Ecological Site Description

Major Land Resource Area 93a

Superior Stony and Rocky Loamy Plains and Hills, Western Part

Till Upland Mesic Hardwood Forests

Sugar Maple – Yellow Birch / Mountain Maple – Thimbleberry /
Spinulose Woodfern – Western Oakfern

Natural Resources Conservation Service

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Front cover: Top photo is of a Till Upland Mesic Hardwoods reference state taken at Tettegouche State Park, Lake County, Minnesota (by Kyle Steele, USDA-NRCS). Bottom left photo is of a black-throated blue warbler (*Setophaga caerulescens*), taken in southern St. Louis County (by Mike Furtman, ©michaelfurtman.com). Bottom right photo is of an eastern red-backed salamander (*Plethodon cinereus*), taken in southern Lake County, Minnesota (by Carol Hall, MN DNR). Both species are reliant upon these forest types found in northeastern Minnesota.

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General Information

Ecological Site Name

Abiotic: Till Upland Mesic Hardwood Forests

Biotic: Sugar Maple – Yellow Birch / Mountain Maple – Thimbleberry / Spinulose Woodfern – Western Oakfern
Acer saccharum – Betula alleghaniensis / Acer spicatum – Rubus parviflorus / Dryopteris carthusiana – Gymnocarpium dryopteris

Ecological Site ID: 093AY001

Hierarchical Framework Relationships

Major Land Resource Area (MLRA): Superior Stony and Rocky Loamy Plains and Hills, Western Part (93A)

USFS Subregions: Northern Superior Uplands Section (212L); North Shore Highlands Subsection (212Lb)

Ecological Site Concept

The Superior Stony and Rocky Loamy Plains and Hills, Western Part is located and completely contained in northeastern Minnesota (Figure 1). 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

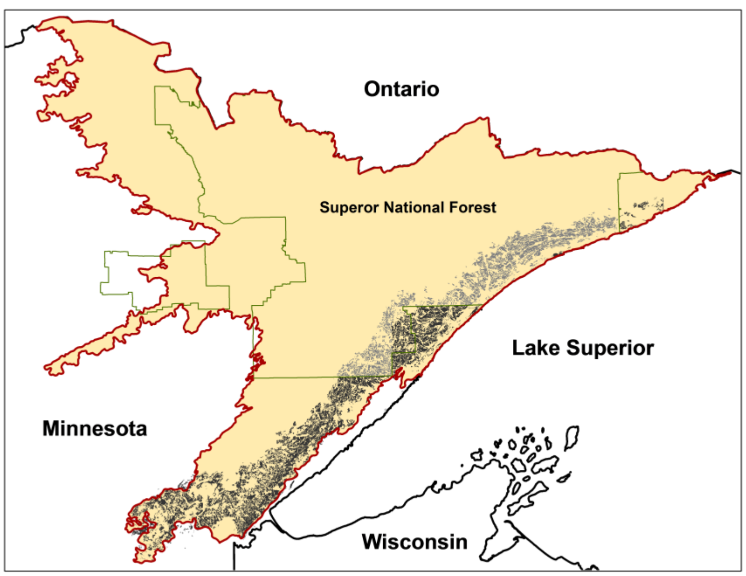


Figure 1. Potential distribution of Till Upland Mesic Hardwood Forests within MLRA 93A. Dark colored polygons show NRCS Soil Survey mapping and light colored polygons show Superior National Forest Landtype Phase mapping.

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).

Till Upland Mesic Hardwood Forest ecological sites are associated with the Automba phase of the Superior glaciation, the first of several main advances of the Superior Lobe along the north shore of Lake Superior (Wright and Watts, 1969). This advance deposited gravelly, coarse-loamy material in the form of till plains, end moraines, and ground moraines. These sites also occur in bedrock-controlled, till mantled landscapes, but still contain soils that are very deep, and thus the bedrock does not affect site conditions for forest communities. They can be located on multiple hillslope positions, including backslopes, summits, and shoulders. Soils are very deep (>60 inches to bedrock), coarse-loamy (<18 percent clay), have <35 percent subsurface coarse fragments, are well or moderately well drained, and often have dense properties in the substratum that can perch water seasonally.

