Ecological site F093AY013MN
Loamy Upland

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General information

Approved. An approved ecological site description has undergone quality control and quality assurance review. It contains a working state and transition model, enough information to identify the ecological site, and full documentation for all ecosystem states contained in the state and transition model.

Figure 1. Mapped extent

Areas shown in blue indicate the maximum mapped extent of this ecological site. Other ecological sites likely occur within the highlighted areas. It is also possible for this ecological site to occur outside of highlighted areas if detailed soil survey has not been completed or recently updated.

MLRA notes

Major Land Resource Area (MLRA): 093A–Superior and Rainy Stony and Rocky Till Plains and Moraines

The Superior Stony and Rocky Loamy Plains and Hills, Western Part is located and completely contained in northeastern Minnesota. This area has both the highest and lowest elevations in the state, as well as some of the state's most rugged topography (Ojakangas and Matsch 1982). The MLRA was glaciated by numerous advances of the Superior, Rainy and Des Moines glacial lobes during the Wisconsin glaciation as well as pre-Wisconsin glacial periods. The geomorphic surfaces in this MLRA are geologically very young (i.e., 10,000 to 20,000 years) and dominated by drumlin fields, moraines, small lake plains, outwash plains, and bedrock-controlled uplands (USDA NRCS 2006). There are thousands of lakes scattered throughout the region that were created by these glacial events. Most of these lakes are bedrock-controlled in comparison to adjacent glaciated regions where glacial drift deposits are much thicker and the lakes occur in depressions atop the glacial drift (Ojakangas and Matsch 1982). In contrast to adjacent MLRAs, the depth to the predominantly crystalline or sandstone bedrock in MLRA 93A is relatively thin because the most recent glacial events were more erosional than depositional (Ojakangas and Matsch 1982).

Classification relationships

Superior National Forest Terrestrial Ecological Unit Inventory (SNF unpublished report a, b): Landtype 14 Upland Deep Medium Loamy and Landtype Phase 55 Unnamed (Superior moraines, well/mod well drained, >40", <18percent clay).

MDNR Native Plant Community Classification (MDNR 2005): MHn45 Northern Mesic Hardwood (Cedar) Forest - Subtypes "a" and "c".

Vegetation Associations (National Vegetation Classification System, NatureServe 2013a: Sugar Maple – Yellow Birch – (American Basswood) – Forest

Ecological Systems (National Vegetation Classification System, NatureServe 2013): Laurentian-Acadian Northern Hardwood Forest

Ecological site concept

Spring flowering, sub-boreal ground flora within a northern hardwoods forest type characterizes the vegetation of this site. Northern hardwoods are nutrient demanding ecosystems requiring a relatively narrow set of growing conditions, always having consistent moisture, high nutrient availability, and lack of fire disturbance (Landfire 2007, MN Div of Forestry 2008, Nyland 1999). Shade tolerant and fire intolerant species like sugar maple, yellow birch, and American basswood are the iconic tree species of this ecosystem. Sugar maple in particular is a dominant species and tends to accumulate in all layers of the overstory and understory (Nyland 1999). Later successional, shade tolerant conifers like northern white cedar and white spruce are also present, which in part distinguishes this site from similar forest types in the region (Flaccus and Ohmann 1964, MN DNR 2005). In MLRA 93A, northern hardwoods are on the northwestern extent of their range. Lake Superior has a significant effect on the climate and thus growing conditions of this ecological site; including a moderation of both summer and winter high and low daily temperatures, increased insulation of the soil surface due to frequent lake effect snowfall, and a longer frost-free period (Albert 1994, Anderson in review, Butters and Abbe 1953, Rosendahl and Butters 1928). Although environmental conditions are suitable for this forest type, this ecological site produces comparatively low quality timber. Average site index at base age 50 of sugar maple was 51 feet (averaged from twelve trees at three Type Locations and using site index curves developed by Carmean 1989, 1978).

Associated sites

F093AY013MN	**Loamy Upland** Spatial distribution of the associated map units for this ecological site currently do not reflect the lake-moderated climate effect. As a result there is likely at least one additional ecological site within the distribution of the components correlated to Till Upland Mesic Hardwood Forests that is not described here. More work is needed and map unit separation will likely be necessary.

Similar sites

F093AY013MN	**Loamy Upland** The northern hardwood forest type is uncommon in this MLRA. However, there may be a similar ecological site of small extent on the deep, loamy till soils derived from Rainy Lobe materials in west-central St. Louis County. There is currently no ecological site developed for this unit. Further investigation is needed.

Table 1. Dominant plant species

Tree	(1) *Acer saccharum* (2) *Betula alleghaniensis*
Shrub	(1) *Acer spicatum* (2) *Rubus parviflorus*
Herbaceous	(1) *Dryopteris carthusiana* (2) *Gymnocarpium dryopteris*

Physiographic features

These sites are located on end moraines, ground moraines, and drumlin-like landforms associated with the Automba phase of the Superior Lobe glacial advance. Elevation is mainly above 1300 feet and below 1800 feet. These sites are most common in morainal areas with thick glacial deposits, but also occur in bedrock-controlled landscapes closer to Lake Superior (e.g., the Sawtooth Mountains Landtype Association). Hillslope positions are summits, shoulders, and backslopes ranging from 0 to 18 percent slope and include all aspect classes. Slopes are often complex and occur in a stair-stepping pattern making it difficult to clearly distinguish one summit position from another. Vertical and horizontal slope shape is variable, but mostly linear and/or convex. These sites generate runoff and lateral subsurface flow to adjacent, downslope ecological sites. These sites do not flood or pond.

