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Tables and Figures for Silvicultural Interpretation: MHc26

The following pages contain for the MHc26 all community the set of standard tables and figures used by ECS staff to write silvicultural interpretations. We call this set of tables and figures (along with some graphics and maps) the "essential elements" required for silvicultural interpretation of how trees contribute to the forest community and what they will "do" under certain circumstances – managed or not.

It will take some time to write all of the interpretations, and this is an ongoing effort of the ECS Program. In the mean time we decided to post the essential elements on our Web site so that foresters can access basic information for all 50 of our managed forest Classes. To help foresters interpret the essential elements, each is followed with a summary of how the tables and figures can be applied to silvicultural problems.

The tables are organized by their data source: Public Land Survey (PLS) bearing tree data, Releve sampling of modern forests, Forest Inventory & Analysis subplot sampling of modern forests, and Summaries that combine data sources.

PLS-derived Tables and Figures

(PLS-1) Historic Abundance of MHc26 Trees in Natural Growth-stages

1. Identify initial-cohort species
2. Identify the successional status of the different tree species
3. Recognize impending decline and replacement
4. Assess the balance of growth-stages on the historic landscape
5. Assess data reliability

(PLS-2) Abundance of trees throughout succession in MHc26

1. Estimate the timing of a species' peak abundance to set commercial rotation
2. Identify basic species' behavior
3. Allow recruitment of advance regeneration prior to treatment
4. Schedule stand evaluations based upon stand age

(PLS-3) Historic Abundance of MHc26 Trees Following Disturbance

1. Interpret the disturbance regime of the community and its normal successional model
2. Estimate which species are likely to respond positively, given a certain disturbance

(PLS-4) Ordination of Historic MHc26 Age-classes

1. Define periods of stable forest composition known as growth-stages
2. Define periods of transition characterized by mortality and replacement
3. Communicate silvicultural ideas by growth-stage

(PLS-5) Historic Windows of Recruitment for MHc26 Trees

1. Identify silvicultural systems that would favor recruitment of selected crop species
2. Identify silvicultural treatments that favor recruitment of selected crop species when regeneration is present.
3. Identify species that might do well when underplanted
4. Schedule examinations to assess recruitment and determine silvicultural action

(PLS-6) Disturbance Regime Summary Table by System/Floristic Region

1. Understand the geography of disturbance in Minnesota
2. Help create fire-regime maps for planning and fire response
3. Examine the difference between natural and commercial rotation on landscape age-class distributions
4. Match silvicultural systems and treatments to NPC classes to emulate the timing and severity of disturbance

Releve-derived Tables and Figures

(R-1) Suitability ratings of trees on MHc26 sites

1. Select crop trees
2. Recognize and introduce missing species
3. Allow for non-commercial species
4. Quantify post-treatment success or failure
5. Anticipate competition given the choice of a crop tree

(R-2) Natural Regeneration and Recruitment of Trees in Mature MHc26 Stands

1. Estimate the overall ability of the community to develop silviculturally significant advance regeneration
2. Estimate seedbed suitability or sprouting ability of trees under the canopy of a mature forest and on an undisturbed forest floor.
3. Estimate the shade tolerance of trees under the canopy of a mature forest
4. Identify recruitment bottlenecks

(R-3) Association of tree regeneration with overstory trees, other regeneration and competing plants

1. Understand how the presence or absence of seed trees affects regeneration potential
2. Identify species that may enhance or inhibit the development of advance regeneration. (i.e. using the current vegetation to predict population changes in tree regeneration)
3. Design silvicultural treatments to encourage or discourage regeneration of particular species

FIA-derived Tables and Figures

(FIA-1) Structural Situations of Trees in Mature MHc26 Stands

1. Estimate the success of trees in the initial cohort, i.e. open strategists that are favored by open conditions and intense, recent disturbance
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.
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.
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).

(FIA-2) Survival of Trees in Different Structural Situations in MHc26 Stands

1. Estimate the near-future (13 years) population dynamics of trees in different situations following an examination or inventory.
2. Estimate the success of trees in the initial cohort in the near future, situation 11.
3. Estimate the amount of self thinning that will occur in the near future, situation 22.
4. Estimate the success of trees as subordinates under a proximal canopy in the near future, situations 12 and 23.
5. Estimate the success of trees beneath a remote canopy in the near future, situation 13.
6. Estimate the survival of canopy trees in the near future, situation 33.

Summary and Interpretive Tables and Figures

(SUM-1) Abundance of MHc26 trees in Pre-settlement and Modern Times by Historic Growth-stage

1. Determine if species have changed their successional position due to the differences between modern land management and natural regenerating events
2. Identify species that are in peril and those that are expanding their range
3. Compare the landscape balance of growth-stages from historic times to the present

(PLS-1) Historic Abundance of MHc26 Trees in Natural Growth-stages

Table values are relative abundance (%) of Public Land Survey (PLS) bearing trees at corners modeled to represent the MHc26 community by growth-stage. Growth-stages are periods of compositional stability during stand maturation. Growth-stage columns are separated by transitions during which relative abundance changes more rapidly than it does during growth-stages. Arrows in the transition columns indicate the direction and magnitude of compositional change. Row 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				
	0 – 35 yrs	35 – 55 yrs	55 – 135 yrs	~ 135 yrs	> 135 yrs
	Young	T1	Mature		Old
Quaking Aspen (incl. Big-toothed)	76%	↘↘↘↘↘↘	22%	↗	26%
Paper Birch	13%	↗↗↗	40%	↘↘↘	20%
Red Oak	4%	↗	12%	↘	11%
Red Maple (incl. Sugar)	1%	↗	5%	↘	2%
Bur Oak (incl. White)	–	↗	5%	↘	4%
White Spruce	–	↗	2%	↗↗	12%
White Pine	–	↗	2%	↗	10%
Basswood	1%	↗	3%	→	3%
American Elm	1%	↗	3%	→	3%
Miscellaneous	4%		12%		15%
Percent of Community in Growth Stage in Pre-settlement Landscape	21%	31%	45%	--	3%