Spring flowering, sub-boreal ground flora within a northern hardwoods forest type characterizes the vegetation of this site. Sub-boreal species are those that have an affinity to the boreal forest biome along with the associated sub-arctic climate. Examples include: thimbleberry (*Rubus parviflorus*), mountain maple (*Acer spicatum*), American fly honeysuckle (*Lonicera canadensis*), bigleaf aster (*Eurybia macrophylla*), bluebead (*Clintonia borealis*), Canada mayflower (*Maianthemum canadense*), wild sarsaparilla (*Aralia nudicaulis*), twistedstalk (*Streptopus lanceolatus*), bunchberry dogwood (*Cornus canadensis*), and small enchanter's nightshade (*Circaea alpina*) (Jim Drake, NatureServe ecologist, personal communication). It is well-established that 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; and Nyland, 1999). Shade-tolerant and fire-intolerant species like sugar maple (*Acer saccharum*), yellow birch (*Betula alleghaniensis*), and American basswood (*Tilia americana*) 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, similar to other northern hardwood types (Nyland, 1999). Later successional, shade-tolerant conifers like northern white cedar (*Thuja occidentalis*), white spruce (*Picea glauca*), and balsam fir (*Abies balsamea*) also are present, which in part distinguishes this site from similar northern hardwoods-dominated ecological sites in the Great Lakes region (Flaccus and Ohmann, 1964; MN DNR, 2005). This is especially true within the northern populations where conifers gradually become more prevalent. Eastern white pine (*Pinus strobus*) may also have been historically important as scattered super canopy trees (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 soils and 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). In comparison, sugar maple site indices can be as high as 80 in the northeastern U.S., while indices between 55 and 65 are generally thought to be good quality sites in other parts of the Midwest (Godman et al., 1990).

Minor variation in composition, structure and response to disturbance likely occurs from southern to northern populations within the MLRA. Northern populations tend to have more of the aforementioned sub-boreal species in the understory along with more coniferous species such as white spruce and balsam fir in the overstory. In comparison, southern populations are more likely to have understory species such as blue cohosh (*Caulophyllum thalictroides*) and a pure stand of hardwoods in the overstory, including American basswood and ironwood (*Ostrya virginiana*; Flaccus and Ohmann, 1964; NatureServe, 2013a). Both are indicative of a somewhat richer and more temperate environment. This gradient is at least partially due to the combination of gradual climate transition as well as possible changes in soil-nutrient status from south to north (Flaccus and Ohmann, 1964).

It is important to note the distribution map included (Figure 1) is the maximum possible extent of this ecological site. It is likely that an additional ecological site will be correlated to map unit delineations outside of the Lake Superior climate effect (which was not considered during the time of soil mapping). We believe interior populations transition from a northern hardwoods type to a mixed mesic conifer-hardwood type. Future soil survey update projects are needed and it is likely a separate climate zone will be described for the distant delineations of these map units.

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 (Table 1). Elevation is mainly above 1,300 feet and below 1,800 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 often are 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 1. Physiographic features.
(Data and information presented here were obtained from the National Soil Information System (NASIS), NRCS integrated plot data, and high resolution digital elevation models.)

	Minimum	Maximum
Elevation (ft.)	1,300	1,800
Slope (percent)	0	18
Aspect (degrees)	0	360
Water Table Depth (in.)	18	80
Flooding	None	None
Ponding	None	None
Landforms: end moraines, ground moraines, and drumlins		

Climatic Features

The average freeze-free period of this ecological site is about 140 days, and ranges from 131 to 149 days (Table 2). 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 (from May through September), and about 21 percent falls as snow (Table 3). 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. Most of the rainfall during the growing season is transpired by plants, which leaves a small proportion of the 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 (Table 3). 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 (Table 4).

Table 2. Frost-free and freeze-free days.
(Data were obtained from NOAA weather stations within the range of this ecological site, using 30-year averages.)

	Minimum days	Maximum days
Frost-free period (32.5°F or greater, 90% probability)	97	124
Freeze-free period (Less than 28.5 °F, 90% probability)	131	149

Table 3. Monthly and annual precipitation and Temperature.
(Data were obtained from NOAA weather stations within the range of this ecological site, using 30-year averages.)

Monthly Moisture (Inches) and Temperature (°F) Distribution			
		------------Temperature------------	
	Average Precipitation	**Average Low**	**Average High**
January	1.21	-0.3	19.0
February	0.86	3.5	24.3
March	1.59	14.8	34.5
April	2.63	28.2	48.6
May	3.25	39.0	61.4
June	4.03	48.6	70.2
July	3.64	53.9	75.6
August	3.70	53.1	73.5
September	3.78	44.7	64.0
October	3.35	33.2	50.8
November	2.50	20.7	35.2
December	1.56	6.1	22.6
Annual	32.10	28.8	48.3

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 4. NOAA climate stations used for data analysis, located within the range of this ecological site.

Station ID	Location	From	To
MN4918	LUTSEN 3NNE	1981	2010
MN8421	TWO HARBORS 7NW	1981	2010
MN9134	WOLF RIDGE ELC	1981	2010
MN4913	DULUTH INTL AP	1981	2010

Influencing Water Features

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

Representative 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; Table 5) and have contact with compacted densic horizons between 20 and 60 inches deep. 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 mostly are 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, thus allowing species characteristic of wetter environments to persist. Buildup 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 (Table 6; 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 5. Representative soil features.
(Data and information presented here were obtained from the National Soil Information System (NASIS) and NRCS integrated plot data.)