Table 2. Representative physiographic features

Landforms	(1) Moraine (2) Till plain
Flooding frequency	None
Ponding frequency	None
Elevation	396–549 m
Slope	0–18%

Water table depth	46–203 cm
Aspect	Aspect is not a significant factor

Climatic features

The average freeze-free period is about 140 days and ranges from 131 to 149 days. Average annual precipitation is 32 inches, which includes rainfall plus the water equivalent from snowfall. About 65 percent of the precipitation falls as rain during the growing season (May through September), and about 21 percent falls as snow. Most of the spring snowmelt runs off the steeply sloping or high relief surfaces into high gradient drainageways and then into wetlands, streams or lakes, and most of the rainfall during the growing season is transpired by plants, which leaves about small proportion of total precipitation for deep aquifer recharge. The high ridges above Lake Superior which support this ecological site receive the most snowfall in Minnesota, averaging over 70 inches annually (Flaccus and Ohmann 1964, MN DNR 2013a). This “lake effect” snow is the result of warm, moist air rising and moving inland from the lake ultimately cooling to produce localized snowfall (Anderson in review, MN DNR 2013a). The average annual low and high temperatures are 28 and 48 degrees Fahrenheit, respectively. These data are derived from 30-year averages gathered from four National Oceanic and Atmospheric Administration (NOAA) weather stations contained within the range of this ecological site and located on correlated map units.

On a multi-regional scale, northern hardwoods forest types are transitional between the oak-hickory types to the south and the boreal forest types to the north (Johnson et al. 2009, Tubbs 1997). The distribution of this ecological site abuts the southern edge of the boreal forest biome. The climate moderating effect of Lake Superior allows this forest type to persist at this latitude (Albert 1994, Anderson in review). In addition to Lake Superior’s overall temperature moderation, the insulating effect of the elevated snowfall on the rooting zone and the near absence of late spring frosts likely provide the opportunity for this forest type to exist in an otherwise inhospitable climate (Albert 1994, Anderson in review, Houston 1999). Even so, this forest type is on the limit of its botanic range and faces a myriad of disturbance factors such as frost cracking, ice damage, and fungal pathogens, as well as herbivory from insects and mammals, and as a result produces poor quality timber.

Table 3. Representative climatic features

Frost-free period (average)	124 days
Freeze-free period (average)	149 days
Precipitation total (average)	1,219 mm

Influencing water features

This ecological site is not influenced by wetland or riparian water features.

Soil features

These soils were formed in glacial till deposited during the first and most extensive advance of the Superior Lobe of the Wisconsin Glaciation. They are very deep (>60 inches to bedrock) and have contact with compacted densic horizons between 20 and 60 inches. Drainage class is moderately well to well drained. These soils are affected by seasonal wetness in the spring months from a water table perched on subsurface dense horizons, which likely promotes the potential for rich, mesophytic vegetation. Soil family is characterized as coarse-loamy, having less than 18 percent clay within the majority of the rooting zone. Soil textural classes include mostly loam or fine sandy loam to a depth of about 5 inches, with weakly developed subsurface horizons of sandy loam or gravelly sandy loam above the dense layer. Coarse fragments are mostly between 5 and 25 percent, becoming more abundant with depth. Soil pH ranges from slightly acidic to nearly neutral (4.5 to 6.8). Since small scale tree throw was the historically dominant regenerating disturbance, characteristic pits and mounds (also known as cradle-knolls) are scattered throughout this site and can provide microenvironments for certain plants and wildlife. For example, the mounds produce microsites for tree recruitment (Kabrick et al. 1997) and the pits can temporarily hold water allowing species characteristic of wetter environments to persist. Build-up of downed woody debris is an important characteristic of properly functioning natural communities within this ecological site. Downed woody debris can help the soil retain moisture, provides refuge and habitat for wildlife (particularly amphibians), and act as nurse-logs that are essential for some species such as yellow birch and northern white cedar to regenerate (Erdmann 1990, Great Lakes Worm Watch 2013, Johnston 1990). Soil series associated with this site are in the Inceptisol order, and include Ahmeek and Normanna.

Table 4. Representative soil features

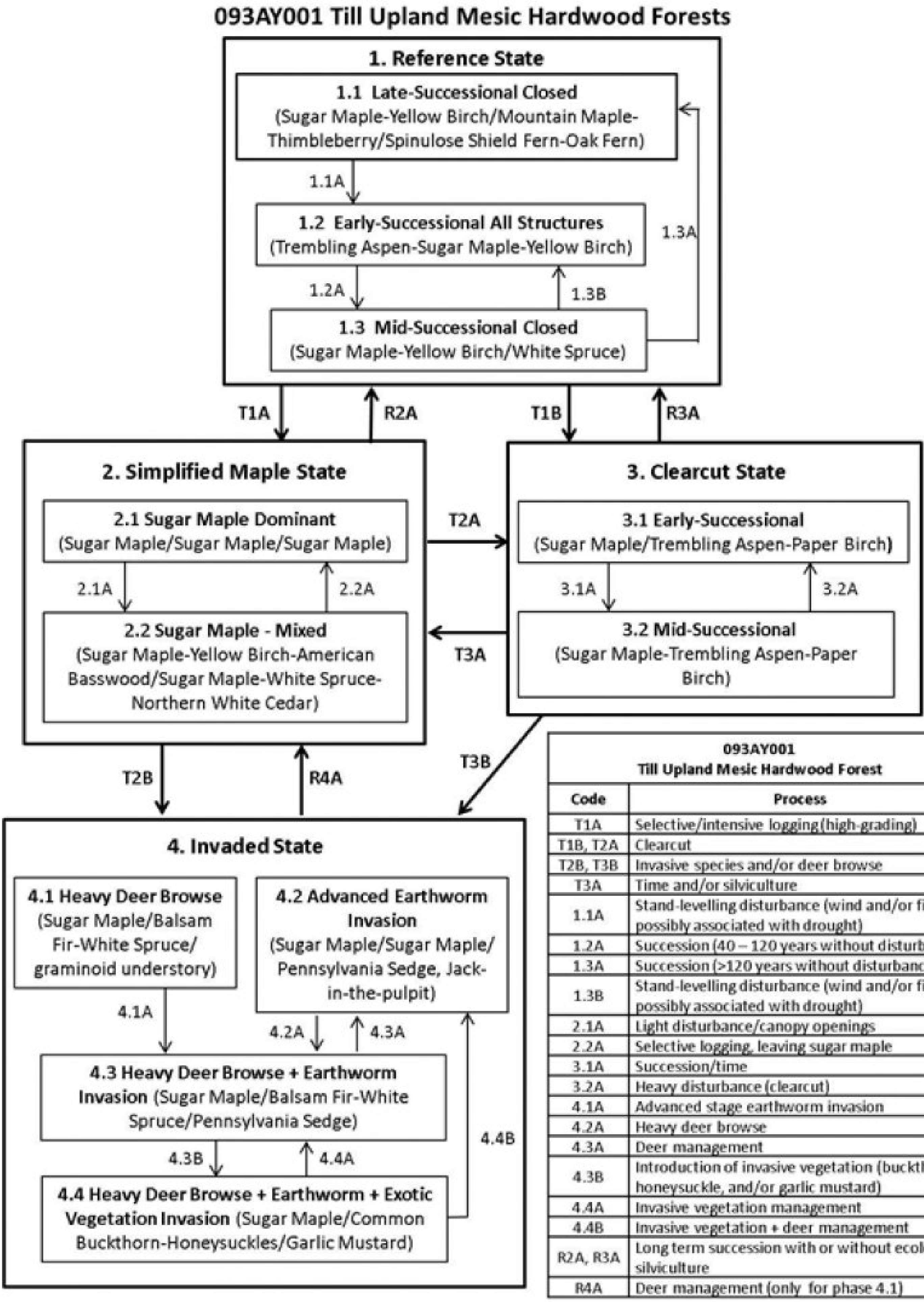
Surface texture	(1) Loam (2) Silt loam
Family particle size	(1) Loamy
Drainage class	Moderately well drained to well drained
Permeability class	Very slow
Soil depth	152–203 cm
Surface fragment cover <=3"	0%
Surface fragment cover >3"	0%
Available water capacity (0-101.6cm)	10.16 cm
Calcium carbonate equivalent (0-101.6cm)	0%
Electrical conductivity (0-101.6cm)	0 mmhos/cm
Sodium adsorption ratio (0-101.6cm)	0
Soil reaction (1:1 water) (0-101.6cm)	4.5–6.8
Subsurface fragment volume <=3" (Depth not specified)	5–25%
Subsurface fragment volume >3" (Depth not specified)	2–10%