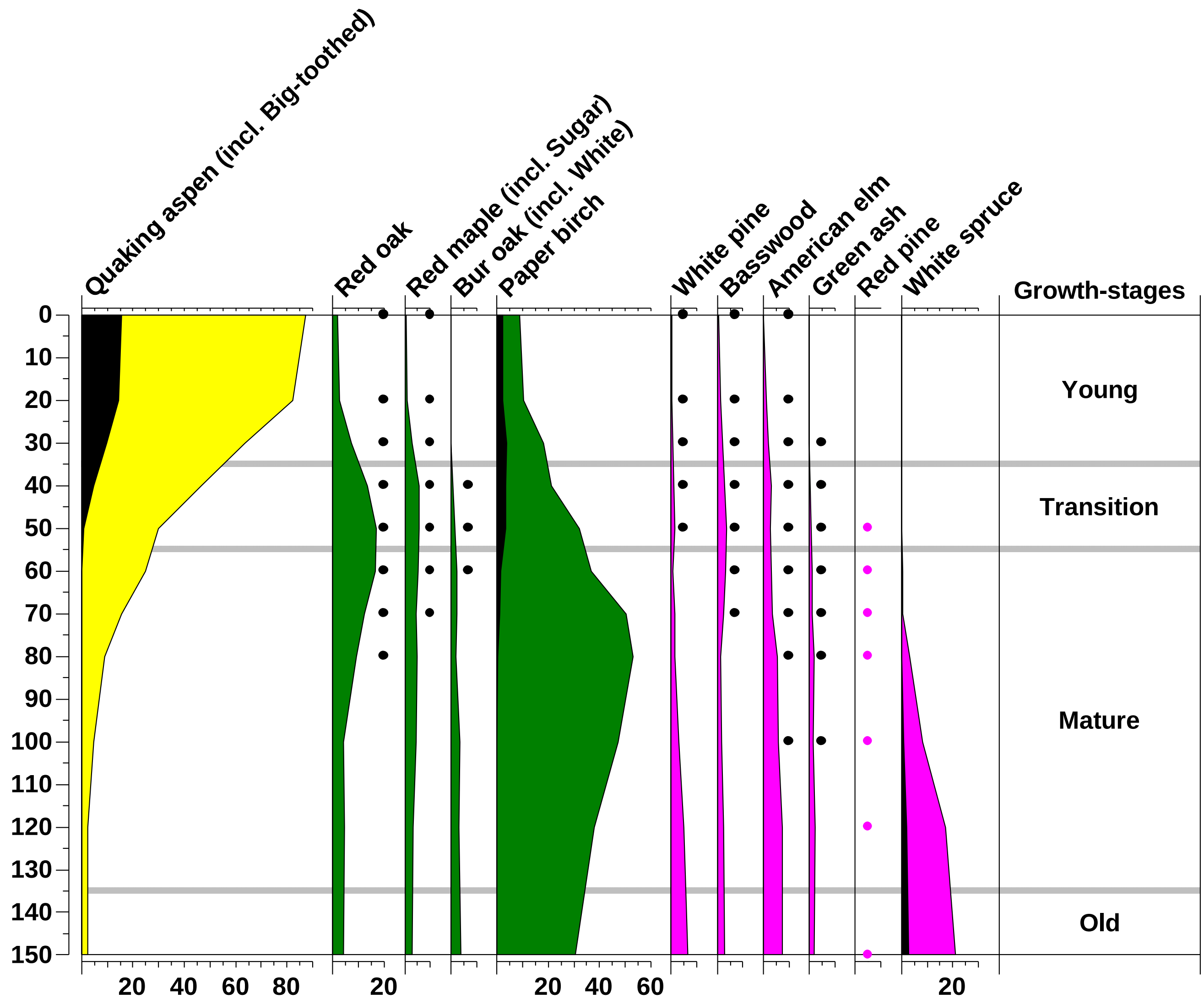
Data for MHc26 comprise 3,567 PLS corners, involving 8,710 bearing trees and about 759,771 acres of the forest class.

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. (i.e. some disturbances strongly favor just one or two species) Thus, the relative abundances of initial-cohort trees in Table PLS-1, do <u>not</u> define a target mixture of trees following a regeneration harvest.
    c. Plantations should be composed of initial-cohort trees.
2. **Identify the successional status of the different tree species**
    a. Species can be placed into four 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.
        iv. Non-successional species are those that dominate a habitat regardless of stand age.
    b. Species can show high abundance in the young growth-stage and not be early-successional, and conversely a species can be abundant in the older stages and not be late-successional . 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.
        iv. Non-successional trees are the exception to this rule.
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 are 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 and age of the stand.
4. **Assess the balance of growth-stages on the historic landscape**
    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 than shown in this table. 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.

(PLS-2) Historic abundance & recruitment of trees throughout stand maturation – MHc26

Graphed for each of the common MHc26 trees is their relative abundance (%) or presence as PLS bearing trees by age class. Shading indicates successional position: early (yellow), mid- (green), late- (fuchsia). For trees with >3% frequency (PLS-1) relative abundance is shown as silhouette curves; for trees that are important now (R-1) but not historically, presence is indicated by colored dots. Black inset curves show the proportion of bearing trees that were small-diameter recruits among larger trees; alternatively, the presence of recruiting trees is indicated by black dots in cases where recruiting tree abundance was low or sporadic among the age classes. The data were smoothed from adjacent classes (3-sample moving average). Data for MHc26 comprise 3,567 PLS corners, involving 8,710 bearing trees and about 759,771 acres of the forest class.



MHc26, J.C. Almendinger, November 2008

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 about 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 maintenance 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, such as intensifying shade and increasingly organic seedbeds.
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 a desirable species, 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.

(PLS-3) Historic Abundance of MHc26 Trees Following Disturbance

Table values are percentages of Public Land Survey (PLS) bearing trees at survey corners modeled to represent MHc26 forests. The columns represent our interpretation of disturbance at the survey corners: burn=burned, wind=windthrown, main=partial disturbance due to maintenance events, mature=no indication of disturbance. Row shading associates trees that peak in the same disturbance category. Percents on the bottom row represent a snapshot of the balance of disturbance classes across the landscape *ca.* 1846 to 1908 AD.

