedlings under self-thinning aspen, and possibly it succeeded as the oak canopy started to close enough to reduce shrub density. In the historic PLS data the small-gap strategy of red maple is supported by: (1) the fact that red maple first appears as only small diameter trees near the beginning of the mature growth-stage **(PLS-5)**, and (2) it has peak abundance in mature, undisturbed forest **(PLS-3)**. The FIA data show red maple to be somewhat successful as seedlings below a remote canopy (situation 13), which is typical of small-gap strategists **(FIA-1)**. The releve sampling clearly supports the idea that red maple is a small-gap strategist. Red maple’s regeneration indices (4.7-5.0) are excellent and in line with small-gap strategists that are good at banking seedlings under a canopy **(R-2)**.

Red maple also shows some behavior typical of trees that use ***large-gaps*** to for recruitment. This notion comes entirely from the modern data in that it didn’t occur often enough as a bearing tree to draw any strong conclusions. In the FIA data, it has very high presence (51%) as poles beneath a tree canopy (situation 23), which is usually a trait of trees needing larger gaps **(FIA-1)**.

In the mature forests that we sampled by releves, red maple's sapling index is perfect and substantially greater than its tree index **(R-2)**, which corroborates the FIA data. Our best guess is that red maple is highly successful at establishment under low light conditions, but recruitment to tree-sized individuals may require an opening larger than the 1-few tree gaps that we associate with small-gap strategists.

Historic Change in Abundance

Populations of red maple have been expanding in Minnesota. In the FFDs37 community red maple abundance has risen from near absence to about 3% in both growth-stages **(PLS/FIA-1)**. Red maple's presence of 29% as trees in releves **(R-1)** and its 69% presence in the regenerating layers **(R-2)** is substantially higher than in the PLS or FIA databases which we compare in Table **PLS/FIA-1**. Given the tendency of releves to be located in stands less-disturbed than the historic or modern average, our interpretation is that red maple has benefited greatly from the lack of fire or logging disturbance. Most important is the lack of surface fires that periodically "cleansed" FDs37 stands of maple regeneration. Logging doesn't eradicate maple as did fire, and modern regeneration harvests simply release advance regeneration of red maple. An amazing fact is that 90% of all the red maple references in the FIA data were in regenerating situations (not situation 33, **FIA-1**). The abnormal abundance of red maple on some FDs37 sites may be a hindrance to managing these sites for the large-gap and open regeneration strategists like oak that were more common historically.

Quaking and Big-toothed Aspen

- ***good habitat suitability ratings***
- ***early successional***
- ***open (large-gap) regeneration strategists***
- ***regeneration window at 0-30 years***

Identification Problems

The PLS surveyors did not distinguish between quaking and big-toothed aspen. Thus, Interpretations of PLS data for the more common quaking aspen should always be done knowing that some of these trees were likely big-toothed aspen. FDs37 releve samples show that for plots with aspen present: none have both species present; 27% are big-toothed aspen without quaking aspen; 73% are quaking aspen without big-toothed aspen. Although the lack of coincidence would suggest some ecological difference, we attribute it to chance due to the low presence of big-toothed aspen. For the most part, we consider quaking and big-toothed aspen to be ecologically equivalent for most silvicultural considerations.

Suitability

FDs37 sites provide ***good habitat*** for **quaking aspen** trees. The ***suitability rating*** of 3.3 for quaking aspen is influenced mostly by its presence (26%) as trees on these sites in modern forests **(R-1)**. When present, quaking aspen is a minor co-dominant tree, contributing 8% mean cover in mature stands. This ranking is tied with big-toothed aspen at sixth among trees common on FDs37 sites. Other than the excellent habitat provided by FDs36 forests, the FDs woodlands offer just good habitat for quaking aspen (see Suitability Tables).

FDs37 sites offer ***good habitat*** for **big-toothed aspen**. The ***suitability rating*** of 3.3 for big-toothed aspen is based upon its high cover-when-present (21%), as it is not often present (10%, **R-1**). This ranking is tied with quaking aspen at sixth among trees common on FDs37 sites. The FDs37 community is the only FDs community to provide reasonably good habitat for big-toothed aspen (see Suitability Tables).