Ecological dynamics

Till Upland Mesic Hardwood Forests were historically uneven-aged, well developed forests with overstories dominated by shade tolerant, fire intolerant species, such as sugar maple, yellow birch, white cedar, and sometimes American basswood. Paper birch (*Betula papyrifera*) was an important component in mid to early stand development stages. Similarly, the shrub and herbaceous layers contained a high percentage of shade tolerant and fire intolerant species such as mountain maple and baneberry (Actaea spp.), as well as many generalist species (i.e., those having little indicator value because they occur on a variety of sites) such as beaked hazelnut (*Corylus cornuta*) and largeleaf aster. In contrast to other ecological sites within the MLRA, deep soils in combination with reliable moisture and nutrients allowed these communities to support many rich-site species and have higher forest site productivity. Nutrient cycling was high, producing enrichment of the soil and resulting comparatively little accumulation of leaf litter in organic surface horizons (Nyland 1999). Altogether, these attributes provided little opportunity for fires to carry. Most communities were steady-state and self-renewing, with tree replacement occurring by means of advance reproduction following individual tree throws. Broad scale fire and wind disturbance return intervals were in excess of 1,000 years. Low intensity surface fires were essentially absent except in extreme dry periods. Fires entering mature forest stands from adjacent fire dependent natural communities would quickly lose vigor and ultimately burn out, rarely injuring overstory trees (SNF unpublished report (a), Landfire 2007). Only in extreme cases would high intensity fires occur, often following stand-leveling blowdowns with subsequent dry conditions, thereby setting succession back to earlier stages. These storm events are estimated to have occurred only one in every 1,000+ years, and one in every 2,000+ years a severe fire would ensue (Landfire 2007, MN DNR 2005, MN DNR 2013). In contrast to more stress-inducing environments, insects, disease, and herbivory were of lesser importance within these sites (Landfire 2007). Variability in soil or landform characteristics likely produced minor differences in vegetation composition, structure, and response to disturbances.

Due to the dominance of sugar maple, during settlement times these forests were not clearcut like other forests in the Great Lakes states. Instead, they were selectively logged (i.e., high-graded) in multiple pulses during the early part of the Twentieth Century, leaving behind mostly stands of inferior quality and composition (Johnson et al. 2009). Very few old growth stands exist today. As a result of these selective logging practices some overstory species may have been essentially extirpated. For example, there is some suggestion that white pine (*Pinus strobus*) was historically a component of these systems, possibly in the form of a super canopy (MN DNR 2005). However, post-settlement land clearing and subsequent problems with pine regeneration limit this species potential in the future forest. Yellow birch was also a preferred species for loggers, which may be part of the reason we see limited yellow birch regeneration today. Most areas are second- or third-growth. As a result, the majority of land area of this ecological site is in comparatively earlier successional state or in mixed stands of early-, mid-, and late-successional species, which is a distortion of historical patterns. Remaining old growth or remnant natural communities have been significantly affected by exotic earthworms and high white-tailed deer (Odocoileus virginianus) densities. Earthworms, which were introduced post-settlement, significantly alter soil surface horizons and disrupt nutrient cycling dynamics and thus directly affecting habitat conditions for native flora (Great Lakes Worm Watch 2013). Selective browse resulting from unnaturally high deer densities has caused decline in many genera and overall loss of species diversity. Although this site (and northern hardwoods forests in general) requires a relatively narrow range of environmental conditions in terms of moisture and nutrients to persist (MN Div of Forestry 2008), when those conditions are met they are resilient and offer many opportunities for restoration (Hale et al. 1999).

