Tables based upon Releves

- **R-1 Suitability ratings of trees**
- **R-2 Natural Regeneration and Recruitment of Trees in Mature Stands**

Releves are large (400m2) sample plots that we used to sample ecologically intact and generally mature forests in Minnesota. The releves are the basis for the Native Plant Community (NPC) classification (Field Guides to the Native Plant Communities of Minnesota), which makes it easy to assemble sets of releves that we can use to make silvicultural interpretations unique for each NPC Class. For silvicultural interpretation, releve data were used to develop two important concepts.

First, releves were used as a means of determining how “suitable” each NPC Class is for growing certain trees, or conversely we wanted to know how well “suited” trees are to a single NPC when compared to other trees. Suitability is probably correlated with forestry concepts like dominance or ecological concepts like fitness, but should not be confused with them or other extended connotations. For our purpose, suitability is a straightforward calculation: it is the product of a tree’s presence times its mean cover-when-present in the set of releves classified as belonging to a particular NPC Class. In English, it means that given a site defined by its groundlayer vegetation and soils (NPC Class), a tree is well-suited if we find it often and in abundance. The suitability values were re-scaled to run from 0-5 so that they could be compared from one NPC Class to another (Statewide Suitability Tables). For a single NPC Class, the Suitability Index (Table R-1) can be used to focus silvicultural attention on the more suitable, crop-tree species.

Secondly, the structural elements of releves were used to interpret the ability of trees to establish themselves and recruit to higher strata under the canopy of a mature forest and on seedbeds associated with older forests. The tree height data on releves was transformed into 4 standard height strata: regenerants <10cm tall, seedlings 10cm – 2 m tall, saplings 2–10m tall, and trees >10m. For each layer we calculated an index of regeneration/recruitment “success” that was the product of a tree’s presence, mean cover-when-present, and the mean strata-when-present. In English, it means that a tree was successful as a regenerant, seedling, sapling, or tree when it often occurs in that layer, it occurs in abundance in that layer, and if it shows recruitment success in several layers on the same plot. The indices were scaled to run from 0-5 so that they can be compared among the layers in a single NPC Class and can be compared from one NPC Class to another. The ordering of trees in Table R-2 by descending presence in the understory places trees capable of significant advance regeneration near the top and those incapable near the bottom.

(Example R-1) Suitability ratings of trees on MHn35 sites

This table presents an index of suitability for trees in MHn35 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 MHn35			
Tree	**Percent Presence as Tree**	**Mean Percent Cover When Present**	**Suitability Index***
Sugar maple (Acer saccharum)	**81**	**32**	**5.0**
Basswood (Tilia americana)	**65**	**15**	**4.8**
Northern red oak (Quercus rubra)	**49**	**20**	**4.7**
Paper birch (Betula papyrifera)	**61**	**13**	**4.6**
Quaking aspen (Populus tremuloides)	**31**	**20**	**4.4**
Red maple (Acer rubrum)	**31**	**12**	**4.1**
Big-toothed aspen (Populus grandidentata)	**13**	**19**	**3.7**
White pine (Pinus strobus)	**7**	**24**	**3.1**
Bur oak (Quercus macrocarpa)	**11**	**10**	**2.5**
Yellow birch (Betula alleghaniensis)	**10**	**9**	**2.2**
Balsam fir (Abies balsamea)	**8**	**8**	**2.0**
*Suitability rankings: **excellent**, **good**, **fair**			

R-1, Methods*

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

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

Because communities have different numbers of plants with >5% presence and because their ranges of index values are different, we calculated a scaled index for comparisons among communities for each tree. The scaling represents a trees rank order on a scale of 0-5, so that the integer of the scaling indicates it's suitability class, e.g. 4.xx is in the excellent class, 3.xx is in the good class, etc. The scaled index=(proportion of plants with lower ranking)/20.

*Nearly all of the data used to calculate the suitability index come from stands near the mid-point of normal stand development (40-80 years). Suitability is expected to change throughout succession, depending upon a tree's seral status: early-, late-, or mid-successional. This table is the best that can be constructed, given the paucity of releve samples in very young and very old forests.

*The table is not intended to take precedence over current stand conditions. There is no better evidence that a tree can grow well and reach commercial stocking levels than the observation that it is currently doing so.

R-1, Silvicultural Applications

1. Select crop trees
    a. In general, trees with higher suitability indices are better choices as crop than trees with lower indices.
    b. If stands are to be silviculturally manipulated to favor one species over another, mean-cover-when-present is the more important element of the index, with the higher covers predictive of the likelihood of higher stocking.
2. Recognize and introduce missing species
    a. Species with a high suitability index that are not currently present on the site can be introduced to the site with less risk than species with a lower index.
3. Allow for non-commercial species
    a. Trees with an excellent, good, or fair rating should be allowed at modest abundance when they have a species-specific attribute that makes them desirable for purposes other than timber production
4. Recognize post-treatment success or failure
    a. The table offers a means of measuring success by species groups (e.g. The treatment is expected to achieve a minimum of 80% stocking of excellent-ranked species at 5 years.)
5. Anticipate competition given the choice of a crop tree
    a. Species with a higher suitability index than the chosen crop tree are more likely to be competitors that need control in order to favor the crop tree.
    b. Species with a lower suitability index than the chosen crop tree are more likely to be subordinates (unless at high abundance) that shouldn't interfere with the regeneration and growth of the crop tree.

(Example R-2) Natural Regeneration and Recruitment of Trees in Mature MHn35 Stands

This table presents an index of regeneration for MHn35 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 MHn35 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 Northern Mesic Hardwood Forest – MHn35

Trees in understory	% presence R, SE, SA	R-index	SE-index	SA-index	T-index
Sugar maple (Acer saccharum)	96	5.0	5.0	5.0	5.0
Ironwood (Ostrya virginiana)	83	4.8	4.8	4.8	3.0
Northern red oak (Quercus rubra)	80	4.2	4.0	3.3	4.3
Basswood (Tilia americana)	80	4.5	4.3	4.5	4.5
Red maple (Acer rubrum)	64	4.3	4.2	3.8	3.8
Balsam fir (Abies balsamea)	51	3.7	3.5	2.5	2.3
Quaking aspen (Populus tremuloides)	47	3.7	3.3	2.7	4.0
Paper birch (Betula papyrifera)	39	1.7	1.3	3.2	4.5
Bur oak (Quercus macrocarpa)	17	2.2	1.7	2.3	2.8
Big-toothed aspen (Populus grandidentata)	11	1.8	1.5	1.8	3.8
White pine (Pinus strobus)	10	2.7	2.3	1.5	3.3
Yellow birch (Betula alleghaniensis)	10	1.3	1.3	2.5	3.0

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

% presence: the percent of 322 MHn35 sample plots with that species present under 10m (33 feet) tall (R, SE, SA layers)
R-index: index of representation as true seedling or under 10cm (4 inches) tall
SE-index: index of representation as seedlings over 10cm and under 2m (0.3-6.6 feet) tall
SA-index: index of representation as saplings 2-10m (6.6-33 feet) tall
T-index: index of representation as a tree >10m (33 feet) tall
All indexes: equally weight (1) presence, (2) mean cover when present, and (3) mean number of reported strata, the frequency distributions of which are segmented equally by area into 5 classes.