Tree	burn	wind	main	mature
Quaking Aspen (incl. Big-toothed)	**61%**	**39%**	**38%**	**32%**
American Elm	**4%**	**2%**	**2%**	**3%**
Bur Oak (incl. White)	**2%**	**10%**	**7%**	**3%**
Red Pine[2]	**0%**	**1%**	**1%**	**0%**
Red Oak	**9%**	**24%**	**28%**	**10%**
White Pine	**2%**	**1%**	**2%**	**2%**
Paper Birch	**11%**	**17%**	**14%**	**33%**
Red Maple (incl. Sugar[2])	**2%**	**2%**	**1%**	**5%**
Basswood	**2%**	**0%**	**1%**	**3%**
Ironwood[2]	**1%**	**0%**	**1%**	**3%**
White Spruce[1]	**1%**	**1%**	**1%**	**1%**
Green Ash[2]	**0%**	**1%**	**1%**	**1%**
Miscellaneous	**5%**	**2%**	**3%**	**4%**
Percent of Community in Disturbance Class in Pre-settlement Landscape	**4%**	**1%**	**6%**	**89%**

1. Important historically but infrequent today.
2. Important today but infrequent historically.

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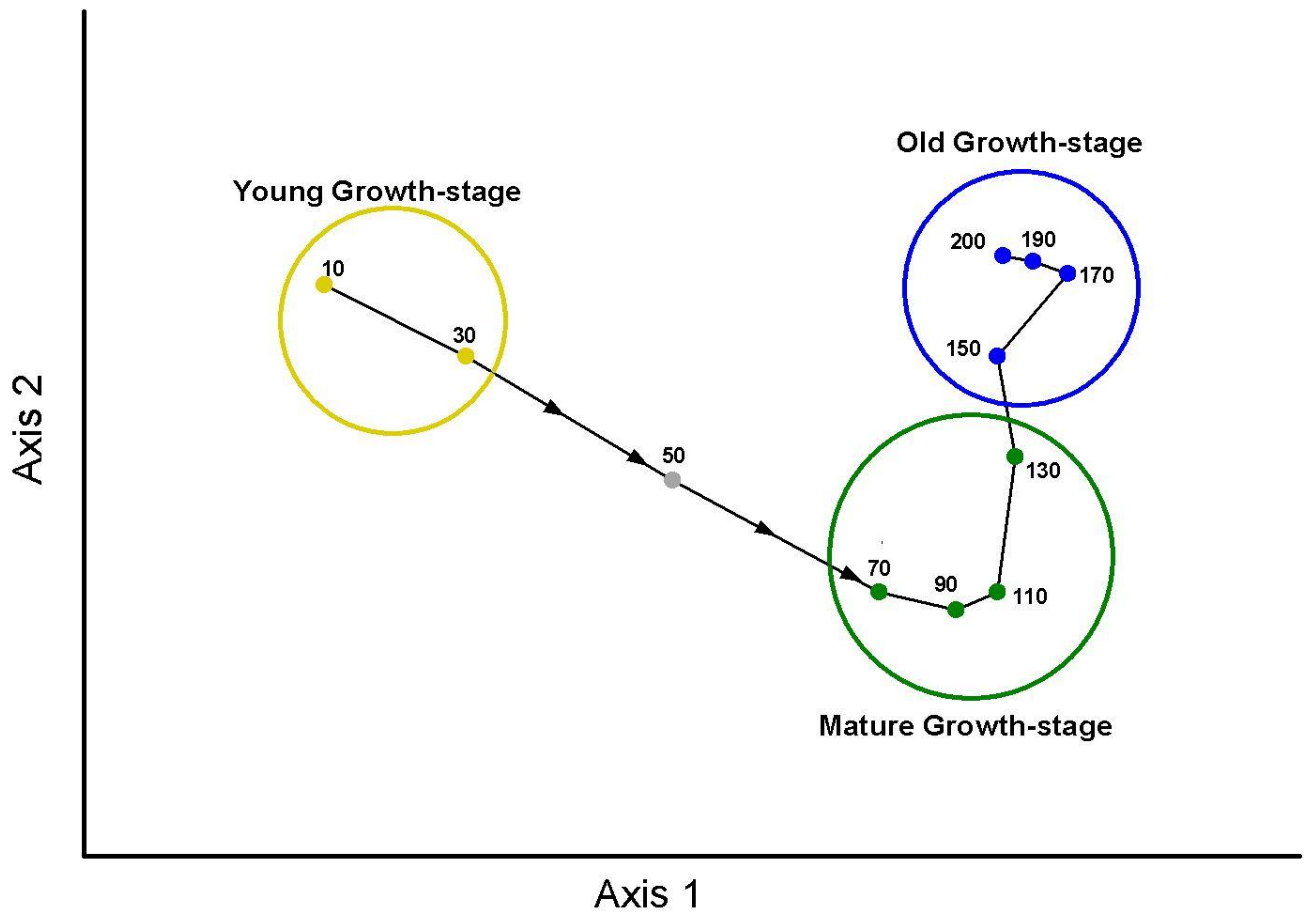
PLS-3, Silvicultural Applications

1. **Interpret the disturbance regime of the community and its normal successional model**
    a. In general, communities with over 90% of their historic landscape in the mature category exhibit succession and have trees able to regenerate in small canopy gaps that were not notable in the survey notes. Succession happens because the rotation (>150 years) exceeds the longevity of initial cohort trees.
    b. In general, communities with under 90% of their historic landscape in the mature category have trees able to regenerate in equally well in the open or in large canopy gaps. Succession happens largely because of differences in longevity of initial-cohort trees with white pine, red pine, and oak outliving all aspens, paper birch, and jack pine.
    c. In general, communities where the sum of mature and maintenance percentage exceeds 95% have strong dominants that constantly occupy those sites: sugar maple, ash, tamarack, black spruce. Succession usually involves changes in minor species about a core population of the site dominant.
2. **Estimate which species are likely to respond positively, given a certain disturbance**
    a. 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.
        i. High fire percentage: open or large gaps with site preparation
        ii. High windthrow percentage: open or large gaps without site preparation
        iii. High maintenance percentage and fire>wind: large gaps with site preparation
        iv. High maintenance percentage and wind>fire: large gaps with no site preparation
        v. High mature percentage: small gaps over advance regeneration
    b. 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.

(PLS-4) Ordination of Historic MHc26 Age-classes

Detrended Correspondence Analysis (DCA) ordination of 20-year age-classes characterized by the relative abundance of bearing tree species at PLS corners modeled to be MHc26 forest of a certain stand age. Long distances between points separate age-classes that are compositionally different; short distances indicate similarity. Connecting consecutive age-classes creates a track in ordination space due to compositional change, i.e. succession. Clusters of age-classes represent episodes of slow change that we call growth-stages (circled). Well-spaced age classes represent episodes of rapid compositional change that we call transitions (not circled, arrows on connections). This analysis in three dimensions (third axis not shown) determined the growth-stages used in the field guides; Tables PLS-1, PLS-5, and SUM-1; and Figure PLS-2. Data for MHc26 comprise 3,567 PLS corners, involving 8,710 bearing trees and about 759,771 acres of the forest class.