State and transition model



093AY001
Till Upland Mesic Hardwood Forest

Code	Process
T1A	Selective/intensive logging (high-grading)
T1B, T2A	Clearcut
T2B, T3B	Invasive species and/or deer browse
T3A	Time and/or silviculture
1.1A	Stand-levelling disturbance (wind and/or fire possibly associated with drought)
1.2A	Succession (40 – 120 years without disturbance)
1.3A	Succession (>120 years without disturbance)
1.3B	Stand-levelling disturbance (wind and/or fire possibly associated with drought)
2.1A	Light disturbance/canopy openings
2.2A	Selective logging, leaving sugar maple
3.1A	Succession/time
3.2A	Heavy disturbance (clearcut)
4.1A	Advanced stage earthworm invasion
4.2A	Heavy deer browse
4.3A	Deer management
4.3B	Introduction of invasive vegetation (buckthorn, honeysuckle, and/or garlic mustard)
4.4A	Invasive vegetation management
4.4B	Invasive vegetation + deer management
R2A, R3A	Long term succession with or without ecological silviculture
R4A	Deer management (only for phase 4.1)

Figure 4. Till Upland Mesic Hardwood Forests

State 1
Reference State

Community phases within the Reference State follow classic successional trajectories. Although we document this historical range of variability, late-successional closed canopy, multistoried forests were the dominant condition during pre-settlement (Landfire 2007, MN DNR 2013, MN DNR 2005). Sugar maple is the most influential species and can even be co-dominant in the early-successional community phase following intense blowdown events due it is ability to accumulate in all layers of the forest understory as advance regeneration. However, if such blowdown events are followed by a combination of drought and fire, trembling aspen (*Populus tremuloides*) and paper birch will be favored (Frelich 1999, Natureserve 2007). Although these events did happen and are possible today, due to the historically infrequent nature of such events we do not describe a separate early-successional community phase. By the mid-successional community phase the canopy is closed and sugar maple and yellow birch begin to take over. The early stages of the late-successional community phase continue to be dominated by sugar maple and yellow birch, but with shade tolerant conifers beginning to take hold (such as northern white cedar, white spruce, and balsam fir). Without broad scale blowdown events, community phase 1.1 is almost self-perpetuating; continuing to favor the most shade tolerant, fire intolerant species. The major regenerating disturbance mechanism is by small scale treethrow events which provides habitat for forest interior wildlife, microsites for tree regeneration, and opportunity for some disturbance-adapted species to maintain themselves (such as beaked hazelnut; Kabrick et al. 1997, Landfire 2007). Coupled with this is the accumulation of coarse woody debris in the way of snags and downed wood in various sizes and levels of decomposition (Hale et al. 1999). In advanced stages of old growth (not described in detail here) there is some indication that sugar maple begins to decline while these conifers ultimately increase in importance (MN DNR 2013b). Today good examples of the Reference State are rare. However, some do exist in a few state parks or natural areas, largely limited to northern populations within large intact landscapes having high biological significance. Post-settlement logging and contemporary forest management in part mimic early- and mid-successional dynamics, and are much more common today.

Community 1.1
Late-Successional Closed

Figure 5. Reference community phase.

By stand age 120 trembling aspen, paper birch and early-successional shrubs and ground flora have completely subsided. Forest interior, shade tolerant ground flora take over, particularly spring flowering species. The dominance of sugar maple and yellow birch may begin to subside while the extremely shade tolerant white spruce and white cedar become more prominent in the overstory (MN DNR 2013). At this stage the forest is essentially self-sustaining, with fine-scale tree throw events providing opportunities for small scale gap regeneration (Kabrick et al. 1997). The resulting “pit and mound” topography adds to habitat and structural complexity resulting in unique niches for certain plant and wildlife species. Beyond age 120 the stand continues to develop structural complexity through structural layering as well as extensive build-up of coarse woody debris (Hale et al. 1999). Old stumps, downed logs, and the mounds created from fallen trees provide regeneration potential species like northern white cedar, yellow birch, and occasionally even the sun-loving paper birch (Erdman 1990, Johnston 1990, Safford 1990). These structural dynamics result in habitat diversity essential to support various species of birds, amphibians, and other forest interior species. Historically this was the most dominant community phase on the landscape.

Table 5. Soil surface cover

Tree basal cover	3-7%
Shrub/vine/liana basal cover	0-1%
Grass/grasslike basal cover	0-2%
Forb basal cover	3-7%
Non-vascular plants	0-1%
Biological crusts	0%
Litter	45-65%
Surface fragments >0.25" and <=3"	0-1%
Surface fragments >3"	0-2%
Bedrock	0%
Water	0-1%
Bare ground	0-1%

Table 6. Woody ground cover

Downed wood, fine-small (<0.40" diameter; 1-hour fuels)	8-12%
Downed wood, fine-medium (0.40-0.99" diameter; 10-hour fuels)	5-9%
Downed wood, fine-large (1.00-2.99" diameter; 100-hour fuels)	3-7%
Downed wood, coarse-small (3.00-8.99" diameter; 1,000-hour fuels)	2-6%
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	5-9%
Tree snags** (hard***)	–
Tree snags** (soft***)	–
Tree snag count** (hard***)	37-62 per hectare
Tree snag count** (hard***)	5-17 per hectare

*** Decomposition Classes: N - no or little integration with the soil surface; I - partial to nearly full integration with the soil surface.**

**** >10.16cm diameter at 1.3716m above ground and >1.8288m height--if less diameter OR height use applicable down wood type; for pinyon and juniper, use 0.3048m above ground.**

***** Hard - tree is dead with most or all of bark intact; Soft - most of bark has sloughed off.**

Table 7. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	0-1%	0-1%	1-5%	1-5%
>0.15 <= 0.3	1-5%	1-5%	1-5%	5-15%
>0.3 <= 0.6	1-5%	1-5%	–	25-50%
>0.6 <= 1.4	25-50%	25-50%	–	–
>1.4 <= 4	50-75%	–	–	–
>4 <= 12	50-75%	–	–	–
>12 <= 24	50-75%	–	–	–
>24 <= 37	0-20%	–	–	–
>37	–	–	–	–

Community 1.2
Early-Successional All Structures

The initiation of the stand development process begins following major blow down events favoring the establishment of early-successional trees and shrubs, such as trembling aspen, paper birch, beaked hazelnut, and Rubus species. In addition, at this time dominance can be shared with sugar maple and yellow birch advance regeneration in place. It has been estimated that about 40 percent of these historically may have burned in the years following the blow down due to extreme fuel build up and dry conditions (Landfire 2007). In these cases, the fire intolerant suite of overstory dominants would have been set back further favoring complete dominance of quaking aspen and paper birch. Historically, a small portion of the landscape was in this phase.

Community 1.3
Mid-Successional Closed

Shade tolerant species (particularly sugar maple) begin to accumulate in all structural layers of vegetation. Quaking aspen and paper birch begin to die out while sugar maple and yellow birch begin to dominate the young forest. Similar transitions are occurring in the herbaceous layer, with shade tolerant mesophytes becoming more prevalent. After about age 75, a more complex canopy structure develops and dominant and co-dominant trees become more susceptible to wind throw, providing the first opportunities for gap regeneration. During this phase, shade tolerant coniferous species like northern white cedar and white spruce begin to accumulate in the understory and midstory. Historically this community phase was more common than 1.2 but it was still a comparatively small portion of the landscape.