	Minimum	Maximum
Surface Fragments less than 3" (percent cover)	0	<1
Surface Fragments greater than 3" (percent cover)	0	<1
Subsurface Fragments less than 3" (percent volume)	5	25
Subsurface Fragments greater than 3" (percent volume)	2	10
Drainage Class	well	moderately well
Permeability Class (most limiting layer)	very slow	very slow
Soil Depth (in)	60	80+
Available Water Capacity (in)	3	5
Soil Reaction/pH (1:1 water)	4.5	6.8

Parent Material – Kind: loamy drift, basal till, and lodgement till
Parent Material – Origin: various igneous and sedimentary bedrock types
Surface Texture: loam, silt loam, or fine sandy loam
Surface Texture Modifier: none
Subsurface Group: loamy

States and Community Phases

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, northern white cedar, and sometimes American basswood (Tables 7 and 8). Paper birch (*Betula papyrifera*) was an important component in mid- to early stand development stages (Figure 2). 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 bigleaf aster (Table 9). 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 to have higher forest site productivity. Nutrient cycling was high, producing enrichment of the soil and resulting in comparatively little accumulation of leaf litter in organic surface horizons (Nyland, 1999). Altogether, these attributes provided little opportunity for fires to spread. Most communities were steady-state and self-renewing, and tree replacement occurred 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 extremely 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 once 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, these forests were not clearcut like other forests in the Great Lakes states during settlement times. 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 eastern white pine 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 a comparatively earlier successional state or in mixed stands of early-, mid-, and late-successional species, which is a distortion of historical patterns (Figure 2). 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 affect 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 an overall loss of species diversity. Although this site (and northern hardwood 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).