Young Growth-stage: 0-75 years

Historically, aspen was immediately important in young FDs37 stands recovering from stand-regenerating disturbance, but its reign diminished by the close of the period to average just 6% relative abundance. Young aspen represented just 4% of the trees at survey corners described as burned **(PLS-3)**, which is related more to the fact that aspen's primary range lies northeast of FDs37 woodlands rather than any shortcomings aspen's ability to survive and dominate sites after severe fires. Aspen seemed more adapted to windthrow, representing 30% of the trees at such survey corners, but the sample size very small and windthrow wasn't an important means of regenerating FDs37 woodlands. The paucity of aspen in the young growth-stage is to some extent the result of our decision to not recognize a short-lived initial growth-stage of FDs37 stands where aspen was abundant. We hesitated to construct a very young growth-stage because there were so few survey corners estimated to be that young. Arguably, there was an immediate post-fire condition lasting until about the 30-year age class where aspen was abundant, representing perhaps as much as half the tree stems **(PLS-2)**. This episode was very short-lived and it seems that survival of aspen was very poor in comparison to the oaks, in spite of the fact that small-diameter aspen bearing trees were usually larger than the oaks at the same survey corner. Our interpretation is that in the post-fire environment, aspen was behaving more like a shrub than a tree. We envision aspen suckers throughout a thicket-like re-growth of hazelnut, gray dogwood, and oak stump sprouts – from which only the oaks would consistently emerge as trees. However, enough aspen did so for us to determine that it was ***early-successional***, peaking immediately after fire and declining in relative abundance thereafter.

Mature Growth-stage: >75 years

At about 75 years the relative abundance of FSs37 aspen dropped to 3% and it persisted at about that level in the following growth-stage **(PLS-1, PLS-2)**. If persistence required regeneration and recruitment, then we must assume that aspen has secondary strategies for behaving like a mid- or late-successional species able to respond to fine-scale or maintenance disturbances. The good ability of quaking aspen to recruit seedlings or suckers through all height strata in modern FDs37 forests suggests that it can persist under a regime of fine-scale disturbance on FDs37 sites **(R-2)**. The peak presence of quaking aspen (?) at mature, undisturbed survey corners **(PLS-3)** is consistent with the idea of modest establishment and recruitment. Big-toothed aspen does not at all share this ability as its regeneration indices beneath a canopy are very poor. Possibly, frequent surface fires maintained some rather permanent openings in the tree canopy and was constantly stimulating some re-growth of aspen, especially the intolerant big-toothed aspen. Consistent with either idea is the fact that in the mature growth-stage, it was more common for aspen to be the smaller tree at survey corners among larger-diameter bur and white oaks. Regardless, the ability of aspen to persist at low abundance in older woodlands is the main reason that it was especially important in the initial post-fire years.

Regeneration Strategies

Aspen's primary regenerative strategy on FDs37 sites is to dominate ***open habitat*** after stand-regenerating disturbance. In the historic PLS data this interpretation is supported by: (1) the fact that aspen's peak abundance is immediate after stand-regenerating fire **(PLS-2)**, and (2) aspen's peak regeneration was in the post-disturbance window **(PLS-5)** with it's absolute peak being the initial age-class. The high percent of quaking aspen in the canopy of young sapling or pole stands (situations 11 and 22) in the FIA data **(FIA-1)** is also characteristic of species that regenerate effectively in the open. Surprisingly, big-toothed aspen was not so common in these situations, as it appeared more often in subordinate situations, which would suggest some large-gap behavior. In the releves however, it is clear that big-toothed aspen needs substantial openings to establish and recruit seedlings **(R-2)**.

Both species were probably capable of filling ***large-gaps***; quaking aspen did this more so than big-toothed aspen. In the historic PLS data this secondary strategy is supported by: (1) the persistence of aspen in the mature growth-stage **(PLS-1)**, and (2) aspen's peak presence at presumably undisturbed mature survey corners **(PLS-3)**. The releve sampling of mature FDS37 forests suggests that quaking aspen is able to function as a large-gap strategist with good establishment and recruitment in the understory strata, but big-toothed aspen is not **(R-2)**. Both species have significant abundance in subordinate situations (12, 23, 13) at FIA plots, which supports the idea that aspen can regenerate in large gaps **(FIA-1)**.

The rotation of just 12 years for maintenance fires (see Natural Disturbance Regime) would suggest that by the time FDs37 woodlands reached the mature growth stage they would have experienced a half-dozen surface fires or similar events that result in partial canopy loss. The natural spacing of bearing trees at about 50 feet (see Natural Stand Dynamics) indicates a density of about a quarter of that considered typical of stocked hardwood forest. We believe that FDs37 woodlands perpetually offered ***large-gap*** openings, that provided habitat for shrubs, prairie grasses, and advance regeneration of mid-tolerant and even intolerant trees like aspen. It is no accident that the surveyors used several physiognomic terms to describe this condition: openings, barrens, thickets, etc. We believe that both species of aspen, contributed to the FDs37 community as coppiced brush as much as they did as canopy trees.