R-2, Methods*
The releve method of sampling forest vegetation describes explicitly how trees occur at different heights. We modified raw releve samples by interpreting the occurrence and cover of trees in four standard height strata: regenerants 0-10cm tall, seedlings 10cm-2m tall, saplings 2-10m tall, and trees taller than 10m. The releve samples all come from forests with an established canopy, so this dataset documents the presence and cover of trees in strata that have formed during the process of stand maturation, i.e. understory development.

We created an index to measure roughly the regenerative success of a tree in each stratum. The index is the product of (1) percent presence in that stratum for all releves classified as that community, (2) mean percent cover of that species when present in a stratum, and (3) the mean number of different strata reported in the releves when that species is present. The indices for all trees were ranked, the range was then scaled to range between zero and 5. The index ratings of excellent, good, fair, poor, and not-applicable are the 5 whole number segments of the index.

***The tree index in table R-2 is not the same calculation or ranking as the suitability index of table R-1.

R-2, Silvicultural Applications

1. Estimate the overall ability of the community to develop silviculturally significant advance regeneration.
    a. In general, trees with excellent-to-good R-, SE-, and SA-indices can be depended upon to produce enough advance regeneration to stock a stand after removal of canopy trees (e.g. sugar maple, ironwood, red oak, basswood, and red maple for MHn35).
    b. In general, the number of native trees (see Tables PLS-1 and PLS/FIA-1) with excellent-to-good R-, SE-, and SA-indices is correlated with the community's historic dependence upon fine-scale or catastrophic disturbance for regeneration. High numbers of trees (e.g. 5 for MHn35) are correlated with fine-scale disturbance dynamics and long rotations of catastrophic disturbance (e.g. for MHn35, the rotations of catastrophic fire or windthrow are about 1,000 years).
2. Estimate seedbed suitability or sprouting ability of trees under the canopy of a mature forest and on an undisturbed forest floor.
    a. In general, trees with excellent-to-good R-index will not require seedbed preparation.
    b. Conversely, trees with fair-to-poor R-index will most likely require a silvicultural treatment that exposes mineral soil for them to germinate or sprout.
3. Estimate the shade tolerance of trees under the canopy of a mature forest
    a. In general, trees with excellent-to-good SE- and SA-index are considered to be shade tolerant and able to recruit into the canopy using small, single-to-few tree gaps.
    b. Conversely, trees with fair-to-poor SE- and SA-index are considered to be shade-intolerant and recruit into the canopy only in rather large gaps or in the open.
4. Identify recruitment bottlenecks
    a. In general, the lowest index among the four (R-, SE-, SA-, T-) indicates the height-class where that tree has the greatest trouble recruiting given the "usual" conditions in mature forests. For the MHn35 example, red oak seems to have some trouble recruiting into the sapling (SA) class, meaning that the growth of red oak seedlings is likely hindered by one or more of the "usual" conditions of a mature MHn35 forest.
    b. Experience with this table suggests that relative declines or dips among the indices need to be about a whole unit to be "significant," meaning that a recruitment problem identified in the table is commonly observed by field foresters familiar with the community.
    c. The absolute values are important, meaning that bottlenecks from excellent to good, present far less a silvicultural obstacle than dips from fair to poor.

Tables & Figures based upon the Public Land Survey

- **PLS-1 Historic Abundance of Trees in Natural Growth-stages**
- **PLS-2 Abundance of trees throughout succession**
- **PLS-3 Historic Abundance of Trees Following Disturbance**
- **PLS-4 Ordination of Historic Age-classes**
- **PLS-5 Historic Windows of Recruitment**
- **PLS/FIA-1 Abundance of trees in Pre-settlement and Modern Times by Historic Growth-stage**

Natural stand dynamics and disturbance were evaluated using data from the original Public Land Survey (PLS) of Minnesota. The investigation started 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-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-1) or graphic form (PLS-2).

Often, the PLS field notes explicitly refer to disturbances that affected the forest and the general availability of bearing trees. This allows us to understand how the different species of trees reacted to fire, windthrow, or finer-scale events that maintained mixtures of species typical more mature forests (PLS-3).

In order to understand how forests have changed since the PLS, we ran a parallel analysis (see below) of trees on FIA subplots (1990 AD) to produce a table comparable to PLS-1. Table PLS/FIA-1 makes this comparison, so that it is easy to see how the landscape balance of growth-stages has changed and easy to see which species have increased or decreased in abundance because logging has largely replaced natural stand-regenerating events.

(Example PLS-1) Historic Abundance of MHn35 Trees in Natural Growth-stages

Table values are relative abundance (%) of Public Land Survey (PLS) bearing trees at corners modeled to represent the MHn35 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 to 1908 AD.

Dominant Trees	Forest Growth Stages in Years				
	0 - 55	55 - 95	95 - 205	205 - 295	> 295
	Young	T1	Mature	T2	Very Old
Paper Birch	38%	||	28%	||	12%
Quaking (Big-toothed) Aspen	20%	||	6%	|	4%
Red Oak	10%	|	5%	|	1%
Balsam Fir	5%	|	3%	|	1%
Basswood	6%	⌉	9%	|	6%
White Spruce[1]	1%	⌉⌉	13%	|	-
Sugar Maple	11%	⌉	14%	⌉⌉	29%
White Pine	1%	⌉	7%	⌉⌉	31%
Miscellaneous	14%		15%		16%
Percent of Community in Growth Stage in Presettlement Landscape	39%	51%	8%	1%	1%

1. Important historically, white spruce is no longer a significant component of MHn35 forests and is not covered in the accounts of potential crop species.