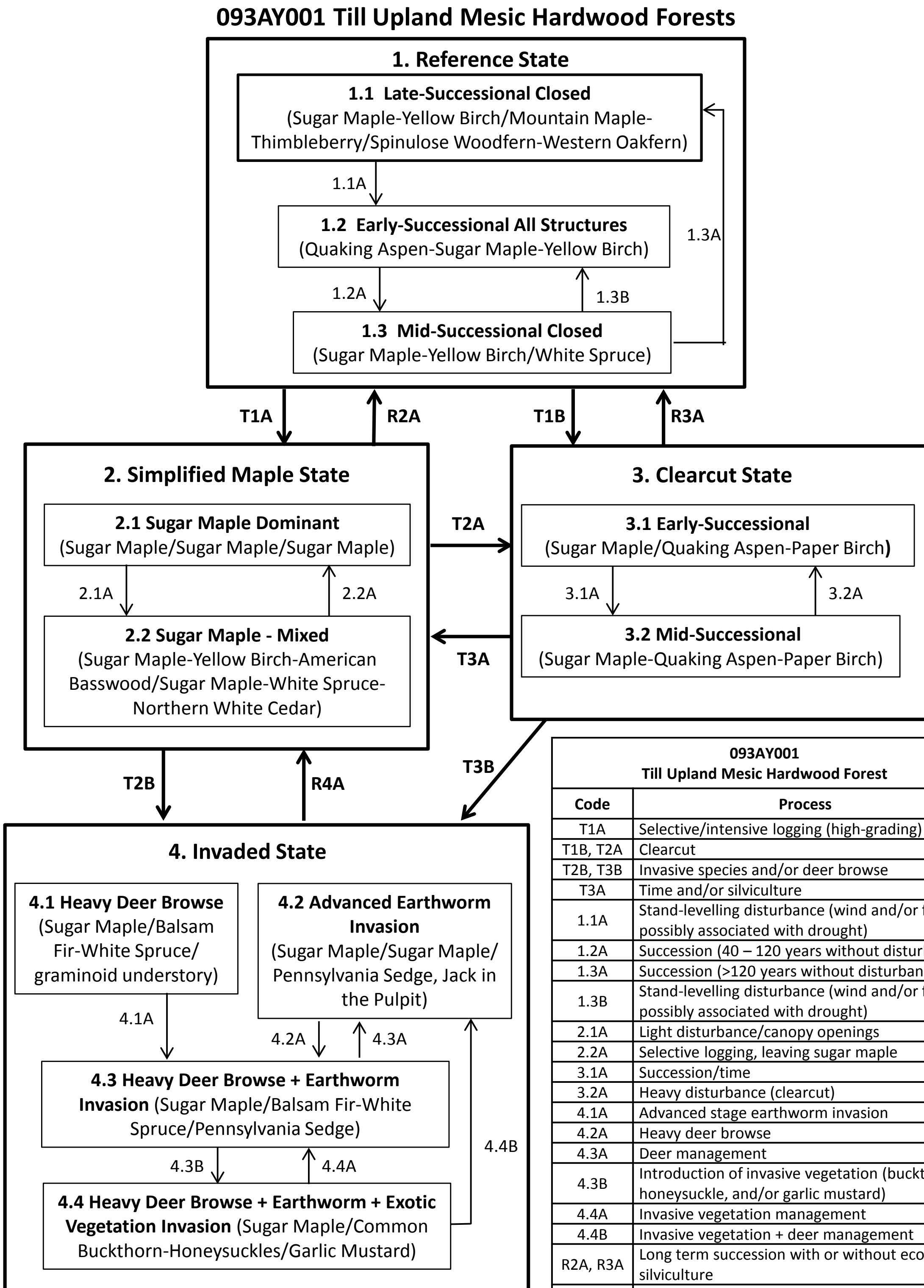
STATE 1 – REFERENCE STATE

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 (Tables 7 and 9; Landfire, 2007; MN DNR, 2013 and 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 to its 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, quaking 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; Table 8). Without broad-scale blowdown events, community phase 1.1 is almost self-perpetuating: it continues to favor the most shade-tolerant, fire-intolerant species. The major regenerating disturbance mechanism is small-scale tree throw events, which provide 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), sugar maple may continue to decline while these conifers increase in importance (MN DNR, 2013b).

Table 6. Reference State community phase 1.1 ground surface cover, downed wood, and tree snags.
(Data presented are based on ground cover transects at three NRCS type locations.)

	Type	Cover (%)
Ground Surface Cover	Grass/Grasslike	1
	Forb	5
	Shrub/Vine	<1
	Tree	5
	Non-Vascular Plants	<1
	Biological Crust	0
	Litter	55
	Surface Fragments (.25-3”)	<1
	Surface Fragments (>3”)	1
	Bedrock	0
	Water	<1
	Bare Ground	<1
Downed Wood	Fine/Small (1-hour)	10
	Fine/Medium (10-hour)	7
	Fine/Large (100-hour)	5
	Coarse/Small (1,000-hour)	4
	Coarse/Large (10,000-hour)	7
Tree Snags (No./acre)	Hard Snags	20
	Soft Snags	5

State-and-Transition Diagram



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 2. State-and-transition model for Till Upland Mesic Hardwood Forests.

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.

Table 7. Reference State community phase 1.1 canopy cover by height class. (Data presented are based on type location from Tettgouche State Park.)

	Percent Cover			
Height Above Ground (ft)	Grass/ Grasslike	Forb	Shrub/ Vine	Tree
0.5	1-5	1-5	0-1	0-1
0.5-1	1-5	5-15	1-5	1-5
1-2	-	25-50	1-5	1-5
2-4.5	-	-	5-25	25-50
4.5-13	-	-	-	50-75
13-40	-	-	-	50-75
40-80	-	-	-	50-75
80-120	-	-	-	0-20

Table 8. Reference State community phase 1.1 overstory diameter, volume, and density.
(Stand totals are based on Hale et al. (1999), species totals are based on importance values listed in Flaccus and Ohman, 1964.)

Species	**USDA Symbol**	**DBH (in)**	**Basal Area (ft^2/ac)**	**Trees Per Acre**
SUGAR MAPLE (*Acer saccharum)*	ACSA3	2-30	70-90	70-90
YELLOW BIRCH (*Betula alleghaniensis)*	BEAL2	2-30	20-40	20-40
AMERICAN BASSWOOD (*Tilia americana*)	TIAM	2-30	0-40	0-40
BALSAM FIR (*Abies balsamea)*	ABBA	2-30	10-20	10-20
WHITE SPRUCE (*Picea glauca)*	PIGL	2-30	5-15	5-15
NORTHERN WHITE CEDAR (*Thuja occidentalis)*	THOC2	2-30	5-15	5-15
STAND TOTAL	-	2-30	130-140	130-140

Table 9. Reference State community phase 1.1 composition.
(Adapted from Flaccus and Ohman, 1964 and MN DNR, 2005, and USDA NRCS integrated plot data. Not all species are assumed to be present in one location.)