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 figures illustrate the reality of continuous compositional change that has been oversimplified for comparable discussions among the NPC Classes.

(PLS-5) Historic Windows of Recruitment for MHc26 Trees

Windows of recruitment are stretches of contiguous age classes where for each species we find it to be the smaller-diameter tree at a PLS survey corner with at least one tree twice its diameter at the same corner. For the small-diameter tree, we interpret this situation as their establishment and growth in response to a disturbance or condition that post-dates the disturbance or condition that established the larger tree(s). The table presents the window of peak recruitment followed by comparative success in standard windows that match growth stages and assumed recruiting environment: PD=post-disturbance recruitment in an open environment, SSG=small sub-canopy gap recruitment during self thinning, LG=large gap recruitment during breakup of the initial-cohort canopy, SG=small gap recruitment in mature or old-growth forest. Row shading associates species that have peak recruitment in the same standard window.

Tree	Peak years	Young		Transition	Mature
		0-15 yrs	15-35 yrs	35-55 yrs	>55 yrs
		PD	SSG	LG	SG
Quaking Aspen (incl. Big-toothed)	0-30	Excellent	Good	Fair	--
Red Maple (incl. Sugar[2])	30-50	Poor	Fair	Poor	Poor to 70
American Elm	30-50	--	Poor	Fair	Poor to 80
Basswood	40	Poor	Poor	Fair	--
White Pine	40	Poor	Poor	Fair	Poor to 60
Paper Birch	40	Fair	Fair	Good	Fair to 70
Red Oak	40	Poor	Poor	Fair	Poor to 70
Bur Oak (incl. White)	50	--	--	Fair	Poor to 70
Ironwood[2]	>50	Poor	Poor	Fair	Good
White Spruce[1]	>70	--	--	--	Fair
Green Ash[2]	90	--	--	Poor	Fair
Red Pine[2]	>90	--	--	--	Poor from 70

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PLS-5, Silvicultural Applications

1. **Identify silvicultural systems that would favor recruitment of selected crop species**
    a. In general, species with high ratings in the PD window are favored by clear-cutting, patch cutting, and seedtree systems.
    b. In general, species with high ratings in the LG window are favored by shelterwood systems.
    c. In general, species with high ratings in the SG window are favored by selection systems.
2. **Identify silvicultural treatments that favor recruitment of selected crop species when regeneration is present.**
    a. In general, species with high ratings in the PD window can be favored by selection of superior trees followed by weeding or cleaning.
    b. In general, species with high ratings in the SSG window are favored by allowing young stands to remain overstocked until there is adequate advance regeneration, which then may be released by thinning or cleaning treatments.
    c. In general, species with high ratings in the LG and SG window can be favored by matching their gap-size requirements to practices such as cleaning, or thinning.
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 when a stand has been readied to meet their LG or SG requirements
4. **Schedule examinations to assess recruitment and determine silvicultural action**
    a. In general, stands should be examined during the initial years of the PD window to assess stocking, survival of planted stock, and to contemplate thinning, weeding, or cleaning.
    b. In general, stands should be examined during the initial years of the SSG window to assess ingress of SSG species and to contemplate underplanting or release.
    c. In general, stands should be examined near the end of the SSG window to assess condition of the initial cohort, stocking of advance regeneration of SSG and LG species, and to contemplate harvest of initial cohort trees in a way that would favor them (most trees removed), LG species (about half of the trees removed), or SSG species (about a third of the trees removed or no harvest).
    d. In general, stands are examined throughout the SG window to assess advance regeneration, condition and quality of crop trees, and to contemplate harvests aimed at regeneration or treatments aimed at improving quality.

(PLS-6) Natural disturbance rotations for Central Mesic Hardwood Forests

Natural rotations are the length of time it takes to disturb an area equivalent to the range of the Native Plant Community. Rotations are presented for three different kinds of disturbance: stand-replacing fire (fire), stand-replacing windthrow (wind), and less severe disturbances that maintain forest communities (main).

Central Mesic Hardwood Forests	Fire	Main	Wind
Central Dry-mesic Oak-Aspen Forest – MHc26	**372 yrs**	**75 yrs**	**907 yrs**
Central Mesic Hardwood Forest (Eastern) – MHc36	1,152 yrs	36 yrs	377 yrs
Central Mesic Hardwood Forest (Western) – MHc37	515 yrs	67 yrs	1,288 yrs
Central Wet-mesic Hardwood Forest – MHc47	2,685 yrs	144 yrs	1,119 yrs
Data for MHc26 comprise 3,567 PLS corners, involving 8,710 bearing trees and about 759,771 acres of the forest class.			

PLS-6, Silvicultural Applications

1. **Understand the geography of disturbance in Minnesota**
    a. In general, the trend of disturbance rotation in Minnesota is for frequent, low-intensity events in the southwest grading to infrequent, high-intensity disturbance in the northeast.
    b. In general, landforms and parent material affect rotation at a finer scale with flat, sandy landforms having shorter rotations and hilly, loamy terrain having longer rotations.
    c. Because each cover type can be expressed in several different NPC classes, a comparison of natural rotations among the classes can help us understand how site and geography affect commercial rotation – why it is shorter in some places and longer in others even though the same species is dominant.
2. **Help create fire-regime maps for planning and fire response**
    a. Landform maps where each landform has been assigned a matrix NPC class and its fire rotation can be used to anticipate and plan fire response.
3. **Examine the difference between natural and commercial rotation on landscape age-class distributions**
    a. Usually, this is done to set rotation parameters in equilibrium models to guess at the departure of historic conditions and modern ones driven by commercial rotation.
    b. Most often, the modeling results are interpreted as to their effect on wildlife populations.
4. **Match silvicultural systems and treatments to NPC classes to emulate the timing and severity of disturbance**
    a. In general, communities for which catastrophic rotation is about equal to that of maintenance rotation can be "naturally" managed with even-aged systems like clearcutting with reserves or with two-step systems like the shelterwood system.
    b. In general, communities for which catastrophic rotation is about twice or three times that of maintenance rotation can be "naturally" managed with three basic strategies:
        i. To maintain early successional species clear-cutting with reserves or shelterwood systems would emulate a common natural disturbance.
        ii. To maintain the late-successional species, systems that maintain a multi-aged stand could be used, with and entry schedule approximating the maintenance rotation.
        iii. To allow a full successional cycle or convert a young stand to an older composition, silvicultural treatments can be used to emulate the natural removal of old early-successional species to release younger late-successional species. The entry schedule for this "flux" harvesting is set by the condition of trees and advance regeneration – not rotation.
    c. In general, communities for which catastrophic rotation is four or more times that of maintenance rotation can be "naturally" managed with selective systems.
        i. Because selective systems have been used so infrequently compared to clear-cutting, "flux" treatments are often needed to bring the community back to dominance of late-successional species.
        ii. The entry schedule is far more frequent than maintenance rotation, and both harvesting and treatments are aimed at improving quality or managing advance regeneration. For an unknown reason, the maintenance rotation often approximates the biological longevity of the dominant, late-successional trees.