Historic Change in Abundance

Today, aspen is the dominant tree on FDs37 sites **(PLS/FIA-1)**. This is most evident in young woodlands where aspen is now 57% of the trees compared to just 6% historically. Mature woodlands are likewise dominated by aspen at 27% relative abundance. Aspen in the releve samples is similarly more abundant than suggested by the historic data at about 25% presence as trees or in the understory. Our interpretation is that the remaining stands of FDs37 woodland are mostly being managed by coppicing aspen and that the sites have gradually been losing the old oak rootstocks under this regime. Because FDs37 woodlands often define the interface of agricultural and forest lands, it is likely that woodlots have been exploited for oak lumber and fuel wood, favoring aspen with little attention to oak regeneration. Aspen is so solidly in place on

FDs37 sites that silvicultural attempts to establish new, seed-origin oaks will require an understanding of the interaction of these species in the modern landscape.

Paper Birch

- ***good habitat suitability rating***
- ***mid-successional***
- ***large-gap (open) regeneration strategist***
- ***regeneration window at 60-90 years***

Suitability

FDs37 sites provide ***good habitat*** for paper birch trees. The ***suitability rating*** of 3.0 for paper birch is influenced mostly by its presence (19%) as trees on these sites in modern forests **(R-1)**. When present, paper birch is a minor co-dominant tree, contributing just 7% mean cover-when-present in mature stands. This ranking is eighth, tied with green ash, among trees common on FDs37 sites. Paper birch has varying suitability among FDs communities (see Suitability Tables). Its good rating on FDs37 sites follows excellent performance on FDs27 site, but is substantially better than others. Birch seems to be favoring the sandier soils among FDs communities, demonstrating its characteristic aversion of prairie soils, where retention of deep organics is easier because of fine soil texture.

Young Growth-stage: 0-75 years

Historically, paper birch was not important in young FDs37 stands recovering mostly from fire **(PLS/FIA-1)**. Birch does not appear immediately after disturbance **(PLS-2),** and was absent from all survey corners showing any level of disturbance **(PLS-3)**. Our interpretation is that paper birch was totally absent from the initial cohort naturally. Birch is consistently present at very low abundance in the string of age-classes from 60-90 years **(PLS-5)**. There was something about the transition from the young growth-stage to the mature growth-stage that allowed for very modest presence of paper birch. Our best guess is that there were limited opportunities for birch to ingress beneath quaking aspen near the close of the young growth-stage. Mostly, this idea comes from modern data as there is now far more paper birch on FDs37 sites enriched in quaking aspen. In the oak-dominated stands sampled by releves, paper birch shows almost no ability to establish and recruit seedlings beneath a canopy **(R-2)**. In both the historic and modern FIA data, birch abundance clearly peaks in stands 70-90 years old, which is why we consider it to be ***mid-successional*** on FDs37 sites.

Mature Growth-stage: >75 years

Historically paper birch was essentially absent from mature FDs37 woodlands **(PLS-FIA-1)**. Thus, there is no historic data to reasonably interpret. Unfortunately, we get different answers from the releve and FIA concerning its current behavior in older woodlands. In releves, it would seem that paper birch has no ability to persist in older woodlands by establishing and recruiting seedlings. Its indices of regeneration are poor or worse (1.0-0.0), beneath the canopy of a mature woodland **(R-2)**. The FIA data present quite a different picture, picking up a fair amount of birch trees **(FIA-1)**. Here we see birch doing rather well in subordinate situations, and its relationship with quaking aspen is quite similar to what we see in any other community where coppicing aspen is the general practice. We must conclude that the releves and FIA plots are sampling substantially different segments of the FDs37 population. Regardless, it is important to point out that paper birch was not really native to mature FDs37 woodlands when they were properly maintained by chronic surface fires.

Regeneration Strategies

Paper birch's primary regenerative strategy on FDs37 sites is to fill ***large-gaps***. The historic data are so sparse that we have drawn this conclusion almost entirely from the fact that birch was most consistently present at a time when we suspect the formation of large-gaps at the seam between the young and mature growth-stages **(PLS-2)**. The peak presence of paper birch as poles in tree stands (situation 23) is entirely consistent with the idea of birch being a large-gap strategist. The releves, however, indicate that birch couldn't possibly fill gaps because it has no capacity to develop advance regeneration **(R-2)**. The releves would suggest that paper birch is an obligate ***open-strategist***. Apparently, regeneration opportunities for paper birch are quite dependent upon the species forming the canopy, whether it is the aspen-dominated canopy more often sample by FIA plots or the oak-dominated canopy situation preferentially sampled by releves.