PLS-1, Methods
Consult Tables & Figures based upon the Public Land Survey for general discussion of how PLS survey corners were modeled to apply to a NPC Class and how their ages were assigned.

Trees included in Table PLS-1 are species with greater than 3% relative abundance in at least one growth-stage. Species that are now abundant in MHn35 forests, but were rare historically appear in Table PLS/FIA-1.

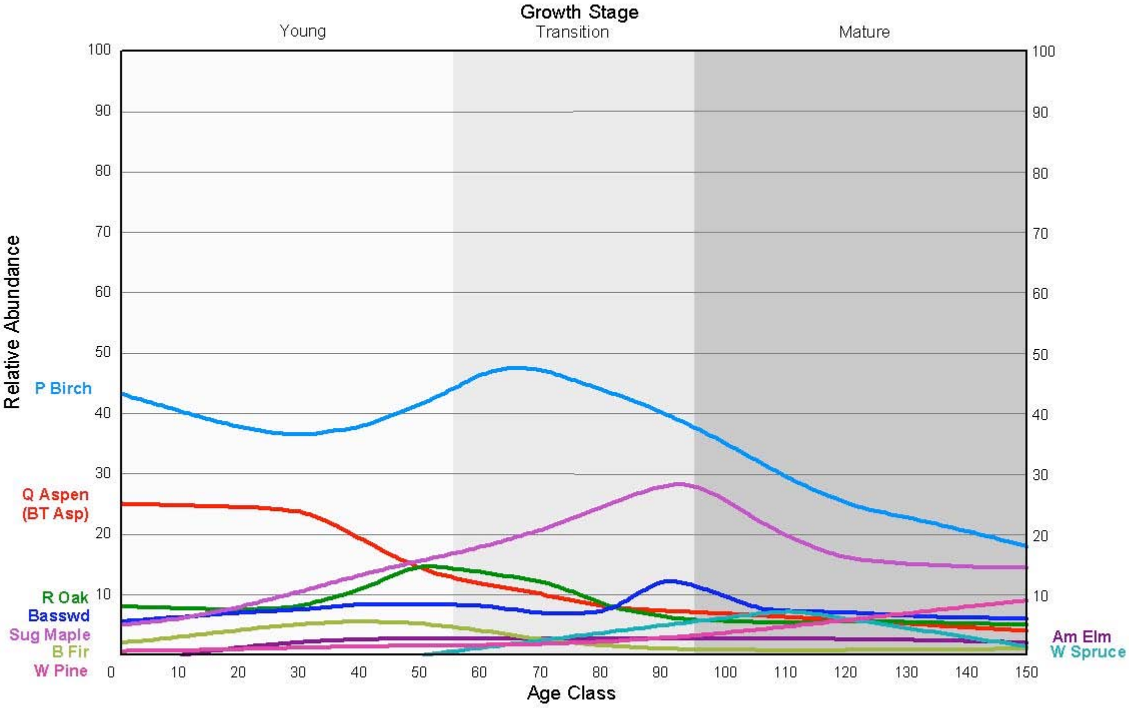
Often, the PLS surveyors did not consistently distinguish some tree species. For PLS survey corners assigned to the MHn35 community they commonly referred to “aspen,” which certainly includes quaking aspen, big-toothed aspen, and possibly balsam poplar. For MHn35 releve samples, “aspen” presence is: 31% for quaking aspen, 13% for big-toothed aspen, and 0.3% for balsam poplar. The convention for dominant tree names in Table PLS-1 is to include all species that make up a minimum of a tenth of the generic presence of “aspen” and to use the predominant species as the name, but parenthetically include the less abundant species.

PLS-1, Silvicultural Applications

1. Identify initial-cohort species
   a. In general, species with more than about 5% relative abundance in the young growth-stage are considered to be initial-cohort trees.
   b. Because of variety in the intensity and type (fire, wind, disease) of stand-regenerating disturbance, most initial-cohort trees were capable of dominating a young stand. The relative abundances of initial-cohort trees in Table PLS-1, do not define a target mixture of trees following a regeneration harvest.
   c. Plantations should be composed of initial-cohort trees. White spruce and white pine would not qualify in this MHn35 example.
2. Identify the successional status of the different tree species
   a. Species can be placed into three general successional categories:
      i. Early-successional species are those with peak relative abundance in the young growth-stage and then show relative decline as stands mature.
      ii. Mid-successional species are those with peak relative abundance in middle (transition or mature) growth-stages.
      iii. Late-successional species are those that increase in relative abundance over the course of stand maturation and peak in the oldest, recognized growth-stage.
   b. Species can show high abundance in the young growth-stage and not be early-successional (e.g. for MHn35 is sugar maple), and conversely a species can be abundant in the older stages and not be late-successional (e.g. for MHn35 paper birch). Species are able to do this because:
      i. Some stand-regenerating disturbances release regeneration accumulated in the older growth-stages
      ii. Trees usually have dual regenerative strategies, like seeding versus spouting
      iii. Some trees are plastic in their response to the environment, able to develop leaves, bark characteristics, storage organs, etc. that are adaptive to the current situation.
   c. It is broadly true that species' successional status is correlated with the intensity and extent of natural disturbance, which can be approximated by the correct combinations of silvicultural system and site preparation.
      i. Early successional trees follow disturbances of high intensity and large extent.
      ii. Mid-successional trees follow disturbances of medium intensity and limited extent.
      iii. Late-successional trees follow disturbances of light intensity and small extent.
3. Recognize impending decline and replacement
   a. In general, the natural transition periods of stand development represent the period of time where it is most important to "capture mortality" and where it is easiest to silviculturally manipulate the future composition of the forest. Transitions the windows of management opportunity.
   b. This interpretation is most important as a planning tool, where it should be used to trigger a stand examination given the landscape goals.
4. Assess the balance of growth-stages on the historic landscape for SFRMP
   a. The landscape balance of growth-stages is a point-in-time (*ca.* 1850-1900 AD) benchmark for debating the landscape structural and compositional needs of forest wildlife.
   b. The alternative method of iterative modeling landscape age-classes using rotation of catastrophic fire and windthrow almost always yields much more old forest at equilibrium. This is so because:
      i. Meso-scale disturbances of 1-several acres were more important that generally acknowledged
      ii. The surveyors biased their selection of bearing trees towards smaller diameter canopy trees that were likely to live longer and perpetuate the survey corner
5. Assess data reliability
   a. In general, the abundance and reliability of PLS data is high for the younger growth-stages and low for older ones. The proportion of the landscape in each growth-stage is a proportional measure of the amount of data within the NPC set contributing to the growth-stage concept and any derived silvicultural interpretations.