(R-1) Suitability Index of Trees on MHc26 Sites

The index of suitability is our estimate of a tree's ability to compete with all plants on MHc26 sites without silvicultural assistance. The raw index is based upon the product of percent presence and mean cover-when-present (below) within the set of MHc26 releves in mature, natural stands. Plants are ranked by their raw index and the full range re-scaled to run from zero to five to yield the suitability index (below). The re-scaling is done so that whole numbers represent 20-percentile classes: excellent=80-100; good 60-80; fair=40-60; poor=20-40; N/A=0-20.

Tree	Presence as Tree	Mean Cover When Present	Suitability Index*
Northern red oak (Quercus rubra)	**81%**	**35%**	**5.0**
Quaking aspen (Populus tremuloides)	**41%**	**21%**	**4.7**
Paper birch (Betula papyrifera)	**58%**	**14%**	**4.7**
Red maple (Acer rubrum)	**44%**	**14%**	**4.5**
Basswood (Tilia americana)	**45%**	**13%**	**4.5**
Sugar maple (Acer saccharum)	**29%**	**16%**	**4.3**
Bur oak (Quercus macrocarpa)	**28%**	**17%**	**4.3**
Big-toothed aspen (Populus grandidentata)	**25%**	**18%**	**4.2**
White pine (Pinus strobus)	**10%**	**19%**	**3.5**
Red pine (Pinus resinosa)	**10%**	**20%**	**3.4**
White oak (Quercus alba)	**9%**	**15%**	**2.9**
Green ash (Fraxinus pennsylvanica)	**12%**	**7%**	**2.3**
Ironwood (Ostrya virginiana)	**10%**	**8%**	**2.1**
*Suitability rankings: **excellent**, **good**, **fair**			

R-1, Silvicultural Applications

1. **Select crop trees**
   a. In general, trees with higher suitability indices are better choices as crop trees 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. **Quantify post-treatment success or failure**
   a. The table offers a means of measuring success by species groups (e.g. 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.

(R-2) Natural Regeneration and Recruitment of Trees in Mature MHc26 Stands

Table values are natural regeneration indices for regenerants (<10cm tall), seedlings (10cm-2m), saplings (2-10m), and trees (>10m) in MHc26 forests. Index ratings express our interpretation of how successful tree species are in each stratum compared to other trees in MHc26 communities. All indices equally weight percent presence, mean cover when present, and mean number of reported strata – the raw index being the product of these numbers. Trees are ranked by their raw index and the full range re-scaled to run from zero to five to yield the R-, SE-, SA-, or T-index (below). Re-scaling is done so that whole numbers represent 20-percentile classes: excellent=80-100; good 60-80; fair=40-60; poor=20-40; N/A=0-20. Also shown is the combined percent presence of trees in the understory strata (R, SE, SA) to provide an estimate of how often one encounters advance regeneration of that species in MHc26 forests.

Tree	Presence R, SE, SA	R-index	SE-index	SA-index	T-index
Northern red oak (Quercus rubra)	85%	4.7	4.7	4.0	5.0
Red maple (Acer rubrum)	83%	4.8	4.8	5.0	4.3
Sugar maple (Acer saccharum)	71%	5.0	4.8	5.0	3.8
Ironwood (Ostrya virginiana)	70%	4.5	4.5	4.7	2.3
Basswood (Tilia americana)	64%	4.0	4.0	4.3	4.3
Quaking aspen (Populus tremuloides)	50%	3.7	3.3	3.0	4.5
Green ash (Fraxinus pennsylvanica)	47%	3.8	3.8	3.0	2.5
Paper birch (Betula papyrifera)	32%	1.7	1.5	2.8	4.8
Bur oak (Quercus macrocarpa)	28%	2.7	2.5	2.8	4.0
Big-toothed aspen (Populus grandidentata)	21%	2.3	2.2	2.3	4.3
White pine (Pinus strobus)	15%	3.3	2.7	1.7	3.3
White oak (Quercus alba)	10%	2.5	2.0	1.8	3.3
Red pine (Pinus resinosa)	3%	0.7	0.7	1.8	3.5

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

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
    b. In general, the number of native trees 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 are correlated with fine-scale disturbance dynamics and long rotations of catastrophic disturbance. Low numbers of trees are correlated with coarse-scale disturbance dynamics and short rotations of catastrophic disturbance.
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. In general, trees with good-to-fair R-index will most likely require seedbed preparation that mixes the organic layer into the mineral soil.
    c. In general, trees with a poor R-index will most likely require seedbed preparation that bares mineral soil.
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.
    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.

(R-3) Association of tree regeneration with overstory trees, understory trees, shrubs, and common herbs in MHc26 forests

This table presents information concerning how seedlings and saplings (< 33' tall) of MHc26 trees associate with other forest plants including their own trees. Coles' coefficient of association (CC) was used to measure the degree and nature of association. The coefficient ranges from -1 (strongly negative) to +1 (strongly positive). All associations in the table are statistically significant (P<0.05). Shown in the leftmost column are the raw counts from 310 MHc26 releve plots used to calculate CC between advance regeneration and its parent tree: U&T, joint presence in canopy and understory; U only, regeneration present but trees absent; T only, trees present but not regeneration; neither, joint absence. The last row of each species block lists the environmental situations that might have favored the positive or negative guilds. This was estimated by calculating the shift in mean synecological scores between the negative associates versus positive associates regarding moisture, nutrients, heat, and light. Shifts greater than a whole synecological unit are in bold text, and the greatest shift indicated by an asterisk.