Historic Change in Abundance

Today there is substantially more paper birch on FDs37 sites than in the pre-settlement landscape **(PLS/FIA-1)**. Young FDs37 sites now have 7% paper birch in comparison to its 1% historic abundance. More impressive is the 14% relative abundance of birch in mature woodlands where it was absent historically. Our interpretation is that aspen has been expanding its range into the FDs37 landscape, and where that has happened it is creating conditions favorable for paper birch as well. Coppicing sites for aspen has probably helped birch to expand its range as well, but no amount of coppicing will create the poorer soil conditions that tends to favor birch statewide. Thus, the rise of paper birch in this region remains a mystery to us if our modeling has been at all accurate.

Green Ash

- ***good habitat suitability rating***
- ***late-successional***
- ***large-gap regeneration strategist***
- ***regeneration window at 40-50 years***

Suitability

FDs37 sites provide ***good habitat*** for green ash trees. The ***suitability rating*** of 3.0 for green ash is the result of balanced presence (12%) and mean cover-when-present (10%) as trees on these sites in modern forests **(R-1)**. This ranking is seventh, tied with paper birch, among trees common on FDs37 sites. Green ash has been invading woodlands in the Eastern Broadleaf Forest Province since settlement of the area. Among FDs communities only the FDs37 and FDs36 offer fair-to-good chances for growing green ash (see Suitability Tables).

Young Growth-stage: 0-75 years

Historically, green ash was not important in young FDs37 stands recovering mostly from fire **(PLS/FIA-1)**. Green ash does not appear until well after stand-initiation **(PLS-2)**, and it was absent from all survey corners showing any level of disturbance (not shown in **PLS-3**). Our interpretation is that green ash was totally absent from the initial cohort naturally. Green ash is consistently present at very low abundance (1-3%) from the 40-year age class forward, and with small-diameter regeneration being most abundant in the 40-50 year age-classes **(PLS-5)**. There was something about the transition from the young growth-stage to the mature growth-stage that allowed for very modest ingress of green ash. In all cases and in contrast to paper birch, the ingress of green ash was beneath the oaks rather than aspen.

Mature Growth-stage: >75 years

Historically, green ash had its peak presence as a minor co-dominant in mature stands, which is why we consider it a ***late-successional*** species **(PLS/FIA-1)**. Its steady increase in relative abundance is the result of modest establishment and recruitment during the mature growth-stage. Small-diameter ash regeneration was present at low abundance until the 80-year age-class **(PLS-5)**. We interpret this as ash establishing a modest seedling bank early in the mature growth-stage as it does in modern stands where it is commonly (45%) present in the regenerating layers **(R-2)**. Recruitment of trees though is unlikely without some kind of opening above the advance regeneration as its tree index of 2.8 is rather low.

Regeneration Strategy

Ash's primary regenerative strategy on MHc26 sites is develop a bank of seedlings that can fill canopy gaps. We are uncertain about the size of the gaps needed. The PLS data argue for ash's ability to fill gaps because ash abundance increases as stands age **(PLS/FIA-1)**, where we presume gap dynamics. In the releve data, green ash shows good establishment and recruitment beneath a canopy. Its indices in the recruiting strata are 3.7, which is indicative of trees able to recruit in ***large-gaps***. Strengthening this argument is the fact that its tree index is just 2.8. meaning that it has some difficulty achieving heights over 10m without more light. To some extent, green ash seems to be playing the role of a tree successful in the understory but not in the canopy. Other trees like ironwood and black cherry do this as well on FDs37 sites.

Historic Change in Abundance

Today, green ash would seem to occur at about the same abundance as it always did **(PLS/FIA-1)**. There is little departure from our historic and FIA assessment of the species, as the tree never amounts to more than a percent relative abundance. The releves, however show considerable amounts of green ash both as a canopy tree **(R-1)** and especially in the regenerating layers of FDs37 woodlands **(R-2)**. This suggests that when relieved of the chronic but natural surface fire disturbances, green ash will continue to increase in the least disturbed FDs37 woodlands preferentially sampled by releves. There seems to be little threat of green ash dominating the canopy or complicating the silviculture of the more abundant native trees.

(PLS-1) Historic Abundance of FDs37 Trees in Natural Growth-stages

Table values are relative abundance (%) of Public Land Survey (PLS) bearing trees at corners modeled to represent the FDs37 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.