Layer	Common Name	Scientific Name	USDA Symbol	Type	Cover (%)	Height (ft)
Canopy	SUGAR MAPLE	*Acer saccharum*	ACSA3	tree	50-100	50-80
	YELLOW BIRCH	*Betula alleghaniensis*	BEAL2	tree	25-75	50-80
	AMERICAN BASSWOOD	*Tilia americana*	TIAM	tree	0-50	50-80
	BALSAM FIR	*Abies balsamea*	ABBA	tree	10-25	50-80
	WHITE SPRUCE	*Picea glauca*	PIGL	tree	10-25	50-80
	NORTHERN WHITE CEDAR	*Thuja occidentalis*	THOC2	tree	10-25	50-80
Sub Canopy	SUGAR MAPLE	*Acer saccharum*	ACSA3	tree	25-50	16-40
	YELLOW BIRCH	*Betula alleghaniensis*	BEAL2	tree	25-50	16-40
	AMERICAN BASSWOOD	*Tilia americana*	TIAM	tree	0-50	16-40
	WHITE SPRUCE	*Picea glauca*	PIGL	tree	5-25	16-40
	BALSAM FIR	*Abies balsamea*	ABBA	tree	5-25	16-40
Shrub/ Seedling	SUGAR MAPLE	*Acer saccharum*	ACSA3	tree	25-75	1-10
	WHITE SPRUCE	*Picea glauca*	PIGL	tree	5-25	1-10
	MOUNTAIN MAPLE	*Acer spicatum*	ACSP2	shrub	25-75	1-10
	BEAKED HAZELNUT	*Corylus cornuta*	COCO6	shrub	25-75	1-10
	CHOKECHERRY	*Prunus virginiana*	PRVI	shrub	5-25	1-10
	AMERICAN FLY HONEYSUCKLE	*Lonicera canadensis*	LOCA7	shrub	5-25	1-5
	THIMBLEBERRY	*Rubus parviflorus*	RUPA	shrub	0-25	1-5
	RED ELDERBERRY	*Sambucus racemosa*	SARA2	shrub	0-25	1-5
Herbaceous	BIGLEAF ASTER	*Eurybia macrophylla*	EUMA27	forb	10-50	0.1-1
	COMMON LADY FERN	*Athyrium felix-femina*	ATFI	fern	5-25	0.1-2
	WILD SARSAPARILLA	*Aralia nudicaulis*	ARNU2	forb	5-25	0.1-2
	SPINULOSE WOODFERN	*Dryopteris carthusiana*	DRCA11	fern	5-25	0.1-2
	BLUEBEAD	*Clintonia borealis*	CLBO3	forb	5-25	0.1-1
	TWISTEDSTALK	*Streptopus lanceolatus*	STLAL3	forb	5-25	0.1-1
	STARFLOWER	*Trientalis borealis*	TRBO2	forb	5-25	0.1-1
	CANADA MAYFLOWER	*Maianthemum canadense*	MACA4	forb	5-25	0.1-1
	LONGSTALK SEDGE	*Carex pedunculata*	CAPE4	graminoid	5-25	0.1-1
	FRAGRANT BEDSTRAW	*Galium triflorum*	GATR3	forb	5-25	0.1-1
	BANEBERRIES	*Actaea rubra / A. pachypoda*	ACRU2/ ACPA	forb	0-15	0.1-2
	HAIRY SOLOMON'S SEAL	*Polygonatum pubescens*	POPU4	forb	0-15	0.1-1
	GROUNDPINES	*Lycopodium dendroideum / L. hickeyi*	LYDE/ LYHI2	forb	0-15	0.1-1
	DWARF RED BLACKBERRY	*Rubus pubescens*	RUPU	forb	0-15	0.1-1
	WHIP-POOR-WILL FLOWER	*Trillium cernuum*	TRCE	forb	0-15	0.1-1

Species list continued

Layer	Common Name	Scientific Name	USDA Symbol	Type	Cover (%)	Height (ft)
	ENCHANTER'S NIGHTSHADE	*Circaea alpina*	CIAL	forb	0-15	0.1-1
	WESTERN OAKFERN	*Gymnocarpium dryopteris*	GYDR	fern	0-15	0.1-1
	ROUGHLEAF RICEGRASS	*Oryzopsis asperifolia*	ORAS	graminoid	0-15	0.1-1
	DOWNY YELLOW VIOLET	*Viola pubescens*	VIPU3	forb	0-15	0.1-1
	SHINING CLUBMOSS	*Huperzia lucidula*	HULU2	forb	0-15	0.1-1
	LONG BEECHFERN	*Phegopteris connectilis*	PHCO24	fern	0-15	0.1-1
	WOOD ANEMONE	*Anemone quinquefolia*	ANQU	forb	0-15	0.1-1
	CAROLINA SPRINGBEAUTY	*Claytonia caroliniana*	CLCA	forb	0-15	0.1-1

Figure 3. Potential Reference State (community phase 1.1) for Till Upland Mesic Forest ecological site; Ahmeek soils. Photo by Kyle Steele at Tettegouche State Park, Lake County, Minnesota, in September of 2013.