Understory Tree	Positive associates				Negative Associates			
	Overstory	CC	Understory	CC	Overstory	CC	Understory	CC
Red Maple	Red maple	0.95	Blue beech	0.83	Bur oak	-0.18	Lrg-flrd bellwort	-0.40
U & T: 115	Red pine	0.66	Big-toothed aspen	0.82	Ironwood	-0.21	Pennsylvania sedge	-0.57
U only: 141	Big-toothed aspen	0.58	White pine	0.59	Basswood	-0.30		
T only: 1	Northern red oak	0.30	Paper birch	0.35				
Neither:53			Northern red oak	0.35				
CC= +0.95			Bracken	0.16				
	Drier, **poorer**, **cooler***, lighter favors red maple				Moister, **richer**, **warmer***, darker inhibits red maple			
Sugar Maple	Ironwood	1.00	White oak	0.71	White pine	-0.34	Mountain maple	-0.16
U & T: 66	Sugar maple	0.94	Large-leaved aster	0.56	Red pine	-0.34	Mountain rice grass	-0.20
U only: 101	Basswood	0.59	Blue beech	0.55			American hazelnut	-0.34
T only: 2	Northern red oak	0.40	Ironwood	0.52				
Neither:141	Big-toothed aspen	0.27	Basswood	0.35				
CC= +0.94	Red maple	0.16	Lrg-flrd bellwort	0.28				
			Northern red oak	0.28				
			Big-toothed aspen	0.24				
			Green ash	0.16				
			Hog peanut	0.13				
	Drier, **richer***, warmer, **darker** favors sugar maple				Moister, **poorer***, cooler, **lighter** inhibits sugar maple			
Paper Birch	Paper birch	0.35	Large-leaved aster	0.84	Bur oak	-0.31	Downy arrowwood	-0.18
U & T: 84	Red pine	0.31	Northern red oak	0.50			American hazelnut	-0.36
U only: 31	White pine	0.24	Red pine	0.40			Pennsylvania sedge	-0.40
T only: 98			Bracken	0.37				
Neither: 97			Red maple	0.35				
CC= +0.35			White pine	0.32				
			Big-toothed aspen	0.19				
			Mountain maple	0.16				
			Rnd-lvd dogwood	0.13				
	Drier, **poorer, cooler***, darker favors paper birch				Moister, **richer**, **warmer***, lighter inhibits paper birch			

Understory Tree	Positive associates				Negative Associates			
	Overstory	CC	Understory	CC	Overstory	CC	Understory	CC
Green Ash	Green ash	0.86	Downy arrowwood	0.48			Mountain maple	-0.25
U & T: 22	Basswood	0.16	Red pine	0.38				
U only: 99	Bur oak	0.16	Bitternut hickory	0.36				
T only: 2			Hog peanut	0.31				
Neither: 187			Gray dogwood	0.30				
CC= +0.86			Basswood	0.24				
			Sugar maple	0.16				
			Ironwood	0.14				
	Drier, **richer**, **warmer***, lighter favors green ash				Moister, **poorer**, **cooler***, darker inhibits green ash			
Ironwood	Ironwood	0.66	Blue beech	0.88	Quaking aspen	-0.15	Quaking aspen	-0.13
U & T: 19	White oak	0.61	Bitternut hickory	0.78			American hazelnut	-0.34
U only: 133	Northern red oak	0.51	White oak	0.61			Mountain maple	-0.36
T only: 4	Basswood	0.47	Sugar maple	0.52			Beaked hazelnut	-0.45
Neither: 154	Big-toothed aspen	0.39	Basswood	0.43				
CC= +0.66	Sugar maple	0.37	Hog peanut	0.36				
	Red maple	0.24	Big-toothed aspen	0.35				
	Paper birch	0.14	Northern red oak	0.32				
			Green ash	0.14				
	Drier, **richer*, warmer, darker** favors ironwood				Moister, **poorer*, cooler, lighter** inhibits ironwood			
Red Pine	Red pine	0.78	White pine	0.68	Northern red oak	-0.43	Pennsylvania sedge	-0.25
U & T: 13	White pine	0.42	Paper birch	0.40				
U only: 3			Green ash	0.38				
T only: 38								
Neither: 256								
CC= +0.78								
	Drier, **poorer***, **cooler**, **lighter** favors red pine				Moister, **richer***, **warmer**, **darker** inhibits red pine			
White Pine	White pine	0.66	Large-leaved aster	1.00	Basswood	-0.35	Downy arrowwood	-0.18
U & T: 31	Red pine	0.54	Northern red oak	0.75	Green ash	-0.82		
U only: 39			Red pine	0.68				
T only: 11			Red maple	0.59				
Neither: 229			Paper birch	0.32				
CC= +0.66			Mountain maple	0.20				
	Drier, **poorer**, **cooler***, lighter favors white pine				Moister, **richer, warmer***, darker inhibits white pine			
Big-thd. Aspen	Big-toothed aspen	0.57	Red maple	0.82			Pennsylvania sedge	-0.15
U & T: 42	Red maple	0.29	Northern red oak	0.54			Mountain rice grass	-0.16
U only: 21			Ironwood	0.35				
T only: 26			Quaking aspen	0.28				
Neither: 221			Basswood	0.27				
CC= +0.57			Sugar maple	0.24				
			Rnd-lvd dogwood	0.24				
			Paper birch	0.19				
	Drier, poorer, cooler*, darker favors big-thd aspen				Moister, richer, warmer*, lighter inhibits big-thd aspen			
Quaking Aspen	Quaking aspen	0.45	Big-toothed aspen	0.28	Basswood	-0.23	Ironwood	-0.13
U & T: 117			Mountain maple	0.22			Bitternut hickory	-0.62
U only: 64			Northern red oak	0.21				
T only: 35			Mountain rice grass	0.15				
Neither: 94								
CC= +0.45								
	Moister, **poorer*, cooler, lighter** favors quaking aspen				Drier, **richer*, warmer, darker** inhibits quaking aspen			