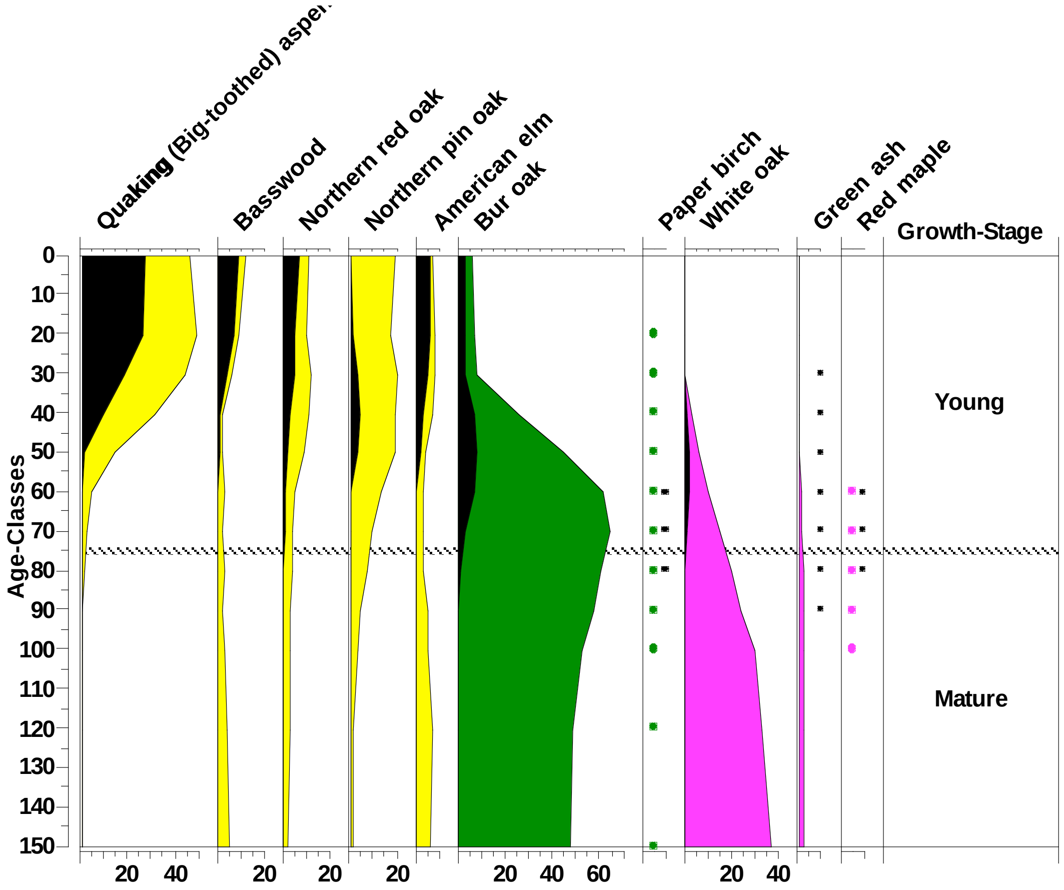
Dominant Trees	**Forest Growth Stages in Years**		
	Young		**Old**
	0 - 75	**~75**	**> 75**
Bur Oak	**57%**	│	**55%**
Red Oak	**12%**	│	**10%**
Quaking (Big-toothed) Aspen[1]	**6%**	│	**3%**
Northern Pin Oak	**6%**	││	**–**
Black Cherry	**1%**	│	**–**
Basswood	**2%**	)	**2%**
American Elm	**3%**	⌉	**5%**
White Oak	**8%**	⌉⌉	**25%**
Miscellaneous	**5%**		**–**
Percent of Community in Growth Stage in Presettlement Landscape	**79%**		**21%**

[1] The PLS surveyors did not consistently distinguish the more prevalent quaking aspen from big-toothed aspen on FDs37 sites.

See linked text on brief methods and silvicultural application for Table PLS-1, file *Figures_Tables_Documentation*

(PLS-2) Abundance of trees throughout succession in FDs37

Graphed for the individual species of FDs37 trees is their relative abundance (%) as PLS bearing trees by age class. Species with good-to-excellent suitability have graphs colored as follows: early successional (yellow); mid-successional (green); late-successional (magenta). The data were smoothed from adjacent classes (3-sample moving average). Black insets show the proportion of bearing trees that were small-diameter trees that were presumably recruiting to bearing tree size (~4” dbh, see **PLS-5**). For infrequent trees, the presence of large-diameter (colored) and small-diameter (black) trees is indicated by dots.