Pathway 1A
Community 1.1 to 1.2

Stand-levelling disturbance from wind. Fire may have worked interactively with drought to intensify disturbance setting succession back even further. Such disturbances were historically uncommon.

Pathway 2A
Community 1.2 to 1.3

Succession (40 – 120 years without disturbance).

Pathway 3A
Community 1.3 to 1.1

Succession (>120 years without disturbance).

Pathway 3B
Community 1.3 to 1.2

Stand-levelling disturbance from wind. Fire may have worked interactively with drought to intensify disturbance setting succession back even further. Such disturbances were historically uncommon.

State 2
Simplified Maple State

This was the most common state that followed the pre-settlement forests, and may be the most common today. In general, forests on this ecological site were not completely cleared like other forests in the Great Lakes states (as in many coniferous forest types). This was largely due to the abundance of sugar maple which was not a sought after species, and partially because maple (and other hardwoods) could not be easily transported along waterways (Johnson et al.2009). Instead, destruction of reference communities came in the way of selective logging of sought after species of adequate size (i.e., high-grading). This occurred in numerous pulses, with large white pine and yellow birch being removed initially, which likely accounts for the limited occurrence and/or decline of these species today. In many cases, overstory vegetation turned into monotypic sugar maple stands, while in other cases some level of diversity in the overstory was secured, although probably less than before. These two situations represent each of the community phases within this state. Like the reference state, these forests tend to be uneven-aged and with natural succession or thoughtful silviculture (e.g., retention of snags, poor quality trees, etc.) it may be possible to restore some sites to reference conditions (Hale et al. 1999). Communities in this state are a common occurrence on the modern landscape, particularly in private landholdings which tend to be unmanaged. Today, depending on the specific location there may be early stages of earthworm invasion (e.g., Dendrobaena octaedra) as well as some elevated deer browse, but not enough to push it into the Invaded State (which is described below).

Community 2.1
Sugar Maple Dominant

Figure 6. Simplified Maple State

This may be the most common community phase we see today throughout the distribution of this ecological site. In this phase sugar maple accumulates to an extreme extent producing many structural layers in the overstory, subcanopy, and understory. Presumably all or nearly all other overstory species have been selectively cut leaving sugar maple to dominate. This is essentially a "high-graded" condition. By removal of the sub-dominants (e.g., yellow birch and scattered conifers) there is a high potential for near extirpation of these species from the site, partly because a legacy seed source is no longer present and partly because of the overwhelming competitive nature of sugar maple. Small sugar maple seedlings also carpet the forest floor, outcompeting forb species as well and further simplifying the diversity of the ecosystem. Due to lack of high quality browse and mast, these monotypic stands produce limited habitat for most wildlife species (MN Division of Forestry 2008), but are often an important local source for maple syrup and are probably under-utilized in this regard. Given time and appropriate silvicultural prescription to improve diversity and structural development this community phase could move to 2.2 or possibly even be restored a reference condition. To promote future diversity in the overstory these stands need to be managed. A common technique is to "thin from below", removing approximately a third of the basal area in the 5-9" and 9-15" diameter classes (Paul Moran, MN DNR Forester, personal communication; Tubbs 1977). Larger trees (>15" diameter) are often very poor quality and take up significant growing space, likely inhibiting regeneration. Unfortunately it is very difficult to remove these trees because they have little timber value. These trees can either be left as residual wildlife trees or cut to promote buildup of coarse woody debris and/or nurse logs for yellow birch regeneration. Foresters often prescribe thinning to be conducted in the summer months in hopes of scarifying the soil surface to produce a suitable seedbed for yellow birch (Paul Moran, MN DNR Forester, personal communication; Tubbs 1977) which cannot germinate in thick maple thatch (Erdmann 1990). Artificial regeneration can also be undertaken during this time by planting bare-root seedlings of white spruce and white pine.

Community 2.2
Sugar Maple - Mixed

This community phase is very similar to 2.1 but has higher species diversity in the overstory and understory. It is not well understood why some sites retain more diversity than others. It is likely these communities may have benefited from legacy trees not removed during post-settlement logging activities. In some cases paper birch, beaked hazelnut, and other sun-loving species are more common, possibly resulting from light to moderate disturbances. This could also be related to inherent site factors affecting drainage and available water capacity. While still within the range of correlated soils, these communities are sometimes found on uncharacteristically coarser-textured soils containing higher amounts of sand and rock fragments than is typical. In addition, sites lacking a dense subsurface layer may affect this. One or both of these factors could be enough to allow a greater diversity of vegetation to compete with the sugar maple. It is presumed that the higher diversity in composition and structure characterized by this community produces better wildlife habitat however, more investigation is needed to understand these dynamics. Similar management recommendations as described in 2.1 should be considered here. Given time and appropriate silvicultural prescription to improve diversity and structural development, this community phase could be restored a reference condition.

Pathway 1A
Community 2.1 to 2.2

Light disturbance providing fine scale canopy openings, possibly coupled with underplanting of appropriate tree species. Size of gap will affect light levels, and thus affect tree seedlings ability to compete.

Pathway 2A
Community 2.2 to 2.1

Selective/intensive logging (high-grading) of conifers and yellow birch, leaving sugar maple to dominate. This community may succeed to 2.1 without management in locations where sugar maple is particularly competitive.

State 3
Clearcut State

Clearcutting in state 1, or more typically in state 2, will convert the community to an even-aged stand which produces an uncharacteristic, age structure for this ecological site. However, community phases within this state can be similar to community phases 1.2 and 1.3 from the reference state, particularly in terms of stand structure. Communities in this state are most common in managed forest settings where forest managers often have goals of improving the sugar maple quality as well as providing better wildlife habitat for various game species, such as white-tailed deer and ruffed grouse (Bonasa umbellus, Tubbs 1977). Besides the occasional paper birch or localized thicket of trembling aspen, the result is generally a dense monotypic stand of sugar maple (Paul Moran, MN DNR Forester, personal communication). As the stand matures opportunities for management and restoration to states 1 or 2 develop. There may be early stages of earthworm invasion (e.g., Dendrobaena octaedra) as well as some elevated deer browse in this state, but not enough to significantly alter vegetation or dynamic soil properties. This state is a common occurrence on the modern landscape, particularly in managed, publicly-owned forestland.