Understory Tree	Positive associates				Negative Associates			
	Overstory	CC	Understory	CC	Overstory	CC	Understory	CC
White Oak	Northern red oak	1.00	Hog peanut	1.00			Mountain maple	-1.00
U & T: 9	White oak	0.58	Basswood	0.74				
U only: 6			Sugar maple	0.71				
T only: 6			Ironwood	0.61				
Neither: 289			Blue beech	0.55				
CC= +0.58			Gray dogwood	0.45				
	Drier, **richer***, warmer, **darker** favors white oak				Moister, **poorer***, cooler, **lighter** inhibits white oak			
Bur Oak	Bur oak	0.38	Early meadow-rue	0.67	Northern red oak	-0.18	Pennsylvania sedge	-0.20
U & T: 52	Quaking aspen	0.24	Downy arrowwood	0.34	White oak	-1.00		
U only: 61			Mountain maple	0.13				
T only: 34								
Neither: 163								
CC= +0.38								
	Moister, **poorer***, cooler, **lighter** favors bur oak				Drier, **richer***, warmer, **darker** inhibits bur oak			
Red Oak	Northern red oak	0.58	White pine	0.75				
U & T: 190	Big-toothed aspen	0.58	Big-toothed aspen	0.54				
U only: 66	Red maple	0.41	Paper birch	0.50				
T only: 15			Rnd-lvd dogwood	0.39				
Neither: 39			Red maple	0.35				
CC= +0.58			Ironwood	0.32				
			Basswood	0.31				
			Large-leaved aster	0.29				
			Sugar maple	0.28				
			Hog peanut	0.27				
			Mountain rice grass	0.23				
			Quaking aspen	0.21				
			Chokecherry	0.18				
			Wild sarsaparilla	0.18				
	Drier, poorer, **cooler***, darker favors red oak				Moister, richer, **warmer***, lighter inhibits red oak			
Basswood	Basswood	0.66	White oak	0.74	Quaking aspen	-0.14		
U & T: 79	Ironwood	0.58	Bitternut hickory	0.68				
U only: 70	Green ash	0.52	Blue beech	0.66				
T only: 17	Sugar maple	0.32	Ironwood	0.43				
Neither: 144	Northern red oak	0.21	Sugar maple	0.35				
CC= +0.66	Red maple	0.17	Northern red oak	0.31				
			Gray dogwood	0.30				
			Big-toothed aspen	0.27				
			Green ash	0.24				
			Chokecherry	0.23				
			Downy arrowwood	0.22				
			Hog peanut	0.22				
	Drier, **richer, warmer*, darker** favors basswood				Moister, **poorer, cooler*, lighter** inhibits basswood			

R-3, Silvicultural Applications

1. **Understand how the presence or absence of seed trees affects regeneration potential**
    a. In general, regeneration with comparatively high joint occurrence and joint absence with their trees (high positive CC) are late-successional species with excellent seedling bank potential.
    b. In general, regeneration with comparatively high U-only counts are species able to develop significant advance regeneration from very few seed (or suckering) trees.
    c. In general, species with comparatively high T-only counts are species that do poorly in mature forests and require silvicultural intervention to build adequate advance regeneration.
2. **Identify species that may enhance or inhibit the development of advance regeneration. (i.e. using the current vegetation to predict population changes in tree regeneration)**
    a. In general, high cover of negative overstory associates in a particular stand would need to be removed to some degree in order to enhance regeneration.
    b. In general, high cover of negative understory associates in a particular stand diminish expectations of adequate regeneration, whether natural, seeded, or planted.
    c. In general, high cover of positive overstory associates in a particular stand increase expectation of regeneration and those trees are good choices as a cover or shelter for regeneration, whether natural, seeded, or underplanted.
    d. In general, high cover of positive understory associates in a particular stand increase expectations of adequate regeneration, whether natural, seeded, or planted.
3. **Design silvicultural treatments to encourage or discourage regeneration of particular species**
    a. In general, silvicultural treatments affect site moisture by: compaction, rutting, residual duff thickness and continuity, residual coarse woody debris, canopy retention, and transpiration potential of residual plants.
    b. In general, silvicultural treatments affect site nutrients by: removal, changing the amount and kind of detrital food available to microbes, the abundance and diameter distribution of woody debris, and conversion to species with richer or poorer litter.
    c. In general silvicultural treatments affect site heat (longer wavelength radiation) and light (shorter wavelength radiation) by: canopy removal or simplification, residual duff thickness and continuity, changing reflectance of the ground surface, and conversion to trees with different architecture and accessory pigments.
    d. The magnitude and sometimes even direction of a factor’s effect on moisture, nutrients, heat, and light (a-c above) depends upon the NPC class, soil texture, topography, and site hydrology.
    e. Synecological coordinates are partially correlated and it is not always possible to design a treatment that will move all four coordinates in the directions needed.

(FIA-1) Structural Situations of Trees in Mature MHc26 Stands

Percentages of structural situations for trees as recorded in Forest Inventory Analysis (FIA) subplots modeled to be samples of MHc26 forests. Subplot (stand) situations are inferred from the diameter of the largest tree at a subplot: 1) young sapling stand (<4"dbh); 2) immature pole stand (4-10"dbh); 3) mature stand (>10"dbh). Different tree situations are generated when the smaller diameter trees at a subplot are tallied as being in the same class or a class subordinate to the largest tree. Situation 33, trees in stands of trees, provides no insight about regeneration, but all other classes indicate the preference of a tree to be in an emerging canopy (situations 11 and 22); immediately subordinate to canopy trees (situations 12 and 23), or remotely subordinate to the canopy (situation 13). Row shading groups trees by their most common situation; trees shown in white are common in releves but were not recovered in FIA subplots. For each species, the raw tree count is provided for assessing reliability.

Species	Tree Count	Structural Situations					
		11	22	12	23	13	33
Quaking Aspen	737	29%	11%	13%	7%	14%	26%
Red Oak	539	1%	6%	1%	20%	2%	70%
Red Maple	408	7%	11%	14%	31%	28%	9%
Basswood	390	2%	8%	16%	18%	18%	37%
Paper Birch	276	4%	22%	5%	36%	5%	27%
Bur Oak	95	3%	14%	2%	31%	11%	40%
Big-toothed Aspen	69	22%	1%	26%	4%	25%	22%
Green Ash	39	8%	10%	5%	26%	28%	23%
White Oak	18	--	--	--	11%	--	89%
Sugar Maple	392	4%	15%	16%	17%	39%	10%
Ironwood	213	15%	4%	23%	2%	55%	--
White Pine	6	--	--	--	--	--	100%
Red Pine	1	--	--	--	--	--	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 (proximal canopy)
12 = Saplings under poles
23 = Poles under trees
Understory Situation (remote canopy)
13 = Saplings under trees

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).**

(FIA-2) Survival of Trees in Different Structural Situations in MHc26 Stands

Thirteen-year survival rate of trees in different silvicultural situations on Forest Inventory and Analysis (FIA) subplots modeled to be MHc26 forests. Survival rate is the proportion of trees recorded in the 1977 FIA cycle that were still alive in the 1990 cycle. Subplot (stand) situations are inferred from the diameter of the largest tree at a subplot: 1) young sapling stand (<4"dbh); 2) immature pole stand (4-10"dbh); 3) mature stand (>10"dbh). Different tree situations are generated when the smaller diameter trees at a subplot are tallied as being in the same class or a class subordinate to the largest tree. Row shading groups trees with peak survival in the same situation. For each species, the raw tree count is provided for assessing reliability. BEWARE, survival rates in parentheses are based upon five or fewer trees in that situation.