(Example PLS-2) Abundance of trees throughout succession in MHn35

Graphed for the different species of MHn35 trees is their relative abundance (%) as PLS bearing trees by age class. The data were initially smoothed from adjacent classes and then by visually fitting lines to illustrate general trends.



PLS-2, Methods
PLS-2 is just the graphic representation of the information in Table PLS-1 except that the 10-year age class data are not forced into broad growth-stages. A shortcoming of the PLS data is that the surveyors tended to record diameters in coarse diameter classes, evens and multiples of 6" for large-diameter trees. Ages estimated from even diameters are more popular than ages estimated from odd diameters and often hit 10-year age classes unevenly, meaning that some age classes by chance have far more contributing survey corners than adjacent classes because they capture one or two even diameters. For young age-classes this affects the estimates of relative abundance due to smaller and greater sample size, and species error is low because the age-diameter curves are not much different among the species for small diameters. For large diameters, the age-diameter curves are significantly different from each other and it is possible for a species to more often placed into one age-class versus another by chance. For this reason, the age-class data are heavily smoothed in PLS-2, reducing the accuracy of peaks and valleys of relative abundance.

Consult Tables & Figures based upon the Public Land Survey for general discussion of how PLS survey corners were modeled to apply to a NPC Class and how their ages were assigned.

Trees included in Table PLS-2 are species with greater than 3% relative abundance in at least one growth-stage in Table PLS-1.

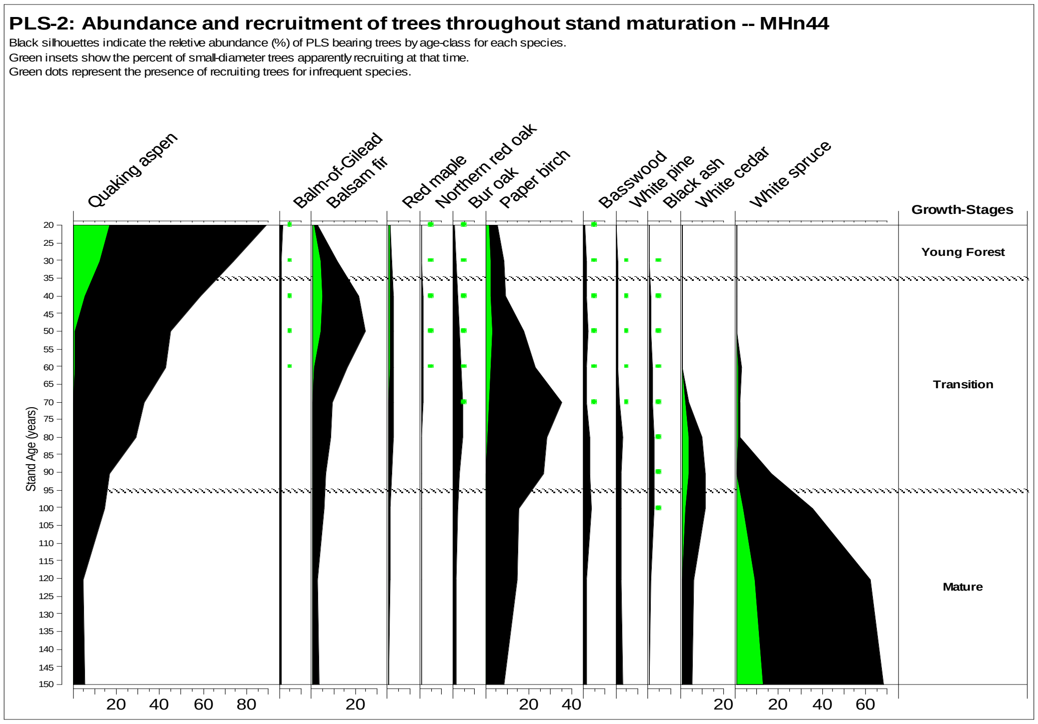
Often, the PLS surveyors did not consistently distinguish some tree species. For PLS survey corners assigned to the MHn35 community they commonly referred to "aspen," which certainly includes quaking aspen, big-toothed aspen, and possibly balsam poplar. For MHn35 releve samples, "aspen" presence is: 31% for quaking aspen, 13% for big-toothed aspen, and 0.3% for balsam poplar. The convention for dominant tree names in Table PLS-1 is to include all species that make up a minimum of a tenth of the generic presence of "aspen" and to use the predominant species as the name, but parenthetically include the less abundant species.

PLS-2, Silvicultural Applications

1. Estimate the timing of a species' peak abundance to set commercial rotation
    a. Species' peak abundance during normal stand maturation is evident in PLS-2, whereas it is often hidden by averaging across entire growth-stages in PLS-1.
    b. Estimates of relative abundance are more reliable for the young age classes because there are more corners contributing to these classes and because the species diameter-age curves are not much different for small diameters.
    c. The accuracy of peaks and valleys is probably not much better than ∀10 years.
    d. For mixed stands it is usually evident that there is no single best rotation age, and the best guesses will depend upon the coincidence of peaks and comparative value of the species involved.
2. Identify basic species' behavior
    a. In general, most trees can be placed into 4 behavioral categories given the usual trends in stand dynamics
        i. Initial-cohort trees are those with high abundance in the young growth-stage and their abundance declines steadily throughout the course of stand maturation. The persistence of these species is dependent upon disturbance.
        ii. Pulsing species are those that show a sharp increase and subsequent decline in relative abundance at some time between the post-disturbance years and old-growth. At this time, only balsam fir and white cedar have shown this behavior.
        iii. Persisting species are those with survival strategies that allow for them to remain on a site regardless of the intensity and type of disturbance. Such strategies usually involve vegetative propagation and allocation of resources underground.
        iv. Ingressing species are those easily killed by stand-regenerating disturbance, but are able to later invade sites when conditions correlated with stand age allow. Intensifying shade and increasingly organic seedbeds are examples of site conditions correlated with older forests.
3. Schedule stand evaluations based upon stand age
    a. In general, stand evaluations should precede transitions because transitions are the time of greatest mortality, replacement, and silvicultural opportunity.
    b. Alternatively, stand evaluations should precede anticipated decline of valuable tree species.