Community 3.1
Early-Successional

Clearcut management produces the potential for more tree diversity in the future canopy. Due to heavy seedling accumulation and advance regeneration sugar maple will continue to be a dominant woody species, even in the early years following overstory removal. Sun loving species such as trembling aspen and paper birch will be co-dominant, along with other early-successional species. Yellow birch may be common in this community depending on biological legacies from the former stand or on adjacent sites. Without fuel management these areas will be prone to wildfire, particularly if a period of drought follows the clearcut.

Community 3.2
Mid-Successional

Figure 7. Clearcut State

Similar to community phase 1.3 in the reference state, shade tolerant species (particularly sugar maple) again begin to accumulate in all structural layers of vegetation. Quaking aspen and paper birch begin to die out while sugar maple and possibly yellow birch begin to dominate the young forest. Similar transitions are occurring in the herbaceous layer, with shade tolerant mesophytes becoming more prevalent. After about age 75, a more complex canopy structure develops and dominant and co-dominant trees become more susceptible to wind throw, providing the first opportunities for gap regeneration. During this phase, shade tolerant coniferous species also begin to accumulate in the understory and midstory.

Pathway 1A
Community 3.1 to 3.2

Succession (>40 years without disturbance).

Pathway 2A
Community 3.2 to 3.1

Clearcut, mechanical removal of all or nearly all trees.

State 4
Invaded State

The Invaded State is the furthest removed from the Reference State and can transition here from either state 2 or state 3 following long term heavy deer browse or advanced stage earthworm invasion from Aporrectodea spp. and/or Lumbricus spp. This state is more common throughout the southwestern part of this ecological site's distribution, where habitat fragmentation and human development are prevalent. Stands in this state can be either even-aged following clearcutting or uneven-aged following selective logging. Herbivory by deer affects both woody and herbaceous vegetation by direct consumption of plant material. In areas of high deer densities sugar maple may become even more favored due to preferential browsing of other woody species, such as yellow birch and northern white cedar (Rooney and Waller 2003). Deer herbivory by itself has the potential to cause extirpation of the most preferred, palatable species, such as those in the lily family (Augustine and Frelich 1998). In extreme cases, vegetation can become so sparse it is possible that changes in soil moisture, soil temperature and dynamic soil properties may occur, such as a reduction in soil organic carbon which may result in a decline in soil moisture or increase in soil temperature. Overall, elevated herbivory can result in distorted vegetation composition and structure in the forest understory (Alverson et al. 1988, Augustine and Frelich 1998) and indirectly alter the trajectory of the entire forest ecosystem, thus creating novel, deer-induced natural communities affecting vegetation as well as wildlife patterns (Rooney and Waller 2003, White 2012). Due to the rich soils and lush vegetation, this ecological site, and mesic hardwood forests in general, are the most susceptible forest types to earthworm degradation (Frelich et al. 2006). The type of leaf litter (e.g., sugar maple, American basswood, etc.) these forests produce has high nutritional value in comparison to the drier and less nutrient rich pine, oak, and spruce-fir forests (Frelich et al. 2006, Godman et al. 1990). In previous states, the organic surface horizons may or may not have been affected by the epigeic (i.e., above the soil surface) Dendrobaena octaedra species of earthworm. This species does not by itself cause transition to the invaded state because it only affects the organic surface horizons, which happens by mixing the Oa (i.e., well decomposed) and Oe (i.e., partly decomposed) horizons, but leaving the Oi (i.e., recent litter) intact (Frelich et al. 2006). The advanced stages of earthworm invasion include the presence of D. octaedra as well as the deeper burrowing endogeic (i.e., beneath the soil surface) species in the Aporrectodea and Lumbricus genera, which cause the most significant dynamic soil property changes (Hale et al. 2006, Loss et al. 2013). Aporrectodea and Lumbricus species completely consume the organic surface horizons and incorporate that material into the upper mineral soil horizons (Frelich et al. 2006), producing an uncharacteristic bloated A horizon, along with mixing of any existing E horizons. In earthworm-free forest soils, there tends to be a net increase in organic material on the soil surface (Great Lakes Worm Watch 2013). In comparison, in the advanced stages of earthworm invasion all this organic material can be completely removed within 3-5 years, making the only input of organic material from new leaf litter each fall, which is quickly consumed, leaving bare soil at the surface by the next fall (Great Lakes Worm Watch 2013). This process completely alters the nitrogen cycle (which is ultimately depleted from leaching) and produces an unnaturally dense, pan-like layer similar to what happens in plowed agricultural soils (Frelich et al. 2006). Changes in dynamic soil properties such as loss of the organic surface along with higher bulk densities in the subsoil could produce drier growing conditions for plants, affecting the ability for characteristic native species to persist. The loss of the organic surface can also expose tree roots, potentially causing long term effects on the life and/or health of trees. However, immature trees (i.e., saplings and seedlings) are likely to be the most at risk to root exposure. Sugar maple seedlings in particular decrease dramatically as a result of earthworm invasion (Hale et al. 2006). Plant seeds are also affected, as the duff layer provides insulation from hot and cold weather extremes and protection from predation by small mammals and birds (Great Lakes Worm Watch 2013). Another negative consequence of advanced earthworm invasion is the effect on important soil bacterial and fungal networks, including symbiotic mycorrhizae, which facilitate essential water and nutrient uptake to many native plant species (Great Lakes Worm Watch 2013). Advanced earthworm invasion results in a dramatically altered plant rooting environment, both physically and chemically. Some species are able to handle these changes, while others are not. Pennsylvania sedge (Carex pennsylvanica), one of the few non-mycorrhizal species, along with wild leeks (*Allium tricoccum*) and jack-in-the-pulpit (*Arisaema triphyllum*), which produce toxic secondary chemicals hazardous to herbivores (and may be avoided by earthworms too), have been shown to increase in these situations (Frelich et al. 2006, Holdsworth et al. 2007). In comparison, other species like largeleaf aster and wild sarsaparilla tend to decrease (Table 10; Holdsworth et al. 2007, Great Lakes Worm Watch 2013). Although earthworms do not kill canopy trees, it is expected long term recruitment will be affected, particularly in the sapling stage. This may cause elevated sunlight to the forest floor increasing the likelihood for dry-mesic, mid-tolerant species to establish (Frelich et al. 2006). Ultimately, the interaction of both heavy deer browse and advanced stage earthworm invasion results in extremely degraded conditions, potentially paving the way for other invasive, exotic species such as common buckthorn (*Rhamnus cathartica*), honeysuckle (Lonicera tartarica, L. morrowii, L. x bella spp.), and garlic mustard (*Alliaria petiolata*; as represented in community phases 4.3 and 4.4. Overall, the combined effects of invasion by deer, earthworms and exotic plants can initiate an ecosystem decline syndrome that can negatively affect all parts of the ecosystem, from overstory structure, to forb diversity, soil properties, bacteria, fungi, insects, birds, reptiles, amphibians, and mammals. Sites near larger cities, heavily-used lakes, or other developed areas are particularly susceptible to the combination of deer, earthworm, and invasive vegetation problems. Currently, we do not believe any community phases with advanced earthworm invasion can be restored. More research on this topic is needed.