FDs37, J.C. Almendinger, April 2008

See linked text on brief methods and silvicultural application for Table PLS-2, file *Figures_Tables_Documentation*

(PLS-3) Historic Abundance of FDs37 Trees Following Disturbance

Table values are raw counts and percentage of Public Land Survey (PLS) bearing trees at survey corners likely to represent FDs37 forests. The columns represent our interpretation of disturbance at the survey corners. Trees in parentheses are minor species that occur in modern forests but couldn’t be separated from more common trees because the surveyors did not distinguish them in their field notes. Shading associates trees that peak in the same disturbance category.

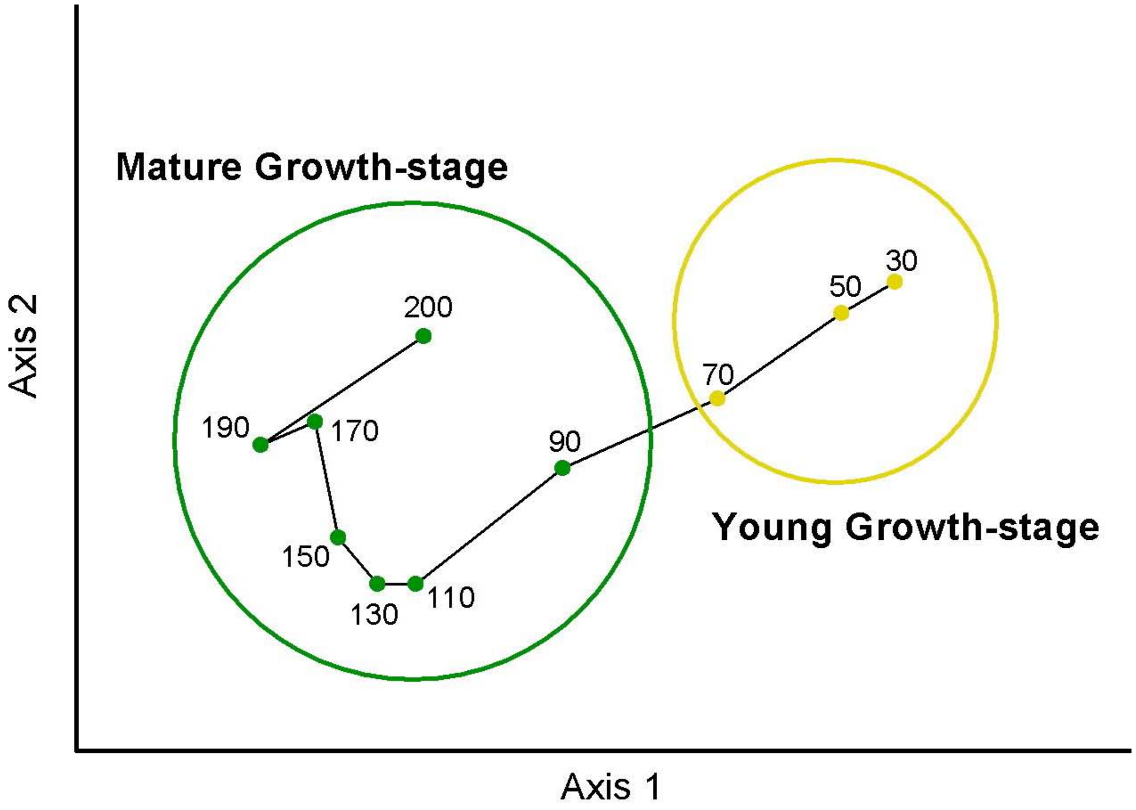
Tree	Burned		Windthrown		Maintenance		Mature	
Bur oak	**462**	**71%**	**6**	**60%**	**1442**	**64%**	**1221**	**53%**
Quaking (Bigtooth) aspen[1]	**23**	**4%**	**3**	**30%**	**79**	**4%**	**182**	**8%**
Northern pin oak	**21**	**3%**	**0**	**0%**	**141**	**6%**	**50**	**2%**
White oak	**100**	**15%**	**0**	**0%**	**306**	**14%**	**451**	**20%**
Northern red oak	**76**	**12%**	**1**	**10%**	**265**	**12%**	**288**	**13%**
Green ash	**2**	**0%**	**0**	**0%**	**7**	**0%**	**48**	**2%**
Paper birch	**0**	**0%**	**0**	**0%**	**8**	**0%**	**18**	**1%**
Black cherry	**0**	**0%**	**0**	**0%**	**5**	**0%**	**32**	**1%**
Red maple	**0**	**0%**	**0**	**0%**	**0**	**0%**	**3**	**0%**
Total (% of grand total, 5204)	**684**	**13%**	**10**	**0%**	**2253**	**43%**	**2293**	**44%**

1. The PLS surveyors did not consistently distinguish the more prevalent quaking aspen from big-toothed aspen on FDs37sites.