(Example PLS-2) Abundance recruitment of trees throughout stand maturation – MHn44

Graphed for the different species of MHn44 trees is their relative abundance (%) as PLS bearing trees by age class on individual ordinates. The data were smoothed from adjacent classes. For abundant species, the percent of the total relative abundance accounted for by recruiting[1] trees is shown as the green inset. For trees at low abundance, age-classes with any recruiting trees are indicated by the green dots.



1. Recruiting trees are those at half the diameter of the largest tree at a survey corner.

PLS-2 Alternate, Methods

PLS-2 Alternate is the graphic representation of the information in Table PLS-1 except that the 10-year age class data are not forced into broad growth-stages. Unlike Figure PLS-2, each species has its own horizontal ordinate in order to eliminate confusion caused by the superposition of species curves that have low abundance and vary little throughout stand maturation when graphed on a single ordinate.

The green insets and dots are intended to show the contiguous strings of age-classes where that species is successful recruiting trees. A bearing tree was assigned to the recruiting class when it was half the diameter of the largest tree at the same corner, meaning that we believed that a <5" tree was unlikely to have been established in response to the same disturbance or event that established a nearby >10" tree. Note that recruitment is not the same as establishment. Establishment curves would need to be back-calculated from the recruitment curves based upon the diameter/age relationships of the species in question. Although there are exceptions, the diameter/age curves for most species are fairly linear for the first 100 years or 20 inches and also, there are not great differences among species. This means that trees recruiting in a particular age class were probably established during the age class that is about half that of the recruitment class. For example, balsam fir has peak recruitment at about age 45 and chances are that the trees contributing to that recruitment were established at about age 20-25.

Consult *Tables & Figures based upon the Public Land Survey* for general discussion of how PLS survey corners were modeled to apply to a NPC Class and how their ages were assigned.

Trees included in Figure PLS-2 Alternate are species with greater than 3% relative abundance in at least one growth-stage in Table PLS-1.

PLS-2 Alternate, Silvicultural Applications

1. Estimate the timing of a species' peak abundance to set commercial rotation
    a. Species' peak abundance during normal stand maturation is evident in PLS-2, whereas it is often hidden by averaging across entire growth-stages in PLS-1.
    b. Estimates of relative abundance are more reliable for the young age classes because there are more corners contributing to these classes and because the species diameter-age curves are not much different for small diameters.
    c. The accuracy of peaks and valleys is probably not much better than ∀10 years.
    d. For mixed stands it is usually evident that there is no single best rotation age, and the best guesses will depend upon the coincidence of peaks and comparative value of the species involved.
2. Identify basic species' behavior
    a. In general, most trees can be placed into 4 behavioral categories given the usual trends in stand dynamics
        i. Initial-cohort trees are those with high abundance in the young growth-stage and their abundance declines steadily throughout the course of stand maturation. The persistence of these species is dependent upon disturbance.
        ii. Pulsing species are those that show a sharp increase and subsequent decline in relative abundance at some time between the post-disturbance years and old-growth. At this time, only balsam fir and white cedar have shown this behavior.
        iii. Persisting species are those with survival strategies that allow for them to remain on a site regardless of the intensity and type of disturbance. Such strategies usually involve vegetative propagation and allocation of resources underground.
        iv. Ingressing species are those easily killed by stand-regenerating disturbance, but are able to later invade sites when conditions correlated with stand age allow. Intensifying shade and increasingly organic seedbeds are examples of site conditions correlated with older forests.
3. Allow recruitment of advance regeneration prior to treatment
    a. This figure allows for a certain amount of guessing as to whether seedlings present during a stand exam are likely to recruit if the stand is left untreated.
        i. In cases where the established seedlings are desirable, the benefit of deferred treatment (no planting or tending) might outweigh any losses in volume.
        ii. In cases where the established seedlings are not desirable, treatment should be immediate.
4. Schedule stand evaluations based upon stand age
    a. In general, stand evaluations should precede transitions because transitions are the time of greatest mortality, replacement, and silvicultural opportunity.
    b. In general, stand evaluations should precede anticipated decline of valuable tree species.

(Example PLS-3) Historic Abundance of MHn35 Trees Following Disturbance

Table values are raw counts and (percentage) of Public Land Survey (PLS) bearing trees at survey corners likely to represent MHn35 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	
Quaking (Big-toothed) aspen	47	22%	14	11%	55	13%	1607	13%
Ironwood	7	3%	0	0%	0	0%	158	1%
White pine	2	1%	5	4%	0	0%	392	3%
Northern red oak	38	18%	34	28%	213	50%	1040	8%
Bur oak	5	2%	3	2%	15	4%	193	2%
Paper birch	68	32%	44	36%	81	19%	5108	40%
Sugar maple	23	11%	10	8%	30	7%	2444	19%
Basswood	14	7%	8	7%	24	6%	972	8%
Balsam fir	9	4%	4	3%	4	1%	598	5%
Yellow birch	0	0%	0	0%	3	1%	179	1%
Red maple	0	0%	0	0%	1	0%	50	0%
Total (% of grand total, 13502)	213	2%	122	0.9%	426	3%	12741	94%

PLS-3, Methods
For the set of PLS survey corners assigned to a NPC Class, we assigned also a disturbance class based upon what the surveyors said about physiognomy, fire, windthrow, or what we could infer from the distances that the surveyors traveled to find suitable bearing trees.

PLS survey corners were assigned to four disturbance classes:

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

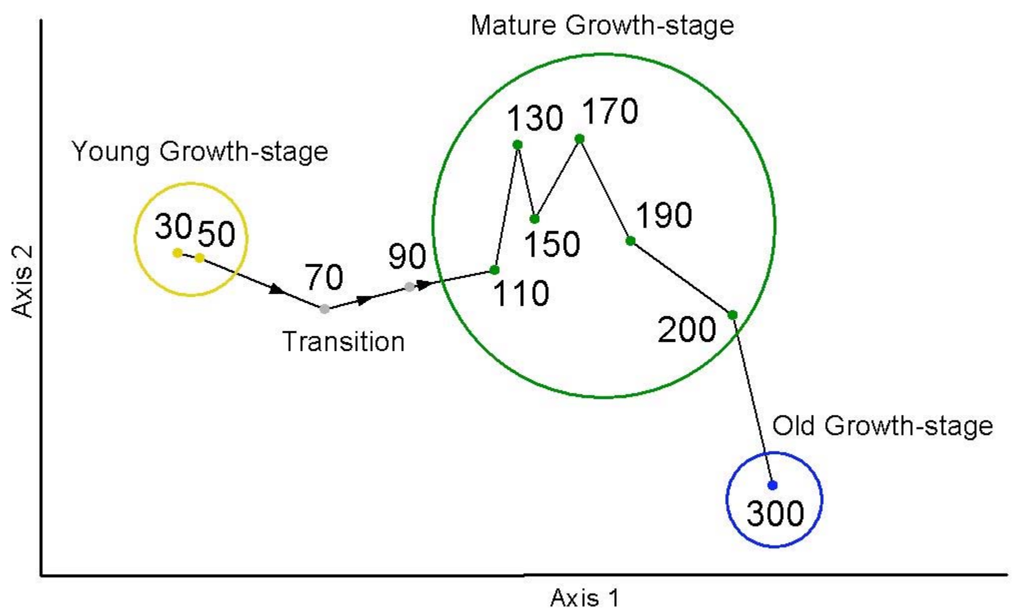
Table PLS-3 includes only trees ranked as having excellent, good, or fair suitability for MHn35 sites. Tree sums will not match the totals in the Natural Disturbance Regime text, because trees of poorer suitability were included in that analysis.

PLS-3, Silvicultural Applications

1. Determine the disturbance that was most prevalent and characteristic of the community
    a. For the MHn35 example it is clear that fine-scale disturbance involving single-to-few tree gaps with little or no soil disturbance was the prevalent means of recruiting canopy trees (94% mature).
    b. It is important to note though that the windows of recognition (i.e. the level of disturbance required for a surveyor to note a disturbance or particular physiognomy) are different among the disturbance classes, which contributes to the balance of observed disturbance. We figure that the window for catastrophic fire or windthrow is about 15 years; the window is about 5 years for maintenance events; and that disturbance in the mature category was never noteworthy. Thus, even for highly disturbed forests, the maintenance and mature categories will usually have the greatest abundance.
2. Estimate which species are likely to respond positively, given a certain disturbance
    a. Because the disturbance categories are rather easily translated into prescriptive levels of canopy removal and soil disturbance, Table PLS-3 can be used to roughly predict the response of species to a prescription by looking at their abundance down the columns.
    b. In general species with a high percentage in a disturbance column are likely to respond positively to a prescriptive disturbance similar to the natural one.
    c. It may be equally important to consider species with low percentages in a disturbance column if the goal is to diminish their populations in the future forest.
3. Estimate which disturbance category was most favorable, given a certain species
    a. By looking across the rows, Table PLS-3 indicates the general disturbance that most favored or most inhibited that tree.
4. Assess data reliability
    a. Table PLS-3 presents the raw counts of trees contributing to the analysis, and this allows one to guess at how reliable the data are.
    b. In general, we tend to question the results when the sum of tree occurrences across a row or down a column is less than 100. In this MHn35 example, our doubt would focus on red maple. MHn35 is an extensive community and we did not display infrequent species with poor suitability ratings. For less extensive communities, the numbers can be quite low causing us to question the behavior of the species or our understanding of a disturbance type.

(Example PLS-4) Ordination of Historic MHn35 Age-classes

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



PLS-4, Methods
For each PLS survey corner we estimated stand age based on the age of the oldest tree as modeled from its diameter. The corners were placed into 20-year age-classes for this analysis. We used coarse age-classes mostly because the surveyors tended to estimate diameters coarsely in even inches.

For each age-class the relative abundance of each bearing tree type was calculated and used to characterize and ordinate the age-classes. Detrended Correspondence Analysis provided the smoothest ordinations, meaning that the age-classes tend to sequentially track across the ordination plot. The right-angle turns in the ordination track, here at 170 years, almost always are caused by the ingress of a species totally absent from the younger classes. For MH and WF systems, this is the ingress of conifers into younger deciduous forests. For the conifer-dominated FD, FP, and AP systems, the tracks tend to be more linear.

There is always some subjectivity and uncertainty in placing the seams between growth-stages and transitions in these diagrams. When uncertain, we placed seams that match process transitions (self-thinning to density-independent mortality, ingress of shade-tolerants, etc.) described in more general models of stand dynamics in silvicultural literature. Also, movement in the third and fourth axes is not evident in PLS-4 but was considered in setting the growth-stage seams.

PLS-4, Silvicultural Applications

1. Define periods of stable forest composition known as growth-stages
    a. Growth-stages were constructed primarily for the purpose of simplifying and communicating the natural stand dynamics of a NPC Class.
    b. In general, significant mortality is not anticipated during growth-stages and silvicultural treatments during those episodes should be aimed mostly at increasing quality more so than volume or compositional change.
2. Define periods of transition characterized by mortality and replacement
    a. In general, transitions are the episodes where commercial harvesting of species in decline is important if timber productivity is the primary management goal.
    b. In general, transitions are the best window of opportunity for silvicultural manipulation through commercial harvesting.
    c. In general, a managed transition (flux harvesting) should start about 10 years before the natural transition.
3. Communicate silvicultural ideas by growth-stage
    a. The growth-stages and transitions evident in PLS-4 are the main way to simplify, organize, and discuss natural stand dynamics and ecological processes that might be emulated by silvicultural treatments.
    b. Most of the PLS-4 tables illustrate the reality of continuous compositional change that has been oversimplified for comparable discussions among the NPC Classes.

(Example PLS-5) Historic Windows of Recruitment for MHn35 Trees

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

Initial Cohort	Species	Peak years	P-D 0-50 years	G-1 50-110 years	I-1 110-190 years	G-2 >190 years
Minor	White Pine	0-40	Fair	--	--	--
Yes	Quaking Aspen[1]	0-30	Excellent	Poor to 60	--	--
Yes	Paper Birch	0-40	Excellent	Fair to 80	--	--
Yes	Basswood	0-40	Good	Poor to 70	--	--
Yes	Sugar Maple	0-50	Good	Fair to 90	--	--
Yes	Red Oak	0-50	Fair	Poor to 70	--	--
No	American Elm	20-40	Fair	Poor to 80	--	--
No	Red Maple	30	Poor	Poor to 70	--	--
No	Balsam Fir	30-50	Fair	--	--	--
No	Bur Oak	50	--	Poor to 70	--	--
No	Yellow Birch	60-80	--	Poor at 60-80	--	--
No	White Spruce[2]	150+	Poor after 30	Poor	Good	--

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

1. Quaking aspen bearing trees couldn't be segregated from bigtooth aspen in the PLS notes for this community. The quaking aspen data probably include some bigtooth aspen, which we consider ecologically similar to quaking aspen.
2. White spruce was important historically but is no longer a significant component of MHn35 forests and is not covered in the accounts of potential crop species.