Community 4.1
Heavy Deer Browse

This community phase can be variable depending on the type, amount, and timing of deer browse. If browse occurs in both summer and winter, all vegetation types are affected. If browse is more common in the winter months woody vegetation will be affected. In these cases no species are spared, however balsam fir and white spruce seem to be the less preferred (Anderson et al. 2002, White 2012). If browse occurs in the summer, mostly forb species are affected, often increasing the importance of grasses, sedges (Carex spp.), and less palatable forb species (such as jack-in-the pulpit and wild leeks; Frelich et al. 2006, Rooney and Waller 2003). Significant deer browse is most common near developed areas, especially around the City of Duluth. In more natural, undeveloped landscapes common in the northeastern extent of this ecological site deer browse is not common. In a more natural landscape setting this ecological site does not provide great deer habitat. In the summer months use these areas as corridors and sporadically browse individual plants. During the winter months these sites often experience heavy lake effect snow that can accumulate to several feet in depth (Chel Anderson, MN DNR Ecologist, personal observation) and as a result deer tend to migrate closer to the shore of Lake Superior where temperatures are warmer and there is less snowfall. In addition, the open nature of a hardwood dominated canopy does not shelter snow well, as one would expect beneath a coniferous forest.

Community 4.2
Advanced Earthworm Invasion

Figure 8. Invaded State

Advanced stage earthworm invasion from Aporrectodea spp. and/or Lumbricus spp. This community phase results in removal of organic duff layers incorporated into the mineral surface horizons affecting rooting and nutrient availability. Pennsylvania sedge and jack-in-the-pulpit increase while others decrease or become extirpated (Table 10). Downed woody debris decays at an accelerated rate affecting various wildlife species, such as salamanders.

Community 4.3
Heavy Deer Browse + Earthworm Invasion

Following the initial pulse of plant mortality by advanced stage earthworm invasion or deer herbivory, the combined effect of both of these unnatural disturbances puts plants at even greater risk of extirpation and produces a severely degraded community. Species already affected in 4.1 and 4.2 are now dangerously susceptible to elimination from the site, in large part due to a higher deer-to-plant ratio.

Community 4.4
Heavy Deer Browse + Earthworm + Exotic Vegetation Invasion

Following the interaction of heavy deer browse and advanced earthworm invasion the ecosystem changes significantly, potentially paving the way for better adapted exotic plant species like common buckthorn, honeysuckle, and garlic mustard. Lack of competition from natives combined with a warmer, drier and sunnier understory is a benefit to these species (Great Lakes Worm Watch 2013).

Pathway 1A
Community 4.1 to 4.3

Advanced stage earthworm invasion by species in the Aporrectodea and/or Lumbricus genera.

Pathway 2A
Community 4.2 to 4.3

Heavy deer browse.

Pathway 3A
Community 4.3 to 4.2

Deer management.

Pathway 3B
Community 4.3 to 4.4

Introduction of invasive vegetation (buckthorn, honeysuckle, and/or garlic mustard).

Pathway 4B
Community 4.4 to 4.2

Invasive vegetation + deer management.

Pathway 4A
Community 4.4 to 4.3

Invasive vegetation management.

Transition 1A
State 1 to 2

Selective/intensive logging (high-grading) of healthy, large diameter conifers and yellow birch.

Transition 1B
State 1 to 3

Clearcut, mechanical removal of all or nearly all trees.

Restoration pathway 2A
State 2 to 1

Long term succession (>120 years without disturbance), including a diversity of canopy species (e.g., yellow birch, American basswood, white spruce, white pine, etc.) from natural or artificial regeneration along with recovery of relevant herbaceous species indicative of the reference state.

Transition 2A
State 2 to 3

Clearcut, mechanical removal of all or nearly all trees.

Transition 2B
State 2 to 4

Introduction of exotic earthworms (particularly Aporrectodea spp. and Lumbricus spp.) or heavy deer browse.

Restoration pathway 3A
State 3 to 1

Succession (>75 years without disturbance), diversity of canopy species (e.g., yellow birch, American basswood, white spruce, white pine, etc.) from natural or artificial regeneration along with recovery of relevant herbaceous species indicative of the reference state.

Transition 3A
State 3 to 2

Succession (>75 years without disturbance), monotypic maple stands.

Transition 3B
State 3 to 4

Introduction of exotic earthworms (particularly Aporrectodea spp. and Lumbricus spp.) or heavy deer browse.

Restoration pathway 4A
State 4 to 2

Currently we only have community phase 4.1 as a potentially restorable community, following the management of deer herbivory. At this time there is no evidence showing it is possible to remove earthworms from a forest soil.