Community Phase 1.1 By stand age 120, quaking 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 northern white cedar become more prominent in the overstory (MN DNR, 2013). At this stage the forest is essentially self-sustaining, with fine-scale treethrow 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; and 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.

Pathway 1.1A - 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.

Community Phase 1.2 The initiation of the stand development process begins following major blowdown events favoring the establishment of early-successional trees and shrubs, such as quaking 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 may have burned in the years following the blowdown due to extreme fuel buildup and dry conditions (Landfire, 2007). In these cases, the fire-intolerant suite of overstory dominants would have been further set back, favoring complete dominance of quaking aspen and paper birch. Historically, a small portion of the landscape was in this phase.

Pathway 1.2A - Succession (40 – 120 years without disturbance).

<u>Community Phase 1.3</u> 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 windthrow, 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 phase 1.2, but it still was a comparatively small portion of the landscape.

Pathway 1.3A - Succession (>120 years without disturbance).

Pathway 1.3B - Stand-levelling disturbance from wind. Fire may have worked interactively with drought to intensify disturbance, setting succession back even further. Such disturbances historically were uncommon.

Transition 1A - Selective/intensive logging (high-grading) of healthy, large-diameter conifers and yellow birch.

Transition 1B - Clearcut: mechanical removal of all or nearly all trees.

STATE 2 – SIMPLIFIED MAPLE STATE

The simplified maple state 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 eastern white pine and yellow birch 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; however, 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 upon 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 later in this Ecological Site Description).

Community Phase 2.1 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 no longer is present and partly because of the overwhelming competitive nature of sugar maple. Small sugar maple seedlings also carpet the forest floor, outcompeting forb species and further simplifying the diversity of the ecosystem. Due to the 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 probably are 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 of very poor quality and take up significant growing space, likely inhibiting regeneration. Unfortunately, it is difficult and economically impracticable 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 also can be undertaken during this time by planting bare-root seedlings of white spruce and eastern white pine.

Figure 4. Photo of Sugar Maple Dominant community within the Simplified Maple State (community phase 2.1) of Till Upland Mesic Hardwood Forests. Photo by Kyle Steele at Finland State Forest, Lake County, Minnesota in September 2012.

Pathway 2.1A - Light disturbance providing fine-scale canopy openings, possibly coupled with underplanting of appropriate tree species, such as yellow birch, white spruce, and northern white cedar. The size of the gap will affect light levels, and thus affect the tree seedlings ability to compete.

Community Phase 2.2 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 to a reference condition.

Pathway 2.2A - 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.

Transition 2A - Clearcut, mechanical removal of all or nearly all trees.
Transition 2B - Introduction of exotic earthworms (particularly *Aporrectodea* spp. and *Lumbricus* spp.) or heavy deer browse.

Restoration Pathway 2A - Long term succession (>120 years without disturbance), including a diversity of canopy species (e.g., yellow birch, American basswood, white spruce, eastern white pine, etc.) from natural or artificial regeneration, along with recovery of relevant herbaceous species indicative of the reference state.

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 quaking aspen, the result is generally a dense monotypic stand of sugar maple (Paul Moran, MN DNR Forester, personal communication). As the stand matures, opportunities develop for management and restoration to states 1 or 2.

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 Phase 3.1 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 quaking aspen and paper birch will be co-dominant, along with other early-successional species. Yellow birch may be common in this community, depending upon 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.

Pathway 3.1A - Succession (>40 years without disturbance).

Community Phase 3.2 Similar to community phase 1.3 in the reference state, shade-tolerant species (particularly sugar maple) will 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 windthrow, providing the first opportunities for gap regeneration. During this phase, shade-tolerant coniferous species also begin to accumulate in the understory and midstory.

Figure 5. Photo of Mid-Successional community within the Clearcut State (community phase 3.2) of Till Upland Mesic Hardwood Forests. Photo by Kyle Steele at Grand Portage State Forest, Cook County, Minnesota in July 2012.

Pathway 3.2A **-** 40 – Clearcut, mechanical removal of all or nearly all trees.

Transition 3A - Succession (>75 years without disturbance), monotypic maple stands.

Transition 3B - Introduction of exotic earthworms (particularly *Aporrectodea* spp. and *Lumbricus* spp.) or heavy deer browse.

Restoration Pathway 3A - Succession (>75 years without disturbance), diversity of canopy species (e.g., yellow birch, American basswood, white spruce, eastern white pine, etc.) from natural or artificial regeneration, along with recovery of relevant herbaceous species indicative of the reference state.

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; for example, a reduction in soil organic carbon, which may result in a decline in soil moisture or an 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) is particularly susceptible 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 (Figure 6).