PLS-5, Methods

PLS survey corners modeled as belonging to a NPC Class were placed into 10-year age classes based upon the age of the oldest bearing tree as estimated from its diameter. For each age class, bearing trees were placed in two categories: larger diameter trees that could be in the same cohort as the oldest tree and small diameter trees that were most likely established and recruited to bearing tree size well after the event that established the oldest tree. The rule for placing a bearing tree into the small-diameter, recruit class was that its diameter was equal to or less than half the diameter of the oldest bearing tree at the same corner.

For each species, we superimposed the plot of all trees and the plot of recruiting trees to show how the abundance of that species' changes through time and how much of the abundance is attributed to small-diameter recruits. The remarkable result was that even for trees present throughout the course of succession, there was usually a single episode of recruitment, and good recruitment was often limited to a few contiguous age classes. We call these "windows of recruitment."

When organized in a table, it is clear that windows of recruitment are correlated with growth-stages and transitions, especially the young growth-stage and the following transition characterized by the death of initial-cohort trees. For this reason, we forced the columns in Table PLS-5 to roughly match the age-seams of the growth-stages, but allowed for some movement if the more detailed (10-year versus 20-year classes) windows suggested that we do so. We aligned growth-stages and windows of recruitment for two reasons. First, it allows us to communicate recruitment concepts using the growth-stages and transitions as a familiar framework. Second, canopy and disturbance characteristics of the growth-stages and transitions explain to some extent why recruitment was possible. Three types of recruitment windows were assigned to the growth-stages and transitions:

1. Post-disturbance (P-D) window: aligned with the young-growth stage, this window represents a time where trees are being established and recruited as they compete to occupy new growing space and often increased nutrient levels in the open.
    a. Interpreting post-disturbance dynamics is hindered by the fact that trees must achieve about a 4” diameter before they could be marked and scribed as a bearing tree. The abundance of trees and recruits in the 0 and 10 year classes is therefore estimated by extrapolating the general trend of the 20-50 year age-classes back to the origin.
    b. The young growth-stage misses entirely density-dependent thinning and most likely, very shaded conditions under a proximal canopy. For this reason, some very shade-tolerant trees show some recruitment near the end of the P-D window. For now, these species are segregated from initial-cohort, intolerant trees by row-shading (gold) rather than creating another column for ingress during self-thinning (e.g. balsam fir, elm, and red maple in this example).
2. Gap (G1, G2) windows: aligned with transitions, represent episodes of fairly synchronous mortality, especially that of the of initial cohort trees. Presumably, few-to-many tree gaps form at this time and allow recruitment of mid-tolerant species or release of shade-tolerant trees established late in the P-D window.
3. Ingress (I-1, I-2) windows: aligned with mature and old growth-stages and presumably, maximum development of a canopy and subordinate strata where only shade-tolerant trees can recruit.
4. A property of PLS data is that diameter variation among bearing trees at the same corner decreases with increasing diameter. Thus, it is common for the older recruitment windows to have few or no recruiting trees. The paucity of data at corners estimated to be older than about 100 years should not be taken to mean that small diameter trees didn’t occur at all.

PLS-5, Silvicultural Applications

1. Identify the peak timing of recruitment for the different species
    a. In general, silvicultural release should occur during peak recruitment periods.
2. Describe the behavior of trees as to how well they recruit under different levels of canopy removal
    a. In general, species that do well under full sunlight and compete well for new growing space are those with peaks in the P-D window.
    b. In general, species that do well under a partial canopy are those with peaks in the gap (G1, G2) windows.
    c. In general, species that do well under a full canopy are those with peaks in the ingress windows (I1, I2).
3. Identify species that might do well when underplanted
    a. In general, all important species that are not usually part of the initial-cohort could, at some time, be under-planted.
        i. Table PLS-5 shows only recruitment windows and not the timing of establishment, which would be when we might want to underplant.
        ii. In general, because the growth-diameter curves are fairly linear and not much different among species in the younger age-classes, one can usually guess that the age of establishment is about half the age of peak recruitment or a little before that. For example, recruiting white spruce are first abundant in the 120 year age-class (not shown in PLS-5), and those trees were probably established naturally at 50-60 years in response to the decline of initial-cohort aspen. Thus, a partial harvest of mature aspen and an underplanting of white spruce would make sense in 50-year old mixed, MHn35 stands.

Tables based upon FIA Subplots

- **FIA-1 Structural Situations of Trees in Mature Stands**
- **PLS/FIA-1 Abundance of trees in Pre-settlement and Modern Times by Historic Growth-stage**

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.

(Example FIA-1) Structural Situations of Trees in Mature MHn35 Stands

This table presents percentages of structural situations for trees as recorded in Forest Inventory Analysis (FIA) subplots that we modeled to be samples MHn35 forests. The purpose of the table is to provide a general impression of how often a species is seen certain regenerative situations: canopy of a regenerating forest (situations 11, 22), in the subcanopy (situations 12, 23), or in the seedling bank below a remote canopy (situation 13). The situation of trees in older stands at tree height (33) provide no insight about regeneration. Species are ordered by the sum of their percents in 12 and 13 situations, which generally ranks them as would shade-tolerance ratings. The total number of trees counted for each species is presented to provide a sense of reliability.

Species	Tree Count	Structural Situations					
		11	22	12	23	13	33
Yellow birch	24	-	4%	-	12%	4%	79%
Paper birch	549	4%	19%	4%	36%	3%	34%
Bur oak	100	2%	12%	2%	18%	5%	61%
Northern red oak	534	3%	8%	4%	15%	4%	67%
Quaking aspen	491	21%	13%	12%	9%	8%	37%
Basswood	840	3%	6%	8%	21%	12%	50%
White pine	11	-	18%	27%	-	-	54%
Big-toothed aspen	31	19%	-	16%	3%	13%	48%
Red maple	340	8%	19%	14%	23%	17%	19%
Sugar maple	1178	2%	16%	13%	19%	28%	2%
Balsam fir	102	8%	15%	28%	30%	17%	3%

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

FIA-1, Methods
FIA plots and subplots were modeled as belonging to a NPC Class. For the acceptable subplots, every tree was placed into one of three diameter classes: saplings <4" diameter, poles 4-10" diameter, and trees >10" diameter. Every subplot was assigned a canopy class based upon the diameter class of the largest trees: sapling stands, pole stands, or tree stands. The frequency of occurrence for every subplot tree was tabulated by all possible combinations of plot and tree combinations.