Additional community tables

Table 8. Community 1.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
sugar maple	ACSA3	*Acer saccharum*	Native	4.9–24.4	50–100	5.1–76.2	–
yellow birch	BEAL2	*Betula alleghaniensis*	Native	4.9–24.4	25–75	5.1–76.2	–
American basswood	TIAM	*Tilia americana*	Native	4.9–24.4	0–65	5.1–76.2	–
arborvitae	THOC2	*Thuja occidentalis*	Native	4.9–24.4	15–40	5.1–76.2	–
white spruce	PIGL	*Picea glauca*	Native	4.9–24.4	15–40	5.1–76.2	–
balsam fir	ABBA	*Abies balsamea*	Native	4.9–24.4	15–30	5.1–76.2	–

Table 9. Community 1.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
longstalk sedge	CAPE4	*Carex pedunculata*	Native	0–0.3	5–25
roughleaf ricegrass	ORAS	*Oryzopsis asperifolia*	Native	0–0.3	1–15
Forb/Herb					
bigleaf aster	EUMA27	*Eurybia macrophylla*	Native	0–0.3	10–50
bluebead	CLBO3	*Clintonia borealis*	Native	0–0.3	5–25
twistedstalk	STLAL3	*Streptopus lanceolatus var. longipes*	Native	0–0.3	5–25
fragrant bedstraw	GATR3	*Galium triflorum*	Native	0–0.3	5–25
wild sarsaparilla	ARNU2	*Aralia nudicaulis*	Native	0–0.6	5–25
Canada mayflower	MACA4	*Maianthemum canadense*	Native	0–0.3	5–25
small enchanter's nightshade	CIAL	*Circaea alpina*	Native	0–0.3	1–15
red baneberry	ACRU2	*Actaea rubra*	Native	0–0.3	1–15
white baneberry	ACPA	*Actaea pachypoda*	Native	0–0.3	1–15
hairy Solomon's seal	POPU4	*Polygonatum pubescens*	Native	0–0.3	1–15
tree groundpine	LYDE	*Lycopodium dendroideum*	Native	0–0.3	1–15
Pennsylvania clubmoss	LYHI2	*Lycopodium hickeyi*	Native	0–0.3	1–15
dwarf red blackberry	RUPU	*Rubus pubescens*	Native	0–0.3	1–15
whip-poor-will flower	TRCE	*Trillium cernuum*	Native	0–0.3	1–15
Fern/fern ally					
common ladyfern	ATFI	*Athyrium filix-femina*	Native	0–0.6	5–25
spinulose woodfern	DRCA11	*Dryopteris carthusiana*	Native	–	5–25
spinulose woodfern	DRCA11	*Dryopteris carthusiana*	Native	0–0.6	5–25
western oakfern	GYDR	*Gymnocarpium dryopteris*	Native	0–0.3	1–15
Shrub/Subshrub					
beaked hazelnut	COCO6	*Corylus cornuta*	Native	0.3–3	25–75
chokecherry	PRVI	*Prunus virginiana*	Native	0.3–3	5–25
American fly honeysuckle	LOCA7	*Lonicera canadensis*	Native	0.3–1.5	5–25
thimbleberry	RUPA	*Rubus parviflorus*	Native	0.3–1.5	0–25
Tree					
sugar maple	ACSA3	*Acer saccharum*	Native	0.3–3	25–75
mountain maple	ACSP2	*Acer spicatum*	Native	0.3–3	25–75
white spruce	PIGL	*Picea glauca*	Native	0.3–3	5–25

Inventory data references

A total of 27 integrated plots, ranging from Tier 2 to Tier 3 intensity, were used as a basis for this ecological site (Figure 8). Three of these were Type Locations representing the data-supported community phase 1.1 in the state-and-transition model (Figure 2) and included all necessary data elements for a Tier 3 dataset (Table 11). No other community phases were supported with quantitative data analysis, and were composed mostly of community phases closely resembling 1.1, 1.3, 2.1, and 4.2. All 27 plots had soil pedon and site data collected by a professional soil scientist using a form equivalent to SF-232. Most pits were hand dug using spade shovel, montana, sharpshooter, and/or bucket auger. A few were collected using a back hoe. Twenty of the 27 plots were located at established MN DNR relevé points, obtained and used with permission from the MN DNR County Biological Survey (see list below). Three additional relevé's were completed by NRCS ecological site staff. Nine locations also had Tier 2 level vegetation data collected, which included species lists and qualitative structure and cover estimates.

List of MN DNR relevé plots used with verified soils data: 100, 106, 117, 891, 983, 984, 4694, 5639, 8268, 8275, 8276, 8279, 8282, 8293, 8294, 8413, 8845, 8846, 8852, and 8855.

Type locality

Location 1: Lake County, MN	
UTM zone	N
UTM northing	5230797
UTM easting	605752
General legal description	Lake County Forest
Location 2: Lake County, MN	
UTM zone	N
UTM northing	5247715
UTM easting	631260
General legal description	Tettegouche State Park
Location 3: St. Louis County, MN	
UTM zone	N
UTM northing	5173652
UTM easting	558883
General legal description	Magney-Snively Natural Area

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Rangeland health reference sheet

Interpreting Indicators of Rangeland Health is a qualitative assessment protocol used to determine ecosystem condition based on benchmark characteristics described in the Reference Sheet. A suite of 17 (or more) indicators are typically considered in an assessment. The ecological site(s) representative of an assessment location must be known prior to applying the protocol and must be verified based on soils and climate. Current plant community cannot be used to identify the ecological site.

Author(s)/participant(s)	
Contact for lead author	
Date	
Approved by	
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

Indicators

1. **Number and extent of rills:**

---

2. **Presence of water flow patterns:**

3. **Number and height of erosional pedestals or terracettes:**

4. **Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are not bare ground):**

5. **Number of gullies and erosion associated with gullies:**

6. **Extent of wind scoured, blowouts and/or depositional areas:**

7. **Amount of litter movement (describe size and distance expected to travel):**

8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):**

9. **Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):**

10. **Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:**

11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):**

12. **Functional/Structural Groups (list in order of descending dominance by above-ground annual-production or live foliar cover using symbols: >>, >, = to indicate much greater than, greater than, and equal to):**

    Dominant:

    Sub-dominant:

    Other:

    Additional:

13. **Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):**

14. **Average percent litter cover (%) and depth (in):**

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15. **Expected annual annual-production (this is TOTAL above-ground annual-production, not just forage annual-production):**

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16. **Potential invasive (including noxious) species (native and non-native). List species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicators, we are describing what is NOT expected in the reference state for the ecological site:**

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17. **Perennial plant reproductive capability:**