In earthworm-free forest soils, there tends to be a net increase in organic material on the soil surface (Great Lakes Worm Watch, 2013). By comparison, in the advanced stages of earthworm invasion, all of 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 also can 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 also are 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).

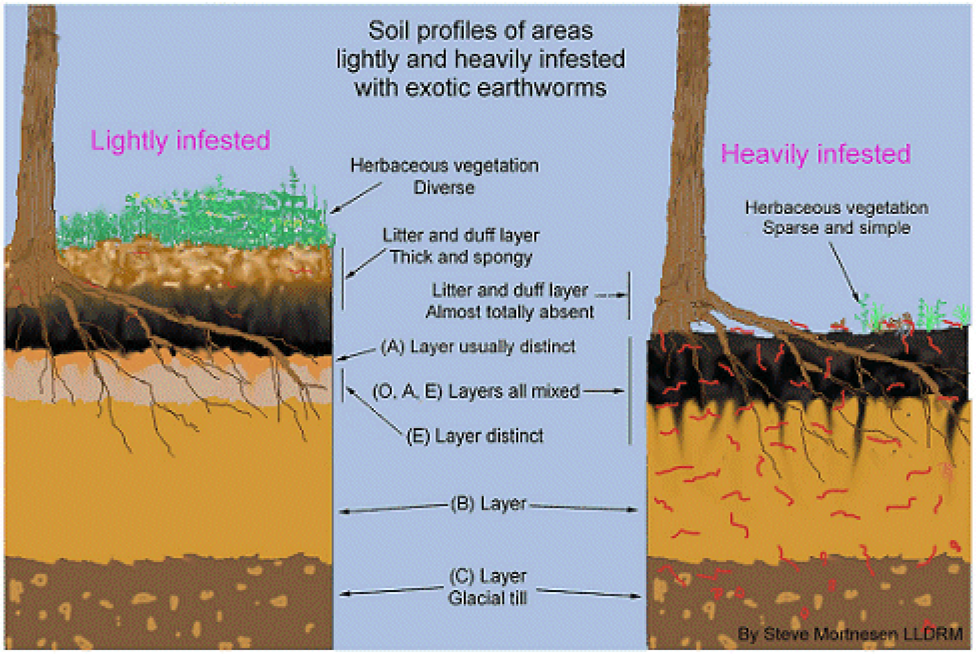


Figure 6. Diagram showing changes in soil and vegetation properties resulting from advanced stages of earthworm invasion. Reproduced with approval by Great Lakes Worm Watch (www.nrri.umn.edu/worms).

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 pensylvanica*), 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 also be avoided by earthworms), have been shown to increase in these situations (Table 10; Frelich et al., 2006; Holdsworth et al., 2007). In comparison, other species like bigleaf 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 that 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; Figure 2). 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 Phase 4.1 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).

Table 10. List of common plant species documented to increase or decrease following earthworm invasion. Reproduced with approval by Great Lakes Worm Watch (www.nrri.umn.edu/worms).

Decreasers			Increasers	
Life Form	**Scientific Name**	**Common Name**	**Scientific Name**	**Common Name**
Forbs and Sedges	*Aralia nudicaulis*	Wild sarsaparilla	*Arisaema triphyllum*	Jack in the pulpit
	Polygonatum pubescens	Hairy Solomon's seal	*Maianthemum racemosum* subsp. *racemosum*	False Solomon's seal
	Uvularia grandiflora	Largeflower bellwort		
	Uvularia sessilifolia	Sessileleaf bellwort	*Carex pensylvanica*	Pennsylvania sedge
	Streptopus roseus	Twistedstalk		
	Aster macrophyllus	Bigleaf aster		
	Hepatica nobilis var. *obtusa*	Roundlobe hepatica		
	Trientalis borealis	Starflower		
Ferns	*Dryopteris* spp.	Woodferns	None	
Tree Seedlings	*Acer saccharum*	Sugar maple	*Fraxinus* spp.	Ash
	Acer rubrum	Red maple		
	Tilia americana	American basswood		
	Amelanchier spp.	Serviceberry		

Significant deer browse is most common near developed areas, especially around the City of Duluth. Deer browse is not common in more natural, undeveloped landscapes common in the northeastern extent of this ecological site. In a more natural landscape setting, this ecological site does not provide great deer habitat. In the summer months, deer 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 and as a result, deer tend to migrate closer to the shore of Lake Superior where temperatures are warmer and there is less snowfall (Chel Anderson, MN DNR Ecologist, personal observation). In addition, the open nature of a hardwood-dominated canopy does not shelter snow well, as one would expect beneath a coniferous forest.