Species	Tree Count	Structural Situations					
		11	22	12	23	13	33
Paper Birch	276	0.86	0.38	0.60	0.54	0.44	0.67
Quaking Aspen	737	0.86	0.50	0.79	0.37	0.71	0.57
Basswood	390	1.00	0.67	0.80	0.95	0.81	0.86
Sugar Maple	392	0.56	0.97	0.89	0.94	0.85	0.61
Red Oak	539	(0.33)	0.35	0.80	0.77	0.48	0.79
Red Maple	408	0.94	0.78	1.00	0.95	0.82	0.86
Ironwood	213	0.73	1.00	1.00	(1.00)	0.87	--
Bur Oak	95	(1.00)	0.76	(1.00)	0.94	1.00	--
Big-toothed Aspen	69	0.88	(0.33)	0.90	(1.00)	0.89	1.00
Green Ash	39	(1.00)	(0.67)	(1.00)	0.71	0.73	1.00
White Oak	18	--	--	--	(1.00)	--	0.73
White Pine	6	--	--	--	--	--	0.75
Red Pine	1	--	--	--	--	--	(1.00)

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 (proximal canopy)
12 = Saplings under poles
23 = Poles under trees
Understory Situation (remote canopy)
13 = Saplings under trees

FIA-2, Silvicultural Applications

1. **Estimate the near-future (13 years) population dynamics of trees in different situations following an examination or inventory.**
    a. The absolute estimates of survival can be applied to estimates of trees-per-acre in a stand to see if adequate stocking of advance regeneration will hold, improve, or deteriorate without silvicultural intervention.
    b. Comparative estimates of survival (between species) can be applied to predict if stand composition will improve or deteriorate without silvicultural interpretation.
    c. No matter what the situation (22 or 23) poles 4-10" dbh have the greatest mortality and need for silvicultural intervention.
2. **Estimate the success of trees in the initial cohort in the near future, situation 11.**
    a. In general, all trees have fairly high survivorship in the 11 situation because they are young (small diameter) and the effects of stand self-thinning have yet to occur.
    b. In general, open strategists have higher survival in 11 situations than small-gap strategists; however large-gap strategists span the full range of survivorship values.
3. **Estimate the amount of self thinning that will occur in the near future, situation 22.**
    a. In general, all trees have peak mortality in the 22 situation because of stand self-thinning.
    b. In general, large-gap strategists have the highest survival during self-thinning. Open and small-gap strategists tend to have lower survival in 22 situations, but there are many exceptions.
4. **Estimate the success of trees as subordinates under a proximal canopy in the near future, situations 12 and 23.**
    a. In general, tree survival beneath a proximal canopy is poor (particularly situation 23), but not as poor as in self thinning stands.
    b. In general, gap strategists (large or small) have better survival in subordinate canopy situations than open strategists.
5. **Estimate the success of trees beneath a remote canopy in the near future, situation 13.**
    a. In general, trees have good survival beneath a remote canopy.
    b. In general, small-gap species have the highest survival in 13 situations; large-gap trees have moderate survival; and open strategists have the poorest survival.
6. **Estimate the survival of canopy trees in the near future, situation 33.**
    a. In general, trees have rather poor survival rates after achieving 10" dbh. This is a surprising result as they are established and have survived natural thinning. However, harvesting is a contributing factor to mortality in our analysis.
    b. In general, and as expected, small-gap species have the highest survival as large trees; large-gap species have intermediate survival; and open strategists have the poorest survival.

(SUM-1) Abundance of MHc26 trees in Pre-settlement and Modern Times by Growth-stage

Relative abundance (%) of trees at Public Land Survey corners and FIA subplots modeled to represent the MHc26 community and estimated to fall within the young, mature, and old growth-stages. Arrows indicate increase or decrease between growth-stages. 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 between the pre-settlement landscape (*ca.* 1846-1908 AD) and the modern landscape (*ca.* 1990 AD).

	Forest Growth Stages							
	0 – 35 yrs		35 – 55 yrs	55 – 135 yrs		~ 135 yrs	> 135 yrs	
Dominant Trees	Young		T1	Mature			Old	
Quaking Aspen (incl. Big-toothed)	76%	50%	↘↘↘↘↘↘	22%	19%	↗	26%	1%
Paper Birch	13%	4%	↗↗↗	40%	11%	↘↘↘	20%	2%
Red Oak	4%	5%	↗	12%	22%	↘	11%	29%
Red Maple (incl. Sugar)	1%	25%	↗	5%	25%	↘	2%	21%
Bur Oak (incl. White)	–	1%	↗	5%	3%	↘	4%	5%
White Spruce	–	1%	↗	2%	0%	↗↗	12%	0%
White Pine	–	0%	↗	2%	0%	↗	10%	0%
Basswood	1%	6%	↗	3%	10%	→	3%	14%
American Elm	1%	1%	↗	3%	1%	→	3%	2%
Black Ash	--	0%	↗	1%	1%	↗	0%	3%
Ironwood	--	6%	↘	1%	5%	↘	2%	4%
White Oak	0%	0%	↗	0%	1%	↗	0%	9%
Miscellaneous	4%	1%		4%	2%		7%	10%
Percent of Community in Growth Stage in Pre-settlement and Modern Landscapes	21%	13%	31% 21%	45%	64%		3%	1%

Data for MHc26 comprise 3,567 PLS corners, involving 8,710 bearing trees and about 759,771 acres of the forest class.
Comparable modern conditions were summarized from 2,525 FIA subplots that were modeled to be MHc26 sites.

SUM-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 condition involves very old or very young forests.