The primary purpose of Table FIA-1 is for checking against Tables R-2 and PLS-5 as to the abilities of trees to recruit beneath a canopy. Reconciliation of these three tables is the primary means of generalizing about species' regenerative strategies: open, large gap, or small gap.

FIA-1, Silvicultural Applications

1. Estimate the success of trees in the initial cohort, i.e. open strategists that are favored by open conditions and intense, recent disturbance
    a. In general, trees with peak presence in situations 11 and 22 are open strategists.
    b. Corroborative evidence in Table R-2 are trees with poor-to-fair R-, SE-, and SA-index.
    c. Corroborative evidence in Table PLS-5 are trees with windows of recruitment where peak recruitment is the initial age-classes (0-20 years).
2. Estimate the success of trees as subordinates under a proximal canopy, i.e. large-gap strategists grow more slowly than initial-cohort trees but outlive them persisting, in the subcanopy to eventually be released in large gaps.
    a. In general, trees with peak presence in situations 12 and 23 are large-gap strategists.
    b. Corroborative evidence in Table R-2 are trees with fair-to-good R-, SE-, and SA-index, usually displaying a recruitment bottleneck at SE and SA heights.
    c. Corroborative evidence in Table PLS-5 are trees that tend to have peak recruitment in a G1 or G2 window and have "humped" recruitment curves (not shown) that start in middle age-classes (non-zero minimums in the peak column).
3. Estimate the success of trees subordinate, "seedling bankers," beneath a remote canopy, i.e. small-gap strategists favored under full canopy and low-light conditions.
    a. In general, trees with peak presence in situation 13 are small-gap strategists.
    b. Corroborative evidence in Table R-2 are trees with excellent-to-good R-, SE-, and SA-index.
    c. Corroborative evidence in Table PLS-5 are trees with peak recruitment windows that start in the mid-successional age classes and increase with time, peaking in and ingress window (I1 or I2).
4. High presence in situation 33 is not diagnostic of recruitment ability because the origin of the stand is not known, but in general, correlate with suitability (PLS-1).

(Example PLS/FIA-1) Abundance of MHn35 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 MHn35 community and estimated to fall within the young, mature, and old growth-stages. Arrows indicate increase or decrease between historic growth-stages only and for the more common trees. Green shading and text was used for the historic PLS data and blue was used for the FIA data. Percents on the bottom row allow comparison of the balance of growth-stages across the pre-settlement landscape (*ca.* 1846-1908 AD) and the modern landscape (*ca.* 1990 AD).

Dominant Trees	Forest Growth Stages in Years									
	0 - 55		55 - 95		95 - 205		205 - 295		> 295	
	Young		T1		Mature		T2		Old[2]	
Paper Birch	38%	9%	||		28%	7%	||		12%	0%
Quaking Aspen	20%	22%	||		6%	4%	|		4%	0%
Red Oak	10%	6%	|		5%	11%	|		1%	0%
Balsam Fir	5%	4%	|		3%	2%	|		1%	0%
Basswood	6%	9%	⌉		9%	19%	|		6%	0%
White Spruce[1]	1%	1%	⌉⌉		13%	0%	|		-	0%
Sugar Maple	11%	24%	⌉		14%	32%	⌉⌉		29%	50%?
White Pine	1%	0%	⌉		7%	1%	⌉⌉		31%	0%
American Elm	3%	2%	|		2%	3%	|		0%	0%
Red Maple	--	9%			--	4%			0%	0%
Ironwood	1%	7%			1%	7%			1%	0%
Bur Oak	1%	1%			2%	3%			0%	50%?
Miscellaneous	3%	6%			10%	7%			15%	0%
Percent of Community in Growth Stage in Presettlement and Modern Landscapes	39%	29%	51%	52%	8%	18%	1%	1%	1%	0%

Natural growth-stage analysis and landscape summary of historic conditions is based upon the analysis of 5,887 Public Land Survey records for section and quarter-section corners. Comparable modern conditions were summarized from 3,470 FIA subplots that were modeled to be MHn35 sites.

1. Important historically, white spruce is no longer a significant component of MHn35 forests and is not covered in the accounts of potential crop species.

2. Just 4 FIA trees contributed to the old growth-stage and the results are unreliable.

PLS/FIA-1, Methods

This table is the result of a parallel analysis of PLS and FIA data. The same modeling technique (LTAs, and tree probabilities) as described for the PLS data and FIA data in general (see above) was used in both cases with the exception that FIA plots allowed for more sophisticated modeling because subplots usually have more trees (>4) and we lumped tree presence across sampling cycles. Otherwise, the same computer program was applied to both the PLS and FIA data.

Columns were set by the growth-stage analysis of PLS data.

PLS-FIA-1, Silvicultural Applications

1. Determine if species have changed their successional position due to the differences between modern land management and natural regenerating events.
    a. In general, it is far more common for trees to occupy the same successional position – early, middle, or late – now as they did historically.
    b. Usually, changes in successional position relate to logging not killing late successional trees (maples and white spruce) as fire once did.
    c. Consequently, prescriptions should focus on diminishing some species as much as the usual focus on regeneration or release.
2. Identify species that are in peril and those that are expanding their range
    a. In general, Table PLS/FIA-1 offers some specificity (NPC Class) to the assessment of population trends of trees in Minnesota.
    b. In general, fire-dependent trees (pine & oak) have populations depressed from their former state and fire-sensitive trees (maple & fir) have increased their range and abundance.
    c. In some cases, species-specific diseases have caused wholesale loss of once-dominant trees (e.g. American elm, butternut, etc.) that are not likely to recover even with silvicultural attention.
3. Compare the landscape balance of growth-stages from historic times to the present.
    a. In general, Table PLS/FIA-1 offers some specificity (NPC Class) to the historic trends in the balance of forest age-classes on the landscape.
    b. In general, NPC Classes show much greater departure from historic conditions than is apparent from cover-type or species summaries. This is broadly true because the current practice of setting rotation age and usually clear-cutting does not offer the variety of disturbance regimes that characterized the different NPC Classes.
    c. In general, the greatest departure from historic conditions involve very old or very young forests.