See linked text on brief methods and silvicultural application for Table PLS-3, file *Figures_Tables_Documentation*

(PLS-4) Ordination of Historic FDs37 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.



See linked text on brief methods and silvicultural application for Table PLS-1, file *Figures_Tables_Documentation*

(PLS-5) Historic Windows of Recruitment for FDs37 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 and gap windows*.

Initial Cohort	Species	Peak years	P-D 0-70 years	G-1 >70 years
Yes	**Quaking aspen[1]**	**0-30**	**Excellent**	**--**
Yes	**Big-toothed aspen[1]**	**0-30**	**Excellent**	**Poor to 120**
Yes	**Northern red oak**	**0-40**	**Good**	**--**
Minor	**Black cherry**	**0-40**	**Poor**	**Poor to 80**
Yes	**Northern pin oak**	**0-40**	**Good**	**--**
Yes	**Bur oak**	**40-60**	**Excellent**	**--**
Yes	**White oak**	**50-70**	**Fair to 70**	**--**
No	**Red maple**	**60-80**	**Poor**	**Poor to 90**
Minor	**Paper birch**	**60-90**	**Poor**	**Fair**
No	**Green ash**	**40-50**	**Poor**	**Poor to 80**

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, quaking aspen, and red oak, 50-110 years

***Note:** FDs37 was fire-maintained woodland and there were probably no real cases of ingress beneath a complete canopy.

-- : 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

[1] Big-toothed and quaking aspen bearing trees couldn’t be segregated in the PLS notes, and they are almost equally important in modern FDs37 forests. Thus, FIA data were used to identify slight differences in their recruitment behavior.

See linked text on brief methods and silvicultural application for Table PLS-5, file *Figures_Tables_Documentation*

(R-1) Suitability Ratings of Trees on FDs37 Sites

This table presents an index of suitability for trees in FDs37 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 FDs37

Tree	Percent Presence as Tree	Mean Percent Cover When Present	Suitability Index*
Northern pin oak (Quercus ellipsoidalis)	62	41	5.0
Bur oak (Quercus macrocarpa)	67	21	4.9
Northern red oak (Quercus rubra)	36	35	4.9
White oak (Quercus alba)	31	24	4.7
Red maple (Acer rubrum)	29	10	3.7
Quaking aspen (Populus tremuloides)	26	8	3.3
Big-toothed aspen (Populus grandidentata)	10	21	3.3
Paper birch (Betula papyrifera)	19	7	3.0
Green ash (Fraxinus pennsylvanica)	12	10	3.0
Black cherry (Prunus serotina)	31	3	2.6

*Suitability ratings: **excellent**, **good**, **fair**

See linked text on brief methods and silvicultural application for Table R-1, file *Figures_Tables_Documentation*

(R-2) Natural Regeneration and Recruitment of Trees in Mature FDs37 Stands

This table presents an index of regeneration for FDs37 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 FDs37 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 regenerants, seedlings, saplings, and trees common in the canopy of Southern Dry-Mesic Oak (Maple) Woodland – FDs37

Trees in understory	% presence R, SE, SA	R-index	SE-index	SA-index	T-index
Black cherry (Prunus serotina)	88	4.2	4.2	4.3	3.0
Red maple (Acer rubrum)	69	4.8	4.7	5.0	3.5
Bur oak (Quercus macrocarpa)	67	3.2	3.0	4.3	4.8
Northern pin oak (Quercus	52	3.8	3.7	4.5	5.0
Green ash (Fraxinus	45	3.7	3.7	3.7	2.8
Quaking aspen (Populus	26	3.3	3.3	3.7	3.8
Northern red oak (Quercus rubra)	26	3.0	2.7	3.5	4.8
White oak (Quercus alba)	21	3.7	3.2	3.2	4.5
Paper birch (Betula papyrifera)	7	0.0	0.0	1.0	3.5
Big-toothed aspen (Populus	5	1.0	1.0	0.3	3.5

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

% presence: the percent of 42 FDs37 sample plots with that species present under 10m tall (R, SE, SA layers)
R-index: index of representation as true seedling or under 10cm tall
SE-index: index of representation as seedlings under 2m tall
SA-index: index of representation as saplings 2- 10m tall
T-index: index of representation as a tree >10m 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.