Figure 7. Photo of Invaded State (community phase 4.2) of Till Upland Mesic Hardwood Forests showing effect of earthworm invasion, including thin seedling layer, loss of organic surface horizons, and Pennsylvania Sedge in the forb layer. Photo by Kyle Steele at Magney-Snively Natural Area, St. Louis County, Minnesota in September, 2011.

Pathway 4.1A - Advanced stage earthworm invasion by species in the *Aporrectodea* and/or *Lumbricus* genera.

Community Phase 4.2 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.

Pathway 4.2A - Heavy deer browse.

Community Phase 4.3 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, due in large part to a higher deer-to-plant ratio.

Pathway 4.3A - Deer management.
Pathway 4.3B - Introduction of invasive vegetation (buckthorn, honeysuckle, and/or garlic mustard).

Community Phase 4.4 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 native plants combined with a warmer, drier, and sunnier understory is a benefit to these species (Great Lakes Worm Watch, 2013).

Pathway 4.4A - Invasive vegetation management.
Pathway 4.4B - Invasive vegetation + deer management.

Restoration Pathway 4A - 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.

Supporting Information

Relationship to Other Established Classifications

Superior National Forest Terrestrial Ecological Unit Inventory (SNF unpublished report a, b); mapping concepts are most similar to:

Landtype: 14 Upland Deep Medium Loamy

Landtype Phase: 55 Unnamed (Superior moraines, well/mod well drained, >40", <18 percent clay)

MN DNR Native Plant Community Classification (MN DNR, 2005); the reference community of this ecological site is most similar to:

Primary: MHn45a,c Northern Mesic Hardwood (Cedar) Forest

Secondary: MHn47a Northern Rich Mesic Hardwood Forest

Vegetation Associations (National Vegetation Classification System, NatureServe, 2013a); the reference community of this ecological site is most similar to:

Primary: Sugar Maple – Yellow Birch – (American Basswood) – Forest

Secondary: Quaking Aspen – Paper Birch / Sugar Maple – Mixed Hardwoods Forest; Paper Birch – Sugar Maple – Mixed Hardwoods Forest

Ecological Systems (National Vegetation Classification System, NatureServe, 2013); the reference community of this ecological site is most similar to:

Laurentian-Acadian Northern Hardwood Forest

Associated Ecological Sites

Spatial distribution of the associated map units for this ecological site currently do not reflect the lake-moderated climate effect. As a result, there likely is 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 likely will be necessary.

Similar Ecological Sites

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 currently is no ecological site developed for this unit. Further investigation is needed.

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 shovels, sharpshooters, and/or bucket augers. A few were collected using a backhoe. Of the 27 plots, 20 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 relevés 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.

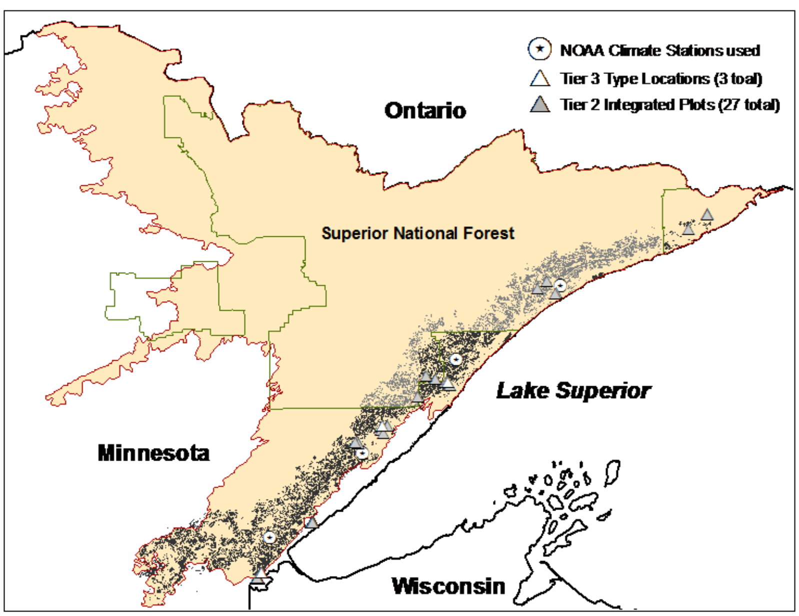


Figure 8. Tier 2 and 3 plot locations used as a basis for this ecological site, and NOAA climate stations used for climate analysis.

Table 11. Location of Tier 3 data used for Type Locations.

State	County	Ownership	Legal Description	Latitude	Longitude
Minnesota	St. Louis	Magney-Snively Natural Area, City of Duluth	T49 R15 S22	46.713714	-92.229563
Minnesota	Lake	Lake County Forest	T55 R10 S28	47.220806	-91.602254
Minnesota	Lake	Tettegouche State Park	T56 R7 S6	47.370343	-91.26156

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