See linked text on brief methods and silvicultural application for Table R-2, file *Figures_Tables_Documentation*

(FIA-1) Structural Situations of Trees in Mature FDs37 Stands

This table presents percentages of structural situations for trees as recorded in Forest Inventory Analysis (FIA) subplots that we modeled to be samples FDs37 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
Black cherry	54	33%	0%	7%	4%	50%	6%
Bur oak	144	2%	18%	16%	13%	11%	40%
Quaking aspen	723	20%	18%	15%	11%	11%	25%
Big-toothed aspen	27	4%	11%	4%	19%	19%	44%
Red maple	39	0%	21%	3%	51%	15%	10%
Paper birch	146	1%	21%	4%	37%	4%	34%
Northern red oak	119	11%	7%	3%	8%	2%	70%
Northern pin oak	10	0%	0%	0%	0%	0%	100%
Green ash	1	0%	0%	0%	100%	0%	0%
White oak	1	0%	0%	0%	0%	0%	100%

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

See linked text on brief methods and silvicultural application for Table FIA-1, file *Figures_Tables_Documentation*

(PLS/FIA-1) Abundance of FDs37 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 FDs37 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 -75		~75	>75	
	Young			Mature	
Bur Oak	**57%**	**7%**	|	**55%**	**12%**
Red Oak	**12%**	**6%**	|	**10%**	**14%**
Quaking Aspen (incl, Bigtooth)	**6%**	**57%**	|	**3%**	**27%**
Northern Pin Oak	**6%**	**0%**	||	**–**	**1%**
Black Cherry	**1%**	**2%**	|	**–**	**2%**
Basswood	**2%**	**8%**	)	**2%**	**14%**
American Elm (incl. Slippery)	**3%**	**3%**	⌉	**5%**	**5%**
White Oak	**8%**	**0%**	⌉⌉	**25%**	**1%**
Red Maple	**0%**	**3%**		**--**	**3%**
Paper Birch	**1%**	**7%**		**--**	**12%**
Ironwood	**0%**	**3%**		**0%**	**5%**
Green Ash	**1%**	**0%**		**1%**	**1%**
Miscellaneous	**3%**	**4%**		**0%**	**3%**
Percent of Community in Growth Stage in Presettlement and Modern Landscapes	**79%**	**66%**		**21%**	**34%**

Natural growth-stage analysis and landscape summary of historic conditions is based upon the analysis of 2,620 Public Land Survey records for section and quarter-section corners. Comparable modern conditions were summarized from 1,624 FIA subplots that were modeled to be FDs37 sites.

See linked text on brief methods and silvicultural application for Table PLS/FIA-1, file *Figures_Tables_Documentation*

Forest Health

Northern 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.

Red 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.

Trembling Aspen

Agent	Growth stage	Concern/ Effect
Armillaria root disease	All stages	Mortality
Forest tent caterpillar	“	Defoliation
Hypoxylon canker	Pole-sized and larger	Topkill and mortality
Saperda borer	“	Mortality
Stem decay = white trunk rot	“	Volume loss

WATCHOUTS!

- In over-mature stands, prolonged defoliation will accelerate mortality.

- Harvest during the winter to ensure adequate regeneration.

- To estimate the basal area of a stand affected by white trunk rot, determine the basal area with conks then multiply that number by 1.9.

- Trees along stand edges, openings and trees in low-density stands are more likely to be infected with Hypoxylon canker and infested with Saperda borer.

- 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.

FDs37 - 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 FDs37 that are more susceptible to compaction and rutting. They are listed in descending order of presence.

Virginia creeper (*Parthenocissus spp.*)
Lady fern (*Athyrium filix-femina*)
Common buckthorn (*Rhamnus cathartica*)
American elm (U) (*Ulmus americana*)
Nannyberry (*Viburnum lentago*)
Box elder (U) (*Acer negundo*)
Jack-in-the-pulpit (*Arisaema triphyllum*)
White avens (*Geum canadense*)
Black ash (U) (*Fraxinus nigra*)
Green ash (C) (*Fraxinus pennsylvanica*

(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

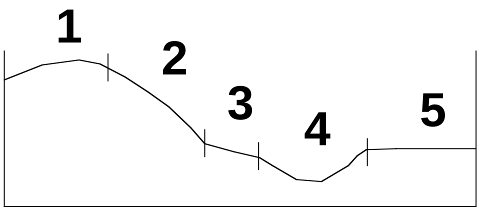
   Poor – water saturation occurs within 10 inches of the surface for most of the growing season

   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

